STOVL Without Tears

The supremely capable fifth-generation jet fighter that outdoes everything that went before – and is the easiest yet to fly

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Hovering slowly and precisely along the taxiway I couldn't help but be reminded of the time I flew a Harrier TMk10. I'd thought that the Harrier was an incredible flying machine, but the F-35 is something else!

In fact, as soon as I settled in the Martin-Baker Mk16 ejection seat it was apparent that the F-35's cockpit is unlike that of any other fighter I've flown. Of course, I should qualify that observation by making it clear that although I've been lucky enough to fly about a dozen different fighters and fighter-trainers, powered by piston, turboprop and jet-engines, I am not a fighter pilot. However, what I can offer is an impression of a flying experience some of *Pilot's* younger readers will eventually get to live for real, as the UK has ordered 138 Lightning IIs and many other western nations will also buy them. In fact, for many countries the F-35 will eventually be the *only* combat aircraft they operate, for – incredible as it may seem – the F-35 is intended to replace a significant percentage of the western world's tactical aircraft, and

will certainly be flying well into the second half of the 21st Century!

It is also a significant aeroplane in that some of the brilliant systems incorporated in the design will eventually filter down to airliners and business aircraft (think of how the B787 and many bizjets have now adopted military-style HUDs – head-up displays). Finally, the F-35 may well be the last ever manned fighter...

So, what is the Lightning II? It is a 'fifth-generation' jet fighter that is produced in three distinct variants: the conventional takeoff and landing (CTOL) F-35A; the short takeoff/vertical landing (STOVL) F-35B and a carrier variant (CV), the F-35C. The UK is buying the B model to equip both the RAF and Royal Navy. Interestingly but unsurprisingly, the programme aim from the outset was to maximise commonality between the three versions, because the costs incurred in developing a jet fighter of this latest generation are colossal. In fact the total life-cycle cost to the US Government alone may well exceed $1 trillion – much more

To minimise the radar signature, making the aircraft as stealthy as possible, all weapons are carried internally. This is the F-35C non-STOVL carrier version, equipped with a tailhook for arrested landings

than any other military aircraft in history. Intended from its inception to be an international programme, this very advanced aircraft relies on an incredible amount of software, with over eight million source lines of code. This is four times the amount used for the first of the fifth-generation fighters, the F-22 Raptor, and reflects just how powerful the F-35's systems and sensors are. They include the Active Electronically Scanned Array radar (AESA), electro-optical Distributed Aperture System (DAS) and an Electro-Optical Targeting System (EOTS). For me at least, the most amazing of these is the DAS, as its six sensors give a pilot unlimited all-round day/night vision. Consequently, if the pilot looks down in the cockpit, they 'see' in their helmet display what is underneath the aircraft!

Before sampling the simulator I took a leisurely walk round the full-scale mock-up. At 15.4m in length and with a wingspan of 10.7m, it's not as big as some fighters – but is quite tall, at 4.3m. In some respects it's not entirely dissimilar to a scaled down, single-engined F-22, although in others it's radically different. One of the first things I notice is that although there are hardpoints on the wings there are no pylons, as all the weapons are carried internally. This keeps the radar signature down, ensuring the aircraft is very stealthy. The wings, tail and undercarriage all look conventional, although I know that the propulsion system on the F-35B variant is far from being so.

The engine is the Pratt & Whitney F135, the most powerful jet engine ever made for a fighter. Additionally, the B model incorporates the Rolls-Royce 'LiftSystem', and this combination enables the aircraft to make a very short takeoff, fly supersonic and then land vertically. I may well run out of superlatives before I finish this article, but the motor really is a mechanical marvel, as is the remarkable LiftSystem.

The F135 is a more powerful derivative of the Pratt & Whitney F119 engine, as used on the twin-engine F-22 Raptor. It can produce up to 28,000lb (124.55kN) of dry thrust and an incredible 43,000lb (191.27kN) 'wet' (with afterburner). To put this in context, the two Rolls-Royce Avon engines of Britain's previous English Electric Lightning fighter each produced 16,000lb wet (32,000lb total thrust)

An interesting facet is that the F135's two spools contra-rotate, which helps to shape the direction of core airflow as it transitions between the high-pressure turbine (HPT) and low-pressure turbine (LPT) improving the efficiency of the engine and possibly reducing the number of rows of static stators and vanes. The LPT also turns the driveshaft that powers the Rolls-Royce LiftFan, located behind the cockpit and ahead of the engine. This is a horizontally-mounted unit consisting of two contra-rotating fans, one directly above the other behind the cockpit and covered by a large door, which is only opened when the F-35B is hovering, performing a short takeoff or transitioning between horizontal and vertical flight. Each fan is driven by a separate bevel gear system contained in a common gearbox to which power is transmitted by a driveshaft which runs along the aircraft's longitudinal axis. In the hover the driveshaft delivers 28,000shp to the LiftFan's clutch-and-bevel-gear system so that the unit provides downward thrust as a column of cool air, along with a pillar of hot gas from the engine's tailpipe, known as the Three-Bearing Swivel Module, or 3BSM. This remarkable piece of equipment consists of three articulated sections of titanium

Sensors give the pilot unlimited all-round day/night vision... if the pilot looks down in the cockpit they see what's underneath

PHOTO: JAMIE HUNTER/AVIACOM

Right: dare we say it – a top glass cockpit like no fighter pilot's 'office' before. Main features, from left to right, include: the sliding throttle, shaped to act as a hand rest; undercarriage lever (red light showing); an instrument panel given over entirely to the touchscreens of the PCD, the lower sections of which are divided into 'portals' displaying pilot selected systems information; and the sidestick (note the arm brace) which offers both conventional flight control and up and down/sideways control in vertical landing mode

Below: aircraft nearest the camera are F-35Bs, parked with LiftFan and Auxiliary Air Inlet Doors doors open

In the hover the driveshaft delivers 28,000shp to the LiftFan's clutch...

nozzle casing, each section connected to the others and driven by its own ring bearing. It can direct air through a 95-degree range, from five degrees forward to horizontally aft. Interestingly the ring bearing actuators for the 3BSM are powered by 'fueldraulics', some of the jet fuel being bled off and pressurised to 3,500psi, functioning as hydraulic fluid to drive the servo-valve actuators. The 3BSM can swivel fully from horizontal to vertical in 2.5 seconds, completely redirecting all the thrust downwards. The final component the vertical lift/control system is the pair of 'Roll-Posts', variable-area nozzles underneath each wing that provide roll control in hover mode by directing bypass air from the engine through a pair of flap-type titanium doors.

Together with the downward thrust produced by the LiftFan and the two wing-positioned 'Roll-Posts', the F-35B can turn 15,700lb of dry tailpipe thrust into 39,400lb of thrust directed vertically downward – in less than three seconds!

As the hover demands very high power, behind the LiftFan's big inlet door are a pair of Auxiliary Air Inlet Doors (AAIDs) which provide additional air for the engine. Below the LiftFan, the variable area vane box (VAVB) directs the cool air driven downwards vertically by the LiftFan. The VAVB's aluminium louvered doors can be angled all the way from 45 degrees back, through fully vertical to five degrees forward.

In good hands

I sit down in the cockpit under the watchful eyes of – unlikely as it may sound – Kenn and Barbie. Kenn Cooper and ex-F-18 driver Craig Dalle (callsign Barbie)

THE SEAT

While at Farnborough I got the chance to examine the ejection seat closely and, unsurprisingly, the Mk 16 is as advanced as every other aspect of the F-35. Having flown while seated upon many different ejection seats (and not all Martin-Baker) ranging in age from a Vampire T11's MB Mk3, up to the Harrier T10's Mk10, the common denominator was that none was particularly comfortable, and all were a bit of a faff to strap into.

With the Mk16 you simply sit down, fasten the harness and click your Personal Equipment Connector into place. Then remove one pin and push the handle to 'Armed'. There are no leg restraints to put on even before you get in and then have to attach to the seat, as they're built into the aircraft, and you don't even have to adjust the rocket motor to accord with your weight. Getting out is even easier, as when you pull the 'arm/safe' handle back to 'egress' it automatically ejects the PEC!

know the systems inside out and back-to-front, so I'm in good hands. The first thing that strikes me is just how clean the cockpit and panel are. There are very few switches, knobs and levers, and even controls you'd think vital for a STOVL aircraft, such as nozzle and flap selectors are conspicuous by their absence. All you really have are the engine start switches, undercarriage lever, emergency jettison button, landing lights, park brake… and that's pretty well it. Everything else is controlled either via the touchscreens or by voice control. Another item missing is the HUD. Nevertheless, F-35 pilots are presented with a truly phenomenal amount of information, much of which is displayed in their helmet visors. In fact, and unsurprisingly, this aircraft's ancillaries (such as the ejection seat and pilot's helmet) are just as sophisticated as the aeroplane itself.

The cockpit is dominated by an L-3 panoramic cockpit display (PCD) with touchscreen control and active matrix liquid crystal displays. The PCD features dual 250 x 200mm screens, mounted on either side of a centrally located 500 x 200mm display. The big screen has a 2560 x 1024 pixel display while the smaller two are 1280 x 1024. They're extremely clear and easy to read. The upper part of the large screen is primarily for sub-system information, such as engine gauges, fuel quantity and undercarriage status, caution and warning systems, plus autopilot/auto throttle and navigation information, and lots more. Tactical information is displayed on the lower part of the screen and is split into four segments called 'portals'. The pilot can place anything anywhere and even change the size of the portals.

While the Harrier was famed for taking the drama out of deck landings, the F-35B makes them easy

Symbology at the bottom left of the display on the F-35B's PCD shows the status of the 3BSM and LiftFan. In the centre of the console is a battery-powered standby flight display. However, most of the information is displayed within the pilot's visor, while situational awareness is enhanced by a voice command system that issues directional threat warning messages.

On the right side of the cockpit is the sidestick, which as well as operating the ailerons and elevator conventionally also enables the pilot of the STOVL variant to hover the aeroplane. The throttle is on the left and moves through a linear slide rather than a rotary arc. Both sidestick and throttle are liberally studded with switches and buttons and the HOTAS 'switchology' is pretty complex, although interestingly there isn't a trim button.

Starting the engine is easy – just turn on the IPP (a sort of APU) then set the engine switch to run and it… well; runs. Taxying is very straightforward: the nosewheel steers through the rudder and for tighter turns you can adjust the steering gain. The field out of view out of the forward hinged canopy is good, although as long as the synthetic vision Distributed Aperture System is functioning correctly the windscreen could be opaque. Out on the runway of the simulated Nellis AFB, I run through the pre-takeoff checks and search in vain for the flap selector, until Barbie reminds me that the flaps are purely automatic. Take off is simple – line up, full 'dry' power then into afterburner. The acceleration is phenomenal, rotate at 150kt after a very brief ground roll then retract the undercarriage as quickly as possible! The speed just keeps building and in no time I'm flashing across the virtual desert at M0.9 and 100ft – what a rush it would be to do this for real! Clever symbology shows when your vector will coincide with the ground – a useful safety factor.

After a very rapid climb to 25,000ft I try some slow flight, but the computer won't let a full aerodynamic stall develop; instead the sink rate simply increases. I add power until the sink rate is arrested at 120kt, then Kenn says "you can loop it from there – just go to full afterburner and pitch up." I can scarcely believe its possible but do as I'm told – and it works as advertised. The power and control available is incredible, yet despite everything the Lightning is just so easy to fly. The roll rate is pretty rapid, but the overwhelming characteristic is just how precise control feels around all three axes. As I'm more interested in flying than fighting in the sim, I don't have time to examine the myriad weapons available, but can't resist dropping a pair of 2,000 pounders on an 'enemy building'. As with every other aspect of the F-35 (with the possible exception of the HOTAS, which clearly takes some learning) target cueing, aiming and bomb release are all perfectly straightforward. I don't miss.

Heading back to the virtual Nellis at M0.9 takes no time at all, but as the field comes into view I realise that although the throttle's a long way back, the F-35 isn't decelerating as much as I'd expected. Sensing my surprise Barbie explains that "it really doesn't like to slow down" so I thumb the airbrakes out to help get the speed below the 300kt VLO. Having selected the undercarriage down I look instinctively for the flap lever, then remember there isn't one!

As Nellis has an elevation of about 1,900ft, I disregard the pressure altimeter and use the RadAlt instead. Having flown a reasonable circuit with the throttle in manual and a Vref of 150kt to a touch and go, I turn downwind at 250kt, re-select 'gear down', punch the 'convert' button and turn back towards the runway. (You can press the convert button at any speed, but the computer simply won't engage the LiftFan above 250.) Symbols on the PCD show that the F-35 is ready to hover, so I simply press the speed command button on the throttle 'in'.

Air speed controlled by a button

Air speed is now controlled by clicking the speed command button up and down to change the selected speed in the

Balancing the thrust of the engine-driven LiftFan in vertical flight, the segmented tailpipe curves to deflect jet exhaust downwards

Even flap deployment is automated – a feature we might like to see in future light aircraft

command box and you simply ignore the throttle and use only the stick: push forward for down, back for up, left to shift left and right to shift right – it really is that simple. Barbie recommends using sixty knots initially, and then slowly reducing as the runway's threshold is approached. He also gently reminds me to stay off the rudder, unless I want to make a 'pedal turn' about the vertical axis. Once over the runway numbers I set 'zero' in the speed command box.

Although its been about fifteen years, I remember vividly that as the Harrier transitioned to purely jet-borne flight it all felt a little 'knife-edge'. As it slowed to a stop in the sky, somewhat improbably poised on four columns of screeching, scorching air, I was very aware that the pioneering British VTOL jet could suffer divergent directional stability if an intake was blanked by yaw while in the hover, and could suffer the same thing in the low speed range when transitioning to and from wing-borne flight. In fact, this situation was so serious (it's a sort of aerial ground loop that almost always ends with an accident) that Harriers were fitted with a device that senses if yaw is starting to develop and shakes the relevant rudder pedal as a cue for the pilot.

The Harrier was a product of a very different technological time – and only the very best pilots were streamed to fly it.

Use only the stick: push forward for down, back for up, left to shift left and right to shift right – it really is that simple

Well, the F-35 is nothing like that. There are no issues with divergent directional stability or a pedal-shaker. In fact it really does seem extremely easy to fly. Of course, having never flown a real F-35 I can't comment on the fidelity of the simulator, but even if a real one is two or even three times harder than the sim, it's still clearly pretty straightforward to fly – which is how it should be. Indeed, along with all the other tasks that a 21st century fighter pilot must perform, simply flying the aircraft is probably the easiest bit!

In fact the F-35 feels rock-solid and very stable as I ease the stick forward and sink onto the runway. Emboldened by my success I fly a STOL takeoff (full afterburner, stick back at sixty knots) then return for some more advanced hovering, including some brisk pedal turns, before descending to twenty feet and hover-taxying along the myriad taxiways at ten knots. I doubt you'd do this in real life as it wouldn't do the tarmac any favours at all (I saw a real F-35 hover at Farnborough the day after my sim flight, and the amount of energy being directed downwards was extraordinary), but it is good fun, while looking straight down through the floor at what is underneath the aircraft is simply surreal. As an experiment I push the stick forward sharply to try and produce a heavy landing, but the computer simply won't allow touchdowns with a sink rate above 750fpm.

As the fuel state is now quite low I try a vertical takeoff and quickly pull the stick back – it goes up like a rocket powered lift. One more vertical landing and its irrefutable – Lockheed Martin has done an amazing job in making an incredibly complex aircraft remarkably *uncomplicated*.

But what a machine! STOVL, stealthy and supersonic, its 'fused' sensor system and stealth design mean the F-35B pilot sees everything, but no one sees the F-35. To paraphrase (I think) Abraham Lincoln, if you're the kind of fighter pilot that likes this sort of thing, then this is very much the sort of thing that you'll like! ■

NOT JUST A 'TALKING HAT'...

The pilot of a Lightning II wears a very sophisticated helmet, which incorporates a Helmet Mounted Display system, or HMD. Made predominantly from Kevlar and weighing less than two kilogrammes (including the oxygen mask), the helmet features active noise reduction and a unit which provides the pilot with an 'out of the canopy display' which ensures that the pilot is continually looking outside in a tactical situation. Furthermore the onboard integrated system presents 'fused' data from all the sensors and data links onto the PCD in such a way that a pilot's situational awareness is enhanced to unheard-of levels, while simultaneously filtering out unnecessary information and prioritising threats and targets. Situational awareness is further enhanced by a voice command system that issues threat warning messages from the direction of the threat, while the aircraft's data fusion engine and the pilot-aircraft interface automatically display air and surface targets on the HMD. As the requirements of operating a stealthy aircraft on the modern battlefield are quite contradictory (emissions and transmissions need to be brief, extremely directional and towards friendly receivers) while networked operations with numerous friendly platforms require multiple emissions and a lot of bandwidth the F-35 will eventually have satellite communication technology.