Q&A with Steven J. DiTullio, VP, Strategic Systems, Draper

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One of the legs of the United States' nuclear strategic deterrent is the submarine-launched ballistic missile (SLBM). Since 1960, ballistic-missile submarines (SSBNs) of the U.S. Navy have patrolled the seas, armed initially with Polaris, then Poseidon, Trident C4, and today Trident D5 and D5LE (Life Extension) SLBMs. Since the beginning of the SLBM program in the mid-1950s, the guidance systems of all Navy SLBMs have been built by The Charles Stark Draper Laboratory, now known as Draper.

DiTullio joined the company in 1984 following a five-year career in the Navy, where he conducted five deterrent patrols while serving as a nuclear-trained officer on the SSBN USS George Bancroft. Upon joining Draper, he supported the company's Strategic Systems program in positions of increasing responsibility before becoming vice president in 2012. In 2017, DiTullio was awarded the Fleet Ballistic Missile Lifetime Achievement Award in recognition of his accomplishments in support of the Navy's strategic missile program.

Getting an SLBM to hit its target perhaps 4,000 nautical miles away is no small feat. DiTullio discussed the guidance system of the Trident missile with Senior Editor Richard R. Burgess. Check out the digital edition of the October issue of Seapower *magazine here*.

What is the scope of Draper's role in the design and production of the SLBM guidance systems?

DiTULLIO: Historically, Draper acted in what we call a design agent role. We did the design and development. The Navy themselves contracted for the production, and Draper assisted the government with the industrial support team that was building them. In the late-1990s or early 2000s, the Navy asked Draper to take on the more classic prime [contractor] role, basically to take over for the lifecycle support of the entire guidance program, not only the design and development, but the procurement and direct management of the subcontractors who build and support the systems.

Today, Draper operates like a classic prime [for the guidance system], no different than Lockheed Martin for the missile or General Dynamics for the fire control system or for some of the other subsystems. Now that Draper is the prime, we have the capability to be a little more dynamic in setting where we operate at any given time. We have been able to gain some synergies in terms of being able to take some development activities and use them as part of our sustainment. If we have a current fleet issue or an obsolescence issue, it is a little more seamless now to bring some technology development, maybe for a future system, and accelerate that to meet an emergent need. Not that we weren't able to do that before but, again, now that it's all under one omnibus contract, it makes that a lot more seamless. We work intimately with the Navy to make sure we always have that right balance.

What kind of guidance system is used on the Trident SLBM?

DiTULLIO: The current system, the Mark 6, is what we would call an all-inertial system. It basically runs autonomously, but we do have the ability to use an external aid: a star sighting.

It's celestial navigation, not much different than the era of wooden ships and iron men. We have a star catalog that sits in [the submarine's] fire control system. As we currently are mechanized with an all-inertial system and because of the types of gyroscopes that we traditionally had used, we are prohibited from moving the guidance systems inertial platform in flight because of the errors that that would induce.

The one big difference between the Air Force ICBM [intercontinental ballistic missile] and the Navy SLBM is the fact that the ICBM has a fixed base and the SLBM has a moving base – on a submarine platform that moves throughout the ocean. The submerged submarine has no ability to know exactly where it is at the time of launch. We do have a pretty good shipboard navigator to assist in that but even that isn't precise enough. The way that we handle that uncertainty is by taking a star sighting during missile flight to then effectively correct for the initial position error.

In general, for the classic gyroscopes that we have used up until the most recent Mark 6 life extension, they were spinning mass gyros, so we apply small amounts of torque to the gyro to maintain the platform fixed in inertial space – we would need to apply a significant amount of torque if we were to use the gyro, because you actually wanted to move the platform. When you apply torque to an electromechanical gyroscope and move the platform, you impart currents. Currents hold a lot of heat and heat causes an error. To avoid that error source, we effectively do not allow the platform to move in flight. We basically just align the platform to a known position based on the star selected in the fire control system. In flight, the idea of a gyro is to keep the platform null to whatever we align it to. That minimizes the disturbances on the gyro.

To do a star sighting with that constraint, we basically are only able to take one star sighting. That would not be a very good fix if you only took one star sighting; you can't really triangulate where you are on the Earth. The way we get around that is that if you can pick a star that is directly over your target, you then are able to basically make some simplifying assumptions that allow you to get the same level of accuracy. The accuracy of the current system is directly related to having what we call an optimum star, the star that is directly over the target. Now, you can't always get that due to occlusion angles from either the sun or moon, or there just are no stars at the time that you want to launch, so that's an accuracy impact that the current system just has to absorb and we've designed for.

In this case, you're actually trying to pick a star based on some conditions that have to do with the target itself. It is not unlimited – then there are also some star characteristics: brightness, stability and others in order to, when we do sight the star, be able to gain the accuracies that we want, but those are second and third order effects.

An MK6 LE guidance system is installed into a pod, which then was installed and flown under the wing of a F-15 during a test of the system. Draper

Does the missile have a lens that enables the star sighting to be made?

DiTULLIO: Yes. The current guidance system is made up of two sections. One is the electronics assembly, an enclosure or a box that houses most of the power supplies, computers, input devices and output devices. The inertial measurement unit [IMU] that holds accelerometers and the gyroscopes has – in the case of the Mark 6 – the stellar sensor, which has a camera that looks out a window on the side of the IMU at an appropriate time when the missile has shed the first three stages. Prior to that, the window is covered by the missile skin.

You must have to make this system very robust to withstand the stress of a launch from a submarine.

DiTULLIO: Yes. One of the things that separates these systems from others is the fact that it's on a 125,000-pound rocket – a lot of vibration and shock. The other is the fact that it needs to operate continuously through adversaries' weapons and operate in any environment it may encounter.

Does Draper get feedback from the Navy's Trident to track the performance of the guidance system?

DiTULLIO: Yes. Every flight that the Navy flies is instrumented such that we can reconstitute and analyze the entire flight trajectory from launch point all the way through impact. We instrument the submarine, the missile and the impact area. All that data can be parsed back together to allow you to effectively pull out what are called Level 3 errors, meaning you can get down to a specific instrument scale factor or bias error.

The Navy undertakes, at a minimum, at least four test flights per year, commissioned for U.S. Strategic Command. Four times per year, Strategic Command sends a message out to an alert submarine to come back into port. At that point, the crew is prohibited from doing any maintenance. The tactical re-entry bodies are removed from a missile and a test missile kit is inserted. The aeroshell itself is the same. Then the boat goes back out to sea and launches the missile. We know the trajectory and the splash point as well as telemetered data from the missile body, which really gives us the factual data. If there were anything broken, any maintenance that was needed that would have prohibited, then they're still prohibited. That's how the Navy certifies the reliability and accuracy to Strategic Command and the Office of the Secretary of Defense.

How is the target location loaded into the guidance system?

DiTULLIO: Through optical data disks — the aim points are loaded into the guidance system through the fire control system. Included in that is also the star catalog information we talked about earlier. There are also files for ballistic parameters such as weather at the targets. And then, based on the launch commands, the system will choose from those target points that are loaded into the fire control system. They will routinely conduct "achievability" checks to make sure that whatever targets in their target package is achievable are based on the submarine’s location. It goes without saying there are some range limitations. You can’t hit every target from one position on the Earth.

As you think to future systems going forward, more and more we want to be able to push that capability out to the warfighter so that the submarines themselves can adapt to whatever changing targets might be based on the situation without necessarily having to have a data load from land.

Back in the day, when you had punch cards to load target data, you didn’t have nearly enough capability or memory to be able to do that. There just wasn’t enough computational capability in the shipboard systems and even in some of the flight systems, so there had to be simplifying assumptions that were made about things like gravity and some trajectory perturbations. Part of the improved accuracy of these systems over time has been the fact that, as we’ve been able to provide more throughput, memory and things like that, we’re able to reduce the number of simplifying assumptions needed to be able to accomplish the mission. Today, our system can operate in an accuracy domain like a regular tactical GPS system or even a commercial GPS system based on its ability to calculate the solution.

For these systems to be robust to the environments, you just aren’t able to operate at the state-of-the-art technology node. Today, if the fastest processor is, say, a gigabyte, we’re probably operating at a megabit. We tend to be one, two, even sometimes three generations behind whatever is current state-of-the-art. In the current system we just deployed — the Mark 6 Mod 1 Life Extension — the largest data rate that we have is a million bits. Your iPad has devices that are significantly larger than that.

Is Draper working on a next-generation SLBM guidance system?

DiTULLIO: Yes. Under the current timeline, the Ohio-class SSBN hulls have been extended out to 2040 by increasing the reactor core life. That meant we needed to have a weapons system out there. The solution was to extend the current Trident D5 Mark 6 guidance system, which we did with the D5 Life Extension program. Now, the Columbia class submarine that will begin to deploy in the early 2030s will have a service life out to 2084. The current weapons system is not designed for that lifespan. The D5 Life Extension 2 program is meant to extend the service life of the Strategic Weapons System out to 2084.

An unarmed Trident II D5 missile launches from the Ohio-class ballistic missile submarine USS Nebraska (SSBN 739) off the coast of California. U.S. Navy photo by Mass Communication Specialist 1st Class Ronald Gutridge

Is Draper working on the Defense Department’s hypersonics program?

DiTULLIO: Yes. We’ve been part of the national team from the start. Draper developed the guidance and navigation system for the Flight Experiments FE-1 and FE-2 that have flown.

The Army and Navy are under OSD [Office of the Secretary of Defense] guidance to come up with the common hypersonic vehicle. The difference is that the Army intends to launch it off the back of a truck and the Navy will look to launch it off either guided-missile submarines or guided-missile destroyers. The Strategic Systems Program office – the customer that manages the Navy’s strategic missiles – is the development agent for the common hypersonic glide body. We are helping with the guidance and navigation. For the flight experiments, we worked with Sandia, the U.S. Army Combat Capabilities Development Command Aviation & Missile Center and other government labs. The government then subsequently awarded a contract to Lockheed Martin with Raytheon to transition that design into production.