ORDER DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

1812.6

9/19/83

SUBJ: SYSTEM REQUIREMENTS STATEMENT FOR THE MODE S SURVEILLANCE AND COMMUNICATIONS SYSTEM

1. PURPOSE. This order establishes the system requirements for the Mode S surveillance and communications system.

2. DISTRIBUTION. This order is distributed to the division level in Washington, regions, and the FAA Technical Center.

3. AUTHORITY TO CHANGE THIS ORDER. All revisions or changes to this order must be signed by the Administrator.

4. PROBLEM DEFINITION. The existing aircraft surveillance and communications systems do not have the capacity to meet the needs of the future air traffic control (ATC) system and were not designed to support advanced automation functions. In the evolution process of automating the ATC system, the all important first step is to obtain a cost effective system which can support the advanced automation accuracy and information requirements.

a. Additional deficiencies in the existing system include interference, beacon garbling, and sidelobe interrogation, which can cause false, split and lost targets and ring-around. These deficiencies in the currrent surveillance system will be aggravated by higher traffic densities. As traffic densities increase, radar surveillance problems will become more acute and may affect the quality of service.

b. Without the advanced automation enhancements and data link capabilities, the FAA cannot take advantage of state-of-the-art technology and our ability to develop a safer, more efficient and cost effective ATC system is severely restrained.

5. MISSION NEED. The basic requirement is to provide an improved aircraft surveillance and communication system necessary to support future demands on the ATC system. The required surveillance system must be compatible with International Civil Aviation Organization standards and existing and planned radar and beacon interrogator/transponder systems. It must provide accurate and reliable surveillance data in a high density traffic environment to reduce or eliminate synchronous garble, interference, reflections, and other significant performance problems. The communication system must provide a reliable, high-speed two-way digital data link. It must be capable of supporting current and potential automated functions and programs designed to enhance the safety and efficiency of the ATC system. These two features, improved aircraft surveillance and high-speed, air-ground communications, are the essential elements of the Mode S program.

Distribution: A-WXZ-2; AAT-100 (20 copies) Initiated By: AAT-150

6. MINIMUM SYSTEM REQUIREMENTS. As previously stated, there are several areas in which any proposed solution must meet minimum requirements. These are surveillance accuracy, system capacity, positional data processing, data link capability including ATC system communications, expanded discrete code capability, target resolution, coverage, throughput time, reliability, and maintainability. The minimum requirements for each are set forth in the following paragraphs.

a. Surveillance Accuracy.

(1) FAA may cover a given volume of airspace with one or more ground stations (sensors). Accuracies of Mode A reported aircraft positions from a Mode S sensor shall equal or exceed those of the existing air traffic control radar beacon system (ATCRBS) (i.e., plus or minus three Azimuth Change Pulse (ACP) (1 ACP = $360°/2^{12} = 0.088°$) and plus or minus 1/32 nautical mile (nmi)). The sensor must be able to decode the aircraft's exact reported Mode C altitude.

(2) In order to maintain current separation standards and to continue the present level of service to the users, the following performance criteria must be equalled or improved by the Mode S system within covered areas.

(a) Accuracy Standards governing positional error:

Site Azimuth Error (SAFI)

Beacon ±3 ACP's
Search ±2 ACP's

Site Range Error
Range ±1/32 NM

(b) Radar Registration Standards governing positional error:

Azimuth ±2 ACP's
Range ±1/8 NM

b. System Capacity. Each Mode S sensor shall be capable of reporting all targets within its coverage to the ATC system.

c. Positional Data Processing. The Mode S sensor must be able to provide target reports including three-dimensional position. It must also be capable of transmitting positional target reports to ATC facilities in the formats in which they presently receive target reports. Time delays for target reports in the Mode S system shall be such that the overall throughput requirements for the Advanced Automation System are satisfied. Sensors must accurately associate primary radar data with Mode S and ATCRBS replies. Mode S installations interfaced with Airport Surveillance Radar (ASR-9) will require reconstituted video to interface with current displays. The Mode S system when interfaced with

ASR-8's or earlier, will provide digital beacon reports when operating normally and analog beacon video in an event of the ARTS-IIA or Mode S processing failure (ATCBI 5 backup mode).

d. Communications Capability.

(1) The Mode S system must support all communications which integrate it into the NAS and take full advantage of Mode S capabilities. Each Mode S unit must support a two-way data link with all equipped aircraft. Each unit must also support a two-way data and control information interface with concerned ATC facilities utilizing existing and planned future systems, remote maintenance monitoring equipment and other systems as required.

(2) The Mode S air-ground link must comply with the Mode S National Standard. All ground-ground communications must employ standard hardware interfaces, bit-oriented communications protocols, and interface with all existing and future planned systems. Data rates and message formats must support overall system operation.

e. Discrete Code Capability. The system shall be capable of interrogating current 4096 (ATCRBS) transponders and system-wide selective addressing of Mode S airborne equipment.

f. Target Resolution. The distance between two aircraft on different transponder codes, at the same range, for separate target declaration, shall be three ACP's or less and shall have a range resolution of 1/16 nmi.

g. Coverage. The system shall provide coverage to the ground at all qualifying airports and elsewhere at and above 6,000 feet mean sea level (MSL) or minimum instrument flight rules (IFR) altitude and above, whichever is higher and provide coverage which will meet the operational requirements.

h. Throughput Time. The maximum throughput time for Mode S, when added to the worst case throughput time for the Advanced Automation System must not exceed 2 seconds from the radar antenna to the controller display.

i. Reliability and Maintainability. In consonance with the maintenance concept of the 1980's, Mode S sensors must exhibit high reliability and require only infrequent, simple maintenance actions. Recovery time from unscheduled service interruptions must not exceed 1 second. Sensor hardware must fully participate in remote maintenance monitoring.

7. POTENTIAL RULEMAKING. Effective use of the Mode S system will require a new generation of cooperative airborne avionics. Proposed rules are being formulated to phase in Mode S transponder equipment over a reasonable time period. The proposed rulemaking reflects the following goals:

a. All traffic in certain designated airspace areas must be either Mode S or ATCRBS-equipped.

b. All transponders manufactured for use in the National Airspace System after 1986 must meet Mode S transponder specifications.

c. Because of the improved service and associated benefits being provided by Mode S, it is anticipated that after 1992, (1) all aircraft whose operators are regulated by Parts 121, 127, and 135 will be Mode S equipped, and (2) all transponders installed in United States civil registered aircraft will meet Mode S transponder specifications.

8. BENEFITS AND IMPACT.

a. The selected Mode S system will provide improved aircraft surveillance accuracy to support automation enhancements. It will also reduce ring-around, false, split and lost targets, and synchronous garble and reflections. In addition, Mode S will provide a digital two-way data communications capability that will support various ATC automation programs, procedures, and other automation services. The Mode S system is fully compatible with the present ATCRBS, and will facilitate the transition from the present to the future enhanced ATC system.

b. Mode S will also provide for new ATC services and benefits using the direct information data link capability to aircraft. The following are examples of such benefits. It must be understood that, as examples, their feasibility has not yet been demonstrated and, accordingly, they will require development and testing prior to implementation. These items are not listed in any specific order and do not imply any order of implementation.

Potential Information Transmitted Via Data Link

(1) Wind Shear Advisory (to aircraft on final approach and prior to takeoff)

(2) RVR (on final approach and prior to takeoff)

(3) Status of Category II/III Critical Areas (protected or not protected)

(4) Clearances and Confirmations

(5) Altitude Assignment and Confirmation

(6) Assigned Runway (to aircraft on final approach and prior to takeoff)

(7) Weather Information to include -

(a) Terminal Forecasts

(b) Surface Observations

(c) Winds Aloft Forecasts

(d) Hazardous Weather Advisories

(e) PIREPS

(f) Graphical Weather Maps

(8) Aircraft Data for Advanced Metering and Spacing

(9) Terminal Information Services, Flight and Airfield Information

(10) Aircraft Position (backup-VOR/DME)

(11) Aircraft Performance Data

(12) Aircraft-Derived Weather Data

c. Although the Mode S data link avionics will support a vast array of services, both general aviation and air carrier users will incur increased costs. For example, the general aviation Mode S transponder, as compared to an equivalent ATCRBS unit (excluding the costs of installation and altitude encoder), may cost in excess of 80 percent more. The cost over the transponder to use data link capability will depend upon services desired, existing on-board equipment, and the type of input and output devices desired.

9. ESTIMATED COST BOUNDARIES. A major objective of the Mode S program is to provide coverage to the ground at qualifying airports (and elsewhere at and above 6,000 feet MSL or minimum IFR altitude, whichever is higher) and provide coverage which will meet the operational requirements by the year 2000. The ground system costs to achieve this objective are expected to be approximately $500M (F&E). User costs will vary depending upon the capabilities and benefits desired and, therefore, on the amount of avionics required to obtain those benefits.

10. ALTERNATIVES. Several alternatives to implementing Mode S have been reviewed.

a. The alternatives were assessed in terms of their ability to meet the following requirements that:

(1) The system be capable of implementation in an evolutionary manner in order to ease the transition into the NAS,

(2) It sufficiently improve aircraft position accuracy to support automation enhancements,

(3) It solve or reduce the problems of the current system, summarized in paragraph 1, and

(4) It provide a two-way automated communications link between the aircraft and the ground ATC system.

b. The candidates that were reviewed and eliminated through this process were the following--and were eliminated for the reasons indicated:

(1) Do nothing: This alternative does not satisfy paragraphs 10.a.(2), 10.a.(3), and 10.a.(4).

(2) Improve ATCRBS with monopulse radar: This alternative does not satisfy paragraphs 10.a.(2) and 10.a.(4).

(3) Implement a satellite based navigation/surveillance system: This alternative does not satisfy paragraph 10.a.(1). Presently, it is not possible to transition directly to such a system; however, in the future it may be feasible to do so.

(4) Improved ATCRBS using monopulse radar, selective addressing, and with a separate data link operating in the VHF frequency range. (See paragraph 10.c.)

c. Only one viable alternative to Mode S emerged from this review. It is an improved ATCRBS using monopulse radar and selective addressing, but with a separate data link operating in the VHF frequency range (paragraph 10.b.(4)). It compares with Mode S as follows:

(1) Both Mode S and the improved ATCRBS can provide an evolutionary implementation and, therefore, satisfy paragraph 10.a.(1).

(2) Both Mode S and the improved ATCRBS use the monopulse radar which can provide the required accuracy to satisfy paragraph 10.a.(2).

(3) Both systems use selective addressing techniques which can solve or overcome the inherent limitations of the present system and, accordingly, can satisfy paragraph 10.a.(3).

(4) Both systems provide a data link which can satisfy paragraph 10.a.(4).

d. It is evident that both Mode S and the improved ATCRBS using monopulse radar, selective addressing, and with a separate data link operating in the VHF frequency range meet all of the assessment requirements. Also, the systems are essentially the same with respect to satisfying paragraphs 10.a.(1), 10.a.(2), and 10.a.(3). While both of these alternatives satisfy paragraph 10.a.(4), there is an important conceptual difference in the provision of communications which has an important bearing on costs. The improved ATCRBS (paragraph 10.b.(4)), which uses a separate data link, would incur greater costs both on the ground and in the aircraft. On the ground, the cost differential is not great, but in the avionics there is a substantial difference. This stems from the fact that improved ATCRBS (paragraph 10.b.(4)) requires two receivers because two different frequencies are needed to support radar and data link information.

11. FIELD IMPACT EVALUATION. Engineering models of Mode S were evaluated and demonstrated to field controllers during the development program at the FAA Technical Center. These evaluations demonstrated the feasibility of Mode S implementation. Accordingly, a formal field impact evaluation is not considered necessary.

12. RECOMMENDATIONS. It is recommended that the Mode S system be implemented in accordance with the National Airspace System Plan.

13 PROGRAM MANAGEMENT RESPONSIBILITY. The Mode S system is a designated Major Systems Acquisition under Order 1810.1C and has been assigned to the Program Engineering and Maintenance Service for implementation.

14. REFERENCES.

a. Order 6365.1A, U.S. National Aviation Standard for the Mode S Beacon System, dated Jannuary 3, 1983.

b. Terminal Air Traffic Control with Surveillance Data from the Mode A System--Result of System Demonstration to Field Controllers. Final Report dated February 1982.

c. DOT/FAA/RD-81/61, Cost Analysis of the Discrete Address Beacon System for the Low-Performance General Aviation Aircraft Community, September 1981.

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Administrator