

CVN 78 *Gerald R. Ford*-Class Nuclear Aircraft Carrier

Executive Summary

- The DOT&E assessment of CVN 78 remains consistent with previous assessments. Poor or unknown reliability of new technology systems critical for flight operations, including newly designed catapults, arresting gear, weapons elevators, and radar, could adversely affect CVN 78's ability to generate sorties. Reliability of these critical subsystems poses the most significant risk to the CVN 78 IOT&E timeline.
- CVN 78 completed its Post Shakedown Availability (PSA) on October 25, 2019. CVN 78 entered the shipyard for the PSA in July 2018 after completing eight Independent Steaming Event (ISE) at-sea periods.
- Since the PSA ended, CVN 78 completed 11 ISEs through September 2020 that addressed a variety of certification and testing requirements. The ISEs included embarkation of the Air Wing and testing of various systems.
- The new weapons elevators on CVN 78 remain behind schedule. The Navy has only accepted 6 of the 11 elevators for use, and expects to accept the remaining elevators installed by 3QFY21.
- Based on ISE results, the reliability of the catapults and arresting gear remain well below their requirements. Reliability of the weapons elevators remains unknown.
- CVN 78 is unlikely to achieve the Sortie Generation Rate (SGR) (number of aircraft sorties per day) requirement. Unrealistic assumptions underpin the SGR threshold requirement. These assumptions ignore the effects of weather, aircraft emergencies, ship maneuvers, and current Air Wing composition on flight operations. DOT&E plans to assess CVN 78 performance during IOT&E by comparing it to the demonstrated performance of the *Nimitz*-class carriers, as well as to the SGR requirement.
- CVN 78 will likely be short of berthing spaces, and may require berthing modifications to accommodate the specific mix of personnel embarked.
- The Navy conducted one operational test for the CVN 78 combat system in FY20. To date, the Navy has conducted two of the four planned CVN 78 operational test events on the Self-Defense Test Ship (SDTS) phase of testing, and has not resourced the two remaining phases of combat system operational testing.
- Deviations from the Navy's 2006 Air Warfare Enterprise construct that leveraged combat system commonalities to share test events, costs, and resources between DDG 1000 and CVN 78 have resulted in a resource-limited CVN 78 Air Warfare test campaign. DOT&E expects the Navy to conduct an adequate Air Warfare test campaign on CVN 79 to fully characterize the performance of the CVN 79 combat system. The CVN 79 Air Warfare testing is also intended to inform future CVN 78 performance once the Navy makes planned changes to the CVN 78 combat system.



- CVN 78 exhibits electromagnetic compatibility problems experienced by new classes of ships and is working to resolve the issues. The Navy continues to characterize the problems and develop mitigation plans.
- The Navy continues to conduct the LFT&E program to provide the data and analyses required for the evaluation of the ship's survivability against operationally significant kinetic threats.

System

- The CVN 78 *Gerald R. Ford*-class aircraft carrier program introduces a new class of nuclear-powered aircraft carriers. It uses the same hull form as the CVN 68 *Nimitz*-class but introduces a multitude of new ship systems.
- The new nuclear power plant reduces manning levels compared to a *Nimitz*-class ship and produces significantly more electricity. CVN 78 uses the increased electricity (instead of steam) to power electromagnetic catapults and arresting gear, both designed to increase reliability and expand the aircraft launch and recovery envelopes.
- The Navy redesigned weapons elevators, handling spaces, and stowage to reduce manning, improve safety, and increase weapon throughput. Weapon elevators use electromagnetic linear induction motors instead of cable-driven systems.
- CVN 78 incorporates a more efficient flight deck layout, dedicated weapons handling areas, and an increased number of aircraft refueling stations designed to enhance its ability to launch, recover, and service aircraft.
- The CVN 78 combat system incorporates changes intended to improve upon the legacy *Nimitz*-class combat system. It consists of:
 - A phased-array Dual Band Radar (DBR) comprised of the SPY-4 Volume Search Radar (VSR) and the SPY-3 Multi-Function Radar (MFR). The DBR replaced several

FY20 NAVY PROGRAMS

- legacy radars used on current carriers for self defense and air traffic control.
- Ship Self-Defense System (SSDS) Mark 2 command decision system.
- Cooperative Engagement Capability (CEC) tracking and data fusion and distribution system.
- SLQ-32(V)6 electronic surveillance system equipped with Surface Electronic Warfare Improvement Program (SEWIP) Block 2.
- Rolling Airframe Missile (RAM) Block 2 and Evolved Sea Sparrow Missile (ESSM) Block 1.
- Phalanx Close-In Weapon System (CIWS).
- The follow-on *Ford*-class aircraft carrier, CVN 79, will have several significant updates to the ship systems, including:
 - Enterprise Air Surveillance Radar (EASR/SPY-6(V)3), along with SPQ-9B and MK 9 Tracking Illuminators, will replace CVN 78's DBR.
 - New capability build SSDS Mark 2 command decision system.
 - SLQ-32(V)6 electronic surveillance system equipped with the Soft Kill Coordination System.
 - RAM Block 2A or 2B variants intended to improve performance against anti-ship cruise missile (ASCM) attack.
 - ESSM Block 2 with an active-all-the-way seeker that could engage ASCMs without the MK 9 tracking illumination radars.
 - CIWS integrated with CEC and SSDS to achieve a fully integrated ship self-defense against ASCMs.
- The ship includes the following enhanced survivability features:
 - Improved protection for magazines and other vital spaces
 - Shock-hardened mission systems/components
 - Installed and portable damage control, firefighting, and dewatering systems intended to expedite response to and recovery from peacetime fire, flooding, and battle damage
- CVN 78 includes a new Heavy Underway Replenishment system capable of transferring cargo loads of up to 12,000 pounds.
- The Navy intends to achieve CVN 78 Initial Operational Capability in FY21 prior to the start of Full Ship Shock Trial (FSST) and Full Operational Capability in FY24 after successful completion of IOT&E and Type Commander certification.

Mission

Carrier Strike Group Commanders will use CVN 78 to:

- Conduct power projection and strike warfare missions using embarked aircraft
- Provide force and area protection
- Provide a sea base as both a command and control platform and an air-capable unit

Major Contractor

Huntington Ingalls Industries, Newport News Shipbuilding – Newport News, Virginia

Activity

- The Navy updated the Test and Evaluation Master Plan (TEMP) 1610 and routed Revision D. This TEMP Revision continues two back-to-back phases of initial operational testing described in previous annual reports. Phase One focuses on routine unit-level operations and the ship's internal workings (including cyclic flight operations with an embarked Air Wing). Phase Two focuses on more complex evolutions, including tests of the integrated combat system in self-defense scenarios, and integrated operations with an embarked Air Wing, Destroyer Squadron, and Carrier Strike Group staffs during the Composite Training Unit Exercise (COMPTUEX) at-sea period. The Navy will examine sustained SGR in the COMPTUEX and surge SGR before the ship's second deployment. TEMP Revision D also outlines the Navy's cybersecurity strategy for CVN 78.
- The coronavirus (COVID-19) pandemic did not impact T&E.

Electromagnetic Aircraft Launch System (EMALS)

- The Navy issued the final EMALS Aircraft Launch Bulletins, required for shipboard operations, at the end of 2019.
- Post PSA, through ISE 11, CVN 78 has launched 3,975 aircraft.

Advanced Arresting Gear (AAG)

- The Navy released the final Aircraft Recovery Bulletins on August 2, 2019. These bulletins are required for shipboard flight operations with fleet aircraft.
- Post PSA, through ISE 11, CVN 78 has recovered 3,975 aircraft.

Advanced Weapons Elevators (AWE)

- The development, installation, and delivery of the AWE remain behind schedule. As of September 2020, CVN 78 had all 11 elevators installed, but the Navy has certified only 6 for use.

Combat System

- The Navy conducted one of the remaining three CVN 78 operational tests planned on the SDTS in the DOT&E-approved CVN 78 test plan and the DOT&E-approved Capstone Enterprise Air Warfare Ship Self-Defense TEMP. The Navy originally scheduled this event for May 2019, but delayed it repeatedly until its execution in August 2020. The reasons for these delays varied, but were generally related to a lack of developmental testing prior to operational testing, which

would have built confidence in combat system performance as well as in the ability of the test range to successfully execute the event. The Navy has delayed one other CVN 78 SDTS test several times; this event, originally planned for October 2019, is scheduled for December 2020. The Navy canceled the one remaining test, the last of the three outstanding CVN 78 events on the SDTS, because the Navy did not incorporate software changes required to conduct the test on SDTS.

- The Navy has not identified funding for combat system testing on CVN 78 or for the modeling and simulation (M&S) suite required to support evaluation of the ship's Probability of Raid Annihilation (PRA) requirement.
- EASR is in developmental testing at the Wallops Island Engineering Test Center, Virginia. The Navy intends to begin combat system integration efforts in FY21.

Live Fire Test & Evaluation

- The Navy continues to plan the CVN 78 FSST and is on track to conduct it in 3Q/4QFY21.
- In 1QFY19, the Navy delivered the Vulnerability Assessment Report detailing an assessment of the ship's survivability to air-delivered threat engagements. The classified findings in the report identify the specific equipment that most frequently would lead to mission capability loss in such engagements.
- The Navy delayed the delivery of an additional report volume intended to detail an assessment of the ship's survivability against underwater threats (and compliance with Operational Requirements Document survivability criteria) to FY21 due to problems with the M&S tool used in the evaluation.

Assessment

- As noted in previous annual reports, the test schedule has been aggressive. The extension in PSA delayed both phases of initial operational testing until FY22.
- TEMP Revision D outlines the Navy's cybersecurity strategy to test CVN 78, but has not translated the strategy into an actionable test plan.

Reliability

- Four of CVN 78's new systems stand out as critical to flight operations: EMALS, AAG, DBR, and AWE. Overall, the low reliability demonstrated by AAG, EMALS, and DBR, along with the uncertain reliability of AWE, could further delay the CVN 78 IOT&E. Reliability estimates derived from test data for EMALS, AAG, and DBR are discussed in following subsections. For AWE, preliminary reliability estimates have been provided on 6 of the 11 elevators, the only ones certified.

EMALS

- The delivery of the EMALS launch bulletins allows CVN 78 to launch all aircraft in the ship's Air Wing.
- During the 3,975 catapult launches conducted post PSA through ISE 11, EMALS demonstrated an achieved reliability of 181 mean cycles between operational mission failure (MCBOMF), where a cycle is the launch of one

aircraft. This reliability is well below the requirement of 4,166 MCBOMF.

- During ISE 8, two separate failures caused individual EMALS catapults to go down for 3 days. One of the failures was attributed to a legacy component.
- The reliability concerns are exacerbated by the fact that the crew cannot readily electrically isolate EMALS components during flight operations due to the shared nature of the Energy Storage Groups and Power Conversion Subsystem inverters on board CVN 78. The process for electrically isolating equipment is time-consuming; spinning down the EMALS motor/generators takes 1.5 hours by itself. This inability precludes EMALS high power maintenance during flight operations.

AAG

- Through the first 3,975 recoveries, AAG demonstrated an achieved reliability of 48 MCBOMF, where a cycle is the recovery of a single aircraft. This reliability estimate falls well below the requirement of 16,500 MCBOMF.
- While in port prior to ISE 9, during maintenance troubleshooting, the AAG system experienced a failure of an Energy Storage Capacitor Bank, which rendered all three engines inoperative. It took the Navy 7 days to investigate the failure and bring AAG back into service by mechanically isolating the failed capacitor bank. The failed parts were repaired during a later in-port period.
- The reliability concerns are magnified by the current AAG design that does not allow electrical isolation of the Power Conditioning Subsystem equipment from high power buses, limiting corrective maintenance on below-deck equipment during flight operations.

Combat System

- Post-PSA sea-based developmental test events show the DBR still experiences clutter tracks, but to a smaller extent and of a different origin than previously reported. The events also show that CEC, in certain conditions, provides inaccurate tracking of air contacts. During these events, SEWIP Block 2 created undesired emitter tracks that could cause the ship to expend more ESSMs and RAMs than necessary to destroy incoming threats.
- The Navy is satisfied with the DBR track support for Air Traffic Control (ATC) after post-PSA at-sea testing. The DBR successfully suppresses the disclosure of the majority of environmental tracks when it sends tracks to TPX-42. The Navy does not plan to conduct any further ATC-type aircraft flights during sea-based developmental testing.
- During the August 2020 missile firing operational test on SDTS, the system demonstrated good tracking performance of the targets by MFR and CEC, and good engagement support by the SSDS MK 2 Mod 6 element, which correctly provided scheduling and weapon assignments. SEWIP Block 2 emitter reporting interfered with optimal engagements against threats. Several problems contributed to the failure of some ESSMs and RAMs to destroy their intended targets.

FY20 NAVY PROGRAMS

- Results of live testing completed to date indicate that CVN 78 has limited self-defense capability against ASCM surrogates, but several challenges persist with respect to the efficacy of the ship's combat system.
- Post PSA through ISE 11, DBR demonstrated a mean time between operational mission failures (MTBOMF) of 100 hours, below the requirement of 339 hours.
- Preliminary results of EASR's early developmental testing indicate that electromagnetic interference, tracking performance, electronic protection, and power compliance testing are focal areas for ongoing system developmental work and improvements. Until operationally relevant reliability data are supplied to DOT&E, system reliability remains a significant risk area for EASR. EASR's combat system integration remains untested.
- Planned operational tests of the CVN 78 combat system continue to be delayed or have been canceled. In the 2006 Capstone Enterprise Air Warfare Ship Self-Defense TEMP, the Navy planned to leverage commonality between the DDG 1000 and CVN 78 combat systems to reduce the number of operational test events conducted on each ship. However, subsequent changes to the DDG 1000 combat system reduced commonality between the two ships and negated the ability to leverage testing and resources across the two combat systems.
- DOT&E recognizes that the CVN 78 Air Warfare test program is resource-limited because the Enterprise Air Warfare approach was not executable due to the divergence of the DDG 1000 and CVN 78 combat systems. DOT&E accepts this limitation expecting that the Navy will plan and execute an adequate air warfare test program for CVN 79. The CVN 79 test campaign is also intended to inform CVN 78 combat system performance once it is retrofitted with planned changes.

SGR

- CVN 78 is unlikely to achieve its SGR requirement. The target threshold is based on unrealistic assumptions including fair weather and unlimited visibility, and that aircraft emergencies, failures of shipboard equipment, ship maneuvers, and manning shortfalls will not affect flight operations. During the 2013 operational assessment, DOT&E conducted an analysis of past aircraft carrier operations in major conflicts. The analysis concludes that the CVN 78 SGR threshold requirement is well above historical levels.
- DOT&E plans to assess CVN 78 performance during IOT&E by comparing it to the SGR requirement, as well as to the demonstrated performance of the *Nimitz*-class carriers.
- Poor reliability of key systems that support sortie generation on CVN 78 could cause a cascading series of delays during flight operations that would affect CVN 78's ability to generate sorties. The poor or unknown reliability of these critical subsystems represents the most risk to the successful completion of CVN 78 IOT&E.

Manning

- Reduced manning requirements drove the design of CVN 78. The berthing capacity is 4,660, or 1,100 fewer than *Nimitz*-class carriers. Based on current expected manning, the berthing capacity for officers and enlisted will be exceeded with some variability in the estimates depending on the specific scenario examined.

Electromagnetic Compatibility

- Developmental testing identified significant electromagnetic radiation hazard and interference problems. The Navy implemented some mitigation measures and conducted follow-on characterization testing during ISEs, but some operational limitations and restrictions are expected to persist into IOT&E and deployment. The Navy will need to develop capability assessments at differing levels of system use in order for commanders to make informed decisions on system employment.

Live Fire Test & Evaluation

- In FY20, the Navy continued with the shock qualification testing of CVN 78 components to support the survivability evaluation of CVN 78 to underwater threat engagements. Due to scarcity of test assets, some components and systems (e.g., DBR) will not be shock qualified before the FSST.
- Adequate use of M&S in the vulnerability evaluation of the ship against underwater threats is at risk. Challenges with the Navy Enhanced Sierra Mechanics M&S tool prompted the Navy to switch back to the Dynamic Systems Mechanics Advanced Simulation M&S tool to complete the vulnerability assessment report. While necessary, the change will require additional verification and validation to ensure the credibility of the survivability evaluation.

Recommendations

The Navy should:

1. Continue to characterize the electromagnetic environment on board CVN 78 and develop operating procedures to maximize system effectiveness and maintain safety. As applicable, the Navy should use the lessons learned from CVN 78 to inform design modifications for CVN 79 and future carriers.
2. Implement the required software changes to multiple combat system elements to allow cueing from external sources necessary to conduct one of the two remaining SDTS test events.
3. Conduct both remaining SDTS combat system test events for CVN 78.
4. Correct the cause of combat system failures that led to ESSMs and RAMs missing their intended targets, and demonstrate the correction in a future phase of operational testing.
5. Fund the CVN 78 lead ship combat system operational testing and the M&S suite required to support assessment of the CVN 78 PRA requirement.

FY20 NAVY PROGRAMS

6. Conduct an operational assessment of EASR at Wallops Island, Virginia. This testing should evaluate EASR's contributions to the air traffic control and self-defense missions, as well as provide an early assessment of electromagnetic interference and radiation hazard concerns.
7. Update TEMP 1610 to include cybersecurity testing on CVN 78 and CVN 79 testing driven by the changes to the ship's combat system, including the introduction of EASR.
8. Complete validation of the M&S tools supporting the LFT&E assessment, including comparison of the FSST data to relevant M&S predictions.
9. Continue to improve availability and reliability for EMALS, AAG, DBR, and AWE.

FY20 NAVY PROGRAMS