Engineering automation

[Content preview – Subscribe to Jane's Navy International for full article]

Advances in ship design, manufacture, and control interfaces can enhance integration through increasing the quantity and complexity of automated systems installed on ships. *Anika Torruella* reports on the benefits, pitfalls, and driving factors for replacing manpower with machines

Automation can relieve the pressure on crews and commanders from repetitive manual tasks that often rely on map, timeline, and vehicle status displays, freeing them for dynamic decision making. There is a clear advantage in increased ship-wide automation playing a role in assisted decision making and planning, predictive analysis, and operational analytics. For instance, one complication is the high-speed buildup of enormous amount of data from various of sources that needs to be sifted through for smart targeting and battlespace awareness capabilities.

Automation enables USS Zumwalt TSCE's mission centre to network communications, weapons, engineering, sensors, and other ship systems, reducing crew requirements to about 147 sailors. (US Navy/Sonja Wickard)

1695410

Increased automation can also deliver more nuanced real-time or near real-time communications in on-the-move maritime environments while undergoing severe weather conditions. Bandwidth or waveform switching can be automatically adapted to increase the security and reliability of communications.

For instance, most modern tactical aircraft today use tactical radars, which are switching from mechanical to electronically scanned arrays (ESAs), which employ automated directionality by electronically phase shifting elements in the antenna array. Phased array systems, such as those

fitted to DDG-51 Arleigh Burke-class guided-missile destroyers, also employ electronic rather than mechanical components to automatically steer beams that create the antenna shape to fit around the machinery.

Cyber hardening that uses automation reduces the attack surface in hardware and software systems. For instance, Intelsat General and LGS Innovations have invested in these reactive automation applications that include automated cyber-threat identification and mitigation that reacts to events as well as learns from them to prevent future vulnerabilities by taking proactive measures.

Giving a keynote address on 11 January 2017 to the Surface Navy Association's (SNA's) annual symposium in Crystal City, Virginia, then US secretary of the navy Ray Mabus highlighted the challenges that necessitated a change in the way the USN approached a fight.

"You hear the argument [that] you need to cut ships because we need the money," Mabus said. "We need the money for maintenance now; we need the money for modernisation now; we need the money for weapons systems upgrades, and whatever, now. If you cut ships you will not save money. The cost of each ship will just go up. If you cut ships you'll just get fewer ships."

"How are you going to deliver those new weapons?" Mabus asked, highlighting the USN's challenges as it balances its ability to respond quickly to crises anywhere in the world, with maintaining its force training and readiness, and modernising systems by inserting relevant emerging technologies. All while operating under a shrinking budget. "How are you going to get them there if you don't have platforms? How are you going to be present around the globe around the clock if you don't have those platforms?"

It is possible that the USN has turned to increased ship-wide automation to help alleviate that balancing act.

Since 2016, the USN's distributed lethality concept has been honed to include elements enabling commanders to employ surface ships in deliberately asymmetric ways. Conflicts with peers that possess technologies key to electronic warfare and information dominance have become more common with some peers operating with sophisticated cyber capabilities that are on par or have even surpassed US capabilities.

Vice Chief of Naval Operations Admiral Bill Moran told the same SNA symposium that "while [the USN has] always operated helicopters and delivered boats, the ability to deploy and operate unmanned systems in the air, on the surface, and underwater has the potential to change the way we fight in the future". With the distributed lethality concept comes an emphasis on leveraging the intelligence, surveillance, and reconnaissance (ISR) community in the form of unmanned aerial, surface, or underwater vehicles (UXVs) as well as networked and autonomous tools.

"We've got to make a concerted effort," Adm Moran continued, suggesting the service look to naval research and laboratories for innovation directly connected to the fleet at all levels, whether junior officers, mid-level, or enlisted. "There is some great work going on by extraordinarily smart engineers who want to take us to the next level. They're experimenting ... on the latest [unmanned underwater vehicle] concepts, many of which are intended to be launched and recovered from surface ships enabling our surface warriors to operate not just in two dimensions but three-dimensional warfare.

"Now all of this, of course, and more has to be balanced by finding the right fit for the right platforms at the right price that we can afford. This is a tough business."

[Continued in full version...]

Inflection point

"There is room in the military for improved automation and the use of robots," said Gouré.

"So, what is it that really is going to make human-machine collaboration and combat teaming a reality? That is going to be advances in artificial intelligence and autonomy that we see around us every day .... Members of the Defense Science Board [DSB] Summer Study on autonomy believed that we are at an inflection point in the power of artificial intelligence and autonomy," said then Under Secretary of Defense Robert Work addressing a Center for a New American Security Defence Forum in Washington, DC, in December 2015.

Automation is capable of supplying persistent coverage with more reliability and at a faster rate than a human task force. In addition, offloading egregious maintenance tasks that distract sailors from decision making to automation also presents savings in costs.

"Because [automation elements] are cheaper, I can buy more of them. I can put more on a station, and I can get persistent coverage," Commander Jason Fox, a military deputy at the USN's Naval Sea Systems Command (NAVSEA) Technology Office, told the American Society of Naval Engineers (ASNE) in Arlington, Virginia, on 16 February 2017.

An MQ-8B Fire Scout lifts off the flight deck using automated flight operations. (US Navy/Antonio P Turretto Ramos)

1695414

"For example, the quick math would say if I needed a persistent presence capability provided by a destroyer right now, the navy needs to buy six destroyers to provide 24/7, 365-[day] coverage indefinitely in a particular spot," Cdr Fox continued. "That's a lot of money, if you start doing the

math. That is just the ships and the crew. But if I can decompose one requirement down to an unmanned system, that's a lot of cost savings. Not just in the cost of the platform, but in the cost of the people."

While automation can improve reaction times, increase efficiency in degraded conditions, reduce the need for manpower or training requirements, enhance safety, and enable adaptable payloads to expand operational reach, how do navies get the right mix between integrating automated combat control systems or partially automated systems with decisions processes and adaptable boundaries? According to Cdr Fox, figuring out "how integrated is integrated" has become vital and the USN is planning war games to inform the integration processes in future ships.

[Continued in full version...]

Manpower reduction

The rapid onset of technology "increased the amount and complexity of automated systems and equipment installed on ships", USN Lieutenant Commander Roxane Powers stated in a 2016 Massachusetts Institute of Technology (MIT) paper 'Automation as a Manpower Reduction Strategy in US Navy Ships'.

Lt Cdr Powers explored the selection, classification, and implementation of automated technology on the DDG-51, LCS, and DDG-1000 Zumwalt-class destroyer. Lt Cdr Powers also researched how system performance, situational awareness, and workload affect automation, how humans interact with automated equipment, and how the type of automated equipment affects ship systems as a whole. "To date, there is little research on how [USN] ship performance has changed since the confluence of manpower reduction and automation proliferation," Lt Cdr Powers stated.

LaserNet Fines self-contained sensors use laser technology embedded into fluid systems to analyse engine oils, such as algae blooms detected on board the USS Freedom (LCS 1) that were corrected before the irregularity could affect ship-service generators or diesels. (Lockheed Martin) 1695411

The USN also told *Jane's* that it had "nothing additional to provide", at the time of writing this article, on broad studies or war gaming endeavours that NAVSEA would be looking forward to that would help inform the USN on integrating autonomous systems into the future fleet.

The Office of Naval Research (ONR) and Lockheed Martin have developed the LaserNet Fines monitoring system onboard the LCSs, which assesses machinery health using laser technology embedded into the ships' fluid systems. LaserNet Fines performs analysis by detecting, counting, classifying, and trending fluid contamination, and then alerts crews to potential malfunctions.

Crews can track from laptops or remote-monitoring stations real-time data from the monitoring system on various contaminants in fuel, lubricants, and hydraulic fluids that affect ship systems.

Another Lockheed Martin software system called Visionary consists of more than 8,000 sensors and around 40 cameras that run the 378 ft (115 m) length of the LCS and collects data from major electrical and mechanical systems to predict mechanical issues and determine root causes. The data feeds from equipment are beamed hourly via satellites to USN and industry teams for analysis. The Visionary monitoring system also compiles and archives the data for trend analysis and possible future system changes.

A third system called Axis manages LCS propulsion, electric plant, auxiliaries, and engineering casualty/damage control systems. Axis is a power plant management system that uses distributed processing, so a single program runs simultaneously at various locations, and fault tolerance, so each operation is performed on more than one system. If an operation fails, another is enabled to take over.

Lockheed Martin's Visionary system is a predictive system condition analyser intended to maximise system availability by performing maintenance procedures from a preventative basis rather than on a schedule -based or reactive-based. (Lockheed Martin)

1695412

Lockheed Martin did not respond to queries about quantifying the performance improvements that these systems have enabled.

According to Lt Cdr Powers, DDG-51 destroyers mainly used proven technologies from the Ticonderoga-class (CG 47) cruisers for initial design inspiration with only incremental design changes occurring between Flight I, Flight II, and Flight IIA DDG-51s. "Selected automation was included in subsequent designs," such as in the Machinery Control Systems (automated engineering control) and Integrated Bridge Systems (automated navigation control), "but there was not a formal automation philosophy, nor were specific systems or functions targeted," Lt Cdr Powers wrote. "Instead, as new technology matured and became available, it was added to the next design .... Thus automation has been used to reduce workload, but is applied more to targeted systems than to ship-wide effects."

In contrast, the DDG-1000s integrated a significant number of new technologies and automation systems in their design. According to Lt Cdr Powers, the DDG-1000 automation philosophy is "that the human is the centre of the system and all automation is to assist, support, and complement the human operator".

Automation was reserved for functions that were "repetitive and logically driven". Integrated automation systems include the Raytheon-built Total Ship Computing Environment (TSCE), which is an encrypted network that controls the shipboard computing applications, such as lights, radar machinery control, and weapon systems.

Other types of automation integration employed by the USN include the linkup between automated systems and various UXVs.

For instance, the Fire Scout can be operated by the USN and Marine Corps from small-deck ships, such as the LCS, even under demanding at-sea conditions. Fire Scout uses the UAV Common Automatic Recovery System (UCARS), a ship-based radar recovery system to provide precision ship-relative navigation for automated landings.

The tailless, unmanned autonomous X-47B UCAS-D conducts flight operations aboard USS Theodore Roosevelt (CVN 71) demonstrating its ability to operate safely and seamlessly with manned aircraft. (US Navy/John M Drew)

1695415

The Unmanned Combat Air System Demonstration (UCAS-D) programme is another automated landing system intended to demonstrate the capability to operate UAVs from aircraft carriers using a GPS-based precision ship-relative system for its automated launch and recovery capability.

Fire Scout's precision ship-relative system capability can also be applied to fixed- and rotary-wing manned aircraft providing navigation and guidance during restricted visibility conditions through ship-based and/or pilot displays that superimpose head-up display symbology over a ship reference display. The intent is to use the precision ship-relative system in the future to automate launch and recovery of manned aircraft with crew members acting as a systems monitor.

Currently, the cockpit has been removed from the Fire Scout and has been put on the ship. Navigation data that would have been on the air vehicle now comes from ship navigation, and the sailors responsible for preventative maintenance, maintaining the cockpit, and accomplishing cockpit functions are engineering and technical services (ETS) crew, who are not as familiar with safety of flight issues as naval aviators would be. The Fire Scout precision ship-relative system may increase the safety of crew not necessarily trained in naval aviation culture requirements and speed up readiness as ETS crew would require less training on the new maintenance concept.

Aviation electronics technicians use a maintenance portable electronic display device to troubleshoot navigation systems for an autonomous MQ-8B Fire Scout aboard LCS USS Fort Worth (LCS 3). (US Navy/Antonio P Turretto Ramos)

1695413

Other future automation efforts of interest to the USN and Marine Corps include a capability of networked autonomous undersea and surface vehicles under discussion by NAVSEA and the Space and Naval Warfare Systems Command (SPAWAR).

An "undersea constellation" mentioned by the 'Navy Future Fleet Platform Architecture Study', an alternative fleet structure study sponsored by the USN and conducted by the Mitre Corporation, would network undersea elements such as "submarines, autonomous unmanned vehicles, distributed sensor networks, undersea cables, and a variety of other systems" to gain a

comprehensive understanding of the undersea environment and maintain a comparative advantage in the undersea domain. Automation advances in swarming algorithms and command-and-control interfaces could also enable operators to manage multiple discrete unmanned systems at sea.

Joe Horvath, deputy for warfare integration and unmanned systems in the Office of the Chief of Naval Operations, told the ASNE that the future "next-generation air dominance aircraft, the Future Surface Combatant, and the SSMX, the next attack submarine" may also integrate higher degrees of automation.

While the integration of automation offers advantages, there are limits to the benefits from reducing manning and manpower. For example, the new Gerald R Ford-class nuclear-powered aircraft carrier (CVN) will be able to launch about 33% more aircraft sorties each day with a crew that is 25% smaller, according to Gouré, but "there are also practical limits to how small a military with global responsibilities can become and still do its job".

[Continued in full version...]