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

Executive Summary

- The Navy's Operational Test and Evaluation Force (OPTEVFOR) conducted a DOT&E-approved operational assessment from September 2015 through July 2017. The assessment was originally scheduled to end in mid-2016 after CVN 78 completed Builder's Sea Trials and Acceptance Trials, but the slip in CVN 78 delivery date led to a delay in the completion of the operational assessment. Testing is now complete.
- DOT&E's assessment of CVN 78 remains consistent with previous assessments. Poor or unknown reliability of the newly designed catapults, arresting gear, weapons elevators, and radar, which are all critical for flight operations, could affect the ability of CVN 78 to generate sorties, make the ship more vulnerable to attack, or create limitations during routine operations. The poor or unknown reliability of these critical subsystems is the most significant risk to CVN 78. Based on current reliability estimates, CVN 78 is unlikely to be able to conduct the type of high-intensity flight operations expected during wartime.
- CVN 78 is unlikely to achieve its Sortie Generation Rate (SGR) (number of aircraft sorties per day) requirement. The threshold requirement 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. 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.
- The Navy previously identified an inability to readily electrically isolate Electromagnetic Aircraft Launching System (EMALS) and Advanced Arresting Gear (AAG) components to perform maintenance. This limitation will preclude some types of EMALS and AAG maintenance during flight operations, decreasing their operational availability.
- The Navy demonstrated, in developmental testing, corrections to previously discovered deficiencies. EMALS testing in 2015 discovered excessive airframe stress during launches of F/A-18E/F and EA-18G with wing-mounted 480-gallon external fuel tanks (EFTs). The Navy discovered similar problems with 330-gallon EFTs on the F/A-18A-D. Additionally, end-of-stroke dynamics with heavy wing stores were discovered for the F/A-18E/F and EA-18G, which would limit maximum launch speed. Preliminary developmental test results indicate that these problems are resolved.
- The Navy continued performance testing of the AAG at a jet car track site at Joint Base McGuire-Dix-Lakehurst, New Jersey. This testing examined the performance of the redesigned arresting gear to meet the system specifications. Runway Arrested Landing Site (RALS) testing with manned aircraft commenced in 2016 and completed over 350 aircraft arrestments as of August 2017. RALS testing supported development of the F/A-18E/F limited envelope Aircraft Recovery Bulletin required for the first arrestments onboard CVN 78, which were completed on July 28, 2017.

- The CVN 78 design is intended to reduce manning. The Navy analysis indicates the ship is sensitive to manpower fluctuations. Workload estimates for the many new technologies such as catapults, arresting gear, radar, and weapons and aircraft elevators are not well understood. Some of these concerns have required redesignation of some berthing areas and may require altering standard manpower strategies to achieve mission accomplishment. The CVN 78 berthing capacity is 4,660; this is more than 1,100 fewer than *Nimitz*-class carriers. Recent estimates of expected combined manning of CVN 78, its air wing, embarked staffs, and detachments range from 4,656 to 4,758. The estimates do not include Service Life Allowance for future crew growth. Consequently, CVN 78 is expected to be short of berthing spaces.
- The CVN 78 combat system for self-defense is derived from the combat system on current carriers and is expected to have similar capabilities and limitations. The program is integrating the ship's Dual Band Radar (DBR) with the combat system, which continues to undergo developmental testing. Testing has uncovered tracking, clutter/false track, track continuity, and engagement support problems affecting air traffic control and self-defense operations. The Navy is investigating solutions to these problems, but as the IOT&E approaches, the likelihood that these problems will persist into IOT&E increases.
- CVN 78 is exhibiting more significant electromagnetic compatibility problems than other Navy ships. The Navy is continuing to characterize the problems and develop

mitigation plans, but current restrictions and performance of various systems will limit CVN 78 operations.
- The development and testing of EMALS, AAG, DBR, and the Integrated Warfare System will continue to drive the *Gerald R. Ford* timeline as it progresses toward IOT&E.

System
- The CVN 78 *Gerald R. Ford*-class aircraft carrier program is a new class of nuclear-powered aircraft carriers. It has the same hull form as the CVN 68 *Nimitz* class, but many ship systems, including the nuclear plant and the flight deck, are new.
- The newly designed nuclear power plant is intended to operate at a reduced manning level that is 50 percent of a CVN 68-class ship and produces significantly more electricity. CVN 78 will incorporate EMALS (electromagnetic, instead of steam-powered catapult launchers) and AAG. CVN 78 also will have a smaller island with a DBR (phased-array radars, which replaces/combines several legacy radars used on current aircraft carriers and serves in air traffic control and ship self-defense).
- The Navy intends for the Integrated Warfare System to be adaptable to technology upgrades and varied missions throughout the ship's projected operating life, including increased self-defense capabilities compared to current aircraft carriers.
- In addition to the self-defense features (hard- and soft-kill), the ship has the following survivability features:
  - Improved protection for magazines and other vital spaces as well as the inclusion of shock-hardened systems/components intended to enhance survivability.
  - Installed and portable damage control, firefighting, and dewatering systems intended to support recoverability from peacetime shipboard fire and flooding casualties and from battle damage incurred during combat.
- The Navy redesigned weapons stowage, handling spaces, and elevators to reduce manning, increase safety, and increase throughput of weapons.
- CVN 78 has design features intended to enhance its ability to launch, recover, and service aircraft, such as a slightly larger flight deck, dedicated weapons handling areas, and an increased number of aircraft refueling stations. The Navy set the SGR requirement for CVN 78 embarked aircraft at 160 sorties per day (12-hour fly day) and to surge to 270 sorties per day (24 hour fly day) as compared to the CVN 68 *Nimitz*-class SGR of 120 sorties per day/240 sorties per 24-hour surge.
- The Consolidated Afloat Networks and Enterprise Services (CANES) program replaces five shipboard legacy network programs to provide a common computing environment for command, control, intelligence, and logistics.
- CVN 78 is intended to support the F-35 and future weapons systems over the expected 50-year ship lifespan. CVN 78 includes a new Heavy underway replenishment system that will transfer cargo loads of up to 12,000 pounds. This Heavy replenishment system is only installed on one supply ship, USNS *Arctic*, with no current plan for more.
- The Navy intends to achieve CVN 78 Initial Operational Capability in FY18 after successful completion of Post Shakedown Availability and Full Operational Capability in FY21 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

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Activity
- A TEMP 1610 revision is under development to address problems with the currently approved TEMP 1610, Revision B. The Program Office is in the process of refining the Post Delivery Test and Trials schedule to further integrate testing and to include the Full Ship Shock Trial (FSST).
- The Navy intends to conduct a live test to demonstrate the SGR with six consecutive 12-hour fly days followed by two consecutive 24-hour fly days. DOT&E concurs with this live test approach; however, the Navy plan for extrapolating the 8 days of live results to the 35-day design reference mission on which the SGR requirement is based is yet to be decided. OPTEVFOR is working with the Program Office to identify required upgrades for the Seabasing/Seastrike Aviation Model to perform this analysis.
- The ship was delivered May 31, 2017, and commissioned July 22, 2017. Slips in the delivery affected schedules for the FSST and the at-sea OT&E of CVN 78. The FSST is planned for late CY19, followed by CVN 78's first Planned Incremental Availability (PIA). The initial operational testing won't occur until after the first PIA. The Program Office is planning for two back-to-back phases of initial operational testing. The first phase examines basic ship functionality as the ship prepares for flight operations; the second phase focuses on flight operations once the ship and crew are ready. The Navy plans to start the first phase of operational testing in early FY21 and complete the second phase of operational testing in FY22, prior to the first deployment of CVN 78. To save resources and lower test costs, the test phases are aligned

with standard carrier training periods as CVN 78 prepares for its first deployment.

- The Navy continues to plan the CVN 78 shock trial for CY19. The Navy has held meetings regularly to discuss shock trial logistics, environmental requirements, instrumentation, and related analyses.

EMALS

- The Navy conducted four F/A-18F launches from CVN 78, the first at-sea EMALS aircraft launches.
- As of July 2017, the program has conducted 3,801 dead loads (non-aircraft, weight equivalent sled) and 523 aircraft launches at the land-based test site.
- EMALS testing in 2015 discovered excessive airframe stress during launches of F/A-18E/F and EA-18G with wing-mounted 480-gallon EFTs. The Navy discovered similar problems with 330-gallon EFTs on the F/A-18A-D. Additionally, end-of-stroke dynamics with heavy wing stores were discovered for the F/A-18E/F and EA-18G, which would limit maximum launch speed.

AAG

- The Navy conducted four F/A-18F arrestments on CVN 78, the first at-sea AAG arrestments.
- The Navy continues to test the AAG on a jet car track at Joint Base McGuire-Dix-Lakehurst, New Jersey. Earlier testing prompted system design changes that the program is now testing. The jet car track testing examined the F/A-18E/F performance envelope with the new design. Overall, land-based jet car track testing has accomplished a total of 1,598 dead load arrestments as of August 31, 2017. Testing at RALS supported development of the limited envelope Aircraft Recovery Bulletin needed for the first at-sea arrestments on CVN 78.

CANES

- The Navy completed the performance and suitability portions of the CANES follow-on operational testing of the force-level CANES configuration used on the *Nimitz* and *Ford* classes. The cybersecurity testing of this variant concluded in 3QFY17. The results of the cybersecurity test are classified and available separately.

DBR

- The radar consists of fixed array antennas both in the X- and S-bands. The X-band radar is the Multi-Function Radar (MFR) and the S-band radar is the Volume Search Radar (VSR).
- The Navy has tested a production array MFR and an Engineering Development Model array of the VSR at the Surface Combat System Center at Wallops Island, Virginia. Integration testing of DBR has concluded at Wallops Island and the program is in the process of installing the MFR on the Self-Defense Test Ship (SDTS) for further CVN 78 testing.
- Limited testing of the production DBR has begun on CVN 78 in the shipyard, in-port in Norfolk, Virginia, and at sea. The at-sea testing has been limited by problems with DBR reliability, uncommanded system resets, and problems with the radar's power supply onboard CVN 78.

Electric Plant

- Following a series of transformer and voltage regulator problems, which damaged two main turbine generators, the Navy decided to accept the ship with only three of the four main turbine generators operating after repairing only one of the two damaged generators. The ship is currently conducting underway testing in this configuration and the remaining damaged main turbine generator will need to be repaired or replaced during the ship's post-shakedown availability (PSA).

Manning

- CVN 78 has been manned in the shipyard and during initial at-sea periods, and the Navy is working with the ship's personnel to refine manpower, personnel, training, and education planning.

Electromagnetic Compatibility

- Preliminary electromagnetic interference (EMI) and radiation hazard (RADHAZ) testing has been conducted by Naval Surface Warfare Center, Dahlgren Division (NSWCDD) and Naval Air Systems Command (NAVAIR). Further testing and mitigation is planned both at sea and in port throughout shakedown and the post-shakedown availability (PSA).

Assessment

- The delays in the ship delivery have pushed both phases of initial operational testing until after the FY20 PIA period. As noted in previous annual reports, the CVN 78 test schedule has been aggressive, and the development and testing of EMALS, AAG, DBR, and the Integrated Warfare System are driving the ship's schedule independent of the requirement to conduct the FSST. The delay in the ship's delivery and development have added about 2 years to the timeline. Given all of the above, it is clear that the need to conduct the FSST has not been a factor delaying the ship's first deployment to FY22.
- CVN 78 has many new critical systems, such as EMALS, AAG, AWE, and DBR; since these systems have not undergone shock trials on other platforms, their ability to withstand shock is unknown. The program plans to complete component shock trials on EMALS, AAG, and the Advanced Weapons Elevators (AWE) during CY19, but because of a scarcity of systems, qualification testing of DBR is behind and will probably not be completed before the FSST.

Reliability

- CVN 78 includes several systems that are new to aircraft carriers; four of these systems stand out as being critical to flight operations: EMALS, AAG, DBR, and AWEs. Overall, the poor reliability demonstrated by AAG and EMALS and the uncertain reliability of DBR and AWEs pose the most significant risk to CVN 78 IOT&E. The Navy is testing all four of these systems for the first time in their shipboard configurations aboard CVN 78. Reliability estimates derived from test data for EMALS and AAG are discussed in the following subsections. For DBR and AWE, only engineering reliability estimates have been provided.

EMALS

- EMALS testing to date has demonstrated that EMALS should be able to launch aircraft planned for the CVN 78 air wing. However, the system demonstrated poor reliability during developmental testing suggesting operational difficulties lie ahead for meeting requirements and in achieving success in combat.
- In its current design, EMALS is unlikely to support high-intensity operations expected in combat. As of June 2017, the program estimates that EMALS has approximately 455 Mean Cycles Between Critical Failures (MCBCF) in the shipboard configuration, where a cycle represents the launch of one aircraft. While this estimate is above the rebaselined reliability growth curve, the rebaselined curve is well below the requirement of 4,166 MCBCF. At the current reliability, EMALS has a 9 percent chance of completing the 4-day surge and a 70 percent chance of completing a day of sustained operations as defined in the design reference mission without a critical failure.
- 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 onboard CVN 78. The process for electrically isolating equipment is time-consuming; spinning down the EMALS motor/generators takes 1.5 hours by itself. The inability to readily electrically isolate equipment precludes EMALS maintenance during flight operations, reducing the system operational availability.
- The Navy demonstrated, in developmental testing, corrections to previously discovered deficiencies related to end-stroke dynamics and excessive airframe stress discovered during EMALS testing in 2015. This technical solution needs to be fully integrated into the EMALS software and re-tested.

AAG

- Testing to date demonstrated that AAG should be able to recover aircraft planned for the CVN 78 air wing, but the poor reliability demonstrated so far suggests AAG will have trouble meeting operational requirements.
- The Program Office redesigned major components that did not meet system specifications during land-based testing. In June 2017, the Program Office estimated that the redesigned AAG had a reliability of approximately 19 Mean Cycles Between Operational Mission Failures (MCBOMF) in the shipboard configuration, where a cycle represents the recovery of one aircraft. This reliability estimate is well below the rebaselined reliability growth curve and well below the 16,500 MCBOMF specified in the requirements documents. In its current design, AAG is unlikely to support routine flight operations. At the current reliability, AAG has less than a 0.001 percent chance of completing the 4-day surge and less than a 0.200 percent chance of completing a day of sustained operations as defined in the design reference mission. For routine operations, AAG would only have a 53 percent chance of completing a single 12 aircraft recovery cycle and a 1 percent chance of completing a typical 84 aircraft recovery day.
- The reliability concerns are worsened by the current AAG design that does not allow Power Conditioning Subsystem equipment to be electrically isolated from high power buses, limiting corrective maintenance on below-deck equipment during flight operations. This reduces the operational availability of the system.

DBR

- Previous testing of Navy combat systems similar to that of CVN 78 revealed numerous integration problems that degrade the performance of the Integrated Warfare System. Many of these problems are expected to exist on CVN 78. Current test results reveal problems with tracking and supporting missiles in flight, excessive numbers of clutter/ false tracks, and track continuity concerns. The Navy recently extended DBR testing at Wallops Island until 4QFY17; however, more test-analyze-fix cycles are likely to be needed to develop and test DBR fixes so it can properly perform air traffic control and engagement support on CVN 78.
- In limited at-sea operations, DBR exhibited frequent uncommanded system resets, and has had problems with the power supply system. These problems combined significantly limited operation and testing during the limited at-sea periods available so far.
- Beyond the above mentioned concerns, the Navy has only engineering analysis of DBR reliability. The reliability of the production VSR equipment in the shipboard DBR system has not been assessed. While the Engineering Development Model (EDM) VSR being tested at Wallops Island has experienced failures, it is not certain whether these EDM VSR failure modes will persist during shipboard testing of the production VSR. Reliability data collection will continue at Wallops Island and during DBR operations onboard CVN 78.

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. 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.
- 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 requirement is well above historical levels and that CVN 78 is unlikely to achieve that requirement.
- There are also concerns with the reliability of key systems that support sortie generation on CVN 78. Poor reliability of these critical systems could cause a cascading series of delays during flight operations that would affect CVN 78's

ability to generate sorties, make the ship more vulnerable to attack, or create limitations during routine operations. The poor or unknown reliability of these critical subsystems will be the most significant risk to the successful completion of CVN 78 IOT&E. The analysis also considered the operational implications of a shortfall and concluded that as long as CVN 78 is able to generate sorties comparable to *Nimitz*-class carriers, the operational capabilities of CVN 78 will be similar to that of a *Nimitz*-class carrier.

Electric Plant

- The Navy manufactured and tested a full-scale qualification unit of the shipboard Electrical Plant and components in a land-based facility in 2004. This test revealed no problems with the design of the original transformers or any other part of the main turbine generator. Following an initial transformer failure, which was determined to be caused by a material failure, the Navy decided to replace the transformers with an existing design used in other Navy applications. The Navy did not perform sufficient land-based testing on the alternate transformer to validate that no system design flaws or vulnerabilities with the revised voltage regulating system design existed. The Navy considered the risk was low and did not want to further delay ship delivery for the testing. However, voltage regulating system design flaws resulted in damage to a second main turbine generator following a subsequent transformer failure. This incident delayed the ship's delivery as well as both live fire and operational testing and currently the ship is operating on three of the four main turbine generators as a direct result of the second failure.

Manning

- Based on earlier Navy analysis of manning and the Navy's early experience with CVN 78, several areas of concern have been identified. The Navy is working with the ship's crew to resolve these problems.
- Based on current expected manning, the berthing capacity for officers and enlisted will be exceeded by approximately 100 personnel with some variability in the estimates. This also leaves no room for extra personnel during inspections or exercises, requiring the number of evaluators to be limited or the timeframe to conduct the training to be lengthened. This shortfall in berthing is further exacerbated by the 246 officer and enlisted billets (roughly 10 percent of the crew) identified in the Manning War Game III as requiring a face-to-face turnover. These turnovers will not all happen at one time, but will require heavy oversight and will limit the amount of turnover that can be accomplished at sea and especially during evaluation periods.
- Manning must be supported at the 100 percent level, although this is not the Navy's standard practice on other ships, and the Navy's personnel and training systems may not be able to support 100 percent manning. The ship is extremely sensitive to manpower fluctuations. Workload estimates for the many new technologies such as catapults, arresting gear, radar, and weapons and aircraft elevators are not yet well understood. Finally, the Navy is considering placing the ship's seven computer networks under a single department. Network management and the correct manning to facilitate continued operations is a concern for a network that is more complex than historically seen on Navy ships.

Electromagnetic Compatibility

- Developmental testing has identified significant EMI and radiation hazard problems. The Navy is continuing to characterize and develop mitigation plans for the problems, 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 utilization in order for commanders to make informed decisions on system employment.

Recommendations

- Status of Previous Recommendations. The Navy should continue to address the seven remaining FY10, FY11, FY13, FY14, FY15, and FY16 recommendations.
  1. Finalize plans that address CVN 78 Integrated Warfare System engineering and ship self-defense system discrepancies prior to the start of IOT&E.
  2. Provide scheduling, funding, and execution plans to DOT&E for the live SGR test event during the IOT&E.
  3. Continue to work with the Navy's Bureau of Personnel to achieve adequate depth and breadth of required personnel to sufficiently meet Navy Enlisted Classification fit/fill manning requirements of CVN 78.
  4. Conduct system of systems developmental testing to preclude discovery of deficiencies during IOT&E.
  5. Address the uncertain reliability of EMALS, AAG, DBR, and AWE. These systems are critical to CVN 78 flight operations, and are the largest risk to the program.
  6. Begin tracking and reporting on a quarterly basis system reliability for all new systems, but at a minimum for EMALS, AAG, DBR, and AWE.
  7. Submit a TEMP for review and approval by DOT&E incorporating the Deputy Secretary's direction to conduct the FSST before CVN 78's first deployment.
- FY17 Recommendations. The Navy should:
  1. Resolve how SGR estimates from the live SGR test will be extended to the 35-day design reference mission.
  2. Continue to characterize the electromagnetic environment onboard CVN 78 and develop operating procedures to maximize system effectiveness and maintain safety. As applicable, the Navy should utilize the lessons learned from CVN 78 to inform modifications to CVN 79 and beyond.