Early Flight Testing of the F-35B Lightning II
Graham Tomlinson, former BAE Systems Senior Test Pilot

This lecture introduced a substantial amount of background knowledge as well as providing a comprehensive insight into the flight-test programme. Graham had joined the then JSF project in 2002 to evaluate and develop the short-take-off and vertical landing (STOVL) properties of the aircraft. He outlined the scale of the programme, with 2,400 aircraft in prospect for the US forces, and over 600 additional airframes expected to be in service worldwide. A delivery rate of 240 aircraft annually is planned. There are three variants:

F35A - conventional aircraft developed mainly for the US Air Force
F35B - the STOVL variant, designed specifically for on-ship operations, and destined to be in service with the US Navy and Marines and the Royal Navy (when the latter's Queen Elizabeth class carriers enter service (probably 2017)
F-35C - a conventional version for the US Navy that embodies arrestor and catapult modifications, and a stronger landing gear for carrier flight-deck operations.

Eleven doors are required to engage the J-35B vertical take-off'/landing systems. These are associated with the rear exhaust and the vertical fan mounted aft of the cockpit. In the configuration shown, 20,000lb thrust is from the fan, 16,000lb from the exhaust and 4,000lb from wing-mounted thrusters.

He detailed the similarities of all the types. They are externally identical: and consistent in terms of aerodynamic shape, stealth properties, and internal weapons carriage capability. He presented considerable detail of the cockpit which embodies a solid-state main display measuring 20 x 8 in (500 x 200mm) on which 'windows' can be displayed that correlate to mission phases, a helmet-mounted sight (HMS) – there is no head-up display – and considerable innovation in the way the fly-by-wire (FBW) system integrates with the pilot, through stick and throttle, in the vertical-horizontal transition modes during STOVL operations. It was this aspect on which the lecture focused most attention.

He presented a thoroughly-enjoyable review of VTOL aircraft evolution, with videos of the UK projects that started with the Rolls-Royce 'Flying Bedstead' and the Short SC.1, and film of several RAF Harrier incidents (some leading to aircraft write-offs). These emphasised the dexterity needed to juggle the conventional stick and pedals, throttle and nozzle lever, as the impact on attitude and flight vector can require careful judgement of the relative position and combination of rates of change of these controls. In the late-1980s the UK RAE installed a re-programmable flight control system (FCS) in a two-seat 'vectored-thrust Aircraft Advanced Control' (VAAC) Harrier. This introduced the engine throttle and nozzle controls, as well as control surfaces and 'puffer' jets, into the FCS algorithms, and aimed to make the transition process more instinctive in the way it blended the use of a minimised set of controls to maintain attitude and control throughout the transition.

The refinement of techniques developed in the VAAC Harrier fed into the F-35B, making the control systems simple to use, and rendering the cockpit conspicuously simple compared to the Harrier.

Note the sidestick (right side) and the single throttle control (left side) which are common across all F-35 variants.

Graham described the FCS 'blend' over the range 0 to 250kts. The command regime is thus:

- throttle position commands acceleration and deceleration in all modes or flight
- backwards/forwards stick position commands vertical velocity in the hover or pitch rate in conventional flight - with a blend between the two
- side-to-side stick position commands roll rate in the hover, or bank angle in conventional flight - again with a blend between the two. If the stick is centred, at any time, the aircraft returns to wings level
- pedal position commands yaw rate in the hover and sideslip in normal flight

He showed film of Yak-38 (Forger) operations from the 1970s, as this used a similar configuration to the F-35B, but did not have advanced FCS. It was much quicker to compromise a pilot than Harrier, with rapid loss of stability. In one remarkable film the aircraft disappeared over the carrier-deck nose and the pilot was ejected: reappearing over the deck and collected in the arms of his deck crew within the space of a few seconds.

The flight test programme for F-35 commenced in 2006, and the first F-35B was flown in 2008. Initially it was flown in conventional flight and the 11 doors (excluding landing gear doors) were exercised. When the fan doors was open the aircraft exhibited more loss of stability than has been expected, and the intake door actuator needed to be strengthened. The first in-flight conversion from 5,000ft/210kts to vertical landing was conducted in January 2010, and a full investigation of transition options was achieved during spring 2010.

He commented that the transition is easy, and does not require the rigorous training that Harrier experience might have led one to expect. He did stress that the configuration is liable to some severe failures, and he showed film from a simulator of a fan-failure, which pitched the aircraft nose-down rapidly. The aircraft will be inverted within 0.6 seconds, so they have adopted the Russian technique of automatic ejection.

There was considerably more detail in his presentation, of the aircraft weapons systems, sensors and electrical power systems for example, and he was asked questions for over 20 minutes from an audience of around 130, whose interest was clearly as broad as the topics he had covered. Colin Moss offered the vote of thanks for what had been a most enjoyable beginning to this year's Branch activities programme.

Mike Hirst