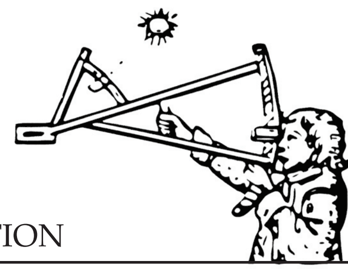
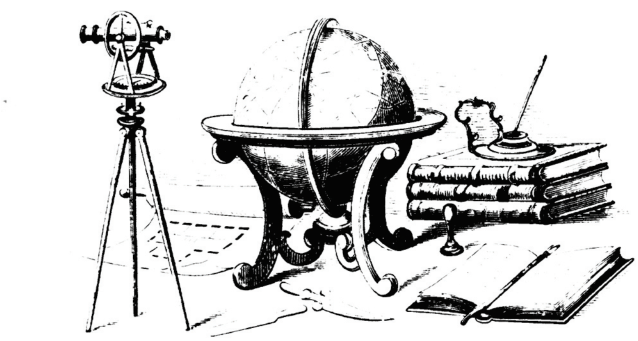
ISSUE 89, FALL 2005

THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a reader forum for the expression of our members opinions and their questions.



ACTIVITIES

By Terry Carraway

As all members know the past 21 months has been a difficult one for The Navigation Foundation. The staffing has always based on an all volunteer cadre of experts in navigation. They all served without compensation except for "out of pocket" expenses. Because most were veterans of WWII and Korea, their expertise was in celestial navigation. Almost all had published texts on celestial navigation, as well as other books on piloting and seamanship. We started with 12 Directors. The first was Roger Jones followed by Dale Dunlop and Mr. Shufeldt along with other notable writers and instructors of celestial navigation. All were willing to donate their time and expertise to The Navigation Foundation.

Because they were all from the pre-WWII era, the WWII era and the Korean War they were aging. Over the years we have lost all original Directors except me and Roger Jones. It has been very difficult to find experienced persons who are willing to contribute their time and expertise as a volunteer to help keep The Navigation Foundation interesting and viable.

The Navigation Foundation has recently been most fortunate in having a person most well know to navigators and boaters to become the editor of The Navigator's Newsletter. Dr. David Burch has volunteered to be the editor of The Navigator's Newsletter. He brings not only an expertise in celestial but is able to bring his expertise to The Foundation in other forms of navigation. We are most fortunate in having him as a Director.

Because of our problems the Newsletter has been delayed, late and somewhat "jumbled." We plan to get back on a schedule by sending the Fall (No. 89) and Winter (No. 90) issues back to back. Dr. Burch has indicated that he will try to get back on schedule following those.

Check the new product area for some new and exciting additions to our services and products.

EDITOR'S NOTES

By David Burch

It was an honor to be asked by Terry Carraway to help with the editing and layout of the Navigator's Newsletter. I have been reading it since its inception, but have not been as active a member as I would have liked. That will change now. In fact, we started off here with a big project—the electronic preservation and archive of all past issues of the Newsletter, more than 1,100 pages in 88 issues dating back to Summer of 1983. I am proud to say that this is now completed and available to all members, as explained elsewhere in this issue. With these ebook files you can read through any of the past issues and search for topics of interest. It will certainly be an asset to this new editor as we can find in a moment the past discussion of topics that might arise again. We hope that others will benefit from it as much as we have.

Our next step will be to produce a detailed index of its contents that will help members and prospective members get a quick overview of what is there and where to start looking, although the powerful search engine in the Elibra Reader (the ebook format we use for the archive) will find any keyword or phrases. There are periodic indexes throughout the issues. The task remaining is to gather these together into a database, expand them as needed, and then extend the list to recent issues.

Work on this archive has reminded me of what a wonderful resource this Newsletter has been over the past 23 years, thanks to the fine work of Terry Carraway and his predecessors at the helm of the Newsletter, and to the very many members who have contributed over the years. Our work is cut out for us to maintain this tradition. We will do our best. I will rely on the guidance of Executive Director Terry Carraway and director Roger Jones and I will be asking for the help of all of our members. To that end, we have added to the regular announcement section on Future Issues a new section on Request for Contributions. We want to reach out to you to send in your ideas of what you want to see in the newsletter or to propose navigation problems or topics that other members might comment on. The Readers Forum has served this function in the past, so this is just a way to highlight this aspect of the Forum.

The Foundation for the Promotion of the Art of Navigation has some 500 active members. Some are new to navigation, but by joining have shown that they support the goals of the Foundation and are eager to learn more personal navigation skills and how to further the goals of the Foundation. Others have been members for many years and represent some of the world's experts in celestial navigation and related skills. We have the resources as a group to tackle any problem in celestial navigation and related aspects of navigation. In celestial navigation we have covered and will continue to cover all aspects of the procedures, instruments, analysis, and actual practice at sea and on land and in the air. The Newsletter has also contained articles on other topics of navigation including charting, piloting, and dead reckoning, along with articles about many navigation instruments and aids.

There has not been much presented on electronic navigation as such, because the internal workings of such systems are not a focus of the Foundation. There are other organizations around the world that cover these subjects in detail. The Institute of Navigation in Washington DC (www.ion.org) and the Royal Institute of Navigation in London (www.rin.org.uk) are two that come to mind immediately, and each has several publications and subgroups on special topics in electronic navigation. They also cover other aspects of navigation. The magazine GPS World (www.gpsworld.com) also does a fine job of covering public, practical, and engineering aspects of this technology

But even though electronic navigation in itself is not a focus of the Foundation, I think it is fair to say that there can indeed be "personal skills" to be learned and shared in the prudent and efficient use of these electronic tools. I give one example in the note in this issue called "How electronic navigation forces us to use celestial navigation." Another example might be the valuable application of electronic charting on a home PC. This can be used to aid just about any navigation task at hand, even for analyzing the work of Lewis and Clark or Capt. Vancouver or Christopher Columbus. There is a related note in this issue on the Google Earth program online. It is a sophisticated form of electronic charting, available to anyone with a new computer and access to the Internet. Navigators have to be geographers on some level, and this new resource is a geographer's dream machine.

Things are changing in navigation, but the requirement for sound knowledge and personal skills of those actually doing it has not changed. To the extent we can promote that sound knowledge we are furthering the goals of the Foundation. We welcome your thoughts and suggestions on these ideas.

Since we have not yet received new content from members, we will share in this issue a few notes of our own. In the last issue (No. 88) there was an interesting report on lifeboat sextants from Capt. Leback. These instruments were the forerunners of several modern plastic sextants. To follow up on that note, we include a few photographs of the original lifeboat sextants.

It was also independently suggested that we include an article on plastic sextants in general, so we have added an article on procedures that might help others obtain optimum accuracy from these instruments. Needless to say, your comments and suggestions on any of the topics presented in the Newsletter are encouraged.

And so, we are underway.

READERS FORUM

Member Capt. Leonard Gray wrote:

Mr. Stone,

I've just read your October 13 letter in the Summer 2005 Newsletter. I'm sorry you ran into some snags working problems in my book. If you let me know which edition you have (1992 or 1999) and send me your work sheets, I'll see if I can find what went wrong.

Do you have the errata sheet for the book? If not, I'll send you a copy.

I'm afraid that what you said about errors may give some readers of the Newsletter the wrong idea about the book. As far as I know, there are no unintentional uncorrected errors in either edition. As I stated in the introduction, to make the problems realistic, I deliberately introduced the kinds of imperfections and occasional blunders that navigators make in actual practice—and all of these are explained in the answers section. I guess I'd better send Mr. Carraway a note to clear this up.

I'll be happy to send you an analysis of your work soon after I get your reply.

Leonard Gray

In response, Mr. Gayle Stone wrote:

Leonard,

In describing my problem I didn't intend the description of my failure to be a disparagement of any part of your book. After a few reductions of my own sights, a daytime Sun/Moon (UL) in March, 2005, which I am very proud of; I decided to revisit your '100 Problems in Celestial Navigation. In doing so I found that I had developed a serious routine error in use of the "d" factor for the moon. So, the error is mine and the only reflection on your book is that in my attempt at Problem 1-10 again, it revealed my wrong doing to Member Roger Jones. In my March 16, 2005 moonUL sights, the declination factor was only 5.5 and the sights were in the early part of the hour, garnering only a corr. value of 0.3. The declination being on the increase, assigning a positive (+) value to the correction was in order. But, I somehow had started to take the "d" factor at face value without reason as to the increase or decrease in declination, so I was always assigning a positive value to the correction. In your 1-10 example, the moon was changing declination at a pretty good clip of 11.2 for "d", DECLINING and with 38 minutes into the hour, the correction is 7.2. With my assignment of a positive value, I was 7.2 miles in the wrong direction. The error doubles to 14.4 miles in the plot. So any problem I worked with medium to large decreasing declination and into the latter part of the hour, I was off in the area of 15 miles. Roger has since given me some informative tutoring on reasoning with declination.

Terry had referred me to Roger and I forwarded my work to him. My restatement of your Introduction about "sighting inaccuracies and an occasional blunder have been included "---" to make them authentic" was intended for Roger's information only because he had not visited your book for many years. I just wanted to remind him of this to temper his investigation. Since he did not have your book at hand, I had also forwarded copies of the 1993 Almanac pages to him. I am sure that my successes with moon, upper limb also mislead him but in reworking them with his forms and procedures, soon found the solution to my problem.

Since I had also received an offer of help from Jim Martin in Australia, I assume the Foundation had sent my letter or Roger's communication with me to members. Jim thought I might be using an artificial horizon and not taking a 15 minute correct. Again, my 15 minute remark was misleading. I agree that some communication should be sent to members to set the record straight about my error and my opinion that your book is a great exercise for us novices and a review for the experts. Since my letter stirred the pot I am sending a copy of this to Terry. I hope it would be adequate to reveal that the snags are mine and not your book.

My copy is well worn, came apart at the binding, so is now punched and in a three ring binder. With the number of hurricanes here in So. Florida this year, I have also revisited your Storm Evasion exercise in 11-4. Present conditions, Epsilon finally diminishing here in the December, prodded me on a little further this time so have reworked it and some "what if's" on the maneuvering board.

Respectfully,

Member Gayle Stone

* * * *

Member Bruce Kachline wrote:

I am a beginner at celestial navigation and need advice in maintaining my Weems & Plath sextant. The late John Luykx sent it to me in beautiful conditions. I cleaned it monthly with household ammonia and it is beginning to show spots that will not come out with the ammonia. Any ideas on how to solve the problem?

Also, when he sent it to me, there was a piece of paper placed between the stainless vernier screw and the brass arc teeth. Should I store it in that manner?

I've dabbled with the TI-35 calculator method of reduction as well as the NASR method. I'm most comfortable with the HO-229 and the Air Almanac for stars. I use the star finder but star identification is still a challenge.

We sailed through Arlene and came through a direct hit from Katrina without a scratch; Rita didn't bother us in the Marina at Slidell, LA.

Thank you for your help,

Bruce Kachline

The Navigator's Newsletter
Issue 89, Fall 2005
Published by
The Foundation for the Promotion of the Art of Navigation
www.navigationfoundation.org
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Rockville, Maryland 20850, USA
Phone or fax 301-622-6448
Executive Director, Terry Carraway
Newsletter Editor, David Burch
Inquires about membership or Newsletter content or contributions can be send to the above address or by email to navigate1@comcast.net.
The Navigator's Newsletter is published four times annually, with our strived-for publication dates of approximately the solstices and equinoxes. Newsletter editing and layout and other Foundation activities are provided by volunteers. Please bear with us if we slip on the dates occasionally.

In response, Director Roger H. Jones wrote:

Terry Carraway has sent to me your inquiry. I need to know just a little more about your apparent problem.

(1) Where are the spots that will not come out—on the mirrors, and if so which mirror?

(2) Ammonia sounds pretty harsh to me. I have always used just distilled water, very carefully. Alcohol would be ok for the clear glass, but be careful in dealing with the silvered mirror. Again, for the silvered mirror, I'd stick with distilled water. Don't use any cleaner like alcohol or ammonia on the silvered side of the mirror.

(3) Did John Lukyx advise you on the cleaning of the sextant, and if so, what was his advice?

(4) There is no need to store the sextant with the paper between the vernier screw and the arc teeth. It would be taking extra care to do so, but I don't really think it will make much difference. I have owned my sextant for over 30 years and have never bothered to store it that way, and it has been with me on many thousands of blue water miles in both sail and power vessels.

(5) If you are comfortable with H.O. 229 that is fine, although I would urge you to take a look at H.O. 249 which is even easier to use for the average small vessel sailor. The practical differences in accuracy that are afforded by 229 are undeniable in theory, but in the real world 249 provides all the accuracy you'll ever need, and it comes in three volumes, as opposed to six.

(6) For star identification there is nothing easier or better than Volume 1 of 249. It is specifically designed to allow you to preset your sextant to a certain "altitude" and you then orient it in a specific direction, and "presto" the star you are seeking is in your sextant optics. (You have to do a little "paper work" first.) Also, the star charts in the Almanac can be very useful in identifying starts by virtue of their location within major constellations, such as Orion, etc.

(7) Sight reduction methods are a matter of choice. You say you are a beginner, and I would strongly urge you to stick with a work form that enables you to record your data and go through the procedures step-by-step. You'll learn a whole lot more that way. I have a form that I devised for use with 249, and it is an all purpose form for use with any body. There is a universal Mercator plotting sheet on the back. If you like I'll send you a copy, and some other material as well. Calculators are fine, but they enable you to make errors without even being aware of them, and unlike a work form, they do not enable easy back-tracking to spot the errors.

You say that Rita didn't bother you in the marina in Slidell. My old friends who lived in Slidell lost their home to Katrina. You were most fortunate.

I'll be most happy to consult with you on the phone, by e-mail, by snail mail, or whatever. I encourage you to stick with it. I am one of the original Directors of the Navigation Foundation and was there at its start along with Terry and Admiral Davies (who is now deceased). So, let me know how I can help.

Regards and lots of encouragement to you.

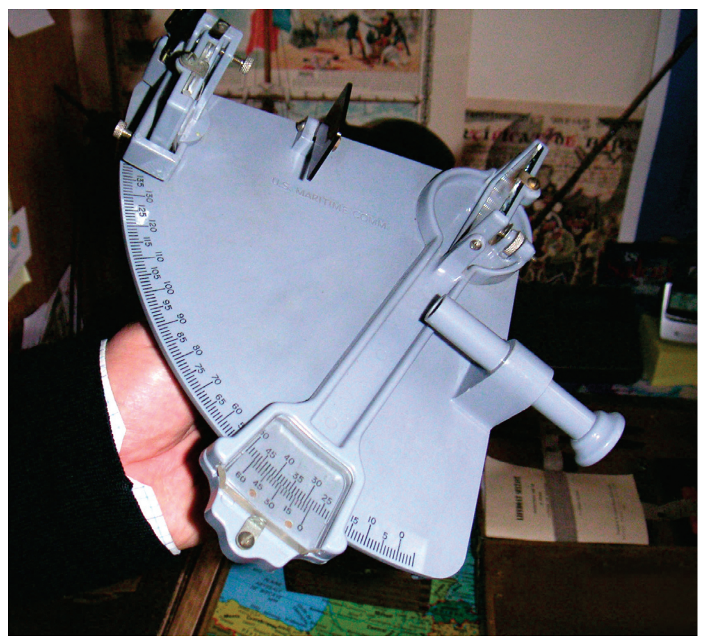
Roger H. Jones

NAVIGATION NOTES

Lifeboat Sextants

In the last issue (No.88) we had a fine article by Captain Warren Leback on the history and use of the lifeboat sextant. I happen to have some photos of one of these and thought it might be interesting to members to see one as a follow up on his article.

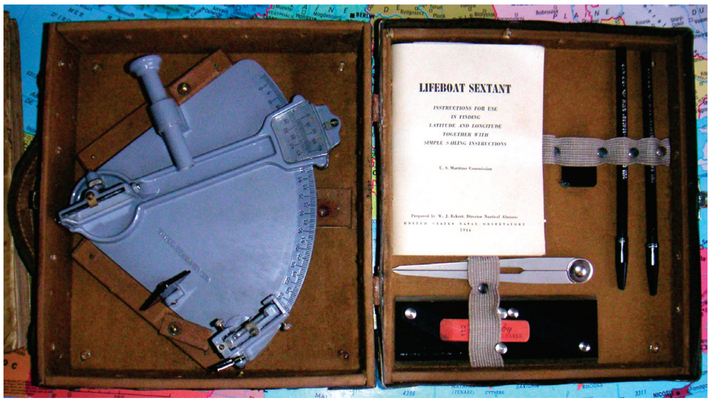
This one belongs to Francosis Meyrier, who is a sailor and celestial navigation instructor in France. Besides offering courses that draw students from throughout the country, he is also the author of a popular book on celestial navigation in both French and English, *Astro Navigation Made Easy*. He also has a most wonderful personal collection of historic navigation instruments and references. His dedicated room for these treasures in his home is one of the most engaging "maritime museums" I have had the pleasure to visit.



As space allows, I would look forward to sharing a few other photos from that visit.

The picture of the open box shows the layout of the included instruments described by Capt. Leback. It is about the same size as the Davis Mark 3, but clearly a more expensive construction, heavier plastic, with more solid fittings and mirror adjustments, and in a stout box with metal reinforced corners and leather handle. But as we will show in the data presented next issue, one can do very well with the modern, inexpensive equivalent, readily available. Also when it comes to sextant piloting, these instruments might even be considered preferred over a full-size metal sextant—but this is the topic of another issue.

The writing on the instruction manual reads: LIFEBOAT SEXTANT, Instructions for use in finding latitude and longitude together with simple sailing instructions. U.S. Maritime Commission, Prepared by W. J. Eckert, Director Nautical Almanac, United States Naval Observatory, 1944.



NAVIGATION BASICS REVIEW

Celestial Sights with Plastic Sextants

by David Burch

These notes are adapted from our course materials intended for those new to sextants. The Foundation has members that are highly experienced in all aspects of sextant use, so we welcome your comments and suggestions (or corrections!) on what we have here. My goal is share what we have and build upon it. In the next issue (No.90) we will present actual test data taken on land and at sea, comparing results from metal and plastic sextants.

Plastic sextants are often disparaged for lack of inherent accuracy and vulnerability to the effects of the sun. But while it is true that they are not as accurate as metal sextants and they are indeed more sensitive to the sun than metal sextants are—thermal expansion coefficients of plastic are some 10 to 30 times higher than for metals—plastic sextants can with special care still be used quite successfully for practical navigation at sea and do provide a less-expensive alternative for new navigators to get their feet wet with sights of their own. Indeed, plastic sextants are in practice easier to use than metal sextants for the actual sight taking because they are so light weight, but this ease of handling is rather outweighed by the extra care required in procedures and analysis. The task at hand here is to explain the issues and then propose a way to compensate for these limitations by presenting a systematic method for taking sights with plastic sextants.

In the author's opinion, the question of thermal effects of the sun have never been a real issue, since we have no reason to leave them for extended periods in the sun, just as we would not leave a thousand-dollar metal sextant in the sun. Whether or not they might thermally change during a particular sight session in the bright sun is not clear, we have one set of sights that might be explained by that, but it is not at all conclusive. [See Note 1]

To understand the limitations and issues at hand we need to look briefly at how sextants work. Most sextants have a series of notches cut precisely 1° apart into the outside edge of the arc of the instrument. The notches are labeled in degrees along the side of the arc. A worm gear at the base of the index arm presses into these notches as it moves along the arc. Large changes in sextant angle are made by squeezing two levers that disengage the worm gear and allow the index arm to slide along the arc. Releasing the levers, engages the worm gear once again, but sometimes a slight twist of the micrometer drum is needed to seat the gear properly. The degrees part of the new sextant angle is read from a reference mark on the index arm against the degrees scale printed or engraved into the side of the arc.

Angle settings in between whole degrees are made by rotating the micrometer drum. This rotation changes the angle continuously from one degree to the next. The drum settings can typically be read to a precision of 0.1' of arc making use of a vernier scale printed along the edge of the drum. Hence if a sextant were set to an angle of 32° 21.8', we would read the 32° from the scale on the arc, the 21' from the micrometer drum, and the 0.8' from the vernier scale.

An ideal sextant has a very positive action of the micrometer drum, meaning no slack in the gears. Turn it to the right by 1' and immediately the angle increases by 1'. Stop and turn it to the left and it immediately starts to go down. A good metal sextant in good condition will behave properly in this regard. Plastic sextants, on the other hand, tend to have a bit of slack in this mechanism, consequently we get slightly different results when turning to the right to achieve alignment as opposed to turning to the left to achieve the same alignment. This is a well known issue with plastic sextants and it is mentioned in the manuals for the Davis Mark 15 and Mark 25 plastic sextants (it does not apply to the more basic Mark 3 model which does not have a micrometer drum). *[See note 2. This is the instrument derived from the lifeboat sextants, shown in this issue.]*

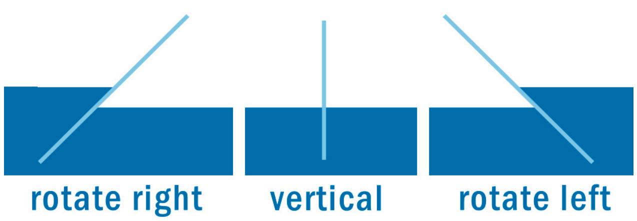
But there is more to this story. We cannot investigate slack in the gears without some means of observing the effects of our rotation of the drum. In other words, we have to decide what is or is not in alignment once we rotate the drum. An obvious time to study this effect is during the index correction (IC) measurement, which is typically done with the sextant set to 0° 0.0' while viewing a distant sea horizon. (Note that there are other, probably even more accurate, means of measuring the IC—and gear slack—but for now we discuss only the more common IC method of using the horizon.)

The sea horizon is the most convenient and most commonly used method, but for precision work it has the limitation of not often presenting a perfectly sharp line between sky color and sea color. Look very carefully at the best horizon and you often see—or at least appear to see—a very narrow line of some other color right at the horizon, or some other slight disruption of a perfect line. Consequently, even when we have a perfect sextant with no gear slack at all, we can still get the appearance of a slight gear slack because the imprecision of the reference line leads to some variance from sight to sight in what the observer might call "perfectly aligned." The amount of this variance will depend on the nature of the horizon, the skill of the observer, the power of the telescope, and with the sextant model. A 6- or 7-power scope is better for IC checks than the 4-power scopes which are standard on most sextants, and this effect is naturally larger when viewed in the 2-power scopes on plastic sextants.

Here is a procedure for investigating this effect:

First remove the side error of the sextant by adjusting the horizon mirror until you can rock (roll) the sextant set at 0°0’ and not detect any splitting of the horizon. Many texts (and Bowditch, of course) explain the procedure. This may also require some collateral adjustment of the index mirror. With plastic sextants we have found that it is often useful to give each mirror housing (not the mirror itself) a bit of a flick with the finger to help the seating of the mirrors before and after the adjustments. If the flick changes things, you have to keep working on it. (Don’t flick it any harder than you would flick your own nose!)

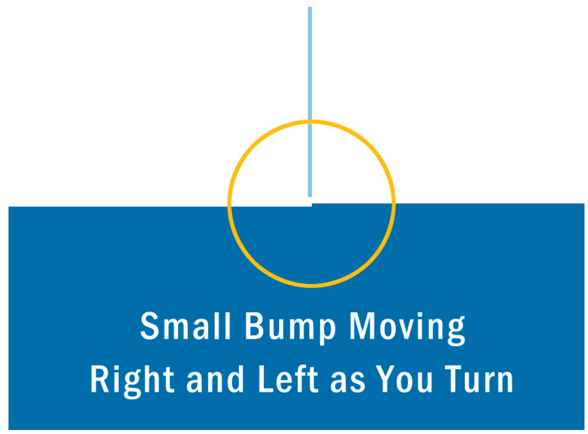
Then with the sextant set to 0° 0.0’, view the horizon



(SIDE ERROR WITH NO INDEX ERROR)

and turn the drum "toward" you (clockwise, angle decreasing) to clearly separate the two horizons viewed directly and by reflection. Then slowly turn the drum "away" from you (counterclockwise, angle increasing) until the horizons just first appear as a smooth straight line, which is what we call in alignment. Be sure to sneak up on this very slowly so you do not overshoot the alignment. We want the reading just as they first become aligned.

Confirm that you are aligned by panning (yawing) the sextant right and left a bit to verify that there is no motion along the horizon. This is a more accurate method than just looking straight at it and concluding it is aligned. If you are just very slightly unaligned, you will notice a slight bump moving right and left at the intersection of the two views, direct and reflected. Once confirmed, record the IC reading to the nearest 0.1’ and label this IC measurement with an "A" to note that you were turning the drum in that direction and a "touch" to note that this was the setting for the first touch of the two horizon views in alignment. If you have overshot the alignment, start all over again.



Now to continue, first double check your notes to confirm which way you are turning and think through the motion, then very slowly and carefully continue turning in the away direction until you can first detect that you are no longer aligned. Again, this is best done by doing a slight rotation then panning the horizon, then another and another pan, until you can detect some motion along the horizon which indicates that you are no longer aligned. Then read and record the new IC and label it with "A" and "leave," meaning this was the value when you left the alignment.

Repeat this 5 or 6 times in the away direction and then do the same in the toward direction. This type of measurement will show what we are up against. You have effectively measured the angular width of "perfect alignment." With a metal sextant and a sharp horizon, the touch and leave values will typically differ by only a few tenths, which reflects our limits on locating the horizon precisely. Put another way, if we just randomly set the sextant to alignment on a series of sights, we could fairly expect to get at least this level of spread in the values we measured, since anywhere between "touch" and "leave" gives the same appearance of alignment.

More to the point at hand, however, is that with a metal sextant, the spread in the touch and leave values will show little if any difference when measured in the toward or away direction. With a typical plastic sextant this is not the case. Not only will you detect larger spreads in the touch and leave values, you will most often note a significant difference in the IC values measured in the toward and away directions, which is a measure of the slack in the gears—or, if not that, at least some measure of the general behavior of the device (the actual worm gear in the plastic sextants is metal, but it seats into notches in plastic).

These IC differences in plastic sextants can also vary from day to day and from the beginning to the end of a given sight session—even if the temperature of the device has not changed at all during the session. Sometimes the toward and away differences might be zero and other times on the same device (without having adjusted the mirrors) be as large as 4’ or 5’. We must stress here, however, that we are describing operational behavior, and not necessarily a limit on the ultimate accuracy obtainable with the sextants. The exercise is intended to show how users might verify for themselves why special care must be taken when doing celestial sights with plastic sextants. Next we show procedures that will to a large extent compensate for these limitations.

Suggested procedures for taking sights with plastic sextants…

(1) Measure the IC values as explained above. The sextant should be in thermal equilibrium with the ambient temperature. *[Sample IC Data are given in the next issue.]*

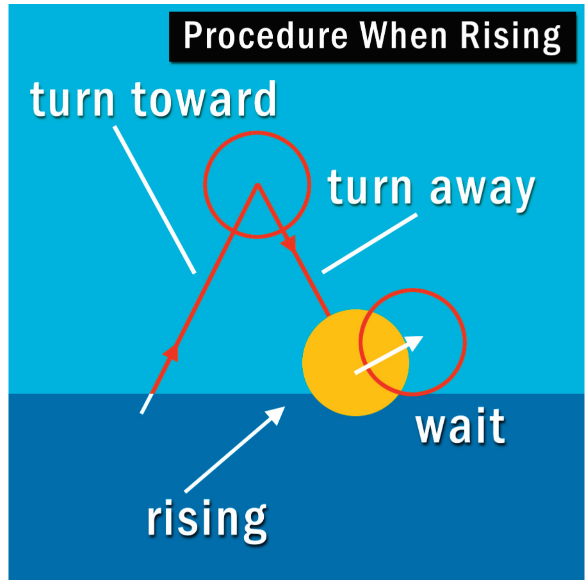
(2) Use the "Set and Wait" procedure for taking the sights themselves, described below..

Set and Wait Method. For objects that are setting (i.e. bearing to the west of south) get object and horizon in view, then turn the drum in the away direction till the object is well below the horizon. Then slowly and smoothly turn the drum in the toward direction until the body is about one-eighth of a sun diameter above the horizon (some 4’ or so). When using the sun or moon, so that the lower limb is just very clearly above the horizon. The goal is to get to this point by only turning in the toward direction and then stopping with no backlash on the drum. Then do not touch the drum any longer but just wait for the sun to set onto the horizon as you continually rock the sextant back and forth to insure a perpendicular measurement. When the lower limb touches the horizon, note the time, and read the dial. Note the reading and that it was a toward sight.

When the body is rising, do the reverse. Turn toward till the body is above the horizon, then carefully and slowly use the away rotation to get the lower limb some 4’ or so below the horizon and then wait for it to rise up to perfect alignment. [note 3]

(3) Do at least 4 or 5 sights of each body. Use the appropriate toward or away IC for correcting the data.

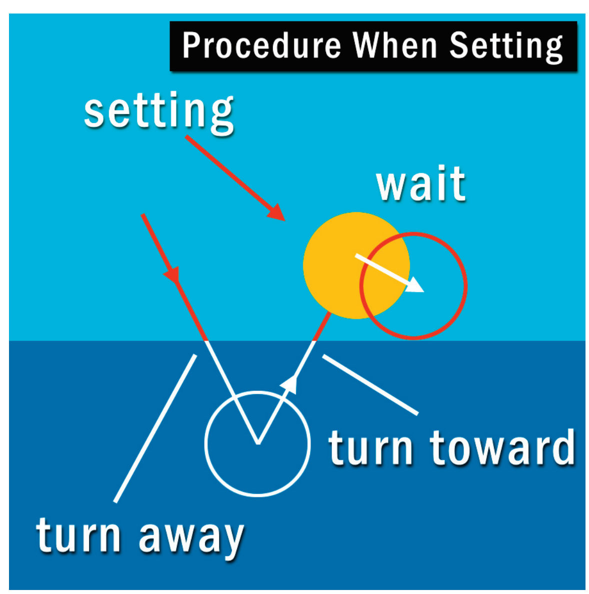
(4) Then analyze your data using the Fit Slope Method *[topic of another issue]* to choose the best sight of the lot for your fix. There is no need to sight reduce all of them if you are doing it by hand, just the best fit or a representative one. The slope analysis will essentially pile all the statistics of the set into that one sight. (Remember, too, that when you compute the Hc values for the theoretical slope of the line over the time range of your sights that you must use the proper DR position for each computation if they are different. When moving at any significant speed, this means updating the DR used at each computation. Sailing south at 8 kts, for example, any two sights of the same body taken more



or less to the south that are 30 minutes apart in time would be some 4’ different in sextant height. We must account for this in the slope analysis.)

I would propose this Set and Wait method as "standard operating procedure" for taking sights with plastic sextants, but should add that this is a good way to do sights in general with any sextant if conditions are a bit rough. It is longer, but much easier, and creates much less internal stress. If you miss it, just start all over again. Trying to cut corners and guess what time it really was aligned is not reliable.

I would also propose—as a broad generalization—that using these procedures one should be able to obtain accuracies of some 5 or 6 miles as a general rule with



plastic sextants. Maybe better in some cases, maybe a bit worse in others. Naturally, one needs to follow good procedures to obtain good fixes, which means well selected bodies (3 near 120° apart) with careful correction for the motion of the vessel during the sight session. Celestial calculators like the Starpath StarPilot do all of the sight reduction and this latter bookkeeping for you automatically. This level of plastic sextant accuracy is to be compared with that obtainable from metal sextants—also requiring good procedures and analysis—of some 1 or 2 miles depending on conditions. *[These are quotes for routine sights underway. With special care in good conditions, one can achieve about 0.5 nmi accuracy.]*

Details of sights at sea and on land comparing metal and plastic sextants will be in issue 90. The results are very encouraging. We used Davis Mark 15 and Mark 3 sextants. Davis also makes a Mark 25 (sells for about $240), which comes with a "full-view" horizon—an optional mirror type offered my all sextant manufacturers now, but I believe it was actually a development of Davis Instruments, themselves (another good topic for an article.) But this is not a (horizon) mirror type that we recommend (and another story!) We will add a few notes on other models of plasic sextants in issue 90

Footnotes

[1] There has been a published study that showed a large temperature dependence of the index correction of plastic sextants, but it is not at all clear that that study is pertinent to practical navigation—nor that the authors actually did measure what they set out to. See: "Temperature Dependence of Index Error," R. Egler, Navigation, Journal of the Institute of Navigation, 42, No.3, Fall 1995. That experiment should be repeated in more realistic circumstances before its conclusions can be extended to real navigation underway.

[2] This most fundamental issue of index correction measurement in plastic sextants is conspicuously missing from the above article which studied the subject.

[3] It may help to remember that turning Toward makes the reflected image rise in your view; turning Away makes it descend in the sextant view.

Davis Mark 15
sells for about $145

Davis Mark 3
sells for about $40

NAVIGATION NOTES... continued

How electronic navigation forces us to use celestial navigation

We have often had occasion to write about the value of learning celestial navigation in the age of GPS, and will do so here again in future issues. But one reason for this we have not actually put into print is what turns out to be the most common actual cause to get out the cel nav tools.

By electronic navigation we usually mean GPS, radar, and a chart plotter. Each of these devices produce the best information if they have a heading sensor input. Thus all modern nav stations include a digital fluxgate comapss. At least one. Some times the one used for the autopilot or one of instruments is not compatible with the other devices, so one can easily end up with more than one digital compass. The readouts from these appear on the display screens of the interlinked instruments. Add to that the conventional steering compass, and oftentimes more than one of these.

Thus it is essentially inevitable that once you are underway, you will notice that these compasses do not all agree. You might say, this is something that should be checked ahead of time (yes, that is true), but I am speaking from actual experience and I have yet to see them agree on any vessel. Sometimes, for example, the output of one is being used for a crucial computation, but is not actually displayed on the instrument using it. Usually what is displayed depends on operator configurations. So you do not know there is a problem till trying to sort out inconsistent derived data.

Or you might have a more conventional problem, such as one of them actually goes wrong underway. An adjustment magnet moves, something iron gets moved near a heading sensor, which are often located inconspicuously in readily accessible places, etc.

The only truly valid, efficient solution to this offshore while still carrying on in the same direction you want to go, is to check one of them with the sun or stars. Pure celestial navigation in its simplest form—not for the purpose of preserving old techniques, nor for personal satisfaction, but simply the best solution to the problem at hand.

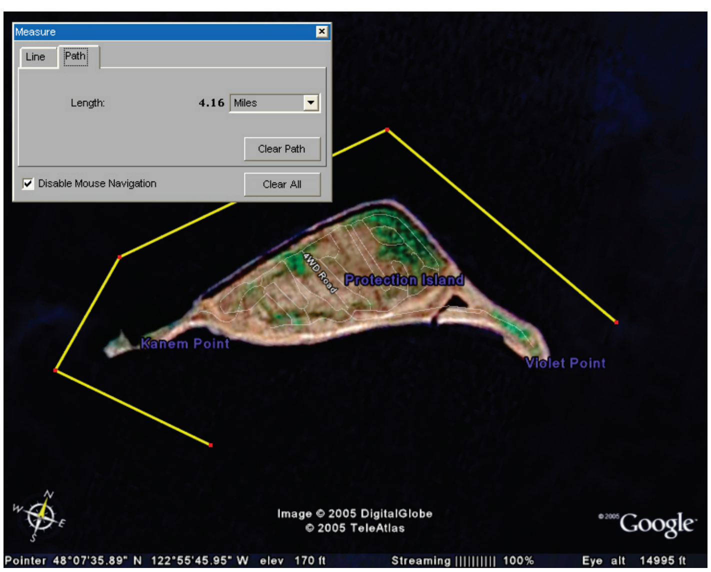
Google Earth—in a word, amazing!

Many areas of human endeavor have been changed dramatically and permanently with this new program and service from Google. If you have not tried it and have the computer and broadband connection to do it, you will be amazed.

Go to *any place on earth* and start zooming in. Then note you are getting high precision Lat/Lon as you meander along the streets and buildings of the place you chose, or as you follow a river, or check the inbound and outbound entrance lanes to the Suez Canal, or find the pyramids, or the shortest route from the Gare Montparnesse to the Eiffel Tower and what the buildings will look like along the way, and how many miles it is. There is also a route tool to measure distance along a path... and more.

Zoom in on the docks of the marina in some small bay in the middle of nowhere before you go to see what it will be like. Lay out your trip in miles counting every turn through the islands. Head north and follow the Northwest passage across Canada, or on around across cape Chelyuskin (northernmost point of Eurasia). If you have an interest in geography of the desert, of jungles, of cities, of anything, you can spend hours with this product, not to mention its value in navigation planning for areas you have not visited before. Sailing to Hawaii or the Canary Islands, just check it out to see what the bays and marinas look like ahead of time, or where the towns are relative to the marinas, and so on. Check elevations as well as distances. (We have since noted that the islands in Polynesia are of course all there, but they do not have hi-res imagery for that region, which is one of the few exceptions we have found.)

To benefit best from the program you need a new, high-powered computer, but it will work on, say, 1 GHz machine with 256 MB of RAM... and broadband connection is required. Might get a hint of what it is like with less power, but to really enjoy it, the more powerful the computer the better. After some testing, you might well consider the use of this resource as reason enough to go that extra step in specs on your next computer.



Above is Google Earth image of Protection Is. and a short route arorund it; on the right is an echart with a similar route. Each can show bearing and distance of each leg. Google Earth will also show elevations.

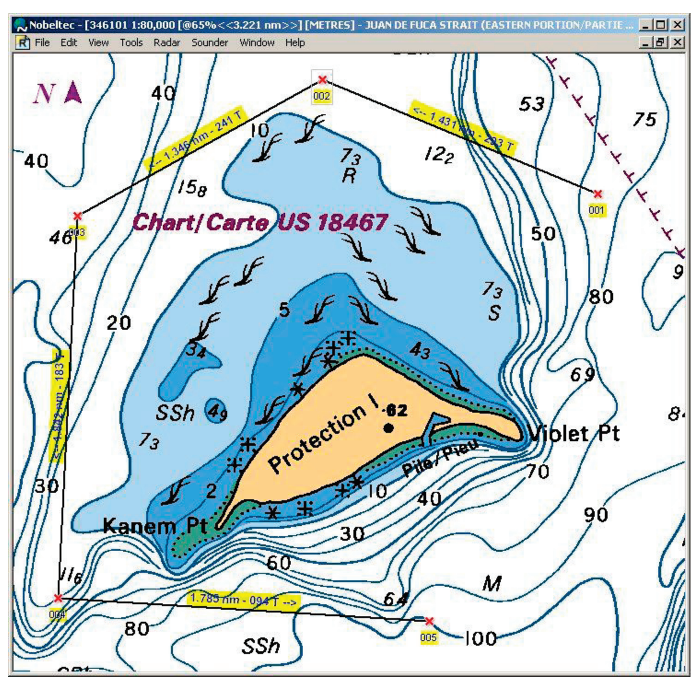
MARITIME INFORMATION NOTES

NOAA digital raster charts now public domain

The US raster charts of US waters that we all use in our electronic navigation programs (in addition to the vector charts we might use) used to be only available for purchase from MapTech or Softchart. These charts in the bsb format are now all available as a free download from NOAA. The link to read about them and download them is the main NOAA Chartmaker site. There is a headline there with the links... not to mention the many other wonderful resources at this site. They became available as of Nov 18th to our knowledge.

The files are provided in a zipped file of several related chart files. We do not yet know which of these related files are actually required to install the charts into your specific chart program (at least two of them are), but if you unzip all of them into one folder then navigate to that folder from the "install (or register) new charts" option in your charting program, the program will take the ones it needs and the chart will be available to you.

We have been told by NOAA that these online charts will be kept up to date, so if there is any doubt at some point in the future, just download the latest. The two we tested were both the latest editions. So if you have been navigating with old electronic charts primarily because of the cost to upgrade, now you can fix all that in a few minutes. Likewise, if you have not yet tried electronic charting systems (ECS) in your own navigation, now is an ideal time to start. Most of the charting programs available have a demo version that can be used for testing. Even if you do not have or desire the ECS capability onboard, the extreme value of this system for planning at home will way more than compensate for the trouble it takes to get involved.



NEW PRODUCTS

Electronic Archive of past Newsletters

It has been a big job, but it is now finished. We have scanned all of the past newsletters from 1983 to 2005, eighty-eight issues and more than 1,100 pages in all, and then converted the images to text and fully-searchable ebooks. Then we went though each issue and added bookmarks to the individual sections of each newsletter.

The documents are presented in three volumes (3 separate, but interlinked files) rather than just one large file to facilitate their reading on less than state of the art computers. Most of our new ebook products are restricted to Win XP, with relatively high memory and speed requirements, but these can be read on Win 98 machines with just modest specifications (128 MB RAM, 500 MHz processor). Needless to say, the performance is better with newer computers, but they will work if you have not updated yet. These days, newer computers have a lot to offer and the prices are very reasonable.

The Archive is available to members as a CD for $49 or as a download for $39. (The non-members price is $79.) The production work on this project has been donated to the Foundation by Starpath School of Navigation, and they will share the income with the Foundation with the hopes of eventually recovering their development costs.

You can read more about the product and the Elibra Reader that is used to access the documents at www.starpath.com/catalog/books/1710.htm. There is also a place there to order it online, or members can place their orders directly with the Foundation. Download orders must be placed online. The downloaded product is identical to the CD version, but costs less and has no shipping charge.

If you are like us, you will be fascinated by the breadth and detail of the content over the years. If you are looking for a particular subject or author, just type in a few keywords to locate all references in the Archive.

Please note that the pages of the Archive cannot be printed, other than by individual screen captures, and the product must be registered online or by telephone before it will open. A process that, by either method, takes just a few minutes. We hope you enjoy it.

REQUEST FOR CONTRIBUTIONS

Members' suggestions on what they would like to see in forthcoming newsletters.

Here is the place we will list specific suggestions for topics that members might write about if they do not already have ideas or articles in mind already that they want to share. So now you can submit what you have already written or submit suggestions on what you want to learn more about. If you then see a topic here you can answer, please send us an email and we can make an announcement in the Forthcoming Issues section. And certainly we can have more than one contributor on the same topic—as we have had in the past.

Director Roger Jones has noted that there is a lot of news these days about the apparent motion of magnetic poles, with indications of increased activity in this area. And that this would be an interesting subject to pursue. Perhaps a member might do some research on this and bring us up to date. A good place to start might be the National Geophysical Data Center, www.ngdc.noaa.govseg/geomag.

As I recall, it was a study of geomagnetism that led to the discovery, or at least confirmation, of plate tectonics theory, besides its obvious application to marine navigation—which brings to mind an interesting analogy I heard recently that illustrates what a dynamic earth we live on. Namely, that the average plate motion on earth is about at the same rate that fingernails grow.

In a forthcoming issue we will add a request of our own. An interesting math problem to be solved (or concluded that it cannot be solved) that could have valuable practical application to mariners and anyone else who might get stuck trying to find directions from the moon!

FUTURE ISSUES

One of the subjects we can look forward to is a review of the history of the Navigation Foundation, itself. There have been many prominent navigators involved with the Foundation over the years, and it has accomplished much in the past. The work on the Peary expedition is just one example. Directors Roger Jones and Terry Carraway will be putting this together for a future issue. It is a big project and worth the wait to complete.

We also hope to include an article by Leif Karlsen, author of *Secrets of the Viking Navigators*. Leif has worked for many years on the subject, especially with regard to the use of sun stones. They are more than mythology from the Sagas, and he will tell us why and how to use them, even today.

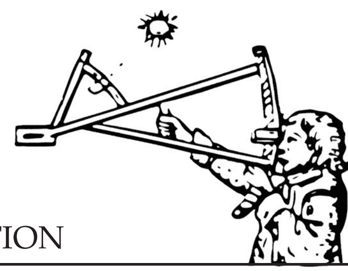
'A AMSTERDAM, chez PIERRE BRUNEL. 1702.

The Foundation for the Promotion
of the Art of Navigation
Box 1126, Rockville, MD 20850

“THE NAVIGATION FOUNDATION”

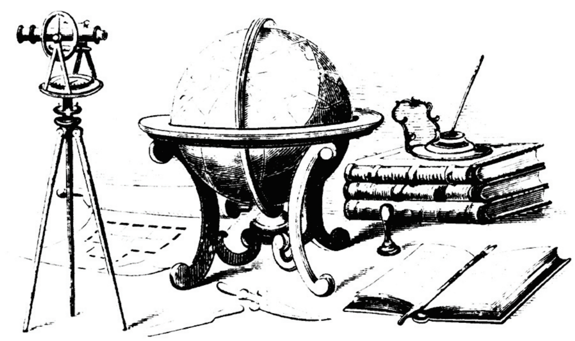
ISSUE 90, WINTER 2005

THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a reader forum for the expression of our members opinions and their questions.



ACTIVITIES

By Terry Carraway

The Foundation is dedicated to keeping the art of celestial navigation skills from eroding. The impact of multitudes of electronic navigational instruments available to the navigator discourages the more difficult art of celestial navigation with a sextant.

We also are dedicated to providing you members with alternative types of navigation. We endeavor to keep you informed so you have many different methods to choose from for your safety. Our members are from all parts of the world and have varied and interesting backgrounds. You can meet these different people through our reader's forum. Many members commence corresponding with other members who they met through the letters that are included in the quarterly newsletter.

The complete set of back issues 1 - 88 of the Navigator's Newsletter is available on CD or as a download, both with search ability. The price is $49.00 for the CD and $39.00 for the download for members. The price for non- members is $79.00 for the CD and $69.00 for the download. Members must order the CD directly from the Navigation Foundation. The download version (and non-member orders) should be ordered directly from the Starpath School of Navigation at starpath.com/navigationfoundation after first sending an email to The Navigation Foundation (navigate1@comcast.net) to verify your current membership. Likewise, if members would like take advantage of the offers in the New Products, section, please contact the Foundation. Discounts on charts are also still available.

EDITOR'S NOTES

By David Burch

This letter is just shortly behind the last, so we do not have much new input from members, as we strive to get back on schedule. We have followed up here with a detailed report on the comparison of plastic and metal sextant sights. It is long. I apologize. But we need some detail to help others make similar evaluations. Statements about sextant sights such as "I got 1.5 miles accuracy" or "I could not do better than 5 miles accuracy"—especially when taken from a moving vessel—are difficult to interpret without the details.

We have had quite a bit of feedback on the Newsletter Archive CD. Members are enjoying it and finding it very useful for looking up past topics. Some have described it as a "must-have" item. It is still listed in the New Products section, with a reminder about member discounts for courses, software, and books.

An important part of this issue is the Member's Survey to help us focus the Newsletter on your interests. Please read about it here and take part if you can.

Starting next issue we will include a new section on Internet Resources. I know from personal contact that some members do not use the Internet very much, whereas others use it extensively. The survey will help us learn more about that. But there are so many really remarkable resources directly related to the goals and interests of our members that this should be a valuable addition. Please think of suggestions you might want to include in this section. We have a list of excellent ones to begin it with. We look forward to hearing from you.

And we have a puzzle to work on if you care to, in the reactivated section on Navigation Problems,

READER'S FORUM

Member J. David Smith wrote:

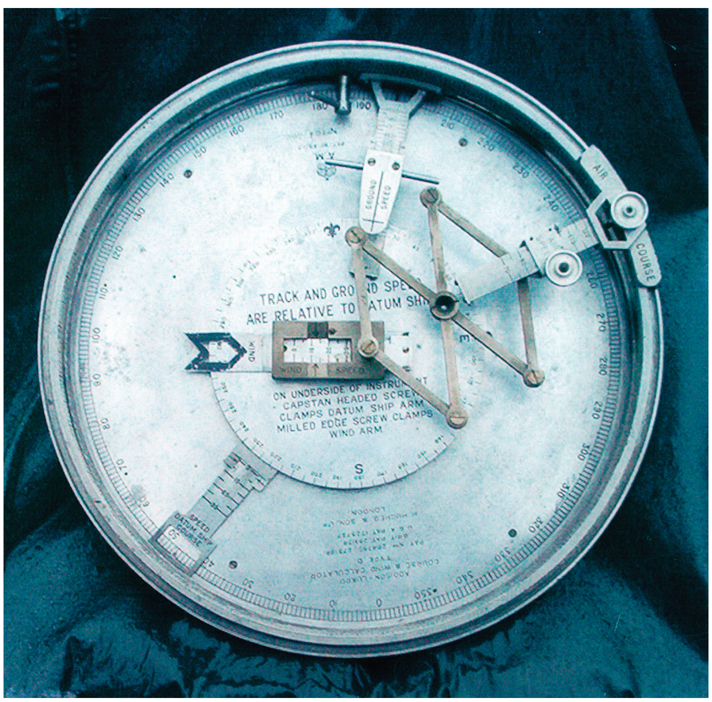
I have included a photo of the Addison - Luard Course & Wind Calculator, Type D used by the Royal Air Force in the thirties.

I rescued this from a scrap aluminum pile in England in 1944. It is 11" Dia, 3" High and weighs over 2 Lbs. The airspeed range is 70 - 120 Knots, the Datum Ship speed is 0 - 30 Knots. I was an Observer (Navigator) on a Lancaster bomber but never used this thing because I could set the resultant of wind and ship vectors on the Dalton computer to establish an air-course.

Does anyone remember using this calculator, pre-war, or know when or where it was used?

Best regards,

J. David Smith.



* * *

Member Stuart Buchmann wrote:

Dear Capt.. Carraway:

You may recall that we exchanged email several months ago. I was a Yeoman 3rd with ComCarDiv20 the fall of 1968 and winter and spring and summer of 1969. I was aboard the ESSEX for the Apollo 7 recovery.

Would you mind if I emailed you intermittently with questions about the Navy and specifically about ComCarDiv20? If I become a pest, just let me know that you do not have the time...or don't answer...I will get the message.

For now, I have a couple questions:

1. The ESSEX became the flagship not long before I arrived in August of 1968. Many of the group had served with ComCarDiv20 on that ship. What was the previous flagship. I believe it was based in Norfolk.

2. My boss was Leon "Devo" Devocaitus (sp?) who was a YN1 and became Chief after I left. I have done an Internet search for him in recent years but haven't located him. Do you have any memory of him? I thought he was a good leader. Our boss in the staff office was Wm. T. Boguslawski who was a LCDR at the time. I believe all the senior officers had been in WWII. Nearly all served in the South Pacific, if I remember correctly. My dad was an Army pilot in New Guinea and the Philippines so I manage to read as much as I can about this theater of the war. If you have any thoughts about your former shipmates at ComCarDiv20, I would enjoy hearing about them. We have covered ADM Davies pretty well previously.

Respectfully,

Stuart Buchmann

Director Carraway replied:

Dear Stuart,

Admiral Davies died in 1991. I was on his staff in the same time period as your tour of duty and stayed with Admiral Davies until he died. I still am the Executive Director of the Navigation Foundation, which he and I set up in 1980.

I sent a copy of our obituary of Admiral Davies to another member of the CarDiv Staff a few years ago. I would be pleased to send you a copy if you will provide me with your postal mailing address.

I was the Command and Control/Electronics Warfare Officer on Admiral Davies Staff. All of the people I knew were in CIC. However, Bill Boguslawski and I were very good friends. He also came to Washington with the Admiral. He was not in the military in WWII but was a child in Poland. When the war ended he was sent to Massachusetts to live with relatives. He entered the 9th grade there not speaking one word of English and graduated from college with honors. He says a German Soldier, who was a cook, gave him food and that was the only reason he was still alive when the war ended. Bill died many years ago of a heart attack. I visited him in the Naval Hospital two days before he died.

Admiral Davies, Captain Palkovic, one other Captain and I were the only veterans of WWII. Admiral Davies Served in the Atlantic, I served in Bainbridge Maryland and Cleveland, Ohio as and enlisted man. Where the others served I do not know.

CarDiv 20 started in Norfolk on the USS Randolph. We transferred to Essex RI and took the USS Essex as our Flagship. It was from Rhode Island where we went to the Med., North Sea and the crash of the Russian plane.

Much of this information is in our obituary of Admiral Davies.

Best wishes,

Terry F. Carraway

Captain, U.S. Navy (Retired)

Executive Director

Member Buchmann replied:

Dear Capt. Carraway,

Thank you for the interesting reply. It is great of you to respond.

I do not recall ever hearing the story about LCDR Boguslawski. At our office at Quonset Point, my desk and his abutted one another so we became as well acquainted as an officer and enlisted man might. I just do not remember him telling us about his experience during the war. I do regret hearing of his death, and I am grateful that you were able to attend his bedside in his waning days.

As for the obit on ADM Davies, you mailed that to me last year and I was really pleased to receive it. I was surprised to learn all of the things he had accomplished while he was a naval officer.

Also, when I first joined the staff, there a CAPT Macon (I believe was his name). I was thinking he was Chief of Staff and CAPT Palkovic later took his position. Anyway, he was there for a few months. CAPT Macon reminded me a lot of the actor, Trevor Howard. Also on staff were CDR Youngblood and CDR Jack Marriott. I would have thought these two, along with CAPT Macon, would have been of WWII vintage also.

You mentioned being at Bainbridge, MD as an enlisted man. In 1968 I attended Yeoman school there before reporting to ComCarDiv20. By May, 1968, Bainbridge was a ghost base. There was a WAVE boot camp still there and the Yeoman School and a Radioman school there plus a support contingent. There were acres and acres of abandoned barracks. Despite the dreariness of the place, it was well kept and there were certain events and things which happened there that helped to endear me to the Navy. I had been there only two days and was really in the dumps. The base staff sponsored a Memorial Day picnic and the site was a really nice wooded park. I didn't want to go but found out the chow hall was not open on the Memorial Day holiday. The officers and their wives served us our meal. As a kid, I had never relished (no pun intended) a hot dog much. I was so hungry that day that I ate more than one and have been eating and enjoying them ever since. With relish, even. I have even been eating cole slaw ever since, too. Anyway, being at Bainbridge started me off on the right track.

Besides the picnic lifting my spirits, the over all experience that I had at Bainbridge taught me a lot. There I learned that the Navy was interested in me and would encourage me along the way and acknowledge my accomplishments. All I had to do was make the effort. I did, and I eventually ended up at CINCLANT / CINCLANTFLT headquarters with a terrific job. Before the Navy, I bungled an attempted at college. When my enlistment was up I got out and returned to Kansas and breezed through college. The short version is that I owe the Navy a lot.

I was thinking that ComCarDiv20 had another flagship after the RANDOLPH and before the ESSEX. INTREPID, maybe?

Respectfully,

Stuart

Director Carraway replied:

Stuart,

You are correct on Youngblood and Marriott was there but too young to have been in WWII, maybe Korea. When you arrived I think Capt. Butts was Chief of staff and Macon was operations.

Intrepid was assigned as our flagship but we never deployed on her.

There is nothing a Bainbridge now that I know of. It has turned into a bigger ghost town than when you were there. My tour at Bainbridge there was 4 regiments each with 4 battalions. Four large drill halls and schools for everything. I went to radio school after finishing Boots and a short tour in the IGU (Out going Unit) standing guard duty.

Hope this helps you remember.

Terry Carraway

* * *

The Navigator's Newsletter
Issue 90, Winter 2006
Published by
The Foundation for the
Promotion of the Art of Navigation
www.navigationfoundation.org
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Rockville, Maryland 20850, USA
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Inquires about membership or Newsletter content or contributions can be send to the above address or by email to navigate1@comcast.net.
The Navigator's Newsletter is published four times annually, with our strived-for publication dates of approximately the solstices and equinoxes.
Newsletter production and other Foundation activities are provided by volunteers. Please bear with us if we slip on the dates occasionally.

Member Dan Cline Wrote:

Dear Terry,

I just received your welcome letter and back issues of the Navigator's Newsletter. Thank you, and I'm looking forward to learning more about the Foundation.

I was recruited by David Burch, and am a "newbie" to celestial navigation and to the study of navigation in general. My formal training in navigation has been primarily through Starpath Home study courses. I'm and attorney by profession and enjoy sailing on Lake Michigan with my wife, Linda. I have a great deal of experience working with tax-exempt charitable organizations, both as an attorney and board member, if this background can be of any help to the Foundation, please do not hesitate to ask.

Operating an all-volunteer organization has to be challenging, to say the least, and I thank you for your efforts. Can you give me some idea of the number of members the Foundation currently has. Would you characterize them as primarily celestial navigation experts?

Dan

Director Carraway replied:

Dear Member Cline,

Thank you for the nice email. As you now know David Burch is our new Editor. Our first newsletter under our new editor is in the mail. However, I do not know if I entered your name and address in our database before I printed out the mailing labels. If you do not receive the navigator's Newsletter Issue #89 in a few days let me know so I can send you a copy.

I thank you for your information as having worked the legal problems of tax-exempt organizations and all volunteer organizations. So far, as a non lawyer, I have beat back the challenges to our status by the IRS, State of Maryland and others who want to tax or destroy us. It has been a challenge but really fun. It keeps me young. After serving 38 years in the U.S. Navy, I have administered The Foundation for 23 years.

Admiral T. D. Davies and I started this organization in 1980 and received our tax-free status in 1983. As being junior to Admiral Davies I was the DJJO, a navy term which means, "dirty little jobs officer." It was my pleasure to be such because he was such a brilliant man. If you would be interested I would be pleased to send you our Newsletter of his obituary that Roger Jones and I compiled.

Thank you for your interest in The Navigation Foundation.

Sincerely,

Terry Carraway

Executive Director

Member Dan Cline replied:

Thank you, I would be very interested in receiving a copy of Admiral Davies' obituary. After a little searching on the Internet, I discovered he was formally involved in nuclear non-proliferation with ACDA. While in law school I took a very interesting course on international arms control from Prof. Eric Stein – perhaps you had the opportunity to meet Prof. Stein, who was my favorite law professor.

Dan

Director Carraway replied:

I will send you Admiral Davies obituary. I was his DLJO (dirty little jobs officer) from 1969 until he died in 1991. I still strive to keep the Foundation going in his memory. I was his military liaison for two years when he was in ACDA and participated in a couple of negotiations with the British and Russians as a technical adviser. I know the name of Professor Eric Stein but never met him personally.

Terry

* * *

Editor's notes:

The obituary of Admiral Davies is presented in the Newsletter, Issue 31, page 1-5. An extended version will appear on the Foundation website (navigationfoundation.org) in the near future.

The composition of member interests will be summarized shortly in the Newsletter when we receive and compile the survey included with this issue.

NAVIGATION BASICS REVIEW

Comparing Plastic and Metal Sextant Sights

Summary: We did sun and moon sights underway and on land using metal and plastic sextants. Each of the average intercepts below represent 4 or more sights. The sun-moon sights were used for running fixes. Details are given below. No special analysis was applied. The averages include *all sights taken*. All can be improved with more careful analysis. Shown here are intercepts from a precisely known GPS position.

1. Metal underway moon	0.9' T ± 1.7
1. Metal underway sun	0.1' A ± 1.3
2. Plastic Mk 15 underway sun	6.7' A ± 1.4
2. Plastic Mk 15 underway moon	4.3' A ± 1.4
3. Plastic Mk 3 underway moon	8.4' T ± 2.5
3. Plastic Mk 3 underway sun	5.8' T ± 2.5
4. Metal underway sun	1.6' T ± 0.4
5. Plastic Mk 15 underway sun	5.1' A ± 1.0
6. Metal on land sun	0.5' A ± 0.6
7. Plastic Mk 15 on land sun	4.0' A ± 2.3
8. Plastic Mk 3 on land sun	1.6' T ± 1.6

Format notes: We use here the StarPilot celestial calculator input format for all angles, since that is the way we did the sight reductions, i.e. Lat 48° 25.6 N = 48.256, and Lon 125° 55.9'W = -125.559 (west is minus, east is positive). For sextant angles, Hs = 33° 02.5' = 33.025, etc. Times are likewise represented as decimals. 13h 23m 44s = 13.2344. If a time has no seconds it is 12.45. We need to be clear on the zones, however, as several were used.

Sights underway

The route was Victoria, BC to Maui HI, on a Beneteau 455f sailboat during a yacht race. We were a crew of 8. Sights were all taken by the author under spinnaker in trade wind conditions, that is surfing in 6- to 8- foot seas with speeds varying from 7 to 14 kts and headings varying some ± 20° or so—not ideal conditions for celestial sights, but still doable, which is one of the points we wanted to make with these data. The motivation for doing them at this particular time was a recent magazine article that raised the issue of cel nav accuracy in general, on land vs. underway, etc. Indeed, one set of sights (first listed below) was taken standing at the boom, directly in the "line of battle"—that is halfway between a food fight from the bow to the cockpit, which occurs in the normal course of events on a racing yacht once a case of spoiled bread rolls is discovered. This involved some dodging of the missiles and the occasional crash of a bread roll on the side of the sextant… again, not ideal conditions for precision work, but at least not boring, even a bonus for the present study of environmental effects on sextant accuracy.

Taking sights on the cabin top. Normally, though, one would stand at the shrouds, or aft near the running backstays. This was to avoid the food fight!

Log of positions

PDT	GPS positions	CMG	SMG
15.44	32.067, -142.246	—	—
17.06	31.594, -142.259	186 T	8.2 kts
17.19	31.555, -142.262	188 T	8.9 kts
17.54	31.489, -142.262	187 T	8.1 kts

Sight notes: At 15.44 PDT on July 5, 2000 our GPS position was 32.067, -142.246. At that time, the indicated SOG was 8.5 kts, and the COG was 185 T. Above we show the averages made good for several intervals that span the sights. Air temperature was 80° F, pressure was 1028 mb. The sun was bright and very hot. Height of eye was estimated to be 11 feet (standing on cabin top, heeled over more often than not), Watch error was 4 s slow. All sights reduced by the Starpath StarPilot cel nav calculator. IC = 0.0 (4 measurements taken after the sights using the horizon: 0.2' On, 0.0, 0.0, 0.0. Note this sextant has historically had 0.0 for IC, checked several ways on land over the past year or more, although in subsequent measurements taken a week later on land in Maui I got 1.0' On as the average of a long series of measurements… so far I do not know the explanation of the latter result. It was applied to the land sights but not to those underway. Sometimes refraction can affect these things as well as psychological effects having to do with the actual colors of sky and ocean, relative brightness, etc.

For an AP or DR position to use for the sight reduction, we will just DR from the 15.44 position using average values made good to a later accurate position recorded at 17.06 of 31.555, -142.255. At this time recent values of SOG, COG were about 8.5 kts at 185 T, about the same as when we started. Unfortunately, these are the only two real positions we recorded in this interval. These two times and positions yield a CMG of 186 T and an SMG of 8.2 kts (from the StarPilot Rhumbline function). Now we choose (arbitrarily, since it doesn't really matter which we use) 16.20 as the "sight time" and our DR position at this time was 32.018, -142.252 from the StarPilot DR-update function.

***

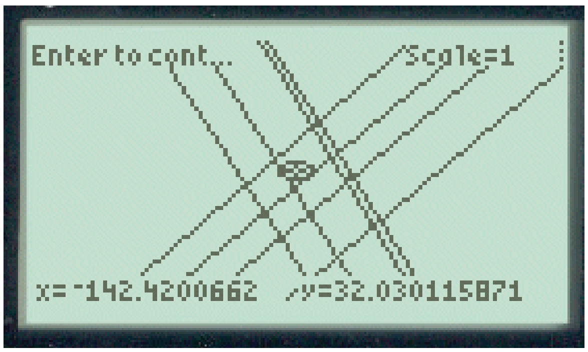
Set 1: Metal Sextant: 15-year-old forerunner of the present day Astra 3b from China. The new models are much nicer, but this one has served us well over the years. First intercepts are for S=0 and constant DR = 16.20 position, second set are advanced to actual sight times using 8.2kts at 186T (set StarPilot DR mode to Speed/time then update DR at each sight).

Upper limb of the moon (16.20 DR)

WT (PDT)	**Hs**	**a -value** (16.20 DR)	**a -value**
16.1220	51.115	1.0' A 115.7	0.6' A 115.7
16.1420	51.370	2.4' T 116.2	2.6' T 116.2
16.1533	51.490	1.0' T 116.5	1.2' T 116.5
16.1710	52.060	0.2' T 116.9	0.4' T 116.9
		avg. =	0.9' T ± 1.7

Lower limb of the sun

WT (PDT)	**Hs**	**a -value** (16.20 DR)	**a -value**
16.1954	64.396	1.2' T 254.8	1.2' T 254.8
16.2114	64.224	0.3' T 255.1	0.3' T 255.1
16.2222	64.072	0.9 A 255.4	1.0' A 255.4
16.2350	63.494	0.7' A 255.8	0.8' A 255.8
		avg. =	0.1' A ± 1.3



Plot output from the StarPilot calculator. All a-values shown here are relative to the 16.20 DR position, updated with the CMG, and SMG in effect at the time.

If we assume the DR is correct (not too good an assumption in our conditions) then the second set of intercepts is a measure of our accuracy. The average of the moon sights is 3.6/4 = 0.9' T. The average of the sun lines is -0.3/4 = 0.1' A. The spread is about ± 1' in each case, but we can later do better by a careful slope analysis of this data. In the meantime, the running fix obtained at 16.20 *using all the data* is off the DR position by 1.3 miles. Since our DR was likely uncertain by 0.5 mi or so, this is not bad. Later we will see how we can improve on this with the slope analysis to sort out which of the sights were best — or maybe it will get worse, we don't know yet. Note it is a good sign that the sights are a mixture of Toward and Away, which gives hope that the errors are more random and systematic.

***

Set 2. Mark 15 Plastic sextant. The main issue with plastic sextant sights is the IC. Notes are below, the IC for the sun sights is taken to be 1.6' On the scale ± 2.4'. For these we will just update the DR using the logbook data above for each sight (15.44 to 17.06 for the sun lines, and 17.19 to 17.54 for the moon lines). Temp, Press, WE, HE are the same as Set 1. DR updated at each sight.

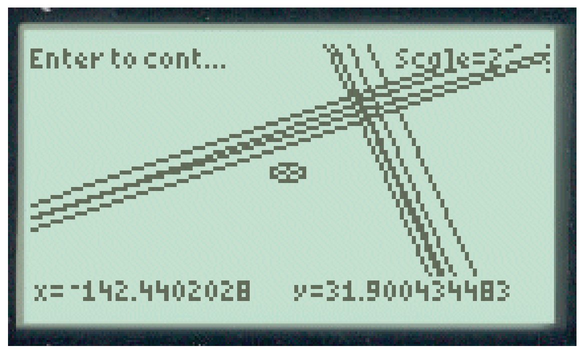
Lower limb of the sun

WT (PDT)	**Hs**	**a -value**
16.3600	61.152	6.3' A 258.6
16.3655	61.020	8.1' A 258.8
16.3743	60.540	6.2' A 258.9
16.3837	60.420	7.0' A 259.1
16.3917	60.350	5.7' A 259.2
		avg. = 6.7' A ± 1.4'

Then we ran for about an hour doing sights with other sextants, and resting from the heat of the sun. Then returned to the Mk 15. We will use these two sets of Mark 15 sights for a running fix. For the moon sights IC = 3.1' On the scale ± 1.0'. See IC notes below.

Upper limb of the moon

WT (PDT)	**Hs**	**a -value**
17.2557	63.153	4.6' A 139.9
17.2853	63.372	5.7' A 141.2
17.3001	63.488	2.9' A 141.7
17.3150	64.015	4.0' A 142.5
		avg. = 4.3' A ± 1.4'



From DR (circle with the cursor in the middle) to the center of the LOP intersections is 10 miles. Slope analysis might improve this by 2 miles or so.

The spread is not at all bad for a plastic sextant: 6.7' A ± 1.4' for the sun and 4.3' A ± 1.4' for the moon, but it is disconcerting that all sights are in the same direction , i.e. Away. This is almost certain proof that there is some systematic error in the data. Note that if the intercept (a) is Away = Hc - Ho, then Hs is too small, which means the 2 or 3' we took off in the IC was too much — or simply the sights are all just too low by that amount. For example, in the last sight if the IC was not -3 but +1 (ie 1' Off) then the a-value would have been about 0. The 17.30 fix obtained *using all sights* is 10.2 miles off of our 17.30 DR. This is a rather poor fix, but we do not have good IC data and the sights themselves were not taken in the proper manner as discussed in Issue 89.

It is fair, however, to say that the sights themselves were only in error by 4.3 miles in one case and 6.7 miles on average in the other, and to stress that the error was in the same direction. This combination of LOPs gives a larger error in the two-body fix, BUT, with a well chosen set of 3 stars, near 120° apart, this near constant error would indeed cancel in large part, and yield a reasonably accurate fix. This is why it is so important to use star sights for fixes, not just running fixes with the sun. Even adding the moon does not help this.

It is interesting to note that the average a-values differed by 6.7 - 4.3 = 2.4 is very roughly the same as the difference in IC's used (3.1- 1.6 = 1.5). In other words, the moon sights would have been 2 miles better using the sun line ICs… but all this is pure speculation, we simply have no better data at present. Later we will do the slope analysis to see if that helps, but we are rather out of range of those corrections.

Notes on the Set 2 Index corrections

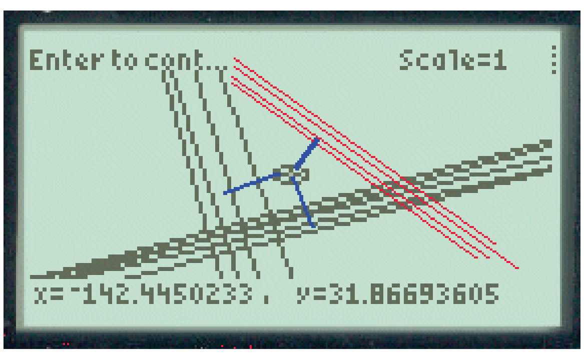
The index corrections were measured several times, but unfortunately not following the careful procedure described in Issue 89. They were just taken in the Toward and Away (up and down) directions before and after each set of sights. Notation: "A3.2 On" means the IC was measured turning the micrometer drum in the Away direction and the value was 3.2' On the scale. See article in Issue 89 for more details on plastic sextant IC measurements.

<u>Before the sun sights (16.32)</u> we have 5 measurements:

A 4.2 On	T 0.5 On
A 4.0 On	T 1.5 On
A 3.2 On	

<u>After the sun sights (16.40)</u> we have 7 measurements:

A 2.2 On	T 2.5 On
A 0.0 On	T 2.0 On
A 0.0 On	T 1.0 Off
	T 0.0 On



From DR (circled) to the center of the true LOP intersections (black lines, left and bottom sets) is 13 miles. The red lines (top-right set) are added to show hypothetically what it might look like if these were 3 star sights with the same approximate constant errors (blue lines, emanating from the center) in each set of sights. In this case, the center of the "cocked hat" is a fairly good fix, even though the individual sights were off by some 6 or 7 miles each. This fact is even more important to plastic sextants than to more accurate ones made with a metal sextant.

Since these were not done with the "touch and leave" procedure and the sights themselves were not taken with the "set and wait" procedure (Issue 89), we do not have such nice results to work with. So for now we just do some averaging and note our uncertainty. The average of all 12 is 1.6' On . The average of all 12 minus the highest (4.2 On) and the lowest (1.0 Off) is also 1.6' On. For now let us just say the IC = -1.6' and the uncertainty is ± 2.4' for all the sun sights.

<u>Before the moon sights (17.22)</u> we have 4 measurements:

T 4.0' On	A 4.0' On
T 4.0' On	A 4.5' On

And after the moon sights (17.33) we have 4 again:

T 1.0' On	A 3.0' On
T 1.5' On	A 3.0' On

Here the average before the sights was 4.1' On and the average after the sights was 2.1' On. For now we will just say that for all moon sights IC = -3.1' and the uncertainty is ± 1.0' Again, we might do better with a more systematic approach but even with this data we are near the limit of plastic sextant accuracy so there is little justification for it.

***

Set 3 Mark 3 plastic sextant. This is the bottom of the line plastic sextant. It does not have a micrometer drum but rather a large vernier scale. It can be read to a precision of only 2'. They sell new for about $50, but are easy to find in swap meets or used marine gear stores for 10 or 15$. We used to have many of these, but they are gone. We bought this one new for these tests.

Notes on Set 3 Index corrections

For the sun sights we set the IC to zero before each sight by adjusting the mirrors and then immediately proceeded to take the sight without further tests of this setting. During the subsequent moon sights and then later on land in Maui, I discovered that whenever I set it to 0 by eye and then measured it I would get 6' Off the scale. This result was rather surprisingly consistent and reproducible…which only goes to show that the use of plastic sextants takes time and study… you must learn your "personal errors" — a term described in Bowditch and elsewhere regarding sextant sights. When we did use this type of sextant in class in the early 80's, we would set them to zero, then paint up all the adjustment screw threads with fingernail polish so they could not turn. It seemed to work well, so we never did do any systematic studies. For now we have this large uncertainty floating around, but it turns out to not make that much difference: first we reduced with 0 for sun lines and +6 for the moon lines, then repeated with + 3 for all sights and got the same answer.

(For the Mark 3 models, adjusting IC to 0 before each set of sights is a good way to proceed, then check it after the sight session as well, and then average the results. This is definitely not good procedure for metal sextants and we do not even do this for the model 15 or 25 plastic sextants.)

Lower limb of the sun

(DR updated at each sight, IC = 0)

WT (PDT)	Hs	a -value
16.5047	58.18	2.7' T 261.5
16.5419	57.38	7.1' T 262.2
16.5643	57.06	5.3' T 262.6
17.0027	56.22	8.3' T 263.2
	average: a = 5.8' T± 2.5	

Upper limb of the moon

(DR updated at each sight, IC = +6)

WT (PDT)	Hs	a -value
17.4106	65.10	7.3' T 147.0
17.4147	65.16	6.2' T 147.5
17.4420	65.35	10.9' T 148.6
17.4750	65.54	8.0' T 150.5
17.4853	66.02	9.7' T 151.0
	average: a = 8.4' T ± 2.5	

These sights *all together* give a 17.45 running fix which is 13 miles off the DR at that time. A slope analysis could improve this if it showed that the lower sights were better. Note an intercept labeled T (= Ho - Hc), means the Ho were too big, which most likely means the +6 IC was too big…. If we had used 0 as in the sun lines, each of these moon lines would be 6' lower and the fix much improved. Unfortunately, we did not have enough time to play with this underway.

In short, we did not do very well with these sights, but since they are all Toward it implies there is definitely some systematic error… or the instrument is just off that amount. Later — I do not know the answers yet — we reduce and report on the land measurements made with this instrument and that may shed some light. Note from the plots that the scatter in the sunlines was also larger than with the moon lines which is what we also got with the other plastic sextant. There was a bright glare from the sun during both of these sets so that might have contributed to this.

***

Set 4 Metal sextant underway

PDT 7/9/00 GPS positions (same sextant as before)

11.37 24.141, -151.290

11.50 24.126, -151.304 CMG = 221 T, SMG = 9.1

12.11 24.106, -151.327 CMG = 226 T, SMG = 8.3

T = 80, P = 1030, HE = 11, IC=0, WE = 5s Slow.. notebook states "VERY HOT with much glare"…. And my old sextant did not have good horizon shade options (the new models have this corrected) so sights were done without horizon shades with consequently not a very good horizon. (High quality shades are a big factor in sextant usage underway.)

Lower limb of the sun

WT (PDT)	Hs	a -value (DR updated to each sight)
11.4046	41.450	1.5' T 081.1
11.4231	42.084	1.5' T 081.3
11.4359	42.264	0.1' A 081.4
11.4544	42.518	1.8' T 081.5
	average = 1.6' T ± 0.4 or so…	

The results are not too bad for the conditions, poor horizon and surfing in big seas. The positions used for comparisons cannot be too poor, however, since we only ran for 2 miles during the sights. Here we really must consider the "best sight' (0.1') as an anomaly and more likely the average with the poor horizon was more like 1.6'.

Set 5 Plastic Mk 15 sextant underway

Notes on IC… again, I did not do proper "touch and leave" measurements, so the data are not as good as they could be. Also the sights themselves were not taken in the "set and wait" procedure, so we don't know which to use anyway.

Before sights at 11.56:

T 3.0 On A 7.0 On

T 3.0 On A 6.5 On

After sights at 12:05

T 5.0 On A 8.0 On

T 5.0 On A 7.0 On

T 5.0 On A 6.0 On

Hence we will just average all of them and use: 55.5/10 = 5.5' ± 3 On the scale for all sights. Again, in principle we could do better if we followed the methods of Issue 89. HE, WE, T, P same as in Set 4. DR using logbook of Set 4.

Lower limb of the sun

WT (PDT)	Hs	a -value (DR updated to each sight)
11.5846	45.460	4.4' A 082.4
11.5938	45.575	4.6' A 082.4
12.0100	46.154	5.1' A 082.5
12.0443	47.044	6.1' A 082.8
	average = 5.1' A ± 1.0	

Again, the spread is not bad, but we are fighting an unknown IC in this case with an uncertainty of 3 miles. But we can at least say that the sights are accurate to within about 5 miles without any sophisticated analysis at all…which is one of the points we wanted to make in the letter to magazine. And these are underway, in poor but realistic conditions. Not on land.

***

Set 5 Metal sextant underway

PDT 7/2/00 GPS positions (same sextant as above)
16.04 37.280, -133.574
16.47 37.233, -134.028 CMG = 222 T, SMG = 9.0
All data same as earlier sights but
WE = 3s Slow, T = 70, P = 1030.

Lower limb of the sun

WT (PDT)	Hs	a -value (DR updated to each sight)
16.3236	54.080	0.2' A 257.1
16.3404	53.521	0.8' T 257.4
16.3527	53.356	0.2' T 257.7
16.3748	53.100	1.7' T 258.2
16.3943	52.484	2.2' T 258.6
	average of all = 0.9' T ± 1.0	

This is a good example of where fatigue or over confidence may have entered in. They were going well till the last two. Also, as we will see later, the slope analysis will help sort this out since they are so different — it will definitely reduce the size of the error bar. Again, in any event, one can conclude that the cel nav LOP was right to within 1 mile. Note that these were actually the first sights done underway, but were in the back of the notebook. I am pleased to observe that one does remember how to do this after not having actually done sights in the ocean for more than two years…. But then again, it is not really much different from doing them on land… even surfing around in a seaway.

***

Set 6 Metal sextant on land

Overlooking the beach on Maui at 20.5753, - 156.4110. July 12, 2000. Very hot. Shade temp = air temp = 85° F, but leaving the thermometer in the sun it heated to 111° F in about 20 minutes. In short, if a plastic sextant is going to go weird in the sun, now will be its time! HE = 17 feet (measured to the foot). Sight times in HST (ZD = +10). WE = 6s Slow. Pressure was 1018 mb.

Note on IC. As mentioned earlier, I found an unusual IC for these sights on land since this sextant has usually had a 0.0 correction. The data were (all On the scale): 1.5, 1.0, 1.2, 1.0, 0.8, 1.0, for an average of 1.0' On the scale, which is what we use here.

WT (HST)	Hs	a -value (DR = actual position = constant)
17.4149	18.401	0.5' A 286.8
17.5323	16.060	0.3' A 287.6
17.5509	15.426	0.2' A 287.7
18.2131	9.537	1.0' A 289.6
18.2256	9.362	0.0' T 289.7
18.2406	9.196	1.4' A 289.8
	average of all = 0.5' A ± 0.6	

A better average would be to throw out the last (boredom factor) and get 2/5 = 0.4 ± 0.4. I have not done it yet, but am willing to bet that a slope analysis will throw out the two high ones, leaving a much better fix, which is more typical of careful sextant sights on land.

***

Set 7 Mark 15 plastic sextant on land

Note on IC: Unfortunately, again, a careful job in this was not done, but it was these measurements that in part lead to the formulation of proper procedures listed in Issue 89 of this Newsletter.

Here are the recorded data.

17.45	T 4.0 On	A 1.0 Off	…just after first sight
17.56	T 1.0 Off	A 0.0	… just before 2nd sight
	T 1.0 On		
18.04	T 0.5 On	A 5.0 Off	… after last sights
	T 0.5 On	A 5.0 Off	

For now, we just average all of these and use that and note the uncertainty. We get 6 On and 12 Off = 6 Off / 9 = 0.7' Off with an uncertainty of ± about 4'. One can do better as we will show later on doing more sights with good procedures. For now: IC = 0.7' Off for all sights. Else, same data as in Set 6.

WT (HST)	Hs	a -value (DR = actual position = constant)
17.4435	17.556	6.3' A 287.0
17.5850	14.472	4.9' A 288.0
18.0040	14.244	3.4' A 288.1
18.0251	13.574	1.5' A 288.3
	average = 4.0' A ± 2.3'	

Note that not only is there clearly some systematic error, i.e. all are Away, but there is also a trend, the a-values getting smaller… in this case it is towards better sights, but that is not significant. The bigger worry is that it does seem to be changing. It is definitely possible that this sextant was not in equilibrium with the local temperature which was extremely hot. In any event, for now, we concentrate on the value itself… 4 miles. Which is not bad for a plastic sextant, even without special care and in the burning sun!

***

Set 8 Mark 3 plastic sextant on land

Note on IC: The measured IC of the instrument was 6' Off the scale. It was this before the sights and after and it is the same as it was underway. Also as mentioned earlier, I can take this one and twiddle the mirrors and then reset them to what appears to be zero when viewing the horizon, and then twiddle the index arm and measure the IC and get 6' Off again. This is a bit surprising, but we will live with it. Take our small blessings as they come. We call the IC 6' Off the scale. Else data are the same as in Set 6 and 7. Recall this sextant can only be read to a precision of 2' and that requires the use of a vernier scale.

WT (HST)	Hs	a -value
		(DR = actual position = constant)
17.5057	16.34	2.4' T 287.4
18.1313	11.40	3.3' T 289.0
18.1419	11.24	1.8' T 289.1
18.1633	10.54	1.2' T 289.3
18.1757	10.34	0.5' A 289.4
	average =	1.6' T ± 1.6

This of course is most excellent, and must be considered part luck. One should consider a consistent under 10 miles as good for this device. On the other hand, it is not surprising to us to see the Mk 3 do as well as the Mk 15. We have noticed this in the past. I am not sure it will hold up if we use good (Issue 89) procedures with the Mk 15. Part of the reason is, you must always move the index arm in the same direction. At least with my operation of it, the only way I can very carefully squeeze and push it to a new angle is to push it down. So if I am below the angle, I must crudely set it too high and then carefully push it down. In other words, the very simple design of the instrument forces users to operate it in a consistent way. And — most important — this is the same motion needed to check the IC, so both are done in the same manner. Also, since there are no optics and the arm is so difficult to set carefully, one is forced to use the "set and wait" method discussed of Issue 89, which is the best way to do plastic sextant sights.

Note in closing: We used the Mk 3 and earlier the Mk 15. But the actual top of the line in plastic sextants is the Davis Mk 25, gray plastic with full view mirror. We did not use it, simply because we did not have one —and we did have this old Mk 15, which turns out to do a fine job.

Hopefully we have made our point about sextant sights. It has taken a lot of time to document what we and many others knew is true without these most elementary examples. With this Newsletter publication, we can now archive this and not have to do it again. We do have much data in old logbooks that can be rejuvenated for more examples.

Later we can follow up to show how 3 well-positioned stars can provide an accurate fix even when each of the individual LOPs is off by some constant amount, as is common with plastic sights. This will clearly show how you can with a plastic sextant get consistent fixes within 5 or 6 miles, even if each of the sights themselves may be systematically off by this amount or even more. And we might want to write up how we can apply what we call the "slope method" to improve the analysis of these or any other set of sights.

REQUEST FOR CONTRIBUTIONS

Member's Survey

Our goal is to have the Newsletter meet members's needs and desires as best we can. The Foundation has been active for many years. We have long standing members and new. We have members with tremendous knowledge of navigation and we have those just learning. My guess is, there is a large number of members who have a sound knowledge of the basic techniques but desire to take that extra step to being even better--better in the sense that you have more versatility and more accuracy—able to solve problems in unusual circumstances, or saving a set of sights that others might have to give up on, and these days this might just mean—or better in the sense that you now understand some new aspect of Lewis and Clark's navigation, or knowing what instruments or knowledge was available to Columbus at the time, what was the change he actually used them, or what were the likely uncertainties.

By the way, though many of us might have strong criticisms of Columbus as a person or even as a navigator in general, there is no doubt at all that he was an absolute master at DR. And this in itself is a tremendous lesson to even modern ocean navigators. Accurate DR remains the key to ocean navigation, even in the age of GPS, or maybe even more so. When taking that extra step mentioned above, there is much value to spending sometime on the history of navigation and the old methods.

We have members who are active navigators at sea and in coastal waters and we have many members who are devoted to the theory, practice, and history of navigation who do not have immediate or even eventual plans for putting it to use in person at sea. The strength of the Foundation is the bringing together of all of these backgrounds and interests to help promote the art of navigation.

We also certainly have members who wish to take a more active part and some who support the goals of the foundation but do not wish to, or cannot at the moment, take a more active part.

We cannot discern these distinctions from membership records alone, nor do we know of your individual interests and personal goals as members. We do get some correspondence and we encourage that. But with your help on this survey we can take a giant step forward in making the newsletter better serve your needs and those of the Foundation. With your help it will not take long till you will be fairly sure that you find not just new information on various aspects of navigation in the next newsletter, but also something directly related to your own personal interests.

...Not to mention that this is the only way we can learn about our fellow members and the overall make up of the Foundation. I do not mean a directory list (we have not had any call for that) but just an anonymous summary of the survey results, showing the makeup and interests of the membership. So please help out and send in the survey. The sooner we get the results, the sooner we can direct the content of the Newsletter to your desires.

NEW PRODUCTS

Navigation courses, print and software

The Starpath home study navigation courses are now available to members at a 20% discount. The course fees include access to an instructor online throughout the training. The course fees (with discount) are $127.20 for either celestial navigation or coastal navigation. These can be ordered directly from the Foundation. They are described in detail at starpath.com. Starpath software products described there are also available to members at a 20% discount.

Newsletter Archive

All 88 issues from 1983 to 2005 on one CD. Available from the Foundation for $49. Fully searchable and easy to use. See Activities note.

Books and Nav pubs

Remember that members also receive a 20% discount on books and publications from celestaire.com and from paracay.com. They each have a large selection including Bowditch, the Nautical Almanac, sight reduction tables, and much more. Their support of the Foundation is not new, but each offers new products on a regular basis. These products can located at their websites, and then ordered directly from the Foundation.

A NAVIGATION PUZZLE

Where's Waldo

Here is an illustration from Frances Wright's booklet entitled *Particularized Navigation—How to Prevent Navigational Emergencies* (Cornell Maritime Press, 1973). It is obviously a decorative cartoon, not intended as a scientific illustration, but definitely showing one way to measure the height of the sun—a small-scale version of what Tycho Brahe (the experimentalist) used to learn enough about celestial bodies in the late 1500's that Kepler (the theorist) could then develop the first realistic model of the solar system. The mariner's ring and simple quadrant are similar devices used in that era and earlier.

A close look at the cartoon shows a zenith distance of 39°, corresponding to a sun height of 51°. Let us presume that this is a precise value, made from the average of many measurements. We do not know how Waldo came to his conclusion about his location, but a common way to find latitude with such a device is a noon sight. For the sake of this puzzle, let us then presume that he has based this conclusion on a noon sight, and that this was the peak height he observed at LAN.

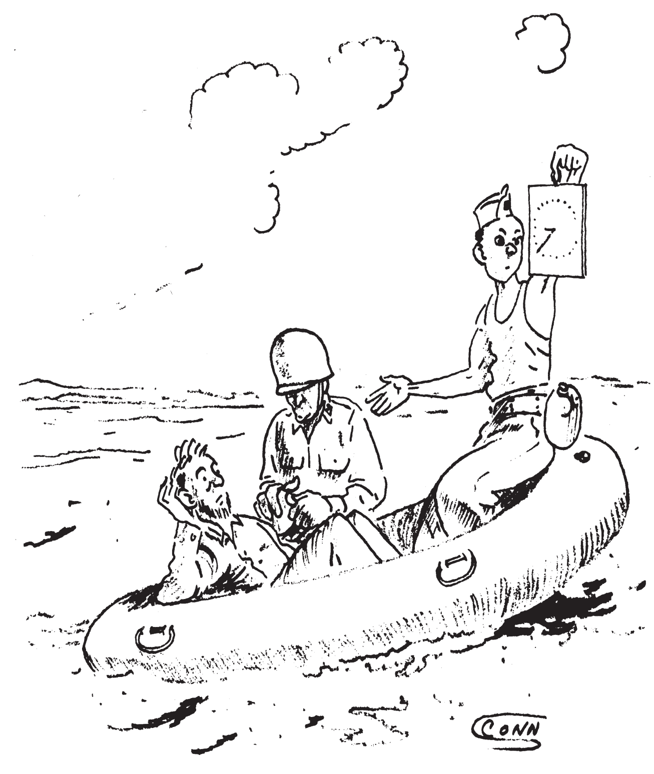
Since he is an ocean-going navigator, we know he means "...2000.3 *nautical* miles south of Honolulu," which we will assume means Diamond Head light at Latitude 21° 16' N.

So the question is, if he is doing a noonsight here, how accurate is he. In other words, knowing what we know, what is the *minimum* uncertainty in his conclusion? The answer should be a number of nautical miles, with a brief explanation of your reasoning.

You can email your answer to the Foundation, or submit your answer on the survey form.

From the collected set of right answers received before March 20, we will randomly draw a winner who will receive a free copy of the Newsletter Archive CD. We will summarize the solutions and announce the winner in the next issue.

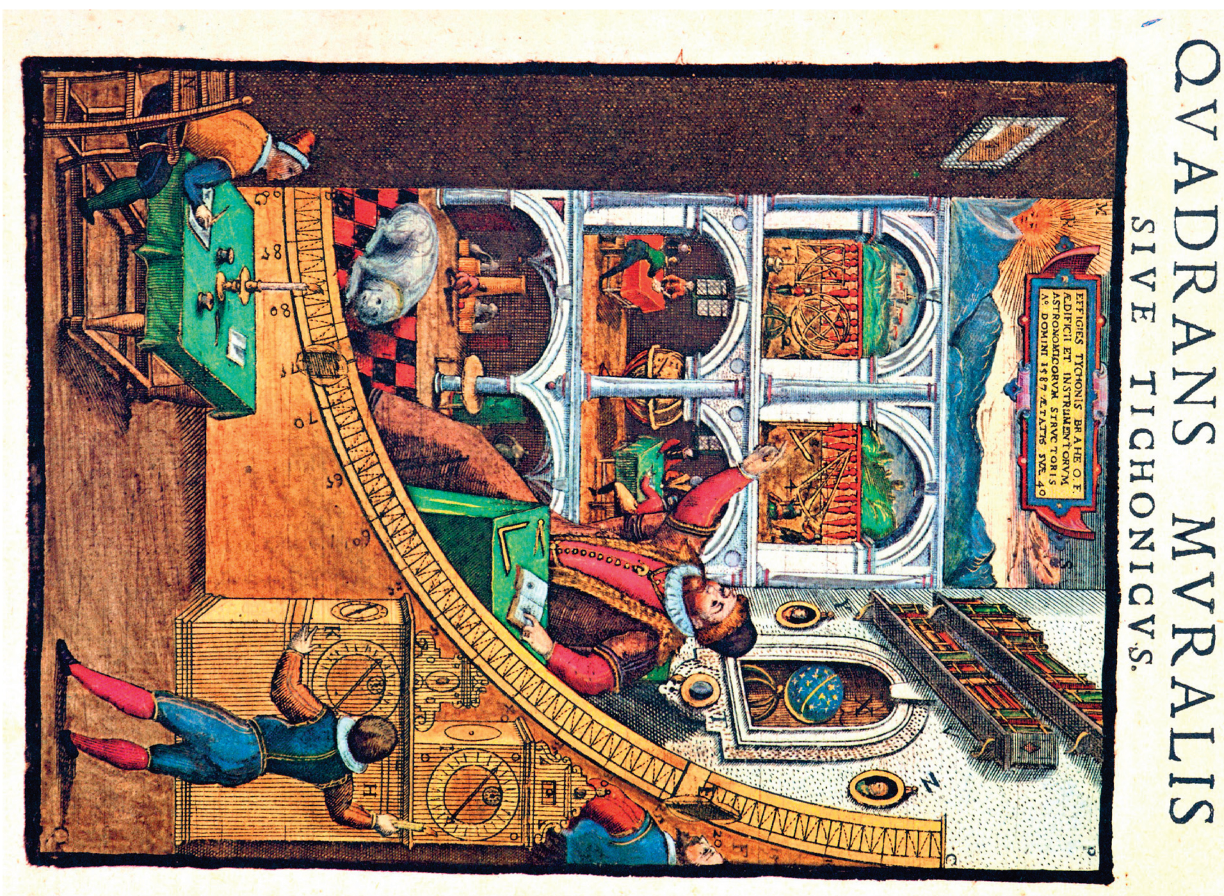
Next month we will carry on with a more conventional exercise in celestial navigation to help Waldo and his friends find their way to safety.



"Nothing to worry about, fellows! I know that we are exactly 2000.3 miles south of Honolulu."

The Foundation for the Promotion
of the Art of Navigation
Box 1126, Rockville, MD 20850

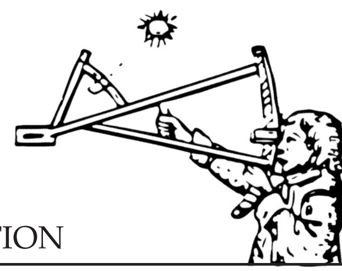
"THE NAVIGATION FOUNDATION"



Tycho's famous mural quadrant. It had a radius of about 6 feet, with which it is reported he could measure altitudes to within about 10' precision (about 0.2 inches along the arc).

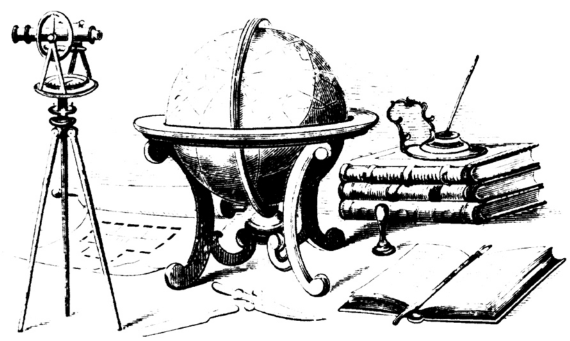
ISSUE 91, SPRING 2006

THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a reader forum for the expression of our members opinions and their questions.



ACTIVITIES

By Terry Carraway

Now is a good time to start thinking about the coming boating season. Through The Navigation Foundation you can get the latest nautical charts, books and publications such as the Government Nautical Almanac or the Commercial version all at a members discount. The discount on your chart orders is 20% for orders up to $100.00 and a 25% discount on all orders over $100.00. Books and publications from the Government Printing Office are discounted at 15% for all others the discount is 20%. You can order either by telephone or fax at 301-622-6448, on the Internet at navigate1@comcast.net or by mail to The Navigation Foundation, 12509 White Drive, Silver Spring, Maryland 20904. This mailing address will get your order filled much faster than the Post Office Box in Rockville, Maryland.

The Electronic Archive CD of The Navigator's Newsletter, issues 1 to 88, the complete catalog from 1983 to 2005, is available through The Navigation Foundation by check or money order. The price is $79 for non-members and $49 for members. The $49 for members includes the discount. Credit card purchases and download options are available at www.starpath.com/navigationfoundation. This fully searchable electronic archive presents all Navigation Foundation newsletters grouped into three volumes, which are interlinked from the title pages of each volume. This Archive includes over 1,100 pages, with many illustrations.

EDITOR'S NOTES

By David Burch

We tried to get caught up by now, but you will notice we have not quite made it. We were over optimistic in our projected dates for summarizing the survey and drawing a winner for the Navigation Puzzle. We will hopefully get to those by the Summer Solstice issue. Please send in your surveys.

We are beginning to hear from members with ideas for topics and actual contributions. Thanks for that. Please keep them coming. Among other valuable contributors, a letter from member John Lewis in the Readers Forum has sparked a new and timely topic (pun intended!) for the Newsletter, and one that is crucial to our craft, namely the fate of the leap second used to keep GMT in sync with the rotation of the earth.

For those new to the subject, some background on the subject (GMT, UTC, UT1, UT, etc..) is valuable, so with that in mind I contacted Richard B. Langley, Professor of Geodesy and Precision Navigation at the University of New Brunswick, who has kindly agreed to let us reprint some of his work on this topic.

He is an expert on the subject and well known for his clarity of presentation of complex subjects. He has written much on the subject in many forums, including GPS World magazine where he writes and coordinates an engaging *Innovation* column on advances and fundamentals in GPS and related technologies.

We also include with these a detailed bibliography for further reading and have added the key Internet links to our new section on Internet Resources. Needless to say, there is still more to cover on this important topic, and we will. Please send in your questions and comments.

I can't help but recall the time zone of the early sixties, when for some reason that fully escapes me now, I purchased a Bulova Accutron wristwatch while still a student at the university. I did not know celestial navigation existed, nor could I afford the luxury, but was compelled by the ability to know the time accurate to the second, regardless of what the classroom clocks read when the bell rang. It must have been just the comfort of knowing one right thing in an otherwise troubling time. We have seen a couple milestones in timekeeping since then, and it looks like another may be on the horizon. For now, in these troubling times, at least we know the right time accurate to the tenth of a second—the time difference between UT1 and GMT is coded in tenths in WWV and similar broadcasts available to the public.

An apology due

It has been brought to our attention that we overlooked an accusation in an earlier Newsletter that would otherwise not have been printed. The accusation was contained within a long list of footnotes and, unfortunately, we did not focus properly on that footnote.

The Navigator's Newsletter unreservedly apologizes to Dr Yallop, Superintendent (retired) & Miss Hohenkerk of H.M. Nautical Almanac Office for allowing Mr. Zevering to lay an accusation of plagiarism in Issue 88 Summer 2005 unchallenged. This Newsletter confirms that the allegation is without foundation.

We have written letters of apology to Dr. Yallop and Miss Hohenkerk, and we will make every effort to prevent such oversights in the future. Mr. Zevering has conveyed his apology for the wording of the footnote.

READER'S FORUM

Member John Lewis wrote:

Congratulations on taking the editorship of the navigation foundation newsletter, and thank you for being willing to make the effort to keep it alive and relevant. I thought readers might be interested in the article on page 10 of the latest Physics Today, concerning definitions and measurement of time, and the geoid.

Will Bruce Stark still be contributing? Haven't talked to him in a couple of years; last time was with regard to a book by a B.C. author about Drake's visit to the PNW, and the giant (supposed) celestial navigation device found etched in the rocks on the Oregon coast.

Would you be interested in contributed book reviews? There's a new one out about Thompson and it makes some reference to his navigation.

Best regards,

John Lewis, Seattle.

Editor's reply:

Yes, thank you, that is an interesting article and one that celestial navigators should note, since the author, Daniel Kleppner, Professor Emeritus in Physics at MIT, poses that we might lose our cherished leap seconds, which are an aggravation to scientists but crucial to the work of celestial navigators, which he refers to as "a vanishing breed."

The Physics Today article is online in full at www.physicstoday.org. I think, however, that the leap second is safe for a long time to come. I recall people telling us we would not need to teach celestial navigation any longer now that the Navy's Transit Satellite system was available to the public, back in the early 1980s.

I have spoken briefly with Bruce and he mentioned he will be taking part later on. I do not know of the celestial device you mention, so that sounds like a good new topic on the horizon.

And yes indeed. A review of the new book on David Thompson and his navigation would be much appreciated by the membership.

* * *

Member Bill Murdoch wrote:

Congratulations on the "new newsletter". Issue 89 was well done. On page 8 David Burch says, "...I believe that it [the full view horizon mirror] was actually a development of Davis Instruments, themselves (another good topic for an article.)" The patent (assigned to Davis Instruments) is US 4,421,407 and is available on the US Patent Office web site. I've attached a copy of the seven images of the patent. I found the patent enjoyable reading, and he is right, it would make an interesting article. I frequently look up patents to better understand what the inventor thinks are the important parts of his invention. He usually sets that out in the Description of the Prior Art and the Summery of the Invention.

Bill Murdoch

Editors reply:

Bill also provided instructions on how to access the patent online, starting at www.uspto.gov. Start with Search to find Quick Search, then quick search for "sextant" in the Abstract line. You will find about 20 patents related to sextants, several of which might be interesting.

The problem is reading the pages online, which are tiff images that require a special browser plug-in. To simply the viewing of this important work, we have made an ebook of it for members that can be downloaded at

www.starpath.com/navigationfoundation/
davispatent.htm

Abstract of the Davis Instruments Patent

"An improved optical measuring instrument having an image combining mirror which reflects part of the light from one source and transmits part of the light from another source and superimposes such reflected and transmitted light over the entire surface of the mirror is disclosed. In the preferred embodiment an improved sextant is disclosed using the image combining mirror. Sextants are double reflecting optical devices which are generally used to measure the angle between a celestial object, such as the sun, the moon, or a star, and the horizon. This measurement is used primarily in navigation for determining the user's location at sea. Prior sextants split the viewing area of the horizon mirror into two fields of view: one-half horizon and one-half celestial object. The improved sextant uses a horizon mirror which combines and overlaps (superimposes) the horizon and celestial images over the entire viewing area. This is preferably accomplished by the use of a spectrally selective dielectric beamsplitter as the horizon mirror, such mirror mainly transmitting light in one spectral region and substantially reflecting light in another spectral region. The result is a horizon mirror which both splits and converges the horizon and celestial images resulting in an enlarged field of view of both the horizon and the celestial object."

Light interacting with the "beam converger" surface

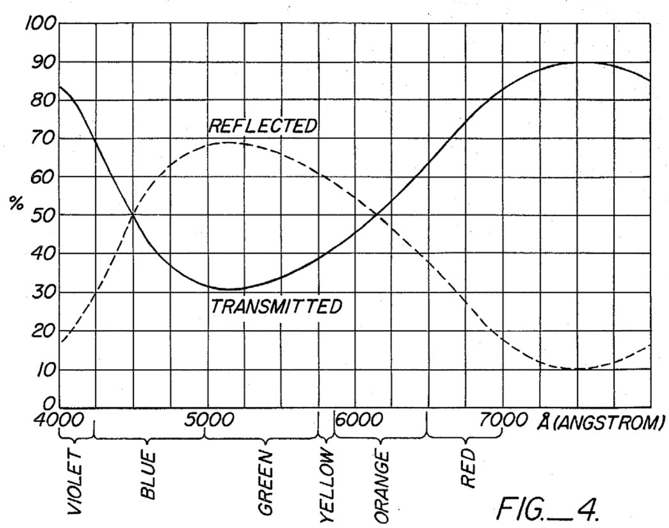


FIG._4.

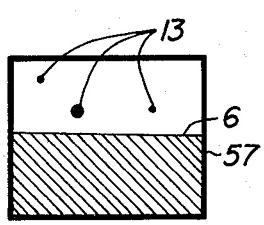
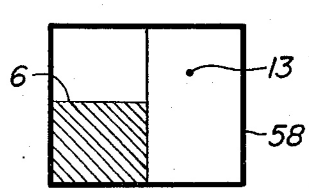


FIG._5.

Beam-Converger horizon mirror

aka

Whole-Horizon or Full-View



PRIOR ART FIG._6.

Traditional horizon mirror

For further notes on this type of horizon mirror, see Navigation Notes

* * *

Member Timothy Prass wrote:

David & Terry,

First of all, Thanks so much for sticking with it! Just got Issue 89 and was encouraged to read what is taking place.

As for what I would like to see in the newsletter, some time ago I purchased Capt. Gray's 100 Problems and had a blast with it. It was great fun taking each voyage. I have all the problems calculated and plotted in a 3 ring binder. I want more! I'm at present a frustrated land-locked navigator. I'd like to think that someday I'll know what it is like to be totally out of sight of land with a sextant and tables in hand. Until then, I'll have to imagine.

The Starpath home study course is what got me started. For fun, I bought an Astra III and have succeeded in confirming Lat & Lon of my driveway from sights taken from a pan of water. I'm hooked. I'd love to be able to experience the journeys of others and play the role of navigator. Knowing the stars by name and being able to practice a skill that has earned its place in history are both extremely important to me. The Foundation and the newsletter are a great help.

Keep up the good work.

Timothy Prass

Thanks Timothy, we will be adding practice problems starting with the June issue.

* * *

The Navigator's Newsletter
Issue 91, Spring 2006
Published by
The Foundation for the
Promotion of the Art of Navigation
www.navigationfoundation.org
P O Box 1126
Rockville, Maryland 20850, USA
Phone or fax 301-622-6448
Executive Director, Terry Carraway
Newsletter Editor, David Burch
Inquires about membership or Newsletter content or contributions can be send to the above address or by email to navigate1@comcast.net.
The Navigator's Newsletter is published four times annually, with our strived-for publication dates of approximately the solstices and equinoxes. Newsletter production and other Foundation activities are provided by volunteers. Please bear with us if we slip on the dates occasionally.

Member Jack Craven wrote:

Terry,

I have been communicating with an old friend, (he's 87 years old and I 83 years old), and I asked him about the up coming date of 6th April 2009. I hope that the National Geographic Society and the Navigation Foundation are both working hard to celebrate Adm. R.E. Peary's trip to the North Pole. I have a copy of William E. Molett's Book "Robert Peary and Matthew Henson at the North Pole" which EP Stafford has mailed to me to read. I also notice that you are mentioned in Adm. Davies study of that journey. Also I noticed the name of Ernest Brown was missing in the later studies of Peary's Methods of polar navigation. That Trip would be a good article for a future Navigation News. Hope to hear from you concerning the above comments.

Jack Craven

Director Terry Carraway Replied:

Dear Jack,

I have heard nothing from The National Geographic Society about Robert E. Peary's trip to the North Pole. After our study there was a little communication from The Society but it soon ceased. Our President Douglas D. Davies has been in contact with Peary aficionados but nothing worth including in the Newsletter. Maybe we did too good of a job and the entire Peary expedition lost its luster as the critics had nothing else to counter our study.

As for the signalling mirrors, they were in every navy "Mae West" and in the raft packs. I still have mine and keep it with my emergency packet for flying, boating and natural disasters. It is a great way to attract attention.

Best regards, Terry

* * *

President Doug Davies wrote:

Terry, I got your letter.

I have been thinking about whether there would be interest in a centennial article about Peary. I haven't been much in contact with the National Geographic people of late, and I am not sure whether they would entertain anything. I have been in contact with Tom Avery, who recently went to the pole with dogsleds in a few hours less than Peary took. He is working on a book, and I have provided copies of Peary's diary, etc.. I haven't heard from him in a few months, and I'm not sure where his efforts stand. He seemed very positive about the fact that Peary's distances were credible. I could certainly do something for the newsletter, or maybe even a revised and updated Report if there is any interest in that. I think there is a fair amount of new material since the last report.

Hope you and your family are all well.

Doug

Editor's reply

Yes, I would think there is broad interest in the membership for a follow-up on this important work of the Foundation. Perhaps we could incorporate some of Roger Jones's experiences with Matthew Henson as well.

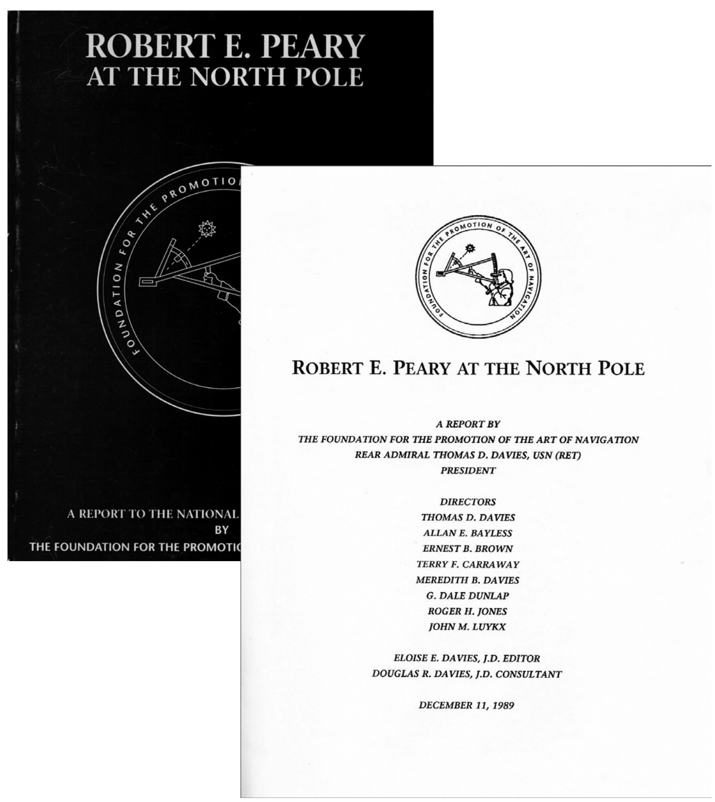
* * *

From member Ed Hooper

We received an excellent suggestion for a course curriculum for schools using celestial navigation as the basis of a program to teach mathematics, astronomy, physics, history, geography, oceanography and much more. Humanities and science, united under the common theme of the role of celestial navigation throughout history.

This is precisely a topic we have been considering here, and Ed has started us off with an excellent, specific program. We will include his program in a later issue where we address this topic (we also need to get a digital copy of the document), but he has offered to share his thoughts and his specific program with anyone who might be interested in the meantime. You can reach him at goathillprint@cox.net.

Thanks Ed. Your idea will be a main focus of a forthcoming issue. We are in contact with several middle school and high school teachers who have very successfully used various aspects of navigation to present a broader range of knowledge. I am sure the Foundation can play an important role in consulting with teachers in this approach, which will help them and further our goals as well.



A Few Facts Concerning GMT, UT, and the RGO*

Richard B. Langley
University of New Brunswick

In answer to the question "Does anyone know the exact difference between GMT and UTC?" Here are a few facts concerning Greenwich Mean Time, Universal Time, and the Royal Greenwich Observatory.

The Royal Greenwich Observatory

Prior to 1948, the observatory at Greenwich (located on a hill back from the River Thames with a view of the London Docks) was known as the Royal Observatory.

In 1948, the observatory moved to Herstmonceux Castle in Sussex, becoming the Royal Greenwich Observatory (yes, even though it wasn't at Greenwich any more!).

The site at Greenwich became known as the Old Greenwich Observatory and the historic buildings and instruments were progressively incorporated into the National Maritime Museum, the main buildings of which are located at the foot of Observatory Hill, close to the river. Highly recommended for a visit if you're in London!

Following the closing of the RGO in the autumn of 1998, the Old Greenwich Observatory was renamed the Royal Observatory Greenwich (see "Where's the RGO Now?" below).

Greenwich Mean Time

Greenwich Mean Time is a time scale based on the apparent motion of the "mean" sun with respect to the meridian through the Old Greenwich Observatory (zero degrees longitude). The "mean" sun is used because time based on the actual or true apparent motion of the sun doesn't "tick" at a constant rate. The earth's orbit is slightly eccentric and the plane of the earth's orbit is inclined with respect to the equator (about 23-1/2 degrees) hence at different times of the year the sun appears to move faster or slower in the sky. That's why an uncorrected sundial can be "wrong" (if it is supposed to be telling mean time) by up to 16 minutes. So if the *mean* (i.e. corrected) *sun* is directly over the meridian through Greenwich, it is exactly 12 noon GMT or 12: 00 GMT (Prior to 1925, astronomers reckoned mean solar time from noon so that when the mean sun was on the meridian, it was actually 00:00 GMT. This practice arose so that astronomers wouldn't have a change in date during a night's observing. Some in the astronomical community still use the pre-1925 definition of GMT in the analysis of old data although it is recommended that the term Greenwich Mean Astronomical Time now be used to refer to time reckoned from noon.)

Mean time on selected meridians 15 degrees apart is generally known as standard time. For example, Eastern Standard Time (EST) is the mean solar time of the meridian at 75° W.

Universal Time

In 1928, the International Astronomical Union recommended that the time used in the compilation of astronomical almanacs, essentially GMT, or what was also sometimes called Greenwich Civil Time, be referred to as Universal Time (UT). The terms "Universal Time" and "Universal Day" were introduced at the various conferences in the 1800's held to set up the standard time system.

There are actually a couple of variants of UT. UT as determined by actual astronomical observations at a particular observatory is known as UT0 ("UT-zero"). It is affected by the motion of the earth's rotation pole with respect to the crust of the earth. If UT0 is corrected for this effect, we get UT1 which is a measure of the true angular orientation of the earth in space. However, because the earth does not spin at exactly a constant rate, UT1 is not a uniform time scale. The variation in UT1 is dominated by seasonal oscillations due primarily to the exchange of angular momentum between the atmosphere and the solid earth and seasonal tides. In an effort to derive a more uniform time scale, scientists established UT2. UT2 is obtained from UT1 by applying an adopted formula that approximates the seasonal oscillations in the earth's rotation. However, due to other variations including those associated with the secular effects of tidal friction (the earth's spin is continually but gradually slowing down), high frequency tides and winds, and the exchange of angular momentum be-

The Royal Greenwich Observatory, from the front cover of The Mirror of Literature, Amusement, and Instruction*, Vol. 14, Issue 404, December 12, 1829* tween the earth's core and its shell, UT2 is also not a uniform time scale.

So rather than base our civil time keeping on the rotation of the earth we now use Atomic Time, time based on the extremely constant frequency of a radio emission from cesium atoms when they change between two particular energy states. The unit of Atomic Time is the atomic second. 86,400 atomic seconds define the length of a nominal "reference" day—the length of the day as given by the earth's rotation around the year 1900. But because of the variations in the earth's spin the length of the actual day can be shorter or longer than the nominal day of 86,400 seconds. The time scale based on the atomic second but corrected every now and again to keep it in approximate sync with the earth's rotation is known as UTC or Coordinated Universal Time. The corrections show up as the leap seconds put into UTC from time to time—usually on New Year's Eve.

With these leap second adjustments, UTC is kept within 0.9 seconds of UT1. Currently, the need for leap seconds is primarily due to the effects of tidal friction. The earth's rotation in space is monitored by the International Earth Rotation Service (IERS) in Paris, France, using a global network of satellite and lunar laser ranging, very long baseline interferometry, and Navstar Global Positioning System (GPS) stations. The IERS, in consultation with the Bureau International des Poids et Mesures in Sèvres, France, determine when a leap second is needed.

In 1928, when the term Universal Time was introduced, variations in the earth's spin were not yet known. So the term GMT was, in essence, replaced by UT1. Despite the official adoption of the term UT, the navigational publications of English-speaking countries retained the term GMT as a synonym for UT1 for some time. So, even today, in astronavigation, GMT can imply UT1. But in general usage (including that of shortwave broadcasters such as the BBC, for example), GMT now usually means the civil (atomic-second-based) time kept in the United Kingdom which is the standard time of the time zone centred on the 0 degree meridian. In this (the most common) usage, the terms GMT and UTC are identical. But because there are two possible meanings for GMT differing by up to 0.9 seconds, the term GMT should not be used for precise purposes—particularly not in reference to GPS observations!

The Origin of UTC

The concept of a coordinated universal time was introduced in 1960 when the British and American national time services initiated a program to coordinate the offsets of the frequencies and epochs (phases) of transmitted time service radio signals from Atomic Time in approximating UT2. Subsequently, other national time services joined the program. The Bureau International de l'Heure (a forerunner of the IERS) was charged with the task of monitoring and maintaining the program and introduced the term Temps Universel Coordinné or Coordinated Universal Time for the coordinated time scale in 1964. Initially, the time scale was derived by offsetting its rate from that of Atomic Time to agree with the average rate of UT2 over the past year and was held fixed at that rate for the following year. If the rate of UT2 changed significantly during the year, then an offset (from 1962, in multiples of 100 milliseconds) could be introduced on the first day of a month. This system of frequency and epoch offsets was continued until 1972 when the current practice was adopted of keeping the rate of UTC equal to that of Atomic Time and introducing leap seconds when needed to keep UTC to within 0.9 seconds (it was 0.7 seconds until January 1975) of UT1.

Sometimes the term "World Time" is used to denote UTC. This strange and potentially confusing term ("UTC for dummies"?) should be avoided. Similarly, there is no clear need for the Swatch watch company's recently introduced "Internet Time" (Central European Time measured in 1/1000 of a day (a "beat")).

GMT and the BBC

The BBC began transmitting time signals in 1924. The chimes of Big Ben were first broadcast at midnight beginning 1 January, and on 5 February, at the recommendation of the then Astronomer Royal, Frank Dyson, the six pips time signal (officially known as the Greenwich Time Signal) was inaugurated.

Control of the BBC's six pips was taken over by the Royal Observatory in 1949 from Abinger to where the time service had moved during the war. The time service moved to Herstmonceux in 1957.

The time service at Herstmonceux closed down during February 1990 when the BBC took over the generation of the six pips. Since 5 February 1990, the 66th anniversary of the start of the Greenwich Time Service, the six pips have been synchronized to UTC by using the GPS satellite signals which are picked up by a pair of GPS receivers atop Broadcasting House in London.

Where's the RGO Now?

In March 1990, RGO officially moved from Herstmonceux Castle to the grounds of Cambridge University's Institute of Astronomy. On 31 October 1998, the RGO was closed by the U.K. Particle Physics and Astronomy Research Council as a cost-saving measure. Some of its research activities have been transferred to the Royal Observatory Edinburgh. Her Majesty's Nautical Almanac Office was transferred to the Rutherford Appleton Laboratory at Chilton in Oxfordshire. With the closure of the RGO, the Old Greenwich Observatory has been renamed the Royal Observatory Greenwich. A laser ranging station and a GPS tracking station still operate at Herstmonceux but the castle and estate is now owned by Queen's University in Kingston, Ontario, Canada, who use it as a satellite campus for their International Study Centre. Queen's purchased the castle in early 1993 for about $8 million (CDN). This money, and an additional $4 million for renovations were gifts from Dr. Alfred and Mrs. Isabel Bader of Milwaukee, WI. Dr. Bader is a Queen's alumnus.

Editors note: H.M. NAO will soon be moving from the Rutherford-Appleton lab to the Admiralty establishment at Taunton, where it will become part of the UK Hydrographic Office (see www.nao.rl.ac.uk).

To Learn More

If you'd like to learn more about time you might look for the book *Greenwich Time and the Discovery of Longitude* by Derek Howse originally published in 1980 by the Oxford University Press. A second edition, titled *Greenwich Time and the Longitude: Official Millennium Guide* was published by the National Maritime Museum and Philip Wilson Publishers in 1997 (ISBN 0-85667-468-0). A special paperback edition is available exclusively from the museum.

An excellent reference on all matters concerning time is the *Explanatory Supplement to the Astronomical Almanac* edited by P. Kenneth Seidelmann of the U.S. Naval Observatory (USNO) and published by University Science Books, Mill Valley, CA (ISBN 0-935702-68-7).

There is also a wealth of information on time at USNO's Directorate of Time Web site

http://tycho.usno.navy.mil/time.html.

For information on Queen's University's International Study Centre at Herstmonceux Castle, visit their Web site

http://www.queensu.ca/isc/.

A GPS World article discussing the future of the leap second can be found here:

http://gauss.gge.unb.ca/papers.pdf/
gpsworld.november99.pdf.

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* This article is reprinted here with the author's permission.

* * *

NAVIGATION NOTES... continued

Just Wait a Second!

Richard B. Langley
University of New Brunswick

The International Earth Rotation and Reference Systems Service has announced that December 31, 2005 will contain an extra second. Rather than the usual 86,400 seconds in a day, the last day of the year will have precisely 86,401 seconds. National time-keeping centers around the globe will insert the extra second or "leap second" into their master clocks and all other clocks which get their time from the master clock will be updated similarly. For example, so-called "atomic clocks" that receive radio signals from a time signal station such as WWVB in the United States will automatically adjust their time for the extra second.

Leap seconds are used to keep our clocks more or less synchronized to the Earth's rotation. Although the Earth appears to rotate uniformly with night following day since time immemorial, the Earth actually does not rotate at a constant rate. It fluctuates slightly due to a variety of causes including variations in winds and ocean currents, the motions of the fluid core, and the friction of tidal currents flowing along the bottom of the oceans. Tidal friction results in a long-term or secular decrease in the Earth's rate of rotation amounting to about 2.3 milliseconds per day per century. This means that over a period of 1,000 days, a clock keeping time based on the rotation of the Earth, a time scale called UT1, would lose about 2.3 seconds compared to the world's standard time scale, Coordinated Universal Time (UTC), which is based on the atomic second and referenced to the period of the Earth's rotation about 100 years ago. To keep UTC to within 0.9 second of UT1, so-called "leap seconds" are periodically added to UTC. While tidal friction is the primary reason for adding these leap seconds, the other factors responsible for the variation in the Earth's spin contribute as well. In fact, negative leap seconds are theoretically possible, although all leap seconds to date have been positive.

The last leap second occurred on December 31, 1998. Previous to that, leap seconds had been added every year or two going all the way back to 1972 when the practice of adding leap seconds to UTC was started. But non-tidal factors have slowed the rate of decrease of the Earth's rotation over the past 7 years or so, so that another leap second has not been needed until now.

The need for a leap second is determined by the IERS's Earth Orientation Centre at the Paris Observatory. Using a global network of satellite and lunar laser ranging, very long baseline interferometry, and Global Positioning System stations, they accurately determine UT1. Then, in consultation with the Bureau International des Poids et Mesures in Sèvres, France, the keepers of the atomic second and the UTC standard, they determine when a leap second is needed to keep UTC in sync with the Earth's rotation.

GPS operations are unaffected by the introduction of a leap second because its time system, GPS (System) Time, is not adjusted for leap seconds. GPS Time was set equal to UTC in 1980 and is currently 13 seconds ahead of it. Come New Year's Eve, this offset will increase to 14 seconds. GPS does provide UTC by transmitting the necessary data in subframe 4, page 18 of its navigation message, permitting a receiver to compute UTC from GPS Time.

The upcoming leap second might be the last. The United States has proposed to a working group of the International Telecommunication Union that leap seconds be abolished. The justification for the proposal is that leap seconds are cumbersome and their incorrect use could lead to problems with electronic navigation systems such as GPS. Furthermore, they would argue that the only reason UTC is being kept close to UT1 is for the sake of navigators making traditional astronomical observations with sextants. And with GPS so widely available, there are fewer and fewer navigators who even know how to use a sextant. But the debate on the abolition of leap seconds is far from over. Stay tuned.

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* This article is reprinted here with the author's permission. It was originally published in several versions in 2005.

* * *

Edditor's Notes (mostly from NIST website)

UTC is presently 0.3 sec behind UT1. If you want to know UT1 with an uncertainty of 0.1 s, you can apply a correction to UTC. UT1 corrections are encoded into the WWV and WWVH broadcasts by using doubled ticks during the first 16 s of each minute. You can determine the amount of the correction (in units of 0.1 s) by counting the number of doubled ticks. The sign of the correction depends on whether the doubled ticks occur in the first 8 s of the minute or in the second 8 s. If the doubled ticks are in the first 8 s (1-8) the sign is positive. If the doubled ticks are in the second 8 s (9-16) the sign is negative.

For example, if ticks 1, 2, and 3 are doubled, the correction is +0.3 s. This means that UT1 equals UTC plus 0.3 s. If UTC is 8:45:17, then UT1 is 8:45:17.3. If ticks 9, 10, 11, and 12 are doubled, the correction is -0.4 s. If UTC is 8:45:17, then UT1 is 8:45:16.6. If none of the ticks are doubled, then the current correction is 0.

To hear these broadcasts without a shortwave or SSB radio, dial (303) 499-7111 for WWV (Colorado) or (808) 335-4363 for WWVH (Hawaii). Callers are disconnected after 2 minutes. These are not toll-free numbers; callers outside the local calling area are charged for the call at regular long-distance rates.

Listen carefully to the first three ticks after the time announcement on the whole minute to hear that they are doubled, or slightly longer, to mark the 0.3 seconds encoding. Note the 30th tick is skipped, which can be used to check clocks without waiting for another whole minute.

To learn more about about WWV and WWVH broadcasts and related practical matters of timekeeping, check the publication list at http://tf.nist.gov/timefreq/general/generalpubs.htm

If you would like a very slick little program that will connect to NIST on the internet, and then set your computer to the precisely right time, you can download one for your operating system at http://tf.nist.gov/service/its.htm. We have used this for years. It is very convenient. You can also confirugre it to update your computer automcatically at preset intervals.

NAVIGATION NOTES... continued

Full-view vs. Traditional Horizon Mirrors

David Burch

As mentioned earlier, this horizon mirror innovation was developed and patented by Davis Instruments, in 1983, but has since been adopted by essentially all sextant manufacturers as an option for the horizon mirror. Davis Instruments used the name "beam-splitter" in the patent, but later trademarked and used the name "beam converger." This name—obscure, for sure, if you have not read the patent—is rarely used, and even Davis Instruments in latest advertising includes the phrase, "...also known as full-horizon mirror." They might as well include "full-view" and "whole horizon," as different companies use different names for the same thing.

This development has since caused sextant sellers to start referring to normal horizon mirrors as either "traditional" or "split-view."

We (at Starpath) are often asked our advice about the best choice of mirror, so we have written up the answer, which is given below.

If you have never taken a sight before and are presented with a sun in midday with a dark blue sea horizon and light blue sky, and you were asked to compare the two types of sextants, which were otherwise identical, you might indeed choose the full-view style mirror. It will, at this first use of a sextant in these ideal conditions, seem easier. And indeed it is this reaction that has led many new users into choosing this option and still leads some sales people and advertisers to recommend it.

What you will soon learn, however, is that this is indeed a very easy sight, and regardless of what sextant you have in your hand, you will in a few minutes of practice be doing it just well, if not better, with a traditional mirror.

With the standard type of sextant mirror (used since 1750's or so) you do have to coordinate keeping the sextant pointed toward the object as you move around some and rotate (rock) the instrument. With the full-view model, you have broader leeway here, and this is easier. On the other hand, for other sights, things are completely different.

The full-view mirror works by splitting the light spectrum in half according to color, by means of special optical coatings on the horizon glass. The surface reflects the bluish half and transmits the yellowish half, as seen in the Fig 4 of the patent abstract. The net effect is you see at the same time light passing through it and light reflected from it—but only roughly half of the light intensity in each case. (It behaves rather like a half-silvered or see-through mirror, but the principle behind this design is much more subtle, as explained in the patent.)

Hence the problem. For faint stars you are losing half the light, so the stars are more difficult to see. But that is not the main problem. The main problem comes in when viewing anything that is about the same color as the sky. A daytime moon in a "white" sky, for example, can sometimes not be taken at all with full-view style of mirror.

Also when the sea and sky are nearly the same color, which is fairly often, then it is difficult with this model to check the index correction precisely, since it relies on colors to separate the images.

These types of mirrors are also more sensitive to salt spray build up on the surface than are traditional mirrors, but we can't really fault them for that, since we should have the policy at sea of cleaning our mirrors before sights in all cases... even when they do not appear contaminated. Spray build-up can deteriorate the viewing long before the glass surface becomes obviously dirty.

Another drawback shows up when you use the sextant for coastal piloting, either with vertical sextant angles or horizontal angles, such as the famous three-body fix, which is such an accurate means of piloting it is usually called sextant surveying—and a focus of this Newsletter in forthcoming issues. In these sights, you are looking at land-overlapping-land images, where oftentimes the targets differ only in the shade of color. These sights are rather significantly more difficult with the full-view type of mirror.

Our nutshell summary is

> *Full-view mirrors make the easy sights easier, and the hard sights harder.*

We do not recommend them as an option for metal sextants if you plan to carry out the full range of celestial navigation sights or sextant piloting. On the other hand, if your goal is to have a sextant for sun sights only, or for celestial backup to GPS only, then the full-view option might be a good choice, since you could pick up the instrument without much practice or after a long time away from it and take good sights in good conditions.

As it turns out, the top of the line plastic sextant from Davis does, reasonably enough, come with them as standard equipment. The next model down in plastic sextants—a good choice for many applications—comes with the traditional mirror. Davis Instruments also sells at a modest price the full package of mirror, springs and screws for both types of mirrors, and they apprear to be interchangeable, though we have not tested this yet.

You can also buy replacement mirrors for metal sextants that are interchangable, but this is not a switch one would want to do very often since the alignment process takes quite a bit of time and care.

For completeness we should mention this special circumstance. Very high sights (Hs > 85° or so) are difficult because with the sun essentially overhead it is difficult to keep the sextant pointed toward the sun's direction—it is very figuratively like deciding which way is south at the North Pole. They are definitely doable (we have many examples), but it takes special techniques in both the sight taking and, of course, in the analysis. You cannot use conventional sight reduction methods for near-overhead sights.

Well... for these rare, high sights, a full-view type of mirror makes them a bit easier than a traditional split-view mirror, because the full-view gives you a larger viewing range for keeping the body in sight as you move around in the waves. (High sights and sights in heavy weather are good subjects for new articles.)

That said, we still do not change our recommendation, but we need that small-print proviso to our nutshell summary.

We should add that the above is a personal view of the author and not a recommendation of the Foundation.

We look forward to the experiences and observations of other members.

* * *

UPCOMING EVENTS

Celestial Navigation Celebration

During the weekend of June 16-18, 2006, the Mystic Seaport Planetarium in Mystic, Connecticut will be hosting a “Celestial Navigation Celebration” devoted to preserving the art and practice of celestial navigation. Planetarium Director and long-time celestial instructor, Don Treworgy, will conduct a tour of part of the museum’s navigational instrument collection. Many of these historical instruments have never been publicly displayed.

Frank Reed (see Internet Resources) will be conducting two presentations on navigation by “lunar distances”, one devoted to historical aspects and basic concepts, the other focused on the mathematical and technical aspects. Anyone interested will have an opportunity to take a lunar distance observation and find the longitude just the way it was done during the late 18th and early 19th centuries (weather permitting, of course). Don Treworgy and other planetarium staff will also do at least one planetarium program demonstrating the use of the planetarium projector and dome in teaching celestial navigation. They also intend to arrange a presentation based on the G.W. Blunt-White Library’s extensive collection of original logbooks, navigation manuals, and almanacs.

Whether you’re just interested in the subject of celestial navigation for the fun and challenge of a nearly lost art, or you’re a professional celestial navigator with decades of experience at sea, they would like to see us there.

If you would like to present a paper at the seminar, or wish to confirm your attendance, please contact FrankReed@HistoricalAtlas.com.

Events of the “Celestial Navigation Celebration” weekend are free of charge and open to all. Check for latest updates on this announcement at www.fer3.com/Mystic2006.

INTERNET RESOURCES

There are so many items that might go here, we can just get started. For topics focused on our membership’s interest, the best solution will be for members to send in suggestions. We start with a few that are certainly well known to some members, but the idea is to share what we may know well with members just getting started.

* * *

Celestial navigation “HQ,” was developed and maintained by long time member Mary Taylor, who has devoted many years and much devotion to making this site as wonderful at it is, the No. 1 find under Google to “celestial navigation.”

www.celestialnavigaiton.net

* * *

The primary reference for actual data and other wonderful resources is the USNO AA site

http://aa.usno.navy.mil.

See especially their resource under Data Services called “Celestial Navigation Data.” This is an ideal output for cel nav teachers or students to make an infinite set of practice problems for any date, from any place in the world. We will add a note later on specifically how to do this, if not apparent. Their counterpart in the UK has already been mentioned: www.nao.rl.ac.uk.

* * *

Another that is popular with some of our members is the navigation mail list often referred to as “the Nav-L list”

http://www.irbs.com/lists/navigation

You will find discussions of cel nav and all aspects of navigation, modern and historic, and on all levels. This is a “mail list” group, so you have the option to just search and read, or actually sign up to be a member,

The United States Naval Observatory, home of the US Master Clock. See www.usno.navy.mil. A time ball on the roof was used in the1800’s for setting ship’s chronometers. Their Astro Apps website is a key resource for celestial navigators. See Internet Resources.

in which case you will get emails every time there is a posting—sometimes a lot of emails. There are many types of newsgroups and listservers related to navigation, but this is maybe the best known. Some input from active users would be helpful here. There is even a (different) mail list devoted strictly to the leap second.

* * *

If you already know and study lunar distance, you will know this link, but If you have just wondered about it, here is an excellent place to start.

http://www.clockwk.com/lunars

It is maintained by Frank Reed, who is coordinating the Celestial Navigation Seminar, announced in our Upcoming Events section.

* * *

Here is a link that is not so much at the top of the list, but is related to recent Newsletter discussions. The Smithsonian Institute has an extensive online list of sextants, with a brief write up of each. Find the list at

http://americanhistory.si.edu/collections/navigation

Since we have discussed the Davis Instruments patent and also their plastic sextants, it might be of interest to read this note from the above site:

"William A. Davis was an Englishman who settled in San Leandro, California, and offered a range of inexpensive plastic nautical instruments for boating enthusiasts. He introduced the Mark III sextant in 1963, and the instrument is still in production. Like the sextant that Cruver made for the U.S. Maritime Commission during the war, the Mark III is made of polystyrene. It has a simple eye tube, and a scale that is graduated every degree from -35° to +100° and read by vernier to 2 minutes of arc. The original Mark III cost $9.95. This example was probably made in the late 1960s."

And there is much more interesting reading at the site on other sextants and navigation instrument manufacturing companies, modern and long-gone.

* * *

There are many sites online offering various time services, but to be safe we may want to rely on the primary source when it comes to accurate time from an Internet resource, so there is this one, or see also similar links from the USNO

http://nist.time.gov

See also the earlier note on a software program that will connect directly with the NIST to set your computer to the proper time.

* * *

FUTURE ISSUES

We have been in touch with member John Hocking, who has agreed to present some of his navigation work starting in the next issue, which will include an introduction to sextant piloting with an article on horizontal sextant angles. We will follow up that with some of the treatments of these topics from the old text books.

Leif Karlsen has also confirmed that he will provide us with an article on sunstones and Viking Navigation.

And we will soon initiate a discussion of using celestial navigation, or navigation in general, as a basis for K-12 education curricula, starting with the suggestions of member Ed Hooper. The Institute of Navigation (www.ion.org) already has an extensive section on Navigation Education Materials, as do other agencies, but few have much on celestial Navigation.

* * *

Does anyone know how to reach

Byron Franklin?

I had corresponded with him five or six years ago, but all addresses and contacts I have are no longer valid. I seem to have exhausted my leads. He has made many valuable contributions to navigation, and even has several of his techniques listed in the Bowditch Glossary of Navigation.

I have several papers and notes of his that he sent us to consider publishing at our school, but this was during a period when we were not in a position to follow through. Now it is obvious that the Newsletter would be an ideal place for some of this work. Please let us know if you have any news of him. He was a member of the Foundation in the 80's, and has published one paper in the Newsletter in 1988 on "Vertical Sextants."

Here is a note about him I found on the Internet:

"Master Chief Byron Franklin was a Quartermaster for 26 years on various surface ships and nuclear submarines before retiring in 1978. Two navigation techniques bearing his name—the Franklin Piloting Technique and the Franklin Continuous Radar Plot—are currently published in navigation texts and training materials. He was awarded the Navy Commendation Medal for his work with the Naval Oceanographic Office on plotting, as well as in radar, celestial, and radio navigation evaluation and recommendations."

* * *

Please continue to send in your letters and contributions. It is your Newsletter. We need your input. Email works fine, as does a handwritten letter. Thanks.

The Foundation for the Promotion
of the Art of Navigation
Box 1126, Rockville, MD 20850

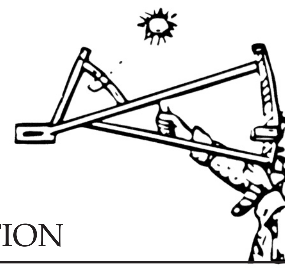
"THE NAVIGATION FOUNDATION"

Do you recognize this most famous of all "pocket watches?"

Hint: its diameter is about 5 inches.

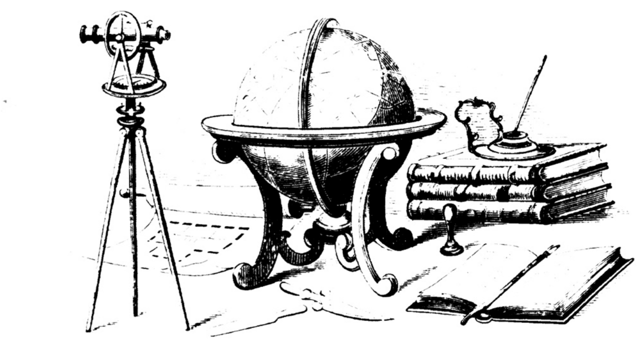
ISSUE 92, SUMMER 2006

THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a reader forum for the expression of our members opinions and their questions.



ACTIVITIES

By Terry Carraway

The Navigation Foundation is pleased to announce this year's winner of the Dutton Award for Excellence in Navigation presented to the top navigation student at the U. S. Naval Academy. The award was presented to MIDN 3/C Michele V. Rollins on 22 May 2006. The Plaque is accompanied by a check for $100 and a letter of congratulation and a one-year subscription to The Navigator's Newsletter.

Michelle is from Fountain Hills, Arizona and has just finished her second year as USNA. She told us ".. my inspiration for being at USNA is my grandfather, who served 28 years in the Navy; he was a Mustang who worked his way up to Commander before he retired. I'm involved with the YP Squadron: our purpose is to learn and experience more of the surface life before we get out to the fleet. We learn to drive and navigate 108' Yard Patrol Craft and can earn an OINC, Small Craft Afloat qualification that stays with us into the fleet. This program has really taught me about navigation—not only doing it myself as we journey up and down the Atlantic coast, but teaching the members of my crew how to do so as well. I was able to serve this past year as a Commanding Officer and then the Training Officer for the Squadron. They say that to teach something you have to know it inside and out, and I can say from experience that I've learned more about navigation through teaching it to first my own crew and then the entire Squadron of approximately 150 members. Unlike many of the mids at the Academy, we get hands-on practice with navigation on a consistent basis, while the others only have a 3 or 4-week block during the summer. It's really a great opportunity both for furthering our professional knowledge and for preparing ourselves to be division officers and future commanders at sea."

Congratulations and good luck with your studies.

MIDN Michele V. Rollins receiving the Dutton Award from CDR Joe Leonard, Chairman of Seamanship and Navigation, and former Commanding Officer of USS THOMAS S. GATES

* * *

Due to the exorbitant cost of postage required to mail The Navigator's Newsletter to our foreign members, The Foundation is contemplating making available an electronic download of the Newsletter. New foreign members and renewals from our foreign members will have a choice of an electronic download at the $35.00 membership or a $45.00 membership to receive the printed paper version. The additional $10.00 is to cover the extra cost of postage for the 4 issues. Details will be reported when finalized.

The Foundation has been receiving praise from many members about the new look and content of the newsletter. We are delighted members like it and we appreciate your feedback. We thank editor David Burch for his efforts in that direction.

If you have not already sent in your Member's Survey, please do so as soon as possible. We are trying to get member's views on what should be in The Newsletter, so every member will find something of interest in each issue. We will postpone the summary till the Sept. Issue to give you time to respond. Thanks.

EDITOR'S NOTES

By David Burch

With this issue we are back on schedule—almost!—and as you will see, we are beginning to get more Newsletter contributions from members. Thank you very much and please keep on sending in your letters and articles.

One project that has kept us from more earlier work on the Newsletter was our custom navigation training program here at Starpath for the only US entry into the Shepherd Ocean Fours Transatlantic Rowing Race. Four Seattle rowers are competing with three vessels from the UK to row from New York Harbor to Falmouth Harbor, UK. The race started on June 10th. It is presented online at <http://www.oceanfoursrowingrace.com>. We wish all the boats well.

Regardless of their background and experience to date, each rower will step ashore as master mariner and expert navigator. They will be spending some 50 to 80 days within 3 feet of the ocean surface. Though they carry state of the art electronics, celestial navigation was a required part of their training, as was weather and oceanography. Their seamanship training and preparation has already paid off, since the horrendous storm child of Alfredo passed right over the fleet with winds of 50 knots or more, providing all with a very tough 24 hour period.

We have compiled the surveys received to date, but would like to get more if we could. We have heard from about 7 percent of our members. Please try to take a moment to send in the survey. The results are already very useful and we will present them next issue. To clarify one point in the survey, the wish list for a book to preserve as an ebook has to be an old one, long out of print, so there is no copyright issue—old Bowditch editions was on the list of many, see the New Products section.

We begin in this issue a discussion of sextant piloting, with a fine article from John Hocking on horizontal sextant angles. John is a retired mathematician from University of Michigan, and a long time sailor and navigator. He has written many interesting articles on navigation and the underlying mathematics, and we hope to publish more. We will include more biographical information in a forthcoming Member Profile.

We are favored with several book reviews this issue. Two from long time Seattle member John Lewis, and we welcome new member Jan Kalivoda from Czech Republic with his review of the Bruce Stark Tables. These tables have been out for some time, and discussed in several places in this Newsletter, but Jan brings fresh insights to the work, specifically pointing out the pioneering aspects of the Bruce Stark approach. Thank you both for these reviews; we look forward to receiving member's reviews of favorite books on navigation or related subjects.

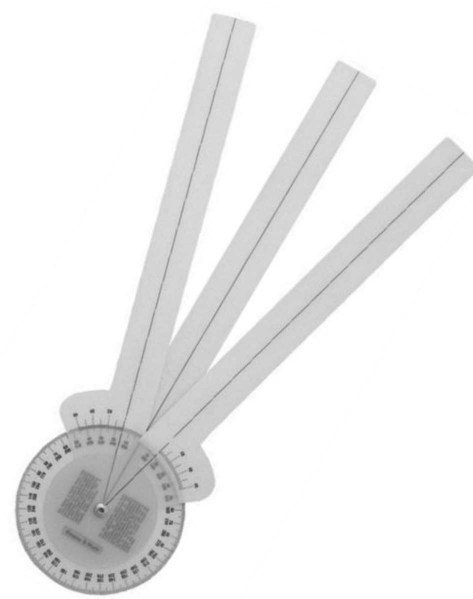
The horizontal sextant angle fix is of high interest to anyone who cares about precision piloting. It is especially valuable these days, even in the age of GPS, as mentioned in the notes following the article. We would welcome any contributions on sextant piloting if you care to participate... or try some of the techniques and send in your experiences.

We will also postpone the solution to the Where's Waldo puzzle from Issue 90, with some elaboration that might help. Assume they got their position from a noon sight, with date unspecified. On different dates, the position error would be different since the declination is different. So the puzzle reduces to which date would give them the smallest error, and what was that error. If you have worked some on the puzzle, maybe that will help. So far we have two answers submitted, both right! And we also change the prize specification. Now everyone who gets the answer right gets a free copy of the Newsletter Archive CD. Deadline now is time of next issue, about Sept. 20.

To get an overview of the past articles in the Navigator's Newsletter, which are all included in the Archive CD, you can see a full index online at www.starpath.com/navigationfoundation. The database can be sorted by date or author, as well as searched for subject matter. We are in the process of creating abstracts for each past article, which would then be online with the index. If any member would like to take part in that process, we will provide them with a complimentary copy of the Archive to work with. Please contact us and we will explain the process.

The "pocket watch" on the cover of Issue 91, was John Harrison's H4 chronometer, which was tested at sea and a key step toward solving the longitude problem. See discussion of it at The British National Maritime Museum <www.nmm.ac.uk>

* * *



Ever wonder what these were for? This is a 3-arm protractor used to plot a position from two horizontal sextant angles. It is an alternative to the numeric and graphic solutions provide in the John Hocking article. This inexpensive, yet fully functional, device sells for $25 from any Weems and Plath outlet. The high precision models called Station Pointers are probably not made any longer. We have a beautiful one at Starpath from 1942, which we have recently published on the Institute of Navigation's Virtual Museum web site. This is an exciting new project from the Institute, which will be online shortly at <www.ion.org>.

READER'S FORUM

Dear Mr. Burch,

Thank you for the information on the UTC-leap second issue presented in the spring newsletter. I thought I should add some more information to that discussion. I will try to be succinct but the issue is very involved both technically and politically!

Dr. Langely¹s second note stated that "The United States has proposed to a working group of the International Telecommunication Union that leap seconds be abolished." That wording is a bit misleading, although some newspaper reports of last summer did put it that way. Indeed, the ITU does have authority over leap seconds, but the proposal was put forward by only about ten people who constituted the U.S. part of the ITU working group that has been looking into the leap second issue.

That proposal did not have the official endorsement of any of the many national technical communities and interest groups that have a stake in the matter. Indeed, the American Astronomical Society did not know of the proposal until after the fact, and is still considering what position (if any) it should take. No federal government agency that I am aware of has taken an official position on abolishing leap seconds; certainly there is divided opinion on it at the U.S. Naval Observatory.

Meanwhile, at a meeting in Geneva last November, the ITU's international leap second working group effectively tabled the U.S. group's proposal, pending more study. In my view, given the implications of such a change, the U.S. group's proposal lacks a well documented justification, and unfortunately was advanced in a somewhat "stealthy" manner.

All that said, there are legitimate technical issues that must be dealt with. The current protocol for keeping UTC within 0.9 seconds of UT1, using leap seconds, has been in place for over 30 years. Because of the widespread and increasing use of UTC for applications not considered three decades ago—such as precisely time-tagging electronic fund transfers and other networked business transactions—the addition of leap seconds to UTC at unpredictable intervals creates technical problems and legal issues for service providers. We also have to face the unavoidable scientific fact that the Earth's rotation is slowing due to tidal friction, so that the rate of addition of leap seconds to UTC must inevitably increase.

Possible alternatives to the present scheme include: using international atomic time (TAI), which is not subject to leap seconds, for technical applications instead of UTC; allowing UT1 and UTC to diverge by a larger amount (e.g., 10 or 100 seconds) before a multi-second correction to UTC is made; making a variable correction to UTC at regularly scheduled dates; eliminating the corrections to UTC entirely and allowing UTC and UT1 to drift apart; or changing the definition of the atomic (SI) second.

No solution is ideal, including the status quo, and each of these possibilities has its own problems. For example, if we keep leap seconds, or a less frequent multi-second correction, can current electronic systems properly time-tag the date and time of an event that occurs *during* the correction?

Would a "new UTC" that increasingly diverges from UT1 provide a legally acceptable representation of civil time? (The U.S. Code provides that our time zones are based on "mean solar time.") If UTC time corrections are made less frequently, will the possibility of technical blunders increase? If leap seconds are eliminated, won't natural phenomena such as sunrise and sunset eventually fall out of sync with civil time? How do we find all the existing computer code that assumes that UT1 is always within 0.9 second of UTC? These issues were considered at a special ITU colloquium held in Torino, Italy, in 2003, and the proceedings are worth reading: see <http://www.ien.it/luc/cesio/itu/ITU.shtml>.

This is a matter that is not going to be resolved any time soon. A working group of the International Astronomical Union that has been considering the future of UTC will report to that body this August, but no formal recommendation by the IAU is expected at that time.

Sincerely, George H. Kaplan

(Although I am an astronomer at the U.S. Naval Observatory, the views expressed above are my own and not those of the U.S. Naval Observatory.)

* * *

I'm a member of the Navigation Foundation, and before I get to my request, I want to thank you all for your dedication in getting folks interested in the art of navigation. I'm a young guy (40s :-) and love using my sextants any chance I get when at sea, or doing lunars in the backyard, and look forward to interesting my son in this art.

I have usually gotten my Almanacs through Celestaire website, but understand members can obtain discounts through the Foundation. Also, as I'm in the market for my own boat, I would like to know what charts might be available at such discount (US West coast, Hawaii, Pacific islands). Please advise how I can obtain this information.

Best regards, Michael Grady

—

Dear Member Grady,

We provide all charts, coastal, inland (except the Mississippi River) and international, all at a discount of 20% for orders under $100 and a 25% discount for orders over $100. We do charge postage for sending the charts to you.

Best regards, Terry Carraway

* * *

Has anyone at the Foundation considered the Bygrave slide rule for a report in the newsletter?

Bowditch (p.559, in the 1958 edition) has an illustration and a one-paragraph description. It's cylindrical, 2 1/2 inches in diameter and 9 inches long, "designed by the Englishman Bygrave to solve the navigational triangle by dropping a perpendicular from the celestial body to the celestial meridian," and calculates with "an accuracy of 1' or 2' . . . generally attainable."

I don't know how many of these were made. I've never seen one in a museum, and couldn't find any listed, in a brief search on the Internet. Why was this device apparently never widely used? I'd guess the subject would be of interest to the members.

Leonard Gray

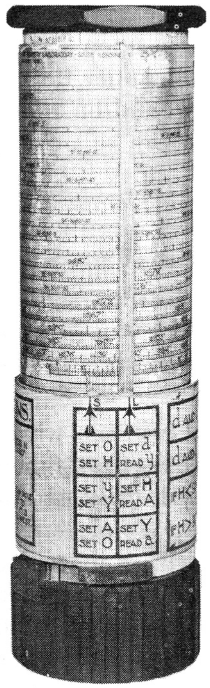


FIGURE 2121b.—The Bygrave slide rule.

Editor's note. We found the above picture in an early Bowditch, but cannot locate any more information on this device. Perhaps some of our British members might have some idea, as it originates in that part of the world.

***

Dear Mr. Carraway,

Enclosed find my check for $49.00 for the Electronic Archive CD of the Navigator's Newsletter.

I Have been a subscriber to the Newsletter for a considerable period of time, and I have enjoyed and learned from the articles in it.

For the last 20 years with the good help of other instructors I have taught the U.S. Power Squadron courses entitled JN and N for our Grand Traverse Bay Squadron. The material in the Newsletter has been interesting and stimulating has facilitated my efforts. Living here in the Great Lakes piloting skills are usually more needed than celestial navigation skills, but your work helps provide an interest for our students,

Thank you for your good work,

Sincerely, Art Dundon

* * *

Claudius Ptolemy (c 85 - c 165 AD), from a 1584, engraving of André Thevet (1502-1590), printed in Les vrais portraits et vies des hommes illustres, Paris, 1584, f° 87.

The Navigator's Newsletter
Issue 92, Summer 2006
Published by
The Foundation for the
Promotion of the Art of Navigation
www.navigationfoundation.org
P O Box 1126
Rockville, Maryland 20850, USA
Phone or fax 301-622-6448
Executive Director, Terry Carraway
Newsletter Editor, David Burch
Inquires about membership or Newsletter content or contributions can be send to the above address or by email to navigate1@comcast.net.
The Navigator's Newsletter is published four times annually, with our strived-for publication dates of approximately the solstices and equinoxes.
Newsletter production and other Foundation activities are provided by volunteers. Please bear with us if we slip on the dates occasionally.

NAVIGATION NOTES

HORIZONTAL SEXTANT ANGLES

By John G. Hocking, Ph.D.

The sextant is the most accurate positioning instrument you have aboard your vessel. What a shame it is that navigators often stow it away when pilot waters are entered. My hope is that, after reading this little treatise, you will join the small group of dedicated sextant users even in the harbors of the world.

Horizontal Sextant Angles

Positioning by means of horizontal sextant angles is the most accurate method available to the small boat navigator. Even Loran C and the Global Positioning System, GPS, do not compare. Surveyors use it, the Coast Guard uses it to position buoys, and many of the world's best navigators do as well.

Suppose that a horizontal angle of 72° has been measured between a buoy and the base of a tower, keeping the sextant carefully horizontal. That angle determines a circular arc between the buoy and the tower (Diagram 1.) And your boat is somewhere along that arc.. In other words, that arc is a circle of position, a COP. The same horizontal angle of 72° will be observed from any point along that arc as is illustrated by points A and B in Diagram1.

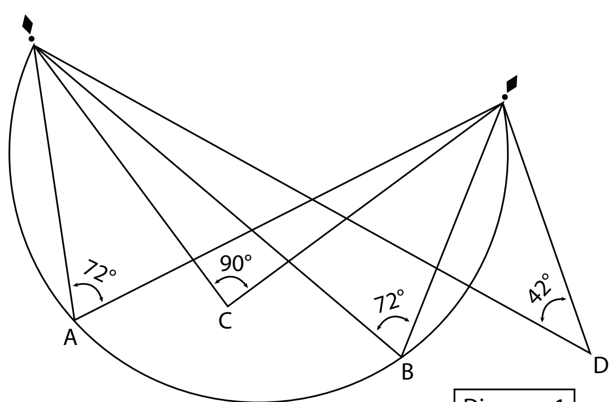


Diagram 1

You may wish to check out a few more points to verify my statement. Use any protractor you may have on your nav table. Also note that from a point inside the arc, such as point C in the diagram, the horizontal angle will be larger than 72° while from a point outside of the arc, such-as the point D, the horizontal angle will be smaller than 72°. Try a few for yourself!

The horizontal angle COP is extremely accurate. Even if the angle is measured with a inexpensive plastic sextant from the deck of a small boat in heavy seas, it wont be in error by more than a few minutes of arc. This means that the error in the resulting COP will be largely a plotting error. The very width of your pencil mark will be more significant than the error in the angle itself!

Plotting Methods

It is easier to plot a horizontal angle COP than to plot an LOP arising from a bearing. First of all, there are no corrections to make in the angle. You don't even have to consider dip, refraction, etc. Just use the angle as you get it, corrected for index error if significant. You do require a draftsman's pencil compass and, depending upon the plotting method you use, you will use a straightedge.

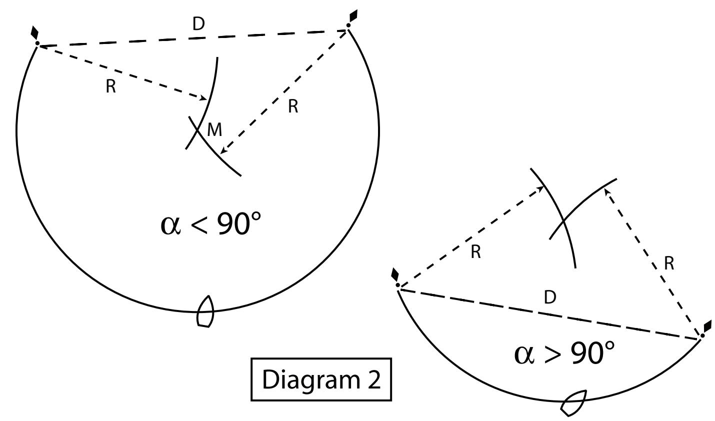


Diagram 2

So let's assume that you have measured a horizontal angle α between two objects out there, objects which are also appear on your chart, of course.

It takes no more than a few seconds down on the nav table to measure the distance D between the two objects on which you got the angle α. Using your scientific calculator compute the radius of the COP using the formula

$$R = \frac{D}{2 \sin \alpha}$$

For example, if D is 1.9 miles and the angle α is 55° 30', then

$$R = \frac{1.9}{2 \sin (55.5)} = \frac{1.9}{2 \times 0.82413} = 1.153 \text{ miles}$$

Using the same scale with which you measured D, set your draftsman's compass to the radius R just computed. Draw two arcs of radius R, one centered at each of the objects, to meet at a point M. These arcs, and the point M, must be on the boat side of the objects if the angle α is less than 90° and must be away from the boat if α is greater than 90°. Look at Diagram 2. That point M where the two arcs intersect is the center of the COP. Keeping the compass set at the same distance R, put its point at M and draw the COP. That's all there is to it! Your boat is somewhere along that COP.

If your scientific calculator has given up the ghost, you can still plot the horizontal angle COP using only a protractor and a straightedge. Here's how: On the chart draw a line between the two objects on which you sighted. If the angle α is less than 90°, construct the complementary angle (90° - α) toward the boat (Diagram 3A). If α is greater than 90°, then construct the angle (α -90°) away from the boat (Diagram 3B). The point M where these two angles meet is the center of the COP, and the distance from M to either of the objects is the radius of the COP. Setting the draftsman's compass and drawing the COP only takes a few more seconds.

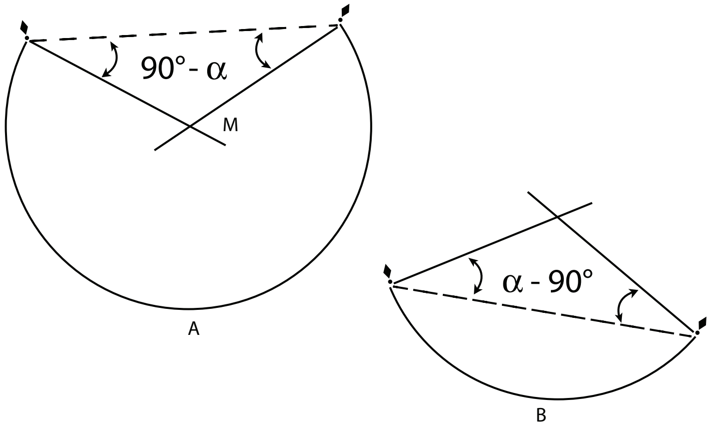


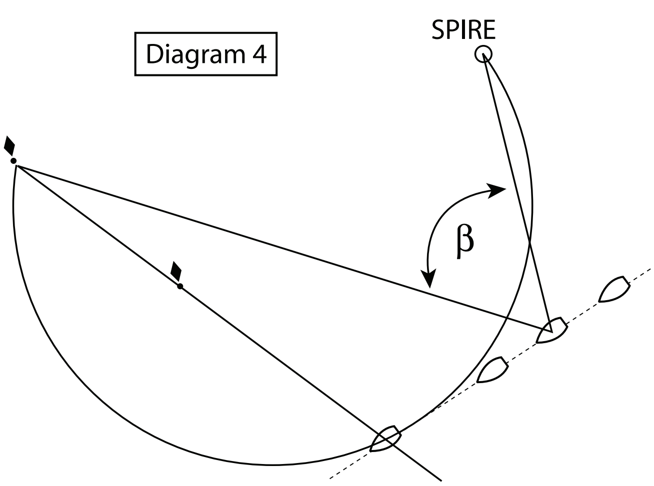
Diagram 3

The book *Piloting* by Frederick Graves is a very good reference on the use of horizontal angles. This fine book was published in 1981 by International Marine Publishing Co. of Camden, Maine. My plotting methods are less cumbersome than those of Mr. Graves and he does not treat angles greater than 90°. The same omission is made by both of the famous books, "Bowditch" and "Chapman." In fact, I do not think that either of these "bibles" of navigation does justice to the use of horizontal angles.

Positioning

Now that you know how to plot them, let's use horizontal angle COPs for piloting. In a test program I ran in Grand Traverse Bay, I found that the most accurate fixes came from combining a range with a horizontal angle COP. Here is my procedure: Approaching a range with a third object off to one side, I simply monitor the horizontal angle between that third object and one of the range markers. The angle I mean is labelled β in Diagram 4. I just keep turning the barrel of the sextant so as to keep the two objects together. At the instant you cross the range all three objects will be superimposed, of course. Just stop turning the barrel and you have it. The horizontal angle and the range will give you the best fix since you left your slip!

Diagram 4



A fix by two horizontal angle COPs is only slightly less accurate than a range-COP fix. To get a two-COP fix you need three or four charted objects in view. A difficulty can arise with a three-object fix, so I will first look at the four-object fix.

When selecting four objects for a two-COP fix, be sure that each pair are on the same level. The four should not lie on, or even nearly on, the same straight line. *The ideal situation would have the two pairs on perpendicular lines*. Diagram 5 approximates that alignment. The hope is to have the two COPs cross each other at an angle as close to 90° as possible.

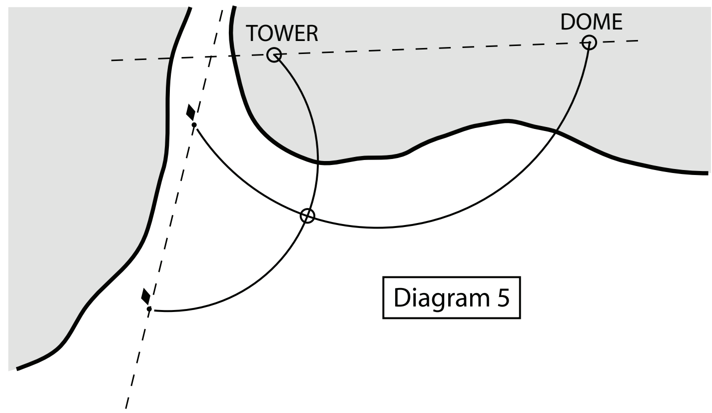


Diagram 5

If there are three objects in view, all on the same level, you can measure the horizontal angles between the center one and each of the outer two to get a very good fix, but there can be trouble here. In high school geometry we all learned that any three points not all on the same line determine a circle. The three objects we have in view determine a circle, of course, and if your boat is also on that circle, or even just near it, you will get no fix at all! See Diagram 6.

This rarely seen situation is often called a "revolver". If the COP you get from the angle between two of the objects also passes through the third object, you have gotten yourself into a revolver. This is exactly what you see in Diagram 6. There I've drawn a 52° horizontal angle COP from tower to mast. Even if that buoy were just close to the COP, a two-COP fix would be quite uncertain because the COPs would cross at such a small angle. So what can be done?

First, you can avoid a revolver by sighting on three objects which themselves lie on a straight line or on an arc that bows in toward the boat, as shown in Diagram 7. If you have no such choice, you might just wait until the boat has moved on far enough that you are no longer in a revolver situation. I've tried several times to put myself into a revolver position and have yet to succeed Nevertheless, the possibility exists and you should be aware of it.

In Diagram 7, you are looking at an accurate fix determined by two COPs. Notice that the two arcs do cross each other at two points. One of those is the center object and you know you are not there! So the other intersection is the fix. You also see in that picture the way in which I label horizontal angle COPs.

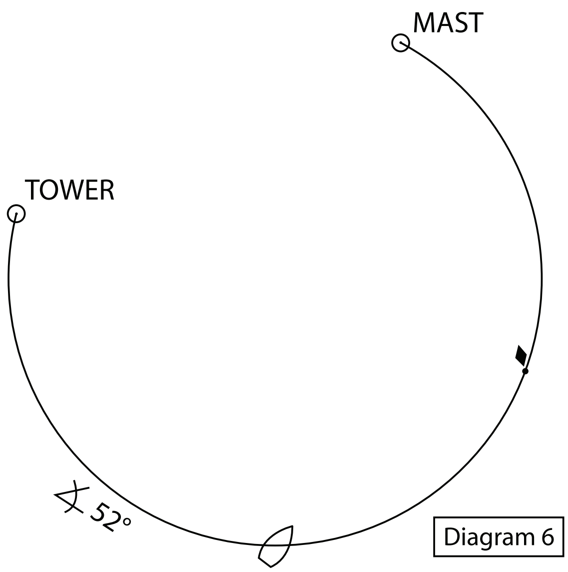


Diagram 6

Applications

Enhanced bearing Fix. I have evolved a procedure for taking a two-object fix that seems to be at least three times more accurate than a two-bearing fix. In a real seaway, it might well be five times more accurate (but that's a pure guess on my part.) Take bearings on the two objects first. Then, using the difference between the two bearings as a first approximation, use the sextant to measure the horizontal angle. Back down at the nav table, work up and plot the bearing LOPS. Then draw a short arc of the horizontal angle COP to cross both of the bearing LOPS with just a bit more to carry the labeling. Now take your fix at the midpoint of the arc between the bearing LOPs. The picture will look like one or the other of the ones in Diagram 8. (I exaggerated the bearing errors in that picture for emphasis.)

Advancing COPs. You can advance a COP for use in a running fix as easily as you advance an LOP. You simply advance its center point. Diagram 9 shows how. Note that I use only a short arc of the advanced COP. Also notice how I show an estimated position on a COP, namely by using a construction line from the center of the COP to the DR position.

A common situation. In Diagram 10 there are only two charted objects in view, but off to one side there is a well-defined edge of land. Measure the horizontal angles labeled α_1 and α_2. The angle α_1 translates into a COP as usual but α_2 does not! Can you see why not?

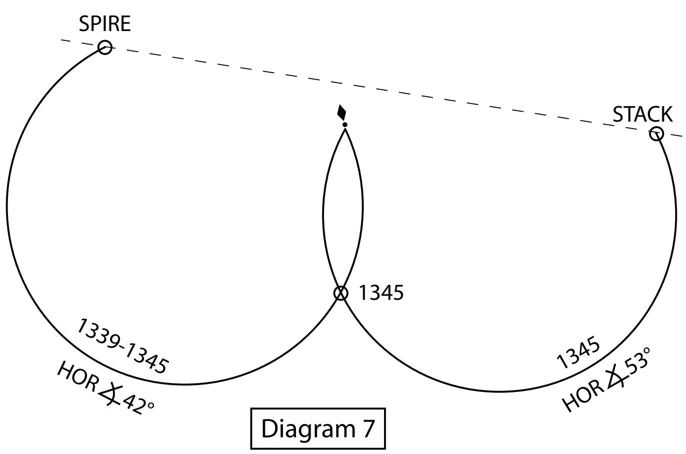


Diagram 7

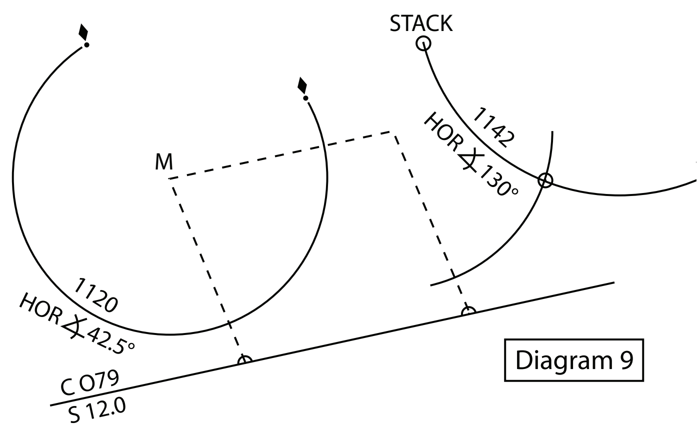


Diagram 9

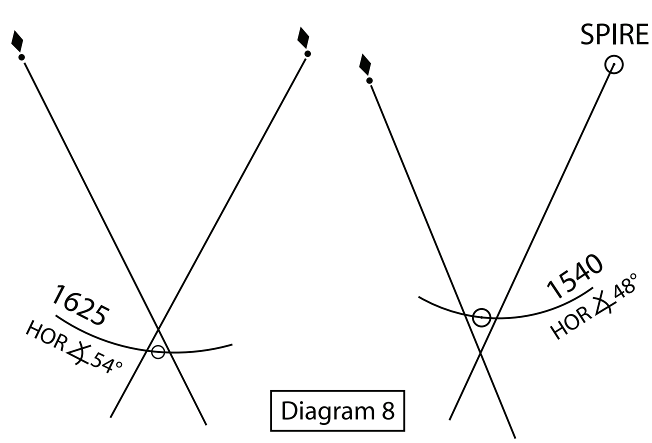


Diagram 8

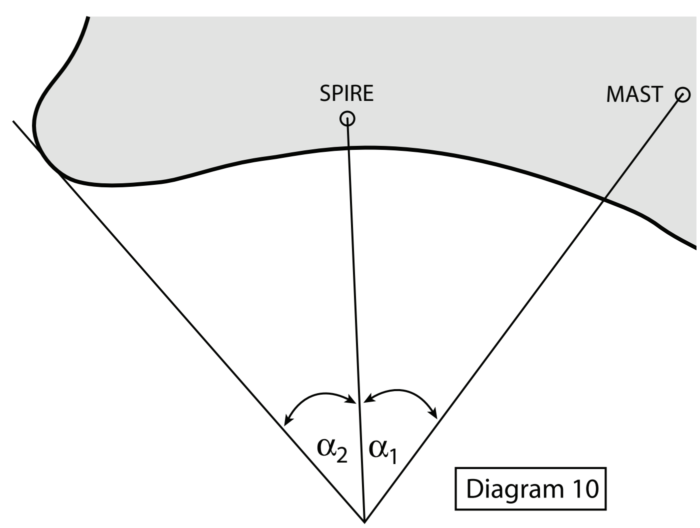


Diagram 10

The answer is that you cannot know the exact point of tangency along the shore. However, do draw the COP between the two objects as shown. Then you can use any sort of a plotter, keeping the zero point along the COP and moving the plotter about until the angle α_2 lines up with the shoreline. A three-arm protractor can be used to advantage here as well but do draw the COP as an added measure of accuracy.

Two Tangents. If there is nothing better to use, you can take horizontal angles between two or even three "edges," as shown in Diagram 11. I cannot find a COP in either of the two cases I picture and am forced to use a three-arm protractor. I do not find that instrument as accurate as the COPS I much prefer, but it does give you better information than anything else you can use in these circumstances. A prudent navigator uses every advantage he can find. He knows his tools and he practices with them assiduously. Do you?

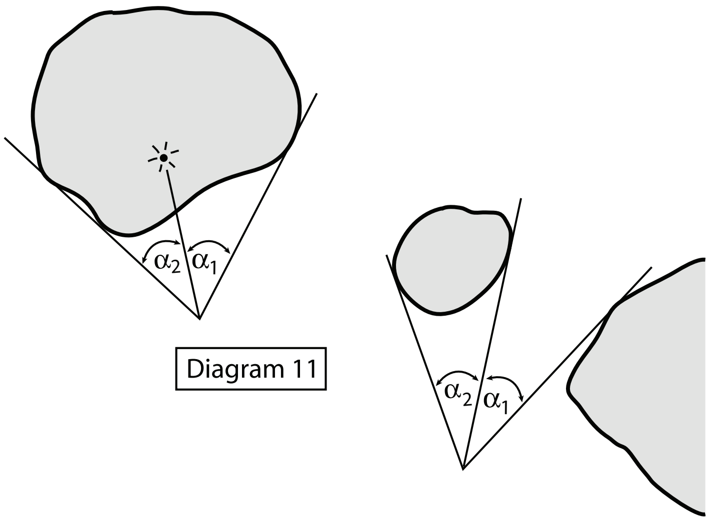


Diagram 11

Danger Angles. Let us turn from positioning to cruise planning. My charts are nicely decorated with red danger COPS as well as red danger bearings. With the aid of a pelorus and a sextant I can make some very tricky passages. So can you! There is nothing more satisfying than a smart bit of boat-handling followed by a precise anchor drop. It can really make your day, particularly if there are other skippers watching you work. Horizontal angles can help it to happen. Other problems can be treated with the same solution with similar results. Gratification!

Let's assume that crew on board want to bird-watch along the shore. You know that there is shoal water off that point up ahead. If you have prepared in advance, you will have a danger angle COP, in red ink, on the chart, so you can monitor the angle α shown in Diagram 12. As long as it remains smaller than the danger angle of 66° you know you are in safe water.

To draw such a danger angle COP we must fall back upon some high school geometry. The first step is to draw the perpendicular bisector of the line between the two objects (the lighted marker and the spire in Diagram 12.) To do this, set your draftsman's compass to any distance greater than half of that between the two objects. Swing arcs from each of the points on the chart to meet at points P and Q as on the diagram. Then the line through P and Q is the desired bisector. See Diagram 13.

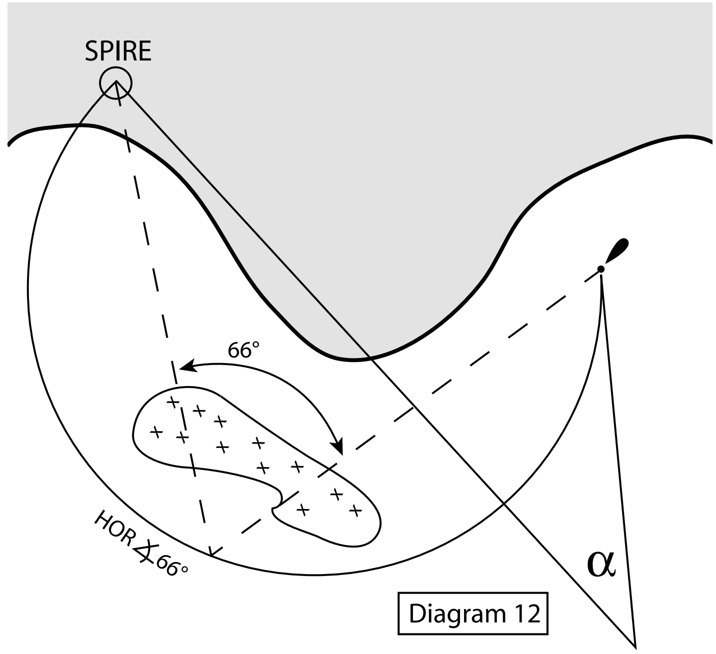


Diagram 12

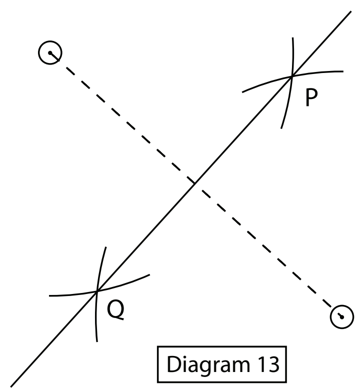


Diagram 13

Next, to draw the danger COP, keep the point of the compass on the perpendicular bisector and adjusting the spread of its legs as you move along, determine the COP that keeps you out in safe water. Draw the COP and then measure the danger angle α by selecting any point at all on the COP, draw a line from that point to each of the objects and use an ordinary protractor to measure the angle. It is easier to do it than it is to describe it!

There will be times when you will want to stay inside of a danger COP. (See Diagram 14 the next page!) To do so you merely keep the horizontal angle a greater than the danger angle you have on the chart. Incidentally, I still follow the teachings of the United States Power Squadrons and use a red pencil to cross-hatch the danger areas delimited by a danger bearing or a danger COP.

By combining danger angles and danger bearings, you can plan, and safely make, some very tight passages. The well-known cruising waters of the North Channel (Canadian Lake Huron) and the Bahama Islands south of Abaco have been the testing grounds for the techniques espoused here. I fully expect them to be as effective wherever they may be employed.

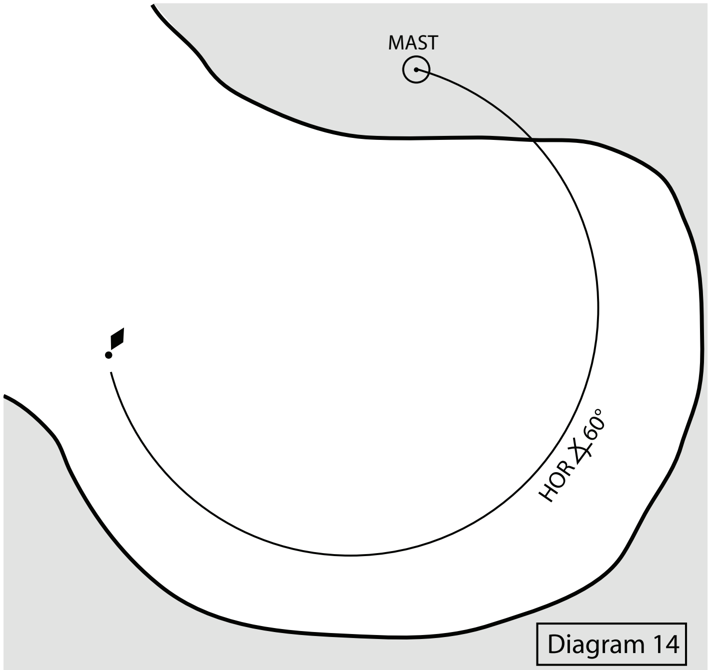


Diagram 14

Anchoring. I'll quit with one last application of a horizontal angle. After setting the anchor, measure the angle between any two fixed objects off to windward. These need not be on the chart, but if they can be seen at night you will feel much safer. I have used street lights, for instance. To ascertain whether or not your anchor is dragging, simply re-measure that horizontal angle. Any change tells you that your boat has moved. Even as little as five feet of movement can be detected this way. You cannot get that degree of precision with bearings, and the sextant is much quicker as well. Please notice that if you've had to anchor off of a lee shore and have taken the angle between two objects ashore, then an increase in the angle means that you have moved toward the beach. Try this the next time you are out there. You will be delighted at the accuracy, believe me!

NOTES ON SEXTANT PILOTING

By David Burch

We agree with John on the limited Bowditch coverage of horizontal sextant angles. The earliest edition we have here is 1851 and that provides only a summary of the mathematical theorems related to the process, without actual practical applications.

Looking at other issues we have, there is little more than a page in the 1919 edition (tan cover), which ends with a suggestion to refer to "...various works that treat the problem in detail." My guess is they refer to Lecky's *Wrinkles of Practical Navigation*, popular in that era and earlier, which does indeed have a long chapter devoted to the techniques.

This level of coverage gradually diminished in subsequent Bowditch editions to the point of just a mention of the danger circle application in the 1962 edition (blue cover). Then there was a resurgence in the 1977 edition (green cover), which coincided with extended coverages of several basic navigation techniques. That edition has a 10-page chapter devoted to the subject, with emphasis on use of 3-arm protractor. But then by the 1995 edition (maroon cover) the subject is gone completely, and it remains absent in the latest edition (2002, with a blue cover). We also note that none of these treatments uses the computed radius method that John describes here, which makes the process much faster whenever a calculator is handy. We have taught this method at Starpath over the years, but I am not sure how much it has been used.

We actually give sextant piloting more emphasis these days in our training materials than we did in the past for several reasons. For one, our work with radar has led us to do more two-range fix plotting, since radar ranges are generally more accurate than radar bearings. Once we get used to using a drafting compass in the pilot house for that application, the transition to other sources of circles of position was a natural step. And this is a bit ironic, since it is likely radar itself that caused the primary demise of the sextant piloting. Once the navigator could read off their position very accurately from the radar, there was less call for other piloting methods.

Another thing that led us to sextant piloting was our experience with the Davis Mark 3 sextants. These are the inexpensive ($39 or so) that John mentions in his article. These devices are easy to store and to use and cost even much less than a good bearing compass. And they are not only accurate enough, they are even preferable to an expensive metal sextant for horizontal angles—some of the *vertical* angle sextant piloting, however, does require a good metal sextant. We hope to cover this subject as well.

Still another reason has been that once we started doing our navigation training cruises on a steel vessel, we were forced to do our precision piloting this way, because magnetic bearing compasses usually do not work well from a steel vessel. We do have radar on the vessel, but the whole idea is to use some non-electronic method to back up the electronics.

Thus we cannot agree more. This technique from the past has every right to be revitalized. With that in mind, we added a very convenient digital solution to the problem in the StarPilot navigation software program. With that program you can simply type in the locations of the targets and the horizontal angles you measure between them and it will plot the circles for you and let you click the intersection for a fix. A time-limited demo version of the StarPilot PC program is available at <www.starpath.com/starpilotdemo>.

Finally we might mention the article "Mathematical 3-Arm Protractor" by W.B. Ruhnow, Navigation: Journal of the Institute of Navigation, Vol 31, No.1, Spring 1984. It provides a relatively simple mathematical procedure for solving for a range and bearing to one of the targets based on the angles measured. Everything is done in convenient relative units, so you could actually input target locations as X and Y coordinates measured in inches from a chart. (See Internet Resources for notes on the ION website).

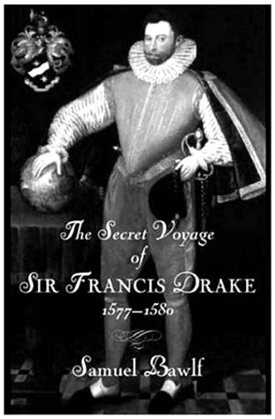
In a forthcoming issue we can compare the various solutions and discuss the criteria for choosing the best combination of targets, which has always been a key issue with this technique.

BOOK REVIEWS

The Secret Voyage of Sir Francis Drake

By Samuel Bawlf

Walker & Company, New York, (2003, 368 pages, $28)



By some standards, Sir Francis Drake's circumnavigation in 1577-1580 was the greatest voyage in history. Samuel Bawlf, a former British Columbia cabinet minister and geographer, has written a provocative new account of Drake's achievements, emphasizing the speculation that Drake sailed much further north on the Pacific coast of North America than the accepted location near San Francisco. A convincing case can be made that he reached present-day Alaska before turning westward across the Pacific. The assertion that this was then kept secret by Elizabeth's government is quite believable, more so after reading recent accounts of the Byzantine intrigue in her government surrounding the death of playwright Christopher Marlowe. The economic and strategic importance of a northwest passage (which Drake may have reported after entering any of several inlets or the Strait of Juan de Fuca) in the ongoing struggle with Spain would have justified not only secrecy, but deliberate falsification of published accounts.

Of particular interest to historians of navigation, however, is the intriguing possibility that Drake laid out a huge horizontal cross-staff on the ground near Neahkahnie Mountain, on the Oregon coast thirty miles south of the mouth of the Columbia River. In Bourne's "A Regiment for the Sea", published shortly before his voyage, Drake may have found a model for this gigantic navigational instrument. Bourne describes the construction of just such a device on the bank of the Thames near his home at Gravesend, although he does not mention its use for lunar distance measurements. Bawlf asserts, " .. it surely was Drake's attempt, employing the lunar distance method, to determine the longitude of the Pacific coast and hence the sailing distance through the northwest passage." When Native Americans showed the markings and inscriptions on rocks to early settlers in the area, speculation centered on their being left by buccaneers to aid in finding buried treasure. Highway construction has since required removal of the evidence to a museum. Maps based on Drake's reports placed the longitude of the coast at 140° W, substantially different from the modern value of 124° W but a "huge correction from the prognostications of Ortelius and Mercator". Since the invention of the telescope and discovery of irregularities in the motion of the moon still lay in the future, Drake's accuracy may have been state-of-the-art for 1579.

Review by John Lewis

John Lewis is taking flying lessons near his Seattle home, so his interests have broadened to include air as well as marine navigation. He is a member of the Puget Sound Maritime Historical Society.

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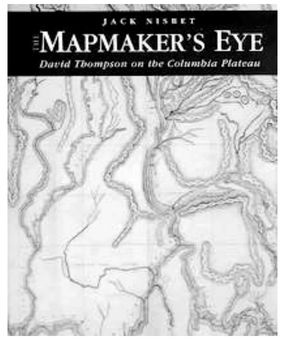
The Mapmaker's Eye

By Jack Nisbet

WSU Press, Pullman, (2005, 180 pages, $19)



Fast-forward 230 years to 1809, and we find lunar distances regularly employed by mapmakers to establish longitudes in remote areas. The frontispiece of Nisbet's fascinating new book on the achievements of David Thompson is in fact a page from Thompson's journal showing his logarithmic calculation of the longitude of a fur-trading post. Unlike the relatively scarce and sometimes dubious evidence of Drake's voyage, Thompson and other explorers of the inland northwest of North America left extensive journals, sketches and paintings. Nisbet's book is handsomely illustrated with drawings from several artists who traveled in this area about the time Thompson was establishing and managing trading posts, negotiating with Native Americans, making repeated trips of hundreds of miles on foot through rugged country sometimes in temperatures far below freezing, and producing meticulous charts of the terrain.

Thompson's first supervisor, at a Hudson's Bay trading post near Churchill, was Samuel Hearne. In Ken McGoogan's "Ancient Mariner: The Arctic Adventures of Samuel Hearne" much is made of the fact that Coleridge talked with Hearne after his retirement to England and may have used him as a model for the Ancient Mariner of the poem. The book is far more worth reading, however, as a moving story of the personal sacrifices these men made in exploring areas still considered remote and inhospitable. The touching account of Hearne's pet otter, and of his tragic forced separation from his native wife (who starved during the ensuing winter), make McGoogan's book another absorbing read.

Review by John Lewis

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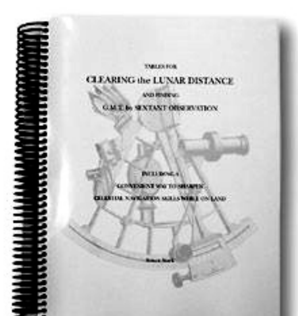
Tables for Clearing the Lunar Distance and Finding G.M.T. by Sextant Observation



By Bruce Stark (1997, 8.5x11, 200 pages, $37)

Despite a longtime interest in the history of navigation, I was late in obtaining a copy of this work of Bruce Stark, the valued historian of navigation.

Nevertheless, after I had studied Bruce's Tables and his explanatory texts, I was astonished by their ingenuity. They don't repeat old solutions mechanically, but are significantly better than renowned works of the past, although they don't misuse the modern technical possibilities and go the fully traditional way of tabular and paper solution. It had to be an intellectual adventure to compose them and it is a delight to study them.

Let me consider them in the historical perspective. I won't repeat information already published elsewhere (you can now read it at <http://members.chello.cz/kalivoda/LunDistClass.htm>). Here would I only remind that two classes of methods for clearing Lunar Distances (LD's) existed:

The "approximate" methods grew ripe relatively quickly and 50 years after the first volume of the Nautical Almanac had been published, they had reached the state of perfection with David Thomson in 1824. After that date no significant development in this field took place. These methods were very popular at sea during the whole 19th century for their speed, simplicity and for the important fact that they required the use of 4-digit logs only. Moreover, in spite of it, they permitted the (nearly) same accuracy as their counterparts - see an exception immediately below.

At <http://members.chello.cz/kalivoda/Thomson.pdf> you can read the detailed description and commentary on Thomson's "Lunar and Horary Tables for new and concise Methods of performing the Calculations necessary for ascertaining the Longitude by Lunar Observations or Chronometers...", London 1824 and subsequent sixty seven editions up to 1880.

Approximate methods had two great drawbacks. Firstly, the most popular and most widely used ones didn't allow the user to take the effect of non-standard refraction upon the measured distance into account, or they allowed it only by very bothersome procedures that would have deprived them of all their advantages, if used. This gap could only exceptionally create an error greater than 30" in the cleared distance, which was not a tragedy. Nevertheless, with these methods and in tropical (or Arctic) latitudes, the navigator had always to doubt of the reliability of his lunar distance (LD) a bit, if he used the Moon or the other distance body in a lower altitude than some 20 degrees.

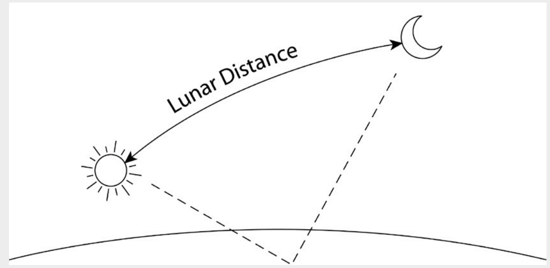
Secondly, the auxiliary tables necessary for use of these methods were very reticent in giving details of their structure and genesis. The sailor had to use them or reject them, but he could not make his own opinion about them. Some of these tables were checked by mathematicians, but only many years after their publication. Some were found very accurate (Thomson), some rather inaccurate (Elford), but without any impact on the sea practice.

It is no wonder that teachers of navigation hid the most popular "approximate" methods from their learners and that sailors with less fatalistic point of view sought another solutions. Such solutions were offered by the second class of methods for clearing LD's, by the "rigorous" methods. These methods were absolutely lucid for men that wanted to understand them. They gave the full control of the calculation, allowed every sort of corrections, the correction of refraction necessary for real atmospheric conditions, needless to say, included. But their drawback was their relative complexity and above all the necessity to use the 6-digit logs in computing and to switch from log values to natural values of trig functions alternately while solving them.

Old astronomers and arithmeticians used to say that each further digit of logs used in calculation increased its length and tediousness by a half at least. If so, the difference between the work with 4-digit or 6-digit log tables was palpable. In our days, when we have the accuracy of a calculation up to 10 digits and more at our disposal within the reach of one button of a hand calculator, we cannot imagine what a burden everyday logarithmic calculations created for ordinary navigators of 19th century.

What are Lunars?

Lunar distances, commonly known as "lunars," allow for longitude to be deduced at sea, after GMT has been obtained by using the Moon as a clock.



The moon moves around the sky once in a month, and a precise angle-in-the-sky between the Moon and Sun (or certain stars) can be compared with a precalculated value from the Almanac. The sextant measurement is made holding the sextant at an angle, so that rim of the sun closest to the moon acts as a horizon to measure the angular distance to the closest rim of the moon.

The measurement calls for all the precision that the observer, and his sextant, could possibly command, because an error of just 1 arc-minute would result in a longitude error of about 30 arc-minutes.

Before the comparison with the almanac could be made, the observation had to be corrected for the effects of parallax and refraction, maintaining high accuracy in that process, which was described as "clearing" the lunar distance. That was a complex business, adding significantly to the time taken and the likelihood of an error.

Through the late 18th and early 19th centuries, great efforts were devoted to simplifying that clearing process, for mariners. Lunar distances are no longer predicted in modern almanacs, but Stark's tables include provision for calculating them as required.

For more information, please see notes at the end of the book review.

Therefore, new rigorous methods for clearing LD's arose repeatedly during the 19th century and none of them was fully successful. They were pressed upon students of navigational courses, but in the sea practice probably only few fans and some snooty navy officers used them. Their main drawbacks mentioned above remained... until the work of Bruce Stark in 1995 and 1997.

Above all, Bruce derived and uses the very apt formula for reducing LD, which is:

hav D = hav (M~S) + (cos M cos S sec m sec s) ×
SQRT{hav [d-(m~s) hav [d+(m~s)]}

M,S,D = true geocentric altitudes of the Moon. Sun or star, and the distance between them.

m,s,d = apparent, (i.e. observed) values

(Maybe it would be useful to consult the excellent article of George Huxtable on logarithmic computations published at

<http://www.irbs.com/lists/navigation/0306/0008.html>, while reading the following text.)

The formula seems horrible, as all "rigorous" formulae do, but with Bruce's comfortable tables and work sheets, only a sharp pencil is needed for quickly resolving it. Its extraordinary advantage (never achieved before) is evident: the term (cos M cos S sec m sec s) excepted (which is taken from tables by inspection), only one trig function (haversine) is needed for computing!

And more: the haversine is extraordinary suitable at this place, as 5-digit log tables of it suffice to obtain the accurate result within the range of some arc-seconds. As you know, the haversine of an angle is the squared sine of the half angle. The squaring beneficially enlarges the differences of log mantissas between subsequent function values and the halving moves the used angle arguments farther from the right angle, where the sine would be very unreliable. Thanks to both of these features, the use of only 5-digit log haversine tables can be accepted. It would be impossible with the sine or cosine, so frequently used in old rigorous formulae. See bellow the third reason permitting the use of only 5-digit values.

The second of Bruce's accomplishments is the manner in which he solved the problem with the addition in his formula. Such addition makes the straightforward logarithmic solution of the equation impossible (see George Huxtable's text mentioned above). Additions, mostly inevitable in rigorous formulae for clearing LD even after torturing them by the most sophisticated trigonometric transformations, used to be overcome by jumping between log and natural values of trig functions. Of course, each such jump enlarged the time and effort demanded by the method and increased the maximal possible error of the result.

Bruce Stark goes another way. He uses the Gaussian logarithms that make possible to remain in world of logarithms all the time of calculation and transform an addition of natural numbers to the addition and subtraction of their common and special logarithmic values by use of a special table. It is much easier than to convert logs to their natural values, to add them and again to convert them to logs. Moreover, Gaussian logs yield greater accuracy of result than the traditional computing method and help 5-digit log values to be sufficiently accurate for this method.

The use of "Gaussians" by Bruce is original in the field of navigation. I don't know another example of using them by seamen or aviators—with the exception of Soviet navigators, which had Gaussians in their standard table sets up to about 1960. The Gaussians were probably regarded by the Soviet Navy as opponents of Anglo-Saxon cosmopolitan and aggressive haversine that was not allowed to the Soviet navigational practice. However, in Bruce's hands, Gaussians coexist peacefully with haversines in rationalizing the LD procedure to the level unknown so far.

The third asset of Bruce is his method of obtaining reference lunar distances that are to be compared with the cleared distance for obtaining G.M.T. One would say that after these distances had disappeared from nautical almanacs in 1907-1924, the death of lunars was imminent. Who was bold enough to tell sailors to compute reference distances by hand?

However, Bruce Stark changed this handicap to the contrary. He proposed the formula for obtaining the reference distances to be compared that is conformal with the well known haversine formula for finding the altitude in Marc St.. Hilaire's method. Therefore, with the prepared work sheet the time and effort for computing them is pressed to an absolute minimum possible. And because with modern almanacs at sailor's disposal one can compute such reference distances for each hour without any interpolation of GHA and declination, the interpolation of G.M.T. from them is much more accurate that in the times when 3-hours almanac intervals were common for tabulated distances. For an user of Bruce's Tables this makes possible to evaluate even very short distances that would have unusable second differences in three hours intervals. In addition, as Bruce Stark emphasizes, such short distances are the easiest ones to be observed from small sailing ships of archeonavigators riding their hobby of the celestial navigation.

Other advantages of Bruce Stark's tables I can mention only briefly, so that I could end this article soon enough. They are:

- Shifting from arc-seconds to hundredths of arc-minutes. This agrees with the custom of modern seamen
- Very handy "inside-out" tables reducing the demand for place
- Combining the corrections of altitudes for dip and semidiameters in one table
- If the user does not care about the principles, he need not even understand the idea of logarithm

After Bruce Stark had published his tables, every sailing navigator (fondling the GPS in his pocket) can revert to the sea history in his practice very easily, if he chooses. He can be sure that with these Tables, the history of Lunar Distances is consummated now and the long line of rigorous methods for clearing them ends successfully—and for the first time, after all of these years.

Review by Jan Kalivoda, jan.kalivoda@ff.cuni.cz

Editor's note. New member Jan Kalivoda is in the Classics Department of Charles University in Prague, Czech Republic. He has written extensively on many aspects of navigation, and we look forward to more of his work in this Newsletter. Some time ago he collaborated with member George Huxtable to compile a list of errors and misprints in the well-known History of Nautical Astronomy *by Charles H. Cotter (Elsevier Science, London, 1968)—errors that are valuable to know about, but do not distract from this otherwise excellent book that has long served as a main references for many topics. You can find this errata list at <http://www.huxtable.u-net.com/cotter01.htm>. The book itself is available in many libraries, but used copies are rare and expensive.*

Charles H Cotter is also the author of The Elements of Navigation *(Pitman and Sons, London, 1953), which includes a valuable treatment of horizontal sextant angles, showing the benefits of thinking of the line between two of the targets as the chord of the circle of position they define from the observer's position.*

We thank George Huxtable for the note on lunars on the previous page, and for his popular in-depth treatment of lunar distance techniques, which can be accessed from links on the www.lunardistance.com website (the fine work of Arthur Pearson) The site seems to be missing over recent times, but it is still registered and it can be reached at <http://members.verizon.net/~vze3nfrm>.

INTERNET RESOURCES

Please share your website discoveries with the membership. These can be general resources, as we have in the featured list below, or timely topics of special interest in navigation fundamentals.

* * *

This past Spring, member Dr. Geoffrey Kolbe participated in an expedition into the Southern Sahara, where he visited the Libyan Desert Glass area, saw rock engravings at the site of the legendary lost oasis of Zerzura, marvelled at cave paintings at Wadi Sora and the Foggini-Mestekawi cave in the Gilf Kebir, and examined the site of "The Largest Crater in the Great Sahara," whose discovery was announced at the beginning of March.

All the while, he kept track of his travels using dead reckoning and fixed the position of his campsites using celestial navigation. If you are interested in reading an account of this exercise in inland navigation using a bubble sextant, he has posted an excellent, well illustrated presentation online at

<http://www.pisces-press.com/C-Nav>,

which includes several links to cel nav related references.

Dr. Kolbe is the author of the *Long Term Almanac 2000-2050 for Sun and Selected Stars*, which also includes a set of concise sight reduction tables, similar to those of the Ageton method. This work is available to members for $20 but if you are in the UK or Europe it is more economical to order directly from Pisces Press in UK. This book was reviewed in the Newsletter by Ernest Brown in Issue 72, Summer 2001.

* * *

I want to emphasize again the value of the email list called Nav-L List, which has been very active since 1996. The goals of the participants are very similar to those of the Navigation Foundation and they discuss various aspects of navigation on a daily basis online. You can monitor the discussion at the link at

<http://www.irbs.com/lists/navigation>,

which is a site that archives the discussion—also offering search capabilities—or you can actually sign up and get the mails in your email daily, which also gives you the opportunity to take part in the ongoing discussion or raise your own discussion topics. Several members of the Foundation are active in the List since its inception.

To sign up send an email to <listserv@listserv.webkahuna.com> and in the message area, put nothing but...

subscribe navigation-l name

where "name" is the name you wish to be known by and the character before that is a lowercase L. You should promptly receive a welcome message back, and you're in. Instructions include how to be removed from the list if you choose. You can watch the archive a while before deciding to join.

* * *

Featured sites from past issues
http://www.celestialnavigation.net
http://aa.usno.navy.mil

FUTURE ISSUES

We have an exciting agenda on the horizon. Thank you all.

We have in hand the article from Leif Karlsen on sunstones and Viking Navigation. This will be in the next issue, along with a source for buying sun stones so you can try it yourself if you like. Thank you Leif.

The note that Leonard Gray sent in about the Bygrave slide rule has reminded me of some of our (Starpath) early work on the subject, namely what we call The N(x) Table — the world's shortest sight reduction table! It is a list of 89 numbers varying in length from 1 to 4 digits, from which you can get Hc and Zn for any sight. Needless to say, it takes some number crunching. We will present this and discuss it next time.

We are also promised an article for the Sept. issue from Bill Cook, chief of the Instruments Department of Captains Nautical supply. "Captains" is a classic navigation supply store. They have been in continuous business serving mariners in Seattle for 105 years. You can read about them at <www.captainsnauticalsupply.com>. Bill will tell us how to make a sextant mirror form readily available stock mirrors, including pros and cons, and tricks for cutting the mirrors. Is it best to cut them underwater?

And in a forthcoming issue, we will hear again from Bruce Stark, who is working on a series of articles on the navigation techniques of Lewis and Clark. I know there are many members interested in the history of navigation who will be looking forward to this work.

Please continue to send in your letters and contributions. It is your Newsletter. We need your input. Email works fine, as does a handwritten letter. Thanks.

NEW PRODUCTS

The following products are available to members at discount. Order directly from the Foundation. None of these is really "new," but they have been mentioned recently, so this is just a reminder.

• Bowditch 1851 edition, as a fully searchable ebook, Includes the text 800 pages and the full set of tables 800 pages. List $29, members discount 20%.

• Bruce Stark's Lunar Distance tables, reviewed in this edition, List $37, member's discount 15% (this is a large book, custom printed by the author.)

• All Starpath training software and course materials are available to members at 20% discount.

• Weems and Plath 3-arm protractor, list $25, member's discount 15%.

The Foundation for the Promotion
of the Art of Navigation
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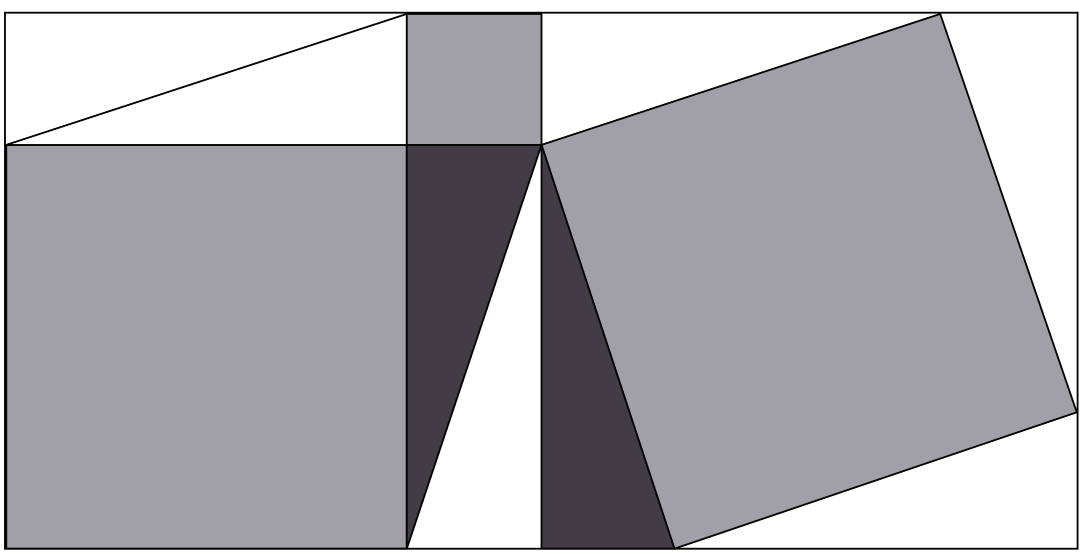
Rockville, MD 20850

"THE NAVIGATION FOUNDATION"



The Pythagorean Theorem ($a^2 + b^2 = c^2$) is a basic concept in navigation in that it provides a working definition of how to compute the distance between two points. If we imagine some grid of perpendicular map coordinates, then we can say that we get from A to B by traveling "a" miles along one axis and then "b" miles along the other axis. The theorem then tells us how to compute c, the distance between A and B.

Bowditch must have considered the theorem fundamental in that he included a proof of the theorem in his first edition, which survived at least to the 20th edition that we have from 1851. The proof he presented is straightforward and based on other theorems he included, but still a bit complex to follow. (Our otherwise earliest edition is 1919, and by then all the mathematical theorems are gone from the text.)

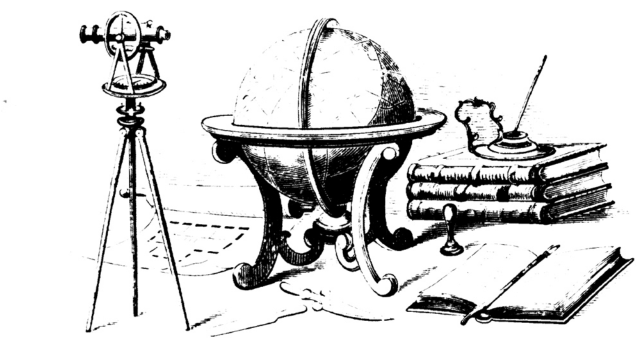
Study the above diagram to note it is a very elegant proof of the theorem all on its own. Practice writing up the instructions. It helps to recall the way Pythagoras presented his theorem in the first place: The square *upon* the hypotenuse is equal to the sum of the squares *upon* the other two sides.

ISSUE 93, FALL 2006

THE NAVIGATOR'S NEWSLETTER

FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a reader forum for the expression of our members opinions and their questions.



ACTIVITIES

By Terry Carraway

As you know from the renewal notices your contribution to The Navigation Foundation is tax deductible. With the costs of postage, printing and office supplies steadily increasing an additional few dollars added to your annual renewal, from those who can afford the extra, would be greatly appreciated. Thank you.

The Navigation Foundation hosted a Chesapeake Bay cruise for nine wounded veterans from the Walter Reed Army Medical Center on August 8, 2006. The cruise was sponsored by the National Capital Maryland Park Police and organized by Mrs. Marie Warner. The cruise toured the inner harbor area of Baltimore, Maryland proceeded out the Patapsco River and into the Chesapeake Bay. The cruise continued out into the Bay to the old Seven Foot Knolls Light.

All went well until our return, when the coolant pump fan belt broke and the engine overheated. Fortunately Mr. Sidney Smith, a Merchant Marine Chief Engineer, quickly replaced the belt and we were on our way back to the Marina. The cruise was suppose to last from 10 AM to 2 PM but because of the distance we traveled and the mechanical problem, it lasted until 5 PM. The Veterans were very happy with the extended time on the water and really enjoyed the day's outing.

In the adjacent photograph the support team are listed, but Walter Reed Medical Center asked that we not list other names.

Front row left to right: Terry F. Carraway, Captain US Navy (Retired), Chief Engineer Sydney Smith, Park Police Officer Heather McLoughlin.

Second row from left to right: One of the Iraq veterans, Park Police Officer Sergeant John Mc Intosh.

Third row right to left: Officer Heather Mc Loughlin's mother and father (they were invited to help in boat handling as they were very experienced boaters.) The persons to the left of Officer McLoughlin are an Afghanistan veteran, a Vietnam War veteran, just in back of this veteran is Mrs. Veronica Kidder (she and Mrs. Marie Warner provide the food for the cruise), to the far left is a Vietnam War veteran. The remainder of the nine are either Iraq or Afghanistan veterans.

EDITOR'S NOTES

By David Burch

May I thank our members once again for their contributions to the Newsletter. We have a full, exciting issue here and more on the horizon. Please keep them coming. You will see in the Reader's Forum that a simple book review has generated a full line of inquiry and debate that we can look forward to in the next issue. So if you have a book you would like to comment on, please do. It could be a new book, or one that has been in print for some time. The Newsletter is an excellent forum to present and discuss all aspects of navigation, modern and historical, as they might find their way into the public literature or news.

I have one in mind myself to comment on as time permits. It is *Daring the Sea*, by David Shaw (Citadel Press, 2003). It is about two Norwegian fishermen living in America who rowed across the Atlantic Ocean in 1894. I was attracted to this book because four young men from our neighborhood here in Seattle have just completed a transatlantic rowing race, taking first place and setting a new world record as the first boat to ever row from mainland US to mainland UK without resupply or tows of any kind. We will write more about this venture later—for details, see www.starpath.com/news.

Ocean rowing navigation is not much covered in standard texts (is that a surprise?) and we have learned a lot about it by following this team very closely for 70 days, from New York Harbor, through the Gulf Stream and numerous weather patterns, and on to Falmouth Harbor, UK. They survived a storm with hurricane force winds among other challenges, including an unusual High pressure system near the finish line that tried to drive them into France, but nevertheless, they ended up precisely where they set off to arrive, which, as it turns out, is quite an achievement in a row boat at sea. Our task will be to somehow write up the nuances of ocean rowing navigation without masking its inherent challenges. It remains a risky sport, but so, to some extent, does crossing the ocean in any small vessel, for that matter.

The chain of Newsletter discussion has also motivated research and an in-depth report by member Dr. Geoffrey Kolbe on the Bygrave slide rule. This topic was requested recently by Leonard Gray. The subject had not been mentioned in the Newsletter since a John Luykx article some 16 years ago.

If you do ever wonder what was covered when, you can refer to the online index of past articles at www.starpath.com/navigationfoundation. Then if you wish to see the full text of the article and do not have the past issues, you can read them all in the Newsletter Archive available on CD from the Foundation.

We are also pleased to have the first in a series of articles on Lewis and Clark navigation by member Bruce Stark, author of *Tables for Clearing the Lunar Distance*, and numerous contributions to the Newsletter. He begins with comments on their Dead Reckoning, which remains the foundation of all good navigation. We have missed Bruce in these pages and look forward to his contributions.

And we thank Lief Karlsen for bringing Viking navigation into our pages. A search of the archive shows that this has not been discussed before. His notes here are adapted from his book *Secrets of the Viking Navigators—How Vikings used their amazing sunstones and other techniques to cross the open ocean*. This book can be ordered from the Foundation at a 20% discount.

The Reader's Forum also includes this time a short biographical note about member Philippe Posth from Plaisance, France. Philippe has been a member for several years and has made many fine contributions to the field of celestial navigation and is a source for related materials in France. And thus we invite other members to send in information about themselves if they care to share it as a way for members to get to know each other. With this in mind, we have started to include brief biographical notes with the articles and correspondence to the extent you care to participate.

Several of the topics we mentioned in the past as likely content of forthcoming issues have been postponed, but all are still on the horizon, including the survey results. Perhaps if we drag our feet another quarter on this one we might get a few more responses! As it is now, we have heard back from just under 10% of our membership. Do I hear the sound of a lead balloon?

Finally we are sad to include the obituary of navigator and author Bruce Bauer. Many of our members are familiar with his book on sextant use and care.

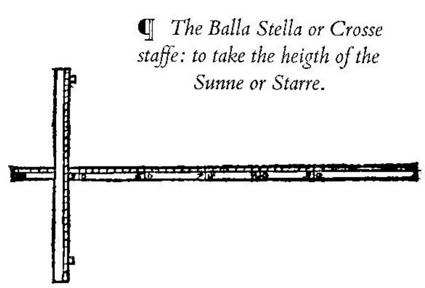
READER'S FORUM

Cross or Cross-staff?

Issue 92 contained a review, by John Lewis, of *The Secret Voyage of Sir Francis Drake*, by Samuel Bawlf. I haven't read that book, and recognize the weakness in commenting from such a position, but Bawlf's assertions, or Lewis' interpretation of them, need to be challenged

Lewis writes: "Of particular interest to historians of navigation, however, is the intriguing possibility that Drake laid out a huge horizontal cross-staff on the ground near Neahkanie Mountain, on the Oregon coast thirty miles south of the mouth of the Columbia River. In Bourne's "A regiment for the sea", published shortly before his voyage, Drake may have found a model for his gigantic navigational instrument. Bourne describes the construction of such a device on the bank of the Thames near his home in Gravesend, although he does not mention its use for lunar distance measurements..."

First, the cross-staff is a hand-held instrument, used at sea for measuring angles in the sky, so what function a "huge horizontal cross-staff on the ground" could possibly serve is hard to imagine.



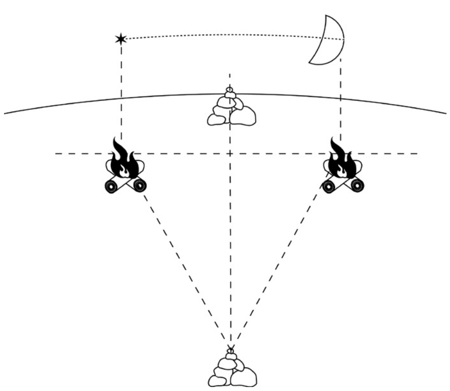
Second, it's true that William Bourne wrote *A Regiment for the Sea*, in that period 1574 and 1582, and that he lived in Gravesend, which is on the bank of the Thames, but the "construction of such a device on the bank of the Thames" is a product of someone's heated imagination. Bourne describes no such thing. What Bourne describes, and illustrates, is the ordinary hand-held cross-staff, which he calls a ballestilla; that's all.

The idea, of using lunar distances to determine longitudes from on land, was certainly around at that time, as pictured in a woodcut from Werner and Apian, 1553. But the technology for sufficiently precise measurement, and enough understanding to predict the Moon's position and allow for its parallax, would not exist until 200 years later. Claims that Drake obtained lunar-distance longitudes need strong evidence before they can be taken seriously. Judging by the cross-staff rock carving story, that seems unlikely.

George Huxtable, Oxon, UK, george@huxtable.u-net.com

Editor's note.
This letter from long time member George Huxtable, FRIN, has subsequently led to a long line of inquiry, with responses from the reviewer John Lewis, and from the author Samuel Bawlf, along with further detailed comments and observations of Mr. Huxtable. This in-depth dialog took shape as the present issue was nearly completed, and as you can see we are chock-a-block with content previously scheduled. Our next issue No. 94 will be devoted in large part to this illustrated discussion, born from this letter about the use of the word "cross-staff." So much in one word.

John Lewis's summary of the book's statement is fair—the author's exact words were "...Bourne had created for Drake the geometric equivalent of a very large cross-staff laid out on the ground." The initial question that occurred to several readers was could this be referring to a religious symbol, rather than a navigation tool. We have since learned that what was meant was not the drawing of a cross-like figure, but apparently something like what we have drawn here, wherein the intention was to find a fortuitous moon-sun or moon-star pair that was low on the horizon whose angular separation might be measured with such an arrangement, essentially two transits. Thus it would act as a cross staff*, in that, in principle, it could be used to measure astronomical angles.*



The questions subsequently raised by George Huxtable to be addressed in next issue go beyond this use of the word cross-staff and look more to the fundamental question of whether or not this arrangement could feasibly carry out its proposed function, along with more inquiry into the possible role the work of William Bourne may have played in this moment of history. We thank the author Samuel Bawlf for providing more details about his conclusions (not part of the published book) and for his request that navigator's pursue these ideas. And we thank George Huxtable for doing just that, along with checking some of the original materials that he had access to in the UK, and for sharing his insights into this question.

In the next issue you will find the clues and claims laid out and discussed. It is an interesting exercise in navigation and historical research. We look forward to the participation of other members as well.

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The Navigator's Newsletter
Issue 93, Fall 2006
Published by
The Foundation for the
Promotion of the Art of Navigation
www.navigationfoundation.org
P O Box 1126
Rockville, Maryland 20850, USA
Phone or fax 301-622-6448
Executive Director, Terry Carraway
Newsletter Editor, David Burch
Inquires about membership or Newsletter content
or contributions can be send to the above address
or by email to navigate1@comcast.net.
The Navigator's Newsletter is published four times
annually, with our strived-for publication dates
of approximately the solstices and equinoxes.
Newsletter production and other Foundation
activities are provided by volunteers. Please bear
with us if we slip on the dates occasionally.

Historical Navigation Texts

I have an assemblage of about five original navigation books, all bound under one cover with the earliest one printed in Dublin, Ireland in 1739. The condition of the material ranges from good (full pages clearly legible) fair (with corners and text missing or pages with water stains but still legible), and poor (with pages missing.) In most places the front-piece of each book is missing. The cover is deteriorated.

Even though the condition of the book is poor, it does contain a wealth of information about the practice of celestial navigation in the mid-1700's. For example, it contains many working examples for finding one's latitude by the sun and stars, but very little about deriving longitude (nothing on lunar sight distance, for example). The book shows how to use the quadrant, forestaff and astrolabe and has tables for the years 1749 -1757 for the declination of the sun and the "place" of the sun related to the first point of Aries. It has tables of the "fixed stars," describes some navigational stars by their location within constellations, and provides the latitude and longitude of Capes, Headlands and Islands along the many coasts of the world, including the Barbery Coast, the coast of Carolina, Virginia, Pennslyvania, New England and Newfoundland. The material seems to be a training manual for sea going navigators and shows quite an amount of computational methods to derive position, including the Gunter method, which I have never seen before. There are other examples of using logarithms to solve navigational problems.

The book also contains tide tables for the coast of Ireland, Great Britain, Flanders, France and Portugal. In addition it provides soundings and description of the bottom materials at various locations near the Uphants and Scilly Islands, (1740) always known as a very hazardous place for boats returning to the English Channel and London. The last part of the assemblage is a series of sailing directions around headlands and into harbors around the English and Irish Coasts, with some pages showing the land profiles from the sea.

This latter element explains how I came in possession of this curious and hopefully useful (to historians) navigational text, tables and diagrams. My grandfather, Henry P.F. Donegan was a yachtsman (and a yachting historian) who sailed out of Cork Harbor and in 1929, and wrote the Sailing Directions for the South and South West Coast of Ireland for the Irish Cruising Club, which he helped to found. He obviously used this material as a source. It is accompanied by a half-page typewritten extract of the approaches to the Old Head of Kinsale that seems to have my father's signature. (My father, also Henry Donegan, cooperated in publishing the Sailing Directions to the South and South West Coast of Ireland.) It also looks like both of them took it to sea a number of times. It has been passed down in the family to me. I grew up in Cork but moved to Columbia, Maryland in 1968. Rather than have it lie in my house, deteriorating as the years go on, I would like to sit down and review it with someone familiar with the history of navigation in the mid-1700's who could evaluate it (not on its condition, which is poor) but on the content, and see if it clarifies or adds new knowledge to the history of the practices of navigation at that time. I'm not particularly interested in establishing the commercial value of it. I'm more motivated that it could be put to greater use in the hands of an historian or museum.

I have some knowledge about Celestial Navigation, and I am particularly interested in the history of navigation. I've sailed offshore many times, before and after GPS, and I used to teach an introductory course for sailors in Celestial Navigation in the non-credit program at Howard Community College, MD for a number of seasons.

I've done some writing in the past, and, perhaps, would be interested in co-authoring with someone who is currently, or is highly interested in, writing or publishing material on the history of navigation of this particular time.

I have not contacted anybody else about this material. I look forward to hearing from you.

Brendan Donegan, Columbia, MD

Editors note: Mr. Donegan has since scanned some sample pages of the manuscript, and we are investigating making an ebook version, which could then be made readily available to those interested. In the meantime, please let us know if you have a particular interest in this period or this publication.

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La Navigation Astronomique

At your request, here are a few notes about myself. I am self-taught in Celestial Navigation: I learned it myself in books 10 years ago, and I've encountered many difficulties to understand how it works. But, one day, the "light switched on" and I began to understand. So, I wrote some simple programs for Casio Calculators, calculating ephemeris and sight reduction. I have published these programs and an explanation of Celestial Navigation "à ma façon" in a book entitled "Navigation Astronomique et calculatrices programmables" edited in 1997. This book encountered a good success because it was the first in french to give this kind of programs and an explanation quite simple of Cel'Nav which is sometimes described in a very complicated way in some books. And I met Mr. François Meyrier at the time, celestial navigation teacher here in France, who you mention in an earlier Newsletter.

After that, when the Internet became popular in France in 1999-2000, I created my first website entitled "La Navigation Astronomique? mais c'est très simple!" with an absolutely free Celestial Navigation course, and many free resources: including ephemeris, all downloadable at the address <http://navastro.free.fr>.

In 2002, I've created my company dedicated to selling Celestial Navigation products: sextants, books, calculators, softwares. I work only on the Internet, with a second website <http://navastro.fr>.

Philippe Posth, Plaisance, France

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NAVIGATION NOTES

VIKING NAVIGATION USING THE SUNSTONE, POLARIZED LIGHT AND THE HORIZON BOARD

by Leif K. Karlsen

How did the Vikings manage to navigate across the open ocean for thousands of miles without conventional instruments? Many books have been written about their amazing voyages, but they don't offer much detail to explain their navigational methods. Furthermore, there are practically no navigational relics from Viking era sites to reveal any secrets; most suspected navigation tools found so far have deteriorated beyond recognition.

To fill in this missing part of Viking lore, we must try to imagine ourselves in that time—driven to explore what lies beyond the sunset, possessing great common sense and courage, but lacking any tools and techniques of modern navigators.

Based upon my experience as a modern navigator and on hints given in the sagas and in the old Icelandic lawbook, the Grágás (Grey Goose), I firmly believe that the sunstone and some sort of a bearing board, similar to the horizon board described later, were used by the Viking navigators to guide them across the North Atlantic, and to other destinations they reached. These simple but effective aids to navigation allowed the Vikings to claim their place as one of history's great seagoing people.

The Vikings mostly sailed in the summer, when the northern latitudes are experiencing long days and short nights. Consequently, the Vikings depended on the sun rather than stars for navigation. At the latitudes where the Vikings sailed, no place in the region experienced true darkness in the summer. At latitude 61° North for example, from the end of April to the end of August the sun was available for more than 14 hours a day. At higher latitudes the sun was visible even longer. What more appropriate scheme could they have discovered to direct their ships, than to use sunlight refracted through a crystal found on the ground in Iceland? This crystal is called Iceland spar.

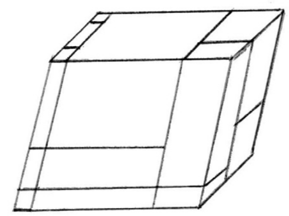
There were times during certain conditions, such as fog, that the sunstone could have been used at sunrise and sunset by the navigator. When very cold air moves over warmer water, wisps of visible water vapor may rise from the surface as the water "steams." In extreme cases this frost smoke, or Arctic sea smoke, may rise from a few feet to a height of several hundred feet. The portion near the surface forms a dense fog which obscures the horizon and surface objects, but usually leaves the sky relatively clear. Often in this type of fog, a ship passing by would have only the top of the mast showing with the surface fog obscuring the rest of the ship.

When the light from the rising or setting sun was lost in the fog bank, but the zenith was cloudless, the navigator could tell the exact position of the sun by using the sunstone, although the sun itself was unseen. Even on clear days, the horizon at sea is often obscured by haze or distant clouds. This is an ideal situation for using the sunstone to find the sun.

The basic principle of the sunstone (Iceland spar) is polarization of light, first described in 1669 by Erasmus Bartholimus, a Danish professor of mathematics and medicine, and a naturalist. Later on in 1678 the Dutchman Christiaan Huygens is his *"Treatise on Light"* writes that he also studied the double refraction Bartholimus had described in Iceland spar.

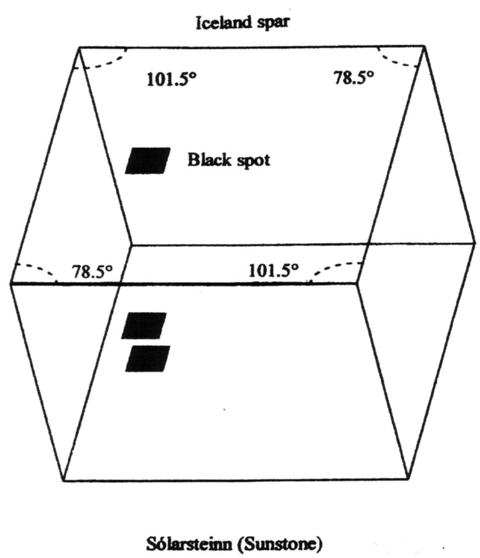
Iceland spar is also known as optical calcite and calkspat. In Iceland it is called Silfurberg. It is composed of molecules of calcium carbonate ($CaCO_3$), with the calcium atoms arranged in planes in a crystal lattice. Such crystal shows a natural cleavage. The crystal can be split into smaller crystals, all the way down to tiny pieces, always with the same angles as the original crystal.

Figure 1.



The crystal has a rhombohedral crystal structure, its opposite faces are parallel but there are no right angles. A perfect crystal is colorless and transparent. The angles are 101° 30´ for the obtuse angle and 78° 30´ for the acute angle. The structure of the crystal leads to the optical phenomenon of double refraction. An object viewed through the crystal will be seen as a double image.

Figure 2.



Direct sunlight is unpolarized, but the reflected sunlight that we observe in the blue sky is partly polarized. When sunlight passes through the earth's atmosphere it is scattered in all directions. The scattering is strongest for blue, the frequency in the visible range nearest to ultraviolet, thus giving the sky its characteristic blue appearance. At *sunrise and sunset,* the light reaching the observer has traveled farther though the atmosphere and those frequencies in the blue range have been removed by previous scattering. This allows the yellow and reds to predominate near the horizon in the twilight sky.

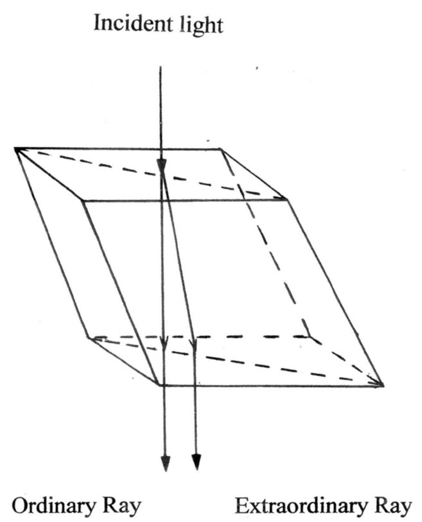
The scattering of sunlight by the atmosphere produces polarized light for a navigator looking at right angles to the direction of the sun, for instance, if he looks straight up at sunrise and sunset. If he is looking towards the sun, he sees unpolarized light that contains more red than blue.

The earth's atmosphere serves as a polarizer. If the sunstone is placed horizontal when the sun is on or near the horizon, it serves as an analyzer. The sunstone provides a directional reference during twilight, or when the sun is near the horizon in a fog bank, or behind an island, provided only that the zenith is cloudless.

A Demonstration using Iceland spar.

Iceland spar is well known material for its double refraction. When unpolarized light enters a calcite crystal it is split into two linearly polarized beams which are refracted by a different amount. The ordinary ray obeys the law of refraction; the extra ordinary does not, it bends away from the ordinary as it enters the crystal. The ordinary and the extra ordinary rays follow different paths inside the crystal, but when leaving the crystal they follow parallel paths.

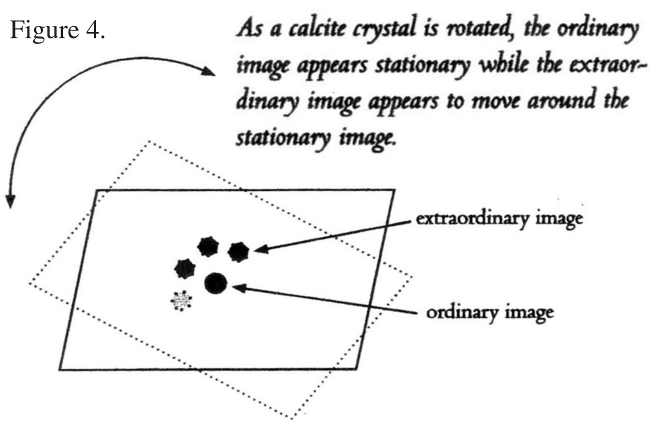
Figure 3.



Double refraction in optical calcite

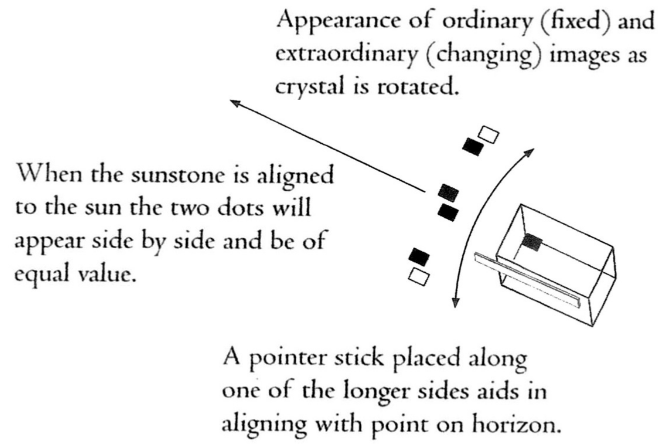
Make a small mark on a piece of paper and place the crystal over it. You will see two distinct marks; both of them sharp an clear. Slowly rotate the crystal. One image will remain stationary as the crystal is rotated, this ray is called the ordinary ray. However, the other image will rotate with the crystal, making a small circle around the ordinary image. This is called the extra ordinary ray.

Figure 4.



In order to use a crystal as a sunstone for finding the sun, a small black dot is placed at the center of the top surface, so it will face up when the stone is held overhead. View this dot from underneath by looking up through the stone while holding it level to the horizon. You will notice the single dot appearing as two dots when viewed through the stone.

Figure 5.



Align a pointer to one of the long sides of he crystal, and point it towards the brightest area of the sky. Upon rotating the stone back and forth in the horizontal plane, you will see that one image fades and the other becomes darker. When the two images appear to be equal in value, note the position of the stone and pointer. The pointer is now aligned to the true bearing of the sun. It is accurate to within one degree.

For accuracy, the sunstone must be level and have an **unobstructed view of the zenith,** for if light does not enter the sunstone perpendicularly, an error is introduced. A thick cloud layer overhead scatters the polarized light from zenith, preventing the use of the sunstone.

Any Iceland spar crystal will work as a sunstone as long as it is optically clear. The thickness of the crystal is important. The thicker the crystal, the better is the refraction (separation) of the black dots.

Bearing at sunset

April 25th, 2006

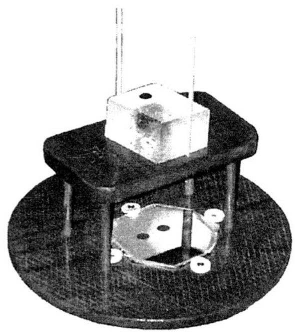
Location: Port Orchard, WA USA

Position: 48° 34.5´ North, 122° 34.0´ West

A bearing was taken at my home at 20:04:28 local time, (GMT 03:04:28) April 26th.

The bearing was taken shortly before sunset. The location of the sun was not visible, the sun was setting behind the forest. The zenith was cloudless. I had made a pedestal with a cutout hole for the sunstone, which sat on a mirror placed on a rotating wooden disk. It also contained two sighting pins on top. Instead of holding the stone up in the air and bending my neck backwards to look through from underneath, I could just glance into the mirror to adjust the stone.

Figure 6.



The author's sunstone stand showing the black dot on top of the stone and the reflected double dots in the mirror underneath. The advantage of this stand is that the observer does not need to hold the sunstone overhead and look up at the sky.

First I lined up the stone toward the relative brightness of the evening sky. Then it was rotated slowly back and forth until the double image was equal in value. I noted the exact time. I left the stand in a stationary position. Then a bearing was taken of the position of the stone, using the two sighting pins on top of the stand. This bearing was taken with a magnetic compass (Silva). After the bearings were taken, I used the Nautical Almanac for the year 2006, and the sight reduction table Pub. No. 249, volume 3 to calculate the true bearing of the sun. The bearing of the sun was 289°.

The bearing of the stone with the magnetic compass was 271° + 18°15´ variation east, =289°15´ true. The sunstone pointed to the hidden sun at 289° true.

I compared the sunstone bearing with the magnetic compass bearing **only** to show the accuracy of the sunstone.

The sunstone and the Horizon Board

The Vikings did not have a magnetic compass, but they had other ways to get their bearings and to guide their ships across the ocean. They divided the visible horizon into eight sections, which they called *attir*, meaning "main directions." They based this on the orientation of the Norwegian west coast, which runs approximately north and south.

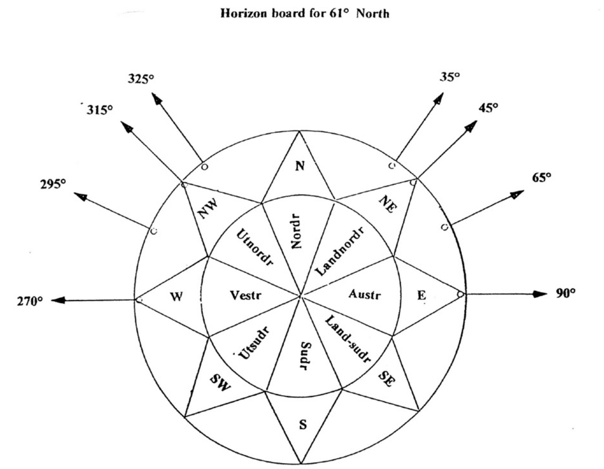
To demonstrate how the Vikings used the horizon board to get their bearings, I have created my own horizon board. This is not a replica of an artifact, but an original device based upon information from the Old Icelandic lawbook Grágás (Grey Goose), a title of uncertain origins.

The horizon board is simply a flat surface, such as a flat board, upon which is recorded the *attir.* Also indicated are the azimuths of sunrise and sunset over the sailing season on a certain latitude. The horizon board shows how this information about the sun and the eight sections of the horizon could be put to use in navigation.

The Vikings referred to latitude not by degrees but by the name of landmarks and places located at the appropriate latitude. For example: Instead of saying latitude 62° north, they used the name Stad, Norway, the place they sailed from, and the name of their destination, Thorshavn, Faeroe. The horizon board shows how the Viking navigator could, with observations he made at home, sail a latitude course from a homeport, across the ocean to his family's homestead, as recorded in the sagas.

The horizon board visually demonstrates the direction of the rising and setting sun during the months of May, June, and July at a given latitude. Small holes on the edge of the horizon board are used with wooden pegs to mark the direction to the sun.

Figure 7.

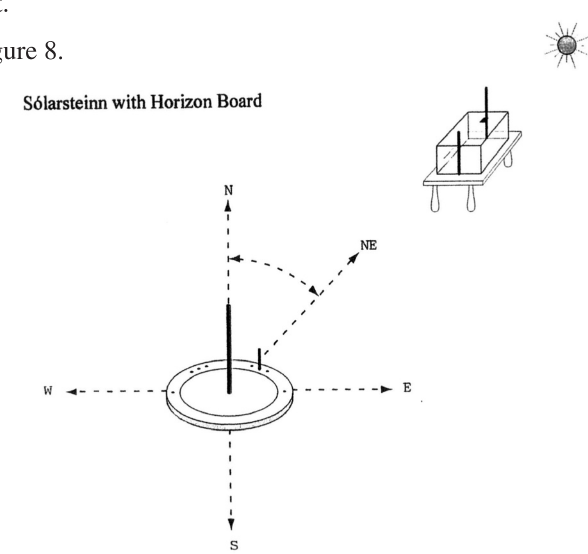


Sunset	Date	Sunrise
325°	June 6	035°
315°	May 17	045°
295°	Apr 19	065°
270°	Mar 21	090°

The horizon board is quite easy to use. For example: assume the navigator desires to set a course due west from his departure point at Hernar Norway (61° North) on May 17st on a clear morning. The sun will rise here at 045°, Northeast. The wooden pegs on the horizon board will be set in the appropriate holes on the horizon board, and the true bearing of the sun will be taken. With an accurate reference bearing, the desired course west can be read from the horizon board. The same procedure is used for all other months. But if clouds or fog hides the sun, as is often the case in these waters, then the sunstone will be needed.

At sunrise on a morning with an obscured horizon and a clear zenith, the sunstone can be set up to find the exact bearing of the sun. When this is done, the horizon board will be aligned with the sunstone's bearing to the sun at 045°. The horizon board shows the sun's true bearing and the desired course can the be determined from it.

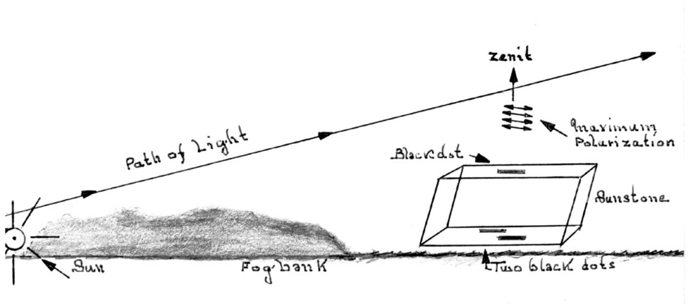
Figure 8.



A horizon board for other latitudes is easily made. The principle is the same except that the bearings are different.

During frequent foggy conditions, the use of the sunstone with the horizon board was a good combination, as the information obtained is truly valuable to the navigator. Knowing the location of the sun, he can align the horizon board and determine other directions hence the heading of the ship. Use of the horizon board also allows the navigator to make good use of the sunstone to find his course amidst a dense fog or clouds on the horizon.

Figure 9.



The sunstone pointing towards the relative brightness of the evening sky. At sunrise and sunset, the sun's rays are horizontal and the light from the zenith should be completely polarized.

References:

Bunn, W. Charles, *Crystals, Their Role in Nature and Science*, New York, Academic Press, 1964.

Huygens, Christiaan, *Treatise on Light*, University of Chicago Press, 1937.

______, *H.O.Publication 216*, United States Government Printing Office, Washington, DC, 1955.

Pedersen, Einar Sverre, *Polar Navigation*, Scandinavian Airline System, 1956.

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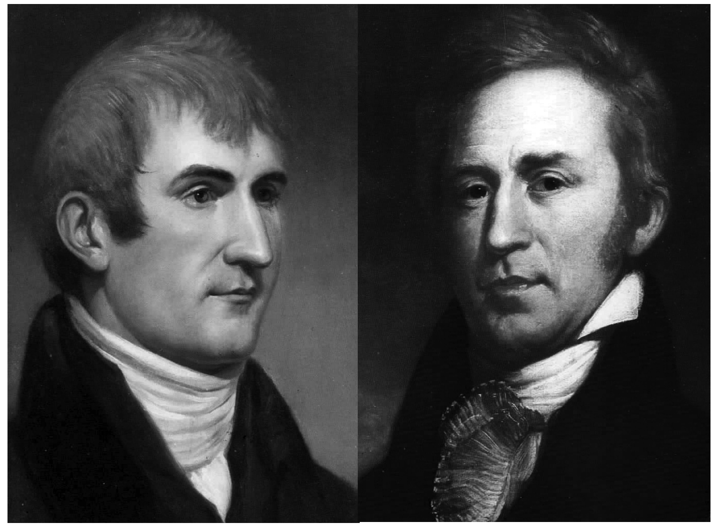
The Author at the helm of the replica Viking ship the "Borgundknarren".

NAVIGATION NOTES

LEWIS AND CLARK'S NAVIGATION, AN OVERVIEW

by Bruce Stark



Meriwether Lewis 1774 - 1809 | William Clark 1770 - 1838

Part 1

Lewis and Clark found their way across the continent and back by following rivers and the advice of Indians. Strictly speaking, they weren't navigating, they were surveying. But that distinction doesn't concern us here. Our interest is navigation, and the Captains were using the techniques of navigation, altered to fit their needs.

Background

At that time the whole of the United States lay east of the Mississippi River. What little was known of the expanse beyond came from the writings and maps of French, Spanish, and British explorers and fur traders. French inhabitants of the lower Missouri had extended the trade up that river all the way to the Mandan Villages, in what is now North Dakota. David Thompson, working for a British fur company, had come to the Villages from the north, and had taken observations for latitude and longitude. The Mandan and Hidatsa informed the French and British that the river's headwaters lay in mountains far to the west.

A British survey of the Pacific coast, under Vancouver, had established the latitude and longitude of the Columbia River and mapped its lower reaches one hundred miles or so to the east.

Jefferson had reason to hope that the headwaters of the Columbia—or perhaps some other western river—lay near those of the Missouri, in the mountains of the continent's interior. If canoes could get to the headwaters of the two rivers, and furs and trade goods portaged between them, the United States would benefit both economically and strategically.

The Corps of Discovery's mission was to find this passage, if it existed. In any case they were to bring back as much practical and scientific information as they could. This would include data for creating a geographically reliable map—ideally a map linking the United States to the Pacific coast.

Dead Reckoning

Since dead reckoning would be the thread holding the map together, I'll discuss it first, putting it in the context of the time.

At sea, dead reckoning was the mainstay of navigation. Although a complex art, the idea was simple enough. Take a "departure" from some point of known latitude and longitude, then keep track of every direction and distance sailed. Direction was determined by the ship's compass, with allowances for leeway and the difference between true and compass north. Distance was determined by speed and elapsed time. The navigator's estimate of speed was checked by log line, every hour on navy ships, every other hour on commercial ships. The number of knots and fathoms of the line that ran out in half a minute gave the ship's speed.

Each day the navigator "worked the day's work." That is, he resolved the courses and distances since the previous noon and brought the ship's dead reckoning latitude and longitude forward to the present noon.

The Voyage of Discovery began in the St. Louis area on May 14, 1804. Lewis stated that the mouth of the DuBois River was the point of departure, and gave the coordinates as:

Longitude West from Grenwh.	89° 57' 45"
Latitude N.	38° 55' 19.6"

From that point on, a record was kept of each day's courses. Here are Clark's entries for August 22, 1804, taken from Volume 2 of Moulton's *The Journals of the Lewis and Clark Expedition*:

S 47° W.	1 1/4	mes. on the S. point.
West	1 1/4	mes. to the lower point of a Bluff on the L. S.
N. 18 W.	2 1/2	ms. to a pt. of high wood on the L. S. passed a Creek
N. 56 W.	5 1/2	Ms to a Clift on the L. S. opsd. a pt. passd a Sand bar on both Sides of the river.
N. 54 E.	2	mes. to a pt. of Sand on the L.S. opsds. the R Souis is near the Missouries.
N. 48 W.	6 1/2	Ms. to a Tree in the Prarie on the S. S. psd a pt. of Sand on the S. S. 2 Sand bars in the
	19	middle of the river-

S. S. is starboard side, L. S. is larboard side. Clark simply added the miles and left the reckoning to be worked out later. There was no need to know where they were in order to shape the next day's course. The river shaped the courses.

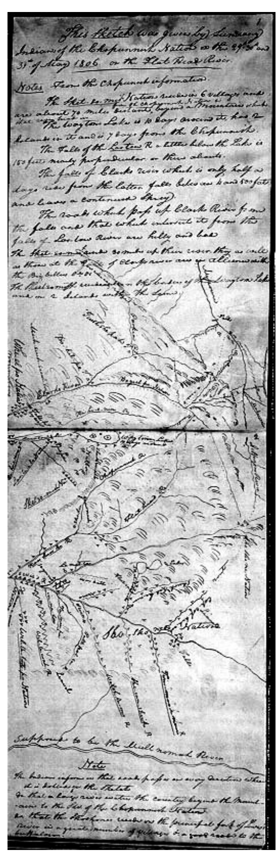
But notice that instead of the usual three columns listing hours, knots, and fathoms, there's a single column giving distance. The reason is fairly obvious. The men were working the boats up a river, dodging floating timber and avoiding snags, sawyers, and sandbars. They would have been shifting about trying to put themselves in the least unfavorable currents. Currents would have varied from one bank to the other and one bend to the next. The log line and steering compass would have been little use under these circumstances. The Captains had to adapt.

Instead of trying to measure distances it seems they simply estimated them. As army officers of their time they should have been fairly good at this. For courses it appears they looked ahead to some point, dead tree, or whatever, and took the bearing of the place they expected to be when abreast of it.

What was the log line for? Perhaps to measure the river's main current for the sake of geographers. Moreover, the expedition may not have carried the usual lengthy line, bulky reel, and sand glass. If the Captains had a pocket watch with a second hand a comparatively short length of line with a ship-log to pull it out would have done the job.

In his journal for July 18, 1804, Clark wrote "Measured the Current and found that in forty one Seconds it run 50 fathoms. . ."

For July 21, 1804 Lewis wrote that: "…from the experiments and observations we were enabled to make with rispect to the comparative velocities of the courants of the rivers Mississippi Missouri and Plat it results that a vessel will float in the Mississippi below the entrance of the Missouri at the rate of four miles an hour. in the Missouri from it's junction with the Mississippi to the entrance of the Osage river from 5 1/2 to 6 from thence to the mouth of the Kanzas from 6 1/2 to 8. — …"



Note that at this time the boats weren't floating down the river, they were being worked up it.

Another possibly misleading tool in the baggage was the two-pole chain. This was a lightweight measuring chain. The pole, like the inch, foot, and yard, is simply a measure of length, a pole being equal to sixteen and a half feet. The expedition's chain was called "two-pole" because it was only half as long as a standard Gunter's chain. Surveyors measured property lines in poles and links, and sometimes chained off baselines to triangulate from when doing accurate surveys. But it's hard to see how the chain could have been much help in the Corps of Discovery's dead reckoning. Like the log line, it had another use.

There's an example of this use in Volume 2 of Moulton's "The Journals of the Lewis and Clark Expedition." Page 88 shows Clark's sketch of the confluence of the Ohio and Mississippi Rivers. Obviously he's used the chain to lay down baselines, and triangulated to find the width of each river. Page 91 shows Clark's data, all in poles and links.

For the fast-moving Corps of Discovery, none of the standard tools for measuring distance were practical. Moreover, they were using compass bearings in a vast region where the change of magnetic variation, from place to place, was unknown. Nothing other than sheer luck could have made their dead reckoning accurate.

Fortunately it didn't have to be accurate to be worth all the effort put into it. All it wanted was a little help from nautical astronomy.

Besides altitude-azimuths for magnetic variation, President Jefferson instructed Lewis to take, and carefully record, observations for both latitude and longitude at all important points, and ". . . other places and objects distinguished by such natural marks & characters of a durable kind, as that they may with certainty be recognized hereafter." Between these anchor points the expedition's dead reckoning could be adjusted to produce a geographically reliable map.

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Rispect?

The following are some excerpts from the Moulton text regarding the unusual spellings found in the journals:

...Grammatical consistency is a vexing problem to any historical editor but particularly to an editor of Lewis and Clark materials. The men's erratic, but delightful and ingenious, manner of spelling and capitalizing creates the most perplexing difficulties of all. "This is expecially true of Clark," one investigator noted, "who was not only the master misspeller of them all, but also displayed dazzling virtuosity in his approach to punctuation, capitalization, and simple sentence structure.

...One researcher discovered that Clark spelled the word Sioux "no less than twenty-seven different ways." Little can be promised in the way of consistency, for no rule can stand against Clark's inimitable style...

...For capitalization some consistencies of the writers have been discovered; otherwise, individual letters have been judged against their rise along the line of writing and compared to the writer's normal usage. This procedure has generated a great number of capital letters. Clark again has confounded any system. One historian who struggled with his handwriting wrote: "In the matter of capitalization, one man has utterly bested me. William Clark, a creative speller, is also a versatile capilalizer—especially in handling words beginning with s. After manv attempts to work out a sane norm I have retired in confusion. Clark uses four kinds of initials and each can be interpreted as a capital."

NAVIGATION NOTES

BYGRAVE SLIDE RULE REVISITED

by Geoffrey Kolbe

Leonard Grey posed a question in the last issue, "Has anyone at the Foundation considered the Bygrave slide rule for a report in the newsletter?" A description of the "Bygrave Position Slide Rule" was given by John M. Luykx in the fall edition of the Newsletter in 1990. But as it happened, I was just in the process of making a "cardboard copy" of a Bygrave type slide rule. I offered David Burch my services to write a piece on the Bygrave slide rule for the Newsletter and he accepted. So, here it is.

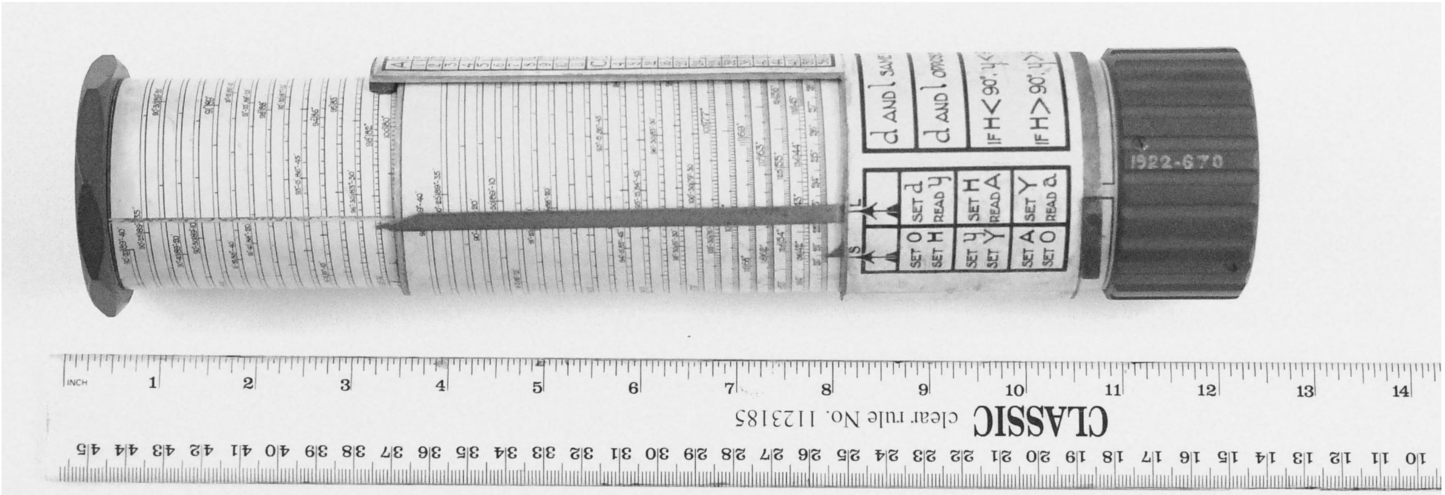
Leonard Charles Bygrave, of 4 Beaumont Avenue, Richmond, Surrey (near London in England), made an application to be granted a patent for "Improvements in Calculating Apparatus" in March 1920. The "apparatus" was a cylindrical slide rule consisting of three concentric tubes. The principal novelty appears to be that scales were wrapped helically around each of the inner two tubes. The outer tube held the cursor to relate the scales of the inner two tubes one to the other. The three tubes were free to rotate and slide within each other.

The patent gave an example of a particular use to which this form of slide rule could be put – namely the solution of the navigational triangle (a spherical triangle formed by a pole, the estimated or assumed position of the observer, and the geographical position of the celestial body). Luykx tells us that Henry Hughes and Son of London, famous as sextant manufacturers, started making the "Bygrave Position Calculator" in 1920. It is for this slide rule as used in navigation sight reduction that Bygrave is remembered today. It is unclear when production of this slide rule ceased, but it would seem to be sometime in the 1930's

Luykx seems to have had a Bygrave slide rule in his own collection. Alas, I am not so lucky, so I made an appointment to view an example held by the Science Museum, which is in the district of South Kensington in London.

The Bygrave slide rule was actually located at Blythe House, which is a vast late Victorian building, two hundred yards long and about eight stories high, planted in the middle of South Kensington suburbia. It has no outward indication as to its purpose and has but two relatively small entrances. Blythe House is in fact the repository for the museums in the South Kensington area where items are stored for which the museums themselves have no room. At entrance "A" I used the intercom to call security. I was expected. Having booked in, I was taken into what appeared to be the film set of the final scene in "Raiders of the Lost Ark", where the camera pans out to show the vast storage building where the Ark was locked away and effectively lost amongst innumerable other objects. I was taken to a table where, next to two life sized dolls in Victorian dress (!), the Bygrave slide rule was set out for me to examine.

In contrast to the slide rule described by Luykx, the example I saw was inscribed "Air Ministry Laboratory, South Kensington,



The original Bygrave slide rule.

August 1920". The base of the instrument bore the logo "AML". It also stated that this was a mark 2, with serial number 105, and bore the legend "Bygrave - Patent Applied For" in small letters. There was no reference to Henry Hughes & Son, which leads me to suspect that this may have been one of a pre-production run of a limited number of instruments made by the Air Ministry – perhaps for evaluation purposes.

It was about 8 inches long when closed and about 2½ inches diameter across the outer cursor tube. The tubes appeared to be made from galvanized steel about a sixteenth of an inch thick. The tubes were covered with thin, celluloid covered cardboard which had the scales and other narrative imprinted upon it – probably by some photographic process.

The spiral scale on the inner tube was graduated in log tangents, that on the middle tube in log cosines and the outer tube formed the cursor. Brief instructions on the use of he slide rule were printed on the cursor tube. The spiral scales had a pitch of three sixteenths of an inch. The log tangent scale on the inner tube ran from 0° 20' up to 89° 40' and was graduated in one minute intervals along the entire scale. Straightened out, the scale would be over 20 feet long. This compares to scales about a foot long for the linear slide rule with which those of us of a certain age will be familiar.

The log cosine scale on the middle tube had (necessarily) the same pitch and if straightened out would be a little over 14 feet long. It was graduated in one minute intervals from 60° to 89° 40', two minute intervals from 45° to 60°, five minute intervals from 20° to 45°, ten minute intervals from 10° to 20°, thirty minute intervals from 3° to 10° and one degree intervals from 0° to 3°.

Actual degrees and minutes were printed at regular intervals on both scales to the right of a graduation, and 180° minus the angle was printed to the left of the graduation.

A number of sight reduction methods divide the navigational triangle into two right-angled triangles to facilitate its solution. Probably the most famous of these is Ageton's method which drops a perpendicular from the geographical position to the observer's meridian. This enables the azimuth and altitude to be calculated using formulae containing just secants and cosecants, the logarithms of which formed a single table which was the basis of H.O. Pub No. 211. The method used by Bygrave was also to divide the navigational triangle into two right-angled triangles by dropping a perpendicular from the geographical position to the observer's meridian. But the formulae used by Bygrave were;

$$\text{Tan } y = \frac{\tan Dec}{\cos LHA}$$

Where the Latitude and Declination have opposite names, Y = co-Latitude – *y*

Where the Latitude and Declination have the same name, Y = co-Latitude + *y*

$$\text{Tan } Zn = \frac{\cos y \tan LHA}{\cos \text{Y}}$$

$$\text{Tan } Hc = \cos Zn \tan Y$$

These formulae are derived from Napier's Rules, though with some manipulation to facilitate use for a slide rule having log tangent and log cosine scales. Given that the log tangent scale can be graduated in minutes along its entire length, greater accuracy in a slide rule application will result from using formulae where the altitude and azimuth are found as the anti-log of tangents, rather than the anti-log of sines, cosines, or their reciprocal in the case of Ageton's formulae.

Additional rules for the use of the slide rule were:

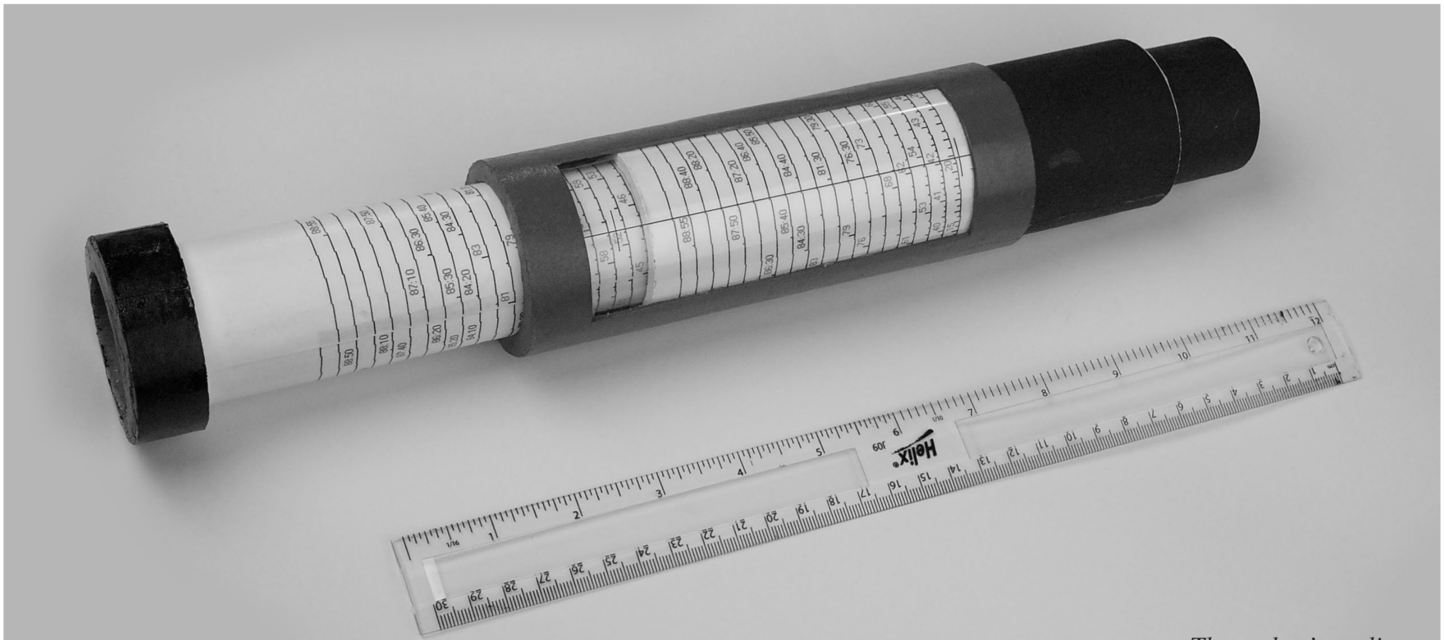
If $LHA < 90°$ then $y < 90°$, if $LHA > 90°$ then $y > 90°$

If $\text{Y} < 90°$ then $Zn < 90°$, if $\text{Y} > 90°$ then $Zn > 90°$

The Local Hour Angle was to be read from 0° to 180° either East or West. The azimuth was to be read from the pole of *opposite* name to the latitude, West if the LHA was West and East if the LHA was East.

I would have liked to try reducing a sight on the Bygrave, but the inner log tangent scale tube was very stiff and I did not want to force things.

A very similar device called the "Besteck-Höhenrechenschieber MHR1" (which literally translates as "Height Calculator Slide



The author's replica.

Set MHR1") was produced by Dennert & Pape in Germany in the 1930s and during WWII. It seems to have been used by the German airforce and navy—possibly the submarine service. On the same day that I viewed the Bygrave slide rule, I took a trip across London to Greenwich and the repository where the National Maritime Museum store all the items for which *they* do not have room.

The National Maritime Museum has a number of examples of the MHR1. On inspecting one, it was quite obvious that this was a direct copy of the earlier Bygrave slide rule as the scales and dimensions of the instrument are almost identical. However, the MHR1 is much the superior instrument in construction and layout. For example, the cursors on the Bygrave consist of two steel pointers, one short one for the log cosine scale and one thin long one for the log tangent scale, which is rather exposed and delicate. The MHR1 has two clear plastic screens—one for each scale—with thin red cursor lines. This makes for greater accuracy in reading the scale and greater robustness in the instrument itself. The MHR1 also has a knob on the top which, when rotated, locks the two scale tubes together. This ensures the scale tubes do not move relative to each other when the cursor tube is being moved. The MHR1 seems to be made from a bakelite plastic and was somewhat heavier than the Bygrave—I would judge about a pound weight, twice that of the Bygrave. The scales appeared to be imprinted photographically on paper sheet, which was then stuck to the tubes.

There is one essential difference between the two instruments, which is that co-tangents were used on the MHR1 place of tangents on the Bygrave. The formulae then became:

$$\text{Cot } y = \cos LHA \cot Dec$$

$$\text{Cot } Zn = \frac{\cos \text{Y} \cot LHA}{\cos y}$$

$$\text{Cot } Hc = \frac{\cot \text{Y}}{\cos Zn}$$

The restrictions on the log tangent or co-tangent scales on either instrument means that it is not possible to enter declinations or LHA's, or read off azimuths and altitudes, within 20 minutes of 0°, 90° or 180. Sight reductions for Polaris or the sun near local noon for example, or bodies near the prime vertical, would not be possible using either of these slide rules. In its description of the Bygrave slide rule, Bowditch (1984) tells us that "altered procedures are required if the azimuth angle is near 90°, or the meridian angle or declination is very small". What these "altered procedures" may conceivably be, I have no idea.

I have to confess too that a good reason why Dennert & Pape should have decided to use co-tangents for the MHR1 rather than tangents eludes me. It crossed my mind that most of the myriad sight reduction formulae created down the years falter somewhere at angles of either 0° or 90° and it may be that the co-tangent formulae are preferable in some way in this respect. But since the scales on either the Bygrave or the MHR1 do not allow angles of 0° or 90° to be entered or read, such considerations are purely academic.

Both the Bygrave and the MHR1 are now very rare and hard to find, which is a pity for anyone wanting to gain experience using one. However, all is not lost in that a cardboard copy is fairly easy to make using cardboard tubes – which is what I did. The attached photo shows the results of a weekend's effort. It is actually more a copy of the MHR1 in that it uses a log co-tangent scale and the cursor tube has a clear plastic window with a cursor line inscribed on it.

Cardboard tubes come in such a variety of different sizes that it is not hard to find at least two tubes around two inches diameter that are a relatively close coaxial fit. A third tube that slides neatly inside or outside the other two can be more difficult to find however. I made the cursor tube for my cardboard copy by cutting a near size thin tube up the spiral wrap on the outside. It was then opened out slightly and fixed by gluing it onto a piece of paper wrapped around the tube over which it was to fit. Another piece of paper wrapped and glued to the outside made a nice strong, stiff tube.

To form the cursor, I cut a window in the cursor tube and fitted in a piece of clear overhead-projector sheet onto which had been printed the cursor line. The cursor line sits directly on top of the log cosine scale, so reading log cosines to good accuracy was not a problem. But there is a gap between the cursor window and the log co-tangent scale on the inner tube, which was of smaller diameter. A thin piece of shim was inserted into the cursor tube at the top of the window so effectively carrying the cursor down to the log co-tangent scale. This was essential to achieve good accuracy for the instrument.

The only real problem is the construction of the scales, which can take many hours of work at the drawing board, depending on how much detail is required.

The log co-tangent scale on this copy is only 12 feet long, a little over half the length of that on the Bygrave, due to the use of a smaller diameter cardboard tube. Graduations are every ten minutes on the co-tangent scale, so some care is needed in interpolating the resulting azimuth and altitude.

Luykx tells us that "nine steps (settings) are required to complete the sight reduction process from given values of LHA, Lat and Dec." A setting was defined as a rotation of one or other of the scale tubes and its alignment with the cursor. Using this definition, I actually count twelve settings are required, the azimuth (Zn) being achieved at the ninth setting and the altitude (Hc) at the twelfth. Pencil and paper are required to calculate Y, (from the co-latitude and y). The azimuth equation requires a two stage calculation with the slide rule and it helps to write down the intermediate result for the multiplication needed in the numerator. The MHR1 actually had a small piece of matt white plastic attached to the cursor tube on which the intermediate and final results could be conveniently written down. With a little practice, one becomes quite facile in the manipulation of the slide rule. Luykx tells us and it is possible to reduce a sight in around two minutes and my experience confirms this.

Despite the coarseness of the graduations on the scales, results using my cardboard copy are actually surprisingly accurate. Azimuths and altitudes as generated on the slide rule are generally within one or two minutes of the result as computed on a calculator – pretty much in line with what Luykx found with his real Bygrave. I tested the slide rule for tendency to be less accurate for altitudes and azimuths near 0°, 45° or 90°. But results seem to be uniformly good regardless of which part of the scales I explored.

Given the evident popularity of the Bygrave and the MHR1 for aircraft navigation in the inter-war years, it is interesting to ask why they lost popularity, and why navigational calculators of this sort were not really made at all after WWII. I think part of the answer was that with the increasing speed of aircraft, the nature of navigation in aircraft changed during WWII. In the early years of aircraft navigation, it was usual to compute position lines during the flight, as one would on a ship. For this, the compactness of a slide rule like the Bygrave - compared to the volumes of look-up tables routinely used on ships - was a great asset given the very restricted space of the aircraft of those days. But with increased aircraft speed, the time it took to do sight reductions became impractical and the use of pre-computed altitudes became the norm. The process of sight reduction was done back at base, where the bulk of a shelf full of look-up tables was not a problem. During WWII, electronic means of navigation, such as LORAN, were introduced which further eroded the need for compact on-board sight reduction equipment.

Then there was the expense. I don't know what a Bygrave or MHR1 would have cost, but considering the time that would have been required to produce the masters for the scales, I don't think they would have been cheap. They would have been more expensive than the volumes of sight reduction tables they were to replace. So was there any advantage in speed? Given that it takes about two minutes to reduce a sight on a Bygrave type slide rule and (for example) it also takes about two minutes to reduce a sight using the NAO sight reduction tables that now come "free" with every Nautical Almanac, it is easy to see why the practical advantage of a Bygrave like slide rule has to be questioned.

But then, truth be told, there is no practical advantage to the use of celestial navigation these days. A GPS receiver is a thousand times more accurate, a hundred times easier to use and a tenth the price of a good sextant. By and large, practitioners of celestial navigation these days do it because – for a variety of reasons – they enjoy doing it. And that, in the end, is the justification for the construction of my cardboard copy of a Bygrave/MHR1 slide rule. It was good fun.

I would like to acknowledge Zvi Doron, who has a passion for slide rules as well as for celestial navigation, for his inspiration to make this cardboard copy of the Bygrave/ MHR1. In particular, I would like to thank Zvi for his help in making the scales which saved me many hours of laborious effort.

Geoffrey Kolbe runs a precision engineering business located in the outbuildings of an old farm in the Borders of Scotland. He lives in the farm house with two neurotic cats! In a previous incarnation, Geoffrey Kolbe did research on the physics of hot plasmas, such as found in the surface of the sun - or an atomic bomb. In this connection, he spent two years in the mid 1980's working at Lawrence Livermore Laboratory in California. It was here that he grew interested in celestial navigation and bought his first Link A-12 bubble sextant. (Livermore is 50 miles from the coast.) Being irked by the necessity of buying a new Nautical Almanac each year, his attention was drawn to the Long Term Almanac in Bowditch (1981 edition) but found it to be inaccurate - so, he wrote his own! The Long Term Almanac 2000 - 2050, for the Sun and Selected Stars *is published by Pisces Press. A revised edition is currently being worked on.*

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NAVIGATION PERSONALITIES

Bruce Bauer

Navy Cmdr. Bruce Allan Bauer, 75, a resident of Deale, MD for 15 years, died of kidney failure during cancer treatment July 16 at Anne Arundel Medical Center after a five-month illness.

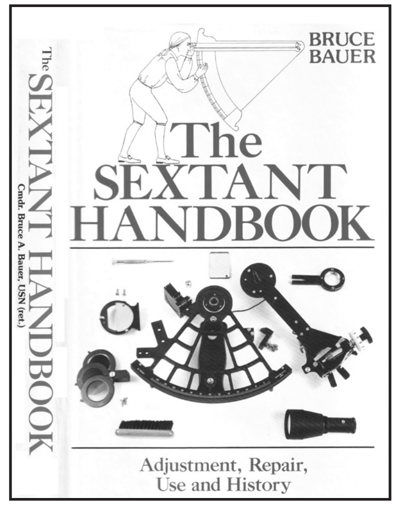
Born April 15, 1931, in Washington, DC, Cmdr. Bauer earned a bachelor of arts degree in English literature and journalism from the University of North Carolina in Chapel Hill on a full Navy scholarship. He earned a master of science degree in international affairs from George Washington University and attended Army Language School in Monterey, CA, where he learned Malay.

Cmdr. Bauer retired from the Navy after 27 years of service. During his military career, he served as Captain of the Destroyer *USS Stribling* (DD 867) from 1970 to 1972 and aboard the *USS Ingraham, USS Bordelon* and *USS San Marcos*.

He was also an Assistant Naval Attache in Djakarta, Indonesia; with the Office of Joint Chiefs of Staff at the Pentagon; an intelligence officer in Naples, Italy and Guam; and mostly recently commanding officer of the Naval Research Lab, Chesapeake Bay Division in Chesapeake Beach from 1975 to 1979.

Subsequently he worked for Masters, Mates and Pilots School in Linthicum as a navigation instructor and was the captain of Monob Research Ship in Port Canaveral, FL. A master mariner, he held a Coast Guard License, 1600 GRT Master, Unlimited Chief Mate, Oceans, Merchant Marine.

He was the author of *The Sextant Handbook*, 1986, and revisor of *Piloting and Dead Reckoning,* 1991. He also wrote for *Cruising World Magazine* and *Bay Weekly*, and was a consulting editor for the *Naval Institute Press* in Annapolis.



His interests included sailing, boat restoration, reading and woodworking, and he was a member of the Chesapeake Environmental Protection Association, St. James Parish in Lothian and the Atalanta Owners Association.

Surviving are his wife, Nancy Bauer, whom he married in 1953; two daughters, Lisa Bauer and Julie Bauer Fox, both of Annapolis; one sister, Darlene Marashlian of Mahwah, NJ; and twin granddaughters. Naval burial was held privately at sea.

* * *

from The Capital newspaper, Annapolis, MD

INTERNET RESOURCES

Local.live nipping at the heels of Google Earth

In a past issue we praised the amazing functionality of Google Earth for viewing any part of the earth in great detail. Then you could add routes and waypoints and more. These free features of early versions now come only with the pay version, but at $20 per year they are still worth it. You can even now upload a track from your GPS—from a voyage or a jog around the park—and have this show up beautifully on high-resolution aerial photographs.

But they are not the only kid on the block any more. Microsoft's new website www.local.live is a similar presentation with, in some cases, much better images. In fact, for a while, there were quite a few places on earth with better imagery on Local.live than on Google Earth, but then Google Earth quickly announced much new imagery available. So competition is good. Now to find the best data for a particular place you have to check both sites.

A remarkable feature of Local.live is what they call "Bird's eye view." This option presents aerial photo perspectives on many locations from each of the cardinal directions. So now you can see all sides of a building or street. Compare your favorite city or home or your next sailing destination to see how things are developing in this wonderful new Internet resource.

Local.live is still a bit clunky, as Google Earth was when it got started, but it is improving fast. It is all browser based, whereas GE is a separate piece of software, essentially a dedicated browser.

* * *

NavL list on the move

The long-running super resource on celestial navigation and related topics has found a new home. Our last announcement on this is outdated. To view the current contents of this discussion group go to http://googlegroups.com/group/NavList. You can see and search on topics there since they moved to that site, along with instructions on joining the list, which would mean getting an email every time someone posted to the list (8 or 9 a day on average). If you want to post your own questions you do have to join the list.

For more information on the list including how to subscribe and how to unsubscribe, along with links to archived postings that date back to 1996, see http://www.fer3.com/NavList.

This list would be one of four good places (beyond classic texts, old and new) to check for technical details and esoterica on celestial navigation. Another one is our own Foundation archive of past Newsletters, which has a link to the index at www.starpath.com/navigationfoundation. A third source is searching the online archives of the Journal of the Institute of Navigation at http://www.ion.org/search/search_journals.cfm, and the fourth would be the British counterpart, the Royal Institute of Navigation, at http://www.rin.org.uk/references/journals.asp. Both of the these Institute journals can be searched online to obtain specific references. Members can download copies of the ION papers, even very early ones, but the RIN papers are not online yet, but hard copies are carried in many university libraries.

* * *

Sources of Almanac Data online

Here are a few places you can get Nautical Almanac data online. The first is ideal for practicing with cel nav as well as a resource for sight reduction and sight planning.

USNO AA
http://aa.usno.navy.mil/data/docs/celnavtable.html

IMCCE
http://www.imcce.fr

JPL (Asteroids and moons as well as cel nav bodies)
http://ssd.jpl.nasa.gov/?horizons

TECPE (Omar Ries)
http://www.tecepe.com.br/scripts/AlmanacPagesISAPI.isa

FER (Frank Reed)
http://www.clockwk.com/lunars/nadata_v5.html

* * *

Navigation Calculators

NIMA (now NGA) set of nautical calculators online. This link is to a convenient re-packaging of these 33 useful computations donated by Starpath. The one NIMA calls "Pub 229" computes Hc and Zn from Lat, Dec, and LHA.

http://www.starpath.com/freeware/nima-nav-calc.chm

Here is the original NIMA product for comparison

http://tinyurl.com/henks

For those not familiar with the site, the above short (tiny) link was created from a long, complex link using the free services of www.tinyurl.com. Very useful in some applications. We do not know how long the links remain in their database, so for completeness (and illustration) here is the actual link compressed above:

http://www.nga.mil/portal/site/maritime/?epi_menuItemID=0feacf38cf96a8b21b2079106327a759&epi_menuID=e106a3b5e50edce1fec24fd73927a759&epi_baseMenuID=e106a3b5e50edce1fec24fd73927a759

NEW PRODUCTS

Starpath School of Navigation has added a webpage that specifically shows which of their products are available at discount to members. See www.starpath.com/navigationfoundation, which does include one brand new product, version 4 of Bowditch Plus!—The complete Navigator's Library. It is a DVD collection of some 140 ebook volumes of reference books, that would cost over $3000 in printed form. Those that change with time have been updated as of Sept, 2006. The member price is $47. It is available on one DVD or two CDs.

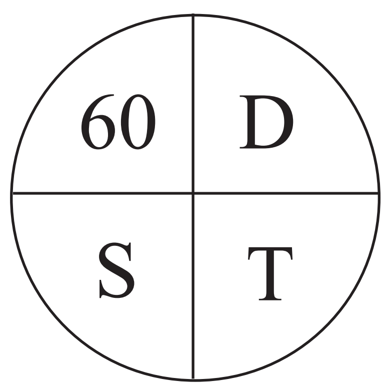
The 2007 Nautical Almanac is also now available from the Foundation, if you might be planning ahead or leaving on a voyage now.

The Foundation for the Promotion
of the Art of Navigation
PO Box 1126
Rockville, MD 20850

“THE NAVIGATION FOUNDATION”

60 “D” Street

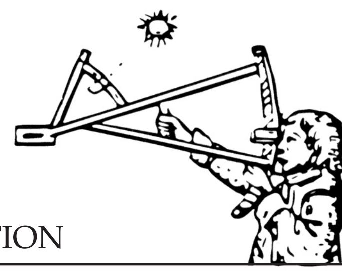
If you have ever taught navigation, chances are you know this address and strange figure very well—otherwise a note for you about what goes on in the classroom sometimes. It is a common mnemonic device for recalling the formulas for speed, time, and distance. D is distance in nautical miles, S is speed in knots, and T is time in minutes. Multiply left-right and divide up-down, moving everything to the other side of what you want. Thus D=SxT/60, S=60xD/T, and T=60xD/S.



We might guess that most navigators are familiar with basic algebra and would not use this type of aid, but that is not always the case. It is a big industry, with many backgrounds. And all involved know they do not want to make a mistake in this reckoning. Professional captains with years of experience and thousands of miles underway use it daily. And on top of that, there is an underlying tradition in marine navigation to make as much of what we do as rote as possible, for the simple reason that we may have to do crucial reckoning when we do not feel well, and we are exhausted from lack of sleep, and the lighting is poor, and the entire world around us is crashing up and down every 7 or 8 seconds.

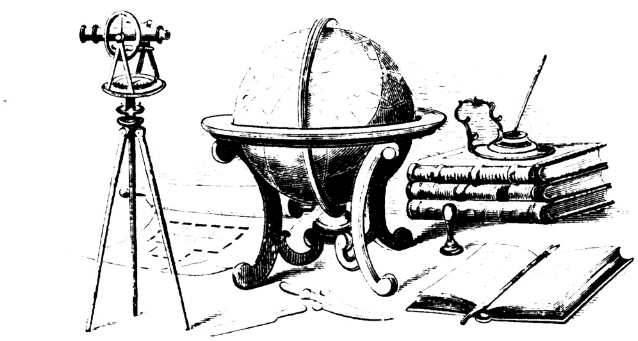
ISSUE 94, Winter 2006

THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a reader forum for the expression of our members opinions and their questions.



ACTIVITIES

By Terry Carraway

The Foundation had planed another Fall "Wounded Veterans Cruise" after the very successful one earlier. The Walter Reed Army Medical Center wanted it delayed until the Spring. We are waiting for the Spring to reschedule a "Day on the Bay" for the wounded veterans.

A first in the 23 years of the Navigation Foundation, the Government Printing Office has reduced the price of the Nautical Almanac. Last year it was $43.00 this year it is $25.00. Members get a 15% discount plus the handling and mailing. The commercial edition is $23.95 with a 20% discount to members, plus handling and mailing.

As you know The Foundation provides a 20% discount on all nautical charts on orders under $100.00 and a 25% discount on orders over $100.00. The Foundation must sell at least $500.00 worth of charts to retain its dealer status. Once this dealership is lost we will no longer be able to provide charts at a discount. To help The Foundation retain this very important service please order all of your charts from The Navigation Foundation. We have had wonderful service in the past year by getting charts to our members in less than one week.

If you have not done so, please renew your membership to support the Foundation and continue receiving the Newsletter. Sometimes we get behind in sending out reminders. Check your mailing label; your renewal date is on that label.

If you care to renew online with a charge card, you can do so from a link on our webpage www.navigationfoundation.org, or renew by standard mail direct to the Foundation. We are in the process of updating our webpage to consolidate the services offered and provide place for newsletter supplements.

Years ago, the Navigation Foundation worked frequently in the field of celestial navigation with the Institute of Navigation in Washington DC. Foundation directors and members contributed papers to *Navigation*, Journal of the Institute of Navigation, (some had contributed even before the Foundation was established) and members and directors served to review papers and help answer questions on the subject of celestial navigation submitted to the Journal's editors. You will see in the Editor's notes below that we have the good fortune to once again work on a project with the Institute. We hope our members and all others that care about celestial navigation will benefit from this collaboration.

EDITOR'S NOTES

By David Burch

I apologize for being late with this issue. We did finally get caught up on the schedule with the last issue, but now we are behind again. But we hope this is just a small step back before taking bigger steps forward. You will notice a new printing format, with which we hope to be able to have better graphics and more efficient production of the Newsletter.

We are now using digitized printing and automated mailing services, which should be a savings to the Foundation. We have to give up our traditional blue ink, which we will miss, but we also are giving up our 25 year old CP/M computer that has till now coordinated the Newsletter mailings—note the dot matrix printing on earlier labels. In other words, we had been truer to the old traditions than many members might have realized.

All the addresses had to be retyped, and in doing so we noted some that are probably not in optimum format, and we may have introduced new errors of our own. So please check your address and send any corrections called for to navigate1@comcast.net.

In this issue we follow up on two topics from Issue 93. One is more discussion of navigation in the time of Francis Drake and his possible routes through the Pacific Northwest. Thanks to author Samuel Bawlf and to member George Huxtable for their contributions. We also have a follow up on the Bygrave slide rule topic from member Dr. George Bennett, who shares information on the

German version of the instrument he possesses (the MHR1)—which immediately brought to mind the wonderful new service of the Institute of Navigation called the ION Virtual Navigation Museum described in the Online Resources section.

And we have Bruce Stark's second installment on the Navigation of Lewis and Clark, with notes on two key people who prepared the captains for their navigation underway. I imagine it will motivate others as it did me to look more into the lives of these two interesting figures who played such an important role behind the scenes of many accounts.

You will find a new section in the newsletter called MEMBER PROFILES. We have finally put a heading on a section that has been slowly evolving with each issue we do. We have had a few notes about members, as they presented them, usually in READERS FORUM or as a byline to an article, but now we have a special place for this, and we encourage members to write in and tell us about themselves, along with any pictures you might have that we could use. And no better way to start it than with a welcome back to Byron Franklin, who was a member for some years in the past. He had left the field of navigation, but has now returned.

You will also find several exciting new announcements along with the introduction of a new online component to the Newsletter at www.navigationfoundation.org. We are slowly making some changes there. We wish to thank Jeff Schroeder who has volunteered his time on the basic design and maintenance of the site over the years.

We are also pleased to have a retrospective on the Peary Report from Douglas Davies, President of the Navigation Foundation.

* * *

READER'S FORUM

Dear Mr. Burch:

I am writing my first letter as a long time member and admirer of the Foundation. I have just stepped down from teaching celestial navigation at the New York Power Squadron for 19 years. My students varied from Power Squadron members wanting to complete advanced grades for a full certificate, to cross Atlantic sailors and a few circumnavigators of the earth. I have used material from "The Navigator's Newsletter" and explorers logs (Byrd, Shackleton) to stimulate their interest in joining a fraternity of navigators that permitted terrestrial man to break free and explore the planet. The students learned that man's successful pursuit of scientific knowledge has closely paralleled his acquisition of navigational sophistication.

I enjoy the varied content of your newsletter especially data from explorers like the articles on Lewis and Clark. I would find polar sight reduction interesting as most of us will never use a pole as an assumed position.

Thank you for all your efforts in publishing a magnificent newsletter for a select membership.

Sincerely,
Thomas R. Kuhns, M.D.

Thank you Dr. Kuhns for your kind words and first letter.

***

Member Frank Bailey sent in to share with the membership two special indexes of past newsletters he made from his own collection of back issues. One is a list of all issues that have an article about a navigation personality and another is the list of all issues that describe a navigation instrument. These lists of people and instruments are interesting compilations that we could not get very easily from our own online index—you can search online for individual words or phrases, but not for categories.

Thank you Frank. We have posted these in our new Online Supplement. The letter below was attached.

* * *

Dear Mr. Burch,

While researching back issues for the enclosed lists, I find 1 am missing Newsletters 2, 41, and 81.

So, my question is: What is the most convenient method for you to perhaps try and get me the missing issues? I am not at present "on line" but have internet access through my son if that would help. We looked at the website but couldn't figure out how to download a back issue. A previous issue of the newsletter said back issues were available fur a small cost so maybe that is still in effect?

I am pushing 82 years of age here so my sailing days on Lake Huron, Michigan, etc. are over but 1 still try to keep up to date on the celestial thanks to the newsletters and the Foundation. With my telescope I was geared up to view the recent transit of Mercury on the 8th but as luck (or God) would have it, I was clouded out.

The Navigator's Newsletter
Issue 94, Winter 2006
Published by
The Foundation for the
Promotion of the Art of Navigation
www.navigationfoundation.org
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Rockville, Maryland 20850, USA
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Executive Director, Terry Carraway
Newsletter Editor, David Burch
Inquires about membership or Newsletter content or contributions can be send to the above address or by email to navigate1@comcast.net.
The Navigator's Newsletter is published four times annually, with our strived-for publication dates of approximately the solstices and equinoxes. Newsletter production and other Foundation activities are provided by volunteers. Please bear with us if we slip on the dates occasionally.

However a few years ago I did catch Venus crossing the big red disk.

Thank you for keeping the Foundation going and before the year is out I will be sending the Foundation a small donation (D.V.).

Sincerely,
Frank Bailey, Grove City, PA

The Newsletter Archive is the easiest way to get the complete set of all back issues. It is available on CD for $39 and can be ordered from the Foundation. Terry does have a few printed back issues of specific years, which he sells for $6 each, 3 for $15, or 5 for $20. Since we made the Archive, however, we now have the capability of reprinting specific back issues, but we have not yet implemented such a system or figured what the cost would be.

* * *

Editor's Note: In the last issue, the question was raised about the possibility that Sir Francis Drake had carried out some form of lunar distance measurement at Nehalem, OR in June or July of 1579, as proposed in the book The Secret Voyage of Sir Francis Drake *by Samuel Bawlf. Questions about this possibility have been raised by member George Huxtable, and some correspondence has transpired on this topic since the last issue. Mr. Huxtable is a Fellow of the Royal Institute of Navigation. His contact information is* george@huxtable.u-net.com.

The author has provided us with an extensive account of his reasoning. Most of this information is in his book, but it is spread throughout the book, so this focused explanation of the reasoning leading to the lunar measurements conclusion is very helpful.

Because most of the subject matter is outside the main focus of the Foundation, I have, with the author's permission, prepared below a brief summary of his article (a long letter), and we have posted the full illustrated article online at www.navigationfoundation.org. Members who do not have access to a personal computer can contact a local printing company such as Kinkos or OfficeMax to obtain a printed copy in color or black and white.

In keeping with this approach, I have also summarized below the detailed response from Mr. Huxtable and my own brief notes on the topic, both of which are also presented in full in the Online Supplement.

My apologies to both authors if I have misrepresented their content in my summaries. Both authors are eloquent and clear in their comments. Thanks to John Lewis who coordinated the communications with Mr. Bawlf.

Summary of Samuel Bawlf's Letter on Drake's Voyage to the Pacific Northwest

The author outlines how he became interested in Drake's travels to the pacific Northwest and in particular his visit and exploration of British Columbia (*the author is a former government minister of BC responsible for the designation and protection of archaeological sites in BC*). He then lists prominent scholars who have reviewed his research and agreed with his conclusion that Drake had "discovered and explored" the coast of British Columbia as he described it. He then outlines his interpretation of the Drake voyage, beginning with its motivation and contacts made in England and the actual route as it developed. Details of its extent in BC waters are followed by the route back down the coast, with the stop in question near Nehalem, OR, where the lunar measurements are proposed.

He then adds more detail and background to the points outlined earlier about Drake's route and its significance. This is followed by a brief outline of early (1498-1571) notions of using lunars for longitude from the writings or referrals to EGR Taylor, Americo Vespucci, Jean Rotz, the woodcut of Werner and Apien [fig. 1], John Dee, Gemma Frisius, Sebastian Cabot, and William Bourne (*subject of discussion in our last issue and later in this one*). He contends that Bourne must have been familiar with lunar methods because of his association with those who did know of them, and that perhaps some surveying schemes he had employed at Gravesend [fig. 2] may have served for astronomic reference measurements that may have assisted the analysis of a Drake measurement made (*presumably*) at Nehalem, because there was a similar surveying plot laid out there [fig. 10] and there was some connection between the two men. *(This is the subject of George Huxtable's comments to follow.)*

There then follows more discussion supporting the idea that Drake may have made these observations at Nehalem, along with an outline of the history of this archeological site at Nehalem and the role of the American Society of Civil Engineers who made a survey of the site, marking the locations of the rock cairns that could have been used as points on a transit to measure lunar distances (*as outlined in Issue 93 of the Newsletter*). A key point to the author's thesis is the labeling of the rocks marking the western most vertex of the transit with the Latin words for heavens or heavenly bodies (deos) and the word for predict (augur).

The author argues from historic map details that this site must be the location that Drake later identified as the "Point of Position" on specific maps, and further that the choice of name and concept of "Position" implies both latitude and longitude, which makes it unique since he had made latitude measurements alone many other places.

In his summary he suggests that modern navigation scholars might be focused on the great accomplishments in lunar theory and practice from 200 years later—when this was an indisputable tool of world travelers—and thus overlook the possibility that pioneers in the field may have themselves derived some utility from their efforts. *(The full 20-page article with 10 illustrations is online at www.navigationfoundation.org.)*

* * *

Summary of Editors Notes on the above letter

According to the author, before Drake's voyage the longitude of the West Coast was thought to be about 190° W, whereas shortly after Drake's voyage it was mapped as 140° west, presumably as a result of his findings. The true value is 124° W, so this was a big improvement.

In the online note we suggest how members might investigate what possible lunar measurements Drake might have made to lead to this improvement, starting with the basic question of which bodies might have been in view at the right angles, at the right time. It is pointed out that one must use the very best almanac programs for this, which are listed in Issue 93 of the Newsletter.

The question is also proposed online to consider what else Drake could have done, unrelated to lunar distances, that could also have lead to the purported improvement in accuracy. These are all interesting questions that some members might wish to pursue, but they are a bit outside of the main focus of the Foundation.

(The full form of these editor's notes are also online at www.navigationfoundation.org.)

* * *

Summary of

Letter to Samuel Bawlf from George Huxtable

Mr. Huxtable points out that he has read the author's book but does not have access to an earlier one of the author's works which was the source for certain details. He notes that from what he has seen he is not convinced of the author's account of the route, and that is in conflict with a few pages in Hakluyt, vol VI.

He then provides quotes and references from William Bourne to support his contention that the structure built at Gravesend [fig 2] was for purposes of terrestrial mapping by triangulation, with no evidence of astronomical observations, nor any connections between that site and what Drake is proposed to have constructed at Nehalem [Fig 1].

He goes on to further point out that he cannot envisage how the measurements could be used as proposed. He suggests that such a proposal should include a proposed procedure, which in turn requires an adequate understanding of the principles of lunar methods. He does not find evidence of this understanding in the book, and gives two examples from the book that point out misunderstandings of the use of the moon for navigation in that period.

The full letter is online at www.navigationfoundation.org.

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NAVIGATION NOTES

PEARY REPORT TO BE REPUBLISHED

One of the exemplary projects of the Navigation Foundation over the years was the project headed by Admiral Thomas Davies, then director of the Foundation, along with current directors Terry Carraway, Douglas Davies, and Roger Jones, and others, to uncover the facts about Robert Peary's navigation to the North Pole. Did he do what he said he did, or was there willful misrepresentation of the data. The project was commissioned by the National Geographic Society. There are several articles in the newsletter archive related to that work, which was culminated in a book known as "The Peary Report," published by the Navigation Foundation.

That valuable publication has long been out of print and very difficult to find in libraries—it was not widely distributed in the first place. And needless to say, interest in the early work at the North Pole remains active, with new histories and anthologies of related works appearing yearly, along with numerous adventurers repeating the trip with modern equipment by various methods, including dog sled as Peary did—those with a desire to repeat such feats should, however, do so sooner rather than later, while there is still ice on the Pole!

It is our goal to reissue that report as an ebook so that it can be readily available to interested readers at a modest cost. The ebook has been produced and we are ready to issue it to members and the public as soon as we receive final copies of certain unpublished errata, that we understand was produced by Admiral Davies, himself. This will make the publication even more interesting and we look forward to completing this project during this next quarter.

* * *

CELESTIAL NAVIGATION FROM THE PAGES OF THE JOURNAL OF THE INSTITUTE OF

We are very pleased to announce that we have been for some time working in collaboration with the Institute of Navigation on a project that many of you will, we hope, find very rewarding. The editors and management of the Journal of the Institute of Navigation have agreed with our request to publish a single CD that contains all of their past articles on celestial navigation. To facilitate this, we selected the articles for them from the full table of contents (1946 to 2002), checking each individually if the title was ambiguous, and then we produced the actual CD image including indexing, links, and other CD features to make searching and access to the articles as easy as possible.

The articles will be in printable pdf format, but the documents remain copyrighted property of the ION. We are confident that readers who wish to access this unique wealth of information will purchase a CD from the ION. Normally individual articles from back issues of their Journal sell for $25 each to non-members of the ION, whereas we are hoping that this entire CD compilation of some 280 articles will sell for about the cost of a single article on other topics.

We are grateful to the Institute of Navigation for sharing our vision of the value of this project and for making access to the production materials as convenient as possible.

The work of the Navigation Foundation on this project has been donated to the ION and to all interested parties in keeping with our goal of promoting the art of navigation. We hope you enjoy it and benefit from it. There are very many interesting articles in this compilation, and, indeed, some of this valuable knowledge has already slipped away from modern texts and reference books on celestial navigation. You can see a list of the articles forthcoming at www.navigationfoundation.org/IONcelnav.htm.

You will see in that list several articles by Byron Franklin (mentioned elsewhere in this Newsletter) in collaboration with Ernest Brown, long time director and editor of our own Foundation and Newsletter during a very productive time of its publication.

* * *

NAVIGATION NOTES

ON THE REPUBLICATION OF THE PEARY REPORT

By Douglas R. Davies, Dallas, TX

The Navigation Foundation's decision to republish its 1989 publication, *Peary at the North Pole—A Report to the National Geographic Society*, will help ensure availability to a wide audience of the work of the late Rear Admiral Thomas D. Davies and his colleagues at the Foundation. Although much has happened since the publication of the original work, nothing has undermined the basic findings of the Report. This is not an update, but rather a republication with only corrections of errors that Admiral Davies himself had marked on his personal copy of the Report.

The Report remains the most comprehensive critique of the various arguments raised during the early part of the last century and repeated, with little new analysis, by Peary critics of the modern era. The main arguments of the skeptics have always been navigation and speed. The Report remains the only careful analysis of the feasibility of Peary's navigation. The Report concluded that Peary's claimed speed was credible in view of historical precedent and the opinions of the majority of experienced arctic sledgers. Recent dog sled expeditions led by Paul Landry and Tom Avery (the latter reaching the pole in the same time it took Peary) vindicate this conclusion.

The Report also made short shrift of the most significant modern "contributions" to the arguments against Peary. Dennis Rawlins claimed that a set of Peary's calculation notes proved that Peary's final camp was over 100 miles from the Pole, but the Report concluded that those figures had nothing to do with the 1909 expedition. (Rawlins has since demonstrated convincingly that the calculation notes were from an observation in Greenland some 15 years earlier.) The centerpiece of Wally Herbert's skeptical work, published a year before the Report, was his theory that winds caused the ice to drift far to the west during the early part of Peary's expedition. However, the Report concluded that Herbert ignored wind data that did not support his theory and, more importantly, ignored eye-witness statements showing that a resupply party heading north after the supposed drift had no trouble finding the trail where it was expected to be.

The Report also included some ground-breaking work in the analysis of Peary's photographs to gain positional information from the sun's elevation. Admiral Davies was always of the opinion that the Report fully supported Peary's claim without this analysis, which was primarily designed to detect any evidence against Peary, rather than to provide affirmative proof of his location. In the only major work on the subject of Peary's claim published since the Report, Robert Bryce dismisses the photographic analysis as "discredited" without reference to any published work. This statement apparently refers to arguments raised by a polar enthusiast with whom Admiral Davies corresponded shortly before his death. The same work was referred to by Wally Herbert (but not presented) at a symposium on Peary at the U.S. Naval Academy in 1991, shortly after Admiral Davies' death. (The undersigned had the privilege of standing in for Admiral Davies at that symposium.)

Neither critic mentioned that the arguments relating to the photos did not suggest that the photos showed that Peary's position was elsewhere than the Pole. Instead, the critical analysis dealt only with the question of what the proper statistical margin of error was. More importantly, the polar enthusiast, after being directed to the relevant sections of a treatise on statistics, conceded, in his last letter to Admiral Davies, that he had made a "major error." Nothing that has been published to date contradicts the conclusion of the Report that the photos are consistent with Peary's claimed position.

The Report hoped to be the last word on the subject of Peary's claim. Events have proved, at least to the undersigned, that there will never be a last word. The Cook-Peary controversy is just too good a story to let go. But the Report is essential reading for anyone interested in the subject.

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NAVIGATION NOTES

ON ANALYZING SEXTANT SIGHTS

One of the beauties of celestial navigation is its transparency. If we make a mistake it stands out, and we can usually go back and find the problem and fix it. We always tell students when they are practicing sights on their own, if they keep a careful record of all related information, we can almost always figure out what was wrong if the fixes are not as good as expected—or as we promised they could be. And we do indeed have many examples of this exercise over the years.

It is a matter of data analysis, just as done in any scientific laboratory dealing with almost any type of measurement, and often this consists primarily of separating random errors from systematic errors, along with understanding typical error sources. To some extent this type of analysis should always to be part of basic training in celestial navigation, because it can well be that we are left with only a limited number of sights or sights from poor conditions, and in these cases we have to do our best to squeeze out the most likely fix from less than ideal sights, and, equally important, to set some realistic uncertainly level to the results.

But that is not exactly the point at hand. The question here is more basic. We were recently confronted with the question of finding the best fix from a large set of individual star sights. Different approaches to the analysis led to different conclusions, which is contrary to the religion just preached. So what might the answer be?

The most important question to ask in such a case is where are the data from? Are they real sights or are they sights presented in a textbook or magazine article. Most examples from the latter sources are made up by the authors—I speak from experience to some extent, though we use both real and contrived data in our course materials. If the examples are made up to meet the specific needs of that section of the book or magazine article, then all bets are off. We cannot make real analysis of artificial data. In these cases, you do whatever the author told you to do, and choose that answer. This is a perfectly reasonable and effective way to teach the subject, but unless the author is specifically training on multi-sight analysis and has done a rather sophisticated presentation of the data, chances are you will not be able to "milk the data" for all that you might do with a similar set of real sights.

That is the main point I wanted to make, but I cannot quite leave it without mentioning another tenet of the religion. Generally you are far better off not taking 15 sights of 15 different stars, but rather to take 5 sights each of just 3, well-positioned stars—that is, as near 120° apart (the main factor) and as close to the same elevation as possible, above, say, 15° and below about 75°, if possible. Take the sights sequentially, 1 - 2 - 3, 1- 2 - 3, and so on. Four sights each would do the job (4 rounds instead of 5 rounds) in most cases, and you do not gain much at all by going to 6 each, but 3 each is not enough for optimum analysis if conditions are less than ideal.

If you are not moving, the rotation is not so crucial, as long as you give the micrometer a good solid twist or two between each sight of the same star, i.e. do not just follow it up or down, but make sure each sight is more or less independent. Note that when underway, the proper correction for your motion during the sight session is usually the dominant factor on your ultimate accuracy.

I will leave that for now and if there is interest come back with a suggested analysis procedure. Perhaps these notes will raise some questions. I know there are knowledgeable people with different thoughts on some of these matters, and there are details to clarify such as is the horizon equally good in the three directions, for example.

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NAVIGATION NOTES

RESILVERING MIRRORS

Article 254 from Bowditch, 1920 edition

Occasion may sometimes arise for resilvering the mirrors of a sextant, as they are always liable to be damaged by dampness or other causes. For this purpose some clean tin foil and mercury are required. Upon a piece of glass about 4 inches square lay a piece of tin foil whose dimensions exceed by about a quarter of an inch in each direction those of the glass to be silvered; smooth out the foil carefully by rubbing; put a small drop of mercury on the foil and spread it with the finger over the entire surface, being careful that none shall find its way under the foil; then put on a few more drops of mercury until the whole surface is fluid.

The glass which is to be silvered having been carefully cleaned, it should be laid upon a piece of tissue paper whose edge just covers the edge of the foil and transferred carefully from the paper to the tin foil, a gentle pressure being kept upon the glass to avoid the formation of bubbles; finally, place the mirror face downward and leave it in an inclined position to allow the surplus mercury to flow off, the latter operation being hastened by a strip of tin foil at its lower edge. After five or six hours the tin foil around the edges may be removed, and the next day a coat of varnish made from spirits of wine and red sealing wax should be applied. For a horizon mirror care must be taken to avoid silvering the plain half. The mercury drawn from the foil should not be placed with clean mercury with a view to use in the artificial horizon or the whole will be spoiled.

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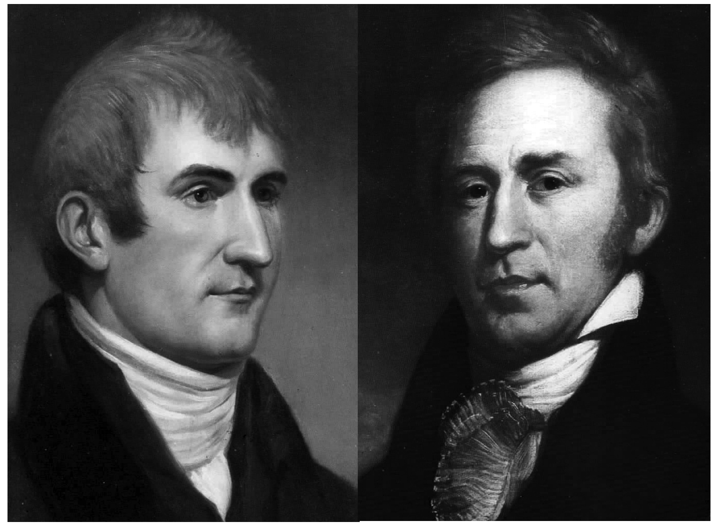
NAVIGATION NOTES

LEWIS AND CLARK'S NAVIGATION, AN OVERVIEW

by Bruce Stark



Meriwether Lewis 1774 - 1809 William Clark 1770 - 1838

Part 2

During the first months of 1803 Lewis was busy finding, buying, requisitioning—and sometimes having made—the various tools, supplies, and pieces of equipment he'd need for the expedition. He had to hurry. He wanted to be across the Alleghenies with all the necessary baggage and down the Ohio in a boat to meet Clark as soon as possible. Then he and Clark would choose a number of good men and get part way up the Missouri before winter set in. Or so he hoped.

But before he could start he would have to gain more understanding in several areas. One such area was nautical astronomy. Dead reckoning (discussed in Issue #93) could not, of itself, provide all the data needed for the accurate map Jefferson wanted. Lewis would have to learn something of nautical astronomy. This might take time. The nautical astronomy of that era bore little resemblance to the (comparatively speaking) easy-to-learn, easy-to-remember celestial navigation of the twentieth century. But how much did he need to know?

President Jefferson had introduced Lewis to astronomy, but was not prepared to teach him the practical details of its use in navigation. In February and March of 1803 he wrote to Andrew Ellicott and Robert Patterson, asking them to give Lewis the instruction he would need.

Patterson was professor of mathematics at the university in Philadelphia, and had a solid background in teaching navigation and nautical astronomy. He was also, at this time, vice president of the American Philosophical Society, the United States' clearing house for scientific information and thought.

Andrew Ellicott was a surveyor who as a youth had studied mathematics under Patterson. Ellicott seemed to consider the older man his mentor, and the two were good friends.

When Ellicott was only thirty the integrity of his work was so well known that, though he was not a citizen of Virginia, that state hired him as their commissioner to complete the Mason-Dixon line. He spent a large part of the next nineteen years surveying in the wilderness, from the US border with the British on the north to the US border with the Spanish on the south.

Although Ellicott adapted well to the hardships and dangers of the frontier, he didn't adapt well to being away from his wife and children months and years at a time. So, in 1801, when offered the highly-paid position of Surveyor General of the United States, he turned it down and accepted a lesser appointment as Secretary of the Land Office of Pennsylvania. This allowed him to settle in Lancaster and live at home year-round. He was in Lancaster when Jefferson wrote for his and Patterson's help.

The letter to Patterson begins:

> Washington Mar. 2. 1803
>
> Dear Sir,
>
> I am now able to inform you, tho' I must do it confidentially, that we are at length likely to get the Missouri explored, & whatever river heading with that, leads into the Western ocean. Congress by a secret act has authorised me to do it. I propose to send immediately a party of about ten men with Capt. Lewis, my secretary, at their head.
>
> *Next, Lewis' qualifications are laid out, then the letter ends:*
>
> He has been for some time qualifying himself for taking observations of longitude and latitude to fix the geographical points of the line he will pass over, but little means are possessed here of doing that; and it is the particular part in which you could give him valuable instruction, & he will receive it thankfully & employ it usefully. The instruments thought best to be carried for this purpose are a good theodolite & a Hadley. He will be in Philadelphia 2. or 3. weeks hence to procure instruments & will take the liberty to call on you; and I shall be particularly obliged to you for any advice or instruction you can give him. I think it adviseable that nothing should be said of this till he shall have got beyond the reach of any obstacles which might be prepared for him by those who would not like the enterprise. Accept assurances of my sincere esteem & respect.
>
> Th: Jefferson

The theodolite idea calls for a digression—Jefferson knew that, in finding longitude by lunar distance, the usual procedure was to use a watch to measure the interval between the lunar observation and the observation for local time. He also knew a timepiece carried on such a long and difficult journey would be apt to break down. Perhaps a theodolite, precisely adjusted in the observers meridian, could be used to find the longitude—even if the timekeepers failed and elapsed time could not be measured. Jefferson seems to have become attached to this idea, and as late as 1805 wrote to William Dunbar, a surveyor friend of Ellicott's, explaining it. Dunbar wrote back laying out its practical and mathematical difficulties, and mentioned a procedure that, for an experienced navigator, would have been obvious:

> ...the best remedy seems to be to have two good observers (three would be better) with excellent instruments & to chuse that time of the day when the Sun or star is at a sufficient distance from the meridian, so that taking the altitude of either will give the apparent time at the moment of taking the distance between the moon and either of those: in this case it will be found always preferable to use the Sun, because it is extremely difficult for inexperienced observers (& for others) to take double altitudes of a star with the artificial horizon...

Dunbar was the first to be so candid with the president. Others had only gone as far as pointing out that a theodolite would be apt to get damaged on such an expedition—end of digression.

In reply to Jefferson's call for help, Patterson wrote:

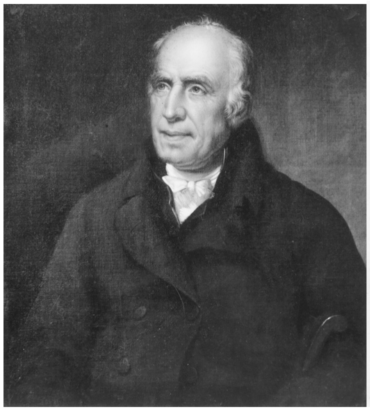
> Philadelphia March 15 1803
>
> Sir
>
> I have been honoured with your favour of the 2d and thank you for your confidence, which I will never abuse. I am preparing a set of astronomical formula for Mr. L. and will, with the greatest pleasure, render him every assistance in my power. I take the liberty of subjoining the formula which I commonly use for computing the longitude from the common lunar observation, illustrated by an example. The other formula for computing the time, alts. &c are all expressed in the same manner, viz. by the common algebraic signs; which renders the process extremely easy even to boys or common sailors of but moderate capacities.

The rest of the letter, which takes three printed pages in Volume 1 of Jackson's Letters of the Lewis and Clark Expedition, is devoted to an example of Patterson's procedure for clearing a lunar distance.

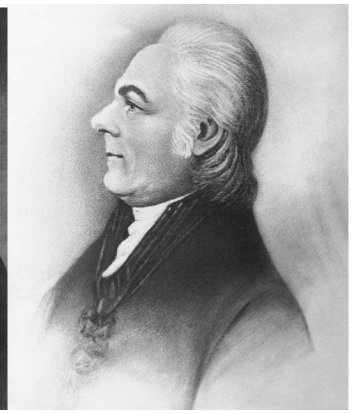
Ellicott's letter from Jefferson must have been similar to the one Patterson responded to. But from Ellicott's reply it seems his ideas of what Lewis should focus on are not the same as Patterson's:

> Lancaster March 6th 1803
>
> Dear Sir
>
> Your agreeable favour of the 26th Ult. has been duly received, and the contents noted. I shall be very happy to see Captn. Lewis, and will with pleasure give him all the information, and instruction, in my power. The necessary apparatus for his intended, and very interesting expedition, you will find mentioned in the last paragraph of the 42d page of my printed observations made in our southern country, a copy of which I left with you. But exclusive of the watch, I would recommend one of Arnold's chronometers, (if it could be had,) for reasons which I will fully explain to Mr. Lewis.

The paragraph mentioned states: "From this example [of time sights and a lunar distance] it may be seen with what ease, both the latitudes, and longitudes of places may be determined on land for



Robert Patterson
1743 – 1824



Andrew Ellicott
1754 – 1820

common geographical purposes with a good sextant, a well made watch with seconds, and the artificial horizon, the whole of which may be packed up in a a box of 12 inches in length, 8 in width, and 4 in depth."

Ellicott's letter continues:

> Mr. Lewis's first object must be, to acquire a facility, and dexterity, in making the observations; which can only be attained by practice; in this he shall have all the assistance I can give him with aid of my apparatus. It is not to be expected that the calculations can be made till after his return, because the transportation of the books, and tables, necessary for that purpose, would be found inconvenient on such a journey.

Ellicott next mentions the temperature compensating pendulum he's made for his clock: "...the work of six sundays, the duties of my office not allowing any other time...," some recent telescope observations, and correspondence with two French astronomers. He then signs off.

But, after having signed off, he picks up the thread again, and in a long postscript discusses the type of artificial horizon he's found to work best (with details of its construction), a way of getting latitude from the sun with a sextant and artificial horizon when its height at noon would make a meridian altitude impossible, and a technique Lewis could use to get both latitude and longitude with the least trouble. He ends with:

> It will be a necessary precaution, to have the Chronometer, with its case, tied up in a bladder when not in use, —it will privent its being injured if by accident it should be thrown in the water by the overturning of a canoe, or other accident.

Thus he brings up the chronometer again. Chances are he'd never seen a chronometer himself, but he wanted Lewis to have one. He'd been communicating with a Spanish traveler who used an "Arnold."

Jefferson, Patterson, and Ellicott would have found it easier to put together a seamless course of study for Lewis had they been able to sit down together a few times and explore each other's thinking. But this first exchange of letters does suggest a sound approach. That is, Ellicott would choose the "apparatus" (as he called the sextant, timekeeper, and artificial horizon) and focus on teaching Lewis how to use it. Patterson would focus on the pencil-and-paper aspects.

Unfortunately, Lewis didn't arrive at Ellicott's home until April 19th, nearly a month behind schedule. He'd been held up at Harpers Ferry, overseeing construction of the brilliantly conceived, but ill-fated, iron frame canoe.

Sources for this second part of the series have been:

<archives.upenn.edu/histy/features/1700/people/patterson>; Mathews' Andrew Ellicott, his Life and Letters; Jackson's Letters of the Lewis and Clark Expedition; and Ellicott's own Journal of Andrew Ellicott (which is his report on the survey of the US-Spanish boundary, from the Mississippi River to the Atlantic coast).

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NAVIGATION NOTES

AN INTERESTING APPLICATION OF A CYLINDRICAL SLIDE RULE

by George G. Bennett

Before the middle of the last century, the only way of accurately determining azimuth was by astronomical means. After that time, the introduction of precise gyroscopic devices using the phenomenon of the rotation of the earth was to give scientists, engineers, surveyors etc an alternative technique that was nearly as accurate as astronomical determinations and in addition had the advantage of being independent of the weather.

In early 1967 the Mine Managers Association of the four principal silver, lead and zinc mines in Broken Hill in the State of New South Wales, Australia, purchased a gyro-theodolite for the purpose of standardizing and orienting all their underground workings. The instrument consists of a gyroscope, with its spin axis horizontal, suspended on a fine thin ribbon of steel. Current to the gyro motor is provided from an external battery through spirals of very fine wire. When brought to operating speed the gyroscope will seek north and in so doing its momentum will carry it past the direction of north and then the restoring couple derived from the earth's rotation will reverse the direction of this north seeking property. The result will be that eventually this oscillation about the north in the horizontal plane will dampen and the gyroscope will come to rest with its axis aligned in the direction of the meridian. There are a number of techniques which can be used to speed up this result without waiting for the gyro to come to rest, by observing the period and amplitude of this simple harmonic motion. An azimuth determination can usually be made in low and medium latitudes in about half an hour with an accuracy of better than a few seconds of arc.

This instrument was donated to the University of New South Wales and with a colleague, Jack Freislich, orientation work in the Broken Hill mines was completed in May-June 1967. Over the next few years, the gyro-theodolite was used for a variety of purposes, particularly where orientation was required in areas of limited access. The conventional method of "azimuth transfer" in mine workings used to be performed by suspending piano wires under high tension to create vertical planes in the mineshafts. The orientation of these planes was transferred by theodolite into the various working levels of the mines. The gyro-theodolite superseded that technique and I used the gyro-theodolite for azimuth transfer in a number of gold and coal mines in the States of Tasmania, New South Wales and Queensland. Of particular interest were two applications which were very difficult to execute because of restricted access. The first one concerned the standardization of the reference lines used for checking aircraft gyroscopes in the avionics complex of Qantas Airways in Sydney. The second application was the standardization and calibration of gyroscopes in the missile destroyers HMAS Perth, HMAS Hobart and HMAS Brisbane whilst they were being refitted in dry-dock.

By now you will be wondering what this has to do with the Bygrave Slide Rule described by John Luykx in Issue 30, 1990 and recently by Geoffrey Kolbe in Issue 93, 2006. My interest stems from being the fortunate owner of a MHR1 Dennert and Pape cylindrical slide rule which is virtually identical with the original version invented by Captain L.C. Bygrave and manufactured by Henry Hughes and Son. I had the occasion to use this instrument in the Antarctic in November-December 1968. In that year the US National Science Foundation approved a grant for me to investigate the accuracy of azimuth and latitude determination by gyro-theodolite under their Antarctic Research Program (USARP). Azimuth and latitude were determined at five sites - Sydney, Australia S33º, Christchurch, New Zealand S44º, and in Antarctica at Hallett S72º, McMurdo S78º and Byrd S80º. At the high latitude stations I was able to determine azimuths to better than ten seconds of arc and latitude, using the period of oscillation of the gyroscope, to better than one minute of arc. For the former the only external reference needed was a terrestrial reference line. Considering the low temperatures (-20º F) at the high latitude stations and the shocks of transporting the equipment on domestic airlines, Hercules and Helicopter, the results of this original research were very gratifying.

The only way to carry out an independent check on the quality of the work was by comparing the gyro results with those derived from accurate astronomical determinations, which in high latitudes was complicated by long periods of daylight and the limited choice of suitable bodies to observe. My solution was to observe bright stars, even in daylight which, in order to locate them, required calculating their azimuths and altitudes, Using the best known values of position and azimuth, altitudes were predicted and set so that the star would appear close to the horizontal cross hair of the theodolite. Time was not critical because altitude change is very slow at high latitudes. Using the initial approximate horizontal circle setting corresponding to the predicted azimuth, the theodolite was clamped on either side of this at intervals of the width of the field of view and scanned until the body was located. This "hose-piping" technique proved to be effective from trials conducted at the low latitude stations.

The problem of calculating altitudes and azimuths at high latitudes at any time was not an easy task. Hand-held electronic scientific calculators were not available and therefore the choice was confined to using tabular or graphical methods of solution under field conditions. Sight reduction tables which used chosen positions were rejected because of the additional complication of dealing with intercepts which were not based on the DR position. My solution to the problem, which proved to be effective, was to use my MHR1 cylindrical slide rule. I found that after a little practice I could obtain an altitude and azimuth of sufficient accuracy for my needs in a matter of a few minutes without thumbing through tables—a considerable advantage at very low temperatures.

The MHR1, which I still have, is in pristine condition in a cushioned wooden box and is inscribed,

Dennert & Pape Fabrik. wissenschaftl. Instr
St-Nr. 26576.
Hamburg Altona

The scales are clear and easy to read. The instructions and rules for use are in German. From my limited searching it appears that these instruments are now quite rare and were probably produced between 1940 and 1945.

Whenever I bring the MHR1 out of its box, my memories go back to those interesting times when I used it with such good effect in Antarctica.

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MEMBER PROFILES

BYRON FRANKLIN

You may recall from a recent issue that we asked if anyone had contact with Byron Franklin, a past member who has made a lot of contributions to fundamental navigation. Well, I would like to say that we found him, but in fact he found us. Quite coincidentally he contacted us about another issue, and has since agreed to share experiences and innovations from his long and productive career as a navy navigator and instructor. For those who are not familiar with his work, we have a few notes below, highlighting just a few of his accomplishments.

Master Chief Byron Franklin was a Quartermaster for 26 years on various surface ships and nuclear submarines before retiring in 1978. Two navigation techniques bearing his name are currently published in navigation texts and training materials. They are listed in the latest editions of *Bowditch's American Practical Navigator, Pub. No. 9* and in the *Radar Navigation Manual, Pub. No. 1310 as:*

> **"Franklin continuous radar plot technique**. A method of providing continuous correlation of a small fixed radar-conspicuous object with own ship's position and movement relative to a planned track. Named for QMCM Byron Franklin, USN."
>
> **"Franklin piloting technique**. A method of finding the most probable position of a ship from three lines of position which do not intersect in a point."

He was awarded the Navy Commendation Medal in 1974 for his navigation work with the Naval Oceanographic Office. For those who take part in the ION CD special mentioned earlier, you will see a couple papers co-authored by Byron Franklin and Ernest Brown, which include several of Byron's plotting techniques (Vol. 19 No. 01, 1972, and Vol. 14 No. 02, 1967), and those who have a copy of the Navigator's Newsletter Archive, will find an article by Byron in Issue 22, Fall 1988, called "The Vertical Sextant," which explains a trick on taking star sights.

As some radar operators are aware these days, one of the best ways to establish your location and orientation on the chart (situational awareness) is to electronically overlay the radar image onto an electronic chart image. This takes special coordinated electronics, which are not available on many systems, but growing more popular each year. Without these special electronics, however, we can still use this method in any echart system that allows for placing range rings on the vessel icon. By setting range rings on the vessel icon that match the ring spacing on the radar, you end up with essentially the same valuable comparison, with even some advantages since radar overlays can sometimes lead to a confusing image.

Another key innovation of Byron, back before any form of electronic overlays or range rings on vessel icons, was his appreciation of the great value of this direct comparison and his development of a way to do it using chart tracings onto transparencies. He called the method "Special Radar." It was deceptively simple and remarkably valuable.

It is great to have Byron back involved with the Foundation. He was good friends with Ernest Brown and John Luykx, both past editors of the Navigator's Newsletter—Ernest Brown was also an editor of *Bowditch* for many years. Byron has send in several papers already for our newsletter, along with the start of a series of True Stories. We hope to start including these in future issues. A review of his plotting techniques will be posted in our new Online Newsletter Supplement (www.navigationfoundation.org). Besides revising his lesson plans on navigation techniques at the request of local navy training personnel, he also teaches oil painting classes in his hometown of Newport, RI. Welcome back Byron, we look forward to your contributions.

* * *

INTERNET RESOURCES

THE ION VIRTUAL MUSEUM

The Institute of Navigation has recently launched a project that they have been working on for some time. It is called the Virtual Museum. It offers a unique opportunity for anyone to share with the world any interesting navigation instruments they might possess. You can get to the museum from a link at www.ion.org.

To see how it works, we posted a few notes and pictures of a beautiful station pointer we have here. The whole process went very smoothly. They have a system set up that lets you see what you have posted and edit it as needed until the final approval and public posting. After that you can still make changes, but then those need to be sent to the manager of the Virtual Museum by email or post.

The procedure is to take a few pictures, and prepare a short write up about the device and then submit them online. It is a fully automatic process that works very well.

I know that many members and their associates have collected rare instruments that we would all like to see and learn about. This is a great place to show them off. It cannot be easier. They have gone to a lot of work to make it so easy for participants to take part.

* * *

And along the vein of online museums, there is a wonderful presentation of navigation instruments by Nicolàs de Hilster at www.dehilster.info, including many that he has created himself.

* * *

An outstanding freeware planetarium program called Stellarium, is available at www.stellarium.org. There is a mac, windows, and linux version. Certainly the nicest looking and easy to use, once you understand their conventions, which is almost on purpose not Windows standards. We have also mentioned earlier another program from France called Cartes du Ciel, available at www.stargazing.net/astropc/index.html.

* * *

For a somewhat friendlier interface to the JPL Horizons ephemeris see www.ephemeris.com.

* * *

NEW PRODUCT

SPECIAL OFFER ON AIRCRAFT SEXTANTS

Member Ken Gebhart of Celestaire, Inc., has offered any member a special on a stock of aircraft sextants he has. He asks for $50 each, mainly to cover his efforts in going through them to find the best of the lot.

He cannot guarantee their proper functioning, nor the bubble being usable. These bubbles, however, are easy to refill by the layman, according to Ken. And, of course anyone who does not want to keep one can return it for full refund. They will just be out the shipping both ways.

These are the RAF Mark IXB aircraft sextants with averager. They are considered by many people to be among the best aircraft sextants made during WW II. They come with a complete manual of operation, and should be easy for the purchaser to get into working order.

If interested, please contact Ken directly at info@celestaire.com, or 800-727-978. These are not part of a Foundation special nor are they a regular Celestaire product. It is just a special offer for those who might be interested. Ken is an expert on these instruments and their use, so he is a good resource for those who want to work with one of these.

There is an article about this sextant model at www.users.bigpond.com/bgrobler/sextant/sextant.html, which includes the above picture.

FUTURE ISSUES

STEEPED IN THE TRADITIONS OF NAVIGATION

We have an exciting plan for a forthcoming issue, hopefully next. There are in the US a handful of companies that have been in the marine navigation supply business for a long number of years, including, of course, our neighbors at Captain's Nautical Supply who have served the Seattle area more or less uninterrupted since 1897. In this group, besides "Captain's," we have New York Nautical in New York City, Baker-Lyman in New Orleans, Weems and Plath in Annapolis, and Robert E. White Instruments in Boston. Representatives of each of these companies have agreed to write up a brief history of their companies including notes on key personalities behind their companies—and we hope for some pictures as well.

We have used as a starting guideline those companies that are still in business and have been so for some 75 years or so. We also hope to include notes on several other companies that were in the charts and marine supply business a very long time, but no longer are.

Further down the line, it would be nice to expand this survey to other parts of the world.

* * *

Also down the line it would be nice to understand the history of this sequence, which we leave in code since those who recognize the code might be most interested!

HO — DMA — DMHTC — NGA

(Hint, look at the who is credited with the publication of Bowditch's *American Practical Navigator* over the years.)

* * *

News update. The US rowing team we mentioned in the last issue has completed the race from NY to UK in grand form, winning the race by more than one week and entering the Guinness Book of World Records as the first rowboat to cross the Atlantic, shore to shore, US to England, without assistance. All earlier attempts ended with a tow to shore from the Bishop Rock region, or a forced diversion to another destination. They were also the only boat in this race to make it to shore on their own. See more notes in our new Online Supplement.

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of the Art of Navigation
PO Box 1126
Rockville, MD 20849

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Permit No. 1441

"THE NAVIGATION FOUNDATION"

Question: Who was the ship captain who made the amazing proposal when steam engines first began to find there way onto sailing vessels, that the chief engineer should start having dinner at the captain's table each night—now standard procedure for the very reasons he anticipated?

Hint: Once the telegraph was invented, it was this same person who made the also startling proposal that fishermen on the east coast of England might predict their weather based on what fishermen were experiencing on the west coast of England, even though present conditions were completely different. For this and related accomplishments he is often considered the father of marine weather forecasting.

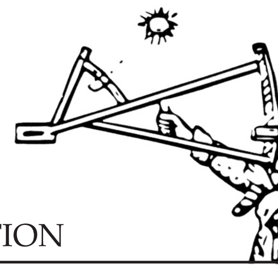
Second hint: He is most famous for something that has nothing to do with either of these acclaims.

The answer is in the mirror.

captain of the beagle, robert fitz roy, who took darwin around the world on his first voyage, primarily so he would have someone interesting to talk to at dinner time .... though darwin was just a young naturalist at the time, not famous at all.

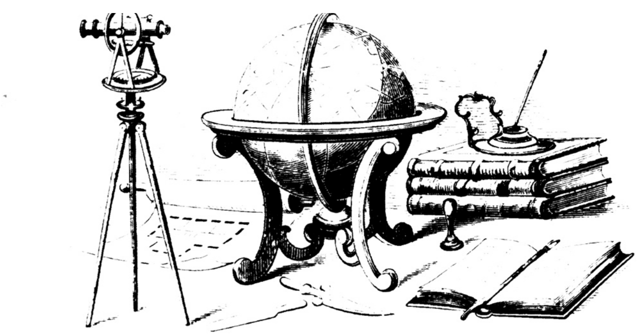
ISSUE 95, Spring 2007

THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a reader forum for the expression of our members opinions and their questions.



ACTIVITIES

By Terry Carraway

Spring has arrived and boating is starting. Now is the time to order your charts. All chart orders of under $100 gets a 20% discount and all orders over $100 gets a 25% discount. Order directly from The Foundation at *director@navigationfoundation.org*. All orders are plus shipping. Normal orders take about one week for me to receive and re-mail them to members. The U.S. Government adds and additional $7.50 on Expedited Orders. However, I get them in one day and can priority mail them to members the next day.

For our Canadian members: Many of our Canadian members order charts and mail in their renewals with a Canadian Postal Money Order or a personal check that has a U.S. Affiliate printed on the front of the check. While the Canadian Postal Money Order is still acceptable to The Foundation, the U.S. Postal Service has designated commercial banks to cash all money orders. There is no charge for U.S. Postal Money Orders but the bank charges $7.00 U.S. on all Canadian Postal Money Orders. The banks consider them to be a foreign check. I have written to the bank and complained to the U.S. Postal service to no avail. If you have a credit card you can join or renew your membership at www.starpath.com/navigationfoundation or celestaire.com/catalog/products/5950.html. On chart or publications ordered directly form The Foundation the Canadian Money order is still acceptable.

For all Foreign Members; you can all join or renew with a credit card at either of the above email addresses.

Our members are aging and unfortunately we are losing many each year. New membership is not keeping up. Unfortunately, if we do not start getting more members there will come a time when The Navigation Foundation is no longer sustainable. With each member getting a new member we can continue to give members articles and information in The Navigator's Newsletter and provide the chart, book and publication service we have been providing for the past 24 years. As you know there are no paid employees in The Navigation Foundation, for us it is the labor of love. We will also be looking into Sponsorship-level memberships as well as Corporate memberships in the near future.

EDITOR'S NOTES

By David Burch

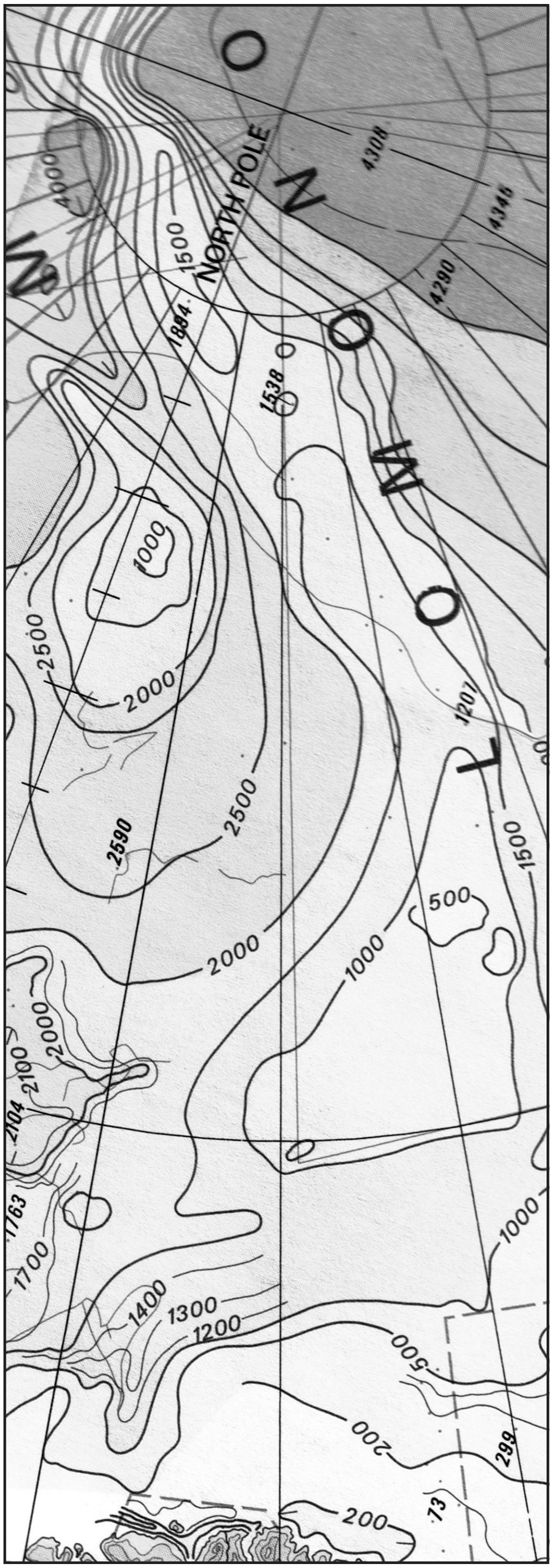
Late again! I am beginning to think there is no catching up. We will try next time, which will have the short histories of several longtime navigation outlets as promised.

Quite a bit of news, however. The ION cel nav CD is now available at www.ion.org/shopping/begin.cfm for $25 plus shipping. There is an index of articles at their site now, as well as at navigationfoundation.org in the Activities section. The ION did a great job in putting together what we sent them, and we are glad to see this project come to fruition. The first few shipments had a couple bugs: some of the articles were not printable as intended and we did overlook two valuable articles, and a page was cut off on one article. They are in the process this moment of fixing these issues and subsequent releases will have this fixed. We are looking into ways to get the earliest customers an update, but this is up to the ION. See New Products Section.

On a related note, the Royal Institute of Navigation in London offers a DVD of all of their Journal articles (not just celestial navigation) from 1948 till the present, along with periodic updates. It is available on CDs or DVD for about $200 (members save 20%). It is a wonderful resource, since one often runs across references from the RIN Journal. It may be something your local library might invest in, since it is outside many of our personal library budgets. See rin.org.uk.

The electronic edition of the Peary Report is also now available. This can be purchased from the Foundation with check or money order for $19.95, or by bank card from elibrabooks.com. Non-member price is $29.95. This is only available as a download, so when you purchase it from the Foundation you receive a serial number that can be used to download the product from elibrabooks.com. You will also need to download the elibra reader from the same site. We would like to thank Douglas Davies, president of the Navigation Foundation, for his work in providing the errata that is included. These errata have been left as a separate file, so the document published here as an ebook is an identical reproduction of the original 1989 edition with the errata and several supplementary reports and documents added to it along with the errata. See New Products section.

* * *



READER'S FORUM

Dear Terry,

The 100th Anniversary of Peary's Trip is not too far away and I am assuming that a lot will be said by many people on the North Pole Trip. A lot of articles have appeared in papers and many books written. I have some such as William E. Mollett's *Robert Peary & Matthew Henson at the North Pole*. For me this book does a good job and I agree with the contents. I also have a book by Matthew Henson titled *A Black Explorer at the North Pole*. I also enjoyed that one. Another one is the September 1988 National Geographic Magazine, which I had some disagreements with.

I have a National Geographic Top of the World Map, which is over 15 years old. The map is from 85° N to 90° N with the Pole at the center and a few contours of depth. There has been a lot of data gathered in the last 15 years such as the T3 and T4 manned weather stations, submarines at the north pole, people with GPS, and satellites in orbit taking pictures etc., which should all help update the polar maps. Do you know or have a good map of the 70° W longitude region with depth contour lines of the bottom?

I assume you have knowledge of Dr. Allen Counter and know what he did for Matthew Henson and family. Both Peary and Henson knew how to use "lesson learned" and that helped in achieving the final results. As a NASA Lunar Module Flight Controller on Apollo 11, I saw how the use of lessons learned put man on the moon.

I also noticed that you were working on Sunday. I think you are trying to catch up. If you are like I am you will never get there.

Jack B. Craven, Jr

***

On the left here is a copy from the Editor's personal files. It is a bathymetric chart over Peary's route at about 70° W. This is data from a 1979 chart. We note that it is different in some respects from that printed in the Peary Report, which is presumably later data.

The Navigator's Newsletter
Issue 95, Spring 2007
Published by
The Foundation for the
Promotion of the Art of Navigation
www.navigationfoundation.org
P O Box 1126
Rockville, Maryland 20850, USA
Phone or fax 301-622-6448
Executive Director, Terry Carraway,
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Newsletter Editor, David Burch,
editor@navigationfoundation.org.
The Navigator's Newsletter is published four times annually, with our strived-for publication dates of approximately the solstices and equinoxes. Newsletter production and other Foundation activities are provided by volunteers. Please bear with us if we slip on the dates occasionally.

NAVIGATION NOTES

THE CONCISE SIGHT REDUCTION TABLES

by P M Janiczek

I am pleased by the opportunity to address the history and method of the sight reduction tables that have appeared annually in *The Nautical Almanac* since 1989. After so many years since the tables were first published (1984) as *Concise Tables for Sight Reduction*, I had forgotten some specific details, and welcomed the opportunity to reconsider them. While doing so, certain people and events that influenced the work came to mind. I hope that readers will excuse a bit of narrative around the presentation of the method and construction of the tables. I think it is important to recognize and to record, at least once, the contributions that others have made, as best I recall them. Sight reduction involves many distinct steps. While using the term here, I will be referring only to that part having to do with transforming local hour angle, latitude, and declination to corresponding computed altitude and azimuth.

Origins

I recall that it was during the early 1980s when the Superintendent of the US Naval Observatory urged that I introduce sight reduction with tables into *The Nautical Almanac*. At first I was cautious about the prospect of putting sight reduction in the Almanac. Although the Observatory had cooperated in the design of reduction tables, and had done most of the computing and typesetting, such tables were never issued directly under Naval Observatory authority. There was the more important issue of relevance. Electronic and satellite systems were available, as well as extensive sight reduction tables. Hand-held calculators were already becoming popular. The major question I faced then was what to put into the almanac that some navigators would use, even if only *in extremis*. With the preceding in mind, I began the task, initially as a part time effort.

A short time before, the Navy Hydrographic Office functions were transferred to the Defense Mapping Agency (DMA). After relocating, E. B. Brown decided that the rare book vault at the Naval Observatory would be an ideal repository for the numerous navigation treatises and tables he had brought with him to DMA. Brown was able to effect an inter-agency transfer, making those additional resources convenient for my task.

I did not want to reinvent any wheels, so I began a survey of older tables, using the 1977 edition of *The American Practical Navigator* (Bowditch) as a guide to what I called the "Brown Collection." I had some understanding of what was current practice and decided on criteria for a tabular method and tables:

1. A short reduction table was essential. Aside from printing costs, publishing lengthy sight reduction tables year after year made no sense; lengthy tables were already in wide use. So the proper role of a reduction method and table within almanacs ought to be as a backup alternative to faster, more direct methods.

2. I was certain that few navigators would accept any method requiring logarithms, and logs could be somewhat confusing to young quartermasters, for example, who could not be expected to have a comfortable working knowledge of them.

3. Because Navy navigators were accustomed to using so-called inspection tables such as Pub. 229 and Pub. 249, all entries and respondents of an alternate tabular method should likewise be in degrees and minutes. In addition, I subscribe to the idea that use of degrees and minutes not only reinforces a mental connection to distances in nautical miles, but also provides a sense of control over the calculations.

4. A short table ought to allow a navigator to initially enter it using an assumed position. That would be consistent with some preferred inspection tables and, therefore, familiar. From the nature of the altitude - intercept process, an assumed position has potential to be as good as any other. This is discussed below.

With the above in mind, I examined only those methods and tables which, from the descriptions in Bowditch, showed promise as adaptable for *The Nautical Almanac* and modern usage. I was particularly impressed by the earliest in a series of tables published privately by the Brazilian naval officer Radler de Aquino. His table, especially, satisfied some of my criteria. However, the navigational triangle, divided into two right spherical triangles, has many uses, and Aquino incorporated several of those in his subsequent editions, under various titles. By introducing several additional notations into the column heads of the tables originally dedicated to sight reduction, in order to support additional uses, the original sight reduction application became but one of many uses and, in my estimation, the multiplicity of table labels became conducive to making blunders.

As others before me, I decided to proceed with a perpendicular dropped from the zenith to the meridian of the observed body. The resulting right angles are then at the body's meridian. One advantage is that initial entry into the corresponding reduction table is with latitude and hour angle. Additionally, all initial entries could be at the same page (one book opening) for all observations. In comparison to dropping the perpendicular from body to vessel meridian, the main disadvantage is that there would be two components of azimuth angle, which have to be combined to determine the azimuth angle according to a set of rules. In turn, as with other methods, the azimuth angle has to be converted to azimuth.

I had written the necessary equations, outlined the development, and looked at a few test cases when Admiral Tom Davies approached me with his idea for a short table for sight reduction. Davies had already worked out many details. However, as I remember, one aspect involved adjustment of computed altitude by means of a tangent function and, I reasoned, that function could cause numerical difficulties for many realistic cases. I persuaded Davies that my scheme showed more promise and we readily agreed to cooperate on development of a method and table, since our goals were essentially the same: a method and tables) that could be stored in a sextant case or, more or less permanently, in an almanac.

Development

Figure 1 shows a divided navigational triangle with parts labeled and the right angles indicated. I assume quantities *LHA*, *Lat.*, *Dec*. are already recognized. For the remainder, *A* is the arc length of the perpendicular from the vessel to the meridian of the observed body; *B* is the arc length from the pole to the point where *A* intersects the body's meridian. The first component of the azimuth angle is Z_1. Since *H* is the computed altitude of the body, to be found by the reduction process, 90°– H is the zenith distance of the body.

Two sides of the second (lower) triangle are A and 90°– H. The third side is 90°– F and must be calculated by hand. Side B in the first (upper) triangle is found by solving that triangle, and body declination, *Dec*., is known from an almanac. Define F as the *algebraic sum* of B and *Dec*. Then 90°– F will be the third side of the second (lower) triangle. *Figure 1* shows the situation in simplest form, where B and *Dec*. are both positive. Angle Z_2 is the second component of azimuth angle. Finally, angle π, sometimes called the parallactic angle, is not formally needed for the solution of either triangle, but it automatically appears (indirectly) during the solution of the lower triangle, as shown below.

In following the development of the method's formulas, you might find that reference to the tables as they appear in *The Nautical Almanac* to be worthwhile. The solution of both triangles uses the sine and cosine formulas of spherical trigonometry. The upper triangle:

From the law of sines

$$\sin Z_1 / \sin B = \sin LHA / \sin A = 1 / \cos Lat,$$

hence,

$$\mathbf{\sin A = \sin LHA \cos Lat.}$$

Also, from the law of cosines,

$$\cos LHA = \sin Z_1 \cos A$$

or,

$$\mathbf{\sin Z_1 = \cos LHA / \cos A.}$$

Returning to the sine expressions above,

$$\mathbf{\sin B = \sin Z_1 \cos Lat.}$$

The three formulas in bold are all that are needed to solve the upper triangle and, in fact, to construct the reduction table. Why this is so becomes evident as the solution of the second triangle is explored.

As mentioned above, B and *Dec*. must be combined to form F. The preceding statement is sometimes written F = B ~ Dec. The symbol ~ is a dead giveaway that sign rules are involved. At any rate, this is a manual step for the user.

$$\mathbf{F = B + Dec.}$$

For the second triangle then, the altitude H is found directly from the cosine formula,

$$\cos (90° – H) = \sin F \cos A,$$

or

$$\mathbf{\sin H = \sin F \cos A.}$$

From the sine formula,

$$\sin Z_2 / \cos F = 1 / \cos H$$

and

$$\mathbf{\sin Z_2 = \cos F / \cos H.}$$

The six equations in bold type solve the problem. However, a table that provides A and B will also provide quantity P in addition to H. Angle P is identified as the complement of π, the parallactic angle. Although not a necessary part of the solution, P will prove useful and the cosine formula for angles gives P explicitly:

$$\sin P = – \cos Z_2 \cos 90° + \sin Z_2 \sin 90° \cos A,$$

or

$$\mathbf{\sin P = \sin Z_2 \cos A.}$$

Note that the formulas for A and H have the same functional form. The same is true for B and P, as well as Z_1 and Z_2. That is why the same table can be used for solving both parts of the divided triangle. Moreover, that sin H and sin P are both given as the product of a sine and cosine provides an alternative for high altitude sights that is demonstrated later.

To keep the reduction table to manageable size, I decided the tabulation would have to require entry using latitude and local hour angle limited to whole degrees only. That meant the die was cast in favor of assumed positions. Adm. Davies later devised a scheme for adjusting computed altitude to reflect DR positions, and that appears in his book.

We began the reduction table. It seemed obvious that latitude entry should be across the top of the table. All possible local hour angles would be in four vertical columns, but that would not restrict a user who preferred meridian angles. The body of the table would consist of three columns per latitude block giving A and H, B and P, Z_1 and Z_2 for every value of local hour angle.

Among the instructions for use of any short table there must be rules for determining the signs of various quantities. I constructed a set that turned out to be too cumbersome. Davies devised rules for signs that were much better. Through the ten years or so following, others found even simpler rules. Among those offering improvements should be mentioned Dr. Allan E. Bayless and Forrest Gibson, both associated with the United States Power Squadrons and its training programs.

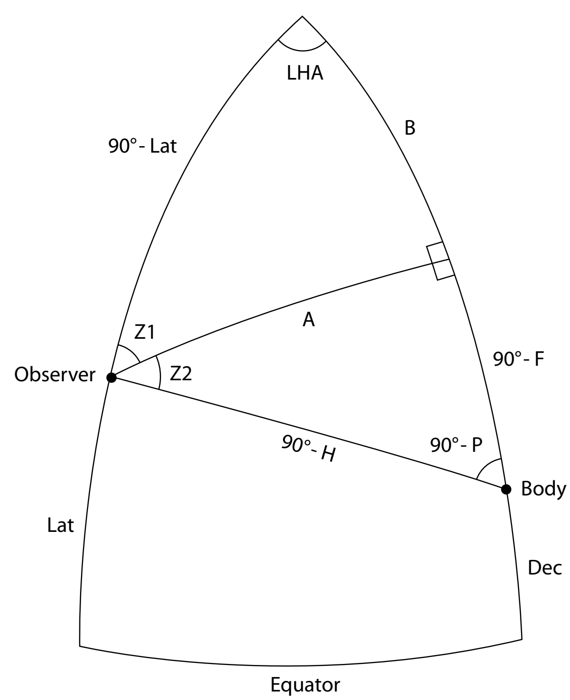


Figure 1 — The divided navigational triangle

With assumed positions, the missing minutes of latitude and hour angles are not needed, because the navigator will be plotting intercepts using the associated assumed positions. However, second entry into the table also uses *A* and *F* in rounded whole degrees. After the rounding, *A* and *F* may be in error by as much as one-half degree and thus impact computed altitude more or less seriously. Unlike the case for assumed positions, there is no straightforward way I know of to adjust the plot for having used rounded *A* and *F*. Thus, the computed altitude from the table should be adjusted for the minutes of *A* and *F*.

We decided to refer to the altitude from the table as "tabular altitude" and denote it by *Ht*. I'll use that notation hereafter. In order to adjust *Ht* for the minutes of *F* and *A*, I devised a correction based on differential calculus but involving only quantities at hand from the second tabular entry results because that minimizes page turning.

Starting with the formula for sin *H*:

$$\sin H = \sin F \cos A$$

and differentiating,

$$\cos H \, dH = \cos F \cos A \, dF - \sin F \sin A \, dA.$$

Divide both sides of the equation by cos *H*. Working with the terms on the right, one has:

$$\cos F / \cos H = \sin Z_2$$

and

$$\sin Z_2 \cos A = \sin P.$$

Also,

$$\sin A / \cos H = \cos P$$

and

$$\sin F \cos P = \cos Z_2.$$

With the simplifying substitutions, and replacing the differentials by finite increments, the correction formula becomes

$$\mathbf{\Delta H = \sin P \, \Delta F - \cos Z_2 \, \Delta A.}$$

I constructed an "auxiliary" table using ΔF = minutes of *F* and ΔA = minutes of *A* as horizontal entries, together with *P* and Z_2 as vertical entries. The table is such that, even with *F* and A having been rounded, the correct increments to *Ht* are produced for observations at reasonable altitudes.

Davies and I also decided to construct a similarly functioning table along a different line. For the alternative "auxiliary" table, we computed many exact solutions to the navigational triangle (about 73 million, I believe). Next we had the computer compare the exact solutions to those that would be derived from the reduction table alone. Those results were then used to refine the increments for *Ht* within the alternative table such that the *largest* errors arising from using the reduction and alternative auxiliary table together would be minimized. We found that both forms of the auxiliary table give almost identical results, differing at most by one minute of arc for a few entries.

What remained were mechanical problems concerning type style and size, page size limitations, etc. I won't go into those here except to note, with persistent sense of irony, that ultimately it is the overall physical dimensions of a publication that determine what, and how, all materials may be incorporated.

Separate Ways

Having completed the main task of a method and tables for sight reduction, Davies decided to extend the usefulness to related problems. I suggested that he publish the tables and extensions as his, but with the understanding that whatever parts of his publication could be copyrighted, the fundamental method and actual tables could not. Davies wisely used generic table headings, and his version of the tables is not cluttered by symbols for his extended applications. Cornell Maritime Press published Davies' version and it received a favorable review in the Royal Institute of Navigation *Journal* by Donald H. Sadler, former Superintendent of HM Nautical Almanac Office. The tables ultimately appeared in *The Nautical Almanac*, where the headings are specific to sight reduction, as that is the only application intended and described. The five-year interval between publications was due to the fact that the publications of the US and UK Nautical Almanac Offices are joint endeavors. At the time, such cooperation saved duplication of effort, but it exacted penalties in the form of time delays involving both exchange of materials and in satisfying overarching bureaucratic requirements of two governments.

An Additional Point

The altitude-intercept procedure of position fixing is an *iterative differential* process. To set the mind at ease, the term "differential" can be replaced by "difference," because in the real world we work with numbers that are differences.

In general, the operation of the differential process begins with an approximate value for a quantity. That approximation is used to calculate values of measurable quantities. Those calculated 'measures' are compared to actual measurements and their differences are formed. The differential process then uses the differences in solving for yet another difference, which is the increment that is to be applied to the initial approximation to give the true value, or at least an improved value. If the improvement is considered inadequate, the iterative nature allows for re-calculation, using the improved value in place of the starting approximation. Of course the measurable quantities must be re-calculated for use by the differential process to find a new solution.

In celestial navigation specifically, the initial approximation for the differential process is an estimated position. It is used to produce a set of calculated altitudes (*Hc*). Sextant altitudes constitute the set of actual measurements (*Ho*). The set of differences between observed and calculated altitudes, together with computed azimuths, determine the positions and orientations of position lines on a plotting sheet. The navigator can then determine the fix directly from the plot, and dividers can be used to determine the distance from the estimated position to the fix. Although it may not be all that important, I'll say that the distance between estimated and fix positions is the actual solution coming from the differential process.

Just as with other differential procedures, a fix is sometimes not satisfactory. The navigator will certainly examine the geometry of the situation and the possibility of blunder. But the point here is that the sight reduction process also allows for iteration. If the geometry is not at fault and no mistakes are present, repeating the reduction and solution based on that first, unsatisfactory, fix could well give a better fix. Because it can be time consuming using tables and forms, repetition is not common practice, but it is an available option worth keeping in mind.

Afterward

Toward the mid-1990s, I was surprised to read a letter accusing *The Nautical Almanac* of stealing the letter writer's work, which I had not seen. He had published a table similar to that in the Almanac, although he had used degrees and decimals in his table. Copyright infringement or plagiarism was not at issue, and I rejected the accusation. The historical record of 100 years counters any possible claim theft.

Breaking a triangle into two so that each part forms a right triangle is certainly nothing new. We are told that navigation tables based on solutions of triangles were being produced in the 15th Century. I believe that such tables involved plane triangles, and that many involved divisions of the triangles. But spherical triangles, coming later, are no exception. Anyone who studies trigonometry, even school children, quickly learns or re-invents the technique of dividing a triangle. There is simply nothing new about that. On the other hand, while dividing the triangle is a very old technique, it could not be found in use for the modern method of position determination before Marcq St.-Hillaire published his description of the altitude-intercept in 1875. As discussed in Bowditch (1977 ed.), Souillagouet was the first to employ the method described here, and his (much lengthier) tables based on it were published in 1891. However, there are 16 additional tables, since produced by other authors, essentially along the same lines, also discussed in the Bowditch '77 edition. Further, it has to be allowed that even the Bowditch discussion is incomplete; no doubt even more such tables were published, perhaps in remote places, that never became widely known. Therefore, my position is that neither the basic method with its equations, nor any *improved* or *revised* reduction table based on them, can ever again be considered an original method according to any reasonable interpretation of what is intellectual property.

* * *

Dr. Paul Janiczek has been a member of the Foundation since its inception. He is the former Head of the Astronomical Applications Department of the US Naval Observatory, now retired. This department remains a primary reference for celestial navigators (see aa.usno.navy.mil—or Google "USNO AA"). He has a review of Nautical Almanacs (The Almanacs—Yesterday, Today, and Tomorrow) in the ION CD discussed in New Products. I understand we can look forward to a follow up on several special topics related to these NAO Sight Reduction Tables.

It is this editor's opinion that these tables have not yet received the attention they deserve. They are ideal tables for modern navigation, which usually relegates celestial to a backup system to GPS, and even the tables solution is often a backup to celestial computations by computer or calculator. They are learned very quickly with a well designed work form, and they are essentially as precise as Pub. 249—and with the form and some practice, they do not take much longer to use than Pub 249.

NAVIGATION NOTES

WHY OLD SAC NAVIGATORS LOVE GPS

by Bill Robinson

A while back I was asked by John Lewis, a Foundation member interested in air navigation, to comment upon some of the practical differences between air celestial and marine celestial navigation. John's interest in my input resulted from his reading of an article of mine, A Hard Day's Night, published in September 2006 issue of Air & Space Smithsonian magazine, recounting one of the 24 hour Chrome Dome, non-stop over the pole, armed airborne alert missions flown by Strategic Air Command (SAC) B-52 crews during the mid 1960's.

I spent most of the 1960's accumulating about 2,800 flight hours as a B-52 navigator-bombardier, so the techniques discussed below are some which I personally used. They do not represent the only way things were done. Air Force technical support folks, training commands, individual navigators, equipment companies such as Kollsman and, yes, the venerable Institute of Navigation, were all constantly involved in improving celestial methods and equipment.

Back in the day, some of the most demanding navigational challenges for USAF navigators were the B-52 missions flown by SAC. In the 1960's we were all dead reckoning navigators. Most bomber missions required reliance upon passive navigational aids (the B-52's excellent ground mapping radar, of little use over water and ice, could only be used intermittently for navigation (radar pilotage) when over enemy territory, and we did not carry LORAN because it was subject to jamming), so the primary high altitude aid to dead reckoning was celestial.

The profile for a routine training mission, average length 11 to 12 hours, combined long stretches of high altitude navigation, high altitude radar bombing, air refueling rendezvous, and hundreds of miles of high speed, low altitude navigation (300' to 800'), target area penetration and bombing. The B-52's navigators, of which there were three, were all dual rated: two interchangeable navigator-bombardiers (left seat bombardier, right seat navigator) and one navigator-electronic warfare officer (EW). Since the periscopic sextant was located at the EW's position, he made all of the sextant shots, using information provided by the navigator via intercom.

In-flight requirements were rigorous. SAC required its navigators to maintain flight corridor limits of five nautical miles either side of the planned track centerline. Control times at all turn points, targets, special reporting points and tanker rendezvous points were to be accomplished within plus, or minus, one minute. Navigational errors of any kind were simply not tolerated. All charts, logs and computation data were collected after every mission to be checked and re-plotted down to the last LOP by the squadron Bombing/Navigation staff. The operative attitude in the Bomb/Nav shop reflected the informal SAC motto: "To err is human, to forgive is not SAC policy."

Celestial fixing was labor intensive and fast paced. In order to avoid errors, however, the navigator had to resist being rushed.

He was able to "stay ahead of the airplane" by thorough mission preparation, meticulous preplanning of the route with detailed chart annotations, pre-selected celestial bodies and pre-planned celestial shot times, and fix times. Everything possible was pre-computed, especially the computations for planned celestial fixes. Unlike marine navigation there was time for only one shot per body, per fix…..no do-over.

For aerodynamic reasons, jet aircraft had no bubble astrodome through which the navigator could survey the sky and locate stars by reference to constellations. The indirect sighting, periscopic sextant was standard equipment. The EW had to locate and identify the star in the sextant's small visual field using exact azimuth and altitude information provided by the navigator. The navigator also called the start and stop times for each shot, the mid-time of which was used for the averaged Ho (observed altitude) used for LOP computations. Most navigators used two minute shots.

Aside from use of the periscopic sextant and celestial precomputation, a major difference between air and marine celestial has to do with how the Line of Position (LOP) was resolved and plotted. It was impractical to take celestial sightings, then do the calculations necessary to plot the Line of Position (LOP). At a ground speed of seven miles per minute (the B-52D's normal true airspeed at cruise altitude was 440 knots), if it took 20 minutes to shoot, compute and plot a three star fix, the celestial position would already be 140 nm behind the aircraft by the time it was plotted.

Precomputing each shot helped, but not enough. Tabulated corrections for the Motion of the Body and the Motion of the Observer were applied to the body's observed altitude in order to adjust the LOP for the difference between observation time and a later fix time. This allowed the navigator to convert, that is, advance each LOP ahead of the aircraft to a common fix time. There are several graphical and mathematical methods to do this.

Here is a somewhat simplified example of a mathematical method:

If a planned night celestial fix time were, say, 0400z (GMT), the first body might be shot at 0348z, the second at 0352z and the third at 0356z. The navigator would enter the H.O. 249's Motion of the Observer table with ground speed in knots and the relative Zn (the azimuth of the body relative to the aircraft track) and obtain a value to be applied to the Ho (observed altitude of the body). This value is tabulated for four minute increments of time, so if the value obtained for the mid-time of the first shot, which was 12 minutes before the common fix time, is +14 , it would be multiplied by three, 14 x 3 = +42 .

SAC used a special table giving Motion of the Body corrections, also for four minute increments of time. The entering arguments were latitude and the True Azimuth (Zn) of the body. The sign of the correction (plus/minus) varied based upon whether the body was rising, or setting. Assume this correction was determined to be -4 . For the 0348z shot the correction would be -4 x 3 = -12. This correction was algebraically added to the Motion of the Observer correction (-12 + 42 = +30) and the combined correction applied to the Ho. The same would be done for each of the three stars so that, when the LOP for the shot is plotted, it is advanced to the common fix time of 0400z. This allowed the navigator to plot the final converted LOP two or three minutes before the scheduled fix, providing time for a DR ahead plot and to give the pilots the heading/airspeed changes necessary to stay on time and on track.

Finally, it's hard to talk about celestial without mentioning polar navigation and the importance of aircraft heading at high latitudes.

On normal polar charts there is one degree of change in true course for each meridian of longitude passed. This change occurs more rapidly as the pole is approached because the convergence angle of each meridian is increasingly acute. Thus, in order to fly a straight chart course, the aircraft would have to be placed in a constant turn—not good.

To avoid this situation, crossing latitudes of 60 to 65 degrees headed for the pole, navigators had to go into grid—a navigation technique used by sea going vessels and aircraft when the unreliability of the magnetic compass and the acute polar convergence of geographic meridians rule out steering by conventional methods. Grid navigation is done by replacing the polar chart with a special blank chart containing a square latitude and longitude grid, which, consequently, requires a reorientation of the compass heading reference to a new grid north.

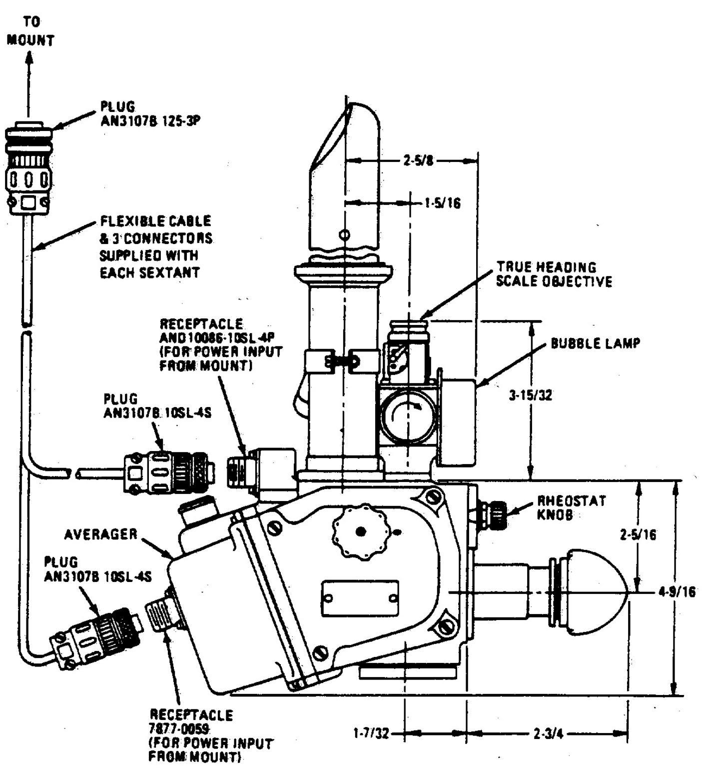
Because the grid chart's meridians are parallel to the Greenwich Meridian, the angle between grid north and true north was calculated to establish a new grid north geographical heading reference. Once grid north was determined, the primary heading instrument, the N-1 Gyro Compass on a B-52, was switched from a magnetic north oriented "slaved" mode, to a gyro stabilized, "un-slaved," free running mode, then reset and maintained at the newly established grid heading. This complicated celestial somewhat, since all azimuths had to be converted to grid azimuths, but it otherwise did not effect how fixes were plotted.

Maintaining a precise grid heading was crucial. A free-running gyro compass is restricted so that its spin axis remains horizontal to the surface of the earth and is free to turn only in the horizontal plane. Any movement of the gyro compass spin axis from its initial horizontal alignment is called precession, usually induced by aircraft motion and the earth's rotation C the Coriolis Force. This causes the compass heading to wander. Precession was the navigator's enemy, since an undetected, cumulative heading error could take the aircraft wildly off course. Regular periscopic sextant heading checks were mandatory between fixes to maintain the correct grid heading by adjusting the N-1 for precession.

The celestial routine on most B-52 missions was to shoot, resolve and plot each fix, adjust airspeed and heading to stay on time and track, take a "heading shot" and, if in grid, reset the heading on the N-1 compass to correct for precession, update the flight log with current flight data (heading, track, airspeed, groundspeed, wind, etc.), recheck ETA'S, dead reckon ahead for the next fix time, update precomputed Combined Motion corrections for significant ground speed and track changes, then begin the process all over again every 20-25 minutes. Now you know why old SAC navigators love GPS.

Editor's Note: We asked Bob to give us a few notes about himself that we could share with our readers.

I am a former USAF navigator with about 2,800 hours in the B-52D and 900 hours in the F4E Phantom II. Celestial navigation in my B-52 days (1964 -1969) was our primary aid, in addition to pressure pattern techniques, to dead reckoning. As I'm sure you are aware, shooting and plotting a celestial fix or sun line at 440 knots is a good deal more complicated than accomplishing the same fix or sun line at 6 knots. With rigorous flight corridor requirements of five NM either side of planned centerline and plus/minus one minute control times on planned turn points, whether over land, water or ice, the work required of the SAC navigator to achieve consistent precision in his fixes was intense, to say the least. Hence, my motivation for the A&S piece, written in this day of GPS chart plotters, was to give to interested general readers, some minimal appreciation of what it took to cross an ice cap or ocean in the 1960's, with highly precise fixing, employing the fundamental manual celestial navigation aids to dead reckoning that have been available mariners over the centuries. I was one of the last generation of military air navigators whose service overlapped the introduction, in the late 1960's, of advanced LORAN systems and Inertial Navigation Systems.



Drawing from the Technical Manual T.O. 5N10-3-2-21 entitled: "Operation and Service Instructions Periscopic Sextant", There is an extended presentation on this instrument in the Virtual Museum of the Institute of Navigation (see ion.org).

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FORTHCOMING ISSUES

In the next issue we have the histories of navigation supply stores, Bill Cook's article on sextant mirrors, and Byron Franklin's notes on how to choose the best sight from a sequence.

NAVIGATION NOTES

SOME NOTES ON AIR NAVIGATION

by John Lewis

Almost all aircraft use a gyrocompass (properly referred to these days as a Heading Indicator) for maintaining course, because at aircraft speeds a magnetic compass suffers from serious turning errors due to the dip (deviation from horizontal) of the Earth's magnetic field. For example, when flying on a northerly heading, if the plane starts a turn to the right, the compass will initially show a turn to the left; on a southerly heading it will show the proper direction of turn but exaggerate the rate. Gyrocompasses avoid these problems; however, a gyrocompass precesses and drifts, so it must be checked regularly against the plane's magnetic compass (while flying a steady heading) and reset. In small aircraft this is done manually by the pilot; in larger aircraft the gyrocompass is normally 'slaved' to a remotely mounted flux sensor. In high latitudes the gyro must be unslaved, and as mentioned in Bill Robinson's article, a 'heading shot' of a celestial body with known azimuth is used to correct for gyro drift.

A great improvement in the navigator's equipment after WWII was the periscopic sextant, the technological breakthrough that freed navigators from shooting with hand-held sextants through astrodomes (Plexiglas bubbles) atop aircraft. No longer did they have to add corrections for astrodome refraction or endure the frustrations of scratched and discolored Plexiglas distorting celestial sights. Determining aircraft heading by periscopic sextant became much more accurate than with the earlier astro-compass, because the periscopic sextant fitting in the overhead of the navigator's station allowed very precise measurement of the angle between the aircraft heading and the shot.

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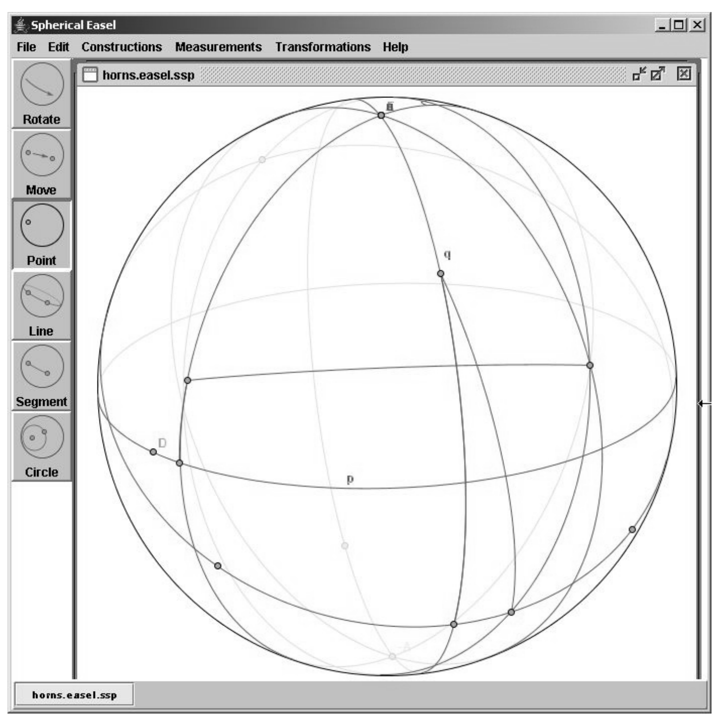
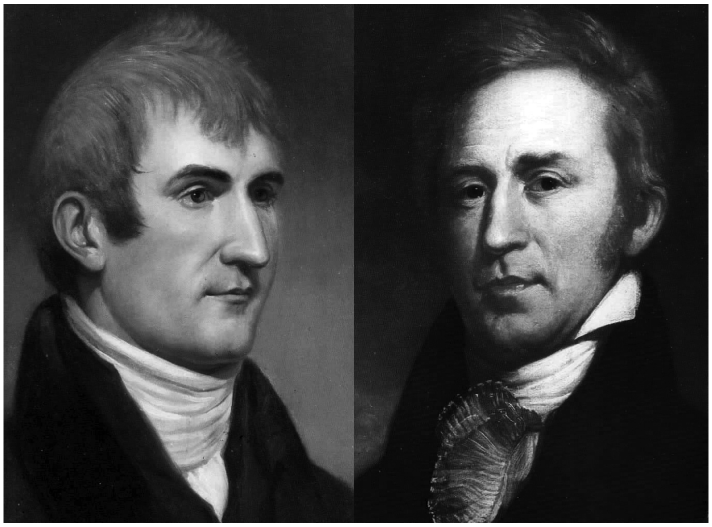


An electronic armillary sphere. See Online Resources, p. 11

NAVIGATION NOTES

LEWIS AND CLARK'S NAVIGATION, AN OVERVIEW

by Bruce Stark



Meriwether Lewis 1774 - 1809 William Clark 1770 - 1838

Part 3

Although President Jefferson hadn't heard from him since March 7th, he knew Lewis was behind schedule. But, rather than add to the pressure his friend was under, he put off writing for details. Finally, on April 23rd, not having heard from Lewis for a month and a half, he wrote a letter in which he briefly mentioned his anxiety:

> "I have no doubt you have used every possible exertion to get off, and therefore we have only to lament what cannot be helped, as the delay of a month now may lose a year in the end."

> And, "Let me hear from you on your receipt of this, and inform me of your prospects of getting off."

He sent the letter to Philadelphia, supposing Lewis would be there by the time it arrived. Two days later he received a shock— in the form of a letter from Lewis datelined: "Lancaster Apr.20th 1803." Lewis was even further behind schedule than he had feared.

Lewis's letter was a long one. In it he explained why he had been held up at Harpers Ferry arsenal, and brought the President up to date on the many things he had accomplished, and the many arrangements he had made, since they last communicated. It ended with:

> I arrived at this place yesterday, called on Mr. Ellicott, and have this day commenced, under his direction, my observations &c to perfect myself in the use and application of the instruments. Mr. Ellicott is extremely friendly and attentive, and I am confident is disposed to render me every aid in his power . . .

And the (somewhat) reassuring:

> Being fully impressed with the necessity of setting out as early as possible, you may rest assured that not a moment shall be lost in making the necessary preparations. I still think it practicable to reach the mouth of the Missouri by the 1st of August.

At Lancaster, the second stage of Lewis' instruction in nautical astronomy began. How far the first stage, with Jefferson, had taken him can be guessed at from remarks in letters the President later wrote to William Dunbar and Robert Patterson. One sentence begins:

> "Having never been a practical astronomer, and a life far other wise spent having even rendered me unfamiliar with the detailed theory of the lunar observations..."

And in another passage—more to the point—he writes that the only instrument he is familiar with is the equatorial sector.

So it seems likely that Lewis had never used a quadrant or sextant before he arrived at Ellicott's. But Jefferson would have made sure that he had a reasonable understanding of the workings of the solar system, a familiarity with the more important stars, and the ability to read a vernier scale. Andrew Ellicott was prepared to take it from there. Practical astronomy and surveying had been his livelihood, and he had honed his skills from the Great Lakes in the north to the Spanish Floridas in the south.

Ellicott had even gotten in a bit of ocean navigation while running the US-Spanish line. With the cooperation of the Spanish Governor-General in New Orleans he had procured a live oak and red cedar hull of 38 or 40 tons burden and had it decked and rigged. But:

> "...I was able to engage but two sailors, and they were both deserters from a British privateer, which lay some days off the mouth of the Mississippi. With these two sailors, who were completely illiterate, I undertook to navigate the vessel. Several masters of vessels offered their service, but the price they demanded was so high, that it was thought more economical to do it myself."

Toward the end of the survey, this little supply schooner took the military escort, and the majority of the survey crew, around the Florida peninsula to meet the rest of the crew in Georgia. The two illiterate British sailors must have been good at their trade. They were the only experienced seamen on board, yet the little ship outran a privateer and survived storms that, as Ellicott found out later, wrecked three vessels "...much better calculated to resist the fury of the winds, and billows than ours."

Not only had Ellicott practiced his skills in a variety of situations, he had become familiar with the virtues and disadvantages of a variety of instruments. For Lewis he believed the best combination would be sextant, artificial horizon, timekeeper, and surveyor's compass. Ellicott's own favorite sextant on the US-Spanish survey was

> "...executed by Mr. Ramsden in superior style. It is 7 inches radius, and by the vernier divides to 20 seconds, which may be again subdivided with ease by the eye, aided with the microscope. This sextant I used in taking all the lunar distances."

At Lancaster, once the proper handling of a sextant had become second nature, Lewis may have taken lunars with the "Ramsden."

As for the artificial horizon, Ellicott wrote, in the postscript to his March 6, 1803 letter to President Jefferson, that:

> "By a practice of more than twenty years, I have constantly found water preferable to any other fluid for an artificial, or portable horizon. The reflection of the Sun from the water it is true, will be fainter than that from the specula, unless the Telescope of the Sextant be directed nearly off the foliated part of the horizon specula. This direction can be easily given to it, by a screw for that purpose, and which carries the Telescope parallel to the plane of the Sextant."

In his Journal, Ellicott had described and pictured an artificial horizon in which the roof sat directly on a two inch deep, three inch wide, five inch long water container. The bottom of the water container was fitted with a lead weight to steady it, and a loose-fitting lip sealed the wind out. But he found later that a hard gust could shake this arrangement enough to disturb the water, so changed the design. The horizon Lewis would use had a roof large enough to sit outside the water container, encompassing but not touching it. Wind could shake the roof without shaking the water.

Good glass plate, with plane and parallel surfaces, must have been expensive. Instead, two thin sheets of talc (isinglass) served as the transparent parts of the roof. Spare sheets were part of the kit. Ellicott's timekeeper was a pendulum clock he'd built himself. On the recent survey of the US-Spanish line, from the Mississippi river to the Atlantic coast of Georgia, this was the clock both he and the Spanish commissioners depended on. When it was to be used a stump or other solid base was prepared, the clock unpacked, put together, fixed in place, and set going. Observations were taken over a number of days to find the clock's error and rate on local time. Before it could be moved the clock had to be dismantled and carefully packed.

Ellicott also had "Two excellent stop watches, with second hands, to be used if any accident should happen to the regulator [pendulum dock], or at places to which it could not be taken." These watches were more in line with what Lewis would want. They were probably no better at keeping accurate time than the dollar watches common a hundred and thirty years later. But nearly every navigator, in the early nineteenth-century, depended on such a watch. He made no attempt to keep track of Greenwich time. He found it occasionally by lunar, compared it with local time for longitude, and forgot it. The Almanac of that era was designed according to a different logic than our present, GHA, Almanac. Only a rough estimate of Greenwich time was needed to get accurate data from it. A navigator made that estimate by applying his dead reckoning longitude (converted to hours and minutes) to his own local time.

To understand how such a System could work—and how it can be made to work even with our present Nautical Almanac—read "Tin Clock and Sextant" in issue #82 of the Newsletter.

But Lewis had been authorized to purchase a Chronometer. He would find one later, in Philadelphia, and get other instruments there. Ellicott provided the artificial horizon, and a box in which it, a sextant, and a watch could be safely packed.

On April twentieth, the day after Lewis arrived at Lancaster, he probably learned how to examine and care for a sextant. After that he would have been set to work developing skill and judgment in its use—taking observations of the sun, moon, and stars.

Ellicott had found by experiment that he could get the error and rate of his pendulum clock just as accurately by sextant as by the passage of the sun or a star over the wires of a transit instrument. He used the "equal altitudes" procedure, but had an unusual way of making contact between the sun's images. In the morning he would bring the sun's reflection in the sextant mirrors down below its image in the water of the artificial horizon, clamp the index there and wait. As the sun rose he noted the dock time of first contact, of congruity, and of Separation. In the afternoon, with the same setting on the arc of the sextant and the sun descending, he noted three times again: contact, congruity, and Separation.

The average of these six times, adjusted for the sun's change of declination (by the equation of equal altitudes), and for the difference between apparent and mean time (by the equation of time), was what the dock read at the instant of local mean noon. For Lewis's expedition, the method would be ideal:

1) The reliability of the numbers brought back would not have to be taken on faith. In the six-number pattern any bad number tends to stand out.

2) Instrument error does not affect the accuracy of the time found. Nor does a mistake in reading the degrees, minutes, and seconds from the sextant's arc and vernier.

3) But, if sextant reading and index error are correct—and the sun was not too near prime vertical (due east or west) when the altitudes were taken—the Observation provides excellent data for calculating latitude. This is especially useful if the sun is too far north for a noon latitude to be taken—that is, when the angle between the noon sun and its reflection in the artificial horizon would be beyond the range of a sextant.

Anyone who has worked with Lewis and Clark's navigation will be familiar with this six-part Observation, and will appreciates its virtues. But it does have disadvantages, one being that the afternoon half is often lost. The sun may be hidden in clouds as it drops to the angle on the sextant, or the observer may be otherwise occupied at the critical moment.

Another problem is that, to avoid blunders in reading the vernier and resetting the angle—and also for absolute accuracy—the sextant was put away with the morning altitude on the arc. It was out of commission until the afternoon contacts were timed. Without another sextant, some of the most convenient lunar distance opportunities were lost. Ellicott had first recommended one sextant. He'd been told there would be only ten or twelve men on the expedition, and in that case, baggage would have to be kept to a minimum. Later, when it became clear there would be more men, he recommended two sextants.

Lewis would have gotten excellent Coaching on sun lunars, but there are reasons to believe he was scanted on his star lunars. For one, it was late April and early May. Nights would have been Short in Pennsylvania. For another, Ellicott seemed to prefer sun lunars. Of the thirty-three lunar observations he had taken on a recent expedition, all but five were sun lunars. This is striking, since his work required that he be up at all hours of the night observing stars, either with a transit and equal altitudes instrument or with a zenith sector, and—with the 120 power eye piece in a large achromatic Dolland telescope—the eclipses of Jupiter's satellites.

But the main reason for believing Lewis was scanted on star lunars is that, while his sun lunars tended to be good, his star lunars were remarkably bad. He had a tendency to leave a large gap between the moon's limb and the star.

Lewis was in Lancaster until the sixth of May. A few days later he was in Philadelphia, where he would find and purchase more equipment, and would continue his crash-course education. He would call on Benjamin Rush for advice on health and medicine; on Caspar Wistar for information on anatomy and fossils; on Benjamin Smith Barton for botanical instruction; and on Robert Patterson for more Instruction in practical astronomy.

Patterson would add a few instruments to Lewis's kit, as well as techniques Ellicott had not taught him. Two of these, the quadrant and the back-sight, would become a Standard part of Lewis and Clark's astronomical routine.

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NEW PRODUCTS

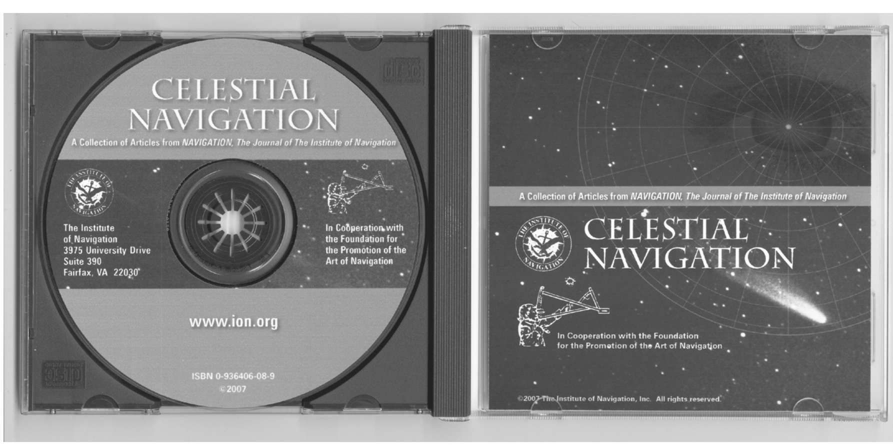
ION CELESTIAL NAVIGATION CD

This compilation of all of their articles on Celestial Navigation from 1948 to 2003 is now available from the Institute of Navigation. The updated version should be available after about May 20. It is only available from the ION directly, and the price of $25 is the same for all customers. See also page 1 notes.

PEARY REPORT EBOOK

The "Peary Report" is shorthand for *Robert E. Peary at the North Pole—A Report to the National Geographic Society by the Foundation for the Promotion of the Art of Navigation,* the full title of the study carried out over more than a year by four directors of the Foundation, three of whom are still active in the Foundation: Douglas Davies, Terry Carraway, and Roger Jones. The original document was 240 pages. The new ebook edition includes the *Supplementary Report,* presenting more data, along with several letters, and a new errata prepared by Douglas Davies, based mostly on unpublished notes from Admiral Thomas Davies, director of the project.

The Report concludes from several independent methods that Peary did in fact make it to the Pole as claimed and that there was no evidence of his having presented false data.

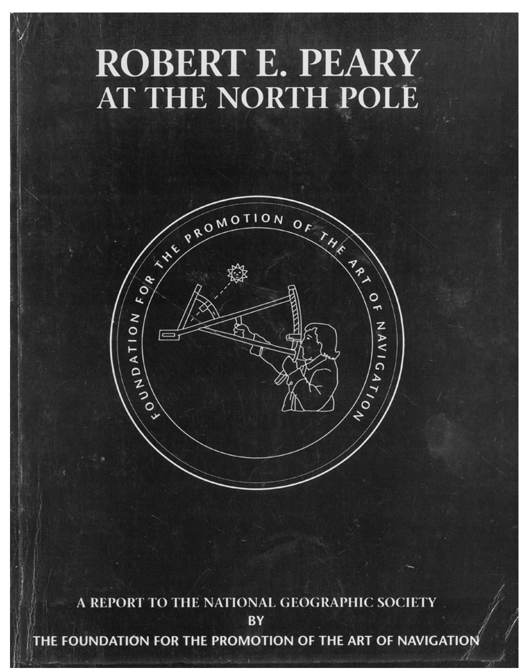


The original book was sold out long ago and has remained out of print until now. This ebook version can be fully searched and you can add to it your own comments, book marks, and highlights. It is available as a computer file download from elibrabooks.com. It can be purchased directly from the Navigation Foundation (director@navigationfoundation.org or 301-622-6448) by check or money order, or it can be purchased online with a credit card at elibrabooks.com. The free elibra reader ver 2 can be downloaded from the same site. When you purchase the Peary Report ebook, you receive a serial number that is needed to download and register the ebook on your computer. Member's price is $19.95; non-members is $29.95.

There is much discussion of the Peary Report and polar navigation in general in the past issues of Navigator's Newsletter, any of which can be accessed from the Electronic Archive of past issues, also for sale from the Foundation. In Issue 32 (summer, 1991), for example, there is a summary of the seminar at the U.S. Naval Institute entitled "All Angles: Peary and the North Pole" held on April 19, 1991 in Annapolis, MD. Douglas Davies, now President of the Foundation, who was the technical consultant on the Report, was joined on the panel by polar navigation expert Lt. Col. William Molett, USAF and Peary critics Dennis Rawlins, Wally Herbert, and Ralph Plaisted. The Newsletter article outlines the discussion of the seminar and shows they did an excellent job of defending the conclusions of the Report from the leading critics of the Peary accomplishment.

ONLINE RESOURCES

Those interested in aircraft navigation will be especially pleased to see the extensive resources at **williams.best.vwh.net**. Among interesting data are a set of equations for many navigation problems. If you have spherical trig problems to solve or drawings to make, there is a wonderful resource called Spherical Easel at **merganser.math.gvsu.edu/easel**. It will solve any triangle you can draw and represent it in proper perspective to boot. It is effectively a super-convenient electronic armillary sphere. See page 8.



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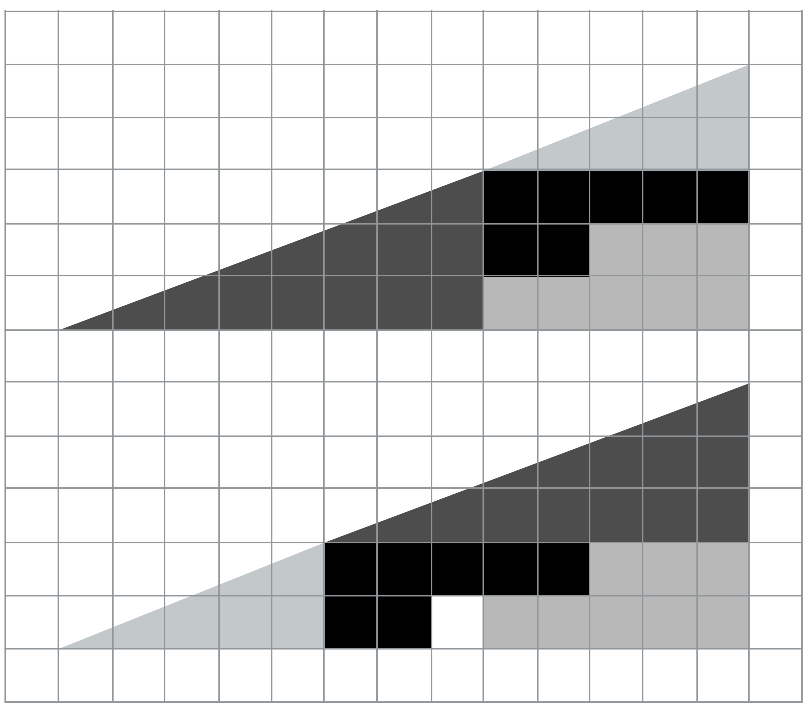
The Navigator as Mathematician... or Magician?

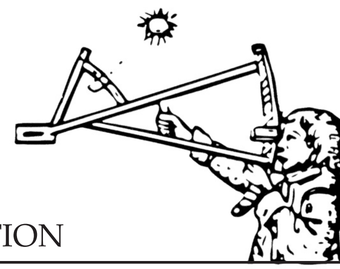


In issue 92 we used geometric similarity for an elegant proof of the Pythagorean Theorem. But what about this drawing? Is this a geometry problem or just smoke and mirrors?

We will give our answer in the next issue.

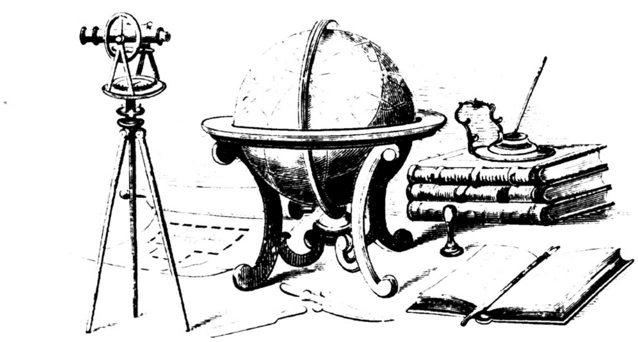
ISSUE 96, Summer 2007

THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a reader forum for the expression of our members opinions and their questions.



ACTIVITIES

By Terry Carraway

Over many years The Foundation has ask its members to remember to order their nautical charts from us. The reason was not only for the benefit of The Foundation but to the benefit of members. We have many members who's only access to current charts is The Foundation. They are government employees stationed in foreign countries and members who are sailing to foreign countries and find they cannot get the charts they need in these countries. We get orders from such members at times.

The reason we are again bringing up the nautical chart issue is because of a letter we received for the FAA (who now handles nautical charts) informing us that we had only sold $484.26 worth of charts. We are required to sell at least $500.00 of charts each year between June 1 and May 31 of the following year. If we do not meet this sales figure we will be canceled as a chart dealer and unable to supply nautical charts to our members at a discount, nor will we get the same service as we do as a dealer.

To increase our sales volume order a chart or two for your friends. You, as a member, are allowed to do so as we are listed as a chart dealer in FAA/NOAA publications. We either meet the minimum sales required or lose our dealership.

We have written a letter to the FAA requesting that we be allowed to continue chart sales for another year hoping to continue to have over $500 in sales per year as we have in the past.

PLEASE HELP.

EDITOR'S NOTES

By David Burch

We are behind our self-imposed schedule once again, but it is not the fault of our excellent membership who have sent in many articles. Thanks very much for that. If you do not have an article to contribute, then please tell us about the latest book you have read related to navigation... or one you read years ago that you want members to know about. Book reviews or reports have been a stimulating source of discussion in past issues.

As you know the production of the Newsletter is all volunteer work, and we have been quite busy here in recent months. If there is any member who would like to help with the production and layout of the Newsletter your help would be very much appreciated. Please send a note to editor@navigationfoundation.org.

As for the puzzle on the cover of Issue 95, it is in fact just smoke and mirrors—more a deception than an honest issue of geometry. It could have been even worse if we had drawn the lines with thicker pen width. As it is, with the pictures drawn rigorously to scale as printed, if you hold up the paper and look carefully at the edge, you will see that the triangles are not symmetric. There will be a slight concave kink where the top two triangles meet and a slight convex kink where the bottom two meet—if you want to make this even more deceptive, draw the lines just thick enough to mask these kinks in the hypotenuses.

There are three triangles involved with ratios of sides equal: 5/13, 3/8, and 2/5. At first glance these appear to be *similar triangles*, meaning the angles within them are the same. This is not the case. The smallest angles in the three are 21.04°, 20.56°, and 21.80° respectively, and it is, further, a malicious choice of angles designed to yield an area difference in the two drawings of exactly 1 unit. The area of the large triangle (5/13) is 32.5 units. The sum of the parts is 32.0 units. The bottom arrangement has an excess above the hypotenuse of 0.5 units and the top drawing has a deficit below the hypotenuse of 0.5 units, and hence the deception.

To relate this to navigation is not so hard. There is a well tested rule in navigation that we should try to avoid relying on just one source of information. Things may not be as they appear to be. A GPS position plus a range and bearing is better then either fix alone—you might just learn, for example, that your GPS datum does not match your chart datum, which later could be crucial to anchoring in the fog or at night in tight quarters. And a pressure drop along with a backing of the wind, is far better than either sign alone that a Low pressure system may be approaching, and so on.

But I cannot help but think in this regard of the role of local knowledge—touted so often as key to good navigation, the trick play that gives us the edge over conventional knowledge. It is easy to eagerly accept information from local mariners who have plied waters for many years that are new to us. But things may not be as they appear to be.

I know of enough actual significant cases to warrant a caution about this. I do not want to seem ungrateful to those who want to help and there may indeed be extremely valuable information to be had from "local knowledge," but it is not guaranteed. The key issue is to compare what you learn with your own basic knowledge. What you know from Pilots, charts, Light Lists, and Sailing Directions, along with your own basic knowledge of how things work. If the advice you get is contrary to any of that, it should be compiled with caution. Not ignored or forgotten of course, that would be negligent, but filed with the understanding that it is either unique or wrong.

Many mariners, even very experienced mariners, do not realize how much you can learn about navigation by study. They do not know the resources that have been available for many years, and with the Internet this situation is improving dramatically each day. It would be a rare passage these days that you could not study and know very well from home before departure.

As mentioned, there are numerous examples. Here is one. There is a vocal school of "local knowledge" that says the best way to traverse the US West Coast, WA to CA or vice versa, is to head off shore some 100 miles and make the run out there. This advice has even found its way into some popular cruising guides by respected authors. But this is simply wrong. Heading off shore like that is just adding two days to the trip (one to get out and one to get back) in order to almost certainly guarantee worst conditions, maybe even very severe conditions. In the past we had to argue the various reasons for this in the classroom, but now we do not. All the mariner has to do is monitor the buoy reports on the Internet along the route for some period of time (day *and* night) to see how the conditions vary as you head off shore.

To make use of our new online supplement section, I will add a few more examples of local knowledge gone wrong to the Foundation website. Two involve faulty water depth advice, one involves some one with great experience not appreciating that there can indeed be a unique weather system coming by.

* * *

In this issue we are pleased to have leaders of the nation's oldest navigation supply stores give us a brief overview of their companies. We call the section "Steeped in the Traditions of Navigation"—a phrase used by one of them rightfully so to describe themselves and similar companies. These are the stores and people mariners from around the world have relied upon for many decades to provide up-to-date charts and publications, new instruments and old, and repairs for both, as well as providing a wealth of information and advice on the resources available to navigators. Thank you all for taking the time to send us these notes.

We also have follow up articles from Bruce Stark on Lewis and Clark navigation and from Paul Janiczek with more notes on the NAO Sight Reduction Tables and a note from Byron Franklin on analyzing sextant sights. We also have Bill Cook's article on sextant mirrors that we have had on file for a couple issues.

* * *

We hope to have the next issue out by the end of October and it will include several fine articles we have had on file for some time now. These include an in-depth article by member Jan Kalivoda in Czech Republic on the navigation of David Thomson and another is from member George Bennett in Australia on the Lunar Altitude method—a reminder and example of work he recently published elsewhere. Thanks to Jan and George for sending those.

We will also include a thought-provoking note from member Captain Warren G. Leback on a unique situation for crossing the dateline and equator simultaneously at 2400, December 30 on the last year of each century. And then we will have to address the issue of how do we resolve such paradoxes in the light of our classroom teaching that affirms there are no mysteries of time keeping in celestial navigation, no tricks, no special procedures required, no matter where you are and no matter when you are there!

* * *

READER'S FORUM

I've been looking forward to Bruce Stark's series on Lewis and Clark, and am delighted to find that he has researched their story, and presented it, in such detail. Here we are at Part 3, and Lewis is still acquiring information, and hasn't yet even picked up his vessels, or his crew, or his partner Clark. There's obviously much more in store, and my only problem is that three months is far too long to wait, between such treats.

I have a few comments, relating to part 3 in particular.

The reference to talc, used for the transparent roof of the artificial horizon, as "isinglass", is somewhat puzzling. I have understood the word talc, in that context, to refer to thin sheets of high-quality mica, which were prized for their optical qualities, in the days when uniform glass plates were so hard to find.

The Navigator's Newsletter
Published by
The Foundation for the
Promotion of the Art of Navigation
www.navigationfoundation.org
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The Navigator's Newsletter is published four times annually, with our strived-for publication dates of approximately the solstices and equinoxes.
Newsletter production and other Foundation activities are provided by volunteers. Please bear with us if we slip on the dates occasionally.

It would be good to see some references, where Bruce quotes original sources (such as Ellicott's interesting account of voyages in his survey vessel), to help the reader to discover more.

Bruce explains well Ellicott's system of 6 timed sextant observations of the reflected Sun, to give a precise value for the difference of the clock from local (apparent) time, and truly says "...in the six-number pattern any bad number tends to stand out."

I have analysed the Lewis and Clark observations made during their initial learning process, as they travelled up the Mississippi toward their wintering point near its junction with the Missouri, in the season before their official expedition started. The data were taken from Gary Moulton's "Journals of the Lewis and Clark Expedition", vol.2. There are indeed many such six-observation sequences, and some show great precision in the observations. Others, however, show serious mistakes, and just as Bruce has said, these stick out like a sore thumb. There are many occasions when the timings are obviously wrong; often, it appears that one or more of the times has been misread from the watch by a whole minute. Presumably, those times were taken by one of the men, at the moment when the observer, Lewis or Clark, called "now". There's no reason to expect the soldiery in 1803 to be familiar with the exercise of reading a watch-dial to the nearest second; something that we take for granted today. Anyway, many such "obvious" errors were allowed to pass undetected into the expedition's journal, sore thumb or not.

That analysis is available, in somewhat preliminary form, at -

http://www.huxtable.u-net.com/lewis02.htm

In addition, there's a transcription of the Astronomical Notebook, written by the astronomer Robert Patterson, which was carried by Lewis throughout the journey. That can be found on Hans Heynau's valuable website-

http://www.lewisandclarknavigation.org/

where you then have to click on Astronomical Notebook. Lots of explanatory comments have been added to help a modern reader to understand what was going on.

George Huxtable

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To the Editor:

I'm pleased that George has joined the Lewis and Clark discussion. He's one of the best informed people alive on navigation history and methods. He, and Bob Bergantino, have worked through some of the most puzzling sets of observations the captains made. When the series finally looks at observations found in the Journals, I hope to get permission to point to the web sites where their work can be found. Those sites, together with a few things the Newsletter has published in the past, should be all that's needed in showing how Lewis and Clark's observations can be analyzed and worked.

The purpose of my series is to provide background, so it will be easier to interpret the observations, and to understand why things were as they were. Also, I'll do my best to explain the nautical astronomy of that day.

George was puzzled by the talc-isinglass connection. In a roundabout way, my unabridged dictionary links talc to mica to isinglass. In a letter to Jefferson, Ellicott writes of the "talk, or isinglass" roof of his artificial horizon. He used the point of a sharp knife to carefully split thin sheets from a block of talc the Philosophical Society had provided Lewis.

As for references, the main ones I use are Moulton's The Journals of the Lewis & Clark Expedition, Jackson's Letters of the Lewis & Clark Expedition, Ellicott's Journal of Andrew Ellicott, and Kraus' The United States to 1865. George is right: Ellicott's Journal is loaded with history, intrigue, and hair-raising adventure " all laid out in the most un-dramatic way.

Bruce

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SPECIAL FEATURE

STEEPED IN THE TRADITIONS OF NAVIGATION

Captain's Nautical Supply, Seattle, WA

Emery Shrock

The year was 1897. Gold had been discovered in the Klondike. Seattle, the nearest major, deep water, rail head sea port in the continental United States, had become a boom-town city as the "jumping-off" point for the Alaska Gold Rush. Washington had been admitted as a State of the Union only eight years earlier. The son of a German immigrant, Max Kuner was drawn to Seattle as an ideal place to establish a business catering to the navigation needs of ships calling on the port. His "Max Kuner Company" opened in 1897 a few doors down the hall from the U.S. Customs Office then at Third Ave. and Spring Street, where, in those days the ship's master had to personally clear the vessel through customs. A few years later the business moved to a larger location at 94 Columbia Street where the banner sign proclaimed "Kuner, Nautical Optician". Additional lettering in the windows announced: "Nautical Instruments, compasses adjusted, chronometer and watch maker" The business also specialized in nautical charts and publications. Today, over a hundred years later, that still describes the core of the business.

The twentieth century passed across the stage of history: Two world wars. A Great Depression. The Max Kuner Company moved to different locations in Downtown Seattle, always not far from the waterfront: The foot of Marion Street opposite the Coleman Dock Ferry Terminal, 1324 Second Avenue, and later, 1914 Fourth Avenue. Max Kuner died June 13, 1939. His widow, Anna C. Kuner carried on the business until her death June 17, 1943. Tom Williamson, a watchmaker who had been employed by Kuner bought the business and continued until his death in 1949.

During this same time period, Seattle native Leonard Shrock had gone to sea on American President Lines ships to the Orient and Hawaii, had graduated from the University of Washington, and been employed by the Navy as a ships' compass adjustor, and as a trainer of compass adjustors in New York Harbor during World Ward II. Prior to the War Leonard had worked as a compass adjustor for the Kuner Company. After the War he became self-employed in Seattle as a compass adjustor. In May, 1948

Leonard opened his own small nautical instrument shop in a little frame building on Dock Four at the Port of Seattle's Fishermen's Terminal, and hired his first employee.

In October, 1949, a small article in the Seattle Times with Leonard's photo announced that he had purchased the Max Kuner Company from the Williamson family following the death of Tom Williamson. At that time the store was located off the pedestrian viaduct, opposite the Ferry Terminal at Marion Street and Alaskan Way. From that time for nearly five decades the company had a store in Downtown Seattle and one at Fisherman's Terminal.

In 1979 the name was changed from Max Kuner Company to Captain's Nautical Supplies to better reflect what we do, and the business, after 82 years as a proprietorship or a partnership, was incorporated. In 1996 the two Seattle locations were consolidated into the present location with sales floors on two levels a mile south of Fishermen's Terminal and the Ballard Bridge. Leonard Shrock continued working in the store, and adjusting compasses past his ninetieth birthday, but died in May, 2004.

Today, Captain's, with a footprint in the nineteenth, twentieth, and twenty-first centuries, is likely the oldest business of its type in America. Modern technology now blends with ancient maritime tradition, and old fashioned, hands-on service. Real people still answer the phone. No, we don't do it "24/7". But if you call during our hours of 8AM to 5:30PM weekdays, 9AM to 5PM Saturdays, Pacific Time, you will not be greeted with an automated attendant. A staff of twelve, many with Captains for ten to thirty years, answers your questions and fills your orders. We think Leonard Shrock and Max Kuner would be pleased. Visitors to our stores are often amazed at the depth of stock in our specialties. Captain's is not a general chandlery with rope, paint, and bilge pumps. Our business includes: World-wide coverage in Nautical Charts, both traditional paper and electronic, Plotting Tools, Sextants, Magnetic Compasses, Clocks, Barometers, & Weather Instruments. Nautical Books & Publications, U. S. and Foreign Flags, Brass Bells, Oil Lamps, REPAIRS of Binoculars, Clocks, Chronometers, Barometers, Compasses, and Sextants.

Captain's is an authorized agent for the British Admiralty, NOAA, NGA, Canadian Hydrographic, and the hydrographic agencies of France, Fiji, New Zealand, and Australia.

See www.captainsnautical.com

* * *

New York Nautical, New York City, NY

Ken Maisler

New York Nautical Instrument & Service Corp. has been serving the maritime community in the port of New York, since the early part of the 1900's. It was originally opened as the N.Y. branch of Kelvin & Wilfred O.White Co., located at 38 Water St. At that time there were also branches in Boston at 112 State St. and in Montreal at 111 Commissioners St. The company was also the American agent for Kelvin Bottomley & Baird (Glasgow), manufacturers of the finest navigational instruments of the time. They also had their own factory in Boston, manufacturing liquid compasses, binnacles, peloruses and sounding machines. It's interesting to note the connection to the present day Kelvin Hughes Co. and Robert White Instruments in Boston. In fact the original president of the company was Wilfred O.White, patriarch of the esteemed White "navigation" family.

The N.Y. branch was officially renamed N.Y. Nautical Instrument & Service Corp. in 1960, when it was purchased by Herbert Maisler, then general Mgr. and Arthur Spina, both long-time, dedicated, & experienced employees of the company.

Despite the advent of all the electronic forms of navigation, N.Y. Nautical has maintained a worldwide stock of paper charts, produced by both the U.S. and British Admiralty hydrographic Depts. Solas regulations promulgated by the IMO (Int'l Maritime Organization, London), still requires the larger commercial vessels to hold onboard paper charts and publications for their intended voyages, regardless of any integrated electronic systems onboard. With their state of the art computer and software system, NYN monitors and maintains the onboard chart inventories for some of the largest commercial shipping fleets worldwide. Any new editions of charts and publications required onboard for each individual vessel is automatically supplied at the designated port of call. (No small task!)

Along with supplying the newer electronic charts and instruments, N.Y. Nautical has managed to maintain an "old world" charm. There is a comprehensive inventory of maritime books and shipping regulations kept on hand, along with traditional Ships bell clocks, beautiful brass barometers, sextants, chronometers, and plotting tools. One can still make arrangements to have a professional compass adjuster come aboard to "swing" their compass! So from the professional navigator, to the armchair sailor, N.Y. Nautical located at 158 Duane St, in historic lower Manhattan, remains quite a vital part of the Maritime community.

See www.newyorknautical.com.

* * *

Baker Lyman and Co, New Orleans, LA

Corinne Titus

In 1920, a small compass business opened at 308 Magazine Street. It was in an area of New Orleans where most of the ship chandlers maintained their businesses and was considered to be the center location for serving the steamship business. This company was called John E. Hand. In 1932 two gentlemen met in one of New Orleans regular meeting places, the corner bar. Captain Lyman and Mr. Robert Baker joined together and bought the small compass business. Capt. Lyman had many years at sea and Mr. Baker's background was accounting. This time frame was basically the end or middle of the great depression. My father, Lloyd J. Titus was fortunate to find a job with the two gentlemen and went to work as a runner.

The sea called Capt. Lyman and he sold his portion to Mr. Baker. The young Titus developed through the ranks of the business and became a Compass Adjuster. The business prospered through World War II and also the Korean War. In 1952, Mr. Baker offered Mr. Titus the business. He basically had the weekend to make a decision. So, Monday morning Mr. Titus became the new owner of Baker, Lyman & Co.

Baker, Lyman did very well over the next three decades. Mr. Titus designed three binnacles and these were manufactured successfully—The Skipper shelf compass, The American Reflector Binnacle, and the American Mate Binnacle. All of which are still in production today. The company also expanded its navigational charts and publications to include British and Canadian items. Baker, Lyman carried a world wide selection of charts and publications to service the shipping industry.

In 1969 the company opened a branch store in Houston, Texas. This store was set up to take advantage of the growth in the Texas port regions. Mr. Titus sent his only son, Robert Titus to Houston to run the business. Unfortunately Robert could not handle the pressures of running the branch and his job was terminated. The business did survive and is still and active and viable part of Baker, Lyman and Company. It is currently being managed by Capt. Fred Chaney. Capt. Chaney came to us from Mobil/Philips with expertise in shipping and operations.

The next boon to the business was the oil boon of the late 1970's and early 80's. It was during this time, that I (the youngest daughter of Mr. Titus) came to work in the business. What a grand time to be in business in New Orleans! Unfortunately, good things come to the end. The phrases in the industry were "survive for 85". Baker, Lyman did survive, but lost 40% of its customer base over night to the oil bust. AND American flag vessels were disappearing from the Port of New Orleans. Times had surely changed. Gone were the prosperous shipping companies and also were gone the booming oil field. Thus began the next phase of the business.

I felt the company needed to be more diversified. The board of directors agreed this would be a good maneuver for the business. In 1986 the company was moved out of the ailing city to Metairie, LA. In the new location, the company added discounted marine supplies for yachts and small boats. This change got the business back on its feet again. Unfortunately in the middle of this move, Mr. Titus passed away. At this point, I became the head of the company and it's C.E.O. The business moved forward with out Mr. Titus and it flourished. The company could now offer not only its chart and books, but marine supplies and electronics. Baker, Lyman joined a national buying co-op which gave it a competitive edge over most local and regional businesses.

If you are familiar with the New Orleans region, you will understand the next phase of the business. With the decline of the oil business and the poor business attitude with the city and the state of Louisiana, just about all of the oil companies slowly left the area. With the lost of these higher income customers, Baker, Lyman gave up on the discount marine supply business and went back to it's roots—charts, instruments and publications.

During the 1990's Baker, Lyman went aggressively after the international market. The plan was to sell directly to the foreign ship owners, which now comprised over 95% of the port's business. By selling directly, Baker, Lyman began to not only stabilize but increase its distribution of its products. In 2001 Michael Serafin Jr. joined the company. Michael was a graduate of the U.S. Naval Academy and had an extensive background in the marine business and the oil field. Mr. Serafin helped us to develop an design software that would meet international standards for monitoring a vessel's chart folio and monitor the vessels compass or binnacles. This software program is called VMS or Vessel Management System. In the first year of its development, business increased 25%. Over the next two years the company experienced increased business and diversities as a result.

In 2005, Baker, Lyman prints in house over $200,000 of nautical charts; we also print our own nautical log books. Baker, Lyman manufactures their own binnacles, compass spiders and more. In addition, the company assembles computer systems for ships, tug, crew, and supply boats. As a result of VMS, the business monitors over 800 vessels world wide.

We believe we have the potential to double our business over the next two to three years. Our printing and publishing is growing annually and the electronic portion is growing monthly. Baker, Lyman will need to add employees with technical expertise with in the next 8 to 24 months.

Baker, Lyman is excited about adding new employees, but has truly proven to be a stable working environment. I have been with the company for 27 years, but Mr. Fred Thibeaud, our machine shop foreman, has been with the company for 67 years! Mr. Jerry Gauthier, our head compass adjustor, 37 years. Kerry Sweeney, who works in the machine shop and the chart room, has 30 years with us. Natalie Camble, our billing clerk, 18 years. As a family business, small business and woman-owned business; we value our current employees, but look forward to increasing our staff with new blood. Baker, Lyman plans to be around for the next generation!

See www.bakerlyman.com.

* * *

Weems and Plath, Annapolis, MD

Cathie Trogdon

Carl Plath started as a small navigation instrument store in Hamburg, Germany in 1837. C. Plath checked and certified sextants, barometers and compasses aboard ships in North Germany and also hand-built these instruments one by one. As the industrial age advanced, Plath began manufacturing a broad line of nautical instruments, including a line of compasses, compass cards, patent logs, sextants and octants. In 1899, Carl Plath's son, Theodor, taking advantage of advancements in precision machinery and electricity, developed a machine which saved hours of manual labor and improved the accuracy of the sextants they produced. The world renowned C. Plath sextants were manufactured on this machine until World War II. C. Plath won awards at international exhibitions including Hamburg, 1889 and Paris in 1900, achievements that cemented the exceptional reputation of C. Plath products throughout the world.

Meanwhile, in America, Philip Van Horn Weems, a Naval Academy graduate, was promoted to Lt. Commander and assigned to the destroyer USS O'Brien for an historic tour of duty for air navigation. Serving as Executive Officer and Navigator, Weems was responsible for the precise location of one of the picket ships for the first Atlantic crossing by a US Navy aircraft—the NC-4.

In May of 1919, the USS O'Brien, just off the Azores, was one of over 20 ships strung out at fifty mile intervals from Newfoundland to Portugal to stake out a path for the three Navy seaplanes attempting to cross. "Suddenly the plane came up over us," Weems said, "It was a great thrill." From that moment Weems caught the vision that would change his career and the world of navigation forever.

While World War II saw Weems recalled to service, C-Plath, the company that miraculously survived World War I, the World Economic Crisis (the Great Depression in the USA), and even WWII was dismantled by Allied Forces due to the prohibition on shipbuilding in Germany after the war. Johannes Boysen, the company president, was required to serve a two year prison sentence because he provided equipment to the German military during the war. At this time, the factory was relegated to manufacturing typewriters, spray guns and the works for station clocks of the Hamburg rapid transit system. But with the relaxing of the shipbuilding prohibition in 1949, C-Plath gradually returned to its roots and began manufacturing marine instruments again. By 1953, Boysen had worked out a relationship with Captain Weems to sell C-Plath sextants and compasses in the USA; hence, the trademark name, Weems & Plath, Inc., manufacturer of fine nautical instruments.

While C-Plath was operated as a family business for three generations, in 1961, the 100 year reign of a German family-owned business ended when Johannes Boysen sold the business to Litton Industries in California. The constant financial need for technological advances in the ever developing marine industry was too much of a strain on the family-owned operation. C-Plath continued to design and improve navigation instruments for commercial use.

In 1972, the company began to standardize module sizes and developed the new spherical Merkur and Venus compasses that Weems & Plath still distributes today. They also developed a more up-to-date sextant, the Navistar Professional, which had fewer than half of the 150 parts of the Classic sextant model. Weems & Plath continued to distribute C-Plath sextants until the year 2000 when the market for sextants had diminished so much that the company decided to stop production of these world-renowned instruments. Still today, after more than 165 years in business, C-Plath is in Hamburg manufacturing the world's finest magnetic compasses and other marine electronic navigation instruments.

The Weems School of Navigation was sold in 1964 and Weems and Plath, Inc. was part of the package. Through various acquisitions, including Times Mirror, Jeppeson, and C-Plath North American Division of Litton Industries, the Weems and Plath name lived on.

Purchased in 1997 by Peter and Cathie Trogdon, who bought it from Litton Industries, that owned C. Plath in Germany, Weems and Plath is, once again a family-owned company. Weems and Plath is still located in the Chesapeake Bay city of Annapolis, where it began nearly a century ago. As a family-owned business, even today, Weems and Plath stakes its reputation on relentless quality improvement, superior product service and customer satisfaction.

Weems' vision of 80 years ago to develop new and innovative products that provide long-lasting service and pleasure to their owners continues today. In fact, several tools developed by Weems more than half a century ago have seen little modification, yet remain best sellers for Weems & Plath today. The Weems Plotter continues to be the #1 selling product after 50 years. The company stands committed to supplying the world with the finest quality products for the wheelhouse, cockpit, home and office and to maintaining the high standards of service that have distinguished Weems and Plath from its inception.

The company founded in 1928, lives on today—nearly 80 years later—as Weems and Plath, Inc., Manufacturer of Fine Nautical Instruments. Weems' vision of three quarters of a century ago to develop new and innovative products that provide long-lasting service and pleasure to their owners continues today. The company stands committed to supplying the world with the finest quality products for the wheelhouse, cockpit, home and office, and to maintaining the high standards of service that has distinguished Weems and Plath from its inception.

See www.weems-plath.com.

* * *

Robert White and Sons, Boston, MA

Robert (Ridge) Eldridge White, Jr.

In 1875 George W. Eldridge published the first Eldridge Tide and Pilot book. "The Tide Book" has been published annually by the same family for over 130 years (see History of The Eldridge Tide and Pilot Book for more). Captain Eldridge's eldest Daughter Ruth married Wilfrid O. White of Williamstown Australia. Wilfrid came from a family of shipbuilders and he was fascinated with navigation. He took an opportunity to study with Lord Kelvin in the UK and when he returned to Boston in 1918 he opened up a small nautical instrument dealership. Kelvin and Wilfrid O. White Co., was located on historic State Street in Boston, a couple of blocks from the busy waterfront. He offered sextants, compasses in large binnacles, chronometers, binoculars, taffrail logs, barometers, and charts for all oceans. For two generations the company manufactured the highest quality navigation instruments.

A display counter in the Robert White showrooms.

In 1950 the company became Wilfrid O. White and Sons, Inc. Wilfrid and his two sons, Robert and Gordon, expanded the company's production to include compasses, binnacles, auto-pilots, depth sounders, and wind and weather instruments.

In 1961 the company was sold (Eastern Company purchased the patents to the compasses and merged it with the Danforth anchor division). Gordon worked for Danforth for a little while but then he left to develop a line of weather indicators that he called "Maximum" because of the clever patented maximum gust register in the anemometers. Maximum Inc. is still making Gordon's instruments along with many newer designs. Although the Maximum company is no longer in the family, we have maintained a very close relationship and are one of their biggest dealers. All Maximum instruments are sold at a year-round discount.

While Gordon was developing Maximum, his brother Robert Eldridge White established Robert E. White Instruments, Inc., a distributor and dealer of premium quality navigation and weather instruments. Included in his offerings were his brother's Maximum instruments and his father's (now Danforth's) compasses. Robert E. White Instruments, Inc. became the distributor of the Eldridge Tide and Pilot Book which was published by Robert and his wife Marion (Molly). Two of Robert's sons joined him and today the company is run by his eldest son Robert Eldridge White, Jr., "Ridge," and Ridge's daughter Alissa.

Today, with the fourth generation in place, Robert E. White Instruments, Inc. continues to have a reputation others would envy. We offer a tremendous array of high quality marine and weather instruments supported by an exceptionally knowledgeable staff.

See www.robertwhite.com

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NAVIGATION NOTES

ANALYZING SEXTANT SIGHTS

By Byron Franklin QMCM (SS) ret

The article in the issue 94 (Analyzing Sextant Sights) reminded me of the few times that I used SCAR gear on the SSBN Abraham Lincoln and a bubble sextant on a Liberty Hull. The SCAR Gear is an artificial horizon in the periscope, much like the bubble sextant. In rough seas (with both types of instruments) the observed body moves violently across the cross hairs, making the observation open to large random errors. The suggested practice is to use an average of many shots of each body to get one acceptable observation for each body or star. After some unacceptable use of the gear, I decided to try another approach to find the best raw shot from a large number of an individual shots.

To find the best shot among the many you need a reliable reference to judge the ever-changing time and elevation of each shot. You must reduce work of each sight to a simple, but easy way of elimination (random) and many shots to one best shot.

I concluded that a better solution to the average would be to plot the individual shots on graph paper with a time line (at the bottom) and a slope that a body is traveling upon. This slope would be a systematic reliable reference line for each shot judgment.

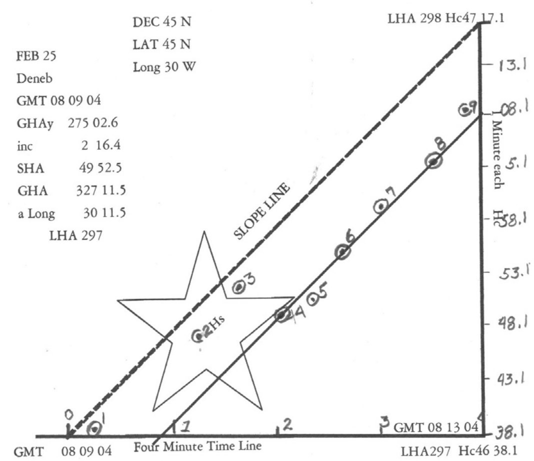
The time of the first shot would be the start of a 4 minuet time line and also time to compute Local Hour Angle LHA for table entree for tabular altitude (tab Hc) of the body.

The far base of the horizontal time line of four minutes, would start with the LHA and end with LHA1+1, four minutes of time to arc, [equals one degree] or LHA297 and LHA298.

At right angle to the time line would be the raw Hc tab. out of the tables, the bottom is LHA297's Hc 46 38.1, the right angle at the top would be 298's Hc 47 17.1. This slope (the "star track") would be drawn from the left beginning of the time line (LHA297 Hc tab. to the top LHA298 Hc tab four minutes later. See graph.

Once the graph is completed and each raw shot Hs is plotted in terms of time and Hs height, the Hc slope can be moved parallel to itself among the plotted Hs's on the time line for best agreement. Each Hs shots should be easy to identify as systematic or random. A selection of one time and Hs shot can then be completed to height observed and to line of position for the fix. (If your Hs don't match the Hc on the vertical, add or subtract an amount to fit, move the slope to select you best shot, than use the original Hs.

The slope could be corrected for speed and direction during the four minutes traveled. In order to accommodate other star's slopes, any time and Hs could be used to finish the sight and fix.



To my knowledge no one except myself has ever use this technique. Perhaps the membership can add to this basic for the betterment of navigation.

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Editor's note: Thank you for bringing this important detail to light. We agree completely with the method and, though not known so well world wide, we have in fact taught this method at Starpath since the late 70's. We call it the "Fit-slope Method" and we will put a copy of a short write-up with an example online.

In passing your comment about not known so well raises a question in my understanding of the Pub 214 data. It was my understanding, though I cannot trace this to a specific reference at the moment, that the reason they provided the slope of Hc (dH/dt) in those tables was for this very application. But maybe that is not the case. Can anyone in the membership shed any light on that?

* * *

Another Question... *while bringing up questions to the membership, does anyone know why the Arc to Time table in the* Nautical Almanac *includes values of arc above 180°? In other words, what would be a specific application of that table in that region these days or in days past.*

* * *

NAVIGATION NOTES

SEXTANT MIRRORS

by Bill Cook

Even though hand-held GPS units have dealt all but the deathblow to the everyday use of sextants, there are still those who realize that any serious mariner should know about as many of the methods and equipment used in navigation as possible—including those that need not rely on satellites or electrons rushing through wires produced by the lowest bidder. Paramount among these instruments is the marine sextant.

To many, the sextant is a very special tool and embodies all that it means to be a navigator. For some, this is so much so that they spend a great deal of time babying their instrument and seeing to it that it is in tip-top shape all the time. As often as not, this sextant husbandry causes more problems than it solves, as soft metal parts become worn through inordinate tweakery.

As a sextant repair and restoration technician, I am frequently asked about ways for mariners to recoat their own sextant mirrors should they fail during extended voyages or lengthy stays abroad.

The first question one might ask is why would anyone want to make their own sextant mirror in the first place; that's what stores are for, right?

From an optician's point of view, one would hope yachtsmen would check the condition of their sextant mirrors before putting out to sea and would have an extra set wrapped neatly and cushioned safely in the case. With a good set of mirrors installed I could see a young boater growing old and selling his or her boat before ever needing to replace the first set!

But what of the person who has only one set and whose instrument takes a spill onto the deck, smashing one or both mirrors? I suppose that could happen. However, in the hundreds of sextants I have repaired, I have only seen one mirror that needed to be replaced due to an impact.

Now, with the logic and history out of the way, we'll get down to brass tacks.

First, with all of today's technology at our disposal, why would anyone even want to recoat or replace their own sextant mirrors? Availability for starters. A good many of the sextants in use today have been out of production for decades and original equipment has become very hard to impossible find. Even C. Plath, the grandfather of the most prized instruments, stopped sextant production years ago.

Also, boaters no longer have the option to turn to any number of local outlets for replacements. In years past, virtually all large American seaports had at least one instrument maker and merchants had adequate inventories of spare parts and craftsmen on hand to make most of those parts—including mirrors—should it become necessary.

As technology advanced, sextant use diminished and as the cost of keeping those craftsmen on the payroll became prohibitive, so too did the merchant's desire to cater to the sextant market.

Yes, there are coating houses in just about every state. However, for these firms, who are used to taking orders for coating jobs of 100 or 20,000 pieces, gigging up to produced an odd-sized sextant mirror a few times a year, has became less than lucrative. Today, many companies wouldn't even consider a one-off project.

The solutions:

1) Contact the seasoned companies to find out if they have the exact part you need. These companies would include Captain's Nautical Supplies in Seattle, (206) 283-7242; Baker Marine in San Diego, (619) 222-8096; Texas Nautical Instrument Repair in Houston, (713) 529-3551; and New York Nautical, (212) 962-4522. Undoubtedly, there are others. However, the only other source I have used was Maryland Precision Instruments, in Baltimore. However, with the passing of longtime owner, and friend to the maritime community, Frank Janicek, the store ceased operation.

2) Try to purchase new mirrors that are large enough to be altered to the size and shape you need. A good source for these would be any of the companies mentioned above or Celestaire in Wichita, (316) 686-9785. Celestaire's mirrors will be from the Astra IIIb and the horizon and index mirrors will cost $70 and $80, respectively. Unfortunately, they only come installed in their housings. Removal, however, is no chore at all.

Once in hand, you can cut them to size with a tile or lapidary saw. Keep in mind that this could be an expensive failed experiment.

3) A better option—and the one I would certainly take, even though I have cut a lot of glass with a lapidary saw—would be to go to a local ophthalmic lens shop and have them create a plastic template the size and shape of the mirror you need. They will then place the template on the side of a diamond edging machine and within a few seconds of whirring and spraying, you will have a mirror cut to size, smoothly edged and ready to install. Note: Ask for your template and keep it in your sextant case.

4) The next option would be to cut a piece of glass from an already silvered or aluminized mirror designed for other purposes. The fastest way to obtain such a mirror would be to head to the local hobby and craft store where you will have a great selection of inexpensive mirrors to choose from. These mirrors may be a bit too thin—most sextant mirrors are 3 to 4.5 millimeters in thickness. In that case, the mirror could be backed by a piece of metal, plastic or glass of the appropriate thickness.

By now, some of you probably think I'm an optical hack eager to cause you to damage your sextant. Relax. The mirrors we are speaking of need not be precision optics. Remember, you are just trying to cover an emergency. In addition, this mirror has no focal length and is not an image-forming element. Its sole purpose is to transfer a line of sight.

Some purists might want to know about what type of "wavefront" errors could be expected from such a piece of glass. Well, don't worry about it! Eighty years ago, when some glass was full of strains, striations and even a tiny bubble now and then, glass quality could have been a concern. Today, it is a non-issue and wavefront errors that must always concern the optical engineer is of little consequence to the practical sailor.

"So," you say, "it looks like I really could use a mirror made from an old bathroom mirror of a medicine chest." In theory, yes. However, remember these mirrors are usually ¼-inch thick and would not fit the frame. In addition, some bathroom-type mirror coaters remove old coatings by buffing, not chemically. If the mirror has ever been stripped and coated, it may be unsuitable for use in a sextant.

"Well, that takes us back to the start. We're cruising the world and I don't recall a lot of 'hobby shops' in Mananara." True. But they do have thrift stores, and thrift stores will always have used purses and make-up kits that not only contain small mirrors but mirrors of a suitable thickness, as well.

5) Now, we get to the I-want-to-do-it-myself part.

For years, people who have sent their mirrors in to be "silvered" have had them "aluminized" instead. Imperceptible to the consumer, aluminization has been the preferred method of adding reflectivity to glass surfaces in consumer optics for decades. Why? While silver is more reflective than aluminum, it is more expensive and more finicky to work with. In addition, aluminum tarnishes more slowly and, in the early stages, forms a thin transparent coating. Silver, on the other hand, begins to tarnish rapidly and it tarnishes in a dark patina, rapidly negating its reflective advantages. This, of course, was the original reason for second surface mirrors to be painted on the sides and back.

The longest part of the coating process is just getting the chemicals and instructions. While coating shops are not exactly plentiful, single sources for the chemicals—especially in less than elephantine quantities—are downright rare.

For mirror silvering chemicals and techniques, I have long turned to Peacock Laboratories in Philadelphia. The processes used in chemical silvering have now been long studied and are presented in more stable prescriptions. In the pioneering days of the amateur coating of telescope mirrors, mixing of the caustic chemicals could leave damaged clothing, body parts and, in the case of an explosion, rooms and marriages.

Obviously such phraseology will cause some to think themselves slightly less of a do-it-yourselfer than they originally thought. Still, it is worth a try, if, for no other reason than personal achievement and bragging rights.

I have made many such mirrors and, over the years, the chemical have gotten better and the techniques easier to follow. Some might assume that they could never produce professional results. This is just not true. The ability to read, be patient and have the customary number of fingers is all that is required of the worker.

The setups offer by Peacock Labs are so effective that the Optical Sciences Center of the University of Arizona—creators of the largest telescope mirrors now being made in the United States—use them in many of their testing procedures.

Chemicals and instructions are available from: Peacock Laboratories, Inc. 54th Street & Paschall Avenue. Philadelphia PA 19143. 215-729-4400.

* * *

Editor's Note: In issue 94 we had reproduced a section from an old Bowditch on how to re-silver mirrors using mercury. What we did not mention, however, is the obvious knowledge we have from modern times that Mercury is very toxic and this was not a recommended procedure. We had included it because there had been a question about this historic procedure and the preface to why it was there was omitted. We can get a kit from Peacock as Bill mentioned, which is a safer technique.

As for the Davis mirrors Bill mentions, their dimensions are: Index mirror 1.48" x 1.97" and the Horizon mirror is 1.65" wide by 1.15" tall, with 0.88" width of silver on the back side. They are both 3 mm thick (0.123"). They are sold separately, including springs, screws, and nuts for $20 per set.

Replacing Davis Plastic Sextant Mirrors

Replacing the Davis Mk 15 plastic sextant mirrors is straight forward, but patience, a comfortable chair, and a clean table top are helpful. There are small, very tight springs that hold them in place and very small inset nuts that accept the adjustment screws. One trick that helps replace the mirrors once they have been taken out is put the nuts in place and then insert the adjustment screws just enough to hold the nuts in place while you squeeze the springs over the other corners—this is the part that takes patience as they are a tight fit, which involves positioning the sextant at various angles, which in turn lets the nuts fall out, and hence the value of inserting the screws. Once the corners are in place, remove the screws) and then attach the identical springs used on the corners, after which the adjustment screws can be inserted again, and readied for use.

Once the mirrors are securely in place with all springs in their grooves and settled in, take a look to the edge of the mirror to see how much is exposed above the plastic housing on each side. There is a tendency for this not to be equal after the mirrors have been replaced. It is logical to back off the adjustment screw to balance it out, but often you back the screw completely out and the mirror remains unevenly seated in the frame. In short, it is stuck. Thus you must just manhandle it carefully down into the frame until it is even. Using two thumbs rock it gently back and forth with periodic pushes from the adjustment screw and it will settle in.

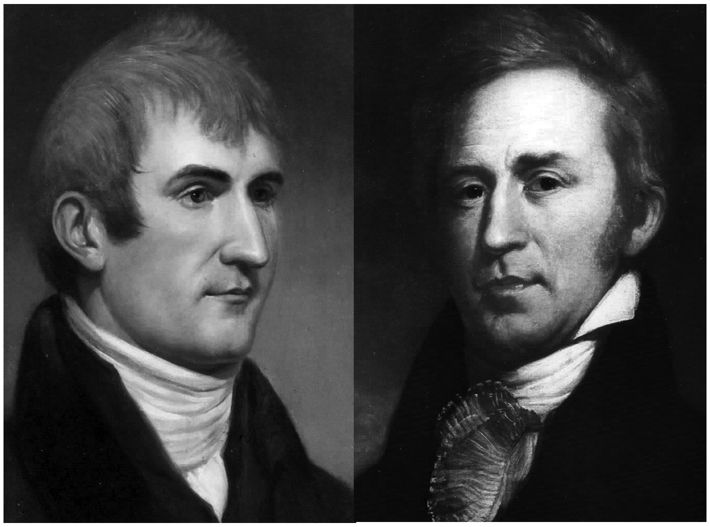
It will be a frustrating process to try to adjust the index error and side error if these mirrors are not uniformly seated in the frames. In fact on any sextant, if you notice you are having trouble adjusting out these errors, then take a look at the alignment of the edge of the mirror relative to the frame. If it is way skewed, then chances are you are better off to just stop. Forget the fine adjustment process for the moment, and just work on getting that alignment even, then start over again on the index and side errors.

* * *

NAVIGATION NOTES

LEWIS AND CLARK'S NAVIGATION, AN OVERVIEW

by Bruce Stark



Meriwether Lewis 1774 - 1809 William Clark 1770 - 1838

Part 4

Having completed two and a half weeks of instruction in the use of a sextant, artificial horizon, and timekeeper with Eilicott in Lancaster, Lewis arrived in Philadelphia. There he would complete his crash-course education: Benjamin Rush would instruct him in medicine; Benjamin Smith Barton in botany; and Caspar Wistar in both anatomy and fossils. From Robert Patterson he would get the third, and last, part of his training in practical astronomy,

President Jefferson had prepared for Lewis* arrival in Philadelphia by writing each of these men, asking them to give Lewis the advice and instruction they felt he would need. The War Department had written to Israel Whelan, purveyor of public supplies:

Sir;

You will be pleased to purchase when requested by the Bearer Captain Meriwether Lewis such articles as he may have occasion for, which he has not been able to obtain from public Stores. By order of the Secretary of War.

J. Wingate Junr. C.C.

And:

Sir,

The Treasurer of the United States has been directed to transmit to you One Thousand dollars for the purpose of purchasing such Articles as you may be requested by Capt. Meriwether Lewis. I am respectfully your Huml. Servt.

H. Dearborn

At Lewis' request, Whelan paid $250.75 for a gold chronometer, another $4.75 for its mahogany box and gimbals, and $2 to have it cleaned and adjusted. Dr. Barton then took the chronometer to Lancaster, where Eilicott regulated and rated it.

Whelan also paid $22 for a quadrant (or octant) with tangent screw for fine adjustment, and $90 for a sextant. He paid another $7 to have a microscope built and fixed to the sextant to aid in reading the vernier.

Altogether, Whelan purchase a wagon load of equipment and supplies for Lewis in Philadelphia — 2700 pounds.

The quadrant was Patterson's choice. He felt it would be more valuable to Lewis than a spare sextant, and it was much less expensive. He taught Lewis how to use its back horizon glass to get noon latitude when the angle between the sun and its reflection, as seen in an artificial horizon, was beyond the 120 degree range of a sextant.

Patterson also provided the design for a pair of artificial horizons that used leveled mirrors, instead of water or mercury, as the reflecting surface. With these, Lewis was able to measure altitudes of bodies that were too dim to be easily seen in Ellicott's water-filled horizon.

It may be worthwhile, before saying more about how Lewis and Clark used their instruments, to mention some aspects of the nautical astronomy of that day.

Good, standard practice was to record timekeeper and sextant readings as they came from the instruments, and leave adjustments and corrections for later. When Lewis and Clark took observations they recorded the hours, minutes, and seconds as read from the chronometer.

Although there were three different ways of reckoning the day the captains used only two. They kept their journals according to the civil day — the same day we use. But, when entering the Nautical Almanac, they had to shift to the astronomical day.

The astronomical day began at noon, when the sun crossed the wires of the astronomer's transit instrument. At noon the date was the same as the civil day, but the date continued on past midnight. Hours of the astronomical day were counted straight through until the following noon,

April 10th, six PM in civil time was still April 10th six hours in astronomical reckoning. But at midnight» when a new civil day began, the astronomical day would continue with date unchanged. April 11th, six AM would be, in astronomical reckoning, April 10th, eighteen hours.

The third way of reckoning the date was used only at sea. The sea, or nautical day, shared the same noon as the other two ways of reckoning, but ended at noon. That's when the navigator "worked the day's work," and found where the ship was in relation to where it had been the previous noon.

Noon April 10th was the last moment of April 10th in the nautical day, the middle of April 10th in the civil day, and the first moment of April 10th in the astronomical day.

It's only natural to suppose the logic of twentieth-century celestial navigation is a guide to eighteenth-and-nineteenth-century nautical astronomy, and that any difficulty is caused by messy details — such as the various ways of reckoning a day.

Unfortunately, this is not the case. The real difficulty isn't messy details. The real difficulty is that our idea of time has changed. Ill try to explain how that change came about.

One of the adjustments made to time read from a chronometer would be for the "equation of time." That is, for the difference between "apparent" time and mean time. This was of no concern to the majority of navigators of that era, but important to anyone who had an accurate timekeeper.

Apparent time is taken directly from the sun and, for that reason, undergoes gradual variations in rate. Since the earth's orbit around the sun is neither a perfect circle nor in the plane of the equator, the time required for the sun to cross a meridian and return to it again changes throughout the year. Measured in absolute time, the length of twenty four hours of apparent time varies as much as fifty seconds during the year. Needless to say, this doesn't work well for accurate timekeeping over long periods.

Astronomers calculated the average, or mean, length of day, and set pendulum clocks accordingly. Their "mean sun" is a steadily moving imaginary companion of the "apparent," or true sun. Four times a year the two suns coincide, but usually one or the other leads across the sky. The most extreme separation is around November 3rd, when the apparent sun is about four degrees ahead, and the equation of time nearly sixteen and a half minutes.

Mean time came into navigation along with the chronometer. It was the first step away from the ancient view of time as a direct relationship between observer and sun. But, no matter whether he was using apparent time or mean time, a navigator still found the time himself — usually by time sight. (Time sights were known as "observations for the time" before sextant measurements came to be called "sights.")

A larger step came with the acceptance of standard time. Local time worked well enough as long as the quickest way to get from one place to another on land was by horse. But once railroads were crossing continents it became inconvenient to use time that shifted, second by second, as you traveled east or west. The solution was to divide the earth into segments, or zones, each assigned a standard meridian from which time was measured. Time became the relationship between the standard meridian of the zone and the mean sun. Neither the navigator himself, nor the sun he saw in the sky, was any longer part of it.

The final, giant step came in the first part of the twentieth century, with the introduction of Greenwich hour angle. GHA was first used by air navigators, but soon proved its value to surface navigators as well. Before that, the east-west position of bodies in the celestial sphere was measured from the vernal equinox, a celestial meridian. Now it was measured from a meridian on earth.

Thus the rotation of the earth became an element in the east-west positions of bodies listed in the Almanac. The Jump in rate of change was terrific. For most bodies, the accuracy of the Greenwich time used in taking data from the Almanac became about three-hundred-and-sixty times more critical. Even for the moon it was about thirty times more critical than it had been with the old Almanac. Accurate GMT was now absolutely essential It took its place, alongside the sextant, at the heart of celestial navigation. For navigators, GMT had become the time.

In Lewis and Clark's day — and for generations afterward — the time was local. Local time kept track of the rotation of the celestial sphere. The Nautical Almanac simply predicted, in terms of Greenwich apparent time, gradual changes within the sphere. To get accurate data a navigator used correct local time, and an approximate Greenwich time. The only occasion for accuracy in Greenwich time was when it was compared with local time for longitude.

But — within less than a century — the old way of thinking was turned upside-down. That's why trying to follow the logic of nautical astronomy while looking through the lens of celestial navigation is apt to cause a headache. According to modern logic there is no way those procedures could get accurate results. Not unless the calculations were repeated again and again, each time using Greenwich time found to take data from the Almanac for the next round. In the present way of thinking, only when Greenwich time found converged with Greenwich time used could the result be trusted.

Of course this was not the case. The critical element was not Greenwich time, but local time. That's why nautical astronomy worked so well. While Greenwich time was hard to come by, and its accuracy problematic, a navigator could — with ease — find local time to within a few seconds of the truth.

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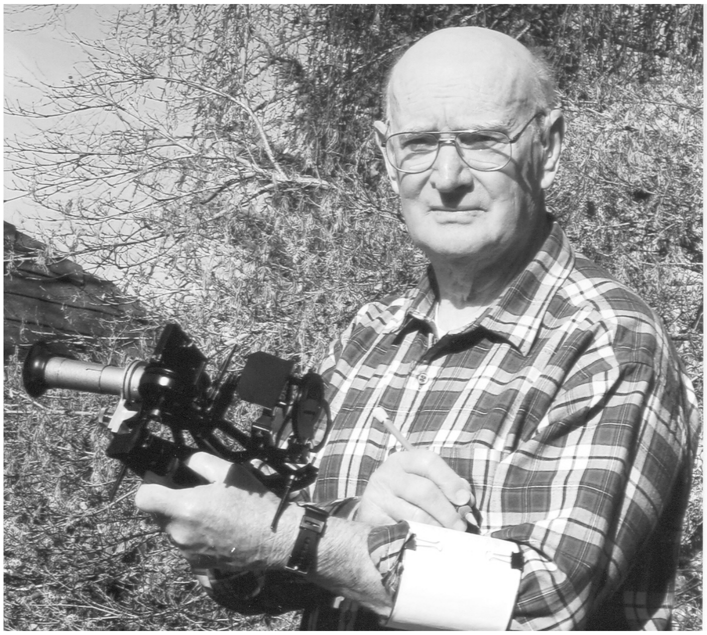
MEMBER PROFILES

We ask Bruce to share a few notes about himself with the membership. Besides being author of the ongoing Lewis and Clark series, he is the author of the now famous set of modern lunar reduction tables, as well as being consultant, teacher and ongoing researcher in the field of what he calls the "old ways of navigation." The seminar on lunars he presented at Starpath in 2001 is still fondly remembered by all that attended (see issue 12 of starpath.com/news).

BRUCE STARK

I was born in 1926 and grew up in a small farming community in Florida. After graduating from high school I joined the Army and served in the infantry and antiaircraft, but didn't see combat. In the meantime my mother and sister had moved to Oregon. Oregon has been my home state ever since.

My interest in celestial navigation came, in a roundabout way, from love of the woods. I'd spent a lot of time in winter living and exploring alone in the lower mountains. At one time I'd considered moving to southeast Alaska. That, in turn, led to thoughts of boats and sailing. Then—because I liked to sail—someone gave me a cheap plastic quadrant. A spark was struck, and an interest in celestial navigation smoldered along for years until, in 1976, it came in contact with the GMT-from-the-moon puzzle. At that point what had been a smoldering interest burst into flame.



Author Bruce Stark

I read everything at hand, and spent all my spare time thinking about the elements of the problem. A couple of lunar distances—measured with a less-than-top-of-the-line Hughes "Mate"—turned out fairly well. But the calculation was laborious, and I looked to the past for better methods. Apparently no one, at that time, was interested in the contents of old navigation manuals. Unless in "collectable" condition, they were extremely cheap. Within a few years I had just about everything wanted, from Maskelyne's *Tables Requisite* to Raper's *Practice of Navigation*. Nautical astronomy had become my number-one hobby.

As for other interests, Janice I enjoy literature and politics, travel and hiking. And, although we're getting a bit old for such things, we aren't ready to give up on backpack camping just yet.

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NAVIGATION NOTES

CONCISE SIGHT REDUCTION TABLES II

by PM Janiczek

Variation for a High Altitude Sight

The description of the concise sight reduction tables (Spring 2007 issue) contained the statement: "Moreover, that sin *H* and sin *P* are both given as the product of a sine and cosine provides an alternative for high altitude sights that is demonstrated later." Some readers immediately saw the possibility implied by that statement, especially if the actual tables were at hand. Nevertheless, I think this variation has not been published elsewhere, and I have been encouraged to explain it here. Interested readers should refer to the previous article for symbol definitions and formulas, and to *The Nautical Almanac* for the actual tables and instructions for ordinary use.

Upon second entry into the concise reduction table, using *A* and *F*, it can happen that the user will be in an area where successive *P* and Z_2 are changing by large and unequal differences, although *F* increases or decreases uniformly. This situation will occur for small values of *A*, coupled with *F* values near 90° or 270°, and it is produced by sextant observations at high altitude. Although it is best to avoid such observations, there are sometimes too few or no other alternatives. For such cases some textbooks recommend plotting the altitude circle directly. Straightforward use of the Concise Tables may not give satisfactory results, but a variation on table use may give much better, if not always exact, results for computed altitude. It is based on the identical functional forms for *H* and *P* as previously mentioned. One essentially exchanges the meanings of some tabulated quantities.

The identical functional forms for *H* and *P* are:

$$\sin H = \sin F \cos A,$$

$$\sin P = \sin Z_2 \cos A.$$

In principle, the method is simple. If you open the table at *A*, and scan the Z_2 column (*not* the *F* column) for the entry corresponding to *F*, then, on that row corresponding to the numerical value of *F*, *P* will be found in the *H* column, *H* in the *P* column, and Z_2 in the first *F* column. Although this can be seen by looking at the above formulas, actual use involves some numerical adjustments that justify specific instructions and an example.

1. If the second entry into the main table using the rounded *A* and rounded *F*, must be for small *A*, and for *F* near 90° or 270°, record *H*t as usual.

2. Round *F* in degrees and minutes to the nearest tenth of a degree and scan upward under the same *A* heading to find a value in the Z_2 column that is closest to rounded *F*.

3. On the same row where tabulated Z_2 and rounded *F* are nearly or exactly equal, take the number from the *H* column and round it to whole degrees. That number will be an improved value for *P* (*not H*t). Again on the same row, take the number from the leftmost *F* column as an improved value for Z_2.

4. Use the improved *P* and Z_2 to compute the corrections to *H*t for minutes of *F* and *A* using the Auxiliary Table.

5. Combine the improved Z_2, taken from the *F* column with Z_1 to produce the azimuth angle. The result should be more accurate than using the original Z_2 from the lower part of the table.

I neglected to mention earlier that Z_1 and Z_2 are tabulated to tenths of degrees to maintain precision while combining the two and adjusting for quadrant. The tenths do not always provide increased accuracy in Zn. Such practices used to be called "carrying guard figures." The following example is for an exaggerated situation – an extreme altitude.

Example 1

A vessel is near 42° North. A sight is taken of a star at 45°01' North and its LHA at the time is taken to be 349° to form as assumed position. The Concise Tables (first entry) provide *A* = 8°09', *B* = 47°28' and Z1 = 82.6°. Immediately, *F* = *B* + *Dec.* = 92°29'. Denote the minutes part of *F* as *F'* (29') and the minutes part of *A* as *A'* (09'), as usual.

1. Open the table at $A = 8°$. At the line $F = 92°$, $Ht = 81°45'$, $P = 13°57'$, and $Z_2 = 14.1°$. For this case, and for all F greater than 90°, F must be subtracted from 180° to give a search value (87°31') corresponding to numbers in the leftmost column. (F cannot be negative for high altitude sights.)

2. Round the search value to 87.5°. Scan upward in the Z_2 column for the closest value to 87.5°. That is found at 87.6°.

3. On that same row, take out the improved value for P: 16°50', from the H column, rounding it to 17°. Again from the same row, take the number from the leftmost (F) column as Z_2: 17°. This alternate value of Z_2, not the original Z_2, should be combined with Z_1 to form azimuth angle according to the ordinary rules.

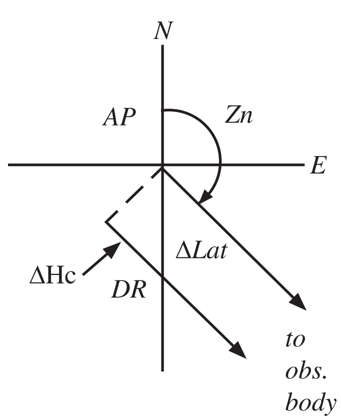
4. The Auxiliary Table, with $P = 17°$ and $F' = 29$ gives the first correction to Ht as 08'. Using $Z_2 = 17°$ and $A' = 09'$, the same table gives the second correction as 09'. With attention to sign rules, and after summing, the total correction to Ht is –17'. Denoting computed altitude as Hc, Hc = Ht + total correction; thus, Hc = 81°45' – 17' = 81°28'.

5. To compute azimuth, combine Z_1 (= 82.6°) with the revised Z_2 (=17°) and observing the sign rules. The result is Zn = 082.6° – 17° = 065.6°. For comparison, the exact answer computed by rigorous formulas is Hc = 81°29', Zn = 065.6°.

Dead Reckoned Positions

Considerable time, care and judgement are invested in maintaining good dead reckoned (DR) positions. Therefore, calculating and plotting from assumed positions (AP) often brings up the question of whether intercepts based on DR positions would provide a more convincing solution (plot geometry) and foster greater confidence and satisfaction with the fix. The Concise Tables can be used to refer a computed altitude to a DR, and some readers may be interested in the technique. Here is a simplified geometric illustration, followed by the actual tabular method and an example.

Figure 1 represents the plane of the horizon, with an arbitrary grid drawn at the AP. For simplicity, a DR, on the same grid, illustrates the situation geometrically. There is no loss of generality involved; differences of latitude and longitude between the two positions contribute separately. The DR is South of the AP, indicating that the DR latitude was rounded up to provide the AP latitude. True azimuth is indicated by Zn in the *Figure*. As usual, symbol Δ signifies either a small difference or a small correction. For example, Δ*Lat* is the difference between the DR and AP latitudes, while Δ*H*c is the incremental correction to be applied to *H*c. In *Figure 1*, parallel line segments from both positions extend toward the sub-stellar (far distant) position of the observed celestial body. Since zenith distance is the complement of altitude, 90° – *H*c, both lines can represent the projection of the celestial body's zenith distance onto the horizon plane. The line through the DR also extends "backward" to the point where it meets a perpendicular drawn from AP. Imagine that the line segment from the AP is moved parallel to itself toward the segment from the DR, with the restriction that the AP end-point moves along the broken line that is perpendicular to both line segments. Then that part of the line segment labeled Δ*H*c represents a necessary adjustment to the zenith distance from the AP in order for it to be exactly equal in length to the zenith distance from the DR. Note that, during this displacement process, *Z*n has not changed.



Now all differences are expected to be small, on the order of arc minutes, justifying the use of plane triangle formulas. Thus Δ*Lat* and Δ*H*c become straight lines. It is seen that a right angle is also involved. By plane trigonometry then, the necessary increment to the AP zenith distance, or alternatively to the altitude *H*c with change of sign, is simply

$$\Delta Hc = \Delta Lat \cos Zn.$$

I'll defer the matter of +/– signs for now.

A method for using the Concise Tables for adjusting computed altitude (*H*c) so that it refers to a DR rather than to an associated AP employs the formula:

$$\Delta Hc = \Delta Lat \cos Zn + \Delta LHA \cos Lat \sin Zn.$$

Here, Δ*LHA* is the difference between local hour angles calculated for the dead reckoned and assumed positions. As above, Δ*Lat* is the latitude difference, and Δ*H*c is the *total* increment to computed altitude. The formula, derived by calculus from the general navigational triangle, shows that the plane triangle approximation used with the geometric illustration above is justified. It also shows that differences in latitude and longitude contribute independently. The formula does not account for an adjustment to azimuth. However, when making the adjustment from the AP to the DR, the true azimuth changes by a negligible amount, except for cases of nearly vertical sights where a significantly different approach may be necessary.

As well known, to calculate local hour angle based on an assumed position, the Greenwich Hour Angle of the body is not changed. It is the DR longitude that must be modified. For what follows *LHA* will still denote local hour angle at the AP, but I denote longitude as *L*o, and the difference between the longitudes of the dead reckoned and assumed positions as Δ*L*o. The formula above then becomes:

$$\Delta Hc = \Delta Lat \cos Zn + \Delta Lo \cos Lat \sin Zn.$$

For use with the Concise Tables, it is necessary to collect all possible cases into an algorithm, or set of rules, that can be used mechanically, without recourse to plotting or mental gymnastics. However, it is fair to advise that the rules given here should be scrutinized. Experience has shown that such rules, as I specify them, can be improved and made more efficient and user friendly. Such improvements are welcome.

Hc for DR Position Using the Concise Tables

1. Calculate *H*c and *Z*n based on assumed position according to the rules for the Concise Tables.

2. Re-enter the main table at the AP latitude opening. Using *Z*n in place of *LHA*, take out the angle under the "*A*" column, calling it *C*.

3. If Zn is greater than 90°, identify the angle in the leftmost LHA column that lies on the same line as Zn, calling it Z_R.

4. Set Δ*L*o = the difference (ignoring sign) between the AP and DR longitudes.

Set Δ*Lat* = the difference (ignoring sign) between the AP and DR latitudes.

5. Enter the Auxiliary Table using rounded *C* in the left-hand column and Δ*L*o as column heading. Extract increment 1 (*incr.*1) from the table body.

6. Re-enter the Auxiliary Table using Z_R (right-hand column) and Δ*Lat* as column heading. Take out increment 2 (*incr.*2) from the table body.

7. Refer to the following scheme for signs of the increments:

Sign Increment 1 for Δ*L*o

sign *incr*.1 ↓ →	0° < Zn < 180°	180° < Zn < 360°	×
DR *East* of AP	+	–	DR *North* of AP
DR *West* of AP	–	+	DR *South* of AP
×	270° < Zn < 90°	90° < Zn < 270°	← ↑ sign *incr*.2

Sign Increment 2 for Δ*Lat*

Use the top row and left column to determine the sign of ΔLo. Use the bottom row and right column to determine the sign of Δ*Lat*.

8. Add *incr.*1 and *incr.*2, according to their signs, to the AP computed altitude. The result is *H*c referred to the DR position.

Note: The extra steps to convert *H*c have the potential to become confusing. Using this procedure warrants specifying additional entries on a sight reduction form.

Example 2

A vessel's DR is 14°32' South, 152°20' West. An observed star has coordinates *GHA* = 99°54', *Dec* = 38°47' North.

1. For the AP: Lat. 15° S (assumed latitude)

GHA 99° 54'
– Lon 151° 54' W (assumed longitude)
LHA 308°

For the assumed position the Concise Tables produce *H*c = 17°33', *Z*n = 041°.

2. At Latitude heading 15° and *Z*n 41°, angle *C* is 39°19', which rounds to *C* = 39°.

3. *Z*n < 90°, so Z_R = *Z*n = 41°.

4. Δ*L*o = 152°20' – 151°54' = 26'; Δ*Lat* = 15° – 14°32' = 28'.

5. From the Auxiliary Table with *C* at 39° and Δ*L*o as 26', *incr.*1 = 16'.

6. From the Auxiliary Table with Z_R at 41° and Δ*Lat* as 28', *incr.*2 = 21'.

7. Referring to the sign rules, above, *incr.*1 is negative and *incr.*2 is positive.

8. Applying the increments to the AP altitude gives altitude referred to the DR:

Δ*H*c = *incr*.1 + *incr*.2 = – 16' + 21' = + 05'

*H*c (DR) = 17°33' + 05' = 17°38'.

Caution:

The procedure and example are for adjusting the computed altitude. It is possible first to compute an intercept, *H*o – *H*c, and to apply the adjustments to the intercept. In that case, the signs of the increments must be changed because the sign preceding *H*c in the intercept is negative. If you prefer to apply the increments directly to AP intercepts, I recommend constructing a table of signs like the one above but with all signs reversed. The reduction process can proceed without the distraction of determining signs then changing them.

Additional Remarks

Whether or not the procedure for converting to a DR altitude is used, the formula in bold type in the previous section is relevant; it can give some qualitative information about altitude from another perspective. Suppose we think of Δ*H*c not as an increment, but as the *error* in computed altitude. The differences, Δ*Lat* and Δ*L*o, should then be thought of as errors in latitude and longitude that constitute the error in *H*c. Specifically, Δ*Lat* and Δ*L*o are not differences for the present purpose; they are errors in position that are to be eliminated by the Fix. The intercept takes the form:

*H*o – *H*c = Δ*H*c = Δ*Lat* cos Zn + Δ*L*o cos *Lat* sin *Z*n.

An observed altitude, *H*o, contains errors also but, since such errors do not depend on position, we can neglect them here and consider the *H*o to be perfect. The purpose of the intercept, and additional intercepts brought to bear, is to locate a Fix position that makes Δ*Lat* and Δ*L*o = 0, or at least minimizes them.

Aside from the magnitudes of Δ*Lat* and Δ*L*o errors however, azimuth (Zn) exerts an influence. In particular, if *Z*n for a sight is near a cardinal point, the difference *H*o – *H*c may be ascribed mostly to one position coordinate, not the other. For example, at one extreme, for an altitude oriented near due North or due South, sin *Z*n ≅ 0, and the error in *H*c must be due entirely to an error in position latitude:

Δ*Lat* ≅ *H*o – *H*c

At the other extreme, if *H*o is almost due East or West (cos *Z*n ≅ 0, sin *Z*n ≅ 1), then:

Δ*L*o ≅ (Ho – *H*c) / cos *Lat*.

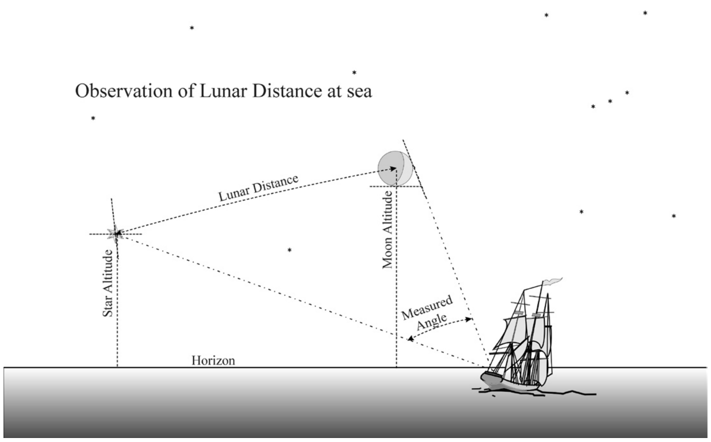
Sights exactly oriented toward any of the cardinal points are obviously rare. Nevertheless, a sight may be sufficiently close to a cardinal point so that it is worth taking that fact into account when assessing the quality of an intercept or sources of error.

* * *

INTERNET RESOURCES

Lunar Distance Theory and Practice

The online wikipedia has become one of the outstanding Internet resources. Almost all topics are covered and often in a concise manner that often meets needs at hand. The beauty (and sometimes hazard) of the resource is it is open source in that any one can contribute to a definition. The good news we share here is the experts on celestial navigation and lunar distance in particular who make up the online NavL discussion group have taken on the task of mentoring the Lunar Distance discussion on the Wikipedia. Besides being the world's experts on the subject, they are notoriously precise and careful in their conclusions, even about the smallest detail. The presentation will be far better for their work and we will all benefit from it—as will all newcomers to the field.



Graphic from the Wikipedia article on Lunars

Some members of our own Foundation take part in this group discussion and we encourage others to do so if they do not. You can read and take part in the discussion at

http://groups.google.com/group/NavList?

The Wikipedia link on Lunars can be seen at

http://tinyurl.com/ytahcp

* * *

Charting Neptune's Realm: From Classical Mythology to Satellite Imagery

An exhibition at the Osher Map Library and Smith Center for Cartographic Education, University of Southern Maine

A wonderful illustrated history of charting and associated sciences of navigation and oceanography presented by the University of Southern Maine Library. Of special note are the high resolution charting and other images they use. (Unfortunately they use a very distracting background image for all pages, but the value of the content is worth the effort needed to overlook that shortcoming.) They also include an excellent in-depth set of lesson plans for teachers who wish to present this type of content—a subject that reminds a keen interest to several members.

Hopefully the Foundation will one day soon be able to contribute to the content and encourage the use of navigation in teaching on all levels. It would seem to be a worthwhile activity of the Foundation and one that is in keeping with our goals.

See the display at

usm.maine.edu/maps/exhibit8

* * *

A Short Guide to Celestial Navigation

If you have not seen this wonderful resource from Dr. Henning Umland in Germany then you have a treat in store. Besides a detailed tutorial with many equations for those who want to program their own solutions—including lunar distance—he has many excellent resources including sight reduction programs as well as many almanacs. He also includes an extensive list of interesting web links. Find the site at

http://www.celnav.de

* * *

Updated ION CD on Celestial Navigation

The first version of the CD that our Foundation made in conjunction with the Institute of Navigation had a couple shortcomings. The main one was that about half the documents could not be printed, which was contrary to our goal and theirs. Second there was an article or two missing, and one article we did include had a defective half page. These issues have all been corrected now. If you have purchased the early one that still had these errors, you can contact the ION and they will send you a new one at no charge. If you do not have one yet and would like a CD, they are available from the ION for $25 at the bottom of the link they call "Online Publications Order Form":

http://www.ion.org/shopping/begin.cfm

They have also added an online table of contents, similar to the one we have at navigationfoundation.org

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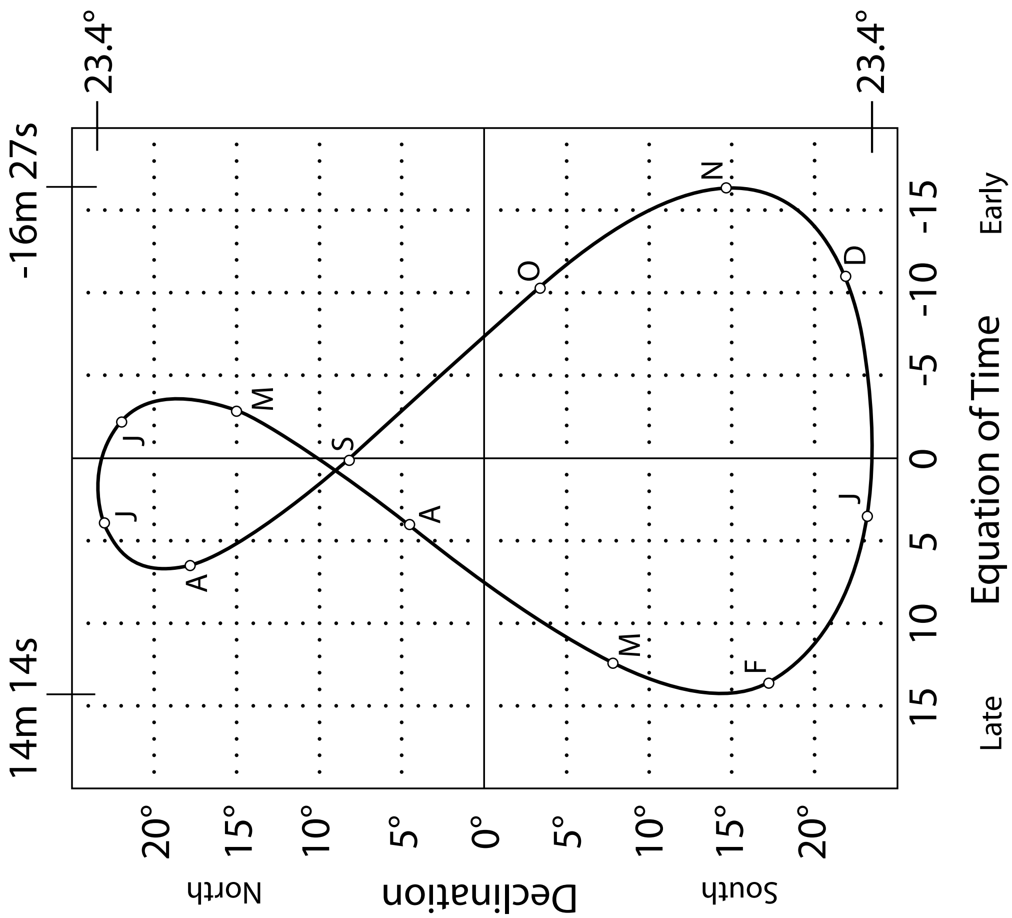
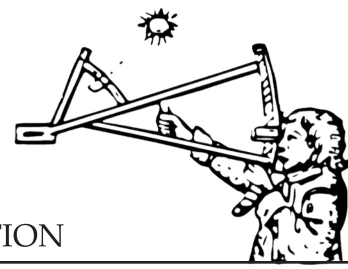


In the category of “well known to those who know it well,” this diagram is called an *Analemma*. In this version it is plotted as the sun’s declination as a function of its equation of time. It can manifest itself in other forms. See www.analemma.com. It was plotted in this clear format for the editor’s new book Emergency Navigation 2nd edition, due out from McGraw-Hill in March of 2008. If you are new to this idea, please check out that web site for the fascinating details.

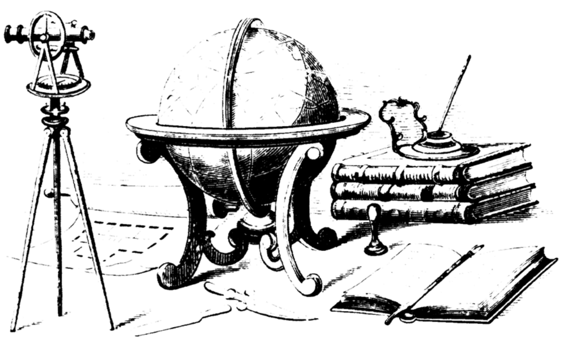
ISSUE 97, Fall 2007

THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a reader forum for the expression of our members opinions and their questions.



ACTIVITIES
By Terry Carraway

On October 6, 2007 Director Roger Jones, Dr. David Burch and I had lunch in Annapolis. Director Jones was in the Washington area on business, Dr. Burch was attending the Annapolis Sail Boat Show and I live in the vicinity. This was the third year we have had the opportunity to meet together.

The main topic of conversation was The Navigation Foundation and its future. One of bright spot of the discussion is the newsletter edited by Dr. Burch. It is one of the best we have had in years and Director Jones and I complimented him on his outstanding efforts.

I broached the subject of membership and the problem of having sufficient funds to continue to pay the reoccurring yearly expenses. The continued increase in cost of almost all areas has left little cushion. The comment was made that with 245 members there should be no problem. The reoccurring expenses are: the newsletter, web page maintenance fee, telephone, Internet access, Business Reply fees, the cost of business reply letters, awards given to The U.S. Naval Academy, The U.S. Coast Guard Academy and The Tabor, Maine Maritime Academy, postage, printing costs for envelopes, and general office supplies to keep the computers up and the printers with ink. However the membership came through by the first of the year and all members renewed giving us a cushion.

Another problem worth noting is the loss of book dealerships with McGraw Hill, The Naval Institute Press, Cornell Maritime Press and the near loss of our nautical chart dealership with the U. S. Government. This has occurred due to inactivity in the accounts. I have received no orders in over 4 years for The Naval Institute Press, Cornell Maritime Press and only one order for McGraw Hill in the past 3 years. This past year we almost lost our chart dealership due to not meeting the required $500 chart purchases in the record keeping year. We are now under probation. The book dealerships cannot be reestablished as the companies noted we did not have enough orders when the accounts were active to pay their administrative expenses.

The suggestion was made that we could look to getting corporate members. This action would require The Navigation Foundation to change the long standing policy set up by Admiral Davies when he and I founded the organization. He did not want any paid employees because of having IRS withholding and Social Security payments. He rejected corporate memberships as a problem for which he did not want to be bothered. Since his death I have continued to honor his desires and resist having The Foundation change from his polices. We will continue to provide as many services as we can and continue on as long as funds last.

I regret that The Navigation Foundation will no longer be enclosing Business Reply envelopes in renewal notices. The cost of Business Reply has gotten so expensive we will now only enclose pre-addressed envelopes. The cost of Business Reply is now $1.10 per letter plus a $175.00 fee just for the privilege of having an account. Many members would place a First Class stamp on the envelope but the Post Office would still charge the $1.10 for the Business Reply envelope ignoring the stamp.

I apologize for the long delay between Newsletters. Over the years I have indicated in our welcome letter the Newsletter could be delayed as all Officials and our Editor are volunteers. Not only do the officials have other pursuits to follow but our editor has a business to run in a time of economic downturn and it takes many hours to compile The Newsletter. We hope not to have such a long delay in the future but with the economy as it is we cannot promise.

***

EDITOR'S NOTES

By David Burch

First and foremost I have to offer my apologies to all members for the long delay in getting out the Newsletters. My own work has kept me even busier than normal over the past months. We do however now have several new navigation teaching products that are in use throughout the US, including complete new courses in radar and marine weather that we at Starpath developed during this period for the American Sailing Association. These new courses are in full swing now across the country.

As Capt. Carraway mentioned, I had hoped to obtain corporate membership support for the Foundation to help with the production of the Newsletter and related logistics since we are short on time ourselves and short on volunteers who can help with the actual mechanical layout and production. I must, however, appreciate and respect the decision of the directorship that the Foundation should remain unchanged in its financial structure, which relies solely on the contributions of the individual memberships. Thus we will do our very best to get back on schedule with our present resources and continue to do so till we can find someone who can help with this.

To that end, I owe a great debt to member John Lewis who has volunteered to join in and help the editing of the Newsletter. He has helped with these issues and has agreed to help with future ones as well. Thank you John. John can help with text editing and compilation of content, but would like to find help with the actual mechanical production.

If there are members who are familiar with page layout software programs who could help with the actual production of the Newsletter that would be wonderful as well. Please let me know at editor@navigationfoundation.org.

Errata

In the last issue (No. 96) we had a note praising the treatment of Lunar Distances on the Wikipedia, pointing out that this online reference was now being looked over by members of the Google group NavList. We used a graphic from that online article to illustrate our note, with the understanding that artwork shown there can be so reproduced. Our timing however was such that when we copied the graphic to use it, there was no reference given for it, but a reference did get posted sometime later. In fact, the excellent illustration was drawn by Clive Sutherland, who had created it for George Huxtable to use with his article on Lunar Distances, which was published in the RIN newsletter called Navigation News, Sept/Oct, 2007. Thanks to George Huxtable for pointing this out. Our apologies to Mr. Sutherland, for our not having known this at the time.

***

READER'S FORUM

The following letter was sent to us by member Gayle K. Stone, to to show us what he had sent to Practical Sailor *Magazine and share with the membership.*

Dear Mate:

Elated to see your "Navigation, a Lost Art?" article in the January issue. Away for the holidays I picked up the issue in my "held mail" today. "The Navigator's Bookshelf references are on target but among other noteworthy sources the "Foundation for the Promotion of the Art of Navigation" (Navigation Foundation)' needs mention.

The Foundation was founded some years ago by Admiral Davies (USN deceased) based on the possibilities of failure of the GPS System you mention. He visualized, not only the necessity of Government shut down (911 a good example) but physical propagation vagaries and electronic failure as well as interference for external sources. The Foundation is manned by a volunteer staff, recently bolstered by the appointment of David Burch as Editor of their monthly newsletter. David is the author of many navigation publications as well as his association with Starpath. His "The Star Finder Book" (A complete guide to the many uses of the 2102-D Star Finder) is not only a Star Finder but using it with the Navy 2102-D kit, one can locate the Sun, Moon and the four navigational planets for any instant in time! Needing a horizon, Stars can only be "sighted" at twilight (dawn or dusk) but predicting when a daytime, Sun/Moon fix is possible can be a savior! Predicting location (azimuth) and height of the sun will prevent burning out one's retina on Sun sights with the sextant.

The Foundation includes neophyte members such as I, as well as experts on the finer arts of navigation. I received expert assistance and encouragement from the staff and even assistance from an Australian member with some of my Moon sights. Your suggestion for reliance on paper charts is in line with services of the foundation for members can obtain charts at a discount Electronic charts are derived from the same information as paper charts and GPS

The Navigator's Newsletter
Published by
The Foundation for the
Promotion of the Art of Navigation
www.navigationfoundation.org
P O Box 1126
Rockville, Maryland 20850, USA
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The Navigator's Newsletter is published four times annually, with our strived-for publication dates of approximately the solstices and equinoxes. Newsletter production and other Foundation activities are provided by volunteers. Please bear with us if we slip on the dates occasionally.

way-points set from any chart may not be accurate, e.g., Chart No. 1 USA states numerous points as PA (Position Approximate). Your advice to look at where you are going instead of the “boob-tube” is right on!

But, one must also consider the times when even celestial bodies are not available. One can be at Sea for days under cloudy skies and that is where your insistence on the use of DR (Ded, Dead or whichever Reckoning) and the old faithful Magnetic Compass comes into play. They should not only be used at these times but continuously, even with GPS in use. GPS users should be logging a note of Latitude and Longitude at intervals depending on speed, maybe every hour, at least, for sailing at 5 or 6 knots and more often for power boats at higher speeds. When GPS failure occurs and you need assistance, the first question asked by the Coast Guard or other agencies is, “What’s Your Position? A half-hour log entry by a six-knot cruiser will not be far off the mark!

In addition to your instances of failure or improper use of GPS (QE2 & Essence) I can add many cases but unfortunately they are hearsay. Charters in the “Spanish Virgin Isles” (Culebre & Sigues) have experienced weird failures. (A presenter at a European trade Show offered a $3,000 device for jamming GPS.) A return crossing from the Bahamas encountered a storm, evasive measures were taken, no one kept track of maneuvers and when the storm abated, the GPS was out and no hand-helds on board. On top of that the compass had never been compensated! Twenty degrees off and headed for Cuba? Luckily power was restored. These are the cases we hear about and usually the crew is ashamed to tell that they let it happen until one spills the beans over a couple of beers six months later. But, what about the ones which we never hear about because they are lost forever!

The number of experts out there is plenty and as far as the math involved it is simple addition and subtraction. It only takes some time and study to use the tools, which were created by Adm. Marcq Saint-Hilaire, Captain Thomas Sumner, Lieut. Arthur Ageton, Comm. P.V.H. Weems and of course Nathaniel Bowditch. They did all the math for us but the sextant must be mastered with practice!

Sincerely, Gayle K. Stone

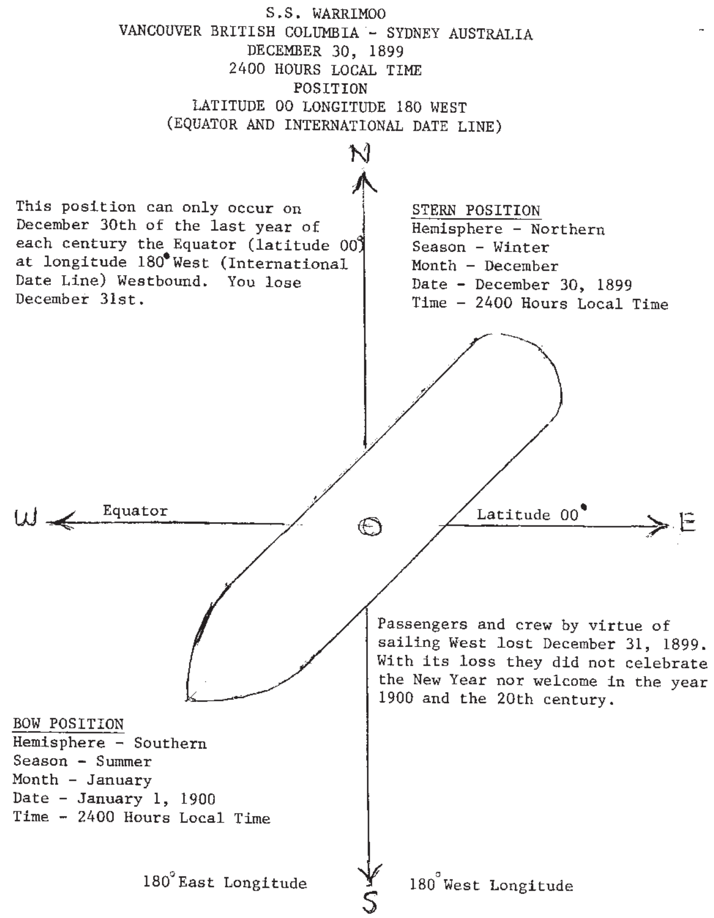
***

Captain Warren G. Leback, a 1944 graduate of the Merchant Marine Academy, sent us an interesting note on a phenomenon which can occur only once in each century, and at only one location on earth: the intersection of the international date line and the equator. Whether you accept that the bow and stern were in different centuries at midnight depends on whether the century begins on 1/1/1900 or 1/1/1901; there were debates about this at the turn of our present millennium. And on whether it makes sense to speak of the bow and stern of a vessel having different dates and times, or whether a vessel has one time throughout; ah, the potential for fine and subtle distinctions is immense.

From Captain Leback:

There is a time and date phenomenon that can only occur once each century and in one location.

Basically, when traveling westbound across the Pacific Ocean either by ship or aircraft you lose a day when crossing the 180° West Longitude (International Date Line). Example, if you cross on Friday, the next day is Sunday.



Here is a diagram of the Capt. Leback’s rare phenomenon:

A ship proceeding westbound and crosses the 180° West Longitude (International Date Line) at the Equator (latitude 0°) the following occurs when the vessel crosses on December 30th of last year of the century at 2400 hours local time.

—The Bow Position- In the Southern Hemisphere- It is summer- Date is January 1st- Time 2400 hours local time

—The Stern Position- In the Northern Hemisphere- It is winter- Date is December 30th- Time 2400 hours local time

A documented occurrence of the phenomenon was recorded aboard the S/S “Warrimoo,” Australian flag, owned by Canadian-Australian Royal Mail Line on its regular voyage from Vancouver, British Columbia to Sydney, Australia. The passengers and crew lost their scheduled New Year festivities including welcoming in the 20th century. Although it is not reported whether or not a party was arranged for the passengers and crew, they were however presented with “The Golden Shellback” certificate, certifying the rare crossing of the International Date Line at the Equator.

***

Thanks to member Fred Hebard for pointing out an interesting article on line at the Physics Today website about time keeping. It expands on exactly the subject we covered earlier on the “leap second” and related aspects of celestial navigation time keeping. Please see: http://www.physicstoday.org/vol-59/iss-3/p10.html. The article is by Daniel Kleppner, Professor Emeritus in the physics department of the Massachusetts Institute of Technology and director of the MIT-Harvard Center for Ultracold Atoms.

NAVIGATION NOTES

LUNAR ALTITUDES REVISITED

by George G. Bennett

In 1707 the loss of four of Admiral Clowdisley Shovel's warships, as well as over two thousand men near the Scilly Isles, gave considerable impetus to the importance of developing a practical and reliable method of longitude determination.

In the mid eighteenth century two methods were vying for the valuable Longitude Prize announced earlier; Harrison's clocks were being developed and an accurate ephemeris of the Moon was being compiled using the work of Mayer, Euler, Halley *et al.* The refinements of both methods has been described in great detail and, suffice to say, Harrison's time pieces eventually became the forerunners of the generally accepted and successful marine chronometer.

The popularity of the Moon as a body for general use in marine celestial navigation declined when radio time signals became generally available at the beginning of the of the twentieth century. Unlike the Sun and stars, the irregularities of the Moon's position in the sky together with a large horizontal parallax requiring additional altitude corrections did not endear the navigator to its use although corrections were not difficult to apply.

As stated in my paper in the U.S. Journal of the Institute of Navigation, a copy of which can be read at

http://gbennett.customer.netspace.net.au/paper/longitudepaper.htm

interest was revived when in 1966 Sir Francis Chichester published a note on the difficulties which would arise at sea if correct time was lost and a radio was unavailable. Since that time many papers have been written under the heading of "Longitude without Time". I have always been intrigued by the adoption of that title which appears to be a contradiction; longitude is inseparable from time in the context of navigation. Chichester suggested using lunar altitudes rather than lunar distances as he stated that the latter required involved calculations.

In his original paper, Chichester was "horrified" at the prospect of observing and calculating lunar distances on a small boat. By observing lunar altitudes most of those objections could be obviated. However, the method naturally depends on the accuracy of observing a sextant altitude, the limitations of which have been described in detail over many years and it would be unnecessarily repetitive to itemise all the various sources of error which could be present. Chichester's starting point was the determination of latitude, which was not affected by an inaccurate knowledge of longitude and on this basis, using a small scale chart, he refined an approximate estimate of longitude from a simultaneous Sun/Moon fix. Since that time most methods have required the adoption of an approximation which is refined in stages and converges to a desired value of longitude and an associated watch correction In the method proposed here a position is first determined using times obtained from a watch which has been set on the best estimate of GMT or Zone Time. Independent timed altitude observations of the Moon are then made and calculations are performed using procedures which are familiar to navigators to determine the longitude of the observer and the watch correction.. The observation of an accurate altitude of the Moon is the crux of the method and should not, from my experience, be significantly different from that made to other celestial bodies used in celestial navigation.

The optimum position for the Moon should be when it is close to the prime vertical (Azimuth 090º or 270º) which can be deduced from the differential relationship,

$$\text{d-Alt} / \text{d-Time} = \cos(\text{Lat}) \ \sin(\text{Azimuth}).$$

In the proposed method the observed position is advanced or retired to the epoch of the timed observed altitude of the Moon. The altitude of the Moon is then calculated and compared with the observed value, which is what one does when determining the intercept of a Line of Position. A second altitude calculation is made using a longitude shifted either East or West by a small amount with an associated watch correction. The choice of these values does not affect the accuracy of the final solution. This choice is not an approximation but a conveniently selected value from which the exact values of the principal unknowns are determined. The diagram in the original publication and the associated sign convention show how this is achieved.

Procedure

Stage 1. (a) Make a set of observations to stars and/or planets at morning or evening twilight or (b) Take circum-meridian altitude observations on the Sun and use the well-known technique of plotting these on piece of translucent squared paper and folding it vertically to provide a simple solution for latitude and local longitude, or (c) Observe and calculate a running fix on the Sun.

Stage 2. Take a set of timed altitudes on the Moon as close as possible to the previous observations.

Stage 3. Advance or retire the position obtained in Stage 1 to the epoch of the Moon observation using the courses and distances run by the boat.

From an old log book the following observations, and later calculations, will demonstrate the method. The original observations were not intended to find longitude but will serve to demonstrate the principles of the technique. "…corroborative detail, intended to give artistic verisimilitude to an otherwise bald and unconvincing narrative. (Poo-Bah in Gilbert and Sullivan's The Mikado)".

Five minutes has been added to the original watch times.

Local date Sunday 5 July 1977. Index Correction -2.2'. Assumed Watch Correction 0 (Time Zone E10h), H of E 9ft., Course 200ºT Speed 6.0 knots. DR position S28º E158º.

At morning civil twilight two stars, a planet and the Moon were observed.

Body	WT	Sextant Altitude	Azimuth	Intercept
Achernar	5h37m42s	59º 50.6'	170º.1	A12.7
Venus	5h41m00s	30º 26.4'	046.0	T0.5
Sirius	5h51m42s	14º 14.4'	101.5	A10.9

Fix at 5h38m S27 º 48.9.0' E157 º 49.5'

At 5h 47m 00s the upper limb of the Moon was observed at a sextant altitude of 43º 00.5'.

See original paper for the sign conventions and definition of the various symbols about to be used.

Advance (Course 200ºT, speed 6.0 knots)

WT	Dist.	Latitude	Longitude
5h 38m	0.9mi	S27 º 48.9'	E157 º 49.5'
5h 47m		S27 º 49.7'	E157 º 49.2'(L_0)

Moon Intercept Calculations* at 5h 47m 00s.

Sextant Altitude 43 º 00.5', Latitude S27 º 49.7.

Watch Correction	Longitude	Intercept
0	E157 º 49.2' (L_0)	A1.4 (I_F)
Slow + 20m (W_S)	E152 º 49.2' (L_S)	A8.1 (I_S)

Note 20m = 5º L_S = E157 º 49.2' + 5º = E152 º 49.2'

$$F = \frac{I_S}{I_S - I_F} = \frac{-8.1}{^{-}6.7} = 1.209$$

Required Longitude

$$L_P = \text{E152 º 49.2' - F x 5º} = \text{E158 º 52'}$$

Required Watch Correction

$$W_F = 2\ 0\text{m}\ (1 - F) = -4\ \text{m}\ 11\text{s (Fast)}$$

Errors: Longitude 12', Watch Correction 49s.

It would be interesting to hear of the results of navigators who have had the opportunity to use the proposed method.

* The calculation of altitude using a DR position can be made in a variety of ways; the most direct being by means of a calculator. Non-calculator techniques such as those using logarithmic and natural functions may also be used. The Ageton Tables (H.O.211) have proved popular and consist of 49 pages of log secants and log cosecants at half minute intervals. A new set of tables based on those devised by Radler de Aquino at one minute intervals has been compiled and occupy 20 pages. These tables which can be down-loaded from the web site given before are identical to those given in The Complete On-Board Celestial Navigator except that the new tables are given to six significant figures instead of five.

Because so many navigators use sight reduction tables it would be a considerable advantage if a simple solution could be effected using tables such as Pub. No. 229.

* * *

NAVIGATION NOTES

NAUTICAL HISTORY CONTRIBUTES TO RESEARCH ON GLOBAL CLIMATE CHANGE

It's not often that nautical history can have a major impact on current political and scientific policy. However, in the ongoing debate over how much of global warming is due to natural variability, as opposed to human activity, it is critical to know as much as possible about climate in eras before the modern industrial age. Old ship's logbooks are a priceless resource, and in recent years have been digitized and analyzed. This work has two main areas of focus: general ocean climate, as in the CLIWOC project, and sea ice conditions in the arctic regions. A very interesting CLIWOC side project was the compilation of a multilingual dictionary of weather and sea-state terminology, so that (for example) the observations of a Dutch East India captain can be compared with those of a French or Spanish captain a hundred years earlier.

Here is a news item from Meteohistory.org

Climate scientists are nowadays very keen to get their hands on historical data. There was a time when some, if not many, meteorologists scorned climatologists as weather stamp collectors, but climate scientists now cannot get enough data from the distant past.

Monies of the order of £200,000 have been made available this year to image and have digitised (via the Climate Data Modernisation Program [CDMP] in the US) the ship log books of the British East India Company (EIC) held in the British Library. Some 2,000 EIC ship log books cover the period around the 1780s to 1830s, with about 900 log books containing instrumental observations. The EIC logs have data for the North and South Atlantic oceans, the Indian Ocean and the South China Sea. In addition, a small amount of monies will be used to complete the digitisation of Antarctic expedition supply ship log books for the first 20-30 years of the 20th Century. Over the 2008 financial year, another £200,000 will be used to image ship log books for an extended World War 1 (WW1) period over the globe (1914-1923). It is estimated that there are over 7,000 WW1 ship log books held in the National Archives of the UK. The 2008 funding will only be enough to get the WW1 log books imaged, and additional funds will be sought to have them digitised.

Alex Kirby summarized the CLIWOC project in BBC News Online in 2003, the year that project was completed:

An international team led by Dr Dennis Wheeler from the University of Sunderland, UK, is compiling the Climatological Database for the World's Oceans, or CLIWOC for short.

19th and 18th Century logbooks from UK, Dutch, French and Spanish fleets yield "consistent and reliable" data, slowly building up "one of the most accurate pictures yet of daily weather over the oceans."

CLIWOC says it "aims to discover more about the changing climate over the world's oceans before industrialization could have had any significant influence on climate and weather."

In 2000, the team began work on the logbooks, which span the years from 1750 to 1850. After that oceanic weather data depended much more on instrumental measurements.

Before 1750 the range of data available was much more limited geographically, but for the century Cliwoc is concentrating on the researchers say they have “a pretty good global spread, except for the Pacific”.

The logs studied include those from voyages made by the explorer Captain James Cook. Dr Wheeler said: “A lot of work has been done recently with world meteorological records going back 150 years. Our work goes back much further.

“Although oceans cover 75% of the Earth’s surface, we had very little information about the weather. These logs help us understand how climate changed in the past, which is a very useful tool when predicting climate change in the future.

“For the first time, with the exception of the Pacific, we can show the daily climate change for all major oceans between 1750 and 1850 and compare it to today’s conditions.”

The Sunderland team works with colleagues from a range of international organizations, including the UK’s National Maritime Museum and University of East Anglia, the University of Madrid, the Royal Dutch Meteorological Institute, and the University of Mendoza in Argentina.

CLIWOC says there are several reasons why the rich source of information the logbooks offer has been largely ignored till now.

One is that the data were not obtained from instruments, but from human observations and estimates, which led some scientists to distrust them.

Another is the difficulty of penetrating “the curious style and vocabulary of mariners of those distant times”.

And the sheer number of records available, the researchers say, “present a challenge, not of data shortage, but of over-abundance”. But they conclude: “The abundance of data for wind force and direction is invaluable. It tells us much about the broad patterns of atmospheric behaviour related to the high- and low-pressure systems.

“These systems govern the everyday weather that we recognise as rainfall, snow, temperatures, cloud and sunshine; in that sense the data can be regarded as more fundamental to our understanding of climate than are instrumental data such as temperature and rainfall measurements.”

“We’ve verified that the data are highly reliable. You find lots of ships sailing in convoy, and they all record the same thing. There’s a remarkable consistency of observation. And remember, the crews’ lives depended on them getting their records right.

“There are 250,000 logbooks in the UK, and we’ve only scratched the surface. There are far fewer in the three other countries - and virtually none in Portugal, where you might have expected many, because the Lisbon earthquake largely finished their collections.”

Links to CLIWOC publications can be found at:

www.knmi.nl/cliwoc/cliwocpub.htm

Of particular interest to readers of this Newsletter is a note on correction of longitude observations:

www.knmi.nl/cliwoc/publications/EGU2004-poster.pdf

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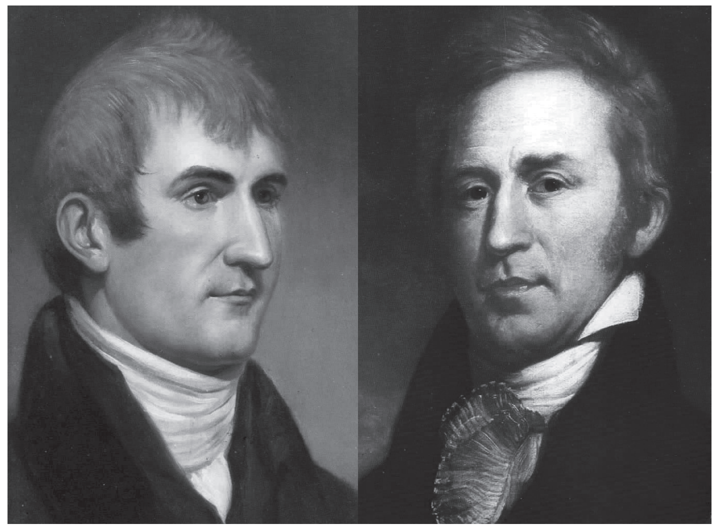
We are very pleased to have another installment of member Bruce Stark’s ongoing series on the navigation of Lewis and Clark. The first 4 parts are in preceding issues.

NAVIGATION NOTES

LEWIS AND CLARK’S NAVIGATION, AN OVERVIEW

by Bruce Stark



Meriwether Lewis 1774 - 1809 | William Clark 1770 - 1838

Part 5

On July 15th, 1803, after a dusty ten days on horseback, Lewis arrived in Pittsburgh. The wagon load of supplies and equipment from Philadelphia was waiting, and the one from Harper’s Ferry was there within a week, ready for the trip down the Ohio.

The Ohio was unusually low even for that time of year — too low for easy navigation — and was falling daily. To make matters worse, all the suitable boats had been taken.

A contractor had agreed to have a keelboat ready by July 20th, but the deadline was not met. As the weeks passed the river continued to fall. Lewis was there every day doing what he could to speed things along, but he was never able to get the contractor and crew to put in a full day’s work. Other deadlines came and went. Had Lewis had been able to round up enough pirogues and canoes to handle the baggage he’d have abandoned the keelboat to the builders. More weeks passed. Finally, on August 31st the boat was finished and on the same day Lewis, with about eleven men, loaded the baggage and headed down the Ohio.

With the river so extremely low they met one bar, or riffle, after another. Sometimes, after unloading the keelboat, they were able to lift and push it across. Other times they dug their way through. But in the worst cases they had to find a farmer with a team of horses or oxen to pull the boat over: " ...payd the man his charge which was one dollar; the inhabitants who live near these riffles live much by the distresed situation of traveller ...charge extravegantly when they are called on for assistance and have no filantrophy or contience..."

Even between the riffles it was no float trip. There was no discernible current to help, and the wind blew upriver four days out of five. Lewis and his crew worked hard with push-poles or oars to get from one riffle to the next.

After nearly a month of this they were no further than Cincinnati, and it seems the experience was doing nothing to improve Lewis' opinion of the boat builders. In a letter to Clark (who was waiting for him down the river) he complained of the "...unpardonable negligence and inattention of the boat-builders who, unfortunately for me, were a set of most incorrigible drunkards, and with whom, neither threats, intreaties nor any other mode of treatment which I could devise had any effect; as an instance of their tardyness it may serfice to mention that they were twelve days in preparing my poles and oars."

Finally, on November fourteenth, they reached the junction with the Mississippi. This was a place the United States might want to build fortifications. The party remained here until the twentieth, exploring and taking the measurements Clark would use in creating his map of the junction.

While the captains explored and measured, the men relaxed and enjoyed themselves. They caught a catfish that was fifty-one inches long, with a girth of forty-five inches. It measured thirteen inches between the eyes.

Although it wasn't mentioned in the Journal until later, the chronometer had stopped and been set going again. Perhaps because the daily winding had been missed, perhaps for other reasons. Chronometers were instruments of delicate temperament. No matter how strongly built, and painstakingly adjusted, they were easily upset by jolts, vibrations, circular motions, possible magnetic effects from nearby iron, and — in spite of compensations — changes in temperature.

Whatever the reason, the loss of Greenwich time took little away from the chronometer's value. More of a concern was a tendency these machines had of adopting a new rate after having stopped, and of taking a while to settle to it.

The best use of a chronometer, on an expedition such as this one, would be in determining the difference of longitude between points along the route. This would mean spending a few days in one place occasionally — long enough to find the chronometer's error on local time, and its rate of gain or loss. On arriving at the next point of interest the error on local time, and rate, would again be found. If the rate had not changed, the time at the previous location could be brought forward and compared with time at the present place. This would give an extremely accurate difference of longitude between the two points — just what a map maker would want.

If the rate had changed, then a certain amount of guesswork would be involved. But the result would still be quite useful.

And, if the chronometer had been allowed to run down, or stopped for some other reason, nothing would be lost but the chronometrical difference of longitude between two points. This could be smoothed over fairly well with the help of all the other data.

Jefferson's intention was that all raw data — from dead reckoning, azimuth observations, latitude observations, equal altitudes, and lunars — would be brought back. It would be put in the hands of a skilled map maker who would do the calculations, compare and weigh various aspects of it, and blend it all into the map Jefferson, and the Nation, hoped for.

Unfortunately, things didn't work out that way.

Clouds prevented Lewis from completing an observation on the fifteenth, but he had better luck on another day.

He labeled his observation an "equal altitude," and that's what it is. Some writers would call it a "double altitude," which worsens an already confused situation. Altitudes measured from an artificial horizon are also called "double altitudes," and in both cases the name is a perfect fit. But historically it belongs to neither. Originally, and on through the nineteenth century, a "double altitude" was an observation of two unequal altitudes and the elapsed time between them.

The purpose of this, the first recorded sextant observation of the expedition, is to find local time. More precisely, to find the difference between chronometer time and local time. That is, "regulate" the chronometer on local time.

Lewis noted the chronometer's reading at each of the six stages of the observation:

Took equal altitudes of the sun

	h	m	s		h	m	s
A.M.	8	33	32	P.M.	2	36	38.5
	8	35	35.5		2	38	27.5
	8	37	30.5		2	40	30.5

Altitude given by sextant sun's center 39° 50' 00"

Beneath this record of his observation Lewis gives his analysis:

Equal altitudes corrected

	h	m	s		h	m	s
A.M.	8	35	35.5	P.M.	2	38	27.5

		m	s
Chronometer too slow	M.T.	22	56.1
do. do.	Apt. T.	22	55.1

What he means by "Equal altitudes corrected" is unclear, though the times are the same as when the sun's two images overlapped. Where the values for chronometer error came from is even less clear, but they can't be right. Here the difference between apparent and mean time — the equation of time — is a mere one second. This is mid November. The difference has to be close to a quarter of an hour.

Actually, it would have been remarkable if Lewis had gotten his analysis right. Five months had passed since he finished his brief instruction in Philadelphia, and most of that time he'd been struggling with boat-builders or the river. There'd been little opportunity to review what he'd been taught. Moreover, he was just recovering — with the help of a dose of Dr. Rush's mercury-laced "thunderbolt" pills — from a fever.

Whether or not Lewis worked this observation, or any other, was up to him. His instructions only required that — once he started up the Missouri — he take and record them. Later on, someone with fewer distractions could do the calculating.

In undertaking the calculations it's a good idea to keep in mind that the numbers you read aren't necessarily the ones the instruments gave. Copying numbers tends to be a blunder-plagued procedure, and the ones we have are the last link in a chain of copies, recopies, and copies of recopies.

In most cases, though, the six-part procedure Lewis followed in taking equal altitudes serves as a framework for examining the individual numbers.

Since he generally preferred the sextant's inverting telescope, with its higher power, superior optics, and collimating threads, Lewis saw everything upside-down. But it's easier to explain the operation as it appears with the regular telescope.

Some time in the morning, preferably at least a couple of hours before noon, bring the sun's image, seen in the sextant mirrors, down below the sun's image in the water of the artificial horizon. Clamp the index, and leave the sextant's setting unchanged until the observation is complete. As the sun rises, note the chronometer times when the two images first touch, when they exactly overlap, and when they separate. In the afternoon, as the sun descends to the same altitude, again note the times of first contact, overlap, and separation.

The intervals between times of contact, overlap, and separation are determined by how long it took the sun to rise or fall its own diameter, and should be nearly equal. However, since the sun rises and falls fastest when near east or west the time of overlap may be one or two seconds earlier for the AM set, and later for the PM set, than would otherwise be expected.

Notice that the first PM time (2:36:38.5) fits poorly in the pattern of the other numbers. It seems reasonable to suppose it was originally 2:36:33.5 and a hastily written 3 was mistaken for an 8 when it was transcribed, probably by the light of a candle lantern, into the Journal. Whatever the reason for the 38.5, the other numbers are united against it, and suggest that 33.5 would be a better fit. Since it is only one of six numbers, making the five second change will shift the the outcome of the observation less than one second.

The overlap times don't look right either. The AM overlap time is too late, the PM time to early. Throwing them both out may improve matters, and won't upset the balance.

Thus adjusted, the average, or "middle," time is 11:37:01.6 — only nine-tenths of a second different than it would have been without the alterations. The six-part procedure makes for a robust observation.

Lewis failed to record the date. But, since latitude of the junction was already known, this is only an inconvenience: With a latitude of 37° 0.'4 N, half the elapsed time, and the altitude, calculate the sun's declination. Then find, in the Almanac, the date this declination fits. In November the sun's declination is changing fast, so there can be no uncertainty: It was the sixteenth.

The average of the six recorded times would be what the chronometer read at noon — if the sun's declination had been the same for both AM and PM times. That's virtually never the case, and an adjustment, called the "equation of equal altitudes" has to be made. I calculate this to be 10.7 seconds, additive to middle time.

Middle time	11:37:01.6
Equation of equal altitudes	+ 10.7
Chro. at Apparent noon	11:37:12.3
Chro. too slow Apparent T.	00:22:47.7

To find the chronometer's error on mean time I took the "equation of time" from an 1803 Almanac, interpolated for an approximate longitude of 90° west, and found that 15 minutes, 4.1 seconds should be subtracted from apparent time.

So it appears that when it was 12:00:00 local apparent noon the chronometer read 11:37:12.3 and, at that moment, local mean time was 11:44:55.9.

This regulates the chronometer: 7 minutes, 43.6 seconds slow on mean noon, November 16th, Ohio-Mississippi junction time.

But the regulation will soon lose its value if rate of gain or loss isn't known. That's why Lewis took another observation on the day before leaving the junction.

Nov. 19th

Took equal altitudes

	h	m	s		h	m	s
A.M.	8	42	18	P.M.	2	25	21.5
	8	44	12		2	27	24
	8	46	10		2	29	26

Altitude Art. Horzn. & sectns. 41° 26' 37" Sextant Error 8' 45"—

That last remark means "To correct the index error, subtract 8' 45" from the sextant's reading."

Notice that the total interval for the PM contacts is twelve-and-a-half seconds more than for the AM contacts. Perhaps the roof of the artificial horizon was starting to fog. Or perhaps two different people were doing the timing and one wasn't familiar with clocks and watches. Various conjectures could be made, but there seems to be no reasonable basis for deciding how the numbers might be improved. Taken as they are and worked for mean time they give: Chronometer too slow 9 minutes, 34.1 seconds. That shows a 1 minute, 50.5 second loss of mean time in three days. The chronometer appears to be losing 36.8 seconds a day.

Lewis didn't record a result here. But it seems, from remarks he made eight months later (volume 2 of Moulton, pages 381, 382, and 412) he thought he'd proved the rate to be 15.5 seconds, losing.

Everything Lewis knew about equal altitudes must have come from Ellicott. There's nothing about them in Patterson's "Notebook," nor in any of the other written material the expedition is known to have carried. Ellicott may or may not have explained how to work them for chronometer error. In his opinion there was no need to spend any of Lewis's brief instruction time on the complexities of calculation. Once the expedition returned, any map maker the data was turned over to would insist on doing that for himself, regardless of whether it had been done beforehand.

The only aspect of nautical astronomy Lewis needed to master was skill in taking and recording observations. And, because there was so little time for for that, it would be wise to keep things as simple as possible. Besides ignoring the more complicated calculations, this would mean passing over a number of useful observations and focusing on a selected few. These few could then be practiced until they became routine.

Lewis could get by with the meridian altitude for latitude, equal altitudes for regulating and rating the chronometer, lunars for longitude, and the altitude-azimuth for compass error.

Equal altitudes were not only the best means of regulating and rating the chronometer, they could take care of another problem as well. In his letter to Jefferson (page 24 of Jackson) Ellicott wrote:

> Although the meridian altitude of the sun, when it exceeds 60°, cannot be taken with a Sextant from the artificial horizon; yet the latitude may be accurately determined by using the altitude of the sun, and the horary angles formed in taking equal altitudes to ascertain the error, and rate of going of either a clock, or watch. This method I have constantly used when the meridional altitude of the sun exceeded 60°...

But Patterson had a different approach to this problem. When the angle between the midday sun and its reflection in water was beyond the 120° range of a sextant, he used a quadrant's back-horizon glass. He suggested Lewis buy a quadrant, then taught him how to take a back-sight in an artificial horizon. There were advantages to this method, but probably not enough to justify the learning time devoted to it, or of having a quadrant instead of another sextant.

Ellicott seems to have approved of the quadrant. But this may have been because—for reasons that will be explained later—he was careful not to step on Patterson's toes.

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INTERNET RESOURCES

Navigation calculators to download

As you may know, the complete Bowditch Navigator is online and there are several links to it. The 2002 bicentennial edition is the latest. The link to it, however, is *very* long and complex. The publisher is the NGA (National Geospatial-intellegnece Agency). You can find a shortcut to this at starpath.com/navpubs which uses a "tiny url" we created to compact the long one. Once you get there you can copy the exact link if you like. On that page you will find a link to a zip file that includes several dozen html pages that carry out standard navigation calculations. The package, however, is not very well indexed so for some it is not so easy to use.

To remedy this, some years ago, we packaged these calculator functions into what is called an html-help file, called nav-calc.chm. and placed this in our freeware section for mariners to use. Thus you can use this link to get these calculators which should be useful to many applications.

http://starpath.com/freeware/nima-nav-calc.zip

When you unzip it you will find a single file called nima-nav-calc.chm, which includes these computations:

- Altitude Correction for Air Temperature
- Altitude Correction for Atmospheric Pressure
- Altitude Factors & Change of Altitude
- Amplitude
- Correction of Amplitudes Observed on the Visible Horizon
- Latitude and Longitude Factors
- Meridian Angle and Altitude of a Body on the Prime Vertical Circle
- Sight Reduction (find Hc and Zn from LHA, dec, Lat)
- Table of Offsets
- Chart Scales and Conversion for Nautical and Statute Miles
- Conversion for Meters, Feet and Fathoms
- Dip of Sea Short of the Horizon
- Distance by Vertical Angle Measured Between Sea Horizon and Top of Object Beyond Sea Horizon
- Distance by Vertical Angle Measured Between Waterline at Object and Top of Object
- Distance by Vertical Angle Measured Between Waterline at Object and Sea Horizon Beyond Object
- Distance of an Object by Two Bearings
- Geographic Range
- Distance of the Horizon
- Length of a Degree of Latitude and Longitude
- Meridional Parts
- Speed for Measured Mile and Speed, Time, and Distance
- Traverse Table
- Time Zones, Zone Descriptions, and Suffixes
- Correction of Barometer Reading for Gravity
- Correction of Barometer Reading for Height Above Sea Level
- Correction of Barometer Reading for Temperature
- Barometer Measurement Conversions
- Temperature Conversions
- Direction and Speed of True Wind
- Relative Humidity and Dew Point
- Great Circle Sailing
- Mercator Sailing
- Log and Trig Functions

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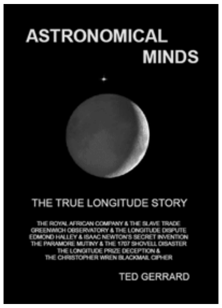
BOOK REVIEWS

Astronomical Minds: The True Longitude Story

By Ted Gerrard

Samos Books, Broadford, Isle of Skye (2007, 268 pages, $27.95)

Book review by George Huxtable



I've been asked for my opinions about Ted Gerrard's new book, "Astronomical Minds". With a slight involvement, having been invited to scan an early draft for technical mistakes as part of the error-checking process, it's not possible to offer a completely independent review. But I'll be as independent as I can, and you can take that for what it's worth.

It covers that fertile century of scientific development from roughly 1650 to 1750, concentrating exclusively on English work, with the Royal Society at its centre. Many well-known names are drawn in, Wren, Hooke, Newton, Flamsteed, Halley, Shovell, Hadley, Harrison, and the book ends about the time when Maskelyne and Cook would appear on scene. The story told by Gerrard deals mainly with the quest for a way to find longitude at sea. It acts as a useful counter to the one-sided picture that's been built up before by Sobel, who concentrated on Harrison's watch-work. Here, the timekeepers gets shorter shrift, and the emphasis is on astronomical solutions. If there's a hero, it's Edmond Halley (and deservedly so). If a villain, that's Shovell.

The book is a riveting read. It's written in a racy style, and if you're an academic historian, that may set your teeth on edge. It has the great advantage of having been written by an experienced navigator, not by a historian confined to a library. So Ted shows his great insight into the practical problems that beset a navigator in finding his position at sea. He allows himself much more freedom to speculate than a historian would, which is fine by me. The weakness, in my view, is the way that plots and intrigues are discovered under every bush. My own view of history is that cockups play a larger part than conspiracies; but everyone to his own taste.

Ted enjoys relating the interactions between these larger-than-life characters, their feuds and their follies. But also, he has delved deeply into the records, so this is far more than a rehash of the standard texts, and becomes a real quest into the way that scientific knowledge unfolded. He has used modern tools, such as sky simulation programs, which have allowed him (and now allow us) to follow events such as Halley's star appulses with the Moon. All this has enabled him to draw conclusions, such as Halley's use of Newton's quadrant, which are new or unrecognized. His sources are well referenced, but with occasional gaps.

Any dislikes? Yes, two. He devotes space to discovering coded hidden meanings in inscriptions and epitaphs. No doubt, a lot of that sort of thing went on in the era, but it leaves me a bit cold. If you're a crossword enthusiast, it may be for you. Or you can skip those bits, like I did. And the other? I couldn't get on with his indexing scheme.

The book costs £13.95 (about US$29), surface shipping worldwide included, from www.samosbooks.org

Review by George Huxtable

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NAVIGATION NOTES

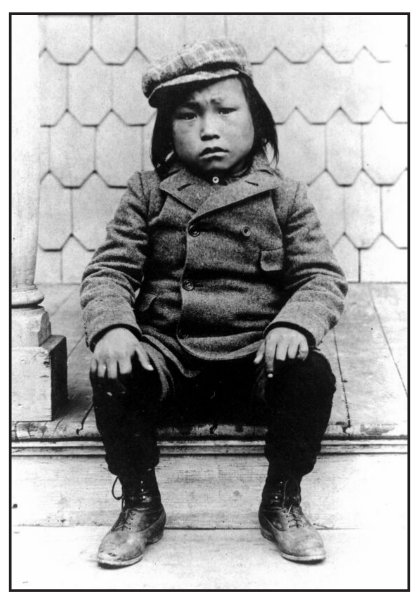
National TV Show Misses the Mark on Peary Accomplishment.

by David Burch

On Mar 31, 2008 the PBS TV show American Experience did a program called "Minik, the lost Eskimo" (www.pbs.org/wgbh/amex/minik) about the sad story of the Eskimos brought back to the US from one of Peary's northern expeditions. The story is reminiscent of that of the Fuegians brought back to the UK by FitzRoy, who later returned the surviving three to Tierra del Fuego on his voyage with Darwin. It took explorers a long time to recognize that no matter how well intentioned (if so), displacing peoples to another culture is rarely successful.

But that is not the issue here, nor are we certain of the factual content of the American Experience retelling of that part of the story. In fact, there is every indication they are not careful about the facts. What is clear is they ended the story with the dramatic mis-statment that the National Geographic Society (NGS), who was a supporter of Peary, had changed their mind and concluded that Peary was a freud and did not reach the Pole. This was presented as if it were the last word, applicable today.

It is well known there was a time that many, including the NGS, doubted Peary's accomplishment, but that is the very reason the NGS commissioned the Foundation to make the definitive study they did. Furthermore, it is almost impossible to do research on this topic and not discover *The Peary Report* that did prove beyond doubt to all professionals, including the NGS, that Peary did indeed do as he claimed. It seems their intention was to use this for a sensational close to the program, with total disregard for the truth.



Minik, the lost Eskimo

I wrote to them explaining the implications of their misstatement, since they plan to use this program throughout the school system, offered to help resolve this in any way we could, and provided references for *The Peary Report*. I received a form letter back, with no indication that anyone read it.

OBITUARIES

long time member Frank Piasecki

Frank Piasecki, 88, an engineer who flew the second successful helicopter in America and built the first technically and commercially viable tandem-rotor helicopter, died Feb. 11 at his home in Havertown, Pa., after strokes.

Mr. Piasecki ranked with Igor Sikorsky and Arthur Young as a major helicopter visionary of the last century. His most significant contribution was creating, in 1945, a helicopter with one rotor each in the front and back, which could carry three times the weight of conventional helicopters.

His work helped extend the helicopter's use beyond aerial observation into combat, commercial and rescue applications.

Roger Connor, curator of vertical flight at the National Air and Space Museum, said Mr. Piasecki's tandem-rotor design was significant because single-rotor designs "had trouble carrying weight of any size because the engine was under the rotor system. Adding cargo would unbalance the aircraft and take it off the center of gravity'

Connor said Mr. Piasecki's tandem-rotor helicopter could "handle large cargo and a shift in weight without difficulty. It greatly increased capability at a time the military was beginning to look at that."

For a time, Mr. Piasecki and Sikorsky were at the forefront of their industry and competed to address problems with carrying ever-larger cargo loads, Mr. Piasecki's designs were first used operationally by the Navy in the early 1950s but were not deployed to Korea during the war there.

Connor said Mr. Piasecki persuaded the French to use a second generation of Piasecki helicopters, the H-21 series, during the Algerian war during the 1950s.

From the successes and failures in Algeria, Mr. Piasecki was better able to refine the aircraft for the U.S. Army and Air Force in the Vietnam War. He continued over the decades to make helicopters compatible with military needs, such as avoiding radar detection and landing in remote or harsh conditions.

Technologies from his early designs led to the later development of the Army's Chinook and Navy's Sea Knight, both of which are still in use.

Frank Nicholas Piasecki, whose father was a Polish immigrant, was born in Philadelphia on Oct. 24, 1919.

As a teenager, he worked at two local companies making autogyros, a precursor to the helicopter. Many may recall the autogyro for its memorable appearance in two popular films of the early 1930s, "International House" with W.C. Fields and "It Happened One Night" with Clark Gable.

Mr. Piasecki was a 1940 aeronautical engineering graduate of New York University and that same year co-founded a company, P-V Engineering Forum, near Philadelphia.

He chose the name, he told the New York Times, "because if you used the word 'helicopter' people thought you were absolutely nuts."

He built his earliest helicopter models from parts he found in an auto junkyard near Philadelphia, and in 1943 followed Sikorsky as the second American to successfully fly a helicopter, the single-rotor PV-2.

Mr. Piasecki did not have an airplane license, and an awkward moment ensued as he prepared to test the PV-2 for military dignitaries at National Airport. A licensing official with the civil aviation agency asked for his airplane pilot's license, and he did not have one. As a result, Mr. Piasecki received the first helicopter license, Connor said.

In 1945, Mr. Piasecki developed the first tandem-rotor helicopter and it was soon put into production by the Navy. It was affectionately known as the "flying banana" for its bent fuselage, which keeps the rotors from hitting each other. In 1960, Boeing bought one of Mr. Piasecki's successor businesses, Piasecki Aircraft Corp., and he continued to work in research and development.

One of his notorious failures was the Heli-Stat, a 343-foot-long airship made from a helium blimp and four surplus Sikorsky helicopters. It was designed for the U.S. Forest Service to help with timber harvesting in remote areas.

His Heli-Stat project ended in disaster when it crashed in 1986 at the New Jersey airfield where the Hindenburg dirigible exploded in 1937. A pilot was killed and three others were seriously injured.

Mr. Piasecki remained a revered figure to many helicopter enthusiasts. He received the National Medal of Technology, the country's highest honor for technological achievement, as well as the National Air and Space Museum's lifetime achievement award. He also was inducted into the National Aviation Hall of Fame.

Survivors include his wife, Vivian Weyerhaeuser Piasecki of Havertown; seven children; and 13 grandchildren.

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The Foundation for the Promotion
of the Art of Navigation
PO Box 1126
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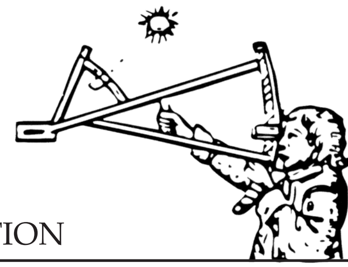
"THE NAVIGATION FOUNDATION"

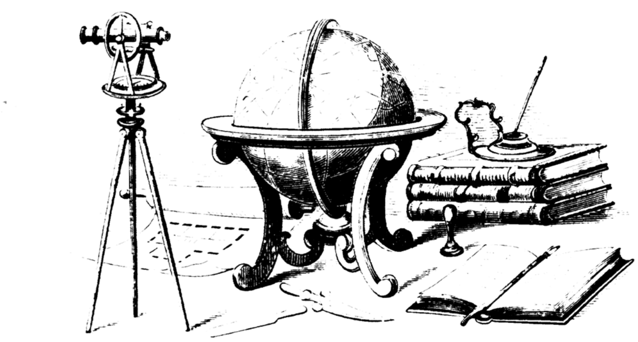
ISSUE 98, Winter 2008

THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a reader forum for the expression of our members opinions and their questions.



ACTIVITIES

By Terry Carraway

As this issue is close on following the last issue as we get caught up on the Newsletters, we do not have new activities per se here, but we will have a report on the Foundation's Tabor Academy Award in the next issue. We are grateful to our members support during this time when we were behind on the Newsletters.

Director Roger Jones has fielded quite a few questions from members and potential members during the past few months about various aspects of celestial navigation. These will be summarized in the next issue as well.

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EDITOR'S NOTES

By David Burch

We have two feature items this issue. One is an in-depth report by member Geoffrey Kolbe on the Celestial Navigation Weekend at Mystic Seaport, which was organized by Frank Reed, celestial navigation expert and comanager of the NavList online discussion group. Thanks to Geoffrey and to Frank for providing these notes on this successful event. I hope members see what a gold mine these weekends can be for those who care about celestial navigation. This was the second of what we hope will be an ongoing event. Notes on the NavList online discussion and future plans are in Geoffrey's report.

The other feature is an extended book extract on the history of Pilot Charts as they arose in the new Hydrographic Office. It features among others the role of Matthew Fontaine Maury, father of our modern Pilot Charts—which, by the way, are not much different now than they were in mid 1800's, and still equally as valuable. Also known as "First Scientist of the Seas," he was head of the USNO for the 16 years leading up to the Civil War, but ended up leaving to serve in the Confederate naval establishment. During the war he developed torpedoes for the Confederacy that were "credited" with doing more damage to US vessels than all other sources combined. After the war he became a Professor of Physics at Virginia Military Institute, sometimes called "the West Point of the South." His story is just one more example of how difficult it is to comprehend this tragic period of American history.

We also sadly include the news of the loss of Leif Karlsen, long time member and author of *Secrets of the Viking Navigators*.

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The Navigator's Newsletter
Published by
The Foundation for the
Promotion of the Art of Navigation
www.navigationfoundation.org
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Rockville, Maryland 20850, USA
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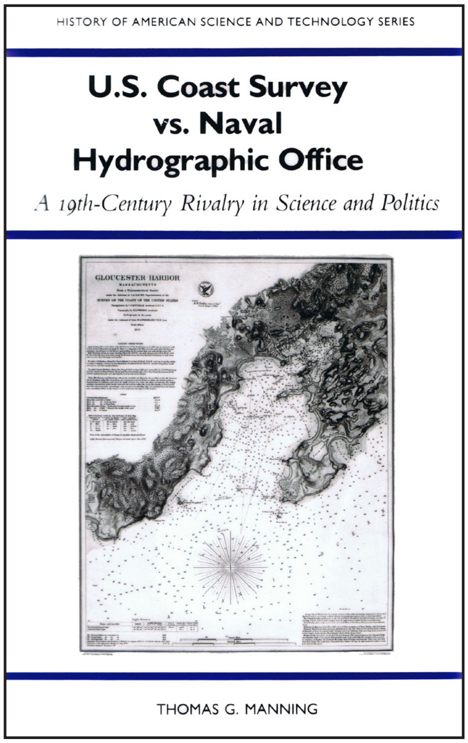
The Navigator's Newsletter is published four times annually, with our strived-for publication dates of approximately the solstices and equinoxes. Newsletter production and other Foundation activities are provided by volunteers. Please bear with us if we slip on the dates occasionally.

BOOK REVIEW

U.S. Coast Survey vs. Naval Hydrographic Office —A 19th Century Rivalry in Science and politics

by Thomas G Manning.
The University of Alabama Press, Tuscaloosa, AL.
216 pages, paperback 2003. $30. ISBN 0-8173-5080-2



During these days when we see the conflict between science and politics as sharp as ever before—with politics clearly winning at the moment (the old Hydrographic Office has evolved into the National Geospatial-intelligence Agency and the Coast Guard is now part of the Homeland Security Department)—we thought it might be of interest to members to recall that this conflict is not at all new. Part of this story is well told and documented in this book, which we recently ran across when researching the history of pilot charts. It tells the story of the "Emergence of the H.O." We look forward to one day having a contribution on the modern history of this Office and its successors, ie HO —> DMA —> NIMA —> NGA. Do we have any volunteers?

We were fortunate to receive permission from the University of Alabama press to reproduce the excerpt below to give members a feeling not only for this history, but for this excellent book itself, which covers other aspects as well. It is readily available online or directly from the publishers.

Note that even though there is reference here to both Robert E Peary and a John Russell Bartlett in the same sentence, this latter figure is not to be confused with Robert A. Bartlett who was Captain of the Roosevelt *who took Peary north on his successful polar venture. Capt Bob Bartlett is a remarkable figure in maritime history, well worth looking into if you are not familiar with his accomplishments. This John Russell Bartlett is also not to be confused with his contemporary also named John Russell Bartlett, who, though he had done some years of survey work, was actually more renown later on for his work in linguistics, published in his* Dictionary of Americanisms *(1848). The Bartlett of this book is another interesting figure, not so well known as the other two, but as this book shows, he deserves to be.*

The following is from Chapter 2 of the book. Thanks again to Claire Evans of UA Press for her stated support of the Foundation and permission to reproduce this extended excerpt.

If you have an early copy of Bowditch*, you will recognise the H.O. as one of its earliest publishers.*

THE EMERGENCE OF THE HYDROGRAPHIC OFFICE

Like the Coast Survey, the Department of the Navy practiced scientific surveying in antebellum times. Twice it had been the sole surveyor of the American coastline, before the Coast Survey had fully organized its systematic mapping. Customarily, non-American shores and waters were the navy's exclusive domain. The climax of naval surveying came during the expedition to the South Pacific, commanded by Lieutenant Charles Wilkes. At home after 1842, Lieutenant Matthew F. Maury exercised leadership in naval science, occupying a dual position as superintendent of both the Naval Observatory and a "hydrographical" office. Maury, a Virginian who had been a midshipman in the navy, could no longer go to sea because of a serious knee injury. His chief rivalries in government science were with Joseph Henry of the Smithsonian over the control of land meteorology, and with Bache about deep-sea soundings in the Atlantic.

Maury made his name in world science when he transformed the hydrographic duties of his job, which, before his time, had merely required the administration of a depot for naval charts and instruments. He commenced with the painstaking collection of information from mariners' logs and, with the knowledge thus acquired, constructed wind and current charts for the Atlantic, Pacific, and Indian oceans. On several series of these charts he plotted winds and currents, and collated statistics on their prevailing directions. He also drew the tracks and gave the names of vessels from whose logs the marine information was derived. Maury recorded water temperature, located breeding grounds of whales, and organized materials on the frequency of storms and rains. A second large accomplishment of this remarkable man was the compiling of sailing directions of coast pilots for coasts other than the American, where, of course, the Coast Survey presided. [1]

The Civil War ended forever Maury's association with governmental science, because he joined the Confederacy. For several years in the 1860s, no appropriation was forthcoming in support of his maritime projects. With the coming of peace, however, and given the friendly disposition toward governmental projects in science, which had inspired the expansion of the Coast Survey, a successful revival of Maury's pre-war hydrography came to pass. Shipmasters and insurance companies presented Congress with a lengthy memorial, Rear Admiral Charles H. Davis of the Bureau of Navigation and Bache of the Coast Survey collaborated, and a military-civilian board declared it a governmental responsibility to publish charts and books for American navigators. [2] Describing his project as a venture in "Foreign Hydrography," Admiral Davis proposed that naval vessels do coastal surveying abroad and that a hydrographic office engrave the results. [3] If charts of foreign shores were already available, let the new agency replenish them as they were disposed of. Also, Maury's wind and current charts would be republished.

In 1866, Congress passed "An Act to Establish a Hydrographic Office in the Navy Department"; this Act made the Office independent of the Naval Observatory and placed it in the Bureau of Navigation. The Treasury and the Bureau of Navigation arranged for the newly created Hydrographic Office to assume responsibility for publishing *The New American Practical Navigator*, which the concern of E. & G. W. Blunt of New York City had been bringing out all through the century. The Blunts were the foremost publishers of nautical textbooks in the United States, and these textbooks provided seamen with all the tables needed for determining latitude and longitude, if they also possessed the Nautical Almanac, which was already being published by the government. In 1867, the Navy Department, Gideon Welles being secretary, found $70,000 to pay the Blunts for the copyright and stereotype plates of the thirty-fifth edition of the *Practical Navigator*.

The Hydrographic Office flourished primarily as a maritime publishing company. During the early seventies, before an economy movement began to undermine government finances, it spent $100,000 annually (almost all of it in Washington) and operated at the well-known Octagon building with a staff of fifty persons, twenty of them naval officers. This place was a compiling, printing, and distributing center, based initially on the past projects of Lieutenant Maury. The new Hydrographic Office reprinted charts from Maury's copper plates, and then began its own engraving of revised charts, whose ancient originals by Maury were frequently overloaded with signs, figures, and lines. It also republished *The New American Practical Navigator*. In 1869 the Office began preparing notices to mariners about man-made and natural changes along all coasts save the American, for which the Lighthouse Board was responsible. Concurrently, the Bureau of Navigation organized an Admiralty chart room, and for many years the Hydrographic Office reproduced charts of the British government,

Matthew Fontaine Maury, Pathfinder of the Seas

then dominant in marine publishing. In 1870, Captain Robert Harris Wyman, author and translator of oceanographic materials, became the leader of the Hydrographic Office. He was the first to be called Hydrographer and served the longest in the agency's history—eight years.

The Office also originated other publishing ventures. Lieutenant Commander Henry H. Gorringe, who later won popular renown by delivering and putting up an obelisk in Central Park, commanded the USS *Gettysburg* in the Mediterranean from 1872 to 1876. Gorringe took soundings, measured winds and currents, described stretches of the coast, and learned about local laws and customs, all of which went into Office guidebooks. Gorringe insisted that he was not making a coast pilot for vessels of war, which, after all, could carry hundreds of charts. His purpose was to help the merchantmen who could not afford a nautical library. His *Coasts and Islands of the Mediterranean Sea*, published by the Hydrographic Office in four volumes between 1875 and 1883, was called a "splendid sailing directory." [4] The reprinting of the pamphlet *Steam-Lanes across the Atlantic* represented a return to Maury, who had first placed the work before the public in the 1850s. The New York Board of Underwriters ordered a thousand copies. Ernst R. Knorr, the civilian head of the drafting department, translated a collective German work on the Gulf Stream, which improved on Maury's presentation of ocean temperature by drawing isothermal lines.

The officer corps of the Hydrographic Office projected their brightest hopes toward the Pacific Ocean, where they most wanted to do research. This ocean seemed the "natural and necessary highway" [5] of great trade to the Far East. The dream of an interoceanic canal also stirred the imagination of naval officers, and they looked expectantly to communication with Japan by cable. Scientific chart making on Mexico's Pacific Coast was the specific activity to which the corps gave their most earnest and continuous attention. Irregular, disconnected, or ancient surveys were characteristic of the long coastline south of the American border. It was easy to compile, from the best London charts, a page of errors on coastal positions, on offshore islands, and on depths and dangerous rocks. Officers hoped the results would compare favorably with the Coast Survey product and lead to the making by the Hydrographic Office of all the maritime charts for American territories around the Pacific basin.

In 1872 an appropriation of $50,000 allowed a start in Baja California and the Gulf of California. [6] For three years, until the lack of money closed down the operation, naval officer George Dewey, commanding the USS *Narragansett*, determined latitudes and longitudes, made soundings, and located positions by the measurement of horizontal angles with the sextant. On land and sea, he took the bearings of the principal peaks and their angular altitudes, and he sketched in the shore as he moved down the Mexican coast into the Gulf of California. To accompany this reconnaissance or running survey, Dewey provided information on winds, currents, and tides, on anchorage, channels, and drinking water. Recognizing Dewey's work as an improvement over the publication of its own Hydrographic Office, [7] the British Admiralty hastened to engrave the results, which was done before the American Office could secure publication funds from Congress.

The Caroline and Marshall Islands were another unknown and threatening region. These islands were the repository of thousands of dangers, many of which probably did not exist or were incorrectly located. Sometimes the same island had half a dozen positions assigned to it, with opinions differing by as much as fifty miles as to its proper location. The only thing that the Hydrographic Office could do at the time to keep ships from piling up on poorly located rocks, shoals, or islands was to update sounding sheets and reports and to publicize reported dangers to navigation in the North Pacific Ocean.

An impressive feat occurred in 1873, when Commander George E. Belknap sailed the USS *Tuscarora* on a deep-sea exploring expedition, his primary purpose being to determine the feasibility of laying a submarine cable between the United States and Japan. Maintaining the antebellum, innovative spirit of the American navy in marine technology, Belknap used steel wire instead of hemp line for the sounding machine, invented by William Thomson. Also, the commander was good at inventing cylinders or cups for bringing specimens up from the bottom. Northeast of Japan, he sounded five and one-quarter miles to pick up five ounces of mud; this was the greatest depth recorded until 1895, when two British ships secured bottom samples in the South Pacific at six miles. [8]

The next prominent hydrographer after Captain Wyman was Commander John Russell Bartlett, explorer, scientist, and naval officer, who made his regime of five years (1883-88) the nineteenth-century climax of the Hydrographic Office. Bartlett inspired his organization with a spirit of improvement that looked to the day when all aids to navigation would be "perfect." [9] He sought new ways of applying scientific knowledge to the navigation of the North Atlantic and hoped, through services performed, to raise the standing and influence of the navy with the commercial and seafaring classes. In his relations with Congress, he managed to reverse the downward trend of the annual budget and bring it back almost to the $100,000 level of Captain Wyman's early years at the Office.

Bartlett presided in the basement of what naval officers liked to call the New Navy Building, which actually was a section of the large and well-known State, War, and Navy edifice next to the Executive Mansion. Although in a basement, their quarters seemed palatial to the officers working there, some of whom remembered the small and crowded rooms in the Octagon building two blocks away, where the lighting had been bad and the corridors jammed with charts. The new rooms had Brussels carpets, oak cabinets, walnut screw stools, and glowing cherrywood desks with olive-green covering and brass handles. Very early in his tenure as Hydrographer, Bartlett felt compelled to assert authority within his own household. He thought that Knorr, the civilian chief draftsman and editor, had too much power and was making charts which lacked uniformity in lettering, abbreviations, and other graphic elements. Knorr's salary was soon reduced 50 percent, and the next year he was dismissed upon Bartlett's recommendation. [10]

Bartlett's happiest innovation, beginning in December 1883, was the publication of a monthly pilot chart for the North Atlantic. He saw how rapidly maritime knowledge was accumulating—from the increase of commerce on the North Atlantic, from the large number of fast steamers, and from the submarine cable—and he proposed that the Hydrographic Office disseminate this knowledge through pilot charts. The pilot chart was Maury's wind and current chart, revised more often now, and furnished with other information of contemporary maritime interest. A composite affair, it had as its base an ordinary chart of the North Atlantic on Mercator's projection, lithographed in black, with such permanent features as a compass card, magnetic variation curves, the line for the depth of 100 fathoms, and small black arrows for the drift of ocean currents. Overlaid in blue color were the weather conditions for the month of publication: blue arrows with crossbars for the frequency and force of winds and blue lines for the region of fogs and icebergs, the limits of trade winds, and the location of equatorial calms. These graphic materials were synopses rather than forecasts; they summarized the experience, since the middle of the century, of ships passing through different areas of the Atlantic Ocean. Steamship and sailing routes were also given. Printed in red on the pilot chart was information drawn from events of the month just before publication: derelict vessels, wrecks, icebergs, the belt of Newfoundland fog, and information about lights and buoys.

As if this was not enough, Bartlett put on the side or back of the pilot chart notices to mariners, weather reviews, listings of other published charts, the circulation of winds around low-barometer areas, and tables of barometric readings. The magazine Science thought it "almost impossible" to publish on one chart such a variety of information. [11]

Bartlett needed new institutional arrangements to make his program of pilot charts work. He felt he must get in touch with the captains of ocean steamers and the masters of merchant vessels to secure materials for the pilot charts, then distribute the finished product to the same people. He went to Congress, therefore, in 1884 and won permission to open branch hydrographic offices in the maritime exchanges of half a dozen leading American seaports: Boston, New York, Philadelphia, Baltimore, New Orleans, and San Francisco. [12] Manned by graduates of Annapolis, these branch offices became at once busy centers where "a continuous stream of people" sought "information of all kinds." [13] The naval officers in charge of these branches sent cards to masters, inviting them to call; they also urged the local press to publicize Navy Department activity; they mailed pilot charts, sorted notices to mariners sent from the central office, and above all talked to sea captains, vessel owners, insurance companies, and maritime associations about the latest nautical knowledge. In one year the New York branch office arranged visits to six thousand vessels, furnished information to eight thousand masters, distributed gratis ten thousand pilot charts, and forwarded to Washington thirty-five hundred reports for preparation of the monthly pilot charts.

The pilot charts and the branch offices were a spectacular success at home and abroad. Often called "aristocratic," the navy did well this time in reaching the man in the street and the man at sea. The Coast Survey had never distributed its own publications but used private agencies, which sold them at a profit. The New York Herald and the Boston Post were two newspapers which reproduced the monthly pilot chart. French and British sea captains were "extravagant" in their praise for the way the Hydrographic Office was collecting and disseminating valuable information.[14] They and American masters, in both steam and sail, showed keen interest in the routes marked on the pilot charts to avoid drifting ice, although the ever curious General Meigs of Civil War fame thought that this information was too general. The Liverpool Underwriters Association informed Bartlett in 1886 that it was impressed by the pilot charts, most of all because they showed that the Hydro-graphic Office was considerably ahead of the British Admiralty in broadcasting knowledge through charts and notices. And John Worthington, the American consul at Malta, was proud of the American charts because of their simplicity, completeness, and usefulness. [15]

One specialized topic which Bartlett exploited was the calming effect of oil on water. Not only were his efforts a service to maritime safety, but they revealed his conception of public science. The use of oil to quiet the seas had been, for the nineteenth century, more a proverb than a practical method of saving life and property from breaking seas, until Bartlett made it his responsibility to bring this matter to the notice of seamen in Europe and America. The Hydrographic Office published a pamphlet by Lieutenant George L. Dyer, *The Use of Oil to Lessen the Dangerous Effect of Heavy Seas*, and the pilot charts also spread the word. Laudatory statements followed quickly, one of the most impressive coming from Captain William J. L. Wharton, hydrographer to the British Admiralty, who said that "thanks to the efforts of the Americans, the facts are well known to all English-speaking mariners, and many are the instances of the successful use of oil."[16] Bartlett drew the greatest satisfaction from his success, which illustrated so nicely the kind of practical knowledge which he believed that governments should cultivate and distribute. The Hydrographic Office did not seek to explain the dynamics of thick, viscous oils; it was satisfied to tell everybody their protective effect in subduing large, damaging waves. "It is not the policy of this office," Bartlett once said, "to go at all into the region of theory; it is prepared only to state and to publish facts."[17] Bartlett's oversimplified approach is here in sharpest contrast with the method of the Coast Survey.

Bartlett watched closely the scientific surveying of his command on the west coast of Mexico and Central America, renewed in 1879 after abandonment for lack of money in 1875. He wanted a set of charts, ranging from San Francisco to Panama, which did not rely on old Spanish surveys of the eighteenth century, some of them fifteen miles off in longitude; and of course he hoped to show that the Hydrographic Office could do better than the Coast Survey.

The Ranger was the surveying vessel, the only one that the Hydrographic Office used almost exclusively for that purpose. Bartlett directed Charles E. Clark, the *Ranger* commander for three years, to follow Coast Survey methods closely, except for detail in topography. However, an inquiry from a European source caused the hydrographer to change his mind. An English mapping firm wanted to know if the contour lines on his charts of the west coast of Central America indicated actual heights, and Bartlett had to admit that the lines were there simply to strengthen the shading of the hills. Not long afterward, he ordered the Ranger to begin contour line drawing for Baja California and to measure more heights on the same peninsula.18

The range of activity of the Hydrographic Office is the final measure of an emerging government scientific organization in post-Appomattox America. Sailing directions for the west coast of Mexico and Central America were published and a copy was sent to the Pacific Mail Steamship Company, which happily acknowledged receipt.19 In 1888 the Hydrographic Office published a fishery limits chart of Newfoundland, indicating where Americans could fish under treaties with Great Britain. The fishermen used this chart, and so did the Senate Foreign Relations Committee. A new U.S. Great-Circle Sailing Chart for the North Atlantic drew enthusiastic response from an officer on the Cunard liner Etruria, who thought the chart was "the nicest thing . . . ever given to Seamen." [20]

Before Bartlett, the Hydrographic Office had constructed a circumpolar chart of the Arctic, where European and American parties had been making their desperate exploration and rescue attempts. Bartlett compiled maps of the Arctic for the Greely Relief Board; and he republished the circumpolar chart, which Robert E. Peary, the explorer, wrote for immediately. The Beacon, a literary weekly in Boston, thought this new edition (in 1885) a marked improvement over current English and German products. It particularly liked the location of the North Pole in the center of the chart. [21] Work also continued toward determining secondary meridians by telegraph from the primary meridian at Greenwich. In Bartlett's time, a chain of these points girded the Caribbean and northern South America.

It was decisive for this story of science and scientific rivalry that not all the naval contingent in hydrography worked for the navy. One or two score officers and several hundred enlisted men did oceanographic research through assignment by the Navy Department to the Coast Survey, a practice begun in the antebellum period. That is to say, naval forces, with their ratings, pay, and rations, constituted the hydrographic parties of the Coast Survey. The Hydrographic Inspector, a naval officer in the Washington office of the Survey, supervised these hydrographic parties, which sometimes numbered a dozen yearly. These naval forces sailed the Survey ships and made the soundings for the charts, which developed the earth's solid surface beneath the waters in Maine on the East Coast, for Florida and Texas on the Gulf, and for the West Coast and Alaska. Lieutenants in command worried about the weather, the ships' boilers, and the supply of coal and fresh water, yet each was pleased to have an independent command in the Coast Survey, rather than standing watch in the navy proper. These officers believed they worked harder than their counterparts in the regular navy, and they were proud of the finished charts, which bore their names as a record of their contribution.

A typical day in hydrography began with a trip through the surf to build signals on trigonometrical positions provided by the Washington office, which in turn had received them from the triangulating forces of the Coast Survey. Reciprocal sighting between land and water was the method of recording positions. The ship, starting outward from a few meters offshore with a signal flying, took soundings with the lead while the ship's officers took angles on triangulation points ashore. Concurrently, personnel ashore sighted on the ship from the occupied points. At the end of the day, recorders transferred the results to the progress sheet. At times, lines of soundings were crossed to check for accuracy. [22]

The doings of these officers and men added one more distinguished chapter to the annals of science by the navy after the Civil War. In command of the *Blake*, a wooden schooner-rigged steamer belonging to the Coast Survey, Lieutenant Commander Charles Dwight Sigsbee made many offshore explorations from 1874 to 1878. Wanting to discover great depths of water (a passion of oceanographers in those days), Sigsbee, who later was to command the Maine at nearby Havana, ran thousands of miles of sounding lines in the Gulf of Mexico; and the superintendent, surprised by the depths of 2,000 fathoms discovered there, named two locations on the Blake's tracks, Sigsbee Deep and Sigsbee Bank. [23]

John R. Bartlett followed Sigsbee on the *Blake*, and this second naval officer developed a submarine valley in the western part of the Caribbean, which the superintendent of the Coast Survey named the Bartlett Deep. Bartlett also constructed a model of the Gulf of Mexico bottom, which impressed many American scientists. All this was before Bartlett became head of the Hydrographic Office.

In 1883 the Coast Survey summed up the harvest of physiographic knowledge by constructing a relief model "of the depths of the sea" for the western Atlantic, the Gulf, and the Caribbean. This model was displayed at the London International Fisheries Exhibition and at the Philadelphia meeting of the A A AS, where it attracted "great attention and favorable comments." [24] After Bartlett came Commander Willard H. Brownson, who north and west of Puerto Rico found 4,500 fathoms of water—the greatest depth yet, he reported, to yield bottom specimens and temperature. The superintendent of the Coast Survey thought this discovery of Brownson's worthy of a special announcement, and the American Journal of Science welcomed the "marvelous facts" about depth along the north shores of the West Indies. [25] One surprise was the revelation that, in the depths of the sea, the differences in height far surpassed those on land.

Naval officers were effective in their probing of ocean depth because they took pains with the technology of their operations. Commander Sigsbee seemed determined to modify and improve every mechanical device aboard the *Blake*. The pitching and rolling of a ship at sea put a heavy strain on the sounding wire, and surveying parties in England and America relieved this strain by using rubber bands called accumulators which, attached to the sounding wire, absorbed the constant jerking through their capacity to bear weight and to stretch. Sigsbee's accumulators were a series of round rubber objects that looked like doughnuts; fitted to the mast, they acted as a spring to absorb the sudden force imparted to the sounding wire by the heaving vessel. [26] He collaborated with Alexander Agassiz, when the Harvard zoologist came aboard early in 1878. Agassiz suggested that the wire rope used for sounding also be adopted for dredging and trawling, and Sigsbee made the successful change from hemp rope. Future oceano-graphic surveys would copy this change.

For five years after he left the *Blake* in 1878, Sigsbee heard praise of his work. In 1880 the Coast Survey brought out his authoritative publication, Deep Sea Sounding and Dredging: A Description and Discussion of the Methods and Appliances Used on Board the Coast and Geodetic Steamer Blake. Thomas A. Edison thought the Sigsbee publication an "original and splendid contribution." A professor at the University of London, who had been a naturalist on the Challenger exhibition, was convinced, after reading Sigsbee, that his methods in sounding and dredging were far superior to those of the British. [27] In 1883, Sigsbee, having built a deep-sea sounding machine modeled after William Thomson's ideas, won a gold medal at the International Fisheries Exhibition. Altogether, the commander constructed four machines for government use: one for the German navy, one for the American navy, one for the U.S. Fish Commission, and, of course, one for the Coast Survey.

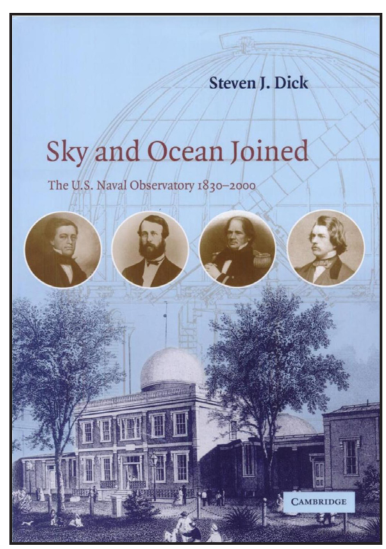
Perhaps the most lasting contribution of the navy to Coast Survey and American science was the work by Lieutenant John E. Pillsbury on the Gulf Stream between 1885 and 1889, where Bache had introduced the Coast Survey before the Civil War. To locate the Blake, Pillsbury designed his equipment to distribute the force of the jerking vessel so that none of the parts—mast, boom, or deckhouse—would receive undue strain. He was able to use Sigsbee's accumulators or arrangement of rubber springs, which under a 15,000-pound strain would compress from 13 to 5 feet. He also designed a current meter, which he lowered by Sigsbee's sounding machine. Pillsbury's main objective was to anchor in the Gulf Stream and observe for current and temperature at various depths. For this purpose, he spent two years at stations established on a line across the Florida Straits from Fowey Rocks to Gun Cay. Afterward, stations on four other lines across the Florida Straits were occupied; one location off Cape Hatteras was made; and stations were established in the passages of the Windward Islands.

In his views on the Gulf Stream, Pillsbury accepted the tradition, now increasingly dominant, that the Stream was the result of water piling up in the Caribbean from wind-driven current, then overflowing north through the Gulf of Mexico and the Florida Straits, where it was joined by other wind-driven currents. Pillsbury fixed the fact, heretofore disputed, that there was a comparatively smooth bottom for the Gulf Stream in the Florida Straits and as far north as Cape Hatteras. Also, he located the axis or maximum flow of the Gulf Stream farther west than was previously supposed. He found no evidence of a polar countercurrent beneath the Gulf Stream, though such a current had been believed in since Bache's time. His laborious effort to show a correlation between changes in the Gulf Stream and changes in the position of the moon were not fruitful. Nevertheless, Pillsbury's scientific reputation endures because of his unique and valuable statistics on the temperature and velocity of the Gulf Stream, which grateful oceanographers have been using ever since. [28]

This chapter has 28 notes on sources and side lights. Please refer to the original book for these details.

* * *

The Manning book is not about the USNO itself, but for completeness, we should mention that there is a more or less official history of the USNO by Steven Dick, a scientist who actually worked there for many years. It is called *Sky and Ocean Joined*, published by Cambridge University Press, 2002. 800 pages, $189. It covers much broader ground, over a much longer period than Manning's book, written 14 years earlier. It covers scientific achievements and instruments as well. You can see the long Table of contents at usno.navy.mil/history.shtml and read long excerpts from Google Books at tinyurl.com/sea-ocean-0.



Discussion and reviews of this book are at tinyurl.com/sea-ocean-1 and tinyurl.com/sea-ocean-2

* * *

NAVIGATION NOTES

CELESTIAL NAVIGATION WEEKEND

June 6th to June 8th, 2008, Mystic Seaport, CT

by

GEOFFREY KOLBE

Had I known early enough about the first Celestial Navigation Weekend back in June 2006, I would have hopped on a plane from my home in Scotland and joined in the fun. As it was, I extracted from Frank Reed—organizer of the 2006 event at Mystic Seaport —that another symposium would be held in June of 2008. Was I interested? "Count me in!" I said.

Frank Reed is the co-manager of the NavList email community, (see http://groups.google.com/group/NavList), who discuss, with much passion and energy, details and methods of celestial navigation. Frank is also a consultant on celestial navigation matters with Mystic Seaport and the very fine nautical museum they have there. So, following the success of his first Celestial Navigation Weekend, Frank organized the second Celestial Navigation Weekend for June 2008 under the overall stewardship of Don Treworgy, director of the Planetarium at Mystic Seaport.

Mystic is tucked away in a little inlet down the coast from the big cities of Boston and Providence, Rhode Island. Anyone cruising South on I95 from those cities to New York would be forgiven for missing it altogether. But to do so would be a shame. On seeing the traditional clapperboard houses nestling in the verdant trees and undergrowth around Mystic, the word 'quaint' came to my mind. (Many Americans tourists, on visiting our ancient little stone built villages in Scotland call them 'quaint', it is nice to return the compliment!) The name 'Mystic' does not have mystical origins, but comes from the name the American Indian tribes (Algonquin, Mohegan, Iroquois) had for the river. 'Miss', meaning great river (the same etymological roots as the 'Miss' in Mississippi, so I was told) and 'tuc' meaning tidal.

Mystic Seaport itself is particularly historic. It started in 1930 in an attempt to preserve the whaling maritime history of the United States, and became a major maritime museum in 1941 with the acquisition of what is now the last of the wooden whaling ships that kept the oil lamps burning in the United States through most of the 19th century. Now, the 'Charles W Morgan' still occupies centre place in what has developed into a sprawling open air museum dedicated to whaling in particular, but also nautical life in general in the 19th century. Viewing Seaport across the water—particularly in the still of the early morning with cool mists rising from the river—is like stepping back in time 150 years, with the masts of no less than three square rigged ships and several other fore-and-aft schooner rigged vessels on the skyline. The barkentine "Mystic" (privately owned and not connected to Seaport) is the most impressive recent resident on the Mystic River estuary, and the schooner "Amistad," built by the shipwrights of Mystic Seaport for the film of the same name, had arrived for a little maintenance just a few days earlier.

I made my way to Seaport early on the Friday to meet fellow attendees—many of them long time correspondents by email on the NavList who I was meeting for the first time—and to register for the event. There was a little time before the main talks got underway, so in spite of a persistent drizzle of rain, Frank took us on a fascinating impromptu tour of grounds of Mystic Seaport. We looked around the "Joseph Conrad", built in Copenhagen (Denmark) in 1882 as a sail training ship; the "Joseph Conrad" is still working now in that capacity out of Mystic. A new 'dry dock' has just been commissioned, where ships can be hauled out of the water for maintenance and repairs. We took in a museum dedicated to small American pleasure sailing craft, some dating back over 100 years. And we saw the "Thames", the other whaling ship at Mystic Seaport that was built about the same time as the "Charles W Morgan" (1841)—or rather, all that was left of her, which was just the keel plank!

Official business got underway at 12:45, with a talk by Frank Reed on the history of the modern Nautical Almanac on its fiftieth anniversary. To illustrate his talk, Frank had filled a small table with just some of his impressive collection of almanacs, the earliest dating from 1768, within a few years of the origins of the Nautical Almanac in 1766. However, it is amazing how little the modern Nautical Almanac has changed since its last great revision in 1958. Frank discussed how our modern almanac resulted from the merger of the "American Nautical Almanac" and the British "Abridged Nautical Almanac" and he also talked a little about the commercial almanacs which have had a significant impact on navigation in the past two centuries.

Frank had "commissioned" a little birthday cake (from his Mom) in the shape and gaudy colors of the US printing of the Nautical Almanac. Since I had travelled all the way from Scotland, so covering the greatest change of longitude to get to Mystic, Frank awarded me the "Longitude Prize" which meant that I got to blow out the candle on the cake!

The next event in the Navigation Weekend was a tour of the Collections Research Center at Mystic Seaport. This is housed in a large red brick building just across the road from Mystic Seaport. It used to be a velvet mill, but has been impressively converted into one of the world's foremost museums of nautical history. This is first and foremost a research facility, housing a vast collection of manuscripts, objects, and small craft which are not on public display. The sheer quantity and variety of objects there is jaw-dropping! For example, Mystic has the largest collection of octants in the world, and the third largest collection of sextants in the world (after Greenwich and the National Maritime Museum in England). We saw shelves stuffed with sextants of all sorts—including a fascinating Hughes that has since been the source of much comment and speculation, where the index mirror was attached to, and tracked along, the arc. This enabled a reduction in size by doing away with the top of the frame, where the index arm is normally attached. There were chronometers by the gross, and a huge warehouse so full of interesting small boats of all sorts—kayaks to small ketches—there was hardly room to move. There was much else, including drawers bursting with scrimshaw and... a whale's eyeball!

At 3:15 on Friday, it was my turn to perform and I gave a presentation on my experiences with inland navigation and position finding. I described my adventures in the Western desert of Egypt, keeping track of position with dead reckoning using a sun compass and the car's odometer, as well as celestial fixes with a bubble sextant. In addition, I talked about my experiences using theodolites to get position fixes and described some of the specialized instruments that have been developed for land-based position finding.

The Navigation Weekend had two principal foci: navigation enthusiasts interested in the details and finer points of celestial navigation (mainly members of the NavList online community), and educators who actively teach celestial navigation and see it as a foundation for teaching many other aspects of science. The next talk was in this vein and Carl Herzog highlighted the surprisingly large number of sailing vessels engaged in sail training and educational programs at sea around the United States. Celestial navigation is actively taught and practiced on these vessels, though of course GPS is the real mode of navigation. Carl described the varying experiences that students have with celestial navigation. Some 'get it' right away (and not necessarily those with science experience), others never quite get it, but all come away with "aha" experiences about the motions of the Sun and stars that they will remember for a lifetime.

For the final talk of the day, Ken Gebhart spoke to us about recent developments at Celestaire. A company which, despite being based in Kansas—about as far away from the sea as it is possible to get in the United States—still succeeds in being the largest producer and seller of sextants in the world today. Ken informed us that sales of sextants have actually been rising significantly in recent years. He sells about 1200 annually, both direct and to other retailers. Ken also reminisced about his experiences dealing with the Nautical Almanac Office here in the UK, who claim the copyright to the Nautical Almanac. The Nautical Almanac Office is of course, now just two people, but they are under considerable pressure to make it pay by getting maximum royalties from the publishers of commercial Nautical Almanacs, of which the most prominent is published by Celestaire. After much discussion and debate in the past few years, Ken has secured a deal which should keep Celestaire's *Commercial Nautical Almanac* available at a reasonable price for years to come. Ken also showed off the newest sextant in their Astra line, complete with a very fine 7x monocular scope, which will also fit Tamaya, Cassens & Plath and C. Plath sextants.

Dinner on Friday was excellent: good food and good conversation. After dinner, Frank took some of us to John's, an 'Irish pub' in downtown Mystic. Frank spotted Amy Blumberg, owner and captain of the "Mystic," the largest sailing vessel built in the United States in sixty years. Amy was there with her First Officer and Chief Engineer, also women. Great conversation. Amy invited us to come over and have a look around the "Mystic" any time.

On Saturday morning, Frank opened proceedings with a talk about lunar distance observations and some of the aspects of clearing lunars, showing examples of the relative importance of some small sources of error in the clearing calculations. In particular, Frank discussed the "fuss" in the 19th century over the "quadratic correction" in series methods. Frank used actual lunar distance calculations extracted from logbooks archived in the Mystic Seaport Research Center to illustrate how 19th century mariners actually practiced lunar distance navigation.

Next, Herbert Prinz talked about Lacaille's solar tables, showing very plainly how the tables were not dependent on modern models of planetary motion but in fact represented improvements derived from technology. The improved solar tables themselves—which were part of the revolution that led to longitude by lunar distances and eventually longitude by chronometers—depended critically on the development of astronomical clocks capable of accurately recording the intervals between transits of astronomical objects. Herbert's talk was packed with information and only the highlights are given here.

Cel Nav Weekend. Seminar organizer Frank Reed, center, showing several sextants from the museum. Seminar photos courtesy of Stan Klein.

At around noon, we left the planetarium lecture room and gathered at the North end of the Seaport complex to try our hand at some lunar distance observations. The thin sliver of a new moon took a bit of finding in amongst the high cirrus cloud, but it was eventually spotted. I had brought along a 1942 vintage Husun sextant, which I have been slowly restoring for the last ten years or so. I had made a 25X scope for it, to see if greater accuracy in lunar distance observations could be obtained, despite the magnified shake and wobble of the image. I have had little opportunity to try it out in cloud covered Scotland, (look at Southern Scotland with Google Earth if you don't believe me about the cloud!), so I was keen to try it out where a clear sky was more assured. I managed a good series of sights, but I suspect that errors on the arc of this war time sextant are now the main handicap to good accuracy and my next task is to determine the errors along the arc of this sextant. Several others in the group had their first shot at measuring a lunar distance, so it was a profitable experience for all of us.

After a brief lunch, we met in the Munson Room of the G.W. Blunt-White Building (formerly the library at Seaport). Philip Sadler outlined the history of celestial navigation at Harvard University. It has been taught there in one shape or form since the late 17th century and continuously since 1896. The modern course is designed to teach very broad aspects of positional astronomy with celestial navigation as the practical foundation. Philip teaches this class with Eliza Garfield, who also attended. Eliza is presently captain of the "Amistad" and had just returned from a long sea voyage where students used celestial navigation extensively. Philip also played a sample from a short documentary produced in 1987 called "A Private Universe", which includes brief interviews with students at Harvard's commencement asking them to explain the seasons—and getting it quite wrong.

Joel Silverberg, mathematics professor at Roger Williams University in Rhode Island, then talked about the principles underlying Bowditch's method for determining latitude by double altitudes. This type of sight, which was extremely popular in navigation manuals in the late 18th and early 19th centuries, allowed a navigator to deduce latitude by taking two sights of the same body separated by some interval of time. Joel is a skilled speaker, and he carefully stepped us through the procedure and the spherical trigonometry of Bowditch's otherwise cryptic method.

Joel was succeeded by Mary Malloy and Steve Tarrant, faculty members of the Sea Education Association (SEA) based at Wood's Hole, Massachusetts. Their joint talk continued Carl Herzog's discussion of how celestial navigation is being taught on sail training ships today. As part of their program with SEA, students are given the task of charting a harbor, first with no tools, then with progressively more useful and technologically sophisticated tools. The emphasis is on letting the students discover the problems of mapping and re-inventing the solutions. In addition, Mary described how she has students study the modern North Atlantic pilot chart and use it to understand the early voyages of Columbus, who was tentatively discovering the most efficient way across an ocean whose currents and winds were, at that time, unknown. Mary and Steve also use early 18th century navigation manuals (e.g. Seller) to teach students the basic aspects of astronomy that are required for celestial navigation.

Fascinating conversations in many topics continued over dinner at Jamms Restaurant in Mystic Saturday evening. During dessert, Don Treworgy, who has been working at the Seaport Planetarium since 1960, talked about the history of navigation at Mystic Seaport and also gave us a little background on Sue Howell's impressive contributions to navigation education and the tragic sinking of the Marques in 1984. Don also demonstrated his skill in the art of punnery and promised to get us all thinking about possibilities for activities in nautical astronomy for 2009 at Mystic Seaport.

Sunday at noon, we got started with a presentation by Don Treworgy on the navigation of C.H. Townshend. Mystic Seaport has an extensive collection of Townshend's journals as well as his navigational instruments including a reflecting circle and one of his chronometers. Don noted that in one of his early logbooks Townshend wrote that ocean sailing was the "life for me" but after a few decades at sea, Townshend was sick of it and wanted nothing more than to tend his oyster beds in New Haven harbor. Townshend was an experimental and enthusiastic navigator who took many exotic sights, seemingly for the fun of it. He worked out one full lunar distance clearing calculation, in a tiny almost unreadable script, in a space that is smaller than 3 inches square —probably for a bet! It's interesting to note that his reason in one case for taking a lunar was a hunt for a small mis-charted island in the Pacific. His chronometer was correct at that point, and he had sailed to the correct longitude but there was no island. So just to be sure he shot a lunar. Eventually it turned out that the "miserable island" was 25 miles away from the charted position. Townshend also notes in one of his journals that he "tried Sumner's method" for longitude and found that, "it worked very well". (It is interesting that this was thirty years after Sumner published his method and yet even this experienced and skilled navigator was only just getting around to trying out the 'new navigation').

Don was followed by Herbert Prinz's talk on determining the Most Probable Position using a graphical approach. This is one of those topics where it helps to have a "captive audience".... The algebraic proof is laborious, and, like most proofs, pretty dull. But without seeing the proof you would probably not accept the conclusion, which was inescapable and unexpected. Quite fascinating.

For the final scheduled talk, Frank chatted for a while about other methods of position finding that could be used at sea today and which could also help elucidate the concepts of celestial navigation for those who teach it on the water. Frank started by talking about determining a position (using widely-available computer software) by observing artificial satellites. It was interesting to see how much discussion this generated—it has the potential for being a very popular method of demonstrating the underlying ideas of celestial navigation.

Cel Nav Weekend. Several participants taking lunar sights at the seminar. The author is on the right side. Seminar photos courtesy of Stan Klein.

In addition, Frank talked about his new innovation of using lunar distances to generate lines of position and a position fix, where GMT is assumed to be known. Frank used computer animated 'cones of position' to show us how moon to other-body distances could be used to generate lines of position on the earth. Useful accuracy in the final fix would depend critically on the accuracy of the measured moon to other-body distances, but the fact that no horizon is required makes this discovery of Frank's a useful tool in the celestial navigation armoury.

That was to have been the final presentation, and though some participants had to leave to make their way home, enough people could stay to make it worthwhile for Stan Klein to discuss the development of his navigation software. It's an interesting product used to teach Power Squadron navigation classes. Stan described how he faced some resistance in the early days from people involved in celestial instruction in the Power Squadron, who were concerned that students might use such software to "cheat" on their exercises. Stan also filled us in on some of the fascinating recent history of other software developers who have worked on similar navigation tools. All in all, an interesting story and a nice way to close out the events of the Navigation Weekend.

Six of us decided to have a late lunch after the end of the conference—and Herbert Prinz reminded us that we had a standing invitation for a tour of the barkentine "Mystic". We walked the half-mile from Mystic Seaport to the drawbridge. The weather, which had been cool and damp on Friday, was now hot and humid. The temperature was up in the 90s and the so was the relative humidity. After spending a few minutes in the marine goods store on the block, which actually had two sextants on sale (!), a Simex in good condition as well as a Davis plastic sextant, we made our way to the "Mystic" and talked one of crew into giving us a tour. (Amy wasn't there, but the first officer was and remembered us as "the navigators from the other night"). It's an impressive vessel, designed for passenger-carrying cruises and excursion sailing. We all took a good look at the navigator's station—no sextant there...

Over our late lunch, in a nice restaurant with a terrific view over the river, we watched the clouds roll in from the West as that tropical Connecticut air boiled up into impressive thunderstorms. Gusty winds whipped up the surface of the Mystic River and we watched the steamboat "Sabino" racing back to port at full speed. The "Sabino" is now over 100 years old and it seems the captain had been afraid that the boat would capsize in the worsening weather. So he had radioed an urgent message for an emergency raising of the drawbridge to allow him to return to port, cutting short the 90 minute evening cruise. And the rain came pouring down. Why did it rain? Why naturally, because we navigators, prepared for any eventuality, had left our cars behind and walked to lunch and none of us had brought umbrellas.

The 2008 Navigation Weekend was a great success. There is the possibility that something similar may happen next year, as part of the Year of Astronomy celebrations at Mystic. However, Frank's current thinking is June of 2010 and possibly in another location—Newport perhaps. The whole area is studded with interesting places to visit and it is well worth making the Navigation Weekend part of a more extended visit. When and wherever it is, I will be sure not to miss it. I do hope I will not be the winner of the "Longitude Prize" next time!

My thanks to Frank Reed, for allowing me to lean heavily on his own report of the 2008 Celestial Navigation Weekend to the NavList group.

* * *

PRACTICE PROBLEM

FINDING LAN POSITION

Here is an example of a set of real sun sights taken during a Victoria-Maui Yacht Race. We have simply changed the date to 2008 so readers can use a current almanac for the analysis. The job is to find your best possible position at LAN.

There are several ways to do this. First you have to determine the time of LAN, which can be determined from the data taking into account the course and speed of the vessel. Next there are several approaches to the solution. A simple one is just a "noon sight" analysis as if we were not moving, then there are ways to correct for motion, or you could do a running fix from all sights or selected sights. Another approach is to use some form of analysis to rule out all but the best sights and then concentrate on those.

Date is July 14, 2008. DR at 1910 UTC = 36° 23'N, 130° 10' W. Course = 210T, speed = 9 kts. Both course and speed steady throughout the sight period. Temp 75°F, Pressure 1020 mb. Height of eye = 9 feet. Index Correction = 2.0' off the scale. Questions: What is the UTC of LAN to the nearest minute? What is your best estimate of your position at this time? Ocean current and leeway can be neglected. Sextant heights for lower limb as a function of UTC are in the table below. For those who want more practice with the analysis, what is the standard deviation of the errors in these sights (taking into account the motion of the boat)?

UTC (h m s)	Hs LL
20 23 04	74° 01.1'
20 24 31	74° 09.5'
20 26 36	74° 16.2'
20 28 19	74° 22.8'
20 30 11	74° 29.0'
20 33 11	74° 37.4'
20 35 05	74° 42.6'
20 37 45	74° 48.4'
20 42 14	74° 53.0'
20 44 40	74° 56.0'
20 47 57	74° 57.4'
20 50 41	74° 57.4'
20 54 58	74° 54.1'
20 57 30	74° 50.0'
20 59 59	74° 48.0'

The answers will be given in Issue 100.

* * *

REMEMBERANCE

Leif Karlsen

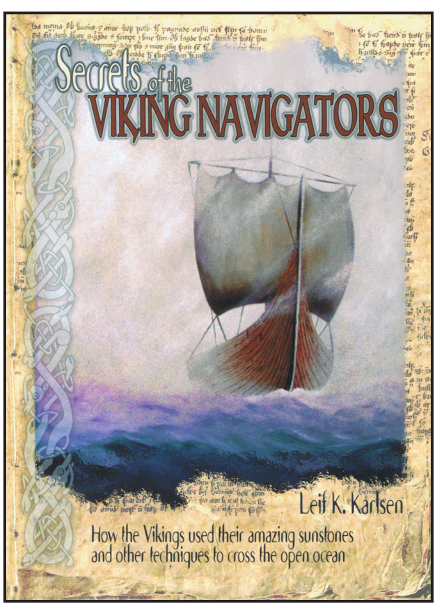
June 12, 1930 — Feb 1, 2008

I knew Leif for many years. During the days when he started work on the Viking navigation book we were neighbors in Seattle, and spent quite a bit of time discussing Viking navigation—as it is known they did it, and how they might have done it. This area was a key research area for him, and after years of study he became recognized as one of the world's experts on the subject. His book *Secrets of the Viking Navigators—How the Vikings used their amazing sunstones and other methods to cross the open ocean* is a wonderful story, not only of the navigation but of Viking life and voyaging as well.

He single-handedly devised the most likely way they used these sun stones (crystals of Icelandic spar, about 2 inches on a side) to get the sun's bearing when obscured by clouds or fog, or just below the horizon. And then he tested it, over and over, in various modifications, and expanded on existing ideas on how they could combine these observations with azimuth rings and other primitive aids that have been recovered.

Quite miraculously, just as his book was going to press, he got word from the UK that within the wreckage of a late 1500's vessel in the Channel Islands divers had found a large piece of Icelandic spar within the shards of a pot clearly used to store it. This was the first ever finding of an actual sunstone on board a vessel, though this vessel was way later than the active Viking period of some 1000 AD. We do not know what its use was in 1500, but the plausibility of it being a navigation aid is very tempting. The presses were stopped, and this story with photographs is in the Appendix to his book.

Leif was born in Asker Norway and grew up there. As a youngster he served in the Norwegian underground during Nazi occupation. Kids were used a lot to carry messages. His father was taken by the Germans to a work camp, but returned safely after the war.



After the war Leif went to sea as a deck boy at age 15. His first ship was an old sailing cargo vessel, one of the last still in use. He sailed on Norwegian and Swedish ships. After a few years at sea, he returned to Norway and attended navigation school. He became an officer, and sailed as Third Mate on the *Stavangerfjord*, a famous passenger ship. Soon after, he went to radio school and became a radio officer. He sailed all over the world in this capacity for the rest of his career at sea.

Leif immigrated to America in 1962. He settled in Seattle in 1984. He met June Garrett-Groshong in 1984 at sea onboard his ship when she joined the crew as officer's messman. He married her in 1986. They purchased rural land in Kitsap County, WA in 2001, where he lived until his death.

While Leif was living in Seattle Washington, he was a member of the Center for Wooden Boats where he restored classic boats. He was a member of the Nordic Heritage Museum and of the Icelandic Club. He was active at the Sons of Norway Lodges. He had a small replica of a Viking boat built in Norway and had it shipped to Seattle. He constructed a red and white square Viking sail for the boat. He sailed the boat on Lake Union and later in the Sinclair inlet by Bremerton.

Leif's fascination with the sea and navigation and the old Viking sagas led him to research and publish his book, *Secrets of the Viking Navigators*. His research took him to Iceland several times. He came to know and love that country and the people.

Before his death, Leif completed a manuscript for another Viking book set in Iceland. Leif was also a noted artist. His painting of Leif Eriksson's ship approaching America is on display in the Icelandic Room at the Nordic Heritage Museum in Seattle. It also appears on the cover of his book.

When Leif and June moved out of Seattle, we saw less of them, but the Starpath office is near the Nordic Heritage Museum, so we were often treated to a visit by Leif on his way to meetings there. These were engaging, laugh-filled times that we will miss.

David Burch,
with a special thanks to June Garrett-Groshong
for providing notes on Leif's background

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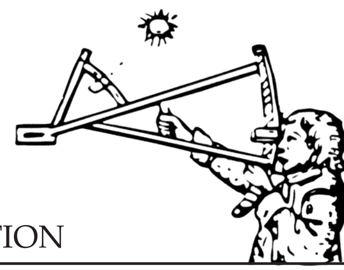
"THE NAVIGATION FOUNDATION"

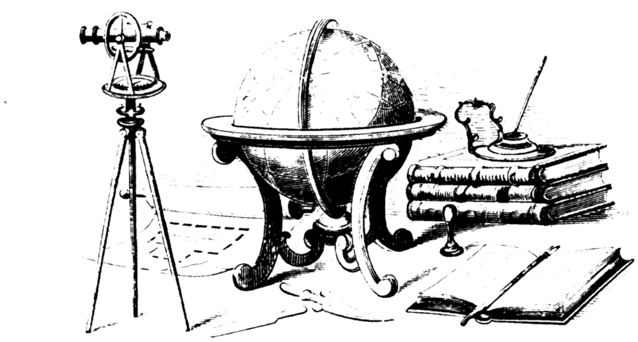
ISSUE 99, Spring 2008

THE NAVIGATOR'S NEWSLETTER



FOUNDATION FOR THE PROMOTION OF THE ART OF NAVIGATION

This letter is published to keep members up to date on the activities of the Foundation, provide useful notes on navigation techniques, review books on the subject and maintain a reader forum for the expression of our member's opinions and their questions.



ACTIVITIES
By Terry Carraway

In a forthcoming issue we will review the past annual awards to students of the Tabor Academy of the RADM Thomas D. Davies Award for excellence in navigation. The first award was given in 1994. We will also at that time review the nautical training programs at the Academy under the direction of Capt. James Geil, Master of the training schooner *Tabor Boy*, and head of the Nautical Sciences Department at the Academy. The following are notes about this year's recipient provided by Capt. Geil.

CHRISTOPHER JAMES HENRY

Chris Henry enrolled as a freshman at Tabor Academy in 2004. That summer he participated in a week-long new student orientation experience aboard the school's 92-foot iron-hulled training schooner *Tabor Boy*. Chris joined the regular student crew that fall and remained with the program during his four years at Tabor. He became a student officer by his junior year and as a senior was finally appointed executive officer of the vessel.

In addition to the day and weekend sails in the Buzzards Bay area, Chris worked in the hired student crew during the *Tabor Boy's* Orientation at Sea Program on the Maine Coast during the summer of 2006. In 2007, Chris worked in the hired crew, this time assisting in fitting out the vessel following an extensive refit. He is aboard again as XO for the Orientation Program this summer, running a hired crew of six and helping mentor and train over a hundred incoming Tabor students during seven one-week cruises.

Chris complemented his training aboard the *Tabor Boy* by taking several nautical science courses offered by Tabor. As a senior, Chris enrolled in celestial navigation and gained a thorough knowledge of its theory and practice. The course includes the altitude-intercept method using the H.O. 229, latitude by Polaris and meridian passage of the sun, selecting stars using the Rude Star Finder and the H.O. 249, and determining compass error by exact azimuth and amplitudes of the sun. Chris also learned the St. Hilaire method for using trigonometry to find computed altitude and azimuth without sight reduction tables.

For his spring break, Chris joined the *Tabor Boy* in the Virgin Islands as a watch-standing crewmember and made the 2000-mile return voyage to Massachusetts. During the trip, Chris made numerous observations of the sun, moon, planets and stars, developing his technique with the sextant and obtaining some excellent lines of position.

Chris was honored to receive the RADM Thomas D. Davies Davies Award from the Navigation Foundation, which was presented upon his graduation from Tabor Academy on May 31. Next fall, Chris will attend St. Mary's College in Maryland.

Christopher James Henry, recipient of the 2008 Radm. Thomas Davies Award for excellence in navigation.

The 93-foot schooner Tabor Boy*. Training vessel of the Tabor Academy, Marion, MA. Capt. James Geil, Master.*

The Davies Award consists of a plaque, a certificate, a check for $100, and an annual subscription to the Navigators Newsletter.

* * *

EDITOR'S NOTES

We are now more or less officially caught up on the Newsletter print schedule. Thank you for bearing with us. In forthcoming issues we will review the Foundations Awards program and consider expanding this program to the extent we can. It has always been my hope to offer an award to the teacher who has best used navigation as an aid to teaching other subjects in the grade school and high school levels. If you have suggestions along these lines please send them to us.

A double thank you to Director Roger Jones for providing a kind review to my new book on marine weather. I thank him as editor and as author.

I would also like to offer my thanks and gratitude to several of our overseas members who have each made multiple contributions over the past several issues. George Bennett from Australia, George Huxtable from England, Geoffrey Kolbe from Scotland, and Jan Kalivoda from Czechoslovakia. Thanks again for your participation and support. It is a great pleasure to see the goals and interests of the Foundation reaching around the world.

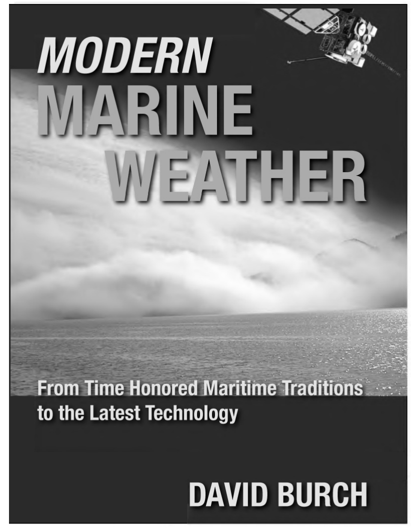
In the category of "someone has to do it" we have included an article on boxing the compass. We are still trying to find out why the process is called "boxing" and we are still trying to find out why it is called a compass "rose." Many say it is because it looks like a rose, but that is likely an oversimplification. The source may be far more mystical... but that is rather beyond our domain. It certainly started out being a "wind rose." So the question might reduce to why was that called a rose?

***

BOOK REVIEW

BY ROGER JONES

Modern Marine Weather, Starpath Publications, Seattle, 2008, 312 pages, paperback. $39, ebook edition is $19. ISBN 0-8173-5080-2. *Weather Workbook*, 70 pages, paperback. $19.



Modern Marine Weather is a brand new and truly extraordinary 304 page "treatise" on an age old subject. Indeed, "treatise" in the classic definition of that word fully applies: "a systematic discussion of facts and principles with inescapable and unquestionable conclusions." It is accompanied by a 68 page companion: Weather Workbook, with questions, answers and resources on marine weather. These two works are much more than the term "treatise" would, standing by itself, imply, however. In addition to the facts, principles and scientific conclusions expertly revealed in layman's terms within their respective pages, these two works constitute a truly complete and insightful guide to the numerous new computer-based resources that are now available in the marine weather field, and David has done an outstanding job of comparing and explaining these independent resources, web-sites, downloads, etc.

He has taken much of the otherwise inevitable "mystery" out of any listing of or reference to these resources by explaining what each of them provides and how they may be most useful to various users with greatly differing needs. He has also paved the way for the legions of mariners who are not at all "computer savvy," and who are perhaps apprehensive that their own personal digital age skills are either non-existent or rudimentary at best. There is a great deal of focus that is not at all dependent upon or related to ownership of a computer and knowledge of how to use one. Many portions of these works will appeal to the "seat of the pants" navigator as well as to those with the most sophisticated approaches to maritime voyaging. And, speaking from the personal standpoint of one with over 50 years experience operating sail and power vessels on oceans and inland waters, and of piloting various aircraft, this new work should appeal to airplane pilots and navigators who operate at the lower and intermediate altitudes, as well as the navigators who are water-borne.

Modern Marine Weather and its accompanying Workbook should be of central interest to every NAVIGATOR, whether he or she is an old salt with a sextant, a dead reckoning sailor, or a fully computer savvy skipper whose helm station includes a full set of digital age charts. These are two volumes that should be at the navigation station of every responsible ocean sailor, Intracoastal Waterway, or river mariner, and every mariner who plies any of the great fresh water lakes anywhere in the world.

David Burch's "style" is neither dry nor confusing. He has woven into his text fascinating historical facts that many 21st Century mariners may not know. Just one example: Robert FitzRoy is famous as the captain of HMS *Beagle*, which carried Charles Darwin throughout the Pacific, but he is not widely known as "the father of marine weather," who was the first to make weather forecasts, the first to compile synoptic charts, the first to advocate the posting of storm warnings at docks, and he played a key role in the development of standardized and rugged marine barometers. Those are but of few of his personal accomplishments.

The Burch style is also anything but confusing. It is clear, very well thought-out in terms of the sequence of his topics, and replete with successful efforts to explain in layman's terms the reasons why and how the many weather phenomena occur. Burch will be read and enjoyed by scientists, meteorologists, yachtsmen, and armchair sailors alike, and *Modern Marine Weather* is destined to become a much thumbed reference work, deserving a place along side of *Bowditch*, *Ocean Passages for the World*, and the works of Jimmy Cornell and others.

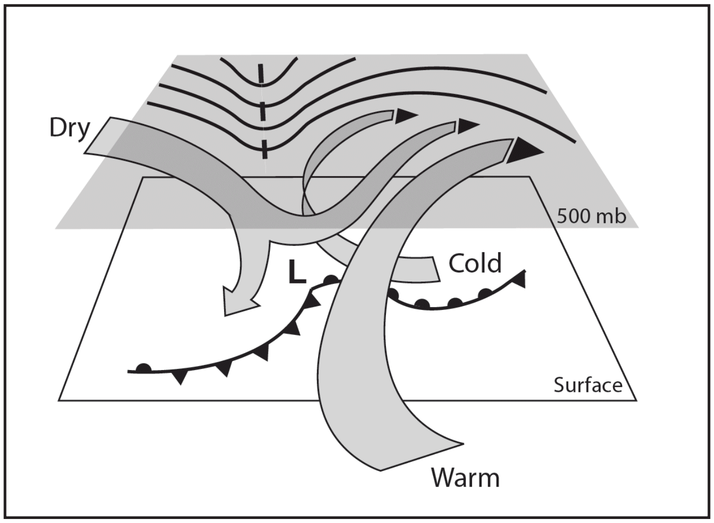
Burch will be appreciated by both Northern and Southern Hemisphere mariners, because he clearly explains why and how the weather systems in the two hemispheres differ and why they differ at various latitudes from the Equator to the Poles. In the judgment of this reviewer, he does a remarkably clear job of explaining the Coriolis effect of the Earth's rotation from west to east, the differences between west and east coast weather systems of continental land masses, the mid-ocean weather systems, the reasons for the differential heating of water and land masses by the sun, with the consequent effects on wind, wave and weather patterns, and the consequent selection of sailing routes and mid-course, real time adjustment of sailing routes at various times of the year, in various oceans and latitudes..

David's eight main sections deal, consecutively, with: Pressure and the Wind; Global Winds and Currents; Strong Wind Systems; Clouds, Fog, and Sea State; Wind and Terrain; Weather Maps Review; Sources of Weather Data; and On-Board Weather Tactics. His 24-page introductory section deals with: Overview; Role of Marine Weather; Elements of Marine Weather; Terminology and Glossaries; Wind Terms and Symbols; Getting Started on Resources, and Units and Time Conversions. He is comprehensive and very complete without being redundant.

One could spend many fascinating hours just absorbing the initial introduction and the ending on-board forecasting and tactics discussions, but that would lead inevitably to many hours in the other sections as well—or briefer forays into various areas of those other sections. They need not be read consecutively, but David's organization is purposeful and very helpful to an over-all understanding of his topics.

This enthusiastic review could go on at length by citing specifics from each section. In the interest of appropriate brevity, I'll conclude with just a few inviting "morsels" from the last main section—the "old sayings explained." Red sky at night, sailor's delight. Red sky in the morning, sailor take warning. Mackerel skies and mare's tales make tall ships set low sails. Long foretold, long to last, short notice, soon past. First rise after the low can portend a stronger blow (the so-called sting in the scorpion's tail). Rain kills the wind. A fair wind follows the sun. Burch tells us how and why the old-timers with little or no formal education, but with lifetimes at sea, came to know a lot about marine weather that has benefited their modern and educated followers.

Mariners young and old, get, keep and read *Modern Marine Weather*. It will take you , as it says it will, "from the time honored maritime traditions to the latest technology." You will be enriched along the way!



"Conveyor belts" of air. These are the typical wind flow patterns that link winds aloft to surface systems. Thus when the winds aloft move east they drag the surface systems with them. The dominant warm air conveyor *brings the warm moist air (fuel for latent heating) from the surface up to the winds aloft over the gentle slope of the warm front. Cold air flowing along behind the warm front (originally running parallel to the polar front) is forced aloft on the* cold conveyor *when it interacts with circulation around the central low at the crest of the wave. Dry air descends in the higher pressure behind the cold front via the* dry air conveyor*, clearing the sky behind the cold front, and sometimes reaching the surface with enhanced gusty winds (called "sting jets"). The extent of this descending dry air is often visible in satellite photos, clearing out a path in the cloud pattern to form a comma shape.*

* * *

NAVIGATION NOTES

CLASSIFICATION OF THE METHODS FOR CLEARING THE LUNAR DISTANCES

Jan Kalivoda, Prague, Czech Republic
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As you all know very well, the key step in the finding the GMT by lunar distances is to compare the distance measured by the sextant or the repeating circle with the values tabulated in almanacs.

But the measured distance is "dirtied" by the effects of refraction and parallax on the altitudes of both bodies (although the parallax of the other body was often neglected, even in the case of Sun or Venus; stars have absolutely negligible daily parallax, of course). Therefore this measured lunar distance must be "cleared," meaning reduced to the theoretical value that would be observed from the Earth's center in vacuum, and only then it can be compared with tabulated values of the Almanac so as to obtain the GMT.

This "clearing" is a difficult part of "lunars," and about a hundred procedures were devised for this purpose, beginning from 1750-1759 when the Frenchman Lacaille (La Caille, known for creating several names for faint southern constellations, too, e.g. Circinus, Fornax, Horologium etc.) proposed the first applicable solution, based on the studies of his countryman Jean Morin, who had analyzed the problem in 1633.

Maybe it would be of some profit to classify these methods according to their principles. I will offer this as a modest addendum to the valuable book of Charles Cotter, *A History of Nautical Astronomy*, London 1968, which pays little attention to older, renowned methods from the times before 1850, when the "lunars" were at their best.

We can distinguish four classes of these methods, which are remotely similar to the classes of the methods for reducing sights by "Marcq St Hilaire (intercept) method," the only method for using celestial lines of position surviving in today's navigation. These are in the order of their increasing length, difficulty, and logical clearness and beauty (in my eyes):

(1) Software solutions; quite common now, and not unknown in the first half of the 19th century!

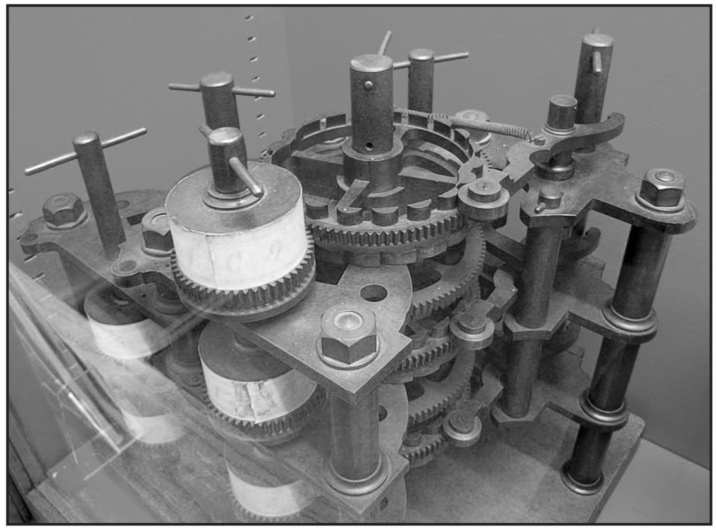
(2) Inspection tables such as HO 214, 218, 240, 229 and ancient Ball's tables, first edited in 1907.

(3) "Short" methods such as Ageton's method in HO 211, Dreisenstock's method in HO 208, Aquino (HO 200), Smart, Ogura, etc. In these methods short tables with auxiliary values are provided that are combined to obtain the end result; these tables were much less bulky and expensive than the inspection tables, but their use was more difficult and time-consuming.

(4) Rigorous solutions, such as using the cosine-haversine formula

1. Software solutions

Yes, the third mechanical computer of human history (preceded by Descartes' and Leibniz' machines) was created for computing



Part of the Babbage mechanical computer from about 1822 in part motivated to compute lunar distances. Picture from the Charles Babbage article in the Wikipedia.

the corrections of lunar distances. Its designer was Charles Babbage (1792-1871), who presented this programmable mechanical device together with Byron's daughter Ada (*Ada Lovelace, the world's first "programmer"*) in 1822. The machine was programmed by predecessors of punched cards. Its prototype survives to our day. (*Editor's note. Recently a prototype was made from his design that did actually work.*)

2. Inspection tables for clearing lunar distances

The plural is not appropriate—only one such work appeared. It was *Tables for correcting the apparent distance of the Moon and a Star from the Effects of Refraction and Parallax*, Cambridge 1772, in folio. It is commonly cited as "Cambridge Tables", or sometimes as "Shepherd's Tables" (A. Shepherd was the author of the preface, but took no part in computing the tables). They were computed and edited in the first spell of enthusiasm for lunars, after Tobias Mayer's lunar tables were published in 1770 and used even earlier in manuscript form by Maskelyne for editing the first volumes of the *Nautical Almanac*.

The *Cambridge Tables* were an incredible deed. After 4 pages of foreword and 7 pages of instructions, 1104 pages follow with up to 370 corrections on each page, together about 300,000 values. Corrections were computed and arranged for each degree of lunar distance from 10 to 120 degrees. Each degree of distance occupied 3-14 pages. For each degree of distance, all possible combinations of the Sun's and Moon's altitudes (stepped by one degree) were evaluated and the corrections of observed lunar distances (LD) for Moon's horizontal parallax of 53 arc-minutes and the mean refraction were given. Two other table columns gave the corrections for the Moon's actual horizontal parallax and the actual air temperature and pressure. Of course, triple interpolation was needed, but second differences were negligible, rarely exceeding 3 arc-seconds. A small table for correcting for horizontal parallax of the Sun (9 arc-seconds) was given. Planets were not yet used for LD's in that time.

The head of the working group of calculators was probably Israel Lyons, who prepared a clever method of computation (one of the "short" methods, mentioned below), as well. After editing this giant work, he took part in Phipps' polar expedition in 1773, but died at home in 1775 at the age of 36.

Of course, these folio tables were too bulky, cumbersome, and costly to gain any popularity at sea. A very small number of their copies have survived to our day in great libraries.

3. "Short" or "approximate" methods

Imagine a triangle in the sky with the vertices Z = zenith, S = true Sun (or star), and M = true Moon. And another triangle with vertices Z = zenith, s = observed Sun (or star), and m = observed Moon. (*See terminology note at the end of the article*.) The two triangles have the common vertex Z, and their respective two sides (zenith distances of the four bodies mentioned) cross at Z and are perpendicular to the horizon. The two triangles are the same except: s lies above S, as the daily parallax—which always lowers the observed body below its true location for an observer on Earth's surface—of the Sun or planet is always much smaller then the effect of refraction, which always raises the observed body above true body. On the contrary, m lies below M, as its great daily parallax is always greater then the effect of refraction. As a result, the third sides (observed and true lunar distance) of both triangles, ms (observed LD) and MS (true LD), cross each other at the common point X. But the sections mM and sS are very short (one degree at most, but mostly shorter), which is essential for further procedures.

Therefore if we drop perpendiculars from the points M and S to the side ms (observed LD), we can trigonometrically deduce an approximate equation permitting us to reduce ("clear") the observed LD to the true LD. (Here you can see a very remote similarity with Ageton's and other methods for resolving the nautical triangle; but these are not approximate in any degree, only their use of perpendiculars to triangle sides is somewhat similar.)

(M,S,m,s are meant as centers of bodies—the limbs are measured, of course, but applying the corrections for the semidiameters of bodies, one obtains the values for centers. I neglect all three effects of the earth's ellipsoidal shape on clearing LD, too; they can make a maximal error of 13 arc-seconds in the true distance cleared, when neglected.)

The final approximate formula can be confirmed directly by calculus (Taylor's polynomials), too, but spherical trigonometry alone can find the long line of always diminishing trigonometric terms of corrections allowing for effects of parallax, refraction, and their combinations on an observed lunar distance. Ten (10) terms were sometimes used for calculation! This formula is called "approximate," as it is not derived strictly, but only in gradually approaching steps and terms; but when a sufficient number of terms is included, its accuracy leaves nothing open.

The first methods of this kind were the method of Lacaille (1759) and Lyons (1766); both were mentioned above. Another was Witchell's method from 1772 (the "fourth method" of Bowditch). But their formulas were too complicated for a seaman's everyday use, therefore Dunthorne's and Borda's rigorous methods (see below in the fourth classification) were more popular then.

But from the beginning of the 19th century seamen were not left alone with the approximate equation. Many proposals of simpler procedures appeared:

D, d = true and observed lunar distances

M, m = true and observed ALTITUDES of the Moon (NOT its centers as above!)

S, s = true and observed ALTITUDES of the Sun or star (NOT its centers as above!)

HP = horizontal parallax of the Moon

The formula for the sea practice, as introduced from 1810:

D = d - HP sin s cosec d + HP sin m cot d + MYSTERY

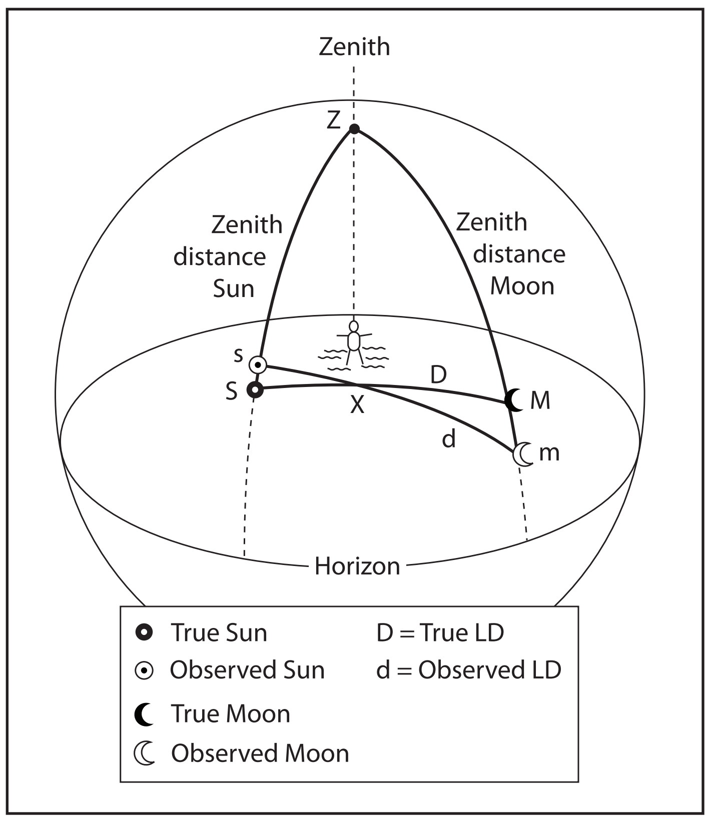
The navigator computed only the two first corrections by logarithms of trigonometric functions to 4 figures, and by proportional logarithms originally tabulated by Maskelyne for interpolating the tabulated LD's in the Nautical Almanac. Those were the two greatest terms of the Moon's parallax in the "approximate" equation, mentioned above.

The "MYSTERY" was the "third correction," tabulated according to the values of the Moon's and Sun's or star's altitudes observed and of the lunar distance observed.

The main difference between various methods of this numerous class was, how many secondary terms (from these remaining eight terms in the "approximate" equation) were taken into account; the authors seldom stated these details and published their tables as they were—sailors, take it or leave it!

The second difference between various tables was their step size, of course, and consequently the amount of the interpolation needed. Several were even arranged as nomograms, in a graphical form.

The first table of this kind (after two unpublished or unnoticed predecessors) was the publication of merchant master Elford from Charleston, which appeared in 1810 for the first time and which was several times reedited and many times stolen by other "authors" up to the end of 19th century. Elford's table of the "third



correction" included only the two greatest terms of refraction, leaving six other smaller refraction and parallax terms aside.

The same value is given in the set of *Linear tables for Correcting the Apparent Distance of the Moon from the Sun or a Fixed Star for the Effect of Refraction*, edited by well-known J.W. Norie in 1815 in London. That work contained 24 nomograms, from which the "third correction" could be taken without any interpolation with the precision of 2 arc-seconds. This set was popular, but never edited again, as original engravings of nomograms were difficult to obtain—so Norie was protected from thieves, which irritated Elford so much, and so often. After the stock was sold out and tables got worn at sea, sailors had to leave this method, as new editions didn't follow.

But the most prominent author of the tables in this class was David Thomson, who published the workhorse of British navigators in the first half of the 19th century: *Lunar and Horary Tables for new and concise Methods of performing the Calculations necessary for ascertaining the Longitude by Lunar Observations or Chronometers...* (London 1824). In 1851 the 42nd edition appeared, in 1880 the 67th edition! (Thanks to Bruce Stark for this information.) As happened with Elford, his main table was "accepted" (i.e. stolen) into many other nautical tables collections.

It was an ace of nautical tools in that time. Firstly, it gave in 51 pages (so that no interpolation was necessary) the value of the mysterious "third correction", allowing (as opposed to Elford and Norie and others) for further smaller terms of the complete approximate formula. It brought an improvement of 90 arc-seconds to the precision of corrections in some (not very frequent) unfavorable situations. A small table was given for reducing the parallax effect of the other body used.

Secondly, the Thomson's table set included auxiliary tables for computing the first two Moon-parallax corrections of the simplified formula mentioned earlier that the seaman had to resolve directly. Taken together, Thomson's tables permitted the shortest method for clearing lunar distance ever contrived—it was shorter than reducing the Sumner line by cosine-haversine method.

Several other useful tables were included, e.g. for resolving "time sights" (i.e. measuring altitudes of celestial bodies for computing their local hour angle to be compared with the chronometer time or "lunar" time for "finding" the longitude), tables for finding azimuths of celestial bodies and so on.

David Thomson went the long route from the ordinary soldier and seaman to the merchant master. He died in 1834 in Mauritius as a storekeeper, an unknown and enigmatic personality. He never specified the method of computing his main table of the "third correction". It was guessed that he had to compute 30,000 lunar distances directly and to interpolate another 50,000 values so as to construct this table. His results were proved to be independent of *Cambridge Tables* and are better than theirs in the average. But his caginess about his computing method prevented his table from entering into the navigation courses and navigation practice aboard navy ships, which were not insured.

Thomson's method and tables (after being simplified) were taken over by Bowditch as his "second method" for clearing the LD's, as Bowditch states expressly—he spells him "Thompson," but in my other sources the name always is "Thomson." The "first method" and "third method" of Bowditch, which were devised by himself, and his "fourth method", improved from Witchell's procedure (see above), were "short/approximate" methods, too. But they were rather obsolete after 1810, as their length and greater number of necessary arithmetical operations in comparison with Thomson's "second method" prove in Bowditch's examples. (The "first method" stood in the appendix in the first Bowditch's editions and only later he shifted it into the main text to the head before Thomson's method—the sign of Bowditch's growing self-confidence.)

Of course, in the second half of the 19th century some other "short/approximate" methods appeared that didn't resemble the Elford/Thomson solution. Some are mentioned in Cotter's book. Another was the method of the American astronomer Chauvenet that replaced all other older lunar methods in *American Practical Navigator* in the year 1888. This method, in contrast to all mentioned above, was capable of taking into account ALL effects of Earth's ellipsoidal shape and temperature/barometric corrections of mean refraction values. In competition with widely used chronometers and owing to very precise lunar positions in almanacs from 1880 (Newcomb's superb equations of planetary and lunar motions began then to be used for ephemerides), the *Bowditch* editors probably supposed in this year that "lunars" should be given a more precise, although more laborious, method in the *American Practical Navigator* if they were to survive, at least for checking the chronometers.

4. Rigorous methods for clearing the lunar distances

The most logical class comes last. Take the triangle (zenith) - (true Sun) - (true Moon) and the second triangle (zenith) - (observed Sun) - (observed Moon) once more. They have the common vertex and angle at zenith. This permits us to compare the basic trigonometric equations for both spherical triangles and deduce various strict trigonometric formulas for finding the true lunar distance, when observed lunar distance and observed and true altitudes of both bodies used are known (we can obtain the true altitudes from observed altitudes very quickly by allowing for refractions and parallaxes).

So again:

D,d - true and observed lunar distances

M,m = true and observed altitudes of the Moon

S,s = true and observed altitudes of the Sun or star

A = auxiliary value

Two most popular methods of this class were Dunthorne's and Borda's method. I won't write out their derivation, only the final forms:

Dunthorne (1766):

$\cos D = \cos (M-S) + \cos M \cos S \sec m \sec s [\cos d - \cos (m-s)]$

Mackay improved this form by using versines instead of cosines in 1793 (he edited tables for this purpose in 1809), removing the small inconvenience of changing the sign of cosine at 90 degrees by this substitution. Young's formula from 1856 is very similar to the original Dunthorne's form.

Dunthorne's method was very popular in German speaking countries and in Scandinavia up to the beginning of 20th century, at least in navigation courses.

Borda (1778):

$$(\cos A)^2 = \cos M \cos S \sec m \sec s \cos[(m+s+d)/2] \cos[(m+s-d)/2]$$

$$(\sin D/2)^2 = \sin[A + (M+S)/2] \sin[A - (M+S)/2]$$

Another slightly simpler form of these equations was also published. In spite of it, I cannot understand why this cumbersome method gained such popularity. But it was widely used in France and other Romance speaking countries and many successors devised similar formulas: Delambre, Krafft (a bulky volume of auxiliary tables in 600 pages was collected for that method by Mendoza del Rios in 1801) and others.

In all these equations the term (cos M cos S sec m sec s) returns again and again. It was called "logarithmic difference" and tabulated in an inspection table according to the observed altitudes of the Moon and of the other body. An error of some 3-5 arc-seconds arose from its use, but this was considered tolerable before 1850.

The great disadvantage of all rigorous methods was that they required the use of logarithms to 6 figures (and some theoreticians frowned at it, vainly requiring the use of the logarithms to no fewer than 7 figures), whereas the approximate methods were quite satisfied with logarithms to 4 figures with the same accuracy. The difference in difficulty of computations is manifest.

On the other side, all rigorous methods were capable of all three corrections for Earth's ellipsoidal shape and of corrections for the actual thermometer and barometer values (effects on the mean refraction), whereas these corrections are difficult or impossible to use in the most approximate methods (except from the tedious Chauvenet's method, see above). And each step of calculation was under the full control of the navigator in rigorous methods, where one can be sure that if logarithmic tables are correct (which could be guaranteed almost surely even in the 18th century), the result depends only on the navigator's sextant, hand, and mind. Approximate methods with their mysterious tables required a bit fatalistic seaman (which was certainly the frequent case).

The last rigorous method invented is the very ingenious procedure of Bruce Stark from recent years, which overcomes the disadvantages of rigorous methods and retains their advantages. See Navigator's News, Issue 92, Summer 2006 for details.

Note to experienced lunarians. *The word "true" as used here is often called "observed," and the word "observed" as used here is often called "apparent."*

* * *

NAVIGATION NOTES

BOXING THE COMPASS

David Burch

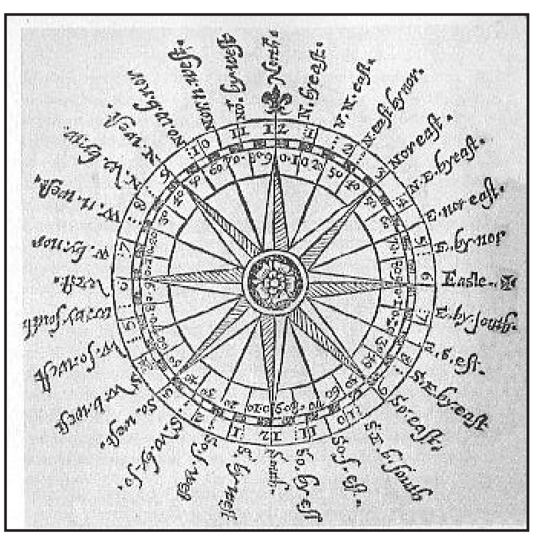
I started out with the intention to round out this issue with notes from the 1851*Bowditch* on the log of his voyage from Boston to Maderia, which he made in 1836. It is a fascinating document that reminds us of many of the fundamentals of marine navigation. One of which is the procedure of "taking a departure" on ocean voyages. Taking a departure means simply recording the bearing to the last land you see as it slips out of sight, and adding to this an estimate of its distance off.

Modern navigators have mostly forgotten about this step in their navigation routine, and to the extent that happens we lose one more of the good procedures established over many years by our seafaring forefathers. Even in the age of GPS, we should take and record our departure. As we sail out of sight of land, it is in a sense the last thing we know for sure!

The first thing you run across in the Boston to Maderia log book is "At 8 PM, Cape Cod Light-house bore S by E 3/4 E, distant 14 miles; from which I take my departure." To a modern reader, the first job is to figure out what bearing this really is. He is speaking in terms of compass points. There is a point on the compass called "South by East," and from this point you turn three quarters of a point to the east, and you are facing the lighthouse.

The general procedure of converting compass points to azimuthal degrees is called "boxing the compass." There are 32 points in a circle, thus each point is 11.25°. Easy enough it would seem, but nevertheless, boxing the compass is no simple matter. And it was at this point I realized that this question comes up to modern navigators more often than we might guess—usually in the context of reading an older book, but sometimes part of navigation tests that choose to hang on to some older traditions. Not to mention that compass points are still marked on the compass roses of many modern US charts and magnetic compass cards, so an instructor is obligated to give some level of explanation. Compass points are also referred to in the *Navigation Rules* in that, for example, sidelights show from straight ahead to two points aft of the beam.

But when it comes to looking up how to box a compass we quickly learn that this is not so easy to find. It has long been dropped out of most modern textbooks, and if you go back to the days when it was commonly used for bearings and courses (1800's) you find that it was then presumed a known basic, and therefore not covered there as well. Thus the best source is a text from early 1900's, such as a 1916 or 1920 *Bowditch.* Referring to the figure of the Kelvin compass card (next page), we see that each point is named relative to the nearest cardinal or inter-cardinal point. Thus the name



A compass rose from John Davis's Seaman's Secrets *(1596). Notice that it shows both degrees and compass points, and in the center there is a rose. The fleur-de-lys is likely a variation of the letter T for Tramontane, the North Wind, and a cross marks the east,...* *...being the direction to Jerusalem, which was on the misguided minds of some chart makers in those days.*

of the third point to the right of north is NE by N and not NNE by S. The word "by" means the point next to the reference point. It is sometimes abbreviated with an "x" such as NE x N.

The finest divisions used are quarter points (11.25/4 = 2.8125°). The labeling of the quarter points is where all the fun begins. Fractional points are referred to the nearest whole point, but which one do you use. For example, the bearing one quarter point N of NE could be called NE 1/4 N or NE x N 3/4 S. Only one is right, however.

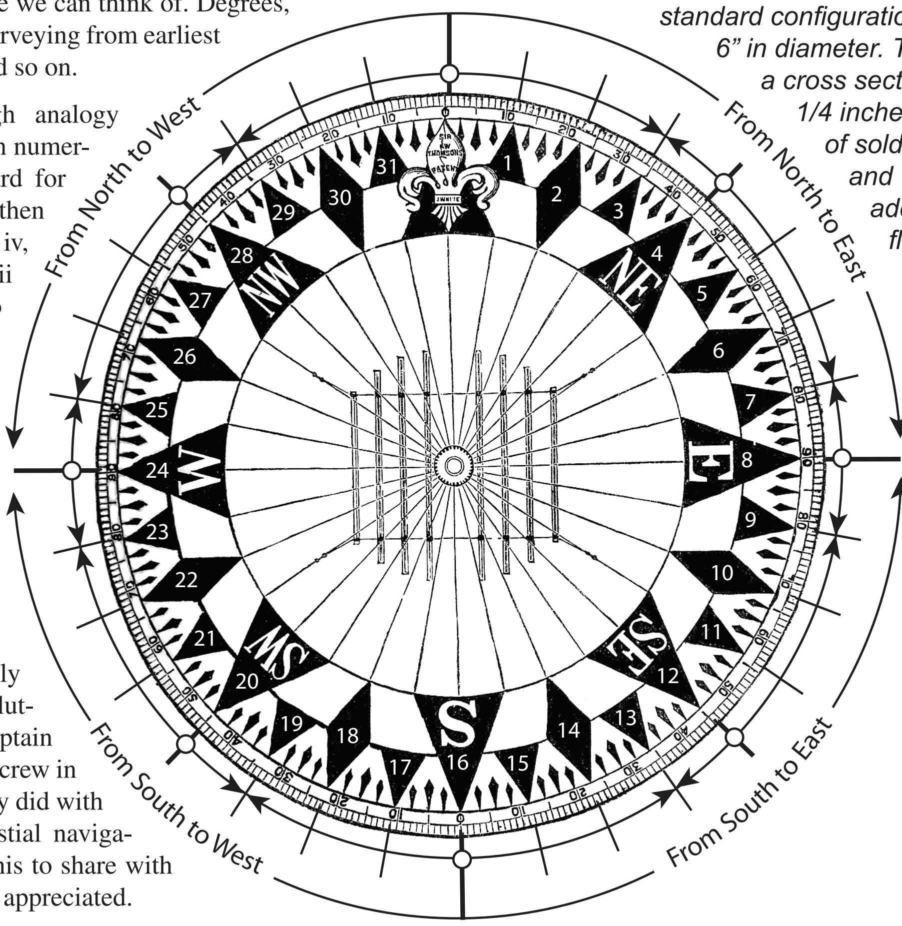
The convention used is to box from the North toward the East and West, and from the South toward the East and West, except that the points adjacent to the cardinal and inter-cardinal points are always referenced to these points. Thus in the example given, the right answer is NE 1/4 N. The Table shown on the next page and the diagram below illustrate this convention.

My question to the membership is why did they use this system when simple degrees were well known and on the dials and easier to use in about every sense we can think of. Degrees, not points, were used in surveying from earliest times, such as N 37° E and so on.

There is some rough analogy here with the use of roman numerals, which proceed upward for a period then back one then upward again: i, ii, iii, iv, V, vi, vii, viii, ix, X, xi, xii etc. Thus we count up to a reference point and the adjacent points to it are referenced to it and not in an ongoing sequence. But we all recognize this as a convoluted way to count. Movie makers even put the date in this format so we can't figure it out as it flashes by.

Could it be the early mariners used this convoluted system to protect the captain from mutiny by untrained crew in the sense that it is said they did with the very practice of celestial navigation. Any knowledge of this to share with the membership would be appreciated.

The back of a modern compass card showing the type of compass "needles" now in use. This is a fairly standard configuration. This card is about 6" in diameter. The magnets have a cross section of about 1/8 x 1/4 inches. There are daubs of solder opposite the S and W points. These are added to balance the floating card against the dip angle of the magnetic field. Thus a compass card in the Northern Hemisphere and the Southern Hemisphere would have these in different locations.



This compass rose is from a drawing submitted with American Patent No 4,923 in 1889 by William Thomson, known also as "Lord Kelvin." In small print in the fleur-de-lys are the words "Sir W. Thomson's Patent". It is marked off in quarter points and degrees. We have added the numbering of the points and we added the markings outside of the azimuth ring of degrees, else it is as he presented it. The inside shows what is presumably his proposed design for the compass needles. A sample of a modern version is shown above. Thomson was one of the leading physicists of the 19th century, but also worked on many practical matters, which brought him great wealth. Besides fundamental physics he (and his large staff of assistants) also worked on such mundane maritime matters as optimizing the design of a compass card and the creation of mechanical machines for tide prediction.

The motivation for the dominant use of compass points for courses and headings throughout the 18th and 19th century in place of actual degrees is not clear to me. We see that degrees were on the compass roses back in the 16th century, and all the reasons we use them now rather than compass points would seem to be true then as well.

0	North	000.0°
	N 1/4 E	002.8°
	N 1/2 E	005.6°
	N 3/4 E	008.4°
1	North-by-east	011.3°
	N x E 1/4 E	014.1°
	N x E 1/2 E	016.9°
	N x E 3/4 E	019.7°
2	North-northeast	022.5°
	NNE 1/4 E	025.3°
	NNE 1/2 E	028.1°
	NNE 3/4 E	030.9°
3	Northeast-by-north	033.8°
	NE 3/4 N	036.6°
	NE 1/2 N	039.4°
	NE 1/4 N	042.2°
4	Northeast	045.0°
	NE 1/4 E	047.8°
	NE 1/2 E	050.6°
	NE 3/4 E	053.4°
5	Northeast-by-east	056.3°
	NE x E 1/4 E	059.1°
	NE x E 1/2 E	061.9°
	NE x E 3/4 E	064.7°
6	East-northeast	067.5°
	ENE 1/4 E	070.3°
	ENE 1/2 E	073.1°
	ENE 3/4 E	075.9°
7	East-by-north	078.8°
	E 3/4 N	081.6°
	E 1/2 N	084.4°
	E 1/4 N	087.2°
8	East	090.0°
	E 1/4 S	092.8°
	E 1/2 S	095.6°
	E 3/4 S	098.4°
9	East-by-south	101.3°
	ESE 3/4 E	104.1°
	ESE 1/2 E	106.9°
	ESE 1/4 E	109.7°
10	East-southeast	112.5°
	SE x E 3/4 E	115.3°
	SE x E 1/2 E	118.1°
	SE x E 1/4 E	120.9°
11	Southeast-by-east	123.8°
	SE 3/4 E	126.6°
	SE 1/2 E	129.4°
	SE 1/4 E	132.2°

12	Southeast	135.0°
	SE 1/4 S	137.8°
	SE 1/2 S	140.6°
	SE 3/4 S	143.4°
13	Southeast-by-south	146.3°
	SSE 3/4 E	149.1°
	SSE 1/2 E	151.9°
	SSE 1/4 E	154.7°
14	South-southeast	157.5°
	S x E 3/4 E	160.3°
	S x E 1/2 E	163.1°
	S x E 1/4 E	165.9°
15	South-by-east	168.8°
	S 3/4 E	171.6°
	S 1/2 E	174.4°
	S 1/4 E	177.2°
16	South	180.0°
	S 1/4 W	182.8°
	S 1/2 W	185.6°
	S 3/4 W	188.4°
17	South-by-west	191.3°
	S x W 1/4 W	194.1°
	S x W 1/2 W	196.9°
	S x W 3/4 W	199.7°
18	South-southwest	202.5°
	SSW 1/4 W	205.3°
	SSW 1/2 W	208.1°
	SSW 3/4 W	210.9°
19	Southwest-by-south	213.8°
	SW 3/4 S	216.6°
	SW 1/2 S	219.4°
	SW 1/4 S	222.2°
20	Southwest	225.0°
	SW 1/4 W	227.8°
	SW 1/2 W	230.6°
	SW 3/4 W	233.4°
21	Southwest-by-west	236.3°
	SW x W 1/4 W	239.1°
	SW x W 1/2 W	241.9°
	SW x W 3/4 W	244.7°
22	West-southwest	247.5°
	WSW 1/4 W	250.3°
	WSW 1/2 W	253.1°
	WSW 3/4 W	255.9°
23	West-by-south	258.8°
	W 3/4 S	261.6°
	W 1/2 S	264.4°
	W 1/4 S	267.2°

24	West	270.0°
	W 1/4 S	272.8°
	W 1/2 S	275.6°
	W 3/4 S	278.4°
25	West-by-north	281.3°
	WNW 3/4 W	284.1°
	WNW 1/2 W	286.9°
	WNW 1/4 W	289.7°
26	West-northwest	292.5°
	NW x W 3/4 W	295.3°
	NW x W 1/2 W	298.1°
	NW x W 1/4 W	300.9°
27	Northwest-by-west	303.8°
	NW 3/4 W	306.6°
	NW 1/2 W	309.4°
	NW 1/4 W	312.2°
28	Northwest	315.0°
	NW 1/4 N	317.8°
	NW 1/2 N	320.6°
	NW 3/4 N	323.4°
29	Northwest-by-north	326.3°
	NNW 3/4 W	329.1°
	NNW 1/2 W	331.9°
	NNW 1/4 W	334.7°
30	North-northwest	337.5°
	N x W 3/4 W	340.3°
	N x W 1/2 W	343.1°
	N x W 1/4 W	345.9°
31	North-by-west	348.8°
	N 3/4 W	351.6°
	N 1/2 W	354.4°
	N 1/4 W	357.2°
32	North	360.0°

Boxing the Compass

This name for the process of listing or reciting the points of a compass card arose after 1851 and before 1911, but we have not found out when or where it was first used. In the 1851 Bowditch *"boxing" was a verb meaning to back wind the jib. In 1911 edition it was used as is done today.*

NAVIGATION NOTES

PHOTO SEXTANT SIGHTS

For those who have an interest in celestial navigation, there is a fun new hobby that you may not have considered. Namely, just taking a picture of celestial bodies low on the horizon at a known time and then analyze them to find a Line of Position, or even an actual celestial fix. The following note on this topic is from the second edition of Emergency Navigation *by David Burch (McGraw Hill, 2008). It is from the section on what do you do if you have everything you need, but you do not have a sextant. Following that are some related notes on the process from the Starpath online course on emergency navigation.*

Another technique that might work in some circumstances, if you happen to have all your tools but a sextant, is to take a photo sextant sight. You'll also need a digital camera (or even a cellphone camera) and a computer on board. (This may seem pretty techie, but is not so unlikely these days. Many mariners document their trips with email logs and even send photos back home via satellite or SSB connections during an ocean passage.) This is another example—like building a quadrant at home—that makes for an interesting hobby activity. This one will make you more familiar with the sky, your camera, and your computer graphics programs.

The trick is to take a digital photo of the sun or moon when low to the horizon and ideally at a time when another celestial body—any star or any planet—is also in the camera's view. When you have such a photo you can get a position fix. Two sights will give you two intersecting LOPs; if you get just the sun or the moon alone, all you'll get is one LOP. With some experience or practice with exposures, filters, and general photography, you can get some pretty good photos. Personally I don't know about such things and have just taken the photo and hoped for the best, or asked others to take them, such as the sun shot shown in Figure 14-10.

Once you have the photo, load it into your computer using your favorite graphics program. My favorite for this operation (and many other things such as weather map analysis) is Paint Shop Pro (paintshoppro.com), although most photo processing or graphics programs will do the job. If you don't have one, do an Internet search on "free graphics programs" to find one you like. For this application, the key program feature you need is a way to measure the pixel-count length of a line, or dimensions of a circle or rectangle. It is a common feature that most such programs will have. You'll also find that a layers option is handy, which lets you create your drawing on a separate, transparent layer on top of the main photo without altering the photo itself. Then if you make a mistake, you can just undo your work without having to worry about the photo; this is more of a convenience than a necessity, however.

Using the program's measurement tool, measure the height of the sun above the horizon in pixels, and then measure the diameter of the sun in pixels—these will establish the scale. Next look up the semi-diameter of the sun (about 16') in the almanac. If the sun, for example, is 5.5 diameters above the horizon, then its height is 5.5 × 32' = 176'; or Hs (lower limb) at the time of the photo is 2° 56'. For these low sights, it is likely best to use the horizontal diameter of the sun as the reference rather than the vertical diameter, since the latter will likely be smaller due to refraction. This is the reason they call this dimension of the sun a semi-diameter and not a radius. An example of the analysis is shown in Figure 14-10.

———

Though it is not mentioned in the *Emergency Navigation* text, we have also done this to analyze lunar sights. An example for a moon and Jupiter picture is shown on the right. This picture was taken by Steve Miller in Florida at 27° 12.2' N, 80° 13.4' W at 05h 38m 23s GMT on March 19, 2006. The moon semi-diameter at this time was 15.3'. We analyzed this sight last year using Paint Shop Pro and got an observed lunar distance of 5° 23.5', which corresponded to a longitude error of 53'. Put another way, had we not known time or longitude, we would have found our longitude this way to within 53'. The details are online in the link given in the figure caption.

Figure 14-10. *Photo sextant sights. Left . With a graphics program we fi t a circle around the circumference of the sun and noted its diameter, 32 pixels in this case. Then we constructed a rectangle to measure the height of the lower limb above the horizon, 302 pixels. At the time of this sight, the semi-diameter of the sun was 16.2' as listed in the Nautical Almanac, so 32 pixels = 2 × 16.2', and 302 pixels = 5° 6', which would be Hs, lower limb. Right. Similar photo of a setting new moon, taken to the West, across Puget Sound. The diameter of the moon as 65 pixels, the semi-diameter at the time was 15.0', and the height was 224 pixels, which leads to Hs = 1° 43'. Both sun and moon sights lead to lines of position within a few miles of the true position. This same moon sight was taken with a cell phone camera and (quite accidentally) gave an even more accurate line of position. See starpath.com/emergencynavbook.*

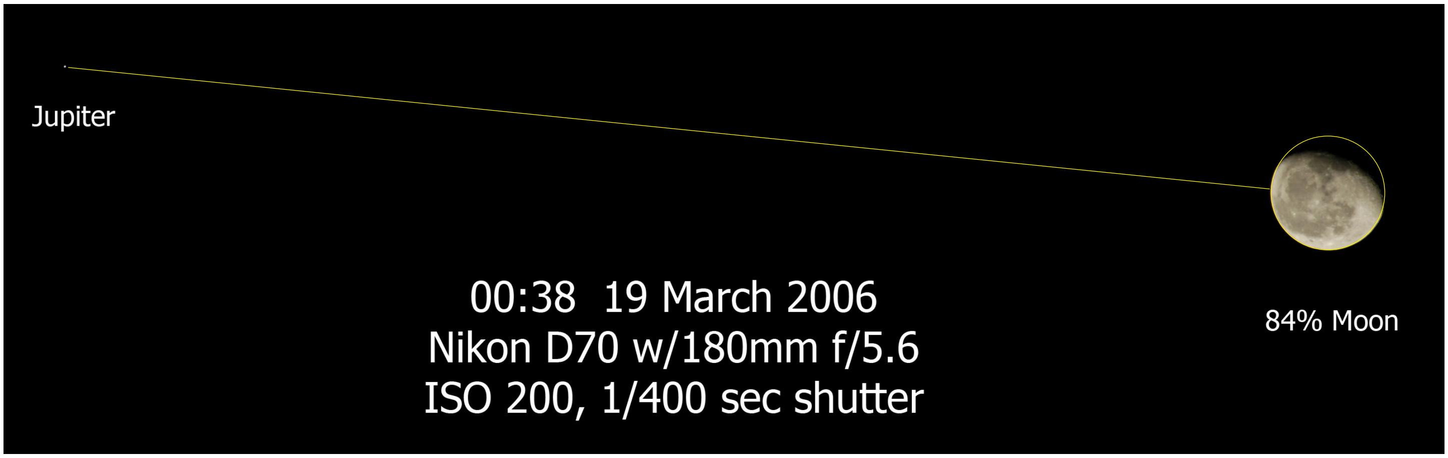
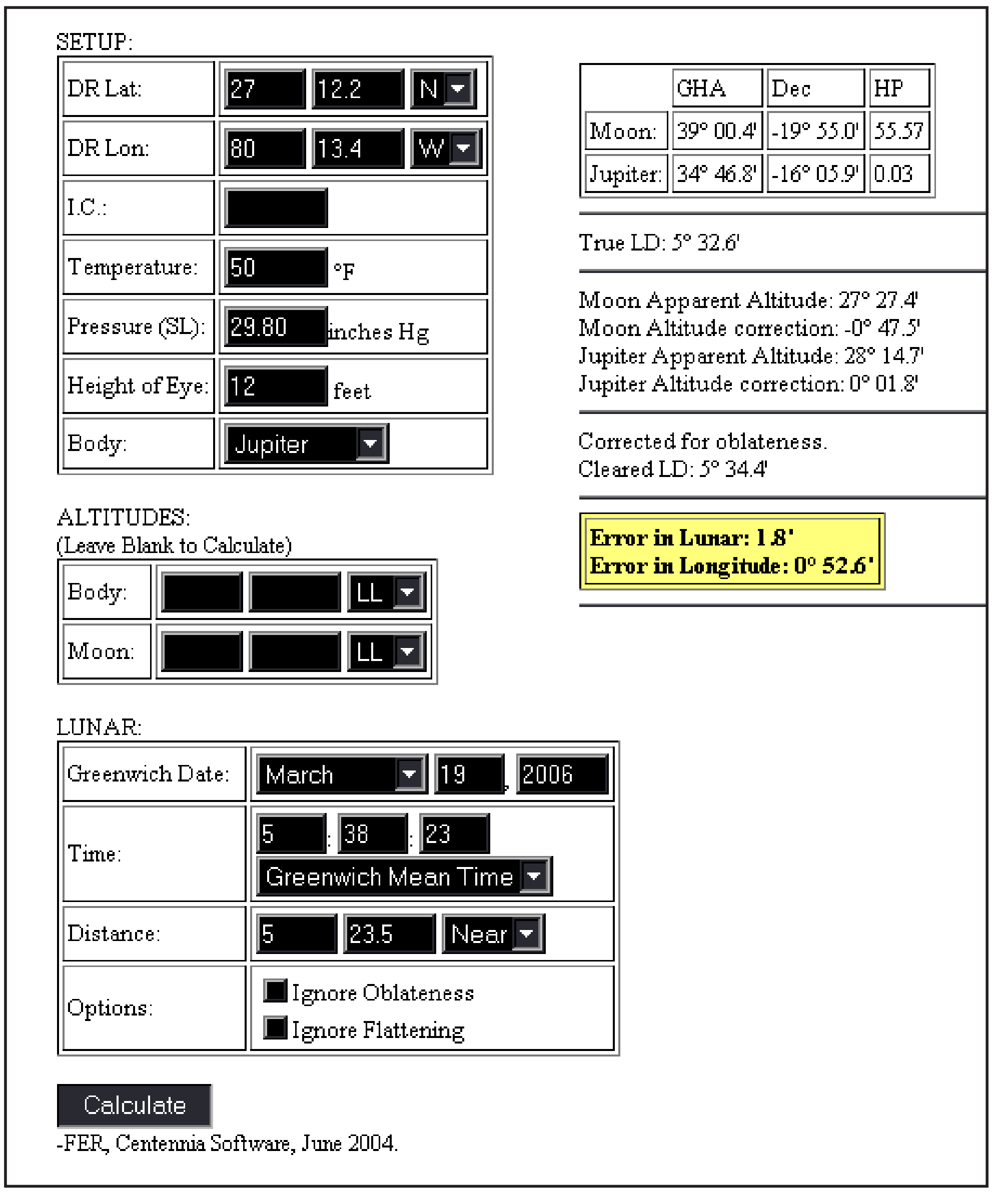


Photo by Capt. Steve Miller, long time Foundation member and celestial navigation instructor at Chapman's School of Seamanship in Stuart FL, and online instructor for Starpath Online Navigation School. For those who want to analyze this on their own, a high resolution image can be downloaded from the Starpath online discussion group on emergency navigation, as well as several other moon-planet photos with time and location documented. See http://tinyurl.com/moonpics. All from Steve Miller.

At this writing we pasted the picture into the article and then overlaid the circle (diameter 0.5953") and the line between them (6.2878") using Adobe Indesign, with which we can lock all the objects, zoom and adjust, and read accurate dimensions. In this case we get LD = (6.2878 / 0.5953 / 2) x 15.3' = 5° 23.2', which agrees with earlier analysis. The lunar distance analysis was done online using Frank Reed's formulation at http://www.historicalatlas.com/lunars. The screen capture of the input and out put is shown here.

We have only analyzed a dozen or so of these photo cel nav sights, but the process seems promising and certainly provides a nice hobby activity for those who enjoy matters of celestial navigation. It is also a test of your photography skills. Steve Miller has written a book on moon photography for any who might be interested. It is called *The Captain's Moon*. See http://starpath.com/catalog/books/1790.htm, which is available as an ebook or in print.

* * *



SETUP:

DR Lat: 27 12.2 N

DR Lon: 80 13.4 W

I.C.:

Temperature: 50 °F

Pressure (SL): 29.80 inches Hg

Height of Eye: 12 feet

Body: Jupiter

ALTITUDES:
(Leave Blank to Calculate)

Body: LL

Moon: LL

LUNAR:

Greenwich Date: March 19, 2006

Time: 5 : 38 : 23 Greenwich Mean Time

Distance: 5 23.5 Near

Options: Ignore Oblateness; Ignore Flattening

Calculate

-FER, Centennia Software, June 2004.

	GHA	Dec	HP
Moon:	39° 00.4'	-19° 55.0'	55.57
Jupiter:	34° 46.8'	-16° 05.9'	0.03

True LD: 5° 32.6'

Moon Apparent Altitude: 27° 27.4'
Moon Altitude correction: -0° 47.5'
Jupiter Apparent Altitude: 28° 14.7'
Jupiter Altitude correction: 0° 01.8'

Corrected for oblateness.
Cleared LD: 5° 34.4'

Error in Lunar: 1.8'
Error in Longitude: 0° 52.6'

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"THE NAVIGATION FOUNDATION"

The Navigator's Newsletter
Published by
The Foundation for the
Promotion of the Art of Navigation
www.navigationfoundation.org
P O Box 1126
Rockville, Maryland 20850, USA
Phone or fax 301-622-6448
Executive Director, Terry Carraway,
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The Navigator's Newsletter is published four times annually, with our strived-for publication dates of approximately the solstices and equinoxes. Newsletter production and other Foundation activities are provided by volunteers. Please bear with us if we slip on the dates occasionally.