DOCUMENT 1

OPERATIONAL TEST AND EVALUATION

OFFICE OF THE SECRETARY OF DEFENSE
1700 DEFENSE PENTAGON
WASHINGTON, DC 20301-1700

JUL 22 2015

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR ACQUISITION, TECHNOLOGY AND LOGISTICS

SUBJECT: Observations on the Marine Corps F-35B Demonstration on USS *Wasp*

During the period of May 18 – 29, 2015, the Marine Corps embarked a total of seven F-35B aircraft onboard the aircraft carrier USS *Wasp* (LHD-1) for a shipboard deployment demonstration.[1] The Marines refer to this demonstration event as "Operational Test One," or "OT-1;" the aircraft were flown by operational pilots, and most of the aircraft maintenance was performed by uniformed military maintenance personnel, albeit heavily supported by contractors. Representatives from the Joint Strike Fighter (JSF) Operational Test Team (JOTT) and analysts from the Institute for Defense Analyses (IDA), the latter representing my office, were permitted to embark for the duration of the event to observe the activities firsthand.

The event was not an operational test, though, in either a formal or an informal sense of the term. Furthermore, it did not – and could not – demonstrate that the Block 2B F-35B is operationally effective or suitable for use in any type of limited combat operation, or that it is ready for real-world operational deployments, given the way the event was structured. That said, the event did provide an opportunity for the Marine Corps to conduct useful training, and provided experience for the Marines assigned to F-35B units and for the amphibious Navy. In particular, by providing initial exposure for squadron ground personnel to the maintenance and operations of the F-35B at sea, and initial exposure for the ship's personnel to the aircraft and its logistical and operational characteristics, the event served to highlight a number of issues – especially aircraft shipboard integration and maintainability challenges – that were important to identify before the aircraft's first operational deployment.

In order to have been a *bona fide* operational test with results that would enable the Department to determine whether the F-35B is operationally effective and suitable, and to demonstrate readiness for real-world operational deployment, testing would have to have been conducted under conditions that were much more representative of real-world operations than those that were used during this deployment. Among other things, the following would be required:

- The testing would have to include the rest of the embarked Air Combat Element (ACE), with all the additional complications that the presence of the other aircraft and personnel from the ACE would inject into F-35B operations and maintenance. The F-35Bs and three H-60 Search and Rescue (SAR) detachment helicopters were the

[1] There were no more than six F-35B on the *Wasp* at any given time. One aircraft was swapped during the demonstration for another aircraft ashore due to a fuel system fault that would have been impractical to fix at sea given the maintenance workload. This gives a total of seven F-35B that participated.

only aircraft onboard for this demonstration event. The full ACE will include over 20 additional aircraft, sharing the same flight deck and hangar deck space and some of the same ground support equipment (SE).

- It would require aircraft equipped with the full complement of electronic mission systems necessary for combat and the exercise of all the normal maintenance procedures necessary to keep those systems in a combat-capable state of readiness. Key combat mission systems were not installed in the aircraft or were not cleared for use (e.g., nose apertures for the infrared Distributed Aperture System were not installed on the aircraft, which is intended to provide missile launch warning and situational awareness to the pilots; use of the night vision camera video in the helmet was prohibited or restricted to no lower than 5,000 feet above the ground – depending on the specific aircraft; limited radar modes were available on some of the Block 2B aircraft). Additionally, degradations in mission systems that would have to be addressed in combat operations were often ignored during this event, as long as the aircraft were able to safely conduct the event's limited training objectives. The test teams neither collected data to support an analysis of mission systems effectiveness or Reliability, Availability, and Maintainability (RAM), nor to assess the impacts of these factors on operational tempo or overall operational effectiveness.
- It would require the loading, carriage, and expenditure of actual ordnance, with all the complications and potential impacts to F-35B and ACE operational tempo that would bring. During the deployment demonstration, the aircraft were not cleared to carry or employ any ordnance.
- It would require that all maintenance activities be conducted by uniformed military personnel with complete maintenance manuals and troubleshooting capabilities, and any contractor technical support would have to be strictly limited to what can be expected in real-world operations in combat. On this deployment demonstration, the uniformed military maintenance personnel received significant assistance from embarked contractor personnel who would not be part of combat operations, in areas where the uniformed maintainers currently lack organic troubleshooting capability.
- It would require the use of fully production-representative SE. The JSF program has yet to provide electrical or cooling carts suitable for the flight deck, and during the deployment demonstration maintainers employed non-operationally-representative workarounds to conduct tasks like fueling. The Marines brought additional, interim SE for use in the hangar bay, but this equipment is not the same as what will be deployed.
- It would require the exercise of and full reliance on the aircraft's intended operational logistics system, the Autonomic Logistics Global Sustainment (ALGS) system, without any reliance on non-operationally-representative supply system workarounds. ALGS will determine what spare F-35 parts will be loaded onboard a ship before deployment, the Afloat Spares Package (ASP), and how the supply system will fill requests for parts not included in the ASP. The spares that the contractor and

program provided for this deployment demonstration, without resorting to ALGS, may not have been fully representative of what future ships will deploy with. Furthermore, several ad hoc supply actions to obtain spare parts were taken during the event, actions that could not have been accomplished in a timely or practical manner when operationally deployed.

The scope and conduct of the event were sufficient, however, to show that shipboard reliability and maintainability are likely to present significant near-term challenges for the Marine Corps, given the present state of maturity of the F-35B aircraft. In spite of the fact that most mission systems problems could be safely ignored during this deployment, and even though the Marine maintainers had rapid, ready access to spare parts from shore and the benefit of the expertise of embarked contractor maintenance personnel, aircraft reliability was poor enough that it was difficult for the Marines to keep more than two to three of the six embarked jets in a flyable status on any given day. The challenges will be substantially tougher when the aircraft first deploys operationally, where working mission systems will not be optional, and where maintenance is likely to be more challenging due to the presence of the rest of the ACE.

Formal Initial Operational Test and Evaluation (IOT&E) of the Block 3F F-35B will overcome the test procedure shortfalls and operational representativeness shortfalls of the deployment demonstration. In the interim, I recommend the program conduct another deployment with a full ACE and a more aggressive set of demonstration objectives, especially for mission systems employment and weapons integration, to extend the scope of what was accomplished during this event and to ensure the issues identified are being addressed. The annexes attached at the end of this memo provide historical background, a detailed account of flight operations, specific operational and maintenance observations that support my overall observations, and a more in-depth list of recommendations.

J. M. Gilmore

J. Michael Gilmore
Director

Attachments:
As stated

ANNEX A - Historical Background

Following the cancellation of the Block 2B Operational Utility Evaluation (OUE) in April 2014, the program replanned the operational test period for Block 2B to include test events led by the individual Services and observed by the Joint Strike Fighter (JSF) Operational Test Team (JOTT). Although it was clear in early 2014 that the program would not be ready to begin spin-up in January 2015 for the Block 2B OUE, the JSF Program Office (JPO) and Services realized the benefit of planning for limited testing of the Block 2B capabilities, since they represent "initial warfighting capability" with the F-35, while focusing the developmental test effort to transitioning to Block 3i and 3F configurations to complete System Design and Development. The Marine Corps developed plans for a deployment of six F-35B production aircraft to the USS *Wasp* as a sustainment exercise in preparation for Initial Operational Capability declaration later in calendar year 2015 (CY15). In a memo dated September 22, 2014, the Deputy Commandant for Aviation (DC-A) requested support from the JPO and JOTT for planning and executing the deployment and for a report of the capabilities and limitations associated with deploying, integrating, and operating the F-35B aircraft in the Block 2B configuration from L-Class ships. Two previous deployments of F-35B aircraft to the USS *Wasp* were completed in October 2011 and August 2013 as part of developmental testing, and were accomplished using developmental test aircraft.

This page intentionally left blank.

ANNEX B - Flight Operations Chronology

The Marine Corps deployed a total of seven F-35B aircraft aboard the USS *Wasp* (LHD-1) over the 12 day period from May 18 – 29, 2015, to conduct the embarked flight operations of an operational deployment demonstration. These seven aircraft included four in the Block 2BS5.0 configuration (BF-21/23/24/37), assigned to VFMA-121 at Marine Corps Air Station (MCAS) Yuma, Arizona, and three in the Block 3iR1 configuration (BF-38/39/42), assigned to VMFAT-501 at MCAS Beaufort, South Carolina. All of the aircraft except BF-42 flew aboard USS *Wasp* on May 18. BF-42 flew aboard on May 26 to replace BF-24, which was permanently flown off the ship the same day because of a maintenance issue with its fuel system that maintainers could not fix quickly. BF-21 was simultaneously down for a different fuel issue, and detachment leadership decided to demonstrate onboard fuel system repair on BF-21, and replace BF-24 with BF-42 in order to meet flight schedules and relieve already task-saturated fuel system maintainers.

Flight operations were conducted every day but one during this period, and included daytime and nighttime Carrier Qualification (CQ) flights, limited daytime tactical proficiency flying, additional daytime take-off and landing demonstrations in support of a preplanned press day for selected organizations from the news media, and the final daytime fly-off at the end of the period. This annex presents a chronological overview of the flight events during the embarked period and the ferry flights bringing the VMFA-121 jets from MCAS Yuma to MCAS Beaufort prior to the fly-aboard. The chronology has been reconstructed from the original flight schedules published by VMX-22 Operations, from pilots' maintenance debrief cards and Naval Flight Records data provided by Maintenance Administration, and from notes published in the VMX-22 commander's daily Situation Reports (SITREPs).

Terminology

Key terms must be defined with precise meaning to ensure the discussion that follows is clear. For the purpose of this and the other annexes of this memorandum, a *mission* represents a tasking on the flight schedule -- planned or accomplished – for a specific event, and may be scheduled or flown as a single aircraft or as a multi-aircraft event. A *flight* represents a single aircraft contribution to a mission. Referencing a portion of the deployment flight schedule from May 26, shown below, helps to explain the use of these terms.

EVENT	TM	C/S	BRF/ETD/ETA	Mode 3 Squawk	ICAO	CREW	T&R	TMR	MSN
2-1	F-35B	STORM 51	0745/0900/1015	5010	LHD1/LHD1	PILOT A	2102	1A1	FAM
3-1	F-35B	STORM 52	0745/1000/1145	5011	LHD1/LHD1	PILOT B	4204	1A4	CQ
3-2	F-35B	STORM 53	0745/1000/1045	5012	LHD1/LHD1	PILOT C	4204	1A4	CQ
2-1	F-35B	STORM 51	0745/1045/1145	5010	LHD1/LHD1	PILOT A	4204	1A4	CQ
4-1	F-35B	STORM 54	0745/1100/1215	5013	LHD1/KNBC	PILOT D		2J2	FERRY
4-2	F-35B	STORM 55	1000/1215/1330	5013	KNBC/LHD1	PILOT E		2J2	FERRY
5-1 5-2	F-35B	STORM 56 STORM 57	1345/1600/1715	5010 5011	LHD1/LHD1	PILOT F PILOT C	6103,3602 3602	1A7	AI
5-3	F-35B	STORM 58	1345/1620/1730	5012	LHD1/LHD1	PILOT G		1A6	DCA
5-1 5-2	F-35B	STORM 56 STORM 57	1345/1745/1900	5010 5011	LHD1/LHD1	PILOT F PILOT C	6103,3602 3602	1A7	AI
5-3	F-35B	STORM 58	1345/1800/1900	5012	LHD1/LHD1	PILOT G		1A6	DCA

Figure B-1. Flight Schedule Planned for May 26, 2015

Every line in the flight schedule represents a mission. The type of mission for each line is denoted by the abbreviation in the column headlined "MSN." In this example, familiarization training (FAM), CQ, a ferry flight between the ship and an airfield ashore (Ferry), Air Interdiction (AI) proficiency training, and Defensive Counter Air (DCA) proficiency training were all planned.

A mission could consist of a single flight (one aircraft and one pilot), or it could include multiple aircraft and pilots, i.e., multiple flights, executing a mission together as a section (two aircraft) or as a division (four aircraft). The seventh mission scheduled on May 26 comprised two flights, 5-1 and 5-2, conducting an air interdiction mission together in a section. The eighth mission for the day comprised a single flight, 5-3, flying a DCA mission as a single aircraft. Note that the training objectives for one mission could be and often were coordinated with those of another mission. On this day, the aircraft for flights 5-1 and 5-2 were scheduled to play the role of anti-surface warfare aircraft trying to interdict the *Wasp*, with the aircraft for flight 5-3 to take on the role of defending the ship from these attackers.

Of note, the term "sortie" has been often used in Marine Corps and press reporting on the deployment demonstration to refer to a flight of one take-off and subsequent landing. "Sortie" is not used in this annex to avoid confusing it with a *flight* event, as described above. Instead, this annex will refer explicitly to conventional take-offs and landings and to Short Take-Offs (STOs) and Vertical Landings (VLs). For instance, in flight event 3-1 on May 26, the pilot accomplished a total of six STOs and six VLs in BF-23, in the 1 hour 36 minute time period between his first STO and his sixth and final VL. In the terminology used in the Marine Corps and most press reports to date, this single flight, as defined herein, would be counted as six sorties.

Reconstructing the flight from the Naval Flight Records on file, BF-23 made two STOs and two VLs in the first 16 minutes of this window, rolling forward immediately after the touchdown on the first VL into take-off position for the second STO. After the second VL, it accomplished hot-refueling (i.e., refueling while the pilot keeps the engine running) for approximately 10 minutes, accomplished two more STOs and VLs in the next 12 minutes, in the same manner, hot-refueled again for another 12 minutes, and then flew for a total of 36 minutes more, in which time it appears to have accomplished 2 more STOs and VLs. Again, in the terminology used in the Marine Corps and most press reports, this flight activity would represent six sorties. In this annex, it comprised a single flight with six STOs and six VLs.

Saturday, May 16 – Ferry Flights of VMFA-121 Aircraft from MCAS Yuma

Ten F-35B aircraft were identified to participate in the deployment demonstration, six of these designated as primary and the other four as back-up aircraft to be prepositioned at MCAS Beaufort. Six of this total (four primary/two back-up), in a Block 2B configuration, were provided by VMFA-121 from MCAS Yuma, Arizona. The other four (two primary/two-back-up), in a Block 3i configuration, were provided by VMFAT-501 from MCAS Beaufort, South Carolina.

On Saturday, May 16, the four primary Block 2B aircraft from MCAS Yuma conducted a ferry flight from MCAS Yuma to MCAS Beaufort to pre-position with the Block 3i aircraft from VMFAT-501 in preparation for the fly-aboard onto USS *Wasp* scheduled for May 18. The ferry flight had been scheduled to take place on May 15, but the tanker aircraft needed to refuel the F-35Bs on the flight cross-country was not available, due to maintenance, sliding the ferry date one day to the right. All eight aircraft were Fully Mission Capable (FMC) in the end-of-day maintenance status reported in the VMX-22 commander's daily SITREP.

Sunday, May 17 – No Flight Operations

Monday, May 18 – Deployment to the Ship and Carrier Qualifications

The initial six aircraft participating in the deployment demonstration were flown aboard USS *Wasp* during the daytime, from MCAS Beaufort on May 18. These initial aircraft were BF-21, BF-23, BF-24, BF-37, BF-38, and BF-39. Each of the aircraft completed one scheduled mission for the day, which was the fly-aboard/CQ event itself. Six of six missions were completed as scheduled. CQ operations for the six pilots flying these aircraft commenced with their first VL onboard the ship. Four of the six pilots completed two VLs and one STO as part of

CQ. The other two pilots shut down their aircraft after initially coming aboard and logged a single VL each and no STOs. Hours flown for the day totaled 8.5 against 9.0 planned in the flight schedule.

On initial landing, BF-37 lost a "turkey feather" retaining pin for the engine, rendering it Not Mission Capable pending corrective Maintenance action (NMCM). The rest of the aircraft were FMC.

Tuesday, May 19 – Day Carrier Qualifications

Day CQ missions continued on Tuesday, May 19. In the morning maintenance meeting, the status of BF-37 remained NMCM, for a lift fan vibration Health Reporting Code (HRC). The remaining five aircraft began the day FMC. A total of four daytime missions were planned on the flight schedule, all of them single-aircraft CQ flights planned for one hour each. The four pilots scheduled for these events were the four who had walked aboard the ship, allowing them to begin their CQ training. The first two missions completed as scheduled. During the first mission, the pilot completed four STOs and four VLs in BF-23 and during the second mission, the pilot completed five STOs and five VLs in BF-24. Missions 3 and 4 terminated early due to the presence of lighting nearby and the flight restriction currently in place, which prevents the F-35 from being operated within 25 nautical miles (NM) of lightning. The pilot for mission 3, in BF-38, completed a single STO and VL before having to shut down. The pilot for mission 4, in BF-21, completed two of each. At the completion of the day's flight operations, two pilots had completed daytime CQ. Hours flown for the day totaled 2.9 against 4.0 planned in the flight schedule. After completion of flight operations for the day, all aircraft were FMC, with the exception of BF-37, which was NMC and required parts not available on the ship and a high-RPM, low thrust ground engine run to resolve the lift fan vibration HRC and an Engine Operating Time (EOT) based scheduled inspection. VMX-22 scheduled a parts pick-up flight for the following day via MV-22, to Naval Air Station (NAS) Norfolk, Virginia.

Wednesday, May 20 – Day and Night Carrier Qualifications

A total of four daytime CQ missions of one-hour duration each and two nighttime CQ missions of 1.5-hour duration each were planned on the flight schedule. A distinguished visitor event was hosted in conjunction with the daytime flight operations, with the distinguished visitors flown onboard and returned to the beach via MV-22. The status of BF-37 at the beginning of the day remained NMCM for a lift fan vibration HRC and awaiting a voltage regulator. The part was ordered from Lockheed Martin (LM) in Fort Worth, Texas, first thing in the morning for same day delivery to NAS Norfolk for an evening pick-up via MV-22. The remaining five aircraft began the day FMC.

All four daytime events completed as scheduled, as did one of the nighttime events. The second night event was cancelled. The pilot for mission 1, in BF-21, completed three STOs and three VLs; the pilot for mission 2, in BF-23, completed two of each; the pilot for mission 3, in BF-39, completed three of each; and the pilot in mission 4, in BF-38, completed two of each. The pilot in mission 5, the second flight of the day for BF-23, completed two daytime STOs and VLs and three of each at nighttime. At the completion of the day's flight operations, four additional pilots had completed daytime CQ and one had completed nighttime CQ. Hours flown for the day totaled 4.3 against 7.0 planned in the flight schedule.

Three of six aircraft were down for maintenance at the end of the day, including BF-21 for a fuel issue that maintenance isolated to a bad fuel boost pump.

Thursday, May 21 – Day and Night Carrier Qualifications

A total of three daytime CQ missions of one-hour duration and two nighttime CQ missions of 1.5-hour duration were planned on the flight schedule. Three of the six aircraft were NMC at the beginning of the day.

Mission 1 was cancelled for reasons not specified in the daily SITREP. The pilot for mission 2, in BF-23, completed three STOs and three VLs; the pilot for mission 3, in BF-39, completed two each. The nighttime missions, 4 and 5, were cancelled due to weather associated with a frontal passage, and associated potential for lightning. At the completion of the day's flight operations, two additional pilots had completed daytime CQ. Hours flown for the day totaled 1.0 against 6.0 planned in the flight schedule.

Four of six aircraft were NMC at the end of the day and one was partially mission capable (PMC). BF-21, BF-37, and BF-38 were Not Mission Capable for Supply (NMCS), and BF-39 was Partially Mission Capable for Supply (PMCS), awaiting parts from the shore. BF-24 was NMCM for a fuel system problem. A parts run to NAS Norfolk was scheduled for May 22 to obtain the parts for BF-21, BF-37, BF-38, and BF-39.

Friday, May 22 – Day and Night Carrier Qualifications and Other Missions

One CQ mission of one-hour duration, one familiarization flight mission of 1.3-hour duration, and a Functional Check Flight (FCF) mission of 1.3-hour duration were scheduled for daytime operations. Two CQ missions of 1.5-hour duration were scheduled for nighttime. The schedule could be met with two available aircraft, as four of the six aircraft were down for maintenance at the beginning of the day.

The pilot for mission 1, in BF-39, completed four daytime STOs and four daytime VLs; the pilot for missions 2 and 3, in BF-23, completed a total of three each over the course of those two events, hot-refueling in between events. The pilot for mission 4 completed one daytime STO, three nighttime STOs, and four nighttime VLs. The pilot for mission 5 completed one daytime STO/VL combination and another at night. At the completion of the day's flight operations, one additional pilot had completed daytime CQ and one additional pilot had completed nighttime CQ. Hours flown for the day totaled 4.6 against 6.6 planned in the flight schedule.

Four of six aircraft remained down at the end of the day and BF-39 remained partially mission capable. The detachment received a fuel boost pump for BF-21 but it was damaged, either in or before shipping. Maintenance re-ordered the boost pump, with the supply system scheduled to deliver three on May 23 via MV-22 in a special arrangement to assure at least one undamaged pump was in the delivery. Due to the complexity of the repairs for BF-21, it was expected to remain down until May 25. Detachment leadership determined that simultaneously attempting to fix the fuel system problem with BF-24 onboard the ship would delay both BF-21 and BF-24's return to flight status, overburden the maintainers responsible for fuel system maintenance, that the detachment only needed to repair one to demonstrate fuel cell maintenance at sea, and that BF-24 was likely capable of a one-time flight. The detachment therefore submitted an action request for a one-time flight to MCAS Beaufort to swap BF-24 for another aircraft.

Saturday, May 23 – Tactical Proficiency Training

Four two-aircraft, daytime missions were scheduled, each scheduled for 1-versus-1 tactical intercept training, with a duration of 1.3 hours for each. Missions 1 and 2, each comprising two flights, were scheduled so that the same pilots and aircraft would accomplish both missions, with hot refueling in between. Missions 3 and 4 were scheduled the same way, and enough time was allotted between the end of mission 2 and the launch of mission 3 to shut down and refuel the aircraft. Aircraft BF-21, BF-24, BF-37, and BF-38 were all down for maintenance at the beginning of the day.

The four missions (eight flights) could have been accomplished with the two available aircraft. However, only BF-23 was able to get airborne on flight 1-2. Once completed, it was hot refueled and accomplished flight 2-2. The pilot logged a total of four STOs and four VLs over the two flights, but both were flown as single ship missions despite being planned as two ship missions. Missions 3 and 4 were cancelled by the VMX-22 commander to allow maintenance more time to complete aircraft repairs and the maintenance demonstration evolutions that had been planned for the deployment. At the completion of the day's flight operations, the last of 10 pilots had completed daytime CQ. Hours flown for the day totaled 2.5 against 10.4 planned in the flight schedule.

Three of six aircraft were down at the end of the day, BF-21 for ongoing work to replace a fuel boost pump and BF-39 for a new issue, a lift fan Full Authority Digital Engine Control (FADEC) sensor HRC. BF-24, although listed as PMCS on the daily SITREP, was authorized via action request for a one-time flight to shore, so it was NMC for shipborne operations. An additional parts run to the shore was scheduled for the following day.

Sunday, May 24 – Tactical Proficiency Training and Ferry Flights

Eight daytime missions comprising 12 flights were scheduled. Mission 1 was planned as a two-ship intended to launch in conjunction with a single aircraft in mission 2. The aircraft in mission 2 was to act the part of adversary ("Red air") for the mission 1 aircraft in a 2-versus-1 tactical intercept and Air Combat Maneuvering (ACM) training. Planned flight duration for both events was 1.3 hours for all three flights. All three aircraft were planned to return to the ship, hot refuel, and launch again to fly mission events 3 and 4 in the same manner, again for 1.3 hours. After missions 3 and 4 had recovered, shut down, and refueled, this tempo was scheduled to repeat for mission 5 (two-aircraft) and mission 6 (single aircraft), with different pilots. Missions 5 and 6 were scheduled to fly the same missions for the same 1.3-hour durations as the earlier ones, then launch again after hot refueling to do the profile one more time on missions 7 (two-aircraft) and 8 (single-aircraft). The 8 missions (12 flights) were scheduled to be completed with the 3 aircraft available, as two were down for maintenance and one was awaiting for a one-time flight to MCAS Beaufort.

For the first launch of the day, BF-37 was unable to get airborne in flight 1-1, so BF-23 and BF-38 trained 1-versus-1 during missions 1 and 2 instead of training 2-versus-1. BF-37 was able to join them for the second launch, however, and missions 3 and 4 completed 2-versus-1 training as planned. On the third launch cycle, for missions 5 and 6, BF-37 experienced a landing gear malfunction after take-off and made an emergency divert to MCAS Cherry Point, North Carolina, escorted by BF-38. The third aircraft, BF-23, did not launch, presumably because of the problems with BF-37 that precluded completion of the planned training mission.

BF-37 made a safe landing at Cherry Point, but was down on arrival and was unable to make mission 7 and return to the ship. BF-38, which had also landed at Cherry Point, refueled and returned to the ship, but did not complete the scheduled mission 8, a training mission. BF-21 launched as a solo aircraft on mission 7, which in effect became a familiarization training flight, since there were no other aircraft with which to conduct tactical intercept training. Hours flown for the day totaled 11.5 against 15.6 planned in the flight schedule, including the divert and return flights.

Four of six aircraft were NMCM at the end of the day. Again, BF-24, although listed as PMCS on the daily SITREP, was authorized via action request only for a one-time flight to MCAS Beaufort, at this point scheduled to occur on May 26. BF-23 was FMC and BF-21, BF-38, and BF-39 had been repaired and were anticipated to be up for flight operations the following day. Parts ordered from LM for fixing BF-37 were arranged to be sent directly to a LM representative onsite at Cherry Point, assisting with the repairs.

Monday, May 25 – Tactical Proficiency Training

As on May 23, four two-aircraft, daytime missions were scheduled, each for 1-versus-1 tactical intercept training and 1.3 hours of duration. Missions 1 and 2 were scheduled such that the aircraft and pilots would remain the same for both, with hot refueling between events. Missions 3 and 4 were scheduled in the same manner, and enough time was allotted between the end of mission 2 and the launch of mission event 3 to shut down and refuel the aircraft and have different pilots for missions 3 and 4. The four missions (eight flights) were completed using the two available aircraft, BF-21 and BF-23. Hours flown for the day totaled 10.0 against 10.4 planned in the flight schedule.

Three aircraft were FMC at the end of the day. BF-37 remained down at Cherry Point, troubleshooting proximity switches on both main landing gear doors. Repairs on BF-39 had been completed but the aircraft required a high RPM, low thrust maintenance turn prior to flight. BF-24, still listed as PMCS on the daily SITREP, was authorized via action request only for a one-time flight to MCAS Beaufort, scheduled to take place the following day. H-60 support was used to fly a Portable Maintenance Aid (PMA) and Portable Memory Device (PMD) from *Wasp* to the maintenance detachment at MCAS Cherry Point for use in the maintenance actions on BF-37. Note that the use of helicopter and MV-22 aircraft to fly maintenance equipment from ship to shore to support the maintenance of divert aircraft will not always be available in a timely manner during real-world operational deployments, in particular when the ship is operating at distances from shore that are beyond the range of one or more of the support aircraft types.

Tuesday, May 26 – Press Day CQ Demonstrations and Tactical Proficiency Training

A total of 10 daytime missions were scheduled for May 26, a designated press day during which members of several different press organizations came aboard to witness and report on the deployment demonstration. Although all 10 pilots had completed their daytime CQ requirements, 3 of the first 4 missions were written into the schedule as CQ flights, and the fourth was scheduled as a single-aircraft familiarization mission, each of which executed a large number of take-offs and landings for the press.

A ferry mission was scheduled to take BF-24 to MCAS Beaufort and another ferry mission was scheduled to bring a replacement aircraft, BF-42, back to the *Wasp*. A third ferry mission to bring BF-37 back to the *Wasp* from MCAS Cherry Point was also completed.

Four additional tactical missions were scheduled for later in the afternoon, after the press corps had departed. The fifth mission on the flight schedule was a two-aircraft mission intended to launch in conjunction with a single aircraft on the sixth mission.[2] The two aircraft in the fifth mission were to play the role of air interdiction aircraft attempting to employ laser-guided bombs on USS *Wasp*. The aircraft on the sixth mission was to play a Defensive Counter-Air (DCA) role in defense of the *Wasp*. This DCA aircraft was to work in coordination with the ship's tactical air intercept controllers and weapons systems operators to simulate defense-in-depth tactics, in which it and the ship's weapons systems each accomplished pre-briefed, assigned defensive tactics in a coordinated and de-conflicted manner. The aircraft and pilots for the fifth and sixth missions were scheduled to return to the ship, hot refuel, and launch again to fly the same scenario a second time, in the seventh and eighth missions.

The sequence and timing of the flight schedule was such that all missions, exclusive of the ferry flights, were capable of being accomplished with the three available aircraft. For the first four missions dedicated to the press visit, one of the three required aircraft was unavailable, resulting in the cancellation of one mission. The remaining three of the first four missions went as scheduled, completing a total of 10 STOs and VLs during the press day period.

For the tactical missions in the afternoon, only one of the two aircraft scheduled to play the air interdiction role for the fifth and seventh missions got airborne. The scenario for the first mission – encompassing the fifth and sixth scheduled flights – was therefore flown with a single air interdiction aircraft versus the DCA aircraft and the ship's air defenses, but was nonetheless considered by the ship's Combat Information Center (CIC) team to be valuable training for them. Although the same two aircraft launched on the seventh and eighth missions, the defense-in-

---

2 Note: The event numbering notation used on the flight schedule for May 26 differs from that used on previous days. Rather that denote the aircraft in the fifth through eighth missions as 5-1/5-2, 6-1, 7-1/7-2, and 8-1 as had been done for a similar schedule for May 24, the aircraft for the fifth mission were denoted 5-1/5-2 and the aircraft for the sixth mission as 5-3, and the 5-1, 5-2, and 5-3 designations were repeated for the seventh and eighth missions.

depth training scenario with the ship was not repeated. This may have been due to other commitments on the part of CIC personnel involved or for some other reason.

At the end of the day, 7 of 10 missions, excluding the ferry flights, were completed using BF-21, BF-23, and BF-38, which logged a total of 14 STOs, 14 VLs, and 7.6 flight hours. The three ferry flights, taken together, added another 3 STOs, 3 VLs, and 3.6 hours for total for the day of 11.2 hours against 14.3 planned in the flight schedule.

Three of six aircraft were NMCM at the end of the day. BF-42, the aircraft that had been brought onboard this day to replace the departing BF-24, was Partially Mission Capable for Maintenance (PMCM) for an Electronic Warfare (EW) system failure. BF-23 and BF-39 were FMC.

Wednesday, May 27 – Tactical Proficiency Training

For the first time during the deployment demonstration, missions were scheduled around the launch of divisions of four aircraft. The first mission event scheduled a launch of four aircraft to perform a 2-versus-2 training mission in which two aircraft were to conduct anti-surface warfare air interdiction against the *Wasp*, with the other two conducting DCA defending the ship. The aircraft and pilots for the first mission were scheduled to return to the ship, hot refuel, and launch again to fly the same scenario a second time, in the second mission.

The third scheduled mission was to be a two-aircraft Surface Search Contact (SSC) mission in which the aircraft were to perform reconnaissance on ships of opportunity in the vicinity of the *Wasp*. The fourth and last mission was scheduled as a two-aircraft launch to conduct 1-versus-1 tactical intercept training against each other. The aircraft and pilots for the third mission were scheduled to return to the ship, hot refuel, and launch again to fly the fourth mission. A total of four available aircraft were required to complete the first two missions and two were required to complete the last two missions.

The first and second division missions were accomplished using aircraft BF-23, BF-38, BF-39, and BF-42. This marked a major milestone for the deployment demonstration, being the first time since May 19, the second day of flying during the deployment that four different aircraft had flown on the same day in scheduled training events.[3] In the course of the second division recovery, the pilots demonstrated the ability to land the division in rapid succession. The division had an assigned "Charlie" time, the time at which the first aircraft in the division was scheduled to touch down, of 12:00. The four landings were accomplished at 12:00:03, 12:01:19, 12:02:28, and 12:03:35.

Only a single aircraft, BF-38, flew in the other two missions, so each of these planned two-aircraft missions became a single-aircraft mission. Hours flown for the day totaled 12.4 against 15.6 planned in the flight schedule, with 10 of 12 scheduled flights completed.

[3] Six different aircraft had flown on May 26, but three of those aircraft had participated only in ferry flights, including the swap of BF-42 to replace BF-24 and the ferry flight to return BF-37 from MCAS Cherry Point, where it had diverted on May 24 for the landing gear problem previously noted.

BF-21 was down after the morning's division events for a problem with its Three-Bearing Swivel Nozzle (3BSN) and BF-39 appears to have gone down for a hydraulic actuator unit, a replacement for which was delivered to the *Wasp* at some point later in the day, by an MV-22. BF-37 and BF-42 annunciated lift fan vibration HRCs, either in-flight or on post-landing inspection; HRCs that were eventually determined to be non-actionable.

Thursday, May 28 – Maintenance Day: No Flights Scheduled

To ensure adequate time to prepare all aircraft for their scheduled departure from USS *Wasp* the following day, no flight operations were scheduled for May 28. During the day, an H-60 helicopter delivered a gasket and sensor from NAS Norfolk for the repair of BF-21.

Friday, May 29 – Redeployment to Shore

All six aircraft flew safely from USS *Wasp* to MCAS Beaufort, marking the completion of shipboard F-35B flight operations as part of the deployment demonstration.

ANNEX C – Flight Operations Observations

Pilot Briefing and Debriefing

Landing Signal Officer (LSO) pre-flight briefs were running longer than standard throughout most of the deployment. This is considered to have been an artifact of this being the first experience with shipboard operations for most of the pilots. The briefing sequence and timing to launch used for most of the deployment worked well. The sequence included 15 minutes for the administrative brief and 1 hour for the tactical brief, walking from the tactical brief to preflight the aircraft 1 hour prior to launch.

The long download times for the Portable Memory Device (PMDs) delayed debriefs by as much as a day. PMD download times were 1:1 (one hour download time per hour of recording) for the Multi-Function Displays (MFDs) in the cockpit and 4:1 for the Helmet-Mounted Display (HMD). For a back-to-back mission with two one-hour sorties flown before shutting down, conducting hot refueling in between, this means eight hours of download time for the HMD video. PMD download delays can also have tactical impacts, since the download delays reduce the ability to get timely intelligence collected during a flight to the intelligence analysts and mission planners.

Launch and Recovery Cycle Times and Basic Ship Operations

The pilots considered the 1+15 (i.e., 1 hour 15 minutes) flight deck launch and recovery cycle time used for most of the deployment other than the Carrier Qualification (CQ) missions to work well for F-35B missions without afterburner use. They recommend the incorporation of 0+45 to 1+00 cycle times at least once a day for running more dynamic missions. Cycle times of 1+30 or greater meant launching below fuel ladder state (the minimum fuel level required to be able to remain airborne until the next scheduled recovery time, without airborne refueling) and are not recommended. Thirty minutes on deck was judged to be the perfect time allowance for hot refueling. In general, events were launching on time throughout the deployment. Near the end of the deployment, on May 27 – the first time a division mission was conducted – the detachment managed to recover the entire division in less than five minutes, all to the same landing spot, Spot 7.

The F-35 LSOs found themselves having to advise the Air Boss on maneuvering the ship to best support F-35B flight operations. The workload associated with this additional tasking over-burdened the LSOs. Similarly, the pilots thought the workload of the Operations Duty Officer (ODO), a squadron pilot who remains in the aircrew ready room during flight operations, manning the phone and serving as the duty operations supervisor, argued for an assistant to be in the control tower with the LSO during flight operations. The use of such an assistant is standard practice in fixed-wing carrier aviation. In addition to providing assistance as needed to the LSO and ODO, they stand by to provide assistance to pilots over the radio in the event of an emergency or other out of the ordinary situations.

Mission Systems Issues and Comments

The pilots noted there was no HAVE QUICK (frequency-hopping Very High Frequency (VHF)/Ultra-High Frequency (UHF) voice radio jam-resistant capability) or KY-58 (encrypted voice radio capability) available from *Wasp* for the entire duration of the deployment. HAVE QUICK and KY-58 communications from aircraft-to-aircraft between the F-35Bs were generally good.

In one or two instances, jets were able to get Link-16 J-Voice (voice radio communications via Link-16) from the ship. Other times they were able to hear that a transmission had been keyed, but with no modulation (no successful voice transmissions). The F-35Bs were sometimes, but not always, successful in establishing J-Voice communications with each other. The pilots were not writing maintenance work orders against this problem, so no attempts were made at troubleshooting it by maintenance.

The Link-16 Precise Participant Location and Identification (PPLI) symbol for the ship showed up on the F-35B cockpits displays as a ground radar symbol instead of the ⊕ symbol that should have been displayed.

One of the pilots said that the radar was "impressive" and that in general the radars did well over the course of the detachment. This positive subjective assessment of radar performance was echoed many times by several different pilots during the detachment. They noted that some jets had known minor, unpredictable problems in the radar and the Electro-Optical Targeting System (EOTS), but that maintenance made no attempt to fix these during this detachment.[4] Also, the radars in some of the Block 2B aircraft did not have Sea Surface Search (SSS) mode enabled, so the overall performance of this mode is not known. Multiple pilots also expressed strongly favorable opinions of EOTS Targeting Forward-Looking Infrared (TFLIR) performance, in informal discussions with test team observers. One of them described the ranges at which he could recognize *Wasp* as first, a large ship, next an aircraft carrier, and finally as being of the *Wasp* class.

For the Block 2B aircraft, the pilots reported that there was some sensor fusion "ghosting," referring to false tracks, but that the EW systems performed well. Recorded cockpit display video showed successful transitioning, at long range, from a ranged EW track to an EOTS TFLIR track to laser target designations on points on the superstructure of the ship. It should be noted, however, that the electronic signals environment in which the deployment was conducted was that of routine civilian air and maritime traffic in a peacetime navigation and air traffic control environment. This signals environment was benign and much less challenging, with respect to EW system performance, than the hostile and more complex signals environments expected in many combat scenarios.

Note: The F-35 has two passive EW systems for detecting, identifying, and locating surface and airborne radar signals. One of them, referred to as the Band 3/4 EW system, detects signals over a wide frequency range and over a 360-degree azimuth field-of-regard around the

---

4 The EOTS is a mid-wave infrared sensor combining long-range, air-to-air, infrared search and track (IRST) functions and air-to-air and air-to-surface forward-looking infrared (FLIR) surveillance and targeting functions.

aircraft, using antennas embedded in the leading and trailing edges of the wings. The other, referred to as the High Gain Electronic Support Measures (HGESM) system, uses the radar array as a passive receive antenna to detect signals over a frequency range just over a third of that of the Band 3/4 EW system and limited to the field of regard of the radar, but with orders of magnitude greater sensitivity. It was not necessarily evident to the pilots whether a detection of a surface or airborne radar signal was made by the Band 3/4 EW system or by HGESM so it is not possible at this time to positively attribute the pilots' favorable impressions of EW system performance to one or the other, or to both.

Tactical Integration with WASP

On at least one occasion no PPLIs were exchanged between the F-35s and *Wasp* Combat Information Center (CIC) because *Wasp's* Link-16 was temporarily inoperable. Although PPLI was available most of the time, the pilots reported that *Wasp* was never able to send or receive Link-16 target tracks to or from the F-35Bs, the only exchange was of PPLI. The *Wasp* combat systems software apparently lacked a necessary F-35B module, which they expected to get with a future software upgrade at a date to be determined.

Operations Administration Issues

For this deployment demonstration detachment, the squadron could have benefited from one more operations officer on the Advance echelon party (ADVON) and one more scheduler throughout the detachment.

There is only one operations planning space that is roughly 15 feet by 15 feet for the entire Air Combat Element (ACE), which the F-35B pilots will have to share with all the MV-22 and helicopter crews. This is anticipated to be very busy and crowded. The squadron needed, but did not have, dry-erase boards in all operations spaces. The additional operations planning tasks associated with the F-35B, over and above those associated with the AV-8B, may put additional strain on the limitations of the operations planning space.

Squadron operations personnel recommend having an automated interface between the Autonomic Logistic Information System (ALIS) and the Marine "Sierra Hotel" Aviation Reporting Program (MSHARP) system. The F-35 program is contractually obligated to use the LM Training Management System (TMS) for the functions done elsewhere in Marine Corps aviation with MSHARP. The Marines on this detachment were manually entering (dual-logging) the flight records data in MSHARP. The process for making the flight schedule involved making it first on a deployable MSHARP laptop that they had brought with them, then operations personnel worked with Maintenance Administration to make sure the flight hours were reconciled with ALIS. Finally, they reconstructed the information in TMS.

This page intentionally left blank.

ANNEX D - Suitability Observations

Deployment

The Marine Corps relocated six F-35B aircraft to the USS *Wasp* (LHD-1), plus all necessary personnel, support equipment (SE), spare parts, and data for 11 days of shipboard operations. This movement included data transfers between Autonomic Logistic Information System (ALIS) Squadron Operating Units (SOUs), and physical movements of people, spare parts, SE, and aircraft. The aircraft initially deployed were four 2B-configured aircraft from MCAS Yuma (BF-21, BF-23, BF-24, and BF-37) and two 3i-configured from MCAS Beaufort (BF-38 and BF-39), out of a pool of 10 aircraft that received modifications for shipboard use. Approximately 220 military and contractor personnel supported the deployment, primarily from VMFA-121, an operational command at Yuma; personnel from VMFAT-501, a training command at Beaufort, and VMX-22, an operational test command with an F-35B detachment at Edwards Air Force Base, California, also participated. This includes contractors required for daily flight operations, personnel with subject matter expertise for specific shipboard suitability demonstrations (e.g., radar gun testing), and observers from the Joint Strike Fighter (JSF) Operational Test Team (JOTT) and DOT&E. The military contingent assigned to the detachment from the three squadrons was approximately 140 Marines. Spare parts and support equipment came from these three bases, as well as from multiple additional contractor sites. This was a much more complex deployment of a composite unit, with more external support, than would be operationally representative.

Several issues arose with the transfer between ALIS SOUs of aircraft, SE, and spares data.

- Unplanned workarounds were needed to successfully transfer aircraft data files between home station and the deployed SOU on *Wasp* to meet mission timelines. Aircraft transfer began Saturday, May 9 and needed to be completed, and data verified for accuracy, before May 11 so that flight operations could continue at the home stations. The deployment plan was for maintenance personnel at Yuma and Beaufort to access aircraft data files via Virtual Private Network (VPN) to the SOU deployed to the *Wasp* once data files were verified, to continue flight operations at the home station with the aircraft being prepared for the deployment. The ALIS Concept of Operations for data transfer is to move items between SOUs via the central Autonomic Logistics Operating Unit (ALOU), the core node of the logistics information system which is managed, operated, and maintained by Lockheed Martin (LM); however, this capability was not available at the time of transfer. The detachment first attempted moving the aircraft data via a proprietary LM server, and then via the U.S. Army's Aviation and Missile Research Development and Engineering Center's (AMRDEC) file transfer server. The download speeds over the ship's Consolidated Afloat Networks and Enterprise Services (CANES) network from both of these servers was extremely slow and would not have allowed flight operations at the home units to continue, requiring the ALIS transfer team to find an alternative method of getting the 400 to 800 Megabyte aircraft data files onboard the

Wasp. To complete the data transfer, the ALIS transfer team on the ship proceeded off base and used commercial Wi-Fi access to download the aircraft files, burned them to CDs, and then manually uploaded the data into the *Wasp* SOU, accomplishing the transfer within the needed timelines.

- Following the transfer, the ALIS team discovered numerous errors with the aircraft data once loaded on the *Wasp* SOU. These errors included inconsistencies between home station and deployed files, missing files, and missing part requisitions for the aircraft being transferred (i.e., the parts which were "on order" in the home station ALIS files were "dropped" during the transfer) . LM Data Base Administrators (DBAs) from Orlando, Florida, and Fort Worth, Texas, were able to resolve many discrepancies online by the May 11 deadline to enable flying to resume, but some issues were still in work as late as May 13. Some of the data transferred for SE and spare parts were lost or corrupted as well. In several cases, missing or corrupted data were not discovered until the detachment went to use the SE or install the spare part while at sea. In these instances, the detachment again relied on reach back to LM DBAs in Orlando via satellite communications to remotely fix these problems, a workaround which may not be practical during some combat operations.
- Maintenance personnel at MCAS Beaufort and MCAS Yuma accessing the *Wasp* SOU via VPN experienced major delays. In one instance, for example, it took four and a half hours to sign off on six work orders for an aircraft at Beaufort via the VPN, a process that normally takes around 45 minutes when done on the local SOU. Whether these delays were associated with data transfer rates over the VPN connection or internal ALIS processing is still under investigation; however, remote access to the SOU onboard, if necessary, may be slower than ship-borne only operations during a deployment.
- ALIS administrators found ALIS cumbersome and inflexible when they needed to make last minute changes to the list of specific items they would transfer to the ship.

Sites moving physical equipment and parts to the ship generally sequestered all gear about a month before the start of a deployment to the *Wasp* to ensure it was on hand and serviceable. These sites shipped the gear to arrive pier side to the *Wasp* about a week before the start of the deployment to allow enough time for a successful on-load.

Aircraft Availability and Utilization Rate, Mission Capable Rate, and Component Reliability

The deployment demonstration provided an opportunity for the Marine Corps to learn how the aircraft integrated with the ship. The Marine Corps did not intend to generate maximum aircraft utilization. The following are informational observations of aircraft utilization, availability, and some component reliability performance demonstrated during the deployment.

- The daily flight schedules during the shipboard deployment period were written to accommodate the anticipated aircraft availability each day, as is standard practice in any squadron. Although the aircraft availability cannot be predicted, a comparison can be made to a notional air plan that was developed during a pre-deployment planning conference in March 2015. The figure below shows the day-by-day comparison between the notional number of flights envisioned as of the pre-deployment planning conference; the actual number of flights scheduled each day, which was designed around aircraft availability; and the actual number of flights accomplished. Two flights were cancelled due to lightning within the limits of an existing F-35 operating restriction and two nighttime Carrier Qualification (CQ) events were canceled for weather that was anticipated to be outside acceptable limits for CQ operations. The other 13 flights scheduled but not flown appear to have all been omitted for aircraft availability.

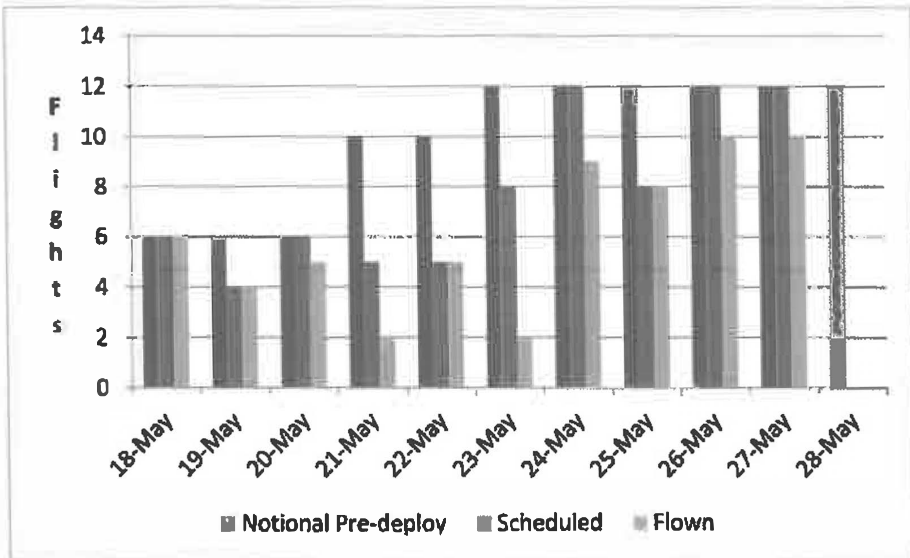

Figure D-1. Daily Flight Activity

- The average utilization rate on a flight basis was less than one flight per aircraft per day, including the ferry flights to the LHD, for the 11 days from May 18 to 28 (including one down day for maintenance to prepare the aircraft for the redeployment). Aircraft utilization was not uniform across aircraft or throughout the time of the deployment. Initial plans were for the number of flights to increase as the deployment progressed; however, flight schedules had to be adjusted daily based on anticipated aircraft availability. The highest utilization rate occurred on May 26 and 27 (days 9 and 10 the deployment underway at sea), at nearly 1.67 flights per aircraft assigned per day.
- The average utilization rate on a flight hour basis was about one hour per aircraft per day. This was a slight decrease compared to shore utilization for VMFA-121, the operational unit at MCAS Yuma, which achieved about 1.3 flight hours per aircraft per day in April 2015, the month before the deployment. However, it was an increase compared to shore utilization for VMFAT-501, the training unit at MCAS Beaufort, which was around half an hour per aircraft per day in April 2015.

- The number of flight hours flown by each aircraft varied widely, with some aircraft in a down status for up to five days in a row, and other aircraft rarely requiring major maintenance. BF-23 performed best, accumulating roughly 23 flight hours over 20 flights, and was the only aircraft to be scheduled and flown every day while underway. Of the remaining four aircraft that completed the entire deployment, BF-37 flew the least, with approximately five hours and four flights, including the fly-on from MCAS Beaufort and a ferry flight to return from MCAS Cherry Point after diverting there. Due to multiple maintenance issues, BF-37 did not fly from May 19 through May 23, flew on May 24, but emergency diverted to MCAS Cherry Point, and then returned to the ship on May 26. It did not fly on May 27 for a maintenance issue, and only flew again on May 29 to ferry off the ship. The figure below shows the flights flown and flight hours accumulated for each of the aircraft that participated in the deployment.

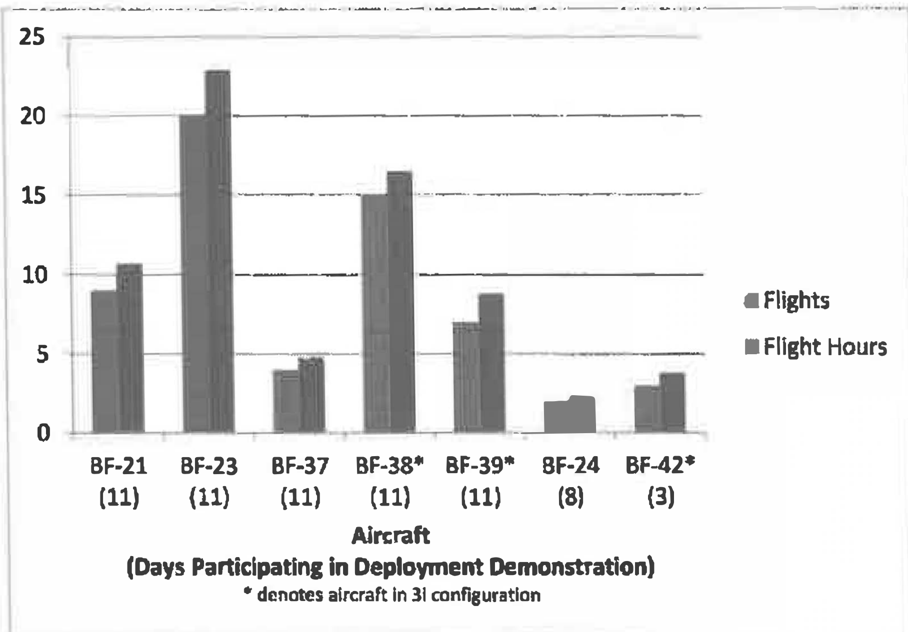

Figure D-2. Aircraft Flights and Flight Hours

- The deployed aircraft were mission capable for flight operations on the LHD approximately 55 percent of the time, based on the maintenance status section from the daily Situation Reports (SITREPs) sent out by VMX-22 during the deployment. These daily SITREPs included each aircraft status at the end of the flying day. With 6 aircraft onboard, there were 66 opportunities to report an aircraft up or down over the 11 day period, including one "no fly" day dedicated to maintenance to prepare the aircraft for redeployment. The reports showed 36 mission capable aircraft at the end of the day over the period and 30 not capable, which included three reports for an aircraft to complete a one-time flight off of the ship to home base. These numbers equate to 55 percent capable and 45 percent not capable. Because aircraft were considered FMC or PMC but capable of participating in flight operations as long as they were safe-for-flight, no flight events were canceled due to lack of availability of combat mission systems. No quantitative data are available from the deployment on the availability of the combat mission systems, so no conclusions can be drawn, either way, as to the impact missions system availability would have had on the deployment's mission completion rate if any of these systems had been a go/no-go criterion for flying a mission. The following table shows aircraft status at the end of each day for all aircraft that participated in the detachment. For comparison, availability rates of approximately 80 percent would be needed to support four-ship combat operations with a standard six-ship F-35B detachment.

Table D-1. Aircraft Daily Maintenance Status at End of Day

Date	BF-21	BF-23	BF-24	BF-37	BF-38	BF-39	BF-42
May 18	FMC	FMC	FMC	NMCM Engine Nozzle	FMC	FMC	Not Deployed
May 19	FMC	FMC	FMC	NMCM Engine	FMC	FMC	Not Deployed
May 20	NMCM Fuel Issue	FMC	NMCM Fuel Issue	NMCM Electrical Power System	FMC	FMC	Not Deployed
May 21	NMCS Fuel Issue	FMC	NMCM Fuel Issue	NMCS ICC #1 Failure	NMCS	PMCS	Not Deployed
May 22	NMCS Fuel Issue	FMC	NMCM Fuel Issue	NMCS ICC #1 Failure	NMCS Landing Gear Issue	PMCS	Not Deployed
May 23	NMCS Fuel Issue	FMC	NMC One time flight	FMC	FMC	NMCM Lift Fan	Not Deployed
May 24	NMCS Fuel Issue	FMC	NMC One time flight	NMCM Landing Gear – Ashore Cherry Point	NMCM Engine Borescope Required	NMCM Lift Fan FADEC HRC	Not Deployed

Date	BF-21	BF-23	BF-24	BF-37	BF-38	BF-39	BF-42
May 25	FMC	FMC	NMC One time flight	NMCM Landing Gear – Ashore Cherry Point	FMC	NMCM Ice Detection Sensor	Not Deployed
May 26	NMCM Lift Fan Vibe & 3BSN leak	FMC	Not Deployed	NMCM Lift Fan Vibe HRC	NMCM Lift Fan Filter R/R	FMC	PMCM EW Fail
May 27	NMCM 3BSN leak	FMC	Not Deployed	FMC	FMC	NMCM Hydraulic Control Unit	PMCM EW Fail
May 28	FMC	FMC	Not Deployed	FMC	FMC	NMCM Hydraulic Control Unit	PMCM EW Fail

FMC – Fully Mission Capable; NMCM – Not Mission Capable pending corrective Maintenance action; ICC -- Inverter/Converter/Controller; PMCS – Partially Mission Capable for Supply; FADEC – Full Authority Digital Engine Control; HRC – Health Reporting Code; 3BSN – Three-Bearing Swivel Nozzle; R/R – Removal and Replacement; PMCM – Partially Mission Capable, Maintenance; EW – Electronic Warfare

The Program Office also reported weekly availability rates for the six aircraft embarked onboard USS *Wasp* over a two-week period. For the week ending May 26, availability was reported around 50 percent, and for the week ending June 2, it was slightly below 70 percent.

- Reliability of major fuel system components adversely affected the deployment. The detachment experienced two major fuel system component failures, a fuel boost pump on BF-21, and a high-level float valve on BF-24. Both of these failures require open fuel cell maintenance to remove and replace these components and long down times due to gas-free certification requirements, situations which are particularly burdensome for shipboard operations. When gas-freeing an aircraft in the hangar bay, a large portion of the bay is secured and certain types of maintenance cannot be conducted on other aircraft in the bay as well. BF-21 was repaired at sea, and the detachment demonstrated the ability to conduct fuel cell maintenance on the F-35B in the hangar bay. However, the Marine Corps sent BF-24 ashore to MCAS Beaufort on a one time approved flight and swapped it with BF-42 to continue flight operations with as many mission capable aircraft as possible, and not overly-burden maintenance.
- The main landing gear tires exhibited less wear per take-off and landing cycle at sea under Short Take-off Vertical Landing (STOVL) flight operations than ashore when doing conventional take-offs and landings. The detachment only had to replace one tire due to wear through May 28, after 94 STOs, 6 conventional take-offs (from base of debarkation), and 100 VLs. Comparing to JPO-published reliability data from

January 2014 to June 2014, the F-35B fleets at Eglin and Yuma replaced 256 tires over 1,304 sorties flown predominantly in Conventional Take-Off and Landing (CTOL) mode. Although older data, and newer versions of the F-35B tire have since been introduced, this comparison of data shows strong statistical evidence that tire wear decreases under STOVL operation. Although somewhat intuitive, since the tires are not exposed to extended spans of runway as in conventional operations, the data show that the rough non-skid of the flight deck does not cause excessive wear on the tires when the aircraft maneuver on deck. Sizing of spares packages for at-sea operations should use STOVL-specific tire reliabilities, and future shipboard operational testing should try to derive STOVL-specific reliabilities for more accurate logistics modeling.

Flight Deck and Hangar Bay Operations

The maintenance activity on both the flight deck and in the hangar bay showed the need for unplanned workarounds or additional personnel to complete tasks.

- The detachment could not apply external power to the aircraft on the flight deck, hindering the ability to conduct troubleshooting, maintenance, and efficient servicing. External power enables the most flexibility in refueling of aircraft, for example. Cooling air is required for the F-35B when on external power, but the Combined Generation and Cooling (CGAC) carts brought to provide this were limited to the hangar bay due to Electro-Magnetic Interference (EMI) concerns. The production electrical and air conditioning carts designed for flight deck use were not ready for the detachment. As a result, only battery, Integrated Power Pack (IPP), or engine power could be used on the flight deck, and the detachment eventually relied heavily on use of the IPP for maintenance and operations. This created an extra burden on IPP turn-qualified maintainers, who were in high demand, and complicated routine maintenance since IPP ignition required approval from flight deck control.
- The hangar bay was the only location where external power could be applied, as cooling air – required when external power is applied to the aircraft – could be provided by the CGAC carts there. The F-35B requires an adapter plug between the aircraft and the ship's Aircraft Electrical Servicing System to convert shipboard power to the 270 Volt DC and 28 Volt DC used by the aircraft. The weight of this adapter puts some strain on the aircraft's receptacle. The Marines expressed interest in a mount to relieve or spread out this strain and prevent possible damage in the long run.
- The Maintenance Interface Panel used to control ground re-fueling operations does not include a fuel gauge or any other fuel indication. When maintainers refueled on battery power, they estimated how much fuel had entered the tanks based on time and flow rate, or monitored a fuel read-out on the left cockpit display. However, this display did not turn-on when using battery power on the 3i jets. Maintainers' initial attempts at battery-only refueling sometimes caused them to pump much more fuel into the aircraft than intended. The cockpit fuel status was available on all jets on IPP

power, but provided significantly different fuel status compared to when the engine was brought online. The detachment eventually settled on refueling primarily on engine power at the beginning or end of a flight, extending start-up or shut down timelines. Although an acceptable workaround for this deployment demonstration, the limitations of operating without external power on the flight deck could affect efficient sortie generation and operations tempo under combat conditions.

- The Maintenance Interface Panel cover panel must be open for most maintenance, but the Marines felt it was not strong enough to handle downwash from jets or helicopters. They resorted to using an additional maintainer to manually hold the panel during flight operations. However, the lift fan, weapons bay, and auxiliary air inlet doors could be opened and closed around downwash during flight operations, although there is some concern with downwash possibly blowing Foreign Object Debris into an open door.
- During a VL, the aircraft downwash produces a large amount of sea spray. The weapons bay, lift fan, and Three-Bearing Swivel Nozzle (3BSN) doors are open, and this spray causes salt water ingestion into these compartments. There is currently no scheduled maintenance after an at-sea VL to inspect and clean these compartments, which contain some avionics and weapons stations that could be damaged by repeated sea spray or salt fog exposure.

There is a greater risk of hot exhaust gas impingement on flight deck gear with the F-35B relative to the AV-8B due to higher idle power and greater exhaust volume directed aft from a single nozzle on the F-35B, vice partially vented downward and spread out across four nozzles on the AV-8B. On at least one occasion, F-35B exhaust from a taxiing aircraft dwelled on the flight deck crash and salvage crane for several minutes as the "aft slash" behind the island had not been packed tightly enough to fit all returning aircraft without moving some parked aircraft. Fortunately the exhaust jet was centered on the crane's engine compartment, designed to withstand heat. Directed elsewhere, it could have caused damage. For some engine maintenance turns, the exhaust nozzle will also deflect down several degrees. Flight deck personnel must take care to position the aircraft such that the nozzle will not point down into the deck-edge catwalks.

Maintenance Evolutions

During the deployment demonstration, the Marines conducted a number of planned, staged maintenance evolutions to explore whether they could be safely performed at sea. These evolutions, listed in the table below, were broken down into three categories: major evolutions, ordnance evolutions, and general evolutions, each including some Joint Technical Data (JTD) verification. Although the F-35B flight clearances, which governed operations for the deployment, did not include authorization to carry weapons, the deployment demonstration did provide training opportunities for several ordnance tasks to be conducted on the ship.

Table D-2. Maintenance Evolutions

Major Evolutions	
M1 – Handheld Imaging Tool (HIT)	M5 – Ejection Seat Removal and Installation
M2 – Lift Fan Removal and Installation	M6 – Canopy Removal and Installation
M3 – Engine Removal and Installation	M7 – Integrated Power Pack (IPP) Removal and Installation
M4-1 – Power Module Transfer via MV-22	M8 – Automatic Logistics Information System (ALIS) Contingency
M4-2 – Power Module Demonstration	
Ordnance Evolutions	
W1-1 – Static Manual Weapons Load (Day)	W3 – Launcher and Pylon Storage within USS *Wasp*
W1-2 – Static Manual Weapons Load (Night)	W4 – Countermeasures Build and Storage
W2 – Uncanning Gun Pod	
General Evolutions	
G1 – Low Power Ground Run / Turn	G22 – Aircraft Strobe Light Activation during Maintenance
G2 – High Speed (RPM) / Low Thrust Turn	G23 – Tasks Requiring Ladders/Maintenance Stands
G3 – IPP Turn	G24 – Radio Communications between Flight Deck / Hangar Bay / Maintenance Control
G4 – Crypto Loading	G25 – Fueling on Deck
G5 – Battery Charging	G26 – Defueling Aircraft
G6 – Jack Aircraft (Axle only) on Flight Deck	G27 – Engine Preservation
G7 – Jack Aircraft (full Jack) in Hangar Bay	G28 – Aircraft Launch Actions
G8 – Joint Oil Analysis Program Oil Analysis Sample	G29 – Aircraft Recovery Actions
G9 – Apply Ships Power to Aircraft 270 Volt DC	G30 – Aircraft Wash at Sea
G10 – Aircraft Mooring for Heavy Weather	G31 – Force Curing (Nut Plates)
G11 – Door Manipulation	G32 – Basic LO Restoration
G12 – Oil Debris Quantitative Debris Monitoring (QDM) Testing	G33 – Processing an Action Request at Sea
G13 – Ship's Inertial Navigation System (SINS) Alignment	G34 – Conduct Post-Operations Service/Inter-Operations Service/Before Operations Service
G14 – Move A/C from Flight Deck to Hangar	G35 – Portable Memory Device (PMD) Download
G15 – Change a Tire/Wheel	G36 – PMD Build
G16 – Change Back Up Oxygen Bottle	G37 – Aircraft Memory Device (AMD) Download
G17 – Assessment of support equipment (SE) use Afloat	G38 – AMD Build
G18 – Canopy Maintenance	G39 – Aircraft Pushback with Engine Running

General Evolutions Continued	
G19 – Saltwater Preservation of Canopy	G40 – Maintenance Quick Turnaround
G20 – Float Coat Maintenance and Usage	G41 – Fuel Cell Maintenance
G21 – Aircraft Panel Removal and Stowage	G42 – 20 Ton Wing Jack Load Test

Major Evolutions

The Handheld Imaging Tool (HIT) is a radar gun system that can verify repairs to Low Observable (LO) surfaces by measuring aircraft signature and presenting an image of any Radar Cross Section (RCS) "bright spots" to the gun user. It uses a series of stands arrayed around the aircraft that emit infrared laser energy to align the gun to the aircraft. Any high RCS spots detected can then be exactly located on the aircraft to indicate LO damage, or a repair accurately scanned. It is a replacement concept for the Repair Verification Radar (RVR) that weighs less, takes up less space, and is designed for shipboard use. HIT is quicker, more capable and more user-friendly than the RVR and was used on occasions for demonstration purposes. Analysis of data collected from the tool is ongoing. Although the HIT team wanted to see if the stand array could maintain alignment during high sea states, none were encountered during the deployment.

The lift fan, engine, ejection seat, canopy, and IPP Removal and Installation (R&I) demonstrations were staged explorations where no components were removed or installed. The detachment did not want to conduct non-required maintenance on an aircraft, and potentially cause damage doing so. For each of these demonstrations, all necessary personnel, tools, SE, and ship's facilities, especially the overhead bridge crane, were laid out in the hangar bay. Maintainers read the JTD instructions and simulated most tasks, exploring if the shipboard environment presented an obstacle to completion. In several cases, items of support equipment were built up as would be necessary, but were not actually used. During these evolutions, the F-35 detachment had most of the hangar bay to itself. Other than the Navy H-60 Search and Rescue (SAR) detachment, there were no other aircraft from the Air Combat Element (ACE) or other items from the Marine Expeditionary Unit (MEU) in the hangar bay that would normally be embarked. Although it was a valuable and necessary training opportunity for examining major tasks that had never been accomplished at sea before, this scenario, because it provided abundant open space, was not operationally representative.

The amount of floor space required to stage the lift fan and engine R&I evolutions, as well as the power module demonstration, was substantial. The size and number of the required SE items, such as multiple types of engine trailers, and the size of the spare propulsion parts and their containers, contributed to this large footprint. These items were mostly operationally representative and likely cannot be made much smaller. The required space could have a significant operational impact on MEU and ACE operations when far more aircraft are present in the hangar bay and on the flight deck. Future operational testing should conduct actual, not simulated, engine and lift fan R&I evolutions with an MEU embarked to determine this impact.

For both the lift fan and engine R&I, minor pieces of SE or tools had been left ashore. This would have prevented the detachment from doing these evolutions if needed, without bringing those items in via helicopter. For the ejection seat R&I, the program is still developing adapters to mate the F-35 ejection seat to the legacy Navy seat stand carried on aviation ships, and hence the detachment could not have done this evolution at sea even if it became necessary.

The detachment accomplished a fit check for re-supplying an engine Power Module (PM) at sea via an MV-22. The PM is the heaviest engine module, but represents only a portion of the entire engine and lift-fan system. In its container, it is too heavy for the traditional re-supply methods of sending it across the current wire system from a Combat Logistics Force (CLF) ship to the LHA/LHD during a connected replenishment, or transferring it from the CLF flight deck to the LHA/LHD flight deck externally slung under an H-60 during a vertical replenishment. A demonstration PM was mated to a special adapter and loaded internally to an MV-22 on land, flown out to the USS *Wasp*, and transferred on the flight deck to a "donkey trailer," a common shipboard SE cart. The demonstration PM was taken down to the hangar bay, and with the overhead bridge crane was moved into and out of a storage container, and a maintenance and transportation trailer. The demonstration PM was then loaded back into the MV-22 on the flight deck and returned to land. This was done over several days and composed both portions of the M-4 evolution. Naval Air Systems Command (NAVAIR) instrumented the PM and intends to characterize if the MV-22 transport damaged it. However, the only available asset for the demonstration was an already-damaged PM since fleet demand for spare PMs is high. It will likely not be known if this transportation method is safe until it can be repeated with an instrumented, undamaged PM. This re-supply method is necessary to efficiently support both F-35Bs and F-35Cs at sea, as it should be applicable to CVN operations as well.

The one major evolution not completed involved releasing an aircraft for flight without having the ALIS SOU available. The detachment could not complete this task, as maintenance control could not view the back-up maintenance files from the SOU on the ship's computers to determine aircraft status, which is required to make a "safe for flight" release of the aircraft. Since the SOU was not actually offline, the detachment released the aircraft safe for flight using normal procedures with ALIS online.

Ordnance Evolutions

Ordnance personnel uploaded and downloaded AIM-120, GBU-12, and GBU-32 rounds to the internal weapons bay stations in both day and night conditions. Personnel conducted loading on the flight deck and used manual hoists. They encountered several significant issues.

- The detachment could not conduct release and control checks before loading weapons since there were no JTD procedures to do this on IPP power, and external power was not available. This issue should be mitigated when the production flight deck cooling and power carts are fielded. To load bombs on stations 4 or 8, the launcher is detached from the aircraft station via the hoist, brought down to the weapon, attached, and the assembly is brought back up into the weapons bay and mated back to the station. This breaks the electrical connections between the aircraft station and launcher, and invalidates the release and control checks. As a worst-case scenario, if a release consent pin is bent while re-attaching the launcher the pilot will have no indication until they command a weapon release and the weapon does not drop.

Marines expressed that this is not how they would prefer to load ordnance in a combat situation.

- Storage space and build up areas for the launchers and external pylons, and for the expendable countermeasures, such as chaff and flares, were adequate. However, some of the launcher and pylon data were lost during the ALIS transfer, but not discovered until the ordnance evolutions. LM DBAs in Orlando transferred the missing data to enable the ordnance loading and downloading to commence.
- The gun pod container was not water-tight. It was packed about three weeks prior to being opened onboard USS *Wasp* on May 20, and had standing water on the bottom of the container, plus condensation on electrical and mechanical components. Mold had started to grow on the gun pod, and the barrel ring and some of the barrels themselves were corroded. There were no JTD procedures for unloading the gun pod from its container, so ordnance personnel used an interim procedure instead.

General Evolutions

The general evolutions were maintenance activities that the detachment expected would happen in the normal course of operations, or staged evolutions that did not rise to the threshold of a major evolution. The list was developed by subject matter experts who thought the activity could be significantly different in the at-sea environment and warranted closer examination. Maintainers discovered issues during a number of the evolutions but could not fully explore several of them.

- The detachment did not need to load any crypto on the aircraft due to the short duration of the deployment. All aircraft were provided with needed crypto keys at MCAS Beaufort before arriving on the ship, and none of those keys expired over the following 11 days. At no point did any of the aircraft drop their crypto keys from memory. Since there are different communication paths to deliver crypto keys to vessels at sea compared to main operating bases, future operational testing should demonstrate the end-to-end the ability to receive and load new crypto keys at sea.
- Joint Oil Analysis Program oil samples could be processed to determine if any excess trace metals are present in the engine oil, but LHA/LHD class ships currently lack the facilities to analyze any metallic debris collected on the engine magnetic chip collectors. Maintainers use both regularly scheduled oil samples and checks for metal chips on the magnetic collectors to determine engine wear, and predict impending engine failure. Oil debris analysis is only required when there are more chips present than a threshold. If so, the engine is put into a down status and the chips must be analyzed to determine if the engine needs replacement. Without a facility onboard to analyze an abnormal sample, the sample must be sent ashore. The subject matter expects estimated it would likely take at least 48 hours to receive a response and expressed a preference to be able to conduct oil debris analysis on the ship.
- Although the hangar bay has adequate space for the equipment and operations of a canopy removal and replacement (R&R), there is no explosives-work-approved

compartment on ship suitable for installing the Flexible Linear Shaped Charge (FLSC) that shatters the canopy for a safe ejection. Replacement canopies are shipped without the FLSC installed for safety. The FLSC is laid into the canopy using Room Temperature Vulcanization and requires a 36- to 72-hour cure, during which time it cannot be disturbed. This condition applies to the legacy AV-8B Harrier as well. Should the need for canopy FLSC maintenance at sea arise, and it cannot be deferred to return to shore for operational necessity, ship and squadron personnel will have to devise workarounds to complete the maintenance with the degree of risk and operational impact they are willing to accept.

- The current vehicle system software configuration violates operational light discipline on the flight deck in some maintenance modes. For example, when the IPP is used to provide power for maintenance on the flight deck, the aircraft strobe lights come on for a few minutes during its start-up cycle and cannot be shut off by the maintainers via the Maintenance Vehicle Interface for this period. The strobe lights can give away the ship's position at night, as well as blind maintainers, creating a safety hazard. The IPP start-up cycle begins with power from the 28 Volt DC battery, which turns on systems that enable the 270 Volt DC battery to crank the IPP. Once spooled up, the IPP provides both 28 and 270 Volt DC power. The strobes come on when 28 Volt DC power is applied, and cannot be turned off until the IPP provides 270 Volt DC power. The program must remedy this software issue before deploying to a ship.
- The LO repair demonstration applied a quick curing paste to a dime-sized chip on the edge of an LO tape application. This was a very basic repair and not sufficient to assess a variety of likely LO restorations that may need to occur aboard the ship on a full deployment. There was no requirement to maintain LO configuration for this deployment event. Future operational testing should demonstrate a greater range of LO repairs.
- Personnel took one action, which had not yet been cleared by NAVAIR authorities because of potential safety concerns. On May 25, flight deck personnel pushed back an aircraft with a tow bar while the engine was still running in an unplanned event. Pushing back an aircraft with engines running is not generally prohibited in any Navy manuals, but it is specifically prohibited for the AV-8B. The detachment planned to avoid doing this since it had not been demonstrated in developmental testing, and they were unclear whether it was acceptable. They intended to discuss the possibility of doing it with flight deck directors, but had not done so before it happened. Personnel briefly entered the danger area for the intake to attach the tow bar, although there were no injuries. The program and NAVAIR should review whether this procedure is a safety hazard, and make a clear determination on whether or not it is allowable to inform future at-sea evolutions.
- Engine data are not readily available to maintenance controllers because propulsion is not yet integrated into ALIS. As a result, personnel could not accomplish

maintenance quick turns during the detachment. Engine scheduled maintenance is based on Engine Operating Time (EOT) vice flight hours, and thus includes time when the engine is turning while on deck. Pratt & Whitney (P&W) ashore calculated engine operating time remaining, but occasionally provided this information after the next day's flight schedule had been written. Maintenance control manually tracked engine and lift fan hours from pilot reports instead, but pilot-reported hours sometimes differed from the P&W calculated hours. At times, last-minute receipt of P&W engine data that differed from the manually tracked data caused maintenance control to reduce available flight times for aircraft after they were scheduled by operations for more flight time. Once propulsion is integrated into ALIS, maintainers should be able to calculate remaining propulsion system hours without waiting for external assistance. The program will integrate partial propulsion support in ALIS version 2.0.2 in mid-2016 with the initial Life Limited Parts Management (LLPM) capability to support Air Force Initial Operational Capability. Full propulsion integration capability will be incorporated in ALIS version 3.0. The Program Office has not set a projected release date for ALIS 3.0, because program re-planning for ALIS has not extended that far.

- The 20-ton wing jack used for the F-35B is larger than the jacks used for legacy aircraft, since the F-35B wing sits higher above the deck. The jack did not fit into the portable load tester on the *Wasp* without adding spacers to the load tester and removing the caster wheels of the jack. The Marines considered this very inefficient and an unacceptable workaround for future deployments to the ship.
- When the aircraft is on jacks, the arrangement of tie-down chains prevents the weapons bay doors from opening. Since the inlet duct for cooling air is located in the weapons bay this will prevent the maintainers from applying cooling air, hindering efficient landing gear maintenance.

In addition to the planned general evolutions, maintainers uncovered several additional widely-applicable maintenance issues. Grounding cables for the F-35B were attached to pad-eyes (divots in the deck with cross members for attaching tie down chains to) but registered very high resistance, likely because the pad-eyes were painted over with multiple coats to protect from marine salt-fog and corrosion. Ships do not have exposed metal grounding points built in to the deck like hangars ashore because they would corrode in the environment and lose conductivity anyway. The F-35 is more susceptible to Electro-Static Discharge than legacy aircraft due to its structural configuration, though, and this could be a potential maintenance hazard. The program should determine if alternate grounding arrangements at sea are required to protect the aircraft.

The toolboxes used during the deployment, which were an interim design, were not durable enough for the shipboard environment. Though the program is still developing the final design and layout of toolboxes for the F-35B, sea-going units require more robust toolboxes.

As with the major evolutions, there was a lack of time and a plan to conduct an assessment of some general evolutions, such as crypto loading or a wide range of LO repairs.

This fact reinforces the observation that this deployment demonstration was a useful training event, and a necessary evolution to ready the F-35B for sea, but not an operational test.

ALIS

The USS *Wasp*'s SOU V1 ran ALIS version 2.0.0.2 during the deployment. Maintenance personnel noted that this was faster than earlier versions of the software, and were generally satisfied with screen refresh times. While refresh rates and load times had improved, many other ALIS issues still affected maintenance and operations.

- The large number of sign-offs required in ALIS to finish work orders take time to complete, even with fast screen refreshes. For example, maintenance controllers reported that signing off all sub-tasks for an Inter-Operations Service could take 20 to 30 minutes. Compared to legacy maintenance information systems, ALIS requires far more sign-offs for sub-tasks, rather than a single or a few sign-offs for overall work accomplished.
- ALIS relies on Electronic Equipment Lists (EEL), which are unique and specific files that serve as the records for each part that can be installed on the aircraft. The supply system must provide the associated EEL for each replacement part delivered, or spare part stored in the local spares package, in order for ALIS to properly track required scheduled maintenance and life usage of these parts, as well as to accurately locate individual spares in the supply system. However, these files often have incorrect data, such as serial number or date of manufacture, or are missing entirely when a part is delivered. When maintainers or supply personnel discover missing or incorrect EEL data they notify LM via an action request (AR) and LM must correct the EEL data online. Typical delays for incorrect EEL data discovered when parts are delivered to operating units can range from 30 minutes to long enough to cause cancelled sorties. Delays for incorrect EEL data discovered while the part is still in the warehouse can be up to six months, during which time the supply system cannot provide that part to the F-35 fleet, compounding supply shortage problems. For this deployment demonstration, LM made DBAs from Fort Worth and Orlando readily accessible to ensure EEL data were corrected as soon as maintainers discovered any discrepancy, representing a level of contractor support greater than current operations at most bases, and which, again, may not be practical under most combat conditions.
- The lack of propulsion integration in ALIS necessitates support from P&W Field Service Engineers (FSEs) in order to process propulsion HRCs from the aircraft Prognostic Health Management (PHM) system.
- HRCs for most aircraft systems are recorded to the PMD in the aircraft during flight, and downloaded afterwards by maintenance and P&W representatives. For both air vehicle and propulsion, PHM generates a large number of "nuisance" HRCs on each post flight download, which erroneously assert in flight indicating a problem where none actually exists. Since ALIS automatically generates work orders from HRCs on the PMD download, it currently has a nuisance HRC filter list that eliminates known

bad codes, and prevents the creation of some unnecessary work orders. This nuisance list is not entirely up to date, however, and maintenance controllers and P&W FSE's still have to manually remove many work orders resulting from nuisance HRCs.

- During the deployment, a lift-fan vibration HRC that has rarely appeared in program history asserted seven times in total, and on multiple different aircraft. Personnel performed significant maintenance as a result of the first several assertions, but found no identifiable discrepancies. The program declared the HRC "non-actionable," but the program does not know why it asserted at a higher rate on ship.
- The PMD does not always consistently record HRCs from the aircraft PHM sensors during every flight. These sensors send out "heartbeat" pulses to the PMD every second to indicate they are still active, but some PMD downloads show periods of time with no heartbeats recorded. When this occurs, the P&W FSEs must conduct a download directly from the engine FADECs to ensure that there were no critical propulsion HRCs asserted during this lost period. This involves removing a panel to gain direct access to the engine and downloading data onto a P&W computer to allow the FSEs to disposition any HRCs that did not write to the PMD. Removing and reinstalling the panel can be a three-hour process.
- The PMD also records mission system data such as helmet video, radar recordings, and other information used in debriefing and for intelligence purposes. Video downloads from the PMD during the deployment regularly took at least two hours.
- Not all Portable Maintenance Aids (PMAs) – which maintainers use to perform most maintenance functions and servicing – could connect to the aircraft and maintainers frequently cycled through several PMAs to find one that would. The PMA will also access the Anomaly and Fault Resolution System (AFRS), which provides maintainers with troubleshooting instructions and links to JTD for many HRCs. AFRS coverage of aircraft systems is incomplete, and propulsion is not yet fully integrated.
- When AFRS coverage is missing for air vehicle systems, LM FSE's performed troubleshooting using their Multifunction Analyzer Transmitter Receiver Interface Exerciser (MATRIX) system. MATRIX is a piece of support equipment used only by the LM FSEs and is designed to troubleshoot and analyze faults at a level not available to uniformed personnel via their PMAs. It was used on the deployment to troubleshoot the fuel boost pump discrepancy on BF-21, as well as a downing Power and Thermal Management System (PTMS) fault, leading to the replacement of an ice detection sensor, for example.
- ALIS offline operations are logistically burdensome. The detachment gained experience with ALIS offline operations from two unplanned contingencies.
  - One aircraft, BF-37, diverted to MCAS Cherry Point due to a landing gear malfunction. In order to complete maintenance actions at the divert base and have the aircraft return to the ship, the detachment on the *Wasp* synchronized a PMA to

the SOU, and flew it to Cherry Point via helicopter. Maintainers at Cherry Point completed work orders on the PMA, and used paper release forms to declare the aircraft safe for flight, allowing the aircraft to return to the ship. The PMA was flown back to *Wasp* and synched back to the SOU.

- Another aircraft, BF-42 from MCAS Beaufort, was swapped for BF-24 due to the fuel float valve discrepancy on BF-24. Prior to deploying to the ship, the pilot signed paper release forms for BF-42 and accepted a CD with all aircraft data files to upload onto the *Wasp* SOU upon landing. Although this CD transfer had far fewer discrepancies than the initial aircraft data transfer at the start of the deployment, the Marines reported it worked more smoothly only due to extensive coordination to ensure that the MCAS Beaufort SOU and *Wasp* SOU were in the exact same configuration, and found the overall process labor intensive.

The JOTT conducted a System Usability Scale (SUS) survey on ALIS during the deployment demonstration. The SUS has become an industry standard that allows organizations to quickly and reliably measure the usability of a wide variety of products and services, including hardware and software. It consists of 10 questions that produce a score between 0 and 100, with 100 representing best possible usability. The JOTT administered the survey to 10 Marine ALIS users that spanned a range of enlisted job functions, and junior to senior ranks, near the end of the deployment. It covered a subset of all tasks within ALIS. The survey responses scored ALIS's usability at approximately 66, representing a system on the low end of the acceptable scale, or marginally acceptable. The spread in responses was notable, however, with a low score of 30 from one respondent and a high score of 95 from another, both with highly different jobs that utilize different portions of ALIS and with different degrees of frequency. The SUS is not diagnostic, however, and the survey responses do not give guidance on which ALIS functions the program can improve to increase usability. The program is still developing ALIS, and any changes the program makes in future versions may increase or decrease user-reported usability. The JOTT should continue to benchmark the usability of ALIS by administering the SUS to users when new versions are released. The DOT&E staff will be available to assist the JOTT in refining human factors testing of ALIS.

Logistics Footprint and Supply Support

Since the Autonomic Logistics Global Sustainment (ALGS) system that will support eventual F-35B deployed operations is still in development, the deployment used interim supply support consisting of a Pack-Up Kit (PUK) of spare parts brought onboard ship, and met additional supply needs with dedicated MV-22 and H-60 logistics runs. The PUK had a total inventory composition of 2,572 items. In spite of the size of these kits, off-ship orders were received on 7 of the first 10 days.

Through May 28, the PUK supply effectiveness was 75 percent, meaning 3 out of every 4 requisitions was completed onboard ship. This metric combines consumable and repairable items. For repairable items, however, the PUK contained only 1 out of 8 requested items for an approximately 13 percent PUK repairable issue effectiveness. This compares to around 45 percent repairable issue effectiveness at MCAS Beaufort, and a 40 percent rate at MCAS Yuma for May 2015, the latest month with complete data available. Yuma, the source of many of the spares, had a 70 percent rate in April 2015. Supply personnel sourced the remaining seven requests off ship from the supply system and the Marine Corps flew them to the *Wasp* via MV-22. The Marines had MV-22s set aside and waiting to conduct logistics runs and LM prioritized support for the deployment very highly, with one requisition shipping from Fort Worth to the *Wasp* within 18 hours. This level of support should not be expected as normal for combat deployments once away from the continental United States. Maintainers reported that for maintenance actions they usually did not have all the necessary items on hand, except for propulsion maintenance, and often relied on logistics runs to be able to complete work orders.

Additionally, some of the SE lacked appropriate tie-down points. These SE were lashed to the deck by wrapping the tie-down chains around them and attaching both ends of the chain to the pad-eyes in the deck. During heavy seas, this may cause rubbing between the chains and the SE, increasing the chances for damage.

Manning and Manpower

The detachment was staffed with approximately 220 personnel onboard USS *Wasp*, including observers and operational test agency representatives. The actual number of personnel varied from day to day. The Marines provided around 140 officers and enlisted, supplemented with contractors needed for daily operations and maintenance.

Marine maintenance leadership assessed two particular functions as being undermanned during the deployment: the power-line division and maintenance control. Power-line Marines perform propulsion maintenance and run the flight line. Maintenance control directs all maintenance activity, certify aircraft safe for flight, and coordinate with the ship and other squadrons. The power-line was heavily tasked with a large number of propulsion and fuel system discrepancies, and provided much of the manpower for the staged maintenance evolutions. Maintenance control would be more heavily tasked with a full ACE onboard as coordination requirements increase with more aircraft and squadrons onboard.

Contractor Support

The detachment relied on contractor support in several areas, many related to ALIS immaturity. P&W FSE's processed propulsion HRCs, calculated engine operating time remaining for scheduled maintenance, and assisted with propulsion logistics and maintenance in general. LM FSE's were required for troubleshooting in areas where AFRS coverage was inadequate, and had access to Aircraft Engineering Instructions that provided information on systems that JTD did not cover. Two members from the government side of the JPO Lightning Support Team (LST) were onboard to assist in submitting and receiving responses on ARs. Both of these members also had airworthiness disposition authority, whereas, by comparison, Yuma currently operates with only one LST representative who lacks this authority. Finally, contractors assisted with the Offboard Mission Support (OMS) system for conducting pilot briefings and debriefings. In addition to the two government LST members, there were six LM FSE's, including one dedicated to SE and one to supply, three P&W FSE's, and one Rolls Royce

FSE. The extent that the services will be able to deploy and sustain combat operations with this level of contractor support is not known.

Safety

The deployment identified several safety factors relevant to the shipboard environment.

- The F-35 is very slick when wet, and there is likely a greater chance of falling off the aircraft on ship, with potentially worse consequences should personnel fall overboard. In order to protect the LO coatings, maintainers normally wear plastic booties over their flight deck boots, but the booties lacked grip on the aircraft's smooth LO coatings when damp. To help counteract the salt-air environment, aircraft at sea are washed twice as frequently as ashore and ships frequently steer towards rain showers as a "free" freshwater rinse for aircraft on deck. Humidity and condensation are also bigger factors at sea. Aircraft on ship will thus likely be wet more often than ashore. The F-35 wings also sit higher off the deck than legacy aircraft, and thus injury from a fall to the flight deck could be more severe. The detachment requested and received approval to not wear the plastic booties when working on the aircraft onboard ship. Maintainers double checked their flight deck boots to ensure no sharp or hard objects were in the treads of the soles that could damage the LO coatings, but the JPO should conduct a review of options to improve safety while preserving the LO surface finish of the aircraft while at sea.
- During aircraft washes and daily canopy cleaning, maintainers had to use a collapsible ladder to clean the canopy. Since the canopy hinges forward it cannot be cleaned without the use of a ladder or stand, and maintenance stands are not allowed on the flight deck. Although ladders are not prohibited, extra care must be taken to stabilize the ladder and prevent a fall. Also, collapsible ladders have generated Foreign Object Debris on past deployments.
- Aircraft noise during vertical landings seemed very loud in certain parts of the ship, particularly in the spaces directly beneath the landing spots seven and nine, but also in the hangar bay. Naval Sea Systems Command (NAVSEA) previously treated several compartments with sound damping materials and collected acoustic data during the deployment with analysis of this data ongoing. Ship leadership required personnel in the hangar bay to start wearing ear plug protection during vertical landings. Noise levels in the Special Access Program Facility, where flight planning and debriefing occurs, and in the ship's Combat Information Center (CIC) were low enough that conversational level speech was easily heard.
- Maintenance personnel and pilots cannot crack open the canopy during ground operations to allow fresh air in, and prevent a greenhouse effect from developing. Opening the canopy is often necessary when pilots or maintenance personnel are required to be in the cockpit for extended periods without the engine running (e.g., towing the aircraft and monitoring the brakes), more common when a full ACE is onboard, or when pilots are sitting in the cockpit for an alert launch in hot locations,

and the canopy cannot be fully open due to flight operations. There is a modification to the canopy actuator to allow it to be cracked open. This modification should be incorporated on any aircraft going to sea before they deploy.

Ship Modifications and Integration

The USS *Wasp* had several ship modifications specifically to integrate the F-35B. The Navy applied Thermion coating to the aft flight deck spots where the F-35B will land. This is a flame-sprayed aluminum-based material with better thermal wear properties than the standard non-skid flight deck coating. By May 25, one week into flight operations, flight deck personnel discovered some corrosion induced delamination of the Thermion along a weld seam. There were several chips about half an inch wide by two to four inches long for a two foot stretch where the top-most layer of Thermion was missing and a lower layer of Thermion was exposed. After several additional landings, observers noted no further degradation, but NAVSEA is still analyzing the performance of the Thermion.

The Navy also installed a large lithium-ion battery charging and storage facility. The battery compartment is designed like a vault, with one set of heavy doors as the only way in or out. The interior includes rows of charging and storage lockers. These lockers are similar to ovens, designed to contain a lithium-ion battery thermal runaway fire, and to flue heat and exhaust gases directly overboard. If a battery fire is detected inside a locker, all electrical charging is secured, an overhead sprinkler system douses the room to cool all lockers, and fans increase the amount of air pulled from the lockers. Thermal runaway fires cannot be extinguished and must run their course, so the compartment is designed to contain fires and prevent heat from spreading to other lockers. The facility appeared robust and well thought out. Personnel accidentally installed the air conditioning unit in the facility backwards and it was leaking water, an unacceptable condition, but one that would not exist for a compartment built correctly. Detachment personnel noted the need for a few minor improvements to charging cable lengths and ratchet hook sizes for securing the batteries to make the facility more efficient.

On the flight deck the F-35 will normally be parked aft of the island, where the AV-8B is currently spotted. There is only one deck-edge power outlet in this area. Although the Marines were operating on IPP power on the flight deck, they expressed interest in additional deck-edge power installations aft of the island once the flight deck cooling air cart becomes available. The detachment also wanted more outlets to connect ALIS workstations throughout the work centers.

ANNEX E – Recommendations

Numerous recommendations need to be addressed by the operational test community, the Services, and the JPO.

- Future F-35B at-sea operational testing should include a full Air Combat Element (ACE) and Marine Expeditionary Unit (MEU) onboard ship, and fly missions that employ the range of F-35B mission systems and flight envelope, including the release of ordnance, to assess sortie generation, shipboard integration, and maintenance workload under operationally realistic conditions.
- The duration underway should be longer than 10 days of flying, perhaps up to a month, and broken into a separate operations phase and then maintenance demonstration phase. Major maintenance demonstrations should not be conducted during the operations phase.
- Future F-35B at-sea operational testing should be conducted with production electrical power and cooling carts, which are considered by the services to be operationally representative.
- The program should review any internal weapons bay ordnance loading procedures that break electrical connections between the aircraft and the launcher conducted after the release and control checks.
- The program should improve the ease and accuracy of Autonomic Logistic Information System (ALIS) data transfer procedures between Squadron Operating Units (SOUs) for aircraft, support equipment (SE), and supply data. Current procedures remain manually intensive and require excessive contractor support.
- The program should determine Short Take-off and Vertical Landing (STOVL)-operation specific main and nose wheel tire reliabilities for sizing spares packages and logistics modelling purposes.
- Future F-35 at-sea operational testing should demonstrate actual engine and lift fan Removal and Installation (R&I).
- Future F-35 at-sea operational testing should demonstrate a wider range of Low Observable (LO) repairs aboard ship.
- Future F-35 at-sea operational testing should demonstrate end-to-end delivery and receipt of crypto keys to a unit deployed aboard ship.
- The program should conduct an analysis of safety measures for personnel working on top of the aircraft when it is wet and that preserve the aircraft's LO properties.
- The program should ensure that maintainers can command the F-35 strobe lights off during all maintenance modes and that they do not come on automatically aboard ship.

- The program should incorporate the ability to crack the canopy open for any aircraft expected to deploy to a LHA/LHD or CVN.
- The program should determine if alternate grounding arrangements at sea are required to protect the aircraft.
- The program and Naval Air Systems Command (NAVAIR) should make a clear determination on whether the F-35 can be pushed back with a tow bar on the flight deck while the engine is running.
- The Navy should investigate alternate portable load testers that can accommodate the F-35 20-ton wing jack.
- The Navy should investigate whether Quantitative Debris Monitoring (QDM) oil debris analysis capabilities should be incorporated in LHA/LHD and CVN class ships.
- The program should ensure the gun pod container is made water-tight.
- The program should investigate the need for an aircraft side mount for the shipboard Aircraft Electrical Servicing System electrical plug converter to prevent damage to the aircraft receptacle.

Most of the above recommendations apply to future operational test events for the F-35C on aircraft carriers as well.