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

Executive Summary

- The Navy's Commander, Operational Test and Evaluation Force (COTF) is conducting a DOT&E-approved operational assessment that began in September 2015. 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's delivery date has led to a slip in the completion of the operational assessment.
- DOT&E's assessment of CVN 78 remains consistent with the DOT&E Operational Assessment report submitted in December 2013. Poor or unknown reliability of the newly designed catapults, arresting gear, weapons elevators, and radar, which are all critical for flight operations, could 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 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 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 plans to examine system improvements in FY17.
- Previous testing at the EMALS functional demonstration test site at Joint Base McGuire-Dix-Lakehurst, New Jersey, discovered excessive airframe stress during launches of F/A-18E/F and EA-18G with wing-mounted 480-gallon external fuel tanks (EFTs). Similar issues were discovered 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 will limit maximum launch speed. These discoveries, until corrected, will preclude the Navy from conducting normal operations of the F/A-18A-F and EA-18G from CVN 78. The Navy plans to correct these problems prior to the end of CVN 78 Post-Shakedown Availability (PSA).
- 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) with manned aircraft commenced in 2016 and completed 200 aircraft arrestments as of October 28, 2016 (188 roll-in arrestments and 12 fly-in arrestments). RALS testing supports development of the F/A-18E/F limited envelope Aircraft Recovery Bulletin required for the first arrestments onboard CVN 78.

- The CVN 78 design is intended to reduce manning. As manning requirements have been further developed, 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 already required redesignation of some berthing areas and may require altering standard manpower strategies to ensure mission accomplishment.
- 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 ship's Dual Band Radar (DBR) is being integrated with the combat system and continues to undergo developmental testing at Wallops Island, Virginia. That testing has uncovered tracking, clutter/false track, track continuity, and engagement support problems typical of those seen in early developmental testing, affecting air traffic control and self-defense operations. The Navy is investigating solutions to these problems, but as ship delivery approaches, the likelihood that these problems will persist into IOT&E increases.
- Funding shortfalls are expected to affect testing of the CVN 78 Integrated Warfare System. In July, the Navy noted that a lack of enterprise funding will result in delays to developmental testing of DBR and the CVN 78 Integrated Warfare System during CVN 78's shakedown period. Ultimately, this will lead

to a 10- to 11-month delay in the ship's Combat System Ship Qualification Trial.
- The development and testing of EMALS, AAG, DBR, and the Integrated Warfare System will continue to drive the *Gerald R. Ford's* timeline as it progresses into OT&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. The CVN 78 will incorporate EMALS (electromagnetic, instead of steam-powered catapult launchers) and AAG, and will have a smaller island with a DBR (phased-array radars, which replaces/combines several legacy radars used on current aircraft carriers and serve 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.
  - Various 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 to increase the sortie generation capability of embarked aircraft to 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 demonstration 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's lifespan. CVN 78 will include a new Heavy underway replenishment system that will transfer cargo loads of up to 12,000 pounds.
- The Navy intends to achieve CVN 78 Initial Operational Capability in late-FY17 or early-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 the 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

Test Planning
- The CVN 78 *Gerald R. Ford*-class carrier Program Office is revising the Test and Evaluation Master Plan (TEMP) 1610 to align planned developmental tests with corresponding operational test phases and to identify platform-level developmental testing.
- The Navy updated the Post Delivery Test and Trials schedule to incorporate the Full Ship Shock Trial (FSST) as directed by the Deputy Secretary of Defense.
- The Navy is planning for 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.

EMALS
- The Navy is conducting installation and checkout of the EMALS in CVN 78. As of July 2016, 121 dead loads (non-aircraft, weight equivalent sled) and 217 no-load tests have been completed on the bow catapults, and 121 dead loads and 168 no-load tests have been completed on the waist catapults.
- In 2014, testing discovered excessive EMALS holdback release dynamics during F/A-18E/F and EA-18G catapult launches with wing-mounted, 480-gallon EFTs. During test launches, the stress limits of the aircraft were exceeded. Testing also discovered similar problems with 330-gallon

EFTs and with end-of-stroke dynamics that affect heavy wing stores. The program has developed fixes, but testing to verify the fixes on manned aircraft has been delayed until 2017 on F/A-18E/F and EA-18G and until 2018 for F/A-18A/B/C/D.

AAG

- The Navy is conducting installation and checkout of the AAG in CVN 78.
- 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 are now being tested. 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 conducted a total of 1,381 dead load arrestments as of November 2016. Testing in 2016 examined degraded mode performance for the safe recovery of aircraft in the event of an AAG component failure. Testing began at RALS to develop 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 is expected to conclude in 2017.
- USD(AT&L) approved full deployment of CANES on October 13, 2015, based on the results of the IOT&E for the unit-level variant conducted from August 2014 through March 2015.

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 is testing 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 continues at Wallops Island and is expected to continue through 4QFY17. The MFR will then be installed 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. While the program has completed over 80 percent of industrial testing, the DBR cannot be fully tested without going to sea and safety precautions within the shipyard limit the extent of testing conducted to date.

Electric Plant

- The newly designed medium-voltage electrical distribution system was initially energized in 2013. Shipboard testing earlier this year, directed by Naval Sea Systems Command (NAVSEA), demonstrated high-power operation of the power generation components using reactor-power generated steam, including support of large electric loads (e.g., EMALS). During recent NAVSEA shipboard testing, an instrumentation transformer associated with the system's main turbine generators voltage regulating system failed. Detailed investigation into this problem indicated that the specific failure was most likely due to a manufacturing defect, but investigation of that original transformer defect continues. To address this component failure and keep the ship on schedule, an alternate design transformer (proven in other electrical applications) was installed but the new configuration was not tested at the land-based test facility to the same degree as the original transformer. Shipboard testing following installation of the alternative transformer revealed design vulnerabilities with the new transformers that must be addressed prior to ship delivery. Voltage regulating system design changes are being implemented and detailed repair plans are in place to address these problems.

Manning

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

LFT&E

- The Navy is making progress for executing the Shock Trial on CVN 78 in FY19. The Navy has held internal meetings to discuss shock trial logistics, environmental requirements, and the way forward regarding component shock qualification of mission critical systems.

Assessment

Test Planning

- 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 schedule to further integrate testing and to include the FSST.
- The Navy has not finalized how it intends to extrapolate the live SGR testing (six consecutive 12-hour fly days followed by two consecutive 24-hour fly days) to the 35-day design reference mission on which the SGR requirement is based. COTF is working with the Program Office to identify required upgrades for the Seabasing/Seastrike Aviation Model to perform this analysis.
- The schedule to deliver the ship has slipped to December 2016 "under review," meaning the Navy is currently evaluating the power plant problems and repair timeline and is determining a new date for delivery. This new date is planned to be announced in mid-December 2016. Further slips in the delivery are likely to affect schedules for the first at-sea OT&E of CVN 78. Currently, the Program Office is planning for two 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 begin the first phase of testing in late FY18 or early FY19 before CVN 78's FSST. The FSST is followed by CVN 78's first Planned Incremental Availability (PIA), an extended

maintenance period. The Navy then plans to complete the second phase of operational testing after the PIA in FY21, subsequent to when the ship would first deploy. 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. Further delays in the ship delivery are likely to push both phases of testing until after the PIA. 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. Continued delays in the ship's delivery will compress the ship's schedule and are likely to have ripple effects. Given all of the above, it is clear that the need to conduct the FSST is not a key factor driving the first deployment to occur in FY21.

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 the Advanced Weapons Elevators (AWEs). Overall, the poor reliability demonstrated by AAG and EMALS and the uncertain reliability of DBR and AWEs pose the most significant risk to the CVN 78 IOT&E. All four of these systems are being tested for the first time in their shipboard configurations aboard CVN 78. The Program Office provided updates on the reliability of these systems in April 2016. Reliability estimates derived from test data for EMALS and AAG are discussed below. For DBR and AWE, only engineering reliability estimates have been provided to date.

EMALS

- EMALS testing to date has demonstrated that EMALS should be able to launch aircraft planned for CVN 78's air wing. However, present limitations on F/A-18E/F and EA-tim18G configurations, as well as the system's demonstrated poor reliability during developmental testing, suggest operational difficulties lie ahead for meeting requirements and in achieving success in combat.
- With the current limitations on EMALS for launching the F/A 18E/F and EA-18G in operational configurations (e.g., wing-mounted 480-gallon EFTs and heavy wing stores), CVN 78 will be able to fly F/A-18E/F and EA-18G, but not in configurations required for normal operations. Presently, these problems substantially reduce the operational effectiveness of F/A-18E/F and EA-18G flying combat missions from CVN 78. The Navy has developed fixes to correct these problems, but testing with manned aircraft to verify the fixes has been postponed to 2017.
- As of April 2016, the program estimates that EMALS has approximately 400 Mean Cycles Between Critical Failure (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 7 percent chance of completing the 4-day surge and a 67 percent chance of completing a day of sustained operations as defined in the design reference mission. Absent a major redesign, EMALS is unlikely to support high-intensity operations expected in combat.
- 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's operational availability.

AAG

- Testing to date has demonstrated that AAG should be able to recover aircraft planned for the CVN 78 air wing, but the poor reliability demonstrated to date 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 April 2016, the Program Office estimated that the redesigned AAG had a reliability of approximately 25 Mean Cycles Between Operational Mission Failure (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 requirement of 16,500 MCBOMF specified in the requirements documents. At the current reliability, AAG has an infinitesimal chance of completing the 4-day surge and less than a 0.2 percent chance of completing a day of sustained operations as defined in the design reference mission. Without a major redesign, AAG is unlikely to support high intensity operations expected in combat.
- 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 CVN 78's revealed numerous integration problems that degrade the performance of the Integrated Warfare System. Many of these problems are expected to exist on CVN 78. The DBR testing at Wallops Island is typical of early developmental testing with the system still in the problem discovery phase. Current 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 that the DBR can properly perform air traffic control and engagement support on CVN 78.

- Currently, 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. The Navy has identified funding shortfalls that are likely to delay important developmental testing of DBR and the Integrated Warfare System. Test delays are likely to affect CVN 78's readiness for IOT&E. Delays in the development and testing of these systems at Wallops Island have significantly compressed the schedule for self-defense testing of DDG 1000 and CVN 78 on the SDTS. This testing is essential for understanding these ships' capabilities to defend themselves and prevail in combat. The completion of self-defense testing for CVN 78, and the subsequent use of Probability of Raid Annihilation test bed for assessing CVN 78 self-defense performance, are dependent upon future Navy decisions that could include canceling MFR component-level shock qualification or deferring the availability of the SDTS MFR for installation on DDG 1002.

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. DOT&E assesses the poor or unknown reliability of these critical subsystems will be the most significant risk to CVN 78's successful completion of 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

- A full-scale qualification unit of the shipboard component was manufactured and tested 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. The design issues revealed during troubleshooting of the failed main turbine generator voltage regulating system transformer were introduced with the design changes incorporated following the transformer failure. Once alternate transformers were selected, the Navy did not perform sufficient land-based testing 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, due to the failure, ship delivery continues to be delayed.

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.
- During some exercises, the berthing capacity for officers and enlisted will be exceeded, 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.

LFT&E

- CVN 78 has many new critical systems, such as EMALS, AAG, AWE, and DBR that have not undergone shock trials on other platforms. Unlike past tests on other new classes of ships with legacy systems, the performance of CVN 78's new critical systems is unknown. Inclusion of data from shock trials early in a program has been an essential component of building survivable ships. The current state of modeling and component-level testing are not adequate to identify the myriad problems that have been revealed only through full ship shock testing. DOT&E has requested that the Navy provide the status of the programs component shock qualification at a minimum on a semi-annual basis to understand the vulnerability and recoverability of the ship.

Recommendations

- Status of Previous Recommendations. The Navy should continue to address the nine remaining FY10, FY11, FY13, FY14, and FY15 recommendations.
  1. Finalize plans that address CVN 78 Integrated Warfare System engineering and ship's 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-of0systems 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. Aggressively fund and address a solution for the excessive EMALS holdback release dynamics during F/A-18E/F and EA-18G catapult launches with wing-mounted 480-gallon EFTs.
  7. Begin tracking and reporting on a quarterly basis systems reliability for all new systems, but at a minimum for EMALS, AAG, DBR, and AWE.
  8. The Navy should ensure the continued funding for component shock qualification of both government- and contractor-furnished equipment.
  9. 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.
- FY16 Recommendations. The Navy should:
  1. Ensure adequate funding of DBR and Integrated Warfare System developmental testing to minimize delays to the test schedule.
  2. Provide DOT&E with component shock qualification program updates at a minimum of semi-annually, and maintain DOT&E's awareness of FY19 shock trial planning.