

## DISCUSSION CONCLUDING AAS 11-669

Steve Allen asked how historically significant changes to almanacs were perceived by practicing navigators, such as the changeover from apparent solar time to mean solar time in 1833, and the changeover from the astronomical day (beginning at noon) to the civil day (beginning at midnight) in 1925. Frank Reed responded that he had found no evidence in the primary-source logbooks available to him that these changes caused serious problems, but secondary source information suggested that there may have been issues.\* Reed thought that the personal memoirs of D.H. Sadler (Superintendent of HMNAO from 1936 to 1971) expressed more anger with the Admiralty than was deserved, but admitted that is the nature of a personal memoir as the recollections of someone at the end of their career. But there was no known primary source documentation of anything bad happening with ships at sea on January 1, 1925, for example.

David Terrett asked if WWV still included “double-ticks” (the encoding of DUT1 in the audio time signal). Reed and others replied affirmatively. Rob Seaman noted that part of the proposed Recommendation TF.460-7 was to eliminate the requirement for DUT1. Reed said he did not think anyone used those anymore, and was not sure he knew anyone who was aware of them. Reed had suggested in his talk that a verbal announcement of DUT1 could instead be declared at some point within the hourly broadcast, but Allen wondered who might have the time or patience to listen to WWV for an hour. Reed clarified that he meant that a verbal announcement could be made at regularly scheduled minutes so that people would know when to tune in to get the information. Reed said that a page within future editions of the nautical almanacs could include a note on how to get UT1-UTC information. Seaman noted that a single page could get ripped out; Reed replied that much of the information within the almanacs is duplicated to a degree, so a page in front and a page in the back should provide desired redundancy.

Wolfgang Dick commented that sailors familiar to him all use GNSS, so it was unclear to him if anyone still used sextants. Reed clarified that he is discussing celestial navigation in the context of providing the “ultimate back-up”. Reed said that if one somehow lost their GPS receiver overboard, one could make it back to port with a sextant in hand without the embarrassment and complications of having to be rescued by the Coast Guard. Although celestial navigation is not actively used by most navies today, all of the leading maritime academies still teach it extensively.

Reed suggested that the amount of navigation taught within the US Navy today is remarkably trivial because surface vessels tend to have both GPS navigation in combination with inertial navigation systems. Thus, the crews of large surface ships can no longer estimate their location by

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\* *Editors' Note:* Mr. Reed provided the following addendum to his remarks following the colloquium. He spent several hours examining two logbooks in the library at Mystic Seaport having hundreds of extensively worked lunars. Both logbooks had worked examples from January and February of 1834 where the navigators were initially confused because the lunars were providing longitudes that did not match the chronometer or the dead reckoning by a wide margin. Logbook notes added later explained that the discrepancy was due to the change from Greenwich apparent time to Greenwich mean time in the Nautical Almanac tables.

observing buoys and lighthouses, and they can literally drive a vessel upon a reef if both systems happen go out at the same time. Modern navigation systems are instead computer driven and the computers combine information from both GPS and inertial navigation. These systems are very advanced and precisely tell a helmsman how to drive a boat, but unfortunately operators know how to turn off the software that is protecting them if it seems to complain too much. Reed said this actually happened a few years ago when a US Navy cruiser was driven on to a reef off of Honolulu International Airport, with the city lights and the airport plainly visible. The navigation system was a mile off course because the crew had turned off the system that could have alerted them to the fact that there was no GPS fix and the inertial guidance system had not been recalibrated for three days.

Reed said this is just an example of just how little celestial navigation is practiced now; today's navies don't really use it much at all anymore and in some respects the practice of celestial navigation is regarded as not much more than a hobby to some. But it still functions as the "ultimate back-up"—useful when all else fails. Tyson offered the caveat that celestial navigation only works as a back-up in fair weather.

Reed continued that celestial navigation still has its place, but mostly in automated systems. For example, Reed said that if GPS were somehow disabled by war, celestially navigated drones could operate at a very high altitude within a theater of operations, providing all-weather navigation signals to specialized receivers on the ground. Rob Seaman asked if this was an operational capability or a concept; Reed replied that to the extent of his knowledge it was still a concept. Seaman said that such capability, if operational, would seem to involve "a heck of a lot of software" that required precise knowledge of UT1. Reed agreed.

Kaplan clarified that the practice of celestial navigation within the US Navy is actually highly variable. While the practice has gone down drastically over time, Kaplan said that some captains still demand that their crews know how to do it, and conduct exercises by establishing a fix in the middle of the ocean with GPS receivers turned off. Yet, because of the high amount of automation within modern navies, there is much gadgetry that demands training. So there is a question as to how much time should be devoted to crew training for celestial navigation versus "the latest gizmo on the bridge." Kaplan therefore reiterated that celestial navigation has not disappeared completely from the Navy; a lot of quartermasters and enlisted personnel still practice it.

Kaplan continued by saying that if celestial navigation is not part of one's daily assignment, then one gets rusty, because it requires a certain level of practiced skill to navigate accurately. Reed said that issue leads to the other problem with changing the time standard; namely, if a navigator hasn't practiced celestial navigation in a long time and the time standard has been changed out from under him, it could be very confusing in a crisis. To avoid risks, word would need to get out about any such change. This is why Reed suggests that a bold notice should be put be a permanent part of future almanacs if a change occurs.