

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

Executive Summary

- On February 2, 2015, DOT&E disapproved Test and Evaluation Master Plan (TEMP) 1610, Revision C because the CVN 78 Class Full Ship Shock Trial (FSST) had been changed in the approved 2007 TEMP 1610, Revision B from CVN 78 to CVN 79. The Revision C TEMP does provide improved integrated platform-level developmental testing, reducing the likelihood that platform-level problems will be discovered during IOT&E. In addition, the Program Office is in the process of refining the post-delivery schedule to further integrate testing.
- On August 7, 2015, the Deputy Secretary of Defense directed the Navy to complete the FSST before CVN 78's first operational deployment. The Navy is updating the TEMP to reflect the Deputy Secretary of Defense's decision.
- The Navy's Commander, Operational Test and Evaluation Force (COTF) began a new DOT&E-approved operational assessment in September 2015, which is planned to end in mid-2016 after CVN 78 completes Builder's Sea Trials and Acceptance Trials.
- 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 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.
 - Reliability for the catapults was last reported in December 2014. While catapult reliability is above the re-baselined reliability growth curve, the re-baselined curve is well below the reliability requirement and the catapults are unlikely to achieve required reliability.
 - Reliability for the arresting gear has not been reported in almost two years. The last reported reliability estimates for the arresting gear were well below the re-baselined reliability growth curve, and indicated that the system was unlikely to achieve required reliability. The Navy began measuring reliability again in 4QFY15, but does not expect to have new reliability estimates until the end of 2015. Additionally, reliability test data are not available for the radar and the weapons elevators.
 - Absent a major redesign, the catapults and arresting gear are not likely to meet reliability requirements.
- In FY14, testing at the Electromagnetic Aircraft Launching System (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). This discovery, until corrected, will preclude the



- Navy from conducting normal operations of the F/A-18E/F and EA-18G from CVN 78.
- In FY15, the Navy identified an inability to readily electrically isolate EMALS components to perform concurrent maintenance. This inability to readily electrically isolate EMALS components could preclude some types of EMALS maintenance during flight operations, decreasing EMALS operational availability.
- In October 2015, the Navy discovered that one of the three Prime Power Interface Subsystems (PPIS) Transformer Rectifiers (TRs) had been damaged during shipboard certification testing. Two of the three TRs are required for normal catapult operations. The TRs were designed to last the life of the ship. Earlier faults discovered during developmental testing resulted in stepwise improvements to the PPIS TR design and construction. This failed TR had one of the four improvements.
- In FY15, the Navy began performance testing of the Advanced Arresting Gear (AAG) at a jet car track site at Joint Base McGuire-Dix-Lakehurst, New Jersey. This testing is examining the performance of the redesigned arresting gear to meet the system specification with improve reliability.
- 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; and 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 re-designation 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

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and is undergoing developmental testing at Wallops Island, Virginia. That testing has uncovered significant 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.

- It is unlikely that CVN 78 will 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.
- CVN 78 will include a new Heavy underway replenishment (UNREP) system that will transfer cargo loads of up to 12,000 pounds. Currently, only one resupply ship has Heavy UNREP on one station. The Navy plans to install a single Heavy UNREP station on each additional resupply ship beginning in FY21 with T-AO(X).
- The schedule to deliver the ship has slipped from September 2015 to April 2016. On September 22, the Navy announced that sea trials would be delayed six to eight weeks due to slower than expected progress in the shipboard test program. The development and testing of EMALS, AAG, DBR, and the Integrated Warfare System will continue to drive the timeline as the ship progresses into test and evaluation.

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 produce 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 serving in air traffic control and in 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.

- 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 for 24-hour surge.
- The Consolidated Afloat Networks and Enterprise Service (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 UNREP system that will transfer cargo loads of up to 12,000 pounds.
- The Navy will achieve CVN 78 Initial Operational Capability in FY17 after successful completion of Post Shakedown Availability and will achieve Full Operational Capability in FY19 after successful completion of IOT&E testing 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 revised the TEMP 1610 to align planned developmental tests with corresponding operational test phases and to identify platform-level developmental testing. DOT&E disapproved this TEMP 1610 Revision C pending the rescheduling of the CVN 78 Class FSST from CVN 79 to CVN 78, before her first operational deployment.

- The Navy is updating the Post Delivery Test and Trials schedule to incorporate the FSST as directed by the Deputy Secretary of Defense.
- The Navy plans 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, resolution of how the Navy

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will extrapolate the days of live results to the 35-day design reference mission on which the SGR requirement is based is yet to be decided. Until this year, the Navy planned to use a model in development by Huntington Ingalls Industries to extrapolate the live test results. In June 2015, COTF told the CVN 78 program manager that because several of the assumptions tied to this Key Performance Parameter are beyond the scope of operational test, COTF would not accredit the Navy's Virtual Carrier (VCVN) model for use during IOT&E. DOT&E agrees with COTF's concerns about the Key Performance Parameter assumptions, and the resulting limitations of the VCVN model.

EMALS

- The Navy is conducting installation and checkout of the EMALS in CVN 78. Initial dead load tests have been completed on the bow catapults, and testing continues on the waist catapults. To date, 109 dead loads and 191 no load tests have been completed on the bow catapults, and 55 no load tests have been completed on the waist catapults.
- The EMALS functional demonstration test site at Joint Base McGuire-Dix-Lakehurst, New Jersey, continues to test the electromagnetic catapult system. The Navy has also conducted over 3,500 dead-load launches (non-aircraft, weight equivalent, and simulated launches) and over 450 aircraft launches at the functional demonstration test site.
- 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.

AAG

- The Navy is conducting installation and checkout of the AAG in CVN 78. Hardware checkout has occurred in preparation for initial shipboard testing.
- 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 has examined the F/A-18E/F performance envelope with the new design. Overall, land based jet car track testing has conducted a total of 1046 deadload arrestments; including, the completion of 76 performance deadload arrestments in 4QFY15.
- Testing has focused system performance of off center and angled (or skew) recoveries that create system instability. This instability is known as divergent trajectory and is created when an aircraft runout trajectory diverges from off center and/or skew engagement conditions.
- Previously, the Navy de-scoped the number 4 AAG engine, reducing the total arresting gear engines on the ship, including the barricade, to three, and diverted the equipment to Runway Arrested Landing Site in Lakehurst to support the test program.

CANES

- The Navy completed CANES integrated testing and currently is performing follow-on operational testing of

the force-level CANES configuration used on the *Nimitz* and *Gerald R. Ford* classes. This FOT&E is scheduled to complete in 1QFY16.

- The Navy conducted integrated testing and IOT&E of the unit-level Aegis destroyer configuration in 3QFY14 and 2QFY15. The system was operationally effective, suitable, and survivable to the cyber threats represented in the test.

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.
- The Navy is testing a production array MFR and an Engineering Development Model array of the Volume Search Radar at the Surface Combat System Center at Wallops Island, Virginia. The developmental testing of DBR resumed in 4QFY14 at Wallops Island and is expected to continue through 3QFY16. The MFR will then be installed on the Self-Defense Test Ship for further CVN 78 testing beginning 2QFY17.
- Testing of the production DBR has begun on CVN 78 in the shipyard. Initial checkout of the equipment has occurred.

Manning

- The Navy conducted CVN 78 Manning War Game III in July 2014 to identify CVN 78 unique manpower, personnel, training, and education planning and execution concerns.

LFT&E

- On August 7, 2015, the Deputy Secretary of Defense directed the Navy to complete the FSST before CVN 78's first operational deployment. The Revision A of the LFT&E Management Plan prepared by the Navy and approved by DOT&E on July 17, 2007, stated the FSST would be conducted on CVN 78. The Navy unilaterally reneged on the approved strategy on June 18, 2012. DOT&E did not approve of the Navy revisions to the new Live Fire Strategy and the Deputy Secretary of Defense concurred with DOT&E.

Assessment

Test Planning

- A TEMP 1610 revision is under development to address problems with the currently-approved TEMP 1610, Revision B. The Navy submitted a revised TEMP 1610, Revision C that was disapproved on February 2, 2015, because the Navy removed the previously (2007) agreed upon FSST. However, Revision C improved integrated platform-level developmental testing, reducing the likelihood that platform-level problems will be discovered during IOT&E. In addition, the Program Office is in the process of refining the post-delivery schedule to further integrate testing. With the Deputy Secretary of Defense's direction to the Navy to conduct the FSST before the initial deployment on CVN 78, the Navy desires to update TEMP 1610, Revision C. DOT&E has not seen the Navy's

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revision plan and given the extent of the updates required may require a Revision D to TEMP 1610.

- The current state of the Navy's VCVN model does not fully provide for an accurate accounting of SGR due to a lack of fidelity regarding manning and equipment/aircraft availability. Due to these limitations, in June 2015, COTF rescinded the use of VCVN for extrapolating live test results. The Navy has not stated how it intends to extrapolate the live results to the 35-day design reference mission on which the SGR requirement is based. DOT&E agrees with the COTF decision. An alternative SGR modeling and simulation approach should be developed by the Navy.
- The schedule to deliver the ship has slipped from September 2015 to April 2016. On September 22, the Navy announced that sea trials would be delayed six to eight weeks due to slower than expected progress in the shipboard test program. The ship's post-shipyard shakedown availability will follow delivery in late 2016. During the post-shipyard shakedown availability, installations of some systems will be completed. The first at-sea operational test and evaluation of CVN 78 is scheduled to begin in September 2017.

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 uncertain reliability of these four systems is 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. Reliability estimates derived from test data for EMALS and AAG are discussed below. For DBR and AWE, reliability data collection has not yet been reported to DOT&E, but is expected to start at the completion of shipboard installation and checkout. Only engineering reliability estimates have been provided to date.
- CVN 78 will include a new Heavy UNREP system that will transfer cargo loads of up to 12,000 pounds. Currently, only one resupply ship has Heavy UNREP on one station. The Navy plans to install a single Heavy UNREP station on each additional resupply ship beginning in FY21 with T-AO(X).

EMALS

- EMALS is one of the four systems critical to flight operations. While testing to date has demonstrated that EMALS should be able to launch aircraft planned for CVN 78's air wing, present limitations on F/A-18E/F and EA-18G configurations, as well as the system's reliability remains uncertain.
- With the current limitations on EMALS for launching the F/A-18E/F and EA-18G in operational configurations (i.e., during test launches with wing-mounted 480-gallon EFTs, the stress limits of the aircraft were exceeded), CVN 78 will be able to fly F/A-18E/F and EA-18G, but not in the configuration that is required for normal operations.

If uncorrected, this problem would preclude normal employment from CVN-78. Presently, this configuration substantially reduces the operational effectiveness in of F/A-18E/F and EA-18G flying combat missions from CVN 78. The Navy has conducted deadload launches for changes to the EMALS Control Software to correct this issue in preparation for land based aircraft test launches in 3QFY16.

- In FY15, the Navy identified an inability to readily electrically isolate EMALS components to perform concurrent maintenance. For safety of personnel, maintenance and repair to catapults will likely be limited to non-flight operations periods. It is not possible to readily electrically isolate equipment during flight operations due to the shared nature of the Energy Storage Groups (ESGs) and Power Conversion Subsystem inverters in the four launcher/three ESG configuration. The primary means of physically disconnecting major subsystems and the launchers are the Cable Disconnect Units (CDUs). There is no circuit breaker or switch to secure power to the CDU; CDUs can only be disconnected by first securing all feeding power, dissipating all stored energy including spinning down the motor/generators, discharging capacitors, and then unbolting and removing the bus disconnect links. This provision would prevent certain maintenance and repair of launcher components while power is present in other components and while other launchers are conducting flight operations. In contrast, on *Nimitz* class carriers with steam catapults, maintenance on non-operating catapults while flight operations are performed on operating catapults is allowed and routine. The effects on operational performance of this are unclear, and will depend upon the extent to which EMALS redundancy permits catapult operations to continue notwithstanding component equipment failures.
- In October 2015, the Navy discovered that one of three PPIS TRs had been damaged during shipboard certification testing. Two of the three TRs are required for normal catapult operations. The TRs were designed to last the life of the ship. Earlier faults discovered during developmental testing resulted in stepwise improvements to the PPIS TR design and construction. This failed TR had one of the four improvements. The PPIS is 130 inches wide, 74 inches deep, 80 inches high, and weighs over 35,000 pounds. The replacement PPIS will be shipped to and fault checked at Joint Base McGuire-Dix-Lakehurst, New Jersey, and then shipped to Newport News, Virginia, for installation on CVN 78. The removal of the old PPIS, which, due to the size and mass of the PPIS will require cutting a hole in the ship's hull, and installation of the new one will take several months, but is not expected to delay testing or ship's delivery.
- As of December 2014, the program estimates that EMALS has approximately 340 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 re-baselined reliability growth curve,

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the re-baselined curve is well below the requirement of 4,166 MCBCF. The failure rate for the last reported MCBCF was 3.7 times higher than should have been expected at this point in the development. Absent a major redesign, it is unlikely EMALS will be capable of meeting the requirement of 4,166 MCBCF.

AAG

- AAG is another system critical to flight operations. Testing to date has demonstrated that AAG should be able to recover aircraft planned for the CVN 78 air wing, but AAG's reliability is uncertain. The Program Office redesigned major components that did not meet system specifications during land-based testing. The Program Office last provided reliability data in December 2013 and estimated that AAG had approximately 20 Mean Cycles Between Operational Mission Failure (MCBOMF) in the shipboard configuration, where a cycle represents the recovery of one aircraft. The requirement is an MCBOMF of 16,500. The Program Office expects to have a reliability estimate for the new design by the end of 2015. The last reported failure rate was 248 times higher than should have been expected at this point in the development.

DBR

- Previous testing of Navy combat systems similar to CVN 78's revealed numerous integration problems that degrade the performance of the combat 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. More test-analyze-fix cycles are necessary for DBR to develop and test fixes so that it can properly perform air traffic control and engagement support on CVN 78. Previous test results emphasize the necessity of maintaining a DBR/CVN 78 combat system asset at Wallops Island. The removal of the MFR and the conclusion of developmental testing was originally scheduled for 3QFY15, but the Navy decided to extend the Wallops Island testing through 3QFY16. DOT&E concurs with this schedule change and considers it a necessary part of delivering a fully-capable combat system in CVN 78.

SGR

- It is unlikely that CVN 78 will 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 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 implications of CVN 78 will be similar to that of a *Nimitz* class carrier.

Manning

- The latest Navy analysis of manning identified several areas of concern. The Navy has re-designated some officer rooms as Chief Petty Officer (CPO) berthing spaces to resolve a shortfall in CPO berthing.
- 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

- The Navy has made substantial progress on defining the scope of the Total Ship Survivability Trial and the Analytical Bridge task. While these portions of the LFT&E Management Plan were adequately defined in the Revision B document, DOT&E returned the LFT&E Management Plan to the Navy solely on the basis of the FSST on CVN 79 versus CVN 78. With the Deputy Secretary of Defense's direction to the Navy to reinsert the FSST, a revised LFT&E Management Plan is under development.
- CVN 78 has many new critical systems, such as EMALS, AAG, AWE, and DBR that have not undergone shock trials

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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 of problems that have been revealed only through full ship shock testing.

- The FSST and component shock qualification test data could affect the design of future carriers in the class and are critical to the assessment of the CVN 78 survivability against operationally relevant threats. The FSST is scheduled to occur on CVN 78 in FY19.

Recommendations

- Status of Previous Recommendations. The Navy should continue to address the seven remaining FY10, FY11, FY13, and FY14 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. Continue aggressive EMALS and AAG risk-reduction efforts to maximize opportunity for successful system design and test completion in time to meet required in-yard dates for shipboard installation of components.
 3. Provide scheduling, funding, and execution plans to DOT&E for the live SGR test event during the IOT&E.
 - 4. 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.
 - 5. Conduct system-of-systems developmental testing to preclude discovery of deficiencies during IOT&E.
 - 6. 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.
 - 7. 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.
- FY15 Recommendations. The Navy should:
 1. Ensure the continuation of funding and testing of the DBR at Wallops Island through 3QYFY16 address the problems discovered during initial developmental testing.
 2. Begin tracking and reporting on a quarterly basis systems reliability for all new systems but at a minimum for EMALS, AAG, DBR, and AWE.
 3. The Navy should ensure the continued funding for component shock qualification of both government and contractor furnished equipment.
 4. 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.