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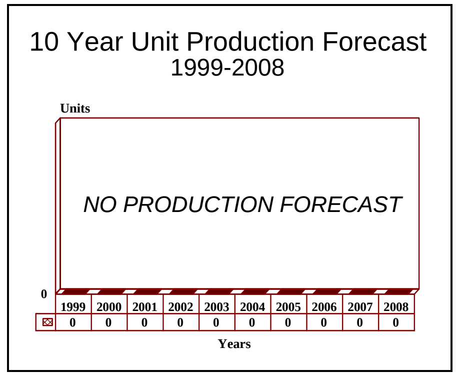
Mode S - Archived 8/2000

Outlook

- Last Mode S installation complete
- Designed to provide more accurate positional information and expanded data transfer
- FAA to develop new beacon interrogators (ATCBI-6)



Orientation

Description. Mode S is a state-of-the-art aircraft location system using both aircraft transponders and ground-based beacon system sensors to increase the accuracy of positional information and minimize the interference in the Air Traffic Control Radar Beacon System (ATCRBS).

Sponsor

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Status. Equipment production and implementation under way.

Total Produced. A total of 148 Mode S systems have been produced.

Application. Mode S improves communications between aircraft and air traffic controllers by assigning each aircraft a unique code for communicating with the airport tower.

Price Range. All prices quoted herein are from the Business & Commercial Aviation International, May 1994 issue, unless otherwise indicated. The Collins TDR-94D Mode S transponder (which also includes Modes A and C) has an indicated cost of approximately US$30,920. Industry sources have stated that transponder costs will eventually come down to the US$3,500 level for general aviation versions. The Bendix/King KT-70 is one of the lowest priced known Mode S-capable transponders at an estimated price of US$4,393.

Technical Data

Design Features. Following the invention of radar in World War II, designers created systems which could provide information on more that just the location of an aircraft. A series of improvements followed, and so did a ever increasing air traffic load with which the equipment had to cope.

By the late 1960s, three problems with existing Secondary Surveillance Radars (SSRs) were limiting the ability of the ATC system to effectively handle the increasing volume and diversity of air traffic. The first of these problems was False Replies Unsynchronized In Time (FRUIT), unwanted responses triggered by other SSR beacons. The second was garble, unusable responses generated when a single beacon triggers responses from two or more aircraft within the same resolution cell. The third troubling phenomenon was ghosts, false or blocked replies caused by terrain, construction, or vehicles on the ground.

In addition to substantially reducing all three of these problems, Mode S was to improve surveillance by increasing the amount of information that ground controllers could get from a single aircraft reply. Improved accuracy and reliability directly enhances traffic flow by reducing spacing between aircraft and by providing more expeditious approach and departure routes. Discrete aircraft addressing and digital data link communications, make Mode S a key element in the mosaic of programs comprising the Capital Investment Plan to upgrade the ATC system. Mode S replaces the current Air Traffic Control Radar Beacon System (ATCRBS).

The Mode S system developed for the FAA is an all-solid-state system. The Mode S Beacon System Sensor transmitter demodulator has a range coverage of over 450 kilometers (243 nm). It selectively interrogates aircraft using the sensor's timing module to assure that responses do not overlap. This essentially eliminates transponder interference from closely spaced aircraft.

The use of a multi-channel monopulse receiver results in extremely accurate aircraft position data, even when used with existing aircraft transponders. Those aircraft which are equipped with Mode S transponders have available an integral digital two-way data link which allows pilots to request and receive weather and other information directly without the need to use crowded ATC voice channels.

Using monopulse processing, Mode S determines the position of a given aircraft with a single reply, instead of eliciting multiple responses as does the present ATCRBS. When selective interrogation is implemented, the availability of more than 16 million discrete identity codes will permit the permanent assignment of a unique code to each aircraft which, in turn, will eliminate the problem of overlapping replies. Selective addressing also makes it possible to use the built-in two-way digital data communications link for exchanging traffic, weather, and flight data either automatically or on demand between an aircraft and ATC. This relieves overburdened voice communication channels and improves the predictive accuracy of ATC computers. This is an essential part of FAA's ATC upgrade plans.

Variants/Upgrades

The trend is to make Mode S capabilities part of an upgrade to existing SSR systems. Most SSRs on the market can be upgraded to Mode S.

Program Review

Background. Mode S development began along independent but parallel paths in both the United States and United Kingdom. The UK was most concerned with eliminating the garble problems their IFF systems were experiencing with exponential increases in traffic loads. The US system was also saturated, and designers were most interested in finding out how to get more information with fewer responses.

Mode S is based on the Discrete Address Beacon System (DABS). DABS was conceived in 1969 as a three-phase development effort. Phase One, begun in 1972, consisted of concept validation and system definition. The completed study confirmed that monopulse processing and discrete addressing had definite potential. Phase Two, prototype engineering and system evaluation, took place between 1974 and 1976. Interface with the Automated Radar Terminal System (ARTS) and other subsystems of the then National Airspace Plan (NAS) plan were studied, system development contractors were selected, and three engineering models were built and tested at the FAA's NAFEC (National Aviation Facilities Experimental Center) facility in Atlantic City, NJ. Phase Three, operational trials, began in 1976, but system modifications interrupted this phase and stretched it out to 1982. By then, DABS had become known as Mode S and incorporated into the NAS plan.

The laborious process of developing national standards for the system began in 1982. By 1984, Technical Standing Order (TSO) C-112 for Mode S had been published. Proposals were circulated to start the process of winning approval for the system as an international (ICAO) standard, with the UK and Canada having already opted for Mode S. In October 1984, the Department of Transportation (DOT) announced a contract award in the amount of US$163.3 million to the team of Westinghouse and Burroughs/System Development Corporation to provide 78 Mode S radar beacon systems, with an option for US$57.8 million to provide another 59 units. The contract called for coverage down to the ground at 108 terminals, and down to 12,500 feet above mean sea level in other areas.

In 1985, the FAA circulated a Notice of Proposed Rule Making which established its strategy for expediting transition from ATCRBS to Mode S. The notice proposed time-phased deadlines for installing ATC transponder equipment in US-registered civil aircraft. In October 1988, the FAA decided to replace all beacon radars with Mode S. This meant that 259 Mode S ground systems would have to be added to the first order for 137 systems issued in 1984. These additional systems would extend coverage down to 6,000 feet above mean sea level or minimum instrument flight rules en-route altitude and above, whichever is higher.

During a 1985 visit to AUSRIRE (All-Union Scientific Research Institute for Radio Equipment) in Leningrad, members of an RTCA (Radio Technical Commission for Aeronautics) delegation noted keen Soviet interest in Mode S, possibly related to air defense applications. AUSRIRE's interest in Mode S was long-standing; in 1981 they sent a brassboard transponder to the FAA to ensure interoperability. Reports presented by AUSRIRE emphasized the value of the Mode S data link in its ability to transmit aircraft bank angle, heading, airspeed, and instantaneous vertical velocity to help ground-based computers predict collision threats and calculate evasive maneuvers.

Members of the RTCA delegation noted that Soviet interest in the data link, potentially useful to vector fighters, was not adequately explained by then-Soviet air traffic density. Also, the USSR was the only country at the time planning to use electronically scanned phased array antennas for Mode S, providing a beam-pointing agility useful in air defense. After the breakup of the Soviet Union, The Commonwealth of Independent States began considering a continuation of the former Soviet plan; however, it is readily acknowledged that not much would be accomplished until the new nations had stabilized their economies.

The manufacturer was originally scheduled to deliver the first full system for FAA testing in April 1987, with delivery of the first system to an operational site slated for May 1988. Delivery of the last system to an operational site was set for January 1992. Delivery of the first full system for FAA testing did not actually occur until February 1992. Delivery of the first system to an operational site took place in April 1993.

The delays resulted from difficulties in designing the software to meet key operational requirements, coding the software to operate as required, and integrating different software modules to work together. The contractor also cited inadequate FAA contract specifications as a contributing factor to delays. The FAA did not fully appreciate the extent of the problems until April and May 1989. A "cure notice" was issued in June of that year. In response, Westinghouse proposed delivering interim systems that would track only 400 targets, versus the contract-specified 700. In April 1990, the FAA allowed the modification of the contract to incorporate further schedule delays, as well as deliveries of interim systems with limited software capability. Delivery of the last system to an operational site under that plan was scheduled for August 1995.

In May 1990, the GAO issued a report reviewing the Mode S program as requests by the Senate and House Subcommittees on Transportation and Related Agencies. The report was critical of the FAA's performance in the program and concluded that the process which the FAA used to buy the first 137 systems, as well as its decision to buy 259 more systems, was fundamentally flawed. Not only was the agency's handling of the contract considered problematical, but the GAO concluded that the agency had not properly evaluated requirements, alternatives, costs, or benefits and was predisposed to conclude that Mode S was the optimal alternative.

The GAO's recommendations to the Secretary of Transportation focused on three areas. First, an independent evaluation of the economic, operational, and technical risks involved in continuing the Mode S contract should be conducted. Second, the FAA Administrator should be directed to cancel plans to replace remaining beacon radars with Mode S and perform a thorough analysis of requirements, alternatives, benefits, and costs. If the analysis supported the replacement of the remaining beacon systems with Mode S, the GAO recommended that no decision to acquire additional Mode S systems be made until the Mode S had been shown to work and to provide the anticipated benefits. Third, the report to the Secretary noted that the FAA's contract administration and major system procurement processes contained internal control weaknesses based on the Federal Manager's Financial Integrity Act.

By December 1991, it was reported that preliminary contractor tests had been completed and the first Mode S sensor delivered to the FAA Technical Center. Contractor acceptance tests were initiated and a Mode S sensor delivered to the Lincoln Laboratory for use in developing a parallel runway monitor capability.

Deliveries of the first Mode S radar systems were expected to begin in April 1992, following successful qualification testing at the FAA Technical Center. In 1994, despite having signed a production contract approximately eight years before, the FAA had not yet received a fully operational system. Additionally, software development difficulties that had delayed the Mode S project for years had not been fully resolved. Certain sections of the software, written separately, continued to fail.

In response to these difficulties, the FAA launched the Interim Beacon Initiative (IBI) and outlined an accompanying operational testing and evaluation (OT&E) program. The IBI provided interim, less capable radar services to operational sites waiting for fully capable Mode S software. Mode S ground equipment, configured to perform basic aircraft monitoring functions, could be installed at designated Mode S sites. At the same time, the OT&E program would test Mode S software to ensure that all integration problems have been resolved.

Because software for the Mode S surveillance and data communication components was still under development at that time, the IBI program became one phase of an incremental strategy to implement the system. The IBI program was the first element of this incremental strategy. It became necessary because it was becoming increasingly difficult to maintain the current aging secondary surveillance radars.

According to the FAA, this interim system would be as accurate as the standard secondary surveillance radars. However, it was to have neither the capacity to interrogate aircraft selectively nor a data communication channel. The FAA planned to implement approximately 37 of these interim systems in terminal sites equipped with ASR-9 surveillance radars.

The operational test and evaluation of this system was completed in November 1992. The first-site implementation date for this interim system was scheduled for mid-1993. Each interim system would be upgraded to full system status once the software was developed to support a full Mode S system. To avoid cost increases and schedule delays during the software's development and testing, the FAA renegotiated the Mode S contract to gain control over these activities.

In the second phase of the implementation, the FAA elected to implement a complete Mode S system for terminal sites. This system is designed to interrogate up to 400 aircraft selectively and operate a data communication channel at 75 percent of its specified capacity. The OT&E of this system was to be completed by fall 1993, an eight-month delay from the original schedule. This delay was the result of the FAA requesting software changes to support the deployment of the system. The first-site implementation date for this system was October 1993. By August 1994, the Mode S system was to be upgraded to interrogate up to 700 aircraft selectively and to operate its data communication channel at full capacity.

As the third element of the program, the FAA would implement a Mode S system for en-route sites using a back-to-back antenna. This antenna would improve the target update rate of the system from 12 to six seconds, and increase the capacity of the data communication channel. The FAA was simultaneously developing two software versions for the en-route Mode S system to ensure timely deployment of Mode S. One version would support the system using one side of the back-to-back antenna as a single-face antenna; the other would support the system using both sides of the back-to-back antenna. If problems prevented the deployment of the back-to-back software, the single-face software could be deployed. When these problems were resolved, en-route Mode S systems that had the software for a single-face antenna could be upgraded with the software for the back-to-back configuration.

From 1992 to early 1993, the costs of the Mode S project increased slightly. According to the FAA at that time, the total estimated costs of the project grew by US$1.7 million, to a total of US$425.7 million. The reason given was the need for additional spare parts. In addition, if the FAA approved new requirements being considered in FY95, the project's total costs could increase by another US$12.5 million. This increase would finance test sets and software changes.

In late December 1993, Rockwell-Collins announced that it had extended the applications of Mode S. Collins reported that it had successfully ground-tested a Mode S data link system with automatic dependent surveillance (ADS) capability. Collins said future plans called for the integrated GPS/Mode S capability to be used for airport surface surveillance. This concept also forms part of a proposed GPS-based TCAS system in which the Mode S and TCAS airborne equipment would be integrated to allow communication of identity, intention, and other information between aircraft. GPS position reports would replace the range and bearing information used in the TCAS.

The OT&E of the en-route single-face Mode S antenna was to be completed by April 1994, a 10-month delay from the originally scheduled date. This delay was the result of a slip in OT&E of the terminal version of Mode S. The first-site implementation date for this system was then set for July 1994. The OT&E of the Mode S with a back-to-back antenna was planned for completion by December 1994. First-site implementation of this version was planned for February 1995. Last-site installation was scheduled for December 1996, with complete implementation of all 137 sites slated to be finalized by late 1997.

In 1995, FAA planners qualified the software needed to upgrade terminal sites from ATCRB mode to Mode S operation. They delivered 90 percent of the Mode S units in the terminal 400-target configurations, and commissioned half of them.

In 1996, the FAA installed four Mode S systems and commissioned 28. They removed 19 ATCBI-4/5 systems from select sites and installed 21. Twelve ATCBI-3s were decommissioned. Mode S en-route software was installed at one key site. Planners completed the ATCRBI replacement survey and benefit-cost ratio.

In April 1999, the last Mode S installation and checkout was completed. This took place at White Plains, New York.

ATCBI-6. In early 1998, the Federal Aviation Administration selected two contractors to demonstrate and test a new civilian secondary radar system as part of the Air Traffic Control Beacon Interrogator (ATCBI-6) competition. The FAA has identified a requirement for up to 150 MSSRs with selective interrogation capabilities to replace obsolete beacon interrogator equipment over 25 years old.

Two teams were selected, Lockheed Martin/Northrop Grumman and Raytheon Systems Company. For the ATCBI-6 program, the Lockheed Martin/Northrop Grumman team plans to offer a new monopulse radar based on Mode S. Raytheon plans to propose the ATCRB system, with a selective addressing capability added, being installed for the FAA and DoD as part of the ASR-11 Digital Airport Surveillance radar (DASR) program.

On August 4, 1998, it was announced that the Federal Aviation Administration had competitively selected and awarded Raytheon Systems Company a contract, potentially worth US$180 million, to manufacture and install up to 152 new Monopulse Secondary Surveillance Radars for the FAA's Air Traffic Control Beacon Interrogator (ATCBI-6) Replacement program. The new units will replace aging civil air traffic control radar beacon systems and will integrate with existing primary surveillance radars operated by the FAA and the Department of Defense (DoD).

Raytheon will supply its latest generation Monopulse Secondary Surveillance Radar presently being supplied to both DoD and FAA as part of the ASR-11/Digital Airport Surveillance Radar program with a Mode S selective addressing capability added. The commonality of the ATCBI-6 with the ASR-11 equipment being installed provides the government with reduced life cycle costs and further solidifies Raytheon's Monopulse Secondary Surveillance Radar production base.

Funding

With the completion of Mode S installations, funding is now for the ATCBI-6 development.

Recent Contracts

No recent contracts over US$5 million recorded.

Timetable

Month	Year	Major Development
	FY72	DABS Technical Development Plan delivered; DABS established as separate funding program
	FY73	Interagency agreement with Lincoln Labs
	FY74	Detailed characteristics documentation
	FY75	DABS RFP issued
	FY76	DABS prototype model delivered to NAFEC (Phase II)
	FY77	DABS prototype evaluated by NAFEC
	FY79	DABS installed in field sites for evaluation
	FY81	Draft DABS standard
	FY82	DABS renamed Mode S
	FY83	National Aviation Standard for Mode S transponders issued
	FY84	Minimum Operational Performance Standard (MOPS) for Mode S issued; Mode S Technical Standing Order (TSO); begins ICAO standard development
Oct	1984	Initial Mode S contract award

Month	Year	Major Development
	FY87	Mode S published as ICAO Annex 10 standard
Apr	1987	Originally scheduled date for delivery of first full Mode S system for FAA testing
Apr	1988	Agreement by the FAA and Westinghouse to delay delivery of the first system for 21 months
Oct	1988	FAA announces that it had decided to replace all beacon radars with Mode S
Mar	1989	Schedule extended by another 15 months
Apr	1990	FAA further extends delivery schedule and agrees to delivery of interim systems
Late	1990	System design completed
Late	1991	System #1 delivered to FAA Test Center
Aug	1992	Initial system acceptance at FAA Test Center and delivery of first sensor to Orlando, FL airport for acceptance
Early	1993	Interim system delivered to the first operational site
Late	1993	Implementation commences
Early	1994	En-route system delivered to T&E evaluation site (Elwood), first ORD complete (Baltimore)
Apr	1994	En-route single-face antenna completed
Aug	1994	Mode S system upgrade to interrogate up to 700 aircraft
Mid	1996	En-route shakedown test complete, ATCRBI ORD approved
Dec	1996	Last Mode S site scheduled to be installed
Feb	1998	ATCBI-6 development contracts awarded (two teams)
Sep	1998	Downselect to one ATCBI-6 development team
Late	1998	Last ORD complete/F&E program complete
Apr	1999	Installation of last Mode S system

Worldwide Distribution

In February 1993, (then) Westinghouse was awarded a US$31-million contract by India to four ASR-9 airport radar systems, making **India** the first country outside the US to have Mode S capability. Contracts have been from **Tunisia**, **India**, **Poland**, and **Morocco** for ASR-9 and monopulse secondary surveillance radars for ATC upgrade efforts.

Forecast Rationale

Mode S is expected to provide improved ATC data coverage at 108 terminals and down to 12,500 feet above mean sea level in other areas. At present, Mode S is primarily a US program, but a variant has been sold to 15 international customers. It is integrated with the ASR-12 solid-state airport surveillance radar operational in Peru, El Salvador, and Mexico. Eurocontrol has begun the Enhance Air Traffic Management and Mode S Implementation in Europe (EASIE) program to implement a Mode S variant, including a requirement for Mode S transponders in aircraft using European airspace by January 1, 1999.

The United Kingdom, Germany, and France are expected to procure Mode S interrogators. Most of the large international ATC manufacturers, such as Northrop Grumman, Thomson-CSF, and Cossor, have configured equipment that is now on the market for easy conversion or upgrade to a Mode S capability.

The increasing application of GPS technology to air traffic control and other navigation techniques can be extended to Mode S. Its application could change the character of Mode S operation and implementation. Continued technical problems, program delays, and cost overruns increase the likelihood of this happening, if only because GPS technology will be given added time to mature more fully. If this happens, a switch to a GPS-based approach could parallel the FAA's abandonment of is beleaguered MLS instrument landing system development program.

Ten-Year Outlook

Production of Mode S ground station equipment is complete.

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