

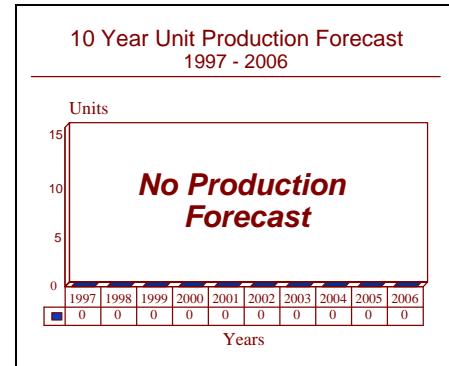
ARCHIVED REPORT

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Foxhunter (AI-24) - Archived 11/98

Outlook

- Unique to Tornado F.3
- Production ceased in 1991/92
- No future orders forecast, but Stage 2 upgrade continues



Orientation

Description. I-band pulse-Doppler radar optimized for airborne interception.

Sponsor

United Kingdom Ministry of Defence Procurement Executive

Contracts Branch CB/AWL31B
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St Georges Court
14 New Oxford Street
London WC1A 1EJ
United Kingdom
Tel: +44 171 632 6014

Contractors

GEC-Marconi Avionics Limited
Radar Systems Division
Crewe Toll, Ferry Road
Edinburgh EH5 2XS
United Kingdom
Tel: +44 131 332 2411
Fax: +44 131 332 0690
(Prime contractor)

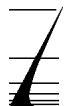
British Aerospace plc

Warwick House
Farnborough Aerospace Center
Farnborough
Hants GU14 6YU
United Kingdom
Tel: +44 1252 37 32 32
Fax: +44 1252 38 30 00
(Production of Tornado F.3)

Motorola Inc
Motorola Center
1303 East Algonquin Road
Schaumburg, Illinois (IL) 60196
USA
Tel: +1 847 576 5000
Fax: +1 847 576 3258
(32-bit parallel processor)

Licensee. No production licenses have been granted.

Status. Out of production; in service with extensive modification programs.



Total Produced. A total of 257 Foxhunter radars were supplied for 186 Royal Air Force and 24 Saudi Arabian Tornado F.3s.

Application. Air Staff Target 395 called for long-range detection of aircraft approaching at low altitude, the measurement of position and velocity of multiple targets, target illumination throughout the engagement

with Skyflash MRAAM, the detection and tracking of targets at short range, air-to-air combat using SRAAM and cannon, and navigation. As originally envisaged, Foxhunter would be supported by the Nimrod AEW (now Boeing Sentry AEW.1) and IUKADGE system.

Price Range. The price could not be determined due to limited contractual information.

Technical Data

Frequency:	I-band
Range:	100 miles+

Design Features. Foxhunter (designated AI-24 in UK service) is a pulse-Doppler radar operating in the I-band (3 cm; 8-10 GHz). The entire system consists of an antenna and scanner, transmitter and receiver, signal processor, and radar data processor. The antenna is based on the Marconi-Elliott twist-reflecting cassegrain type combined rigidity and light weight, with extremely low levels of spurious radiation lobes. The antenna has two reflectors, a front hyperbolic subreflector and a larger rear parabolic reflector. The scanner drive employs a hydraulic drive mechanism with high-grade servos to achieve the beam pointing and stabilization demanded while the aircraft is maneuvering under conditions of high G-forces and rapid rates of roll.

Foxhunter utilizes a pulse-Doppler technique known as frequency-modulated interrupted continuous wave. The transmitter uses traveling wave tube technology and offers both pulse and pulse compression modulations. The signal processing system is built around fast fourier transform (FFT) techniques of frequency analysis. This filters the signal returns into narrow channels enabling target echoes to be segregated from clutter returns, giving a uniform detection threshold against all target velocities. Digital data display removes clutter and presents a clear television image enabling the operator to concentrate on tactics.

The radar comprises five primary units. First, the aerial and scanner group includes a multifrequency aerial covering the prime radar, the continuous wave illuminator and the IFF bands. High gain is achieved from the cassegrain reflector and monopulse feed, and agile tracking is provided by a hydraulically actuated low inertia aerial. Second, the transmitter group uses a Traveling Wave Tube (TWT) with high mean power. The integral CW illuminator guides the MRAAM, and pulse and pulse-compression modulations are available. Third, the receiver group has a very low noise factor and is optimized for handling high clutter and low signal returns. Fourth, the signal processor group produces spectra corresponding to all received signals

in digital form and eliminates clutter, interference and jamming signals, presenting only target-related spectra to the operator. The fifth unit is the Radar Data Processor.

The radar is made up of 12 liquid-cooled LRUs forming two basic groupings. The front end uses analog techniques, while the back end uses digital processing. The radar transmitter is centrally located with the other LRUs grouped around it. The radar features low weight through the use of magnesium (rather than aluminum) for cast components, plated aluminum instead of copper for the cabling and waveguides, and structural components made of honeycomb or composites.

There are six modes available to the operator. The radar is constructed as a cylinder supported on four anti-vibration mounts. The radome hinges to starboard, allowing access to the antenna assembly. The antenna assembly also hinges to starboard, allowing access to the remaining Line Replaceable Units (LRUs). The cooling, hydraulic and electrical connections between the mainframe and the peripheral LRUs are all made with quick release couplings to expedite the replacement of faulty components.

Foxhunter has built-in test equipment (BITE). Each LRU contains its own microprocessor test center which carries out both continuous and interruptive monitoring of faults. The radar's main computer exercises overall control and sequences fault interrogation. Second line testing of LRU serviceability and fault diagnosis are carried out by two types of automatic test equipment (ATE).

Data on each tracked target are produced on the navigator's tactical electronic display, which gives an overall view of the entire tactical area. Weapon selection is then made and the attack can be initiated employing head-up or head-down target data. As the attack develops, the navigator continues to process target data and to monitor the overall tactical scene. An IFF interrogator is integrated with the radar and

correlated returns are displayed, hopefully distinguishing between hostile and friendly signals. The Tornado crew operates the system via controls and displays in both cockpits. From the rear cockpit, the navigator controls two TV tab displays, each with a multifunction keyboard, and the radar. In the front cockpit the pilot has a TV tab monitor and a stick-mounted instant control override switch.

Operational Characteristics. Foxhunter is designed to locate and track subsonic and supersonic targets at

ranges in excess of 100 nm at both high and low levels. Although it is intended to form part of an overall defense system, the equipment has been designed to operate independently, since either the ground or AEW control environment may be degraded by countermeasures or physical attack. Foxhunter-equipped aircraft are integrated into the overall UK Air Defense Ground Environment, unified by the Joint Tactical Information Distribution System (JTIDS) ECM-resistant datalink fitted into the aircraft.

Variants/Upgrades

Stage 2 upgrade. Originally scheduled for introduction in August 1990 but delayed for five years, Stage 2 was a preplanned product improvement intended to improve close combat capability, target data handling, and ECM

resistance. Specific improvements include modified transmitter and receiver paths, a redesigned data processor, and software upgrades.

Program Review

Background. A possible air defense role for the Panavia Tornado was announced when the Interdictor/Strike (IDS) program was launched in 1968. Low-key studies were initiated on the concept of a Panavia Tornado Air Defence variant during 1969. The United Kingdom Ministry of Defence issued Air Staff Target (AST) 395 in 1971 covering the development of an interceptor with advanced technology radar and Skyflash air-to-air missiles.

In early 1974 it was announced that Marconi-Elliott (subsequently GEC Avionics) had been awarded a major contract by the MoD to develop the initial phase of the advanced airborne interception radar system envisioned for the Panavia Tornado ADV. At the same time, it was announced that Ferranti would play a role in the development as a major subcontractor to the program. The contracts were of the cost-plus type with the MoD acting as program manager.

Full-scale development of the Tornado ADV was authorized by the MoD on March 4, 1976. In October 1979 Marconi announced that the MoD had awarded it a contract for the initial production of an airborne interception radar. At that time (1979), prototypes had been built and tested, and a modified Buccaneer aircraft had been fitted and prepared as a testbed for the flight trials of the Tornado AI radar.

The first flight of a Tornado F.2 equipped with Foxhunter AI-24 took place in June 1981. Flight trials also continued aboard modified Canberra and Buccaneer aircraft. The first two production Tornado F.2s were rolled out on March 28, 1984, and after flight trials were delivered to Boscombe Down in the summer

of the same year. The initial production batch of 18 aircraft began to enter service with the RAF, and 12 of the aircraft had been flown by the middle of 1985. It is not clear exactly how many of them were fitted with Foxhunter, but by December 1986, all 16 Operational Conversion Unit F.2s had been fitted with the radar.

In October 1984, the first BAe Tornado F.3 left the Wharton Factory. The Tornado F.3 is the definitive version of the Tornado ADV and formed the bulk of the RAF's requirement. By December 1986, 11 F.3s had flown, of which nine had been delivered to RAF Conningsby for 229 Squadron (OCU). The next two Squadrons to become operational were Numbers 5 and 29, then equipped with BAe Lightnings and McDonnell Douglas Phantoms respectively. A Tornado F.3 Squadron formed every six months until 1990, when the planned force total of seven squadrons was reached.

Foxhunter has been continuously upgraded, with the main computer being uprated in 1985. The development program was hampered by the limited number of preproduction models and airframes in which to evaluate them. The loss of a Buccaneer over the Irish Sea while on flight trials with the new radar, and the subsequent grounding of that aircraft type, was a major source of delay. GEC Avionics also pointed out that the RAF continually adjusted the radar requirement. An often overlooked feature of the old cost-plus system was the opportunity it offered the client to change specifications more easily while in mid-development.

In early 1987, the MoD announced that the government was defining a program with GEC Avionics to resolve the problems and achieve an acceptable standard. The



problems included difficulty with multi-target tracking, vulnerability to jamming and non-electromagnetic compatibility with Skyflash. In addition, the original contract did not specify compatibility with the US AMRAAM missile, calling only for operability with BAe's Skyflash. The MoD was also said to be anxious to place the program on a fixed-price contract footing.

GEC Avionics was restructured in the wake of the Nimrod AEW cancellation. An ancillary to the main reorganization was the transfer of responsibility for Foxhunter radar to Marconi Defence Systems Limited. A deadline was imposed, calling for a resolution to Foxhunter's problems by the end of 1987. Confirmation that any further work beyond that point would be undertaken under a fixed-price contract was also given. At the same time it was revealed that following an "unanticipated capability" demonstrated by Tornado F.3 in close combat, the Foxhunter specifications were to be altered.

New modes would be provided by increasing the radar data processing capability using a Motorola 32-bit parallel processor. The RAF hoped the system would fully meet its specifications within two to three years. However, by April 1987 the RAF was becoming frustrated by the lack of progress, and looking at new alternatives became a possibility. It was also reported that the RAF had stipulated no more than US\$150 million be spent on turning the program around. This news came when RAF aircrews claimed to experience serious overall problems with the system's level of efficiency. Reports also surfaced that British Aerospace had complained to the United Kingdom MoD that delays in receiving Foxhunter radars continued to hinder production of the Tornado F.3 at its Wharton facility.

By November 1987, the RAF announced that the interim radar was performing acceptably and was an improvement over the system used in RAF Phantom interceptors. The MoD said that specifications for Foxhunter had been agreed upon, and a fixed-price contract only awaited an agreement on price to be signed. In late December 1987, the fixed-price bid for the completion of radar development and the manufacture of 165 production units was handed to the UK MoD by Marconi Defence Systems. Two standards of radar featured in the bid: an interim solution for early fitting to the RAF Tornado F.3 and export aircraft, and a (definitive) production solution incorporating greatly enhanced processing capability. It was anticipated that the second option would be available for export as a retrofit package.

In December 1987 deliveries of the interim standard radar system were keeping pace with new aircraft

deliveries. Detection performance had improved with software changes and was close to RAF specifications. In March 1988, Marconi Defence Systems announced that agreement had finally been reached with the MoD over Foxhunter. The production radar featured increased automation and reserve computing capacity to cope with new weapons, communications, and IFF systems planned for the Tornado F.3 in current and future update programs.

In April 1989 the first Stage 1 Foxhunters were delivered to the RAF. The later Stage 2 upgrade was scheduled for introduction from 1990 onward but remained under development for several years. This was intended to improve close combat capability, target data handling and ECM resistance. The program was split into two because the new radar multi-microprocessor was not available until after the 227 radar systems were delivered. The new processor allowed the introduction of beyond-visual-range threat assessment, while improving Foxhunter's disappointing multitarget performance in track-while-scan mode.

Following a contract signed in 1985, Riyadh agreed to buy 48 BAe Tornado IDS and 24 BAe Tornado ADVs, the latter to be equipped with Foxhunter radar. The whole package, which included quantities of BAe's Hawk trainer plus unspecified support equipment, was valued at about US\$7 billion. By the middle of 1988, a further letter of intent for 48 Tornado F.3 was placed as part of a contract worth about £10 million British. This also reportedly included 24 Tornado IDS, 54 Hawks and 60 Westland Black Hawk helicopters. Rumors started to spread in mid-1990 that the second batch of Tornado F.3 aircraft would be canceled. Initially these were dispelled by the Iraqi invasion of Kuwait but, following the poor performance of the Tornado F.3 and the excellent reputation acquired by the F-15, the option was dropped and no further acquisition of the Tornado F.3 was planned.

Tornado F.3 aircraft were among the first to be deployed to the Arabian Gulf after the Iraqi invasion of Kuwait in August 1990. A composite squadron of 12 aircraft were deployed to Bahrain, this subsequently being increased to 18, with basing moved to the Saudi Arabian mainland. The 24 Saudi Arabian Tornado F.3 aircraft had been delivered by this time. Foxhunter then revealed a whole new clutch of problems, the most serious being a habit of reverting unexpectedly to memory mode while tracking multiple targets. When switched back to track mode, many of the targets were found to have been lost and required reacquisition. It has also been disclosed that because of the Tornado F.3's poor dogfighting ability and inadequate electronic countermeasures – many F.3 aircraft do not even have

chaff/flare dispensers – RAF fighter pilots were under strict orders not to fly over hostile territory.

Once hostilities were started, the Tornado F.3 force was restricted to “deterrence patrols” within Saudi Arabian airspace. Tornado fighters sent to the Gulf had a number of upgrades applied to them, including the provision of HOTAS controls and an improved version of the Foxhunter radar. In an address to the House of Commons on April 30, 1991, Defence Procurement Minister Clarke stated that “the improvements applied to Foxhunter were not absolutely uniformly faultless.” The Gulf modifications to the Tornado F.3 were to be expanded to cover the rest of the fleet, but the major mid-life upgrade for the Tornado F.3 was canceled in early 1991.

During 1992, sources within the MoD stated that at least two squadrons of Tornado F.3 would be disbanded within the next few years. The first such disbandment took place in June 1993, reducing the front-line force to six squadrons. Under the 1993 UK defense review, the RAF Tornado F.3 force was reduced to 100 aircraft, with further reductions likely.

During early 1994, the Italian Air Force agreed to lease up to 24 Tornado F.3 aircraft made surplus by the

reductions in RAF force levels. This was a response to the increasingly serious situation in the former Yugoslavia. The primary determinant in this agreement was commonality between the Tornado F.3 and the existing Italian fleet of Tornado IDS strike aircraft. The first group of twelve aircraft were delivered in September 1995, with the rest to follow in 1996/97.

A series of air combat trials and other tests using the Sea Harrier FA.2 showed that this Royal Navy aircraft had a very marked combat edge over the Tornado F.3, primarily due to the Sea Harrier’s combination of the Blue Vixen radar and the AIM-120 missile. This revived the concept of replacing the Foxhunter radar with Blue Vixen on at least some Tornado F.3 aircraft.

As part of the RAF’s £125-million- (US\$194 million) upgrade to the Tornado fleet, an announcement came in March 1996 that BVR AMRAAM (advanced medium-range air-to-air missile) and ASRAAM (advanced short-range air-to-air missile) would be adopted. Also part of this upgrade was the Stage 2 improvement program to Foxhunter, taking advantage of the radar’s compatibility with the medium-range missiles.

Funding

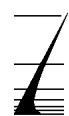
The development program was funded by the United Kingdom Ministry of Defence under a contract awarded in early 1974. A further contract was awarded in 1979 for the supply of preproduction Foxhunter radars, valued in the region of US\$30 million. The 1990 Defense White Paper stated total expenditures for Foxhunter as approximately £960 million (US\$1.728 billion). Foxhunter program was not provided in the UK Defence Estimates after that time.

Recent Contracts

No recent contracts have been identified.

Timetable

	1968	Air defense role for Panavia Tornado identified
	1969	Studies of possible ADV variant development
	1971	UK MoD issued Air Staff Target (AST) 395
	1974	Marconi awarded contract for advanced radar
	1974	Ferranti announced as major subcontractor
Mar	1976	FSD for Tornado ADV authorized by UK MoD
Oct	1979	Initial production of Foxhunter began
Jun	1981	First flight Tornado F.2's
Mar	1984	First two production Tornado F.2 rolled out
	1985	Initial production Tornado F.2 entered service
	1985	Order for Tornado F.2 from Oman
Sep	1985	Order for Tornado F.2 from Saudi Arabia



Feb	1987	AI-24 contract for renegotiation
Mar	1988	Foxhunter contractual problems resolved
May	1988	100th Foxhunter delivered
Jun	1988	Westland awarded test equipment contract
Jul	1988	Order for Tornado F.3 from Saudi Arabia
Apr	1989	Stage 1 production Foxhunters delivered to RAF
May	1990	Tornado production batch 8 canceled
Aug	1990	Operation deployment of Tornado F.3 as part of Operation Granby
Jan	1991	Combat debut of Tornado F.3
Dec	1992	Foxhunter production ceased

Worldwide Distribution

UK - 203 (for 162 RAF Tornado F.3 aircraft)

Saudi Arabia - 30 (for 24 Royal Saudi Air Force Tornado F.3 aircraft)

Italy - 24 (for 24 F.3 aircraft on 10-year lease from the UK)

Forecast Rationale

Production of the Tornado F.3 ended in 1992, and Foxhunter along with it. The mid-life upgrade of the Tornado F.3 fleet, scheduled to take place during 1992-1997, was also canceled. As a direct result of the Gulf War, however, some of the planned work was undertaken on an emergency basis.

In March 1996, the idea of adopting AMRAAM and ASRAAM for the RAF's F.3 fleet was revived, which – together with full JTIDS capability (planned by December 1997) and the Foxhunter Stage 2 upgrade

(finally introduced in 1995) – is intended to keep the Tornadoes suitable to the RAF's needs until the Eurofighter 2000 enters service. The missiles will be drawn from existing stocks or orders, and likewise, no new Foxhunter radars are expected to be procured.

The production forecast has been deleted, reflecting the terminated status of the Foxhunter radar. Due to ongoing upgrade activity, this report has been maintained; however, it will be dropped from future supplements.

Ten-Year Outlook

No production is forecast.

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