National Security Matters

The Art and Science of Navigation

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The Institute of Navigation's mission is to be *the world's premier professional society advancing the art and science of positioning, navigation, and timing (PNT).*

The reference to advancing the **art and science** of navigation has been the foundation of the Institute since its inception. Navigation has always required rigorous science and engineering, but it also depends on a prudent navigator's ability to factor experience, intuition, and multiple sources of information into sound decisions. The **art** of navigation is knowing when to trust the instruments, when to question them, and how to adapt when the unexpected occurs.

Today, we may be experiencing one of the most dynamic periods in the history of navigation. From the proliferation of global navigation satellite systems (GNSS) to the pursuit of resilient PNT architectures, the field is undergoing a profound transformation. Precision timing networks, inertial navigation, modernized celestial navigation, visual navigation systems, terrain matching, signals of opportunity, low-Earth-orbit constellations, quantum sensing, artificial intelligence (AI), and other emerging technologies are collectively reshaping how we determine position, velocity, and time.

But amid this technological revolution, it is worth asking a simple question: Are we placing enough emphasis on preserving the **art** of navigation?

In preparing this newsletter, I will share three of my own experiences that have shaped my appreciation for both the **art and science** of navigation.

A Sloop Named Touché

The first experience goes back more than fifty years to when I was a 4th-class cadet at the U.S. Coast Guard Academy.

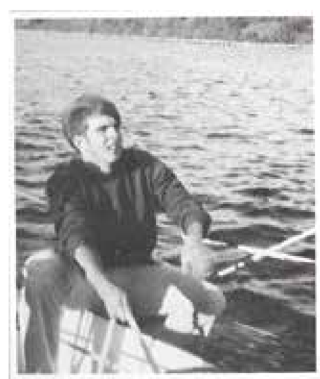
In the spring of 1973, I was a crew member on one of the Academy's ocean racing yachts, a 48-foot cutter-rigged wood-hulled sloop named Touché. My primary duties as a 4th classman during a yacht race were straightforward: be an unquestioning, *head-and-eyes-in-the-boat* winch grinder.

My first enduring lesson in navigation began on a Friday evening in the spring of 1973. After Friday classes, our seven-man cadet crew, with a commissioned Academy safety officer aboard, departed the Academy bound for Block Island by way of Fishers Island Sound. The plan was for us to sail to Point Judith that Friday evening, spend the night, and then continue to Block Island the following morning for a Saturday regatta.

By the time we cleared the Thames River, turned to port into Fishers Island Sound, secured the engine, and set sail, darkness was setting in with steady winds out of the southwest and calm seas. The current was running strongly in our favor, and in hindsight, the degree to which it was contributing to our speed over the bottom was significantly more than anticipated.

Our 2nd-class cadet navigator (who shall remain anonymous) was responsible for keeping us on course using the traditional tools of navigation: a paper chart; visual bearings to shoreside landmarks; buoys; a magnetic compass heading; the fathometer; and the boat's pit log (measuring speed through the water in knots).

The lesson that still sticks with me today was misjudging the strength of the current, the boat's set to leeward, and ultimately, the speed we were making over ground. The fatal error was made when our navigator misidentified a combination of buoys and mistook a fixed aid that he thought (in retrospect) to be for Stonington but was really a light near Watch Hill. Individu-



Doug Taggart, 1973, on Touché

ally, none of the errors seemed significant. Together, however, they placed us just far enough off the intended track that we ended up running aground on a sandy shoal inside the Watch Hill breakwater.

Attempts to pull ourselves off the shoal using a stern-rigged anchor and the engine were futile. In the end, we had no choice but to radio the Coast Guard to send a 44-foot small boat to tow us off the shoal. Fortunately, the sandy bottom spared us any damage, and after an over-the-side inspection on Saturday morning, we continued our sail to Block Island and ultimately participated in the regatta.

While the incident ended with little more than bruised egos, it left me with a lesson that has shaped my approach to navigation ever since. The art of navigation is not simply plotting a position or following a course. It is the discipline of continuously integrating every piece of information available. A prudent navigator must consider the wind, the current, the tides, the sea state, visual cues, charted hazards, aids to navigation, your boat's maneuvering capabilities, and sometimes a gut feeling that something doesn't look right.

Precision Intracoastal Loran Translator

Moving to the early 1980s, I was assigned as a Lieutenant to the Coast Guard's Research and Development Center (R&DC) in Groton, Connecticut. In my first assignment following graduate school, I was a project engineer involved in the Coast Guard's efforts to advance electronic navigation on the Great Lakes using the St. Marys River Mini-Loran-C Chain. Our project was to test and evaluate an innovative onboard electronic navigation system known as **PILOT** (Precision Intracoastal Loran Translator), developed by the Johns Hopkins Applied Physics Laboratory.

PILOT was one of the earliest electronic moving-map display systems. It presented a vessel's position on a manually digitized nautical chart that included surveyed Loran-C waypoints along the 70-plus-mile St. Marys River, the waterway connecting Lake Superior and Lake Huron through the Soo Locks at Sault Ste. Marie, Michigan.

M/V G.A. Stinson

To evaluate PILOT's capabilities, the Coast Guard partnered with four Great Lakes iron ore carriers that routinely transited between Duluth and the auto manufacturing ports in Detroit and Cleveland. These vessels operated continuously from the spring thaw, when the ice cleared from the St. Marys River, until late November, when the river froze and the navigation buoys marking the shipping channels were removed. The objective of the project was to determine whether safe navigation could be maintained without relying on the buoys marking the channel boundaries.

I could write an entire paper about this experience as I actually presented my first ION paper in 1985 on this area of work, but cutting to the chase, this second lesson came from my time spent aboard one of the 1,000-foot ore carriers, the M/V George A. Stinson.

With the pilothouse located aft, more than 900 feet from the bow, the Stinson's Captain had become so comfortable and confident with the PILOT display that he began using it as an aid in ship handling. Specifically, he relied on the display to determine when the bow of his vessel came abeam of the digitized representation of the guide walls extending outward from the entrances to the Soo Locks. When the PILOT display indicated that alignment had occurred, he would use that cue to begin his backing maneuver.

It is important to appreciate the magnitude of this situation: The Captain was making a critical ship-handling decision based on the position of the bow located more than three football fields ahead of him, using a graphical display that provided a representation of the vessel's position relative to the digitized chart's rendering of the guide wall just before the locks.

On witnessing this, I vividly recall mentioning to him the many technical factors that could influence what the display was actually depicting. His response was simple but profound: He never trusted the display by itself. Rather, he correlated the information from the PILOT system with his own visual observations, the reports he was receiving from his forward line handlers, his own feel of the ship, and his years of experience navigating the river and entering the locks. He understood, and I never forgot the lesson.

Coast Guard's Training Ship *EAGLE*

The third and final experience I will share is one that I devoted my Fall 2016 *ION Newsletter* to. Titled *Time*, the article reflected on the opportunity I had, forty years after graduating from the U.S. Coast Guard Academy, to once again sail aboard the Coast Guard's training ship *EAGLE.*

In that article, I applauded the Academy's decision to reintroduce celestial navigation into *EAGLE's* summer training curriculum, but I also shared a moment of disappointment and, admittedly, embarrassment when I discovered that the *EAGLE* no longer had a ship's chronometer for keeping the ship's time and, more importantly, providing a "time hack" for conducting celestial navigation observations.

When I asked one of the cadets how

they obtained their time reference for celestial sights, the response revealed a troubling disconnect. Without hesitation, or any apparent recognition of the flawed logic, the cadet answered that they simply went to the Electronic Chart Display and Information System (ECDIS) display and used the UTC time shown in the upper left corner of the screen. When I pointed out that ECDIS obtained its time reference from GPS, the cadet quickly replied, “But we don’t look at the position information.”

That response, and the cadet’s confidence in voicing that point back to me, reveal the challenge facing modern navigation: the distinction between using technology as a tool and understanding the underlying principles that make the technology work.

While electronic navigation systems have transformed our ability to determine position and time, true navigational proficiency requires an appreciation of the fundamentals and a true understanding of the vulnerabilities that exist when one relies on a single source without question.

The rapid emergence of AI introduces both extraordinary opportunities and important responsibilities. AI has the potential to revolutionize navigation by fusing multiple sensor inputs, detecting anomalies more quickly than humans, recommending alternate routes, predicting system degradation, and assisting operators in making better-informed decisions. Properly implemented, AI may become one of the most valuable navigation aids ever developed. But AI should remain exactly that, a navigation aid.

The invention of the chronometer did not replace seamanship. The magnetic compass did not eliminate seamanship.

Doug Taggart aboard the EAGLE *in 2016*

Radionavigation did not replace chart work. GPS did not eliminate the need to understand navigation principles. Likewise, AI should not replace the navigator's ability to think critically.

As systems become increasingly autonomous, the ION must ensure that future navigators continue to understand the underlying principles governing the **art and science** of safe navigation.