Active-array-radar and towed-decoy upgrades are already in store for the Boeing F/A-18E/F

fare systems. Support electronics at each sensor send digitised waveforms via fibre-optic databus to the Raytheon-develop CIPs, where the data is fused to create coherent tracks for display to the pilot.

Boeing began flight-testing of a prototype APG-77 in its 757 flying tested in November 1997, following over a year of ground testing in a Northrop Grumman rooftop laboratory. The radar is installed in an F-22 forebody which has been attached to the nose of the 757. The aircraft is now being operated from Northrop Grumman's Baltimore, Maryland, plant to collect data to verify the radar performance model. Only the liquid-cooled radar and CIP are installed for these initial tests. In August, the 757 is scheduled to be returned to Boeing for installation of the other F-22 sensors, and integrated-avionics flight-testing is planned to begin in September. This will precede flight testing of the avionics suite in the fighter itself. The first radar-equipped F-22, the fourth of nine development aircraft, will not be flown until 1999.

Before then, beginning this May, the APG-77 will be exercised thoroughly in Boeing's F-22 Avionics Integration Laboratory (AIL) in Seattle. One of the 11 prototype radars to be built during the current development phase will be installed in the AIL tower at Boeing Field for early testing to identify anomalies before avionics flight-testing begins in earnest in the F-22. A Lockheed T-33 will be used as a calibrated airborne target, allowing data from the APG-77 to be compared with cross-section measurements now being made at Boeing's radar range.

A major part of the APG-77 development effort has been devoted to driving down the size and cost of the solid-state transmit/receive modules. That effort had made it possible to consider upgrading existing fighter radars with active arrays. The reasons for such an upgrade include increased capability and increased reliability: agile, electronically steered, beams allow near-simultaneous multi-mode operation; while radar performance degrades gradually with the failure of individual transmit/receive modules in the array.

Northrop Grumman is planning an ASEA upgrade of its APG-68 radar for the F-16C/D, dubbed the Agile Beam Radar (ABR). The APG-68ABR has been proposed for advanced F-16 versions offered to both Norway and the United Arab Emirates (UAE). Details are scant, but the APG-68ABR is likely to incorporate exciter, receiver and processor upgrades developed for the APG-68(V)X radar now being offered for the F-16. The upgrade increases reliability and reduces costs. The APG-68(V)X is to be available in 1999, a year ahead of the active-array APG-68ABR.

Raytheon Systems (formerly Hughes) has embarked, meanwhile, on a programme to upgrade its APG-73 radar in the Hornet which could see introduction of an active-array antenna soon after the improved F/A-18E/F enters service in 2001. The ASEA upgrade will build on hardware and software improvements, now in production, which give the APG-73 the ability to generate high-resolution ground maps comparable with those produced by the company's APG-70 radar in the F-15E and ASARS-2 in the Lockheed U-2. While the US Navy plans to retrofit the reconnaissance module to existing F/A-18C/D radars, the active array may be limited to new F/A-18E/Fs.

MODULE COSTS

Successful launch of ASEA upgrades for both the F-16 and F/A-18 radars should reduce the cost of active arrays and help JSF designers meet tough targets for avionics affordability. The JSF programme office hopes to reduce both acquisition and operating costs by increasing avionics integration beyond that achieved in the F-22. A key element of the planned JSF avionics suite is the multi-function integrated radio-frequency system (MIRFS). This is essentially a nose array combining radar, communication/navigation/-identification and electronic-warfare functions.

Hughes (now Raytheon) and Westinghouse (now Northrop Grumman) were awarded contracts in February 1996 to demonstrate a lightweight, low-cost, multi-function nose array (MFA). Ground tests of competing MFAs will begin in 1998, leading to flight tests in late 1999.

So far, neither of the JSF concept-demonstration teams – led by Boeing and Lockheed Martin – have selected a MIRFS supplier, but Lockheed Martin and Northrop Grumman have agreed to fund a joint effort to flight-test the JSF avionics architecture, including the MFA. The Co-operative Avionics Testbed (CATB) project involves modifying Northrop Grumman's BAC One-Eleven with the sensors, processors and software for the proposed mission avionics. The aircraft will be equipped with the Raytheon (formerly Texas Instruments) integrated core processor selected by Lockheed Martin for its proposed JSF, which will handle all signal and data processing for Northrop Grumman's MFA, shared-aperture electro-optical/infra-red sensors and electronic-warfare system. CATB flight testing is scheduled for mid-1999. Boeing may flight-test its JSF avionics architecture in the 757 testbed.

INTEGRATED INFRA-RED

The F-22 is the first US fighter with a designed-in missile launch-detection (MLD) system, again because the stringent requirements of stealth demand an integrated approach. The MLD, developed by Lockheed Martin company Sanders, consists of conformal infra-red (IR) sensors mounted above, below and either side of the F-22's forward fuselage. They are the only IR sensors on the aircraft, as an infra-red search-and-track (IRST) system planned for the fighter was cancelled for lack of funds. Provision has been made for an IRST, however, which could be used to accommodate an IR targeting system in a potential precision-strike derivative of the F-22, considered a likely replacement for the US Air Force's F-15Es and Lockheed F-117s.

The threat posed by shoulder-launched, IR-guided, surface-to-air missiles which cannot be detected by traditional radar-warning receivers is spurring the development of missile-warning systems (MWSs). It has been calculated that 80% of combat-aircraft losses between 1958 and 1992 – and 75% of US losses in the Gulf War – were to IR-guided missiles, but most fielded self-protection systems provide warning of radar-guided threats only.

There is a bewildering array of systems already available or under development for retrofit to current fighters. Most available MWSs use passive ultra-violet (UV) sensors, but there are systems now under development incorporating "two-colour" IR sensors which are less prone to false alarms. The F-22 MLD, for example, uses a staring (non-scanning) two-colour IR sensor.

Available MWSs include the Cincinatti Electronics/Raytheon AAR-44, Northrop Grumman AAR-54, Lockheed Martin Sanders AAR-57 and Daimler-Benz Aerospace/Litton AAR-60. In development are two-colour-IR upgrades of the AAR-44 and AAR-57, and an advanced IR MWS from Northrop Grumman designated the MIMS-2000.

The imaging-UV AAR-54 is in production for UK and Australian helicopters and UK, US and Portuguese transport aircraft and is being flight-tested by Norway for possible use on mid-life update (MLU) F-16s. Six MWS sensors have been installed in two wing pylons ▶