AIRBORNE TELEMETRY: THE ADVANCED RANGE INSTRUMENTATION AIRCRAFT

Lawrence G. Avery, Jr. , 1Lt, USAF
ARIA Programs Division
Directorate of Flight Test Engineering
4950th Test Wing
Wright-Patterson Air Force Base, Ohio

ABSTRACT

The topic of this paper is the history of ARIA from its beginning during the Apollo program to its current use as an airborne telemetry platform for orbital, ballistic, and cruise missile testing.

The evolution of ARIA telemetry equipment from 1968 to the present will be discussed, as well as plans for future modernization and improved capability.

Specific areas to he covered include: real-time data relay, pseudomonopulse tracking, onboard data processing, computer controlled tracking, new receivers, new recorders, and planned modifications to meet future requirements.

BACKGROUND

In the early 1960's the National Aeronautics and Space Administration (NASA.) identified the need for a worldwide network of tracking and telemetry stations to support the lunar missions of the Apollo program. The Department of Defense (DOD) had a similar need for its unmanned orbital and Ballistic missile programs.

A network of land based stations was ruled out due to geographical constraints since much of the required support would be in broad ocean areas. A fleet of tracking ships was considered too costly and not flexible enough because of their relatively low speeds. Finally, a fleet of high speed aircraft was chosen to provide maximum flexibility at a relatively low cost for modification and operation.

To implement the airborne station concept, NASA and DOD jointly funded the modification of eight C-135A jet transport/cargo aircraft. This fleet, designated EC-135N Apollo range instrumentation aircraft (ARIA), became operational in January 1968, at a cost of $4.5 million per aircraft. The Air Force Eastern Test Range at Patrick AFB, Florida waS selected to operate and maintain the ARIA fleet in support of the space and missile community.

in December 1975, the ARIA fleet (redesignated the advanced range instrumentation aircraft after the completion of the Apollo program) was transferred to the 4950th Test Wing at Wright-Patterson AFB, Ohio.

THE ARIA MISSION

The mission of the ARIA is to track and obtain telemetry data in support of NASA and DOD space and missile programs. The types of programs that ARIA supports can be broken down into three basic categories - orbital vehicles (Figure 1), ballistic -missiles (Figure 2), and cruise missiles (Figure 3). This includes telemetry coverage of launches conducted at Cape Canaveral AFS, Vandenberg AFB, Hill AFB, Edwards AFB, and from submarines deployed worldwide.

The types of ARIA coverage can be broken down into two basic categories.

1. Nonreal-time coverage. A nonreal-time mission is one in which the ARIA receives and records telemetry data for later evaluation by the launching agency. Most ballistic missile and several orbital vehicle launches are nonreal-time missions.

2. Real-time coverage. A real-time -mission is one in which the ARIA receives and records telemetry data as well as transmits the data, or selected portions of the data, to the launching agency. That agency can then evaluate the data in real time and take corrective actions for any launch anomalies. All cruise missile, most orbital vehicles, and several ballistic missile launches are real-time missions.

In addition, ARIA can provide onboard data evaluation during either type of coverage described above. During these missions, ARIA crewmembers evaluate the incoming data for critical events, known as “mark events,” and report their occurrence via HF radio to the launching agency. A “mark event” could be any significant event, ranging from a rocket engine igniting or cutting off to the solar array deployment of a new satellite.

THE ARIA SYSTEM

Each ARIA has undergone extensive external and internal modification. The most obvious difference from a standard C-135 aircraft is the large bulbous nose. This nose is actually a ten-foot radome that houses a seven-foot steerable dish antenna used for telemetry reception. Other external modifications include probe antennas on each wing tip and a trailing wire antenna mounted on the bottom of the fuselage, all used for high frequency (HF) radio transmission and reception. There are also antennas mounted on the top of the fuselage used for data transmission via satellite.

The internal modification to the cargo compartment is in the form of a 30,000-pound modular package of instrumentation subsystems (Figure 4) called prime mission electronic equipment (PMEE). There are also facilities for the crewmembers who operate the PMEE and for the aircraft maintenance personnel who deploy with the ARIA.

PRIME MISSION ELECTRONIC EQUIPMENT

Six instrumentation subsystems and a master control console comprise the PMEE. These subsystems are as follows:

Antenna Subsystem

The antenna subsystem initially acquires and then tracks the target using the seven-foot dish antenna. The operator has three tracking options - manual, automatic, and computer controlled. The manual mode of operation is used primarily to position the antenna for initial acquisition and as a backup if automatic and/or computer controlled modes should fail. Automatic tracking is used if adequate signal strength is present. The automatic tracking system uses a monopulse system combined with conical scanning techniques known as a pseudomonopulse tracking system. The computer controlled mode uses the vehicle’s theoretical trajectory and the actual aircraft position to determine antenna positioning. The antenna can be modified with feeds and amplifiers for the P, L, and S frequency bands as well as 136 MHz, 400 MHz, and 1702.5 MHz.

Radio Frequency (RF) Subsystem

The RF subsystem consists of the data and tracking receivers which demodulate the telemetry data from its carrier signal. The data baseband is then routed to the record subsystem for recording; to the communication subsystem for retransmission; and/or to the data separation subsystem for subcarrier demodulation, reformatting, and evaluation. The RF subsystem in conjunction with the antenna subsystem provides signals for automatic tracking. The receivers have the capability to demodulate phase modulated, frequency modulated, and phase shift key modulated carriers. In addition to the receivers, the RF subsystem contains much of the test equipment used for total PMEE calibration.

Record Subsystem

The record subsystem consists of two recorders, two multiplexers, and various calibration equipment. The recorders are Inter-Range Instrumentation Group (IRIG) standard 14-track wideband magnetic tape recorders. Each unit is capable of recording signals from dc to 2.0 MHz. The multiplexers are used to mix up to 18 low frequency signals for recording on one track.

Timing Subsystem

The timing subsystem is the central timing facility for the ARIA electronic system. Its primary function is to generate time codes and precision pulse repetition rates which are subsequently recorded to provide time correlation of the data. The system uses a rubidium frequency standard as the primary signal source. It is capable of providing accuracy within five milliseconds when referenced to National Bureau of Standards timing broadcasts on HF radio. Accuracy within 10 microseconds can be achieved when the system is synchronized to the onboard portable clock. In addition, the subsystem provides each equipment operator with displays of universal coordinated time and mission countdown/elapsed time.

Communications Subsystem

The communications subsystem consists of three 1000-watt HF radios and a 1000-watt UHF satellite terminal. The HF radios are used primarily for air-to-ground launch network communications, but can be used for transmission of low bit rate digital data and analog data of up to 3.0 kilobits per second (kbps). The UHF satellite terminal is used for real-time transmission of data at rates of up to 256 kbps. Due to the limited availability of satellite bandwidth, 65 kbps is generally the highest bit rate that may be transmitted. These radios operate using the Air Force satellite communication (AFSATCOM) network.

Data Separation Subsystem

The data separation subsystem or data processing subsystem consists of signal conditioning and demodulation equipment used to improve, demodulate, decommutate, and/or reformat the incoming telemetry data. This subsystem allows the data to be “stripped out” for onboard evaluation of “mark events.” One of the main features of this system is a minicomputer that can be used to reformat high bit rate digital data into low bit rate digital data by selecting only critical parameters. This program, known as the data separation and storage buffer (DSSB), is used when sufficient satellite bandwidth is not available to transmit the entire bit rate.

Master Control Console

The master control console in the instrumentation area is manned by the mission coordinator (MC). Here, the MC provides onboard supervision of the instrumentation crew during a telemetry gathering mission. The master control console has status indicators used to monitor the equipment during a mission. It also serves as the communications center for interplane and HF radio communications. The MC is the point of contact between the flight crew and the instrumentation crew as well as between the ARIA and the launch network.

IMPROVEMENT AND MODERNIZATION

The ARIA has undergone a series of modifications to improve. and upgrade its capabilities. Some of the modifications were done to meet new requirements, while others were done to upgrade an existing capability. These improvements and modernizations began as soon as the fleet became operational.

Addition of the data separation subsystem and the real-time satellite relay subsystem are examples of PMEE system modifications that have been used extensively. Examples of more recent ARIA upgrades include:

1. Improvements to the antenna tracking system. The new pseudomonopulse tracking system became operational in 1979. It eliminated phasing problems encountered with the previous system and allows ARIA to track accurately for longer periods of time.

2. Cruise missile modification. Four ARIA have been modified to support air-launched and ground-launched cruise missile (ALCM/GLCM) testing. During ALCM/GLCM tests, ARIA serves as the prime data link between the missile and ground stations. Modifications for cruise missile testing include the following: (1) three L-band transmitters for real-time relay of data, (2) a remote command and control system for ARIA control of the missile during special tests, (3) a special computer/inertial navigation system (INS) interface to provide real-time antenna positioning capability for missile tracking, and (4) displays in the cockpit to provide the pilot with aircraft ground speed and the navigator with aircraft distance and azimuth from the ALCM.

3. New antenna control system. This modification included the addition of an onboard trajectory processing unit (TPU). The TPU consists of a Rolm 1602B mini-computer with flexible disk drives and a plasma display. The theoretical trajectory of the target vehicle is stored on the flexible disk and compared to the aircraft INS to develop antenna look angles. This system adds great flexibility for ARIA in case of bad weather at the planned test support position (TSP). A clear area can be picked by the navigator using a weather

radar and the new TSP can be evaluated onboard to determine its validity for good data reception.

4. Data separation subsystem update. New equipment was added and the racks were redesigned for ease of operation. The new system can process two PSK subcarriers for simultaneous decommutation and mark event reporting. At the same time, it can process one link of FM data with up to twenty IRIG subcarriers.

5. New recorders, new time code generators (TCGs), and incorporation of the two subsystems into one. This modification included the installation of dual Bell and Howell AN/USH-30 recorders. The new recorders are 14-track IRIG units with 2.0 MHz bandwidth capability (versus 1.5 MHz for the previous recorders). Also included is a microprocessor-controlled calibration system. The new TCGs are capable of both modulated and unmodulated time codes compatible with the latest IRIG standards. The two subsystems were incorporated into the same rack to allow easier operation by One technician.

6. Pershing II modification. Four ARIA have been modified to accept contractor-owned equipment needed to support Pershing II missile re-entry tests. This modification includes the wiring and racks needed to accept a special receiver and wideband video recorder for unique telemetry requirements.

7. Receiver replacement. New Hartman Systems receivers with combined data and tracking functions are replacing the old ARIA receivers. The new receivers have increased bandwidth (20 MHz), better sensitivity, phase-locked loop (PLL) circuitry for faster locking to a signal, and surface acoustic wave (SAW) filters for better filtering characteristics. Further improvements include synthesized signal tuning to reduce drift and phase noise, PSK demodulation and tracking capability, and increased reliability, maintainability, and operability.

AIRFRAME IMPROVEMENT AND MODERNIZATION

The ARIA fleet has undergone several airframe updates since it first became operational. The airframe modifications include:

1. Conversion of two aircraft to EC-135B ARIA. This modification was accomplished by removing the entire PMEE system from an EC-135N and reinstalling it in a C-135B aircraft already modified with the bulbous nose radome. The EC-135B, equipped with turbofan engines, provided longer time on station and reduced operating cost due to better fuel economy.

2. Re-engining of three EC-135N ARIA with turbofan engines. This modification was accomplished by removing the old J-57 turbojet engines and replacing them with JT-3D turbofan engines from used Boeing 707 aircraft. This model is called the EC-135E and has fuel consumption and range characteristics similar to the EC-135B.

FUTURE ARIA IMPROVEMENT AND MODERNIZATION

The ARIA fleet will continue to be updated as requirements change. Future modifications include:

1. EC-18B ARIA. Newly acquired airframes, designated the C-18, are being converted to ARIA to replace some of the EC-135 airframes. The C-18s are actually used Boeing 707 aircraft. These aircraft are larger and thus can hold more equipment. They also can operate from shorter runways than the EC-135s. The two EC-135B aircraft have been taken out of service as ARIA and their equipment is being reinstalled in the first two C-18 airframes. The first converted C-18, designated EC-18B ARIA, will be operational in 1985.

2. Cruise missile mission control aircraft (CMMCA). This program involves installing redundant real-time telemetry display systems and redundant remote command and control/flight termination systems on one ARIA. This aircraft is projected to support cruise missile tests in FY 85.

3. Advanced medium-range air-to-air missile (AMRAAM). ARIA support for the AMRAAM program will signal ARIA's first use in air-to-air missile testing. No special ARIA upgrades are required, but only cruise missile capable aircraft will be used because L-band real-time data retransmission is required. The first ARIA support of AMRAAM is projected for 1985.

4. Incorporation of a sonobuoy missile impact location system (SMILS), optics system, and meteorological sampling system on the EC-18B ARIA. This advanced SMILS will utilize global positioning system (GPS) satellites and/or deep ocean transponders (DOT) to provide re-entry body scoring of ballistic missile tests. The optics portion will provide motion picture and still photographic coverage to verify survival of the re-entry bodies and document their flight performance prior to impact. The meteorological sampling system will use dropsondes to determine pertinent weather conditions in the impact area. The EC-18B ARIA/SMILS/optics/meteorology system will begin operation in FY 87.

CONCLUSION

The final ARIA fleet will consist of four EC-18B and three EC-135E aircraft with varying configuration for mission support. The present capabilities of the ARIA coupled with an ongoing improvement and modernization program make it a truly unique and versatile airborne telemetry platform.

ACKNOWLEDGEMENT

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REFERENCE

1. Bell, Gerald F., July 1981, "ARIA Operational Capability Report," ARIA Engineering Division, Directorate of Flight-Test Engineering, 4950th Test Wing, Aeronautical Systems Division, Wright-Patterson AFB, Ohio 45433.

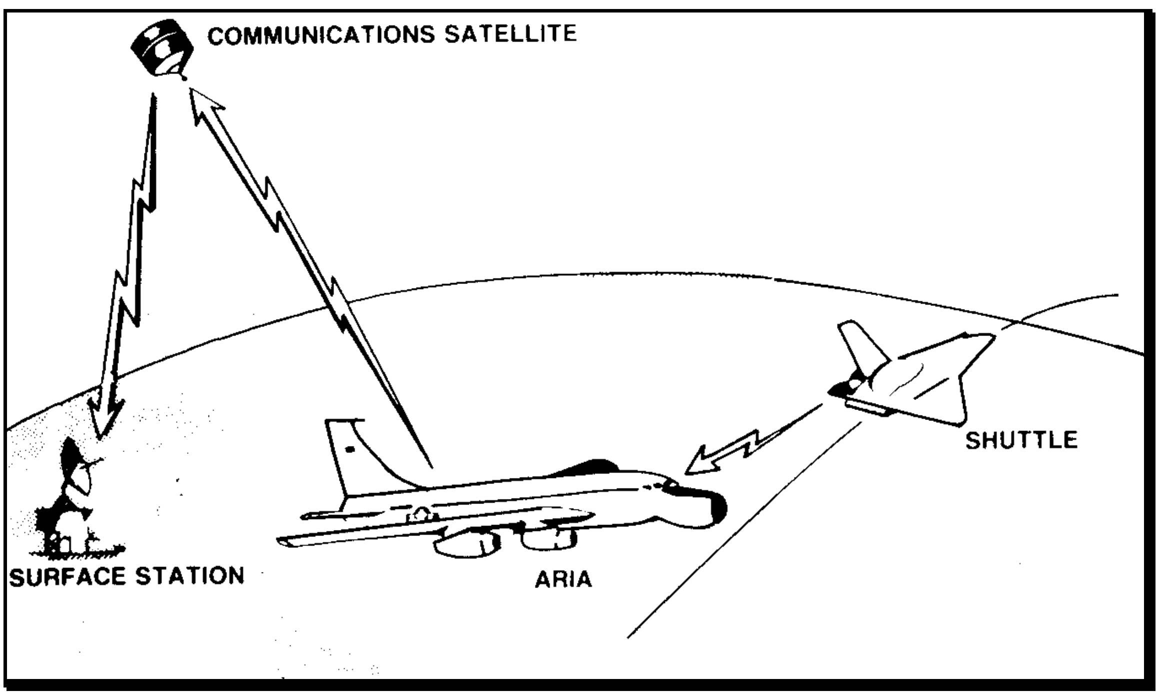

FIGURE 1. ORBITAL SUPPORT

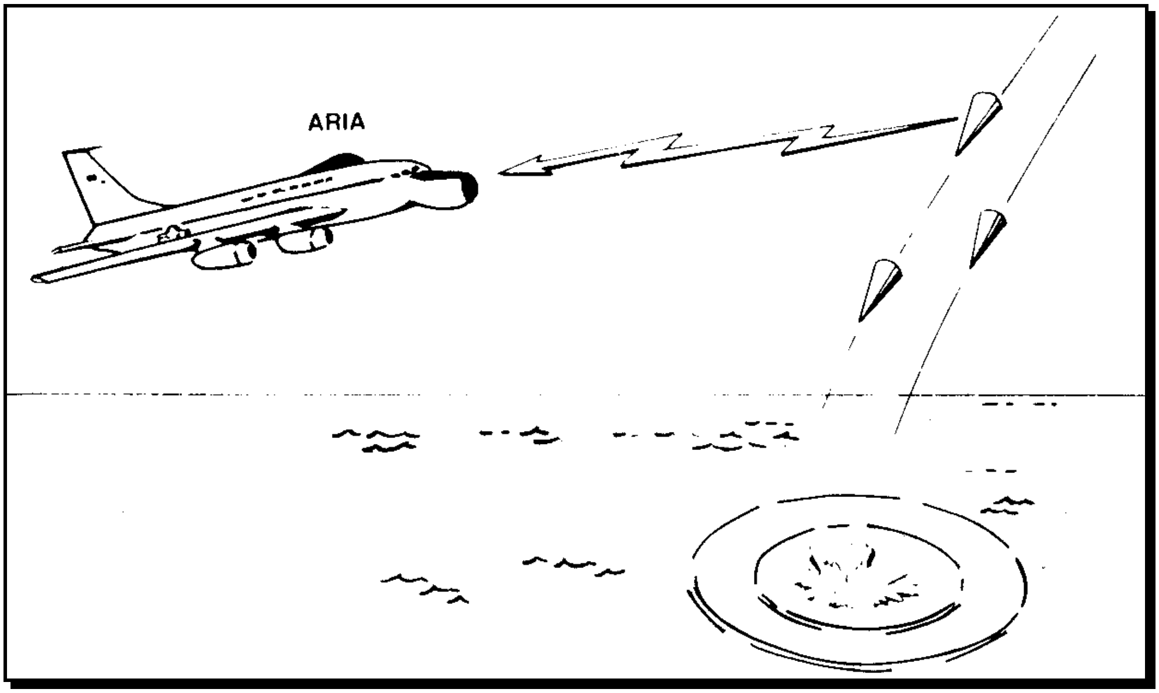

FIGURE 2. RE-ENTRY SUPPORT

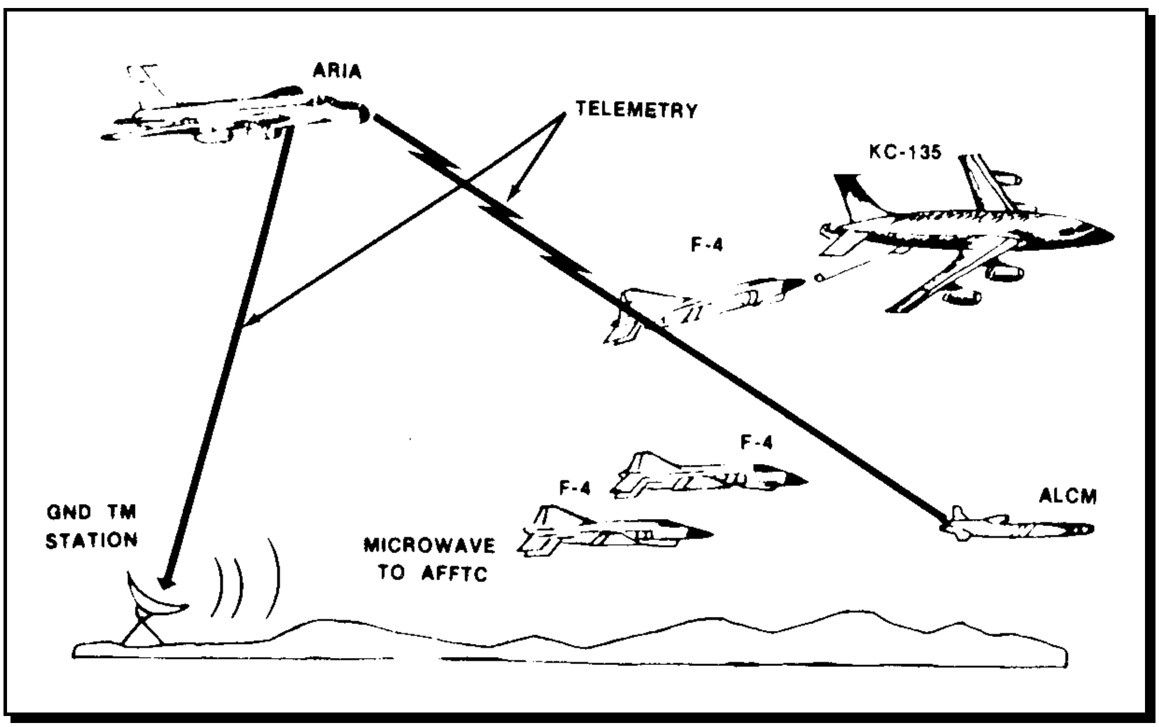

FIGURE 3. CRUISE MISSILE SUPPORT

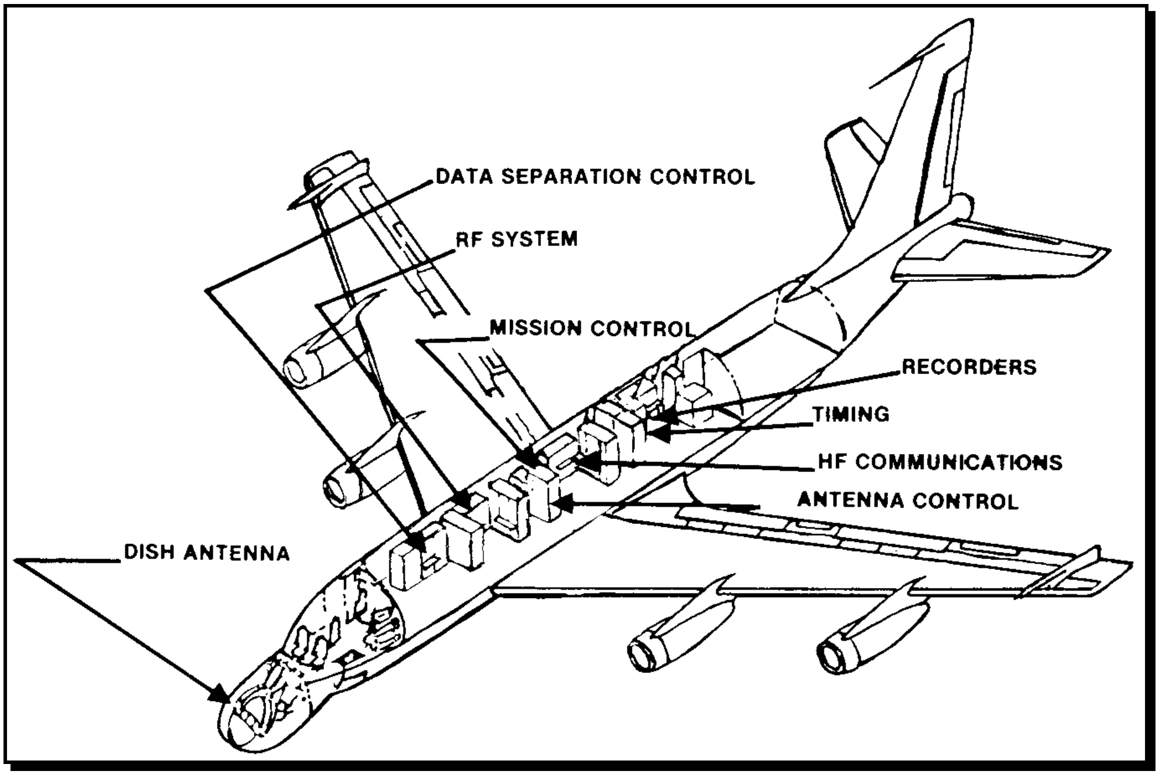

FIGURE 4. ARIA PMEE SUBSYSTEMS