ASTOR

Outlook

- U.K. MoD designates ASTOR radar and host platform aircraft as Sentinel R1
- All five British ASTOR-equipped aircraft are operational
- Raytheon likely to market the ASTOR design internationally in near future
- The ASTOR platform is complete; therefore, this report contains no forecast chart
- This report will be archived next year, December 2011

Orientation

Description. The Airborne Stand-Off Radar (ASTOR) is a long-range battlefield surveillance radar for the U.K. armed forces, incorporating synthetic aperture radar and moving target indicator technology in this role.

Sponsor

United Kingdom Ministry of Defence
Procurement Executive
Main Building, Whitehall
London SW1A 2HB
United Kingdom
Tel: + 44 171 218 90 00

Status. In operations service.

Total Produced. Five aircraft systems produced; an additional eight Ground Segment stations produced for the U.K.

Application. ASTOR provides corps commanders with primary intelligence in and beyond the immediate battle area. The primary tactical role of ASTOR is to deny surprise to an enemy and to assist in the organization of effective defenses in threatened areas. All solutions must provide considerable out-of-area capability.

Price Range. A fixed amount of funding, GBP950 million ($1.8 billion) in 2007 currency, was allocated for the ASTOR production program, which consisted of airborne and ground segments.

Contractors

Prime

Raytheon Systems Ltd	http://www.raytheon.co.uk, Harman House, 1 George St, Uxbridge, UB8 1QQ Middlesex, United Kingdom, Tel: + 44 1895 816200, Fax: + 44 1896 814829, Email: corporatecommunications@raytheon.co.uk, Prime

Subcontractor

General Dynamics C4 Systems	http://www.gdc4s.com, 8201 E McDowell Rd, Scottsdale, AZ 85252-3812 United States, Tel: + 1 (877) 449-0600, Fax: + 1 (877) 449-0599, Email: info@gdc4s.com (ASTOR Ground Segment)

Comprehensive information on Contractors can be found in Forecast International's "International Contractors" series. For a detailed description, go to www.forecastinternational.com (see Products & Samples/Governments & Industries) or call + 1 (203) 426-0800.

Contractors are invited to submit updated information to Editor, International Contractors, Forecast International, 22 Commerce Road, Newtown, CT 06470, USA; rich.pettibone@forecast1.com

ASTOR

Technical Data

	Metric	U.S.
Defined Characteristics		
Modes	Swath SAR Spotlight SAR	
MT		
Range	up to 300 km	up to 186.4 mi
Defined Characteristics		
Look-up mode		
Azimuth	270°	
Trackable targets	100+	
Look-down mode		
Azimuth	360°	
Trackable targets	100+	
Resolution (fixed targets)	0.5 m	1.64 ft
Minimum speed of trackable targets	10 kmph	6.2 mph

Design Specifications. ASTOR project definition studies were concluded in September 1996. The airborne component of the system includes several radar-equipped aircraft, which are backed up by a number of ground stations (the number of which has varied from 8 to 14). Secure datalinks enable imagery gathered by ASTOR to be disseminated quickly across the military establishment. ASTOR also provides 24-hour coverage in all weather conditions.

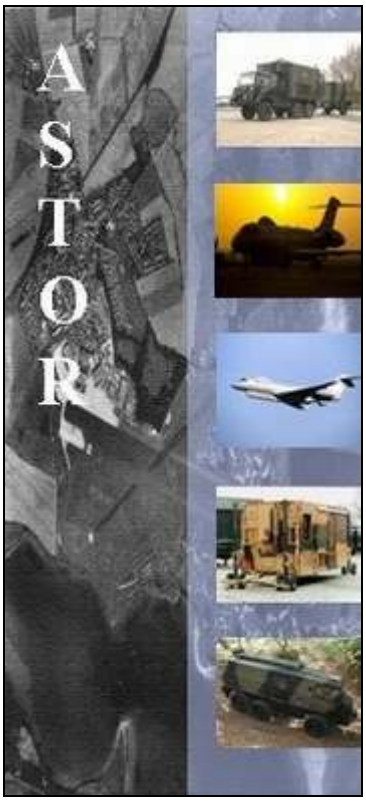
Compatibility is an important requirement. ASTOR must be NATO-compatible and able to interact with the Joint Tactical Information Distribution System (JTIDS) and the Multifunction Information Distribution System (MIDS). Ground stations will have to connect with such command information systems as Linked Operations and Intelligence Centers, Europe; the Battlefield Information Collection and Exploitation System; the Joint Operational Tactical System; and the Royal Air Force's Lynchgate intelligence information dissemination network. Also, large imagery intelligence files and other data must all be manageable.

Operational Characteristics. The main value of ASTOR is its ability to provide commanders with an overall battlefield display. Both enemy targets and friendly forces (stationary and mobile) are identified and tracked to provide a comprehensive overview. ASTOR operates in three modes: spotlight SAR, with 5-meter resolution for small-area surveillance of fixed targets; swath SAR, which provides large-area surveillance of fixed targets; and MTI, for large-area surveillance of moving targets (including helicopters) traveling at a minimum of 10 kmph. Airborne operators can analyze and transmit data securely and in near real-time to ground stations, where the target is further analyzed (i.e., located by longitude and latitude, classified, and assigned a priority number).

The system's operating altitude is between 12,802 meters (42,000 ft) and 15,240 meters (50,000 ft). From this height, its radar sensors are able to detect targets at a range of up to 300 kilometers (186.4 miles). Aside from battlefield scenarios, ASTOR could be used to monitor natural disasters, pollution, and smuggling activities. This potential may become clearer as further export possibilities are explored.

Variants/Upgrades

No variants or modifications have been developed.



Airborne Stand-Off Radar (ASTOR)

Source: U.K. Ministry of Defence

ASTOR in Flight

Source: Raytheon

ASTOR

ASTOR Ground Segment Station

Source: General Dynamics C^4 Systems

Program Review

Background. The ASTOR program can be traced to the Corps Airborne Stand-Off Radar (CASTOR) concept. Between 1983 and 1985, the U.K. Ministry of Defence evaluated two approaches to the CASTOR concept: a high-and-fast solution using SAR technology on board a Canberra, and a low-and-slow solution using advanced multimode conventional radar on board a Defender aircraft. The high-altitude SAR/MTI solution would provide the RAF with a means of locating targets in enemy rear areas. It would have a dual capability – a primary mapping mode and a secondary MTI mode. The low-altitude MTI solution was favored by the Army and would have been configured to provide a primary MTI mode supported by a secondary mapping mode.

Thorn-EMI was awarded a follow-on study contract in August 1983 to investigate the application of SAR for battlefield surveillance and to make recommendations to the MoD. The Concept Engineering Definition (CED) phase was conducted using subsystems from a series of radar developed by Thorn-EMI, together with new SAR techniques developed specifically for CASTOR. The core technology was provided by the system's Searchwater radar, already in service with the Royal Navy, Royal Air Force, and overseas clients. While not taking part in the CED for the original CASTOR program, GEC Avionics was involved as subcontractor of the SAR proposed by Thorn-EMI. The results of the high-altitude SAR/MTI CED were submitted to the MoD in 1985.

Ferranti (later GEC-Marconi, and currently BAE Systems) was awarded a contract from the U.K. MoD in April 1984 to provide a CASTOR solution to implementing the low-and-slow operation favored by the Army. Less than one month later, a modification of GEC-Marconi's Blue Falcon radar design was fitted on board a PB-N Defender. The Ferranti CASTOR was a compact, lightweight, all-weather radar that provided wide-area coverage against moving and fixed targets. It was a coherent-pulse Doppler radar operating in the I-band. The results of the CED carried out by Ferranti were submitted to the ministry concurrently with those of Thorn-EMI.

In June 1985, the MoD announced its intention to conduct competitive trials. In July 1986, the CASTOR program was renamed ASTOR. A MoD Request for Proposals was issued for ASTOR high-altitude SAR/MTI and ASTOR low-altitude MTI solutions over the period October/November 1986. Although Thorn-EMI had originally been involved only in the high-altitude SAR/MTI solution, the company was able to leverage work carried out on the Skymaster Advanced

Early Warning (AEW) program to adapt its Searchwater radar to the ASTOR low-altitude MTI requirement. Consequently, Thorn-EMI made proposals for both halves of the MoD's ASTOR Technical Demonstration Program. Both development contracts were awarded to Thorn-EMI, and both high-altitude SAR/MTI and low-altitude MTI solutions made extensive use of Searchwater/Skymaster technology.

In June 1986, the United States became involved in the ASTOR program when a Memorandum of Understanding was signed between the governments of the U.K., U.S., and France. The MoU envisioned cooperation in a joint program known as the Airborne Radar Demonstration System. France had been developing a battlefield surveillance radar system of its own, designated Orchidee. Orchidee was canceled in 1990 but was subsequently revived in simplified form following the successful use of the prototype during the 1991 Persian Gulf War.

Putting Theory into Practice

On July 21, 1987, Thorn-EMI was awarded two contracts by the U.K. MoD to provide technology demonstrators for its ASTOR requirement. The ASTOR low-altitude MTI solution was based on the Skymaster radar system and was used to investigate low grazing angles and image exploitation on board a PB-N 2T Defender. The principal difference between Skymaster AEW and Skymaster ASTOR is the software. The ASTOR high-altitude SAR/MTI solution was based on a Searchwater radar system, which was modified using technology developed by Thorn-EMI in association with the Royal Signals and Radar Establishment and GEC Avionics.

Flight tests of the low-altitude MTI solution were completed in late 1990. Those of the high-altitude SAR/MTI solution were completed by the end of March 1991. These technology demonstration program contracts expired at the end of 1991.

In July 1992, the U.K. MoD stated that it would be issuing equipment specifications during the first half of 1993 for the operational ASTOR system. The MoD stated that although details of the Army and Air Force requirements differed, there was sufficient common ground to make a single solution possible. This strongly suggested an orientation to the high-altitude SAR/MTI concept. This assessment was confirmed with the announcement of the preferred platforms, which included the Gulfstream IV, the Canadair Challenger, and the Dassault Falcon. The projected timetable included an initial batch of five aircraft, which were to be acquired around 1994-1995.

In August 1993, GEC-Marconi Avionics (now BAE Systems) was awarded a contract by the Defense Research Agency to develop a SAR to act as a functional prototype for the ASTOR system. This positively identified high-altitude SAR/MTI as the preferred solution and confirmed that the low-altitude MTI option had been discarded. The prototype radar was completed by 1995.

Also in 1993, the U.K. MoD announced that three project definition contracts for ASTOR would be placed by the first quarter of 1994. One would be for the new GEC-Marconi radar mounted (initially) in a BAe-111, with a Gulfstream V as the final solution; the second would be for the U.S. JSTARS radar mounted in an Airbus A320; and the third contract would be awarded to either one of the former Thorn-EMI, Thomson-CSF, Hughes, Grumman, or Norden.

A cardinal points specification was announced in November 1993, with the U.K. MoD inviting tenders from the industry to undertake the preliminary development (PD) phase of the ASTOR program in January 1994. In response, bids were submitted by the following teams: Loral/Racal Defence Systems/Logica; Northrop Grumman/BAE (bidding JSTARS); GEC-Marconi/Thomson-CSF/Westinghouse/EASAMS; Hughes/Siemens-Plessey/FR Aviation; Raytheon Electromagnetic Systems/UK Defence Research Agency/Hunting Defence Ltd; and Lockheed Martin/E-Systems.

In April 1995, teams led by Raytheon and Loral (now Lockheed Martin) won competitive 18-month PD study contracts. These proposals led to a full-scale engineering and production effort. The MoD reportedly had a goal of achieving Initial Operational Capability in 2001, and Full Operational Capability in 2003.

Competition Heats Up

Further details on the offerings of the Lockheed Martin and Raytheon teams were disclosed at the 1996 Farnborough Air Show. Both ASTOR models equipped five business jets, which were also equipped with three datalinks. Lockheed's model equipped the Gulfstream V, and Raytheon's was installed on a modified Bombardier Global Express. Both jets can fly at altitudes of 51,000 feet.

The rival companies assembled teams with several U.K. members, which likely reflected the MoD specification for 100 percent offset of the purchase cost. But the companies might also have considered that the U.K. MoD would be more inclined to select a system with good export potential – especially in view of NATO's parallel quest for an airborne ground surveillance system, for which the ASTOR system would be a prime

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candidate. Lockheed Martin's British subsidiary, Lockheed Martin U.K. Government Systems in Portsmouth, was designated to serve as that team's leader. Raytheon set up a new company, Raytheon E-Systems Ltd, Essex, U.K., to head up its ASTOR operations.

Though fully developed and immediately available, JSTARS aircraft, as originally offered, fell short of the specified ASTOR requirements in several areas. The JSTARS Boeing 707 cannot reach the specified altitude of 50,000 feet; its maximum altitude is 42,000 feet (Northrop Grumman officials, however, noted that JSTARS could perform the ASTOR's surveillance functions without reaching the specified height because its SAR imaging capability is superior). Also, JSTARS is much more expensive than competing aircraft, as its C^3I capabilities go beyond the ASTOR specifications.

Business Jet to Be Main Airborne Platform

The ASTOR-equipped business jet was envisioned primarily as a sensor platform, with three operator consoles integrated with a secure, jam-resistant datalink to send raw or processed sensor data to up to 14 ground stations. JSTARS was designed for use as an airborne command center and is equipped with 18 consoles. Northrop Grumman stated that it could lower the number of consoles for JSTARS sales to the U.K. MoD, which would reduce the system's cost. But another limitation of JSTARS was that its modified Boeing 707 had restrictions regarding landing on a short runway.

In the final judgment, however, the Lockheed and Raytheon proposals had some important advantages over those of their competitors. They offered innovative technology specifically tailored to meet the U.K.'s airborne ground-surveillance needs, and they offered brand new aircraft. In March 1997, ASTOR was given procurement approval from the U.K. MoD's Equipment Approvals Committee. Lockheed and Raytheon remained to submit their best and final offers.

JSTARS Returns to Compete as Wizard

Then, in a controversial move, the U.K. began reconsidering a JSTARS variant as an ASTOR contender in late 1997. A statement to this effect was sent to Lockheed Martin and Raytheon in September, followed by an official request of a best-and-final offer from Northrop Grumman in December. This re-evaluation was based on some crucial alterations to the radar and airborne platform. Under the new proposal, the radar would incorporate fourth-generation technology based on the U.S. Air Force's Radar Technology Insertion Program (RTIP); the host aircraft would be the Gulfstream V. This special variant of JSTARS, called the Wizard solution, would be smaller and highly capable, which in itself has appeal. However, the U.S. DoD's backing of this proposal was disconcerting to Lockheed Martin and Raytheon.

As reported by *Flight International* (February 4, 1998), in January 1998, a U.S. delegation of senior Northrop Grumman managers and Air Force staff discussed the new proposal with U.K. MoD Procurement Executive officials and Air Vice-Marshal Chris Coville. It became clearer over the course of 1998 that the JSTARS bid for ASTOR would also entail cooperative development of the RTIP for upgrade of the USAF's JSTARS, essentially an ASTOR U.S.-U.K. development effort. This turn of events became the source of a dispute between Northrop Grumman and Raytheon, as Raytheon claimed that it was to participate in the RTIP under a June 1997 contract struck between Northrop and Hughes, and if it did, Raytheon technology would be used to the detriment of Raytheon's own interests in the valuable ASTOR program. In November 1998, the U.S. Department of Defense stepped in and forced Northrop Grumman and Raytheon to cooperate regarding the RTIP. In that same month, the U.K. MoD dropped the ASTOR requirement for long-range electro-optical systems, opting to use unmanned aerial vehicles (UAVs) for that purpose.

In February 1999, the ASTOR fielding date, originally 2003, was pushed back to 2006. While the key competitors claimed they would be ready, it is believed that none could effectively meet the deadline. Tense negotiations followed throughout February and March. In late March, U.K. Defense Secretary George Robertson announced that the key players would deliver their final bids before a select committee prior to a decision being announced.

Raytheon Takes the Prize

Raytheon was announced as the preferred contractor in June 1999. The final contract, worth more than $1.3 billion, called for five ASTOR systems to enter service between 2005 and 2006. The system would consist of Raytheon's Advanced Synthetic Aperture Radar II mounted on twin-engine Global Express business jets by Canada's Bombardier. The contract also called for eight ground stations, to be produced by Motorola.

In August 1999, two months after Raytheon was announced as ASTOR's preferred contractor, Raytheon reported it would be building a new facility in Northern Ireland. The new software-development center is reportedly devoted to fulfilling Raytheon's U.K. contracts – primarily the ASTOR program.

In addition to the U.K. ASTOR program, Raytheon reportedly began to market the ASTOR radar on the

international market in December 1999. This radar was designated the Ground Surveillance Airborne Radar System (GSARS). Although no known contracts have been awarded for GSARS, the system was reportedly displayed by Raytheon at the Farnborough Air Show 2000.

In the fall of 2000, Raytheon awarded an $85.5 million contract to Motorola Ltd to provide ground stations and software for the ground segment of the ASTOR program. Another contract was awarded for production of an electronic warfare self-protection system. Meanwhile, under a $30 million contract, BAE Systems North America would provide the Defensive Aids Group sensors for the five ASTOR platforms. This EW sensor suite consists of the BAE ALR-56M radar warning receiver, the BAE AAR-57 Common Missile Warning System, the W. Vinten Series 455 chaff/flare dispenser, and the Raytheon High-Power Fiber-Optic Towed Decoy.

In June 2001, Raytheon issued a contract to Thales Defense Communications for application of its Local Area Subsystem (LAS) technology in the widespread and data-intensive ground Integrated Command and Control Subsystem (ICCS) environment. Additionally, Thales is to create the infrastructure and LAS for the ASTOR ground stations.

ASTOR-Configured Aircraft Platform Makes First Flight

On August 3, 2001, an ASTOR-configured Bombardier Global Express prototype made its first flight. A series of tests were conducted during the three-hour flight at altitudes up to 25,000 feet and speeds up to 288 mph. Flight trials (designed to validate the aerodynamic assumptions of the ASTOR-configured Bombardier Global Express) continued through 2002.

In February 2002, a Global Express aircraft was delivered to Majors Field (located at the Raytheon facility in Greenville, Texas) for modification to the ASTOR configuration before commencement of aerodynamic-validation flight testing. Once these test flights were completed, this aircraft was returned to the U.K. to be fitted with mission equipment and tested before being delivered to the No. 5 Squadron at the U.K. Royal Air Force base at Waddington.

In the spring of 2004, the bid for ASTOR to become part of NATO's Alliance Ground Surveillance (AGS) network was rejected. Instead, the Transatlantic Industrial Proposed Solution team led by EADS and Northrop Grumman won the NATO AGS contract.

The first integrated ASTOR aircraft, officially designated the Sentinel R Mk 1, made its maiden flight on May 26, 2004. During the four-hour, 24-minute flight, the aircraft reached an altitude of 15,500 feet (4,725 m), and all systems are said to have performed well. The remaining four aircraft are being modified at Raytheon's Broughton facility in Wales.

Ground Segment Running According to Plan

Progress on the ground segment of the ASTOR program continues on schedule. In early 2004, the ASTOR Ground Segment Integrated Project Team successfully completed the first ground segment "power-on" and subsystem built-in test. A wide array of equipment including datalinks, radios, and crypto gear were evaluated.

ASTOR Completes Capabilities Testing

In July 2008, Raytheon Systems and the U.K. MoD successfully completed capabilities assurance mission testing of the Airborne Stand-Off Radar system. Six CAM tests were conducted with one built on another in complexity to demonstrate how the system would work in an actual mission scenario. The team tested airborne components of the system on the ASTOR Sentinel aircraft. The team also tested tactical ground station aspects within the U.K. MoD infrastructure and rated the overall performance of the surveillance system.

ASTOR entered limited service in Afghanistan (more like "live fire" testing) where three ASTOR-equipped platforms were believed to be in various stages of limited or restricted operational use and testing. In December 2008, the U.K. MoD designated the ASTOR radar and host platform aircrafts (Nimrod MRA4 and Nimrod R1) as Sentinel R1.

Final ASTOR-Equipped Aircraft Delivered to RAF Testing

Raytheon delivered the fifth and final Sentinel R1 aircraft to the U.K. Royal Air Force at RAF Waddington during February 2009. With this handover, Raytheon's U.K.-based subsidiary Raytheon Systems Limited has now completed delivery of all Airborne Stand-Off Radar equipment to the U.K. Ministry of Defence. With the five Sentinel aircraft, Raytheon delivered eight ground stations (six tactical ground station units and two operational level ground station units), support vehicles, and an extensive and sophisticated support infrastructure. A 10-year contractor logistics support program sees RSL directly supporting the front line on operations and in training and logistics, including what is known as "Contractor Support to Deployed Operations."

All five Sentinel R1 aircraft (ASTOR-equipped Bombardier Global Express business jets) and eight Ground Segment stations became fully operational in 2009.

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Funding

The value of the program is estimated at GBP950 million ($1.8 billion).

Contracts/Orders & Options

No recent contracts valued over $5 million have been identified.

Timetable

Month	Year	Major Development
	1980	CASTOR program initiated by U.K. MoD
	1983	Thorn-EMI awarded CASTOR study contract; BAE Canberra chosen as platform for CED study
	1985	PB-N Defender chosen as demonstrator platform; U.K. MoD demonstrator contract decision
	1986	U.K., U.S., and France MoU collaborate on CASTOR; CASTOR renamed ASTOR; MoD issues RFP for low-altitude MTI solution and SAR/MTI solution
	1987	Thorn-EMI selected to provide low-altitude MTI and SAR/MTI solutions
Sep	1989	Thorn-EMI hands ASTOR Defender to RAF
	1990	Low-altitude MTI demonstration program completed
Mar	1991	High-altitude SAR/MTI demonstration program completed
Jan	1992	Completion of technology demonstration program analysis
	1993	GEC-Marconi wins development contract
	1994	NATO establishes ground surveillance system project office
Apr	1995	Parallel PD contracts awarded to Raytheon and Lockheed Martin teams
Sep	1996	PD reports submitted by Raytheon and Lockheed Martin teams to U.K. MoD
Mar	1997	U-2 and JSTARS eliminated from U.K. competition; U.K. Equipment Approvals Committee approves ASTOR; MoD requests best-and-final offers from Lockheed Martin, Raytheon, and Northrop Grumman teams
Jun	1999	Raytheon team chosen as ASTOR preferred contractor
Jan	2000	Raytheon awarded final U.K. ASTOR contract
Aug	2001	First flight of ASTOR-configured Bombardier Global Express prototype
Feb	2002	Delivery of first Global Express slated for the U.K. ASTOR program
	2004	First flight of integrated ASTOR aircraft
	2006	ASTOR used on limited basis
Dec	2008	U.K. MoD designates ASTOR radar and host platform aircraft as Sentinel R1 and system declared in-service with RAF
	2009	All five ASTOR/Sentinel R1 units operational

Worldwide Distribution/Inventories

Five ASTOR/Sentinel R1 aircraft and eight ASTOR ground systems are currently in service with the **United Kingdom**.

Forecast Rationale

The U.K.'s Airborne Stand-Off Radar (ASTOR) system is installed aboard five Bombardier Global Express airplanes with dual-mode (synthetic aperture and ground moving target indicator) radar equipped by Raytheon with the entire package designated Sentinel R1 by the U.K. Ministry of Defence (MoD). Integrated platform workstations aboard each aircraft permit mission management, imagery exploitation, and transmission of the imagery by secure datalink to the brigade and divisional/joint level ASTOR ground stations. The system includes eight ground stations (six for tactical purposes and two at the operational level) and full mission support capability from Raytheon Systems Limited, the prime contractor and major supplier to the U.K. MoD.

Production for ASTOR has been completed, and the system is operational. While no new production contracts have been reported for the United Kingdom or elsewhere, manufacturer Raytheon still believes there is a potential international market for roughly 40 airborne systems comparable to ASTOR. However, under current economic market conditions, such an outlook appears to be wishful thinking at this time.

This report will be archived next year, December 2011.

Ten-Year Outlook

Production has been completed. This report therefore contains no forecast chart.

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