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

Poor or unknown reliability of systems critical for flight operations, including newly-designed catapults, arresting gear, weapons elevators, and radar continue to pose the most significant risk to CVN 78 demonstrating operational effectiveness and suitability in IOT&E scheduled for 2QFY23. Testing of the CVN 78 Integrated Combat System (ICS) was not adequate to assess the combat system's capability against supersonic anti-cruise ship missiles (ASCMs), and there are no future test events planned that could provide additional data on these threats.

CVN 78 Full-Ship Shock Trial (FSST) results identified several design shortfalls not previously discovered by modeling and simulation (M&S) or component-level testing, that, if addressed, could improve the survivability of the CVN 78 against underwater threat engagements.

System Description

The CVN 78 *Gerald R. Ford*-class aircraft carrier is a new class of nuclear-powered aircraft carriers based on the CVN 68 *Nimitz* class hull, with significant design changes intended to enhance CVN 78's ability to launch, recover, and service aircraft while reducing the manning capacity by approximately 20 percent. CVN 78 includes a new nuclear power plant, increasing the electrical power capacity to power among other systems, electromagnetic catapults, and arresting gear. CVN 78 also incorporates a more efficient flight deck layout with additional aircraft fueling stations, redesigned weapons elevators, weapons handling spaces, and magazine stowage to reduce manning, improve safety, and increase weapon throughput. The CVN 78 ICS incorporates several changes, including the:

- Dual Band Radar (DBR) that combines the phased-array SPY-4 Volume Search Radar and the SPY-3 Multi-Function Radar, which will be replaced with the SPY-6(V)3 Enterprise Air Surveillance Radar (EASR) and the AN/SPQ-9B Anti-ship Missile Defense Radar on CVN 79.
- Ship Self-Defense System (SSDS) Mark 2 Mod 6 combat management system, which will be replaced with the new capability build SSDS Mark 2 Baseline 12 on CVN 79.
- Cooperative Engagement Capability (CEC) USG-2B tracking, data fusion, and distribution system.
- SLQ-32(V)6 electronic surveillance and warfare system equipped with Surface Electronic Warfare Improvement Program Block 2, which will be equipped with the Soft Kill Coordination System on CVN 79.
- Rolling Airframe Missile (RAM) Block 2 and the Evolved Sea Sparrow Missile (ESSM) Block 1; RAM Block 2 will be replaced by RAM Block 2A and 2B on CVN 79.

- Phalanx Close-In Weapon System (CIWS) radar, which will be integrated with CEC and the gun integrated with SSDS on CVN 79 to achieve a fully integrated ship self-defense against ASCMs.

The CVN 78 class ships also have enhanced survivability features, including improved protection for magazines and other vital spaces, shock-hardened mission systems and components, and installed and portable damage control, firefighting, and dewatering systems intended to expedite response to, and recovery from, 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.

Program

The CVN 78 *Gerald R. Ford*-class is an Acquisition Category IC program. DOT&E approved the Test and Evaluation Master Plan (TEMP) Revision B in 2007, but disapproved TEMP Revision C in 2015 because it proposed deferring full-ship shock trials. The Navy withdrew TEMP Revision D in 2019 before submitting it to DOT&E for approval and is still drafting TEMP Revision E. The first ship in the *Ford*-class, CVN 78, was delivered to the Navy in 2017. It completed Post Delivery Test and Trials in 2021 to demonstrate the basic functionality of the carrier, certify the flight deck, embark an air wing, and serve as the East Coast carrier qualification platform for fleet naval aviators. CVN 78 is now in a planned incremental availability phase that will be followed by IOT&E starting in early 2023 and subsequent deployment. CVN 79 delivery is scheduled for 2024, at which time it is expected to be able to support F-35 operations. CVN 80 construction began in 2017.

The Navy has yet to provide funding for the M&S suite required to evaluate CVN 78's Probability of Raid Annihilation requirement against subsonic ASCM targets. The Navy agrees an unmanned test asset is required to adequately and safely test the self-defense capability of CVN 79 against ASCM surrogates. The Navy committed to providing the resources required to retain this capability via a planned maintenance availability of the Self-Defense Test Ship (SDTS) (i.e., *Paul F. Foster*), as well as the procurement and installation of the necessary CVN 79 combat system elements on this test ship.

Major Contractors

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

Test Adequacy

In December 2020, the Navy concluded the Self-Defense Test Ship phase of CVN 78 ICS operational test by conducting a test against supersonic ASCM surrogates. The Navy completed three of the four planned Self-Defense Test Ship tests in the DOT&E-approved test plan, and those that were completed deviated from the approved test plan. Testing was not adequate to assess the combat system's capability against supersonic ASCMs and subsonic maneuvering ASCMs, and there are no future test events planned that could provide additional data against these threats. DOT&E will issue an interim assessment of CVN 78 self-defense capabilities in FY22.

Only a limited assessment of CVN 78 combat system effectiveness is possible. The 2008 DOT&E-approved Enterprise TEMP called for the use of DDG 1000 combat system performance data to supplement the evaluation of the CVN 78 combat system; however, the redesigned DDG 1000 system differs significantly from the CVN 78 system. The Navy did not supplement the CVN 78 test campaign to compensate for the 10 test events it originally expected to leverage from DDG 1000 testing.

The Navy tested the combat system aboard CVN 78 during Combat Systems Ship's Qualification Trials (CSSQT) and combat systems operational rehearsal events. This testing was not covered by a DOT&E-approved test plan.

From June to August 2021, the Navy completed FSST to assess CVN 78's combat shock survivability. The trial was adequate to evaluate the ship's operational survivability after exposure to an underwater threat induced shock. The trial consisted of a series of three nearby underwater explosions of increasing severity up to two-thirds of the design level requirement/specification. The ship was manned and operational during each shot. Testing included a demonstration of the ship's ability to continue its primary missions after shock. Where shock-hardened ship systems and equipment could not continue operating after shock, trial cards were

written to identify shock deficiencies for correction. In accordance with the approved trial plan, the ship was not outfitted with live ordnance or an air wing, and most JP-5 aviation fuel was removed.

The Navy expects to begin IOT&E in 2QFY23, following planned incremental availability at Newport News Shipyard. The Navy is planning to conduct IOT&E in accordance with draft TEMP Revision E and DOT&E reports to Congress dated November 30, 2018 and November 26, 2019, but the TEMP Revision E and required test plans have not yet been submitted for approval by DOT&E.

While the Navy has proposed several strategies to test the cyber survivability of CVN 78, none of these strategies have been finalized, adequately resourced, or formally approved by DOT&E.

Performance

Effectiveness

Combat System

In accordance with the CVN-78 Security Classification Guide, the effectiveness of the combat system is detailed in the Controlled Unclassified Information edition of this report. The report details the capability of the combat system to detect, track, engage, and defeat the types of threats for which the system was designed.

Sortie Generation Rate (SGR)

CVN 78 is unlikely to achieve its SGR requirement. The target SGR threshold is well above achieved historical rates and based on unrealistic assumptions, including fair weather and unlimited visibility, along with the expectation that aircraft emergencies, failures of shipboard equipment, ship maneuvers, and manning shortfalls will not negatively affect flight operations. Poor reliability of key systems that support sortie generation on CVN 78 could cause a cascading series of delays during flight operations that would likely negatively affect CVN 78's ability to generate sorties. The reliability of these critical subsystems represents the most risk to the successful completion of CVN 78 IOT&E.

Electromagnetic Spectrum Compatibility

Developmental testing identified significant electromagnetic radiation hazard and interference problems. The Navy implemented some mitigation measures and conducted follow-on characterization testing during Independent Steaming Events (ISEs) in developmental test, 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 to inform decisions on system employment.

Suitability

Reliability

The low reliability of the following four new CVN 78 systems stand out as the most significant challenges expected to affect the ship's flight operations:

Electromagnetic Aircraft Launch System (EMALS)

During the 8,157 catapult launches conducted through ISE 18, EMALS achieved a reliability of 272 mean cycles between operational mission failures (MCBOMF), where a cycle is the launch of one aircraft. This reliability is well below the requirement of 4,166 MCBOMF. The reliability concerns are amplified by the fact that the crew cannot readily electrically isolate EMALS components during flight operations because of 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 and generators alone is a 1.5-hour process, precluding some EMALS maintenance during flight operations.

Advanced Arresting Gear (AAG)

During 8,157 recoveries, AAG achieved a reliability of 41 MCBOMF, where a cycle is the recovery of a single aircraft. This reliability estimate falls well below the requirement of 16,500 MCBOMF.

The reliability concerns are amplified by the AAG's design, which does not allow the Power Conditioning Subsystem equipment to be electrically isolated from high power buses, limiting corrective maintenance on below-deck equipment during flight operations.

Advanced Weapons Elevators (AWE)

While all 11 AWEs have been installed, only 8 of the 11 have been formally delivered to the Navy. The

other three are installed, but are still the responsibility of the manufacturer. Therefore, only preliminary reliability estimates are available to compare to the requirement of 932 hours between operational mission failure. Through the first 14,842 elevator cycles, 68 operational mission failures were reported. AWE system reliability will be critical as the Navy completes delivery of the remaining three elevators and develops standard procedures for moving ordnance from magazines to the flight deck.

Dual Band Radar (DBR)

Through ISE 18, DBR demonstrated a reliability of 102 hours mean time between operational mission failures. This is below the requirement of 339 hours. However, DBR was operationally available 96 percent of the time, close to the 98 percent requirement.

Survivability

While shock trial data analysis is ongoing, the Navy has already identified several survivability improvement opportunities for the CVN 78 class against underwater threat engagements. Details will be provided in an interim, classified CVN 78 FSST report expected to be published 2QFY22 after all data and observations have been adequately reviewed and analyzed.

The survivability of CVN 78 in a cyber-contested environment has not yet been evaluated. Many subsystems on the ship were tested to various degrees in both developmental testing and operational testing on other ship platforms. However, required CVN 78 platform-level testing has not yet occurred, and some systems specific to CVN 78 have yet to undergo any operational cyber survivability assessments. These assessments will need to be conducted as part of CVN 78 IOT&E.

The survivability of CVN 78 in a contested and congested electromagnetic spectrum environment has not yet been evaluated. Discussions on how to evaluate CVN 78 survivability in contested and congested electromagnetic spectrum environments are ongoing with the Navy.

Recommendations

The Navy should:

1. Address combat system issues identified during CVN 78 ICS testing during CSSQT and on the SDTS.
2. Fund the M&S suite required to assess the CVN 78 Probability of Raid Annihilation requirement for subsonic targets.
3. Implement the recommendation contained in DOT&E's FY20 report to complete Self-Defense Test Ship test events.
4. Continue to improve availability and reliability for EMALS, AAG, DBR, and AWE.
5. Implement major fixes to CIWS hardware and software to improve the system's reliability and operational availability.
6. Continue to characterize the electromagnetic spectrum 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 modify the design of CVN 79 and future carriers.
7. Implement design changes to address survivability issues identified during the FSST.
8. Complete validation of the M&S tools supporting the LFT&E assessment, including comparing the FSST data to relevant M&S predictions.
9. Continue to fund the maintenance availability for the current SDTS (e.g., *Paul F. Foster*) to ensure its readiness to support CVN 79 combat system testing.
10. Continue to fund the procurement and installation of the necessary CVN 79 combat system elements on the Self-Defense Test Ship.
11. Conduct a shore-based operational assessment of EASR at Wallops Island, Virginia. This testing should evaluate EASR's contributions to air traffic control and self-defense missions, as well as provide an early assessment of electromagnetic interference and radiation hazard concerns.
12. Update the CVN 78 platform TEMP to include cybersecurity testing on CVN 78 and testing of the combat system on CVN 79 to assess the effectiveness and suitability of the new combat system with EASR.