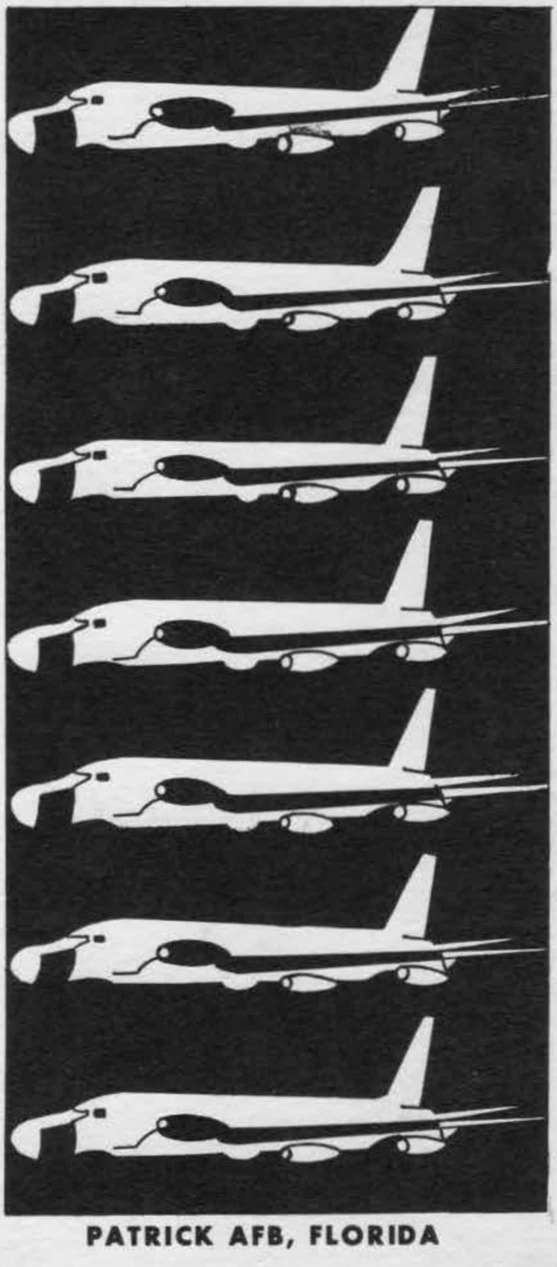
APOLLO RANGE INSTRUMENTATION AIRCRAFT

UNITED STATES AIR FORCE

AIR FORCE EASTERN TEST RANGE



PATRICK AFB, FLORIDA

ARIA INTRODUCTION

The information contained in this booklet is intended to give the background of the APOLLO RANGE INSTRUMENTATION AIRCRAFT and its use in supporting the United States missile and space programs.

Early in 1964 an agreement between NASA and DOD determined that high-speed instrumented aircraft were needed to support test needs of both agencies and that these aircraft would be placed in a pool operated by DOD. This same NASA/DOD agreement concluded that the eight aircraft should be modified from existing inventory to meet the unique requirements of Apollo.

The definition phase of the modification task began in April, 1965 and was completed in August, 1965 with joint funding by NASA and DOD. NASA funded for all instrumentation modification and tests necessary to support Apollo needs and DOD provided the eight aircraft and funded for additional modification required by DOD necessary to support other range needs.

The management responsibility for the modification program and the operation of the aircraft after modification was given to a variety of military and civilian agencies. Agencies involved in the program are specified below with general comments on their relationship.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

The National Aeronautics and Space Administration participated in all development phases of the Apollo Range Instrumentation Aircraft Program. A project officer was established at the Goddard Space Flight Center (GSFC) for working level coordination, monitoring and support of the development of plans and specifications. He was also responsible for design review, configuration approval, and monitoring the achievement of NASA program requirements. In addition, NASA provided an additional suitably configured test support aircraft containing Apollo communications equipment for simulation testing of the prototype ARIA during early testing.

Goddard Space Flight Center (GSFC) is responsible for ensuring the overall technical readiness of the Manned Space Flight Network (MSFN) for missions and its operation as an integrated entity during mission periods.

The Manned Spacecraft Center (MSC), in its overall responsibility for manned space flight mission operations, provides requirements for ARIA support. During the period from terminal count to mission termination, Mission Control Center (MCC) exercises appropriate operational control of the MSFN including ARIA and the Aircraft Operations Control Center (AOCC).

DEPARTMENT OF DEFENSE

The Director of Defense Research and Engineering was primarily concerned with policy considerations relative to requirements, funding levels, priorities and broad management aspects of DOD range support activities.

AIR FORCE SYSTEMS COMMAND (USAF)

The Air Force Systems Command was the responsible Air Force Command for overall acquisition and operation of the ARIA System.

ELECTRONIC SYSTEMS DIVISION (USAF)

The Electronic Systems Division (ESD), AFSC, was responsible for the acquisition management phase of the ARIA System in accordance with Air Force principles of systems management. To simplify and expedite the technical and management decisions, a close working relationship was established between AFSC and the NASA Goddard Space Flight Center. A project office was formed at ESD to act as the focal point for systems acquisition.

CONTRACT MANAGEMENT REGIONS/DISTRICTS (USAF)

The appropriate Control Management Regions and Districts administered ARIA contracts issued during the Acquisition Phase.

AIR TRAINING COMMAND (USAF)

The Air Training Command was responsible for assisting in the development of the personnel subsystem and provided full support toward the training of operations and maintenance personnel.

OKLAHOMA CITY AIR MATERIAL AREA (USAF)

The Oklahoma City Air Material Area (OCAMA), AFLC, provided airframe engineering approval and support to ESD during the system acquisition. OCAMA still retains C-135A systems support management for the basic (unmodified) portion of the aircraft.

AIR FORCE EASTERN TEST RANGE (USAF)

The Air Force Eastern Test Range (AFETR), operates the ARIA system throughout the world. During modification the AFETR provided systems support for ARIA with the exception of the basic C-135A aircraft, which remains the responsibility of OCAMA. In addition, the AFETR provided test support, as required, prior to operational use. This test support included personnel and resources to support the Apollo compatibility tests.

Operational control, maintenance, and logistic support of the ARIA fleet is the responsibility of the AFETR. Apollo operational support requirements are submitted by NASA to DDMS, who, in turn, tasks the AFETR to provide the needed support.

McDonnell-Douglas Corporation, formerly Douglas Aircraft, prime contractor and Bendix Corporation, the major subcontractor, performed design, acquisition, installation, aircraft modification and test of the electronic equipment.

M O D I F I C A T I O N

The Apollo Range Instrumentation Aircraft (ARIA) became fully operational in January, 1968. The fleet consists of eight modified standard C-135A four-engined jet aircraft containing highly sophisticated instrumentation systems. Each of the ARIA were modified from the jet transport/cargo aircraft at a cost of about $4 million each. As ARIA, the aircraft have been redesignated EC-135N.

These aircraft were prepared specifically to meet NASA requirements for high speed instrumented aircraft support of the Apollo lunar mission. They also meet DOD requirements for instrumented aircraft capable of operating on a worldwide basis in support of other missile and space programs.

The fleet of aircraft have been developed to supplement existing ships and land based stations. Operating in conjunction with a worldwide surface communications network, ARIA provides two-way voice relay between the spacecraft and Mission Control Center, Houston, Texas (MCC). It also receives and records (telemetry signals from the spacecraft while in earth parking orbit), injection into lunar orbit, and re-entry. Delivery of this data is possible in that the recorded telemetry signals can be "data transferred" from the aircraft in flight to NASA ground stations which can then send the data "hard wire" to Houston or other using agencies. The aircraft provides versatile, quick reaction test support over wide earth areas. It is highly mobile and can be relocated to any test support area in the world on relatively short notice.

Each ARIA has a 10-foot radome added to the nose. Inside this bulbous radome is the world's largest airborne steerable antenna, a 7 1/2-foot parabolic dish used for telemetry and communication reception. In addition to the "droop snoot" nose, the EC-135N has a probe antenna on each wing tip for High

Frequency (HF) transmitting and receiving.

Other outside modifications include a saddle antenna flush mounted in the tail, a Very High Frequency (VHF) 3 1/2-inch fin antenna and a Ultra High Frequency (UHF) flush mounted antenna located on the underside of the aircraft. Also, there is an HF trailing wire antenna mounted on the belly which can be extended to variable lengths up to 120 feet while the aircraft is in flight.

In addition to the normal modifications made to the aircraft, four were modified to accept the Airborne Lightweight Optical Tracking Systems (ALOTS) to provide optical coverage for missile launches including liftoff, staging, and re-entry.

INSTRUMENTATION CAPABILITIES

Aside from the nose modification only a few outside changes distinguish the ARIA EC-135N from its original appearance as a transport/cargo aircraft.

However, inside the fuselage, the aircraft has been configured to handle the bank of electronic equipment needed to provide support of the Apollo mission.

Each is equipped with communication and telemetry systems with the following capabilities:

a. Two-way voice communications with the ground via HF.

b. Two-way teletype communications with ground via HF teletype.

c. Two-way voice communications with spacecraft from the aircraft or from MCC when the ARIA is in the remote mode. The ARIA/spacecraft voice communication is via a VHF simplex system and the full duplex Unified S-band (USB) system.

d. Reception and recording of telemetry signals via VHF and S-band systems.

e. Playback and transmission to ground of recorded telemetry signals via VHF and UHF (data transfer feature), single track each channel.

The ARIA voice communications system is capable of receiving one USB and one VHF voice signal from the spacecraft and relaying the received signals to a ground station via HF single sideband (SSB). Conversely, the aircraft can receive HF voice from a ground station and relay the voice to the spacecraft via VHF and USB. The ground-to-ARIA HF link is full duplex, whereas the ARIA to spacecraft link is simplex on VHF and duplex on USB.

The telemetry capabilities are as follows:

a. Data - The ARIA is capable of receiving and recording nine links of telemetry in the VHF and S-bands.

b. Data and Voice - Reception and recording of VHF and S-band telemetry is possible simultaneously with periods of voice relay.

c. Delayed Data Transmission - Transfer of telemetry data (received on VHF and S-band links) to a ground station for relay to MCC may be accomplished if there is an MSFN station within range. The ARIA must be within approximately 175 miles of the station to effect a transfer. This means that the ARIA, in order to transfer, might have to divert to a ground station. Due to fuel considerations, such activity must be accounted for in the flight plan prior to departure to the Test Support Position (TSP). One data transfer run can transfer two tracks of recorded data, one on VHF and one on S-band.

ARIA INSTRUMENTATION DESCRIPTION

Three electronic subsystems and a master control console provide the instrumentation capability of the ARIA. The Prime Mission Electronic Equipment (PMEE) required for support of Apollo missions are voice and telemetry, timing and HF communications.

A. VOICE AND TELEMETRY SYSTEM

The Voice and Telemetry electronics system includes the Antenna Group, Radio Frequency (RF), and Record Group.

1. Antenna Group

The Antenna Group acquires the spacecraft and maintains track. This is accomplished by using a seven-foot parabolic antenna dish to receive VHF and S-band signals from the spacecraft. These signals are routed through pre-amplifiers before arriving at the telemetry receivers in the RF group.

2. RF Group

The RF Group consists of UHF and VHF transmitters and receivers which are used to transmit voice information to the spacecraft, and to receive voice and telemetry data from the spacecraft. These receivers also provide steering information to the tracking antenna. Additional low-power (9.5 watt) UHF and VHF data transfer transmitters are provided for transferring recorded data to ground stations. VHF voice transmit/receive is operated in simplex mode while Unified S-band format is operated full duplex.

Provision is made for reception of standard IRIG telemetry signals as well as non-standard telemetry signals. Telemetry receiving frequencies in the VHF band are 225 to 260 MHz and in the UHF band are 2200 to 2300 MHz. Seven dual-channel telemetry receivers are provided which can be configured for either UHF or VHF by front panel plug-in modules, depending on mission requirements.

Tracking receivers provide steering error information to the antenna control loop. Spacecraft signals processed through four tracking receivers (normally two UHF and two VHF) result in tracking error signals which allow automatic tracking in seven different modes. The operator may choose to manually track the spacecraft using error signal meters. This tracking system allows maximum signal reception but will not provide range or range rate information.

Spacecraft telemetry data recorded on the ARIA may be transferred to ground stations via the UHF and VHF data transfer facilities. This equipment consists of two transmitters, one UHF and one VHF, the same as the spacecraft downlink.

3. Record Group

The Record Group uses standard equipment to fulfill ARIA requirements for data storage, monitoring, and playback. Two wide-band magnetic tape recorders and an audio tape recorder are provided for these purposes.

The wideband recorders are 14-track recorders with a bandwidth of 5 KHz to 1.5 MHz at 120 inches per second (ips). They are used to store telemetry data, timing signals, and on-board voice annotations. A separate track is used for each telemetry channel with vital equipment signals required for later mission analysis being multiplexed and recorded on one channel.

The audio recorder stores voice communications received from the spacecraft and ground, as well as ARIA intercommunications, voice annotation and redundant time signals. It is a seven-track recorder with operating speeds of 1 7/8, 3 3/4, 7 1/2 and 15 ips.

B. TIMING SYSTEM

The Timing System is a central timing facility for the ARIA electronics systems. Its primary function is to generate time codes and precision repetition rates or frequencies for the correlation of recorded and transmitted data. In addition, it provides displays of standard (GMT) and mission countdown/elapsed time.

The source of all timing signals is a rubidium prime frequency standard providing a time correlation capability sufficient for Apollo support and other anticipated high-accuracy mission requirements. A precision crystal oscillator serves as a back-up for this standard. A WWV receiver is provided for timing standard synchronization.

C. HF COMMUNICATIONS SYSTEM

The HF Communications Subsystem provides voice and teletype communications between the ARIA and ground stations. The HF system relays spacecraft voice transmission to a ground facility over HF radio and receives voice transmissions from a ground facility for relay via VHF or S-Band to the spacecraft. It also transmits and receives teletype and voice to and from ground stations via HF link for administrative purposes and provides coordination among all instrumentation systems during specified pre-mission, mission, and post-mission activities including handover and voice remoting control.

Normal operation for Apollo support will include a full duplex net for voice relay (Goss Conference Net) plus a full duplex teletype net for administrative and coordination activities.

In the voice relay mode, MCC personnel may talk to the spacecraft crew if required. MCC voice is transmitted on HF radio. It is received on one of three HF receivers aboard the ARIA, transferred to the VHF or S-Band transmitter, and transmitted to the spacecraft. The spacecraft transmits to the aircraft on VHF or S-Band and the voice is relayed to MCC on one of three ARIA HF transmitters having a nominal output power of 1000 watts. The voice transmission from MCC is controlled by voice operated relay.

The aircraft is equipped with a full-duplex diversified tone telegraph terminal with two keyboard send/receive units. Normal teletype operation will be in the half-duplex mode. The ARIA transmits a 425 Hz reference signal along with the teletype to allow for doppler correction at the ground station. To be compatible with the ground station the ARIA must also receive a 425 Hz reference tone along with the teletype from the ground. This is compared to an on-board reference frequency of 425 Hz to correct for doppler variations in the received signal. Teletype transmission during voice reception is possible provided a frequency separation of 10 per cent exists between teletype transmit and voice reception frequencies.

MISSION COORDINATION

The Mission Coordinator is provided a console to monitor the status and operation of all on-board subsystems and to initiate on-board commands. The console has inter-phone facilities to permit the mission coordinator to talk on private lines with each ARIA operator, the aircraft flight crew, and to talk on HF, VHF, S-Band or aircraft UHF transmitters.

MISSION COMMAND AND CONTROL

The focal point for command and control of the Air Force EC-135N ARIA is through a command post located in the Aircraft Operations Control Center (AOCC) at Patrick AFB, Florida.

It is from this command center that deployment and monitoring of the ARIA is maintained. Using a complex worldwide communications network, personnel on duty at the AOCC make certain that the ARIA covering an Apollo flight are in position to support the mission at the right place and at the right time. Personnel at the AOCC are in continuous contact with all airborne aircraft, regardless of their worldwide location. The AOCC is linked to a network communication system made up of both the NASA Manned Space Flight and Department of Defense networks. There are two circuit links between the AOCC and each ARIA. One circuit permits communications between the crews in the aircraft and personnel at the AOCC. The other circuit is configured to relay voice contact with the astronauts through Cape Kennedy Air Force Station where it is tied-in with the NASA network and fed to MCC in Houston.

The AOCC team acts as a key communication link between the Mission Control Center, Goddard, and ARIA. The system can receive, verify, and relay voice and teletype messages and information.

Throughout the entire mission, constant updated spacecraft trajectory information is provided to the AOCC from the MCC in Houston. If, for any reason, the planned orbit of the spacecraft changes, the MCC can query the AOCC about the feasibility of redeploying the ARIA. By use of high speed computers, personnel in the AOCC can provide alternate test support positions and compensate for almost any contingency. In addition, they continuously monitor the quality of the ARIA support.

Operations at the AOCC are controlled through 14 sections comprising two major consoles. The two consoles, located stairstep fashion, are the nerve center of the entire operations. It is through these consoles that personnel at the AOCC are able to maintain contact and control of the airborne aircraft on a worldwide basis.

The primary console contains the command and control elements. It accommodates three AIRA controllers, ARIA task force commander, AFETR commander, and a ground communications coordinator.

The other console, the staff support section, comprises those elements necessary to maintain status of the various aircraft. It includes positions for a navigator, an instrumentation advisor, computer advisor, mission advisor, Department of Defense Representative, a documentation clerk, and a status and records clerk.

Since becoming operational in November 1967, the AOCC has been used for five missions. Three of the missions were manned - Apollo 7, 8, and 9 - and two were unmanned - Apollo 5 and 6.

MISSION SUPPORT

Individual mission requirements determine ARIA's deployment times, records, and test support positions (TSP).

Deployment of the ARIA is from Patrick AFB, Florida. The aircraft depart as much as seven days prior to launch time in order to arrive at predetermined locations at or near their staging area two to three days before launch. This early arrival permits crews to make any last minute adjustments and maintenance as necessary.

The ARIA leave their staging bases at predetermined times in order to be at the exact locations prescribed for their performance in the mission.

ARIA will support the following mission phases:

a. Coverage of predetermined areas during critical phases of the mission, including periods before, during, and subsequent to any critical decision.

b. Parking orbit checkout to assure spacecraft readiness for lunar trajectory, supplementing ships and ground station coverage.

c. Voice relay and telemetry coverage during injection of the spacecraft into a translunar injection (TLI).

d. Gather telemetry data from the earth's atmosphere from the command module from the end of the communications blackout to final landing.

e. Voice relay from end of blackout through recovery.

f. Capability of locating spacecraft if it should land at a non-programmed location.

Apollo lunar missions will be launched on an azimuth of 72° to 108° into a 105 nautical mile circular parking orbit. Actual azimuth depends on time of day and day of the lunar month.

During the flight in parking orbit, a complete checkout of the Apollo spacecraft and the S-IVB stage will be accomplished by aircraft, ships and land stations to assure its readiness for the next powered flight phase, the injection into a lunar trajectory. This checkout is in effect an in-orbit countdown, with telemetry data being transmitted to the ground stations for examination and decision.

TLI will occur on the second or third orbit. The TLI point is determined by the relative position between the earth, the spacecraft, and the moon. Prior to the TLI burn, precision tracking of the spacecraft is required in order to make a go/no-go decision on the mission.

Since the injection phase of the flight may occur anywhere over that portion of the earth subtended by the path of the parking orbits (with launch azimuth as determined by the time of the launch), ARIA will fill the gaps between ships and land stations in the Manned Space Flight Network.

During the return flight to earth some eight to 14 days later, the Apollo spacecraft will execute the trajectory corrections needed to attain the proper path for reentry. Just before reentry the service module, which contains the engines for these corrections, is jettisoned. Reentry into the earth's atmosphere is the next critical phase of the flight for which tracking is mandatory. Because of the maneuverability features of the Apollo spacecraft, reentry may occur from 1,500 to 5,000 miles back from the landing area at a predetermined point. Two landing areas must be available; one in the Northern Hemisphere and one in the Southern Hemisphere. Because the reentry areas are located over vast ocean areas, ARIA are again required to cover portions of the areas.

Mission requirements during this portion of the flight and until the astronauts are recovered safely include:

a. Gathering telemetry data from reentry into the earth's atmosphere of the command module from the end of the communications blackout to final landing.

b. Voice relay from the end of blackout through recovery.

c. Capability of locating the spacecraft if it should land at a non-programmed location.

A R I A   S P E C I F I C A T I O N S

Speed		450 knots
Flight duration		10 hours +
Average altitude		35,000 feet
Range		4,500 nautical miles +
Weight		
Basic aircraft		100,000 pounds
ARIA instrumentation		30,000
Fuel		144,750
Crew		2,750
	Total	277,500
Crew		
Pilots		2
Navigator		1
Flight Mechanic		1
Mission Controller		1
Electronics Operators		6
	Total	11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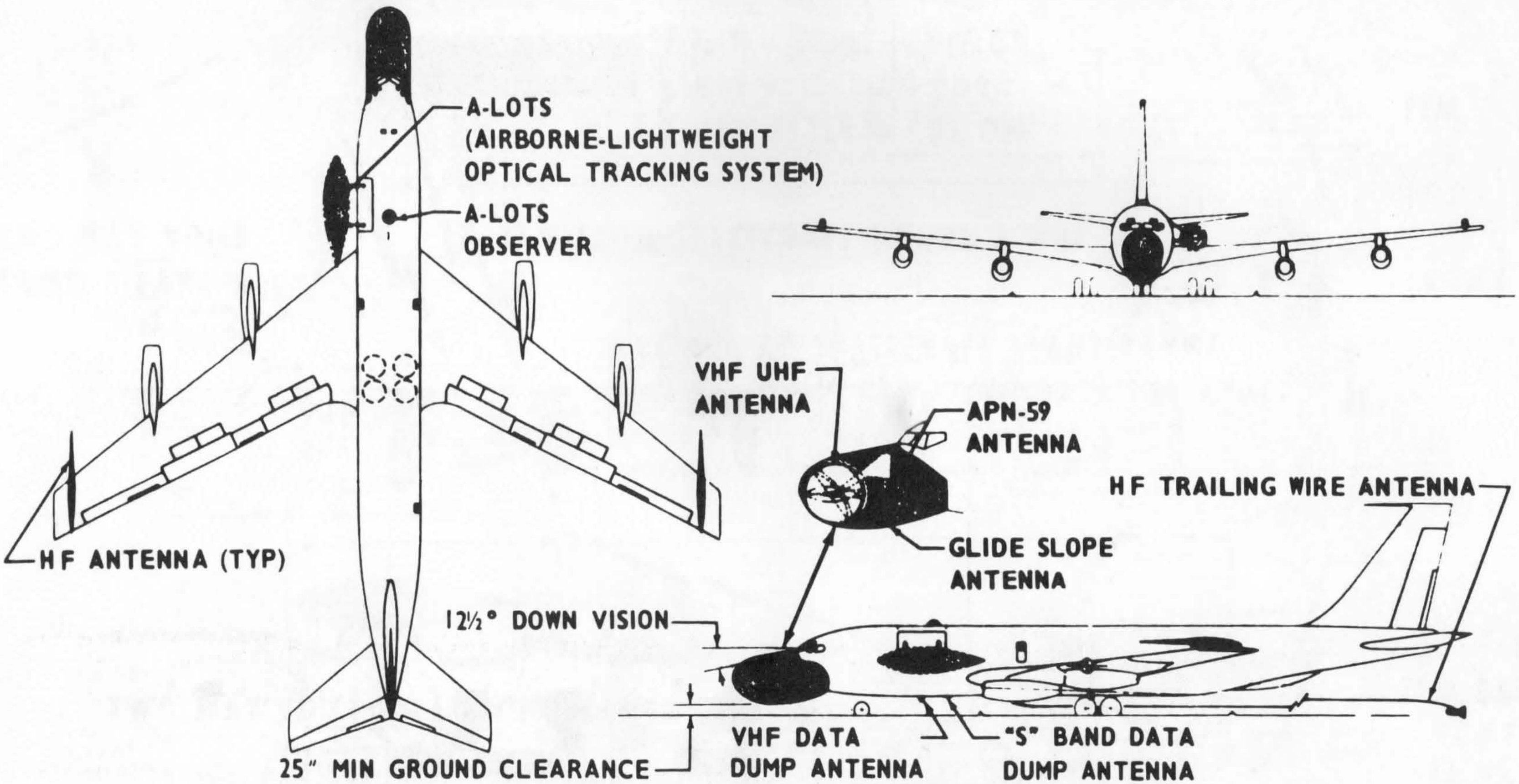
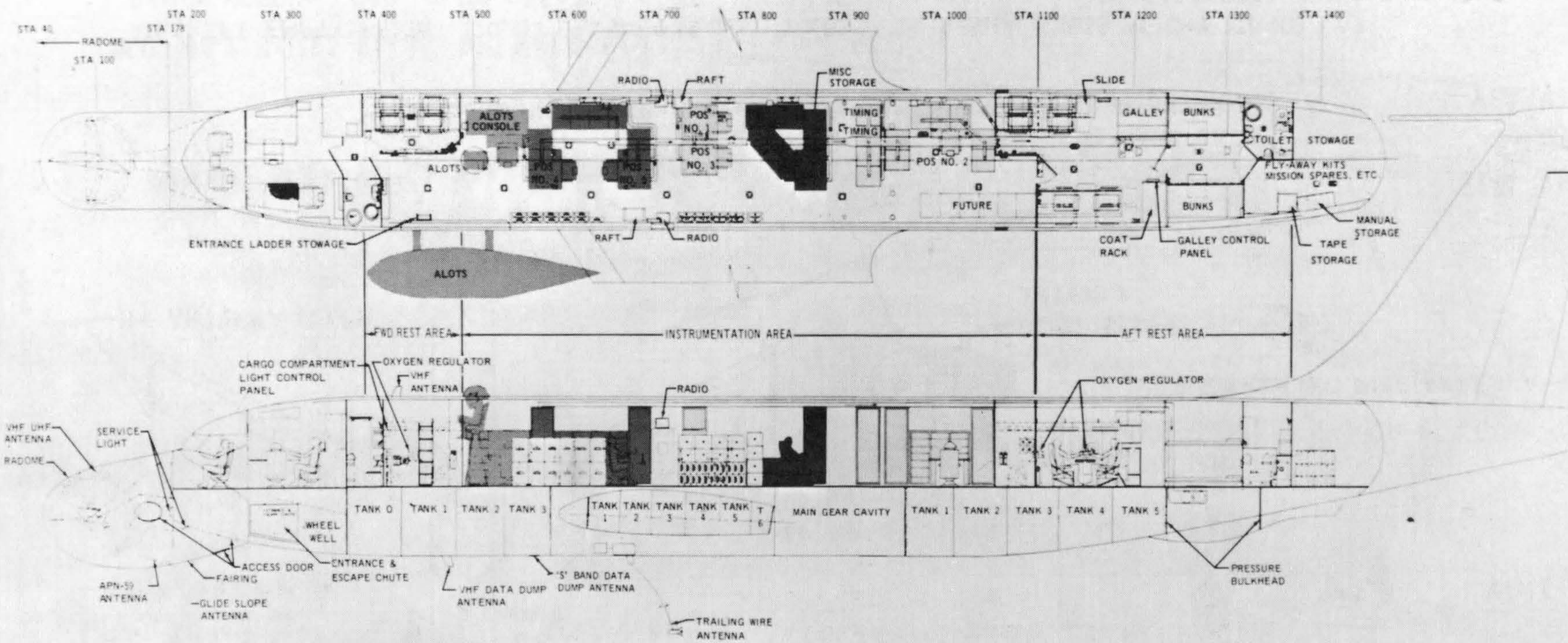
A/RIA
(APOLLO/RANGE INSTRUMENTED AIRCRAFT)



AIRCRAFT EMPTY WEIGHT 120,494 LBS A-LOTS 126,372 LBS
DESIGN USEFUL LOAD 149,506 LBS LBS A-LOTS 143,628 LBS

DESIGN GROSS WEIGHT 270,000 LBS
MAXIMUM ALTERNATE GROSS WEIGHT 279,500 LBS

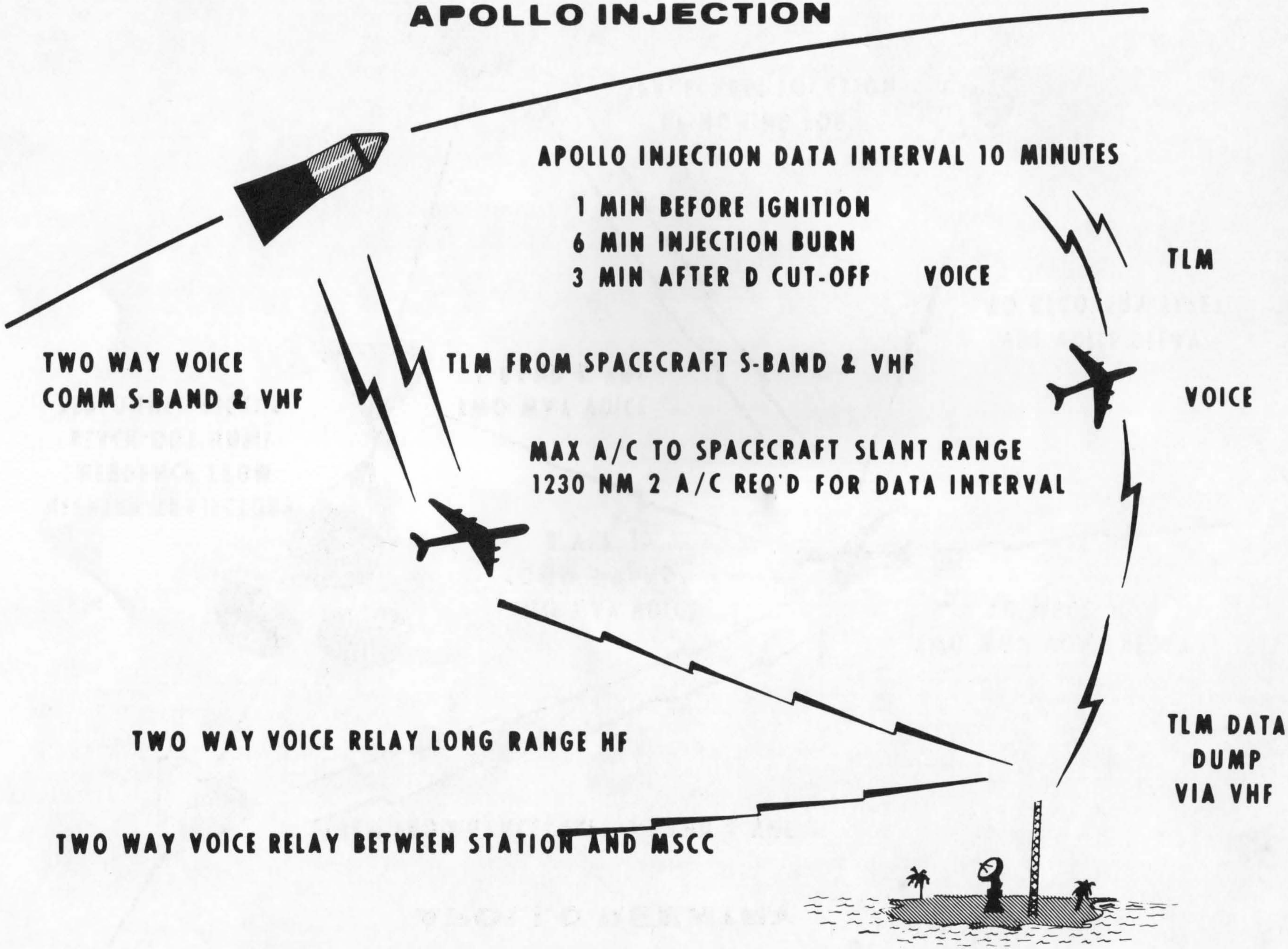


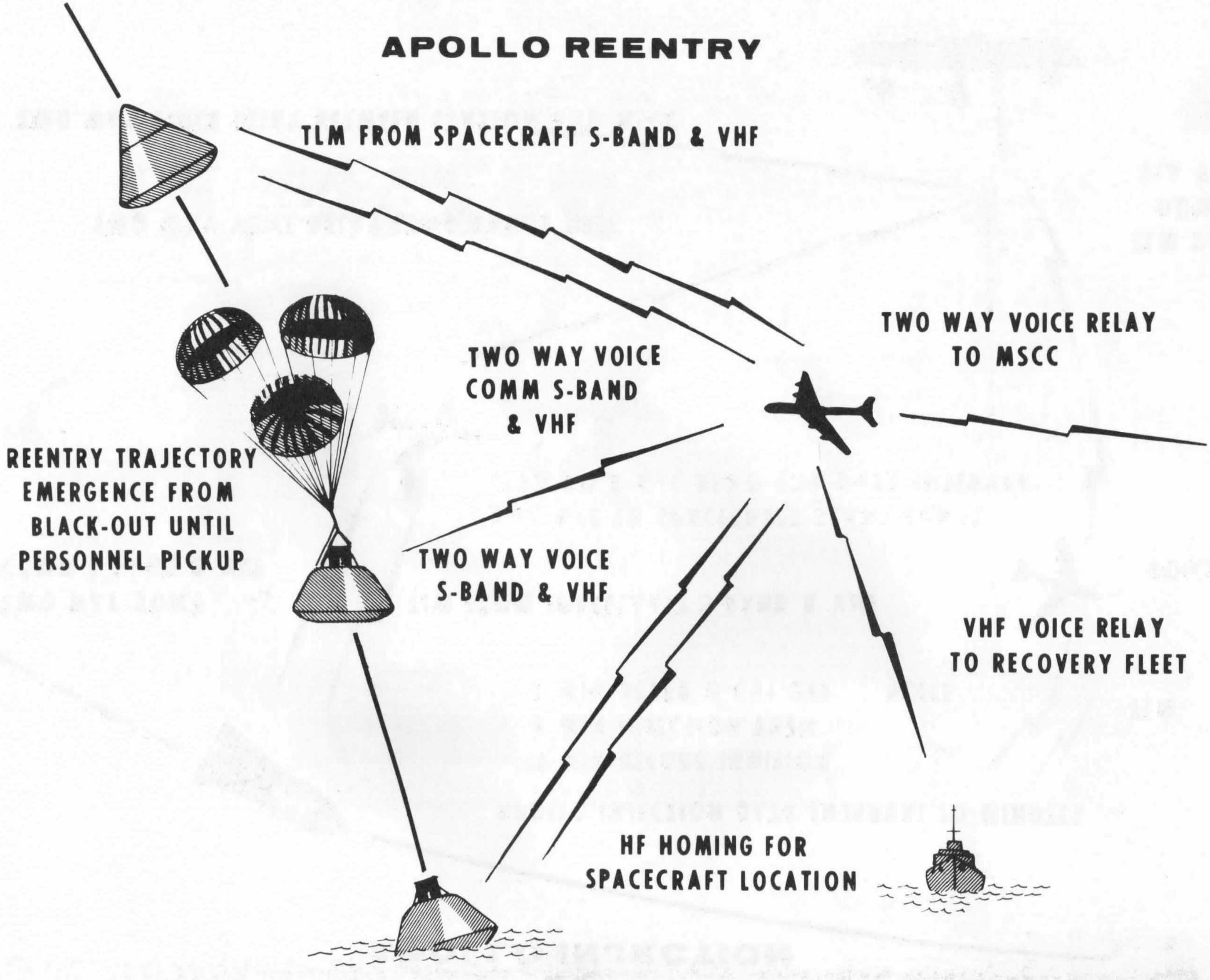
LEGEND

POS 1	MISSION COORDINATOR		PORTABLE OXYGEN BOTTLE		SPEAKER
POS 2	RECORD OPERATOR (T M)		FIRE EXTINGUISHER		TROOP WARNING LIGHT
POS 3	ANTENNA CONTROL OPERATOR		AN 3039-5 LIGHT ASSY		EMERGENCY EXIT LIGHT
POS 4	SPACECRAFT COMM OPERATOR		MS 25358-5 LIGHT ASSY		BUNK LIFE SUPPORT PANEL
POS 5	SPACECRAFT COMM OPERATOR		BAIL OUT ALARM BELL TYPE J-3		SELECTIVE LIGHT DIMING
POS 6	GROUND COMM OPERATOR		BAIL OUT ALARM BELL TYPE J-3 AND LIGHT A-2301-R-24		PARACHUTE
	FIRST AID PACKET				ANTI-EXPOSURE SUITS STOWAGE
	OXYGEN BOTTLE RECHARGER		LIGHT CONTROL SWITCH		SURVIVAL KIT

NOTE:
ELECTRICAL POWER IS SUPPLIED BY FOUR C-141 AIRPLANE -TYPE GENERATIONS. THESE ARE 40 KVA A.C. ENGINE DRIVEN BRUSHLESS UNITS IN PLACE OF THE C-135'S THREE REGULAR GENERATORS.

APOLLO INJECTION




APOLLO REENTRY
TLM FROM SPACECRAFT S-BAND & VHF
TWO WAY VOICE RELAY
TO MSCC
TWO WAY VOICE
COMM S-BAND
& VHF
REENTRY TRAJECTORY
EMERGENCE FROM
BLACK-OUT UNTIL
PERSONNEL PICKUP
TWO WAY VOICE
S-BAND & VHF
VHF VOICE RELAY
TO RECOVERY FLEET
HF HOMING FOR
SPACECRAFT LOCATION


U.S. AIR
10327