Another Yea

Above: ***Not an official milestone for the F-35 programme, but impressive nevertheless, was a two-ship formation seen flying through a canyon in southern California on December 3. Both aircraft, F-001 (c/n AN-01) and F-002 (c/n AN-02), are assigned to the Royal Netherlands Air Force's 323 Test and Evaluation Squadron based at Edwards Air Force Base, California; one of five test units assigned to the JSF Operational Test Team.*** *Dan Stijovich*

Below: ***USS America (LHA 6) underway off the coast of California on the first day of the Lightning Carrier Proof of Concept Demonstration with 12 F-35Bs on deck.*** *Cpl Thor Larson/US Marine Corps*

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At the close of another year of test and front line ops for the F-35 Lightning II programme, David C Isby and Mark Ayton cover some recent events

What is it like to fly – and fight – in fifth-generation fighters: the Lockheed Martin F-22 Raptor and the F-35 Lightning II Joint Strike Fighter? At a discussion hosted by the Mitchell Institute in Washington on November 7, 2016, pilots from the US Air Force and US Marine Corps, including Major General Glen Van Herck, commander of the Air Warfare Center at Nellis Air Force Base (himself a B-2 stealth bomber pilot also qualified in the F-35) described their experience of flying fifth-generation fighters.

Gunn

F-35A pilot Lieutenant Colonel Scott Gunn, US Air Force, described the difference between a fourth-generation fighter, such as the F-15 Eagle or F-16 Fighting Falcon, and a fifth-generation fighter as comparable to the difference between a flip phone and an iPhone: "Multiple technologies fused together in a single piece of equipment. The F-35 is a sensor-processing machine that just happens to have an aircraft wrapped round it."

Sensor fusion includes the F-35's passive sensors that, Gunn continued, "suck in the 'trons [electrons from an emitting threat radar], then the radar captures a SAR [synthetic aperture radar] map. I get a map of what this thing [detected by the passive sensor] looks like. If I see a little bright spot, I point the EO/IR [electro-optical/infrared] sensor at that and can see [in more detail] what it looks like, from a long stand-off range."

This enables an F-35 to find things that are unlocated, "like SAMs [surface-to-air missiles] that are long-range threats. Fourth-generation fighters can't fly close enough to find them effectively. With enough [networked] F-35s [in the area], each one provides a piece of the puzzle. That's the beauty of networks as they evolve."

Other participants can share the picture. However awesome the speed, manoeuvrability and weapons of fifth-generation fighters may be, what matters most is their sensors and the ability to fuse and share the information obtained from them.

Berke

US Marine Corps F-35B pilot Lieutenant Colonel David Berke previously flew F/A-18 Hornets and served two exchange tours with the US Air Force flying F-16s and F-22s. When he first flew the F-22, he said he was enamoured by how powerful the airplane was, but he soon realised its sensor and information fusion capabilities were more important: "Without information, the fastest airplane out there is the first to die." He said the differences between fourth-generation and fifth-generation fighters are very stark: "The F-22 and F-35 are more like each other than they are like anything else." He described the F-35 as a very innovative airplane that has inherent plasticity to evolve.

Berke has worked on initiatives for integrating fourth-generation and fifth-generation fighters, flying F-22s in a six-month test programme: "The two simplest ways to measure a fighter's effectiveness are [by] its survivability and lethality. For a fourth-generation fighter, the presence of fifth-generation fighters improves the two things exponentially. Their ability to survive increases, because a fifth-generation platform provides information they cannot get on their own and from places where

they cannot go. Fifth-generation makes fourth-generation airplanes more lethal." He cautioned that while fourth-generation airplanes also enhance fifth-generation aircraft, there will be a time when fourth-generation aircraft simply cannot operate.

The US Marines Corps will fly F-35Bs off the US Navy's big deck amphibious assault ships, a major advance in capabilities over today's AV-8B Harrier IIs, in the words of Lt Col Berke: "It is infinitely, exponentially, generationally beyond anything that airplane can do."

Berke said the F-35B is critical for the US Marine Corps: "It can operate anywhere. The F-35B opens up opportunities to operate where Marines could never operate before and in ways not available before. This includes operating way inland, in conjunction with the [Bell-Boeing] MV-22 [Osprey tilt-rotor] and the [Sikorsky] CH-53K [heavy-lift helicopter]."

The F-35B's ability to function as a sensor platform and transmit a fused picture of the battle space to other aircraft, ships and ground units is according to Berke a contribution difficult to overstate: "The F-35 combines information [from multiple sensors] in environments where we currently operate and in places the joint force currently cannot operate or will not be able to operate five years in the future [because of ever more capable threats]."

Deptula

US Air Force Major David Deptula flew F-22s in combat missions over Syria. Like Gunn, he considers the F-22's greatest strength as providing information and situational awareness: "An F-22 can detect targets in the air or on the ground and distribute target information to air and ground recipients with near simultaneous capabilities, so that pilots in other friendly aircraft can view and disseminate the information to those that matter."

Major Deptula explained how on a combat mission F-22s can identify aircraft and unknown tracks, and immediately feed that information to other aircraft for dissemination to the right people: "Having real-time information allows everyone in a strike package to do their job better. Even in areas of a potential SAM threat, the F-22 has access to the area and can pull information quickly that can benefit, in a typical strike, US, Moroccan, Emirati and Jordanian F-16s. US mission commanders help them work through complex target sets. Today we can have an F-22 – or an F-35 in the future – pass on information about situations going on in the area of responsibility from hundreds of miles away."

Stolee

Major Andrew Stolee, a chief F-22 instructor at the Fighter Weapons School at Nellis Air Force Base, teaches air warfare doctrine. Not going to the fight alone is one doctrine, and one that includes fifth-generation fighters. Major Stolee underlined that the revolutionary capabilities of fifth-generation fighters are not just about information, but also include stealth and the seamless display of information to the human being that has to make a decision: "Information is now immediately displayed to people that are in aircraft in the AO [area of operations] who can immediately apply some sort of effect, either kinetic or non-kinetic."

Major Stolee is currently developing joint tactics for the F-22 and F-35 and already recognises the higher demand placed on the F-22 to make decisions and integrate information. Explaining the demand, Stolee said on-board systems increase the speed of decision-making and the information provided delegates decision-making to individual F-22 pilots, because they see the same picture, operate in places others cannot and focus on the mission while the actual machine is collecting information: "Fifth-generation fighters shift roles very quickly. F-22s can go in and kick in the door against advanced IADS [integrated air defence systems] with robust SAM threats and lots of airplanes. F-22s start a mission undertake the air superiority role to ensure hostile aircraft are not in the way of F-35s finding something, with F-35 pilots focused on the air-to-ground role. They can shift roles swiftly, so F-35s are protecting F-22s while the F-22 pilots look at their SAR, then switch back to the opposite role, perhaps with F-35s attacking from a different direction."

Major Stolee's bottom line: "The symbiotic relationship between the F-22 and F-35 will only continue to grow."

Van Herck

According to Major General Glen Van Herck, the battle space is going to change faster and faster. He provided his own insight to the F-35 in that arena: "The F-35 is incredibly lethal with multiple options for air-to-air and air-to-ground weapons and incredibly survivable due to its low observable design." He described the improvements in stealth technology used on the F-35 compared to the B-2, his previous mount, as "just incredible".

Major General Van Herck's bottom line: "Connected battle space from fifth-generation fighters is just crucial."

All of the observations and points listed are applicable to all F-35 international customers, who today, together with the schoolhouse at Eglin Air Force Base, Florida, are working to develop effective tactics, techniques and procedures. However, the importance of sensors and networks – more than traditional speed and manoeuvrability – for future air combat comes across loud and clear.

David C Isby

F-35B BF-05 from Air Test and Evaluation Squadron 23 (VX-23) 'Salty Dogs' launches from the flight deck of USS America (LHA 6) loaded with four externally carried 500lb inert GBU-12 test vehicles during DT III. *Petty Officer 3rd Class Kyle Goldberg/US Navy*

Dutch muscle. The test pilot of F-35A F-001 passes through the canyon with the afterburner engaged. Pratt & Whitney's F135-PW-100 axial-flow engine produces up to 43,000lb (191.2kN) of thrust with the afterburner engaged. Dan Stijovich

F-35B DT III

On October 28, seven F-35Bs landed on the flight deck of USS *America* (LHA-6) at the start of what was called Developmental Test Phase III at sea or DT III. This was the final evolution for the F-35B in its current configuration during 21 days at sea that concluded on November 17.

DT III involved seven F-35B Lightning IIs: two from Air Test and Evaluation Squadron 23 (VX-23) 'Salty Dogs' based at Naval Air Station Patuxent River, Maryland; two from Marine Operational Test and Evaluation Squadron 1 (VMX-1); and three from Marine Fighter Attack Squadron 211 (VMFA-211) 'Wake Island Avengers'.

DT III Objectives

- *Day carrier qualification (CQ)*
- *Initial pilot CQ*
- *Flight deck crew familiarisation*
- *Night operations with Gen III helmet-mounted display*

Shipboard Launch and Recovery Expansion

- *Short take-off flying qualities and envelope expansion*
- *Vertical landing flying qualities and envelope expansion*
- *Vertical landings to spots 2, 4, 5, 6, 7 and 9*
- *Vertical landing and short take-offs with symmetric and asymmetric external stores carriage*
- *Vertical take-off*
- *Increased deck motion operations in solid sea state four conditions up to +/-5.5° roll and +/-2° pitch*
- *Joint precision approach and landing systems testing*

Logistical Test and Evaluation

- *Engine*
- *Lift fan*
- *Maintenance support*
- *Footprint support*
- *Weapons loading*

Flight Deck Ops

DT III was technically known as an operational test (OT) assist development test (DT) event, in which qualified OT test pilots conducted some of the DT test points.

The primary objectives of the 21-day period were shipboard launch and recovery expansion test points focused on the evaluation of flying qualities at various aircraft weights, crosswinds, sink rates and high sea states, and clearing the F-35B for maximum gross weight take-offs involving a lot of missions loaded with externally carried stores, a load configuration not done on previous F-35B detachments DT I and DT II.

A high sea state was key to meeting test objectives on DT III, a step-change from fairly calm sea states and the resultant steady deck present during DT I and DT II.

F-35 Chief Test Engineer Andrew Maack said the team wanted to be able to test up to +/-5° roll and +/-2° pitch movement of the flight deck: "We easily found those conditions that were new for the F-35B, but it performed very well: 60 flights; 53.5 flight hours; 128 vertical landings; 126 short take-offs; and two vertical take-offs."

Weapon loads comprised various combinations of 1,000lb GBU-32 Joint Direct Attack Munitions carried internally; 500lb GBU-12 laser-guided bombs carried externally on the wing stations; and AIM-9X Sidewinders carried on the wing tip stations.

Gabriella Spehn, an F-35 weapons engineer from the F-35 Integrated Test Force based at Patuxent River, said: "We're augmenting the existing weight centre of gravity effects of the aircraft to expand the envelope with wind over deck, and different lateral symmetry and asymmetry configurations."

The DT III weapons team tested all of the take-off and landing worst-case scenarios and endpoints. Spehn said the only way to increase the endpoints is to test on board a ship for sink rates and high sea states.

Explaining the test effort, Andrew Maack said: "We conducted max load-out launches, looking for the short take-off spotting position on the deck to enable

The first two F-35I Adirs for the Israel Air Force, 901 (c/n AS-01) and 902 (c/n AS-02), arrived at Nevatim Air Base on December 12. Aircraft AS-02 completed its first flight on August 8, 2016 from Naval Air Station Joint Reserve Base Fort Worth. Carl Richards

us to determine the absolute minimum performance acceptable for the aircraft. We produce the performance bulletins to be used by the fleet."

The other critical stage of flight that asymmetric loading can affect is the vertical landing. In the fleet, external asymmetrically loaded stores are brought back to the ship either because the pilot did not have cause to expend the stores or because reasons dictated an inadvertent bring-back.

Andrew Maack explained that the most critical variable for the build-up of asymmetric loads and the associated handling qualities are the environmental conditions in which the test is conducted: the wind direction relevant to the aircraft, either down the deck or a crosswind.

Consequently, the critical build-up was in the environmental conditions, rather than a regimented set of different asymmetries. However, the primary driver for max load-out take-off conditions tend to be performance oriented, as Maack explained: "We're looking for the minimum short take-off performance and those tests require a steady deck. A moving deck makes it difficult to sort the data and map to models, which is ultimately what we are trying to do."

Maintenance

There were multiple maintenance test events conducted. One involved a dedicated spare engine placed on board for the purpose of evaluating an engine module replacement; an intermediate level maintenance procedure on the engine that would be done in a maintenance back shop evolution. Other big maintenance procedures were an engine removal and installation on one of the jets, and a lift-fan removal and installation on another jet.

Andrew Maack said there was also a considerable amount of publications verification conducted, much of which involved evaluating the publications used by fleet maintainers to ensure processes are being done in the most effective manner and the documentation is adequate for a fleet maintainer to be able to conduct the procedure at sea.

Operational testers VMX-1 had a deployable ALIS unit on-board, which was evaluated by a team led by the ALIS testers from the Pax-based ITF. ALIS is the acronym for the F-35's Autonomic Logistics Information System.

ALIS SOU Version 2 was delivered to Marine Fighter Attack Squadron 121 (VMFA-121) 'Green Knights' in June 2015.

The system is not fully mature, but in the configuration now fielded proved its capability during DT III aboard the USS *America*.

The ALIS servers have been reconfigured to disassemble into man-portable sections, and are now the primary system used by operational F-35B squadrons; this type of server was used on board USS *America*.

Maack gave some perspective: "The amount of logistics test and evaluation conducted on DT III was more than we had done on all the previous detachments combined. This was a function of the OT team being on board and dedicating an aircraft to support the effort."

Summing up DT III, Maack said the big thing was testing in high sea states with stores: "Once all of the data is analysed, it will determine operating envelopes for the F-35B that will be used by the fleet for decades. The F-35 is a tremendous capability. Just the touch-down dispersion and accuracy when the pilots put the aircraft down during all of the demanding conditions was remarkable."

Proof of Concept Demo

Once the 21-day DT effort was complete, VMX-1 started a three-day Lightning Carrier Proof of Concept Demonstration on November 18–20 with an F-35-heavy Aviation Combat Element. Twelve F-35Bs were involved from three units: the Salty Dogs of VX-23; Marine Fighter Attack Squadron 211 (VMFA-211) 'Wake Island Avengers', based at Marine Corps Air Station Yuma, Arizona; and the F-35 detachment of Marine Operational Test and Evaluation Squadron One (VMX-1), based at Edwards Air Force Base,

The UK is gradually building up its fleet of F-35Bs. In early December F-35B ZM140 (c/n BK-06) was delivered to Marine Corps Air Station Beaufort to join the ranks of Marine Fighter Attack Training Squadron 501 (VMFAT-501) 'Warlords'. UK F-35Bs ZM141 (c/n BK-07) and ZM142 (c/n BK-08) shown here are already flying with Lockheed Martin at Fort Worth. Carl Richards

California. However, for the first time during a period spent at sea by the F-35B, the Carrier Proof of Concept Demonstration also involved other types from a Marine Expeditionary Unit. VMX-1 deployed two MV-22B Ospreys, one UH-1Y Huey and one AH-1Z Cobra.

The Lightning Carrier Proof of Concept Demonstration was designed to evaluate the F-35B's suitability and effectiveness at sea alongside other Marine Air to Ground Task Force assets to the maximum extent possible. Specifically, assessment was made of the F-35B while operating across a wide array of flight and deck operations, including mission systems, support equipment and procedures, maintenance operations and logistical supply chain support in an at-sea environment. Operational testers also conducted risk reduction demonstrations in the shipboard environment, in preparation for upcoming operational missions.

Demo Objectives

- *Execute numerous day and night take-offs from and landings on USS America*
- *Operate in the Block 2B, Block 3i, and Block 3F software configuration aboard USS America with applicable sustainment support and infrastructure*
- *Execute and assess standard day and night extended range operations*
- *Assess aircraft-to-ship network communications interoperability*
- *Assess the efficacy of the F-35B landing signals officer's launch and recovery software*
- *Assess the crew's ability to conduct scheduled and unscheduled maintenance activities*
- *Assess the suitability of F-35B maintenance support equipment for shipboard operations*
- *Assess the integration of the F-35B alongside other MAGTF assets*
- *Execute and assess day and night weapons loading including live ordnance releases*
- *Assess all aspects of the logistics and sustainment support of the F-35B while deployed at sea*

Flight Ops

Flight operations focused on routine mission sets from sea, such as strike missions, close air support, armed reconnaissance, assault support escort and maritime strike.

For the final event, VMX-1 conducted a combined mission to San Clemente Island, a multiplatform mission off the ship into an objective area.

In addition to mission sets, other operationally relevant tests were performed to evaluate interoperability of the aircraft-to-ship network communications: F-35B landing signal officer's launch and recovery software; the crew's ability to conduct scheduled and unscheduled maintenance activities; the suitability of F-35B maintenance support equipment for shipboard operations; day and night weapons loading, including the first live ordnance drops from sea-based F-35s; and all aspects of the logistics and sustainment support of the F-35B while deployed at sea.

For the weapons loading, USS *America*'s weapons department assembled 72 GBU-12s and 40 GBU-32 JDAMs. Armament Marines assigned to VMX-1 then used the assembled munitions to undertake daytime and night-time weapons loading. From the arsenal of assembled weapons on board, some were live and were dropped by VMX-1 test pilots for the live fire events. Over two consecutive days VMX-1 dropped six GBU-12s on a live weapons range in Yuma, Arizona.

VMX-1's Commanding Officer, Colonel Rowell, said: "We learnt a lot of valuable lessons about ALIS: the configuration of the brief and debrief facility; which landing spots are convenient for the F-35; how we move F-35s around the deck and the hangar bays; and a lot of maintenance knowledge."

Data and lessons learned from the demonstration are now being used for developing the concept of operations for F-35B deployments aboard US Navy amphibious assault ships beginning in 2018.

Demo Facts

- *Dubbed the next phase of the F-35B Lightning II's advancement in naval integration*
- *November 18–20*
- *Explored the best way to integrate a larger package of F-35Bs into the current Navy-Marine Corps structure to bring the most power projection from the sea*
- *Ratified procedures between the US Navy and US Marine Corps in preparation for upcoming deployments in 2018*
- *Carrier-qualified 19 Marine Corps pilots in a three-week at sea period. Prior to the demo, only eight Marine Corps F-35B pilots had carrier qualified in the last four years*

Accomplishments

At the conclusion of the DT III, the longest at sea period undertaken by the F-35B, the combined DT and OT teams accomplished: the first integration of ALIS SOU version 2 aboard a ship; the first engine and lift fan removal and installation aboard an amphibious assault ship; the first live ordnance operations aboard a ship; the first F-35B integration with AEGIS; the first F-35B integration with MV-22B Ospreys, a UH-1Y Venom and an AH-1Z Viper aboard a ship; the most F-35s ever embarked aboard a ship (the previous record was six); the first time Block 3F OT at sea; and the first Royal Navy F-35B pilot became carrier qualified. At the end of 2016, F-35s had been handed over to Australia, Israel, Italy, Japan, the Netherlands, Norway, the United Kingdom and three of the US armed services.
In 2017, the F-35 System Design and Development phase is expected to finish, the initial operational test and evaluation will begin and the US Marine Corps will deploy the first F-35 squadron to an overseas location. Much work still has to be completed on the jet, but based on comments given to AIR International by DT, OT and front-line pilots at this early stage of its service career indicate the F-35 to be a world-beater.

Mark Ayton

Japan's second F-35A, 69-8702 (c/n AX-02) made its first flight from Naval Air Station Joint Reserve Base Fort Worth on November 30. The aircraft will be delivered to Luke Air Force Base to join the international training programme.
Carl Richards