2. Mission Description

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ABSTRACT

The Apollo-Soyuz mission was the first manned space flight conducted jointly by two nations. The United States and the U.S.S.R. achieved a substantial degree of success in (1) obtaining flight experience for rendezvous and docking of manned spacecraft and developing a docking system that would be suitable for use as a standard international system, (2) demonstrating in-flight intervehicular crew transfer, and (3) conducting a series of science and applications experiments. The Apollo and Soyuz spacecraft, with minor exceptions, were similar to those flown on previous missions, but a new Apollo module, the docking module, was built specifically for this mission. The mission started with the Soyuz launch on July 15, 1975, followed by the Apollo launch on the same day. Docking of the two spacecraft occurred on July 17, and joint operations were conducted for 2 days. Both spacecraft landed safely and on schedule; the Soyuz landing in the U.S.S.R. occurred on July 21, and the Apollo landing near Hawaii occurred on July 24. Twenty-eight science experiments were performed during the mission.

INTRODUCTION

The first international manned space flight, the Apollo-Soyuz Test Project (ASTP) (fig. 2-1), was highly successful. The primary objectives of the joint U.S.-U.S.S.R. project were to test systems for manned spacecraft rendezvous and docking that would be suitable for use as a standard international system and to demonstrate crew transfer between spacecraft. An additional objective was to conduct a program of science and applications experimentation. Joint and unilateral experiments that provided data and experience in the fields of Earth resources, Earth gravity, Earth atmosphere, astronomy, solar science, life sciences, and space processing were conducted. (The arrangement of these experiments within this report is given in the Table of Contents.) Some of these experiments were conducted in pioneering fields. For example, the first measurements of atomic nitrogen in the Earth's atmosphere at orbit altitudes were made, and a search for discrete sources of 5- to 100-nm (50 to 1000 Å) extreme ultraviolet (EUV) radiation outside the solar system was made for the first time. In addition, space science awareness was promoted through extensive commercial television (TV) broadcasting and filming of flight experimentation and through in-flight science demonstrations.

SPACECRAFT DESCRIPTION

An overview of the two spacecraft and the docking module (DM) is shown in figure 2-2, and the ASTP experiment locations are shown in figure 2-3.

Apollo Spacecraft Description

The Apollo spacecraft used for this mission was similar in most respects to those employed to ferry crews to and from the Skylab space station, but it differed in some significant aspects that will be pointed out in this discussion. The significant differences among four generations of Apollo spacecraft are summarized in table 2-I.

[a]NASA Lyndon B. Johnson Space Center.

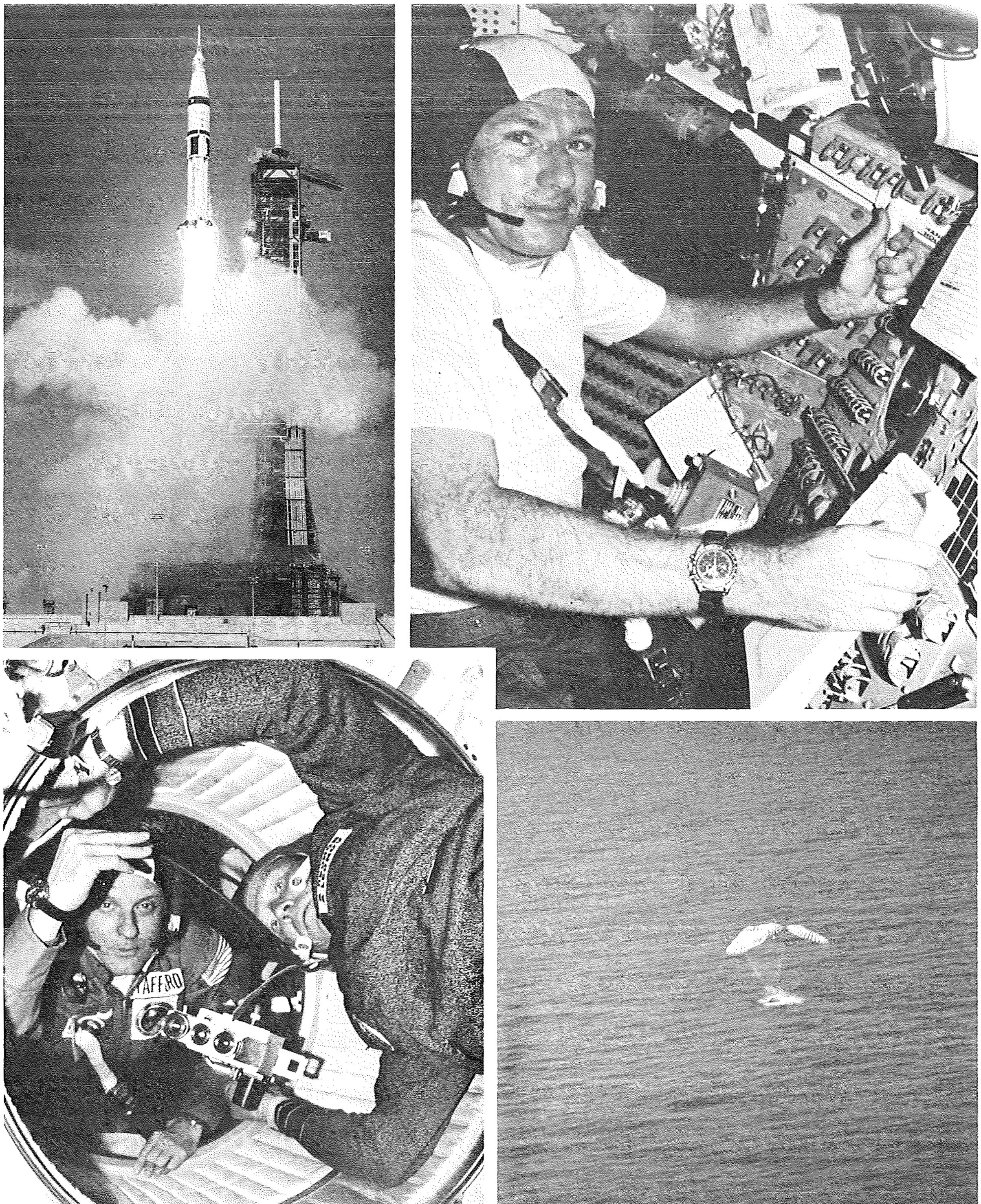

FIGURE 2-1.—Pictorial summary of Apollo-Soyuz mission.

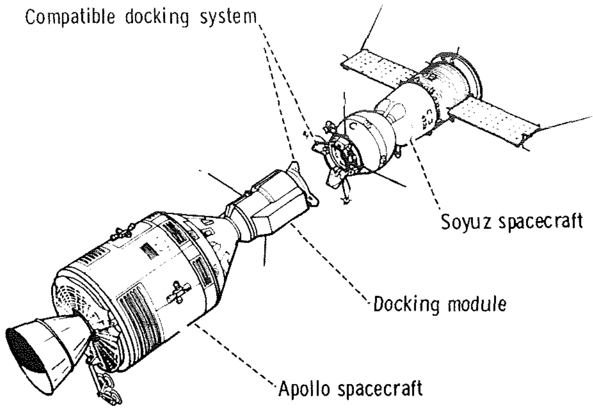

FIGURE 2-2.—Apollo-Soyuz rendezvous and docking configuration.

Command and service module.—The Apollo command and service module (CSM) flown on the Apollo-Soyuz mission was closely similar to the command and service modules used for the Skylab flights, but some modifications were made to fit mission needs. Additional controls for the docking system and special CSM-to-DM umbilicals were added together with experiment packages and their controls. Also, the steerable high-gain antenna used for deep-space communications during the Apollo lunar missions but not needed for the Skylab missions was reinstalled on the Apollo-Soyuz command and service module. The antenna was used to establish a relay link with Applications Technology Satellite 6

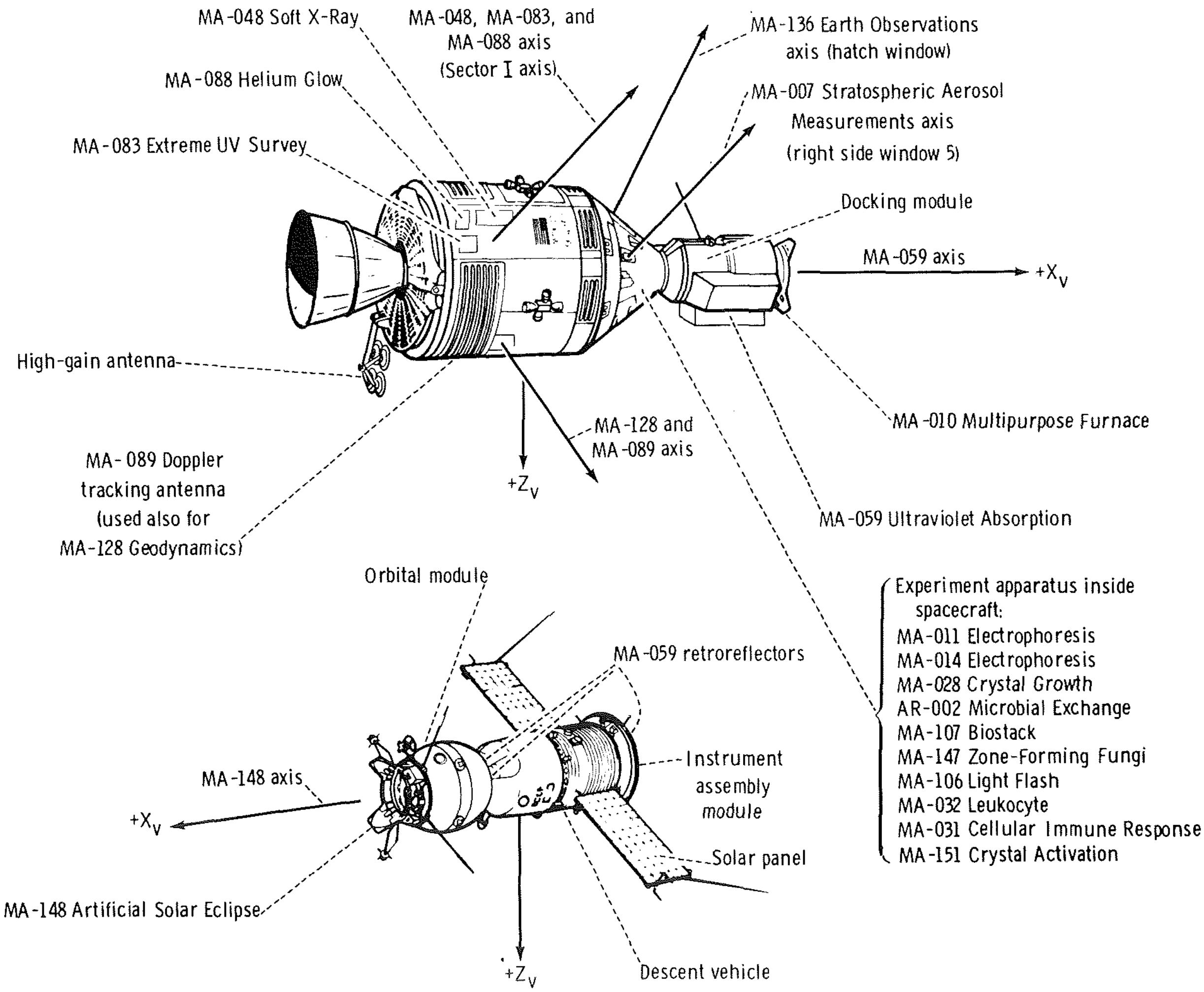

FIGURE 2-3.—ASTP experiment mounting locations.

TABLE 2-I.—Significant Apollo Spacecraft Configuration Differences

System	Area of difference	Mission			
		ASTP	Skylab	[a]Apollo 11 to 14	[b]Apollo 15 to 17
Command module					
Electrical power system	Lunar module umbilicals			X	X
	Skylab tunnel umbilical		X		
	Docking module umbilicals	X			
	Drag-through umbilical	X	X		
Experiments	Stowable	X	X	X	X
	Coldplate mounted	X			
Television	Cameras and monitors	X	X	X	X
	Video tape recorder	X			
Communications	Speaker box	X	X		
	ATS-6 equipment	X			
Environmental control system (ECS)	Extravehicular activity capability		X		X
Displays and controls	Experiments	X	X		X
	Docking module	X			
	Compatible docking system	X			
	ATS-6 communications	X			
Stowage	Apollo Block II			X	X
	Skylab		X		
	Modified Skylab	X			
Service module					
Experiments	Scientific instrument bay	X			X
	Lunar sounder				X
	Doppler tracking receiver	X			
	Remotely controlled doors	X			X
	Extravehicular retrieval capability				X
Service propulsion system	Propellant utilization gaging system (flight)			X	X
	Propellant utilization gaging system (ground)	X	X		
	Four propellant, two pressurant tanks			X	X
	Two propellant, one pressurant tank	X	X		
Environmental control system	Heaters deactivated	(c)	X		
	Coldplates for experiment cooling and ATS-6 equipment	X			

[a]Lunar-landing missions.
[b]Lunar-landing missions with expanded scientific data return capability.
[c]ESC radiator heater motor switches placed in open position before launch.

TABLE 2-I.—Concluded

System	Area of difference	Mission			
		ASTP	Skylab	[a]Apollo 11 to 14	[b]Apollo 15 to 17
Service module - concluded					
Reaction control system (RCS)	Propellant storage module	X	X		
	RCS quad heaters	X	X		
Thermal protection	Increased cork insulation	X	X		
	[d]Additional cork insulation	X			
Communications	Rendezvous radar transponder			X	X
	ATS-6 power amplifier system	X			
	High-gain antenna	X		X	X
Electrical power system	Two fuel cells		X		
	Three fuel cells	X		X	X
	Descent batteries		X		
	Extra water tank		X		
	Increased cryogenic storage capacity			X	X
	Return enhancement battery			X	X
Spacecraft adapter					
Panels	Jettisonable	X		X	X
	Deployable		X		
Structural support	Lunar module			X	X
	Docking module	X			

[a]Lunar-landing missions.
[b]Lunar-landing missions with expanded scientific data return capability.
[d]For long-duration RCS firings.

(ATS-6) in synchronous orbit to provide communications with the Mission Control Center for 55 percent of each orbit.

Docking module.—The docking module was basically an airlock that permitted the crewmen to transfer between the two spacecraft, which had different internal pressures and atmosphere constituents. The docking module had docking facilities on each end that enabled rigid coupling of the Apollo and Soyuz spacecraft and was a cylindrical pressure vessel with an internal diameter of 1.42 m and an overall length of 3.15 m between the docking interfaces.

The principal external attachments to the docking module were a Doppler transmitter antenna for the Doppler Tracking Experiment, an ultraviolet spectrometer for the Ultraviolet Absorption Experiment, a docking target that enabled the Soyuz crew to observe the Apollo docking approach through the Soyuz periscope, three very high frequency (VHF) antennas, three adapter mountings, a vent housing, and four gas storage tanks. The external and internal arrangements of the docking module are shown in figure 2-4.

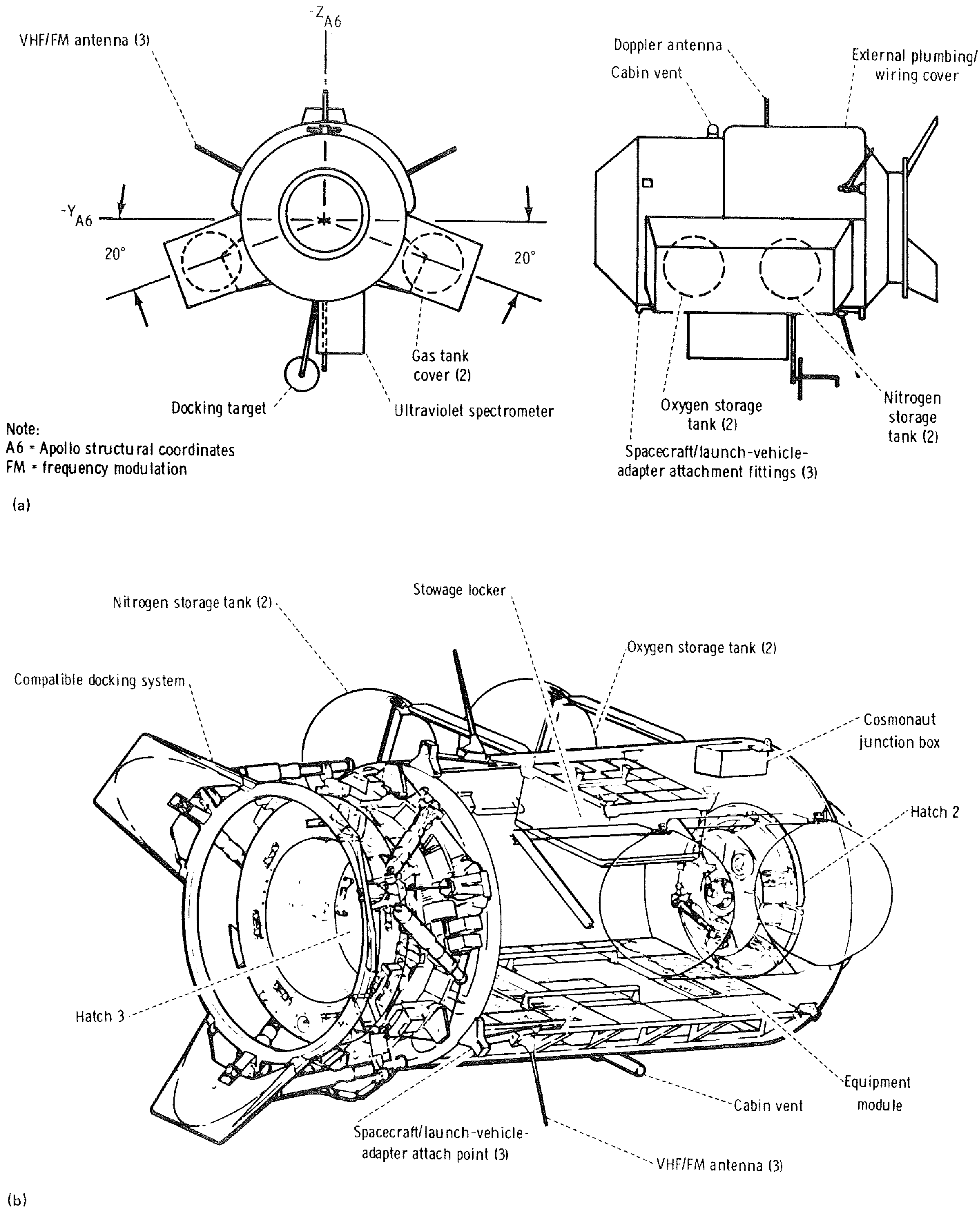

FIGURE 2-4.—Docking module. (a) Exterior. (b) Interior.

Soyuz Spacecraft Description

The Soyuz spacecraft consisted of three modules, which are discussed in the order of their proximity to the Apollo spacecraft when docked.

The orbital module, which provided the Soyuz portion of the compatible docking system, was used for work and rest by the crew during orbit. The module contained a side hatch for crew entry before launch, a forward hatch for crew transfer to and from the docking module, and an aft tunnel for crew transfer to the descent vehicle. Two windows were provided: one forward of the side hatch for earthward viewing, and the other on the opposite side of the module for outward viewing.

The descent vehicle, with the main controls and crew couches, was occupied by the cosmonauts during launch, dynamic orbital operations, descent, and landing.

The instrument assembly module, which contained subsystems required for power, communications, propulsion, and other functions, was located at the aft end of the Soyuz spacecraft. Two sets of winglike solar battery panels were mounted 180° apart on the exterior of the module.

TRACKING AND COMMUNICATIONS

Flight control personnel maintained contact with the Apollo and Soyuz spacecraft through the Spaceflight Tracking and Data Network (STDN). This network consisted of a complex of fixed ground stations, portable ground stations, specially equipped aircraft, and an instrumented ship. The mission was supported by 14 Spaceflight Tracking and Data Network stations, as well as by a U.S.S.R. network consisting of 7 ground stations and 2 ships. Communications opportunities with the use of the Spaceflight Tracking and Data Network alone encompassed 17 percent of the mission time; but, for the first time, an Applications Technology Satellite that increased the total communications coverage to 63 percent was employed (fig. 2-5). The increased coverage with the ATS-6 was of significant importance to several science experiments. The Apollo-Soyuz Test Project communications are shown schematically in figure 2-6.

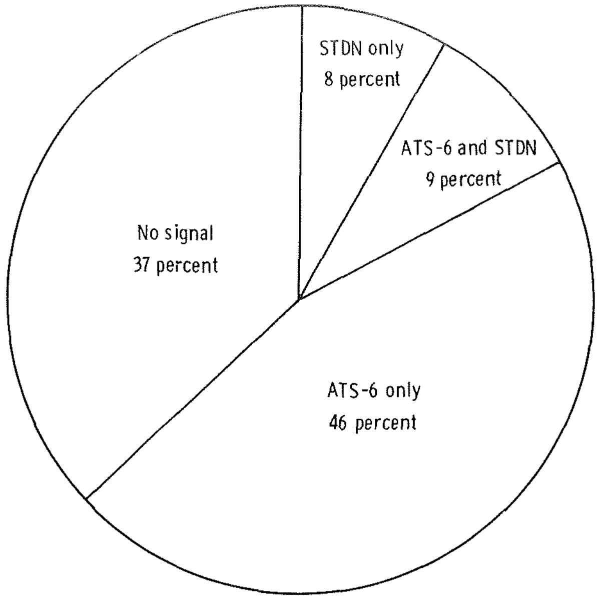

FIGURE 2-5.—Communications with command and service module for 24-hour period.

NARRATIVE FLIGHT SUMMARY

Launch and Rendezvous Maneuvers Phase

The Soyuz spacecraft, manned by Alexei A. Leonov, commander, and Valeri N. Kubasov, flight engineer, was launched from the Baykonur, Kazakhstan, launch complex at 12:20 UT on July 15, 1975. It was launched in a northeasterly direction and was inserted into a 186- by 222-km orbit at an inclination of 51.8°. On the fourth orbit after lift-off, the first of two maneuvers to circularize the Soyuz orbit at 223 km was initiated. The second circularization maneuver occurred on the 17th Soyuz orbit.

Seven and one-half hours after the Soyuz launch, the Apollo spacecraft, manned by Thomas P. Stafford, commander, Vance D. Brand, command module pilot, and Donald K. Slayton, docking module pilot, was launched from the NASA John F. Kennedy Space Center in a northeasterly direction and was inserted into a 149- by 168-km orbit, also with an inclination of 51.8°. One hour fourteen minutes after lift-off, the Apollo command and service module was separated from the Saturn-IVB stage, and the crew began the

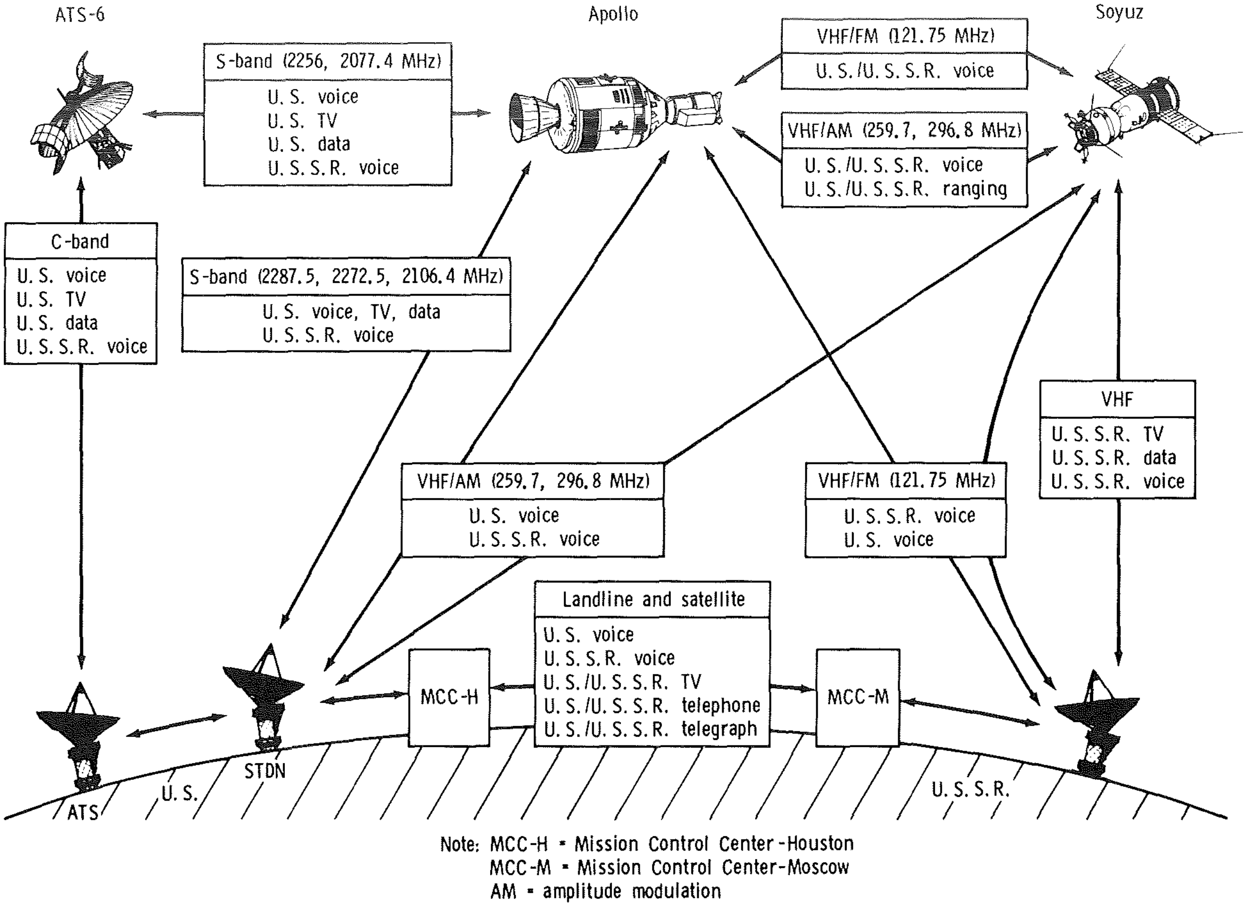

FIGURE 2-6.—Apollo-Soyuz communication overview.

transposition and docking procedure to extract the docking module from the launch vehicle. Although these operations were generally normal, the removal of the docking probe was hindered by a misrouted pyrotechnic connector cable. A corrective procedure given to the crew was used successfully to remove the probe, and extraction was completed at 22:24 UT. After performance of an evasive maneuver to avoid recontact with the launch vehicle, a circularization maneuver at the third apogee, and additional phasing and plane correction maneuvers, the first day of maneuver activities was concluded for both crews.

Before the end of the day, several science experiment operations were performed. The Zone-Forming Fungi (ZFF) Experiment, which had been photographed at 12-hour intervals beginning July 13, 1975, was again photographed at 12:30 Soyuz ground elapsed time (GET). Simultaneously, the Biostack Experiment was activated for approximately 12 hours of operation. The first Geodynamics Experiment data take was initiated at 15:12 GET and continued through the next three ATS-6 passes by the Apollo spacecraft. Major mission events and data collection periods are shown in figure 2-7.

The second day was devoted primarily to predocking checkout activities, rendezvous maneuvers, and science experiments. The first biostack data take was concluded at 25:38 GET, and the killifish experiment was initiated at 27:18 GET. Earth observations activities were initiated after starting the killifish experiment and extended into the period of Ultraviolet Absorption (UVA) Experiment lamp burn-in, which started at 27:40 GET. Multipurpose furnace experiment preparations were also made during the lamp burn-in period, and the ultraviolet absorption crew optical alinement sight calibrations were made. After another Geodynamics Experiment data take, multipurpose furnace operations were started with the Surface-Tension-Induced Convection Experiment cartridges. Simultaneously, the Electrophoresis Experiment (EPE) was prepared and operated; the Extreme Ultraviolet Survey, Helium Glow (HeG), and Soft X-Ray Experiments were checked out; several geodynamics data takes were made; and zone-forming fungi photographs were taken. Unfortunately, a malfunction developed in the Soft X-Ray Experiment after only 10 minutes of normalcy during the initial operation of the experiment on the second day of flight. However, good data were obtained again, intermittently, during the sixth through eighth days of flight.

Joint Phase

Docking occurred on the 36th Soyuz orbit and the 29th Apollo revolution. The time of docking was 51 hours 49 minutes Soyuz GET on July 17, 1975; and the orbit of the docked spacecraft was nearly circular at 223 km with an eccentricity of less than 1 km. The Apollo and Soyuz spacecraft remained docked for approximately 2 days.

After docking, hatch 1 was opened, and several transfers of both crews, television tours of both spacecraft and of the United States and the U.S.S.R., a news conference, and official ceremonies were conducted. The Surface-Tension-Induced Convection Experiment in the multipurpose furnace was continued during this period, and the collection of microbial samples for the Microbial Exchange Experiment was accomplished by the two crews. The multipurpose furnace was shut down at 58:05 GET and was reinitiated for the U.S.S.R. Multiple-Materials Melting Experiment at 58:45 GET.

Several other science experiments were conducted during this first docked phase. The Zone-Forming Fungi Experiment was photographed again; several Earth observations and geodynamics data takes were made; the Microbial Exchange Experiment was conducted; the U.S.S.R. multiple-materials melting was concluded; and the zero-g processing of magnets in the multipurpose furnace was conducted.

After the two spacecraft had been docked for nearly 44 hours, the first undocking was performed normally, and the joint Artificial Solar Eclipse Experiment was performed. A second docking was then performed at 96:14 GET to test the docking system with the Soyuz docking system active.

Final undocking was 99:06 GET, after which the Ultraviolet Absorption Experiment was conducted to conclude the joint phase of the flight. The Apollo spacecraft began stationkeeping 18 m ahead of the Soyuz spacecraft. The Apollo spacecraft then was maneuvered to a 150-m displacement out of the Soyuz orbital plane. At 99:40 GET, a 10-minute data take was performed as the command and service module swept through a 30° arc at the 150-m radius from the Soyuz spacecraft. Similarly, a 500-m out-of-plane data take was made starting at 101:18 GET. After the 500-m data take, the command and service module was positioned back into the Soyuz orbital plane, and an in-plane final evasive maneuver was begun at 102:22 GET.

During the 150-m data take, no reflected signal was detected by the spectrometer. Assessment of the problem by ground personnel indicated a contaminated Soyuz side reflector or possible locking of the star tracker onto a different light source. Therefore, the Soyuz aft reflector was used for the 500-m data take.

Soyuz Deorbit and Landing

The Soyuz deorbit maneuver was performed at 141:50 GET. The reentry vehicle was brought to a safe landing in Kazakhstan at 10:51 UT on July 21, 1975, after a flight of 142 hours 31 minutes.

Apollo Orbit Continuation Phase

The Apollo spacecraft continued in orbit for approximately 5 days after separation from the Soyuz spacecraft. Following the ultraviolet absorption joint phase data takes, one revolution of

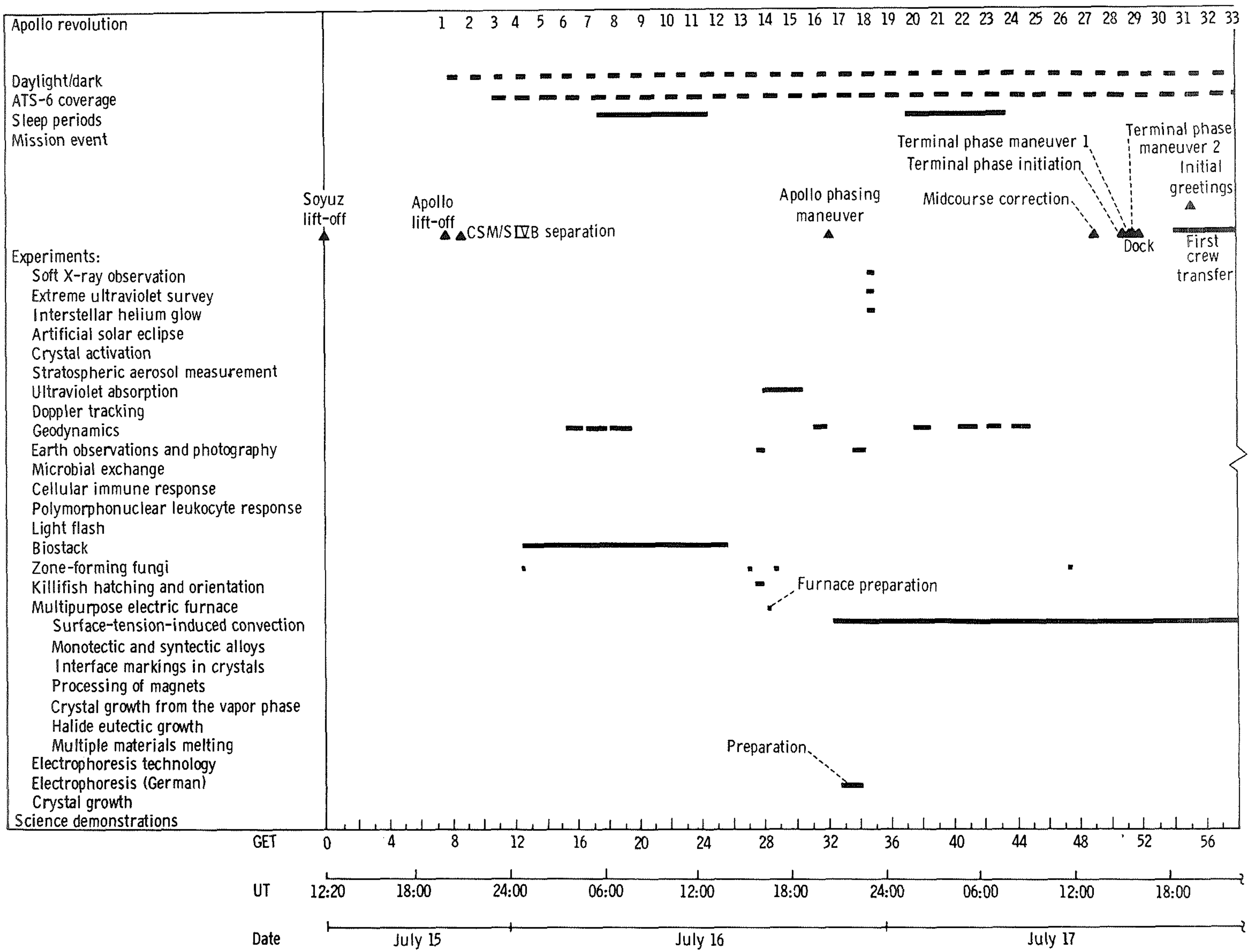

FIGURE 2-7.—Major mission events and data collection periods correlated to UT and GET.

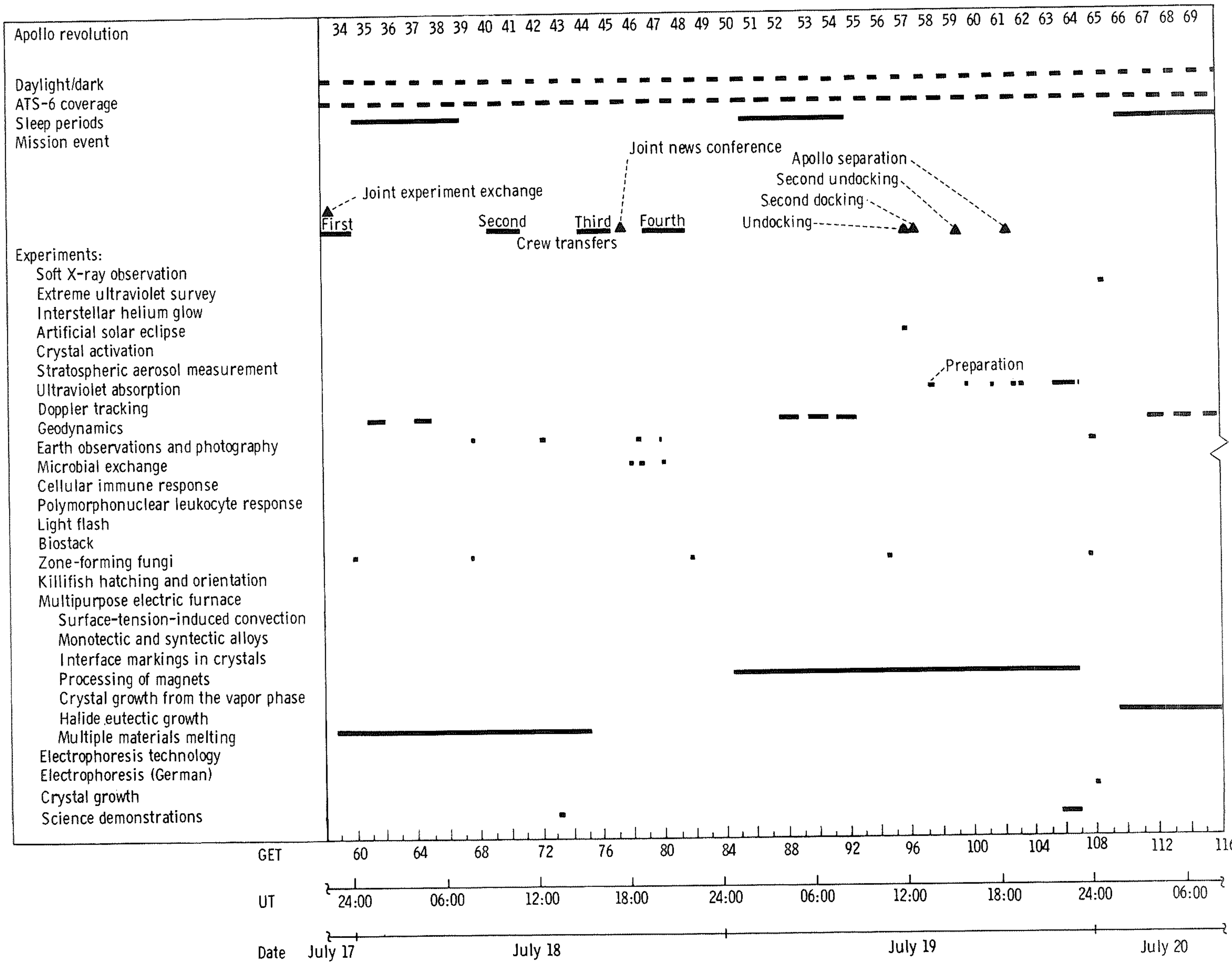

FIGURE 2-7.—Continued.

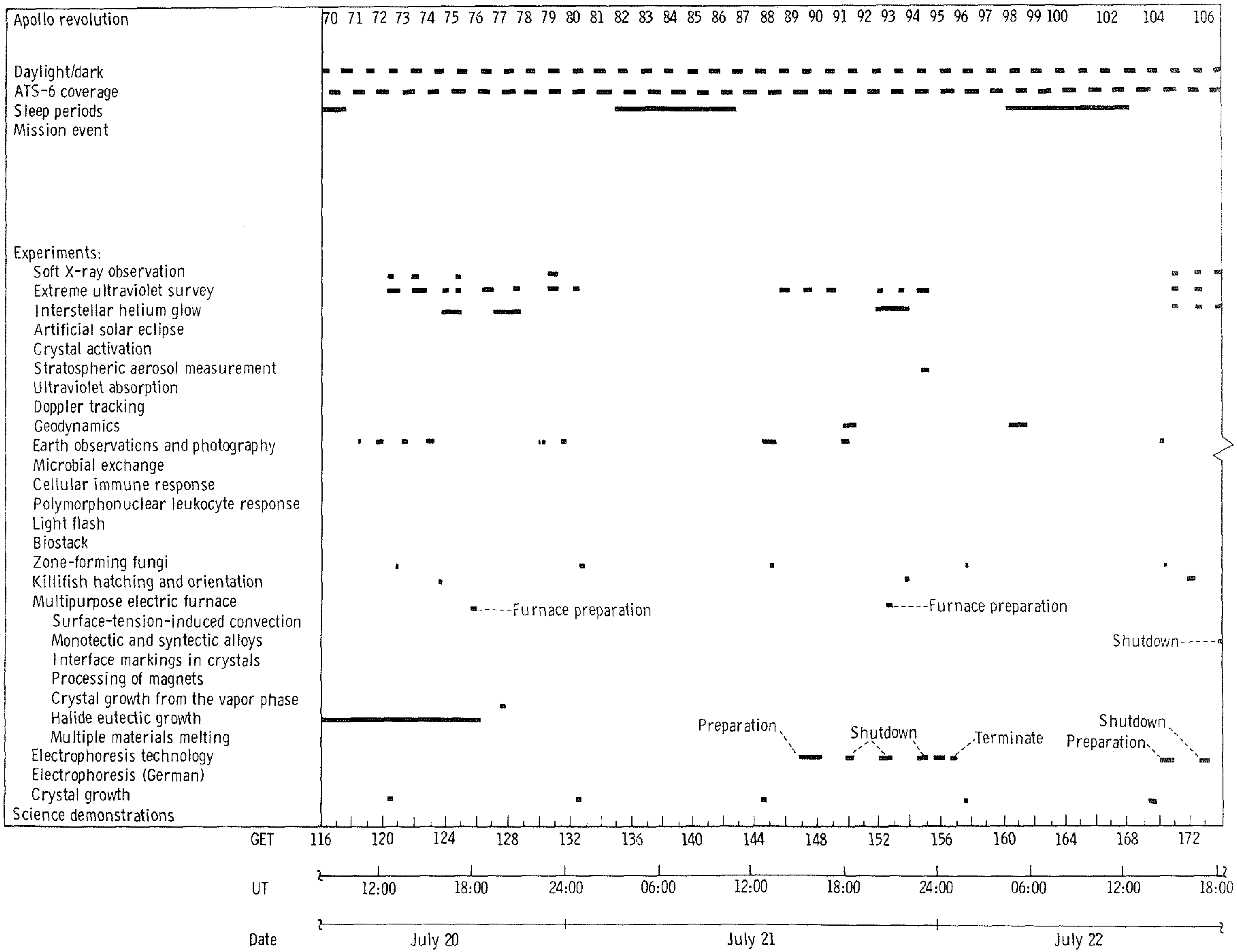

FIGURE 2-7.—Continued.

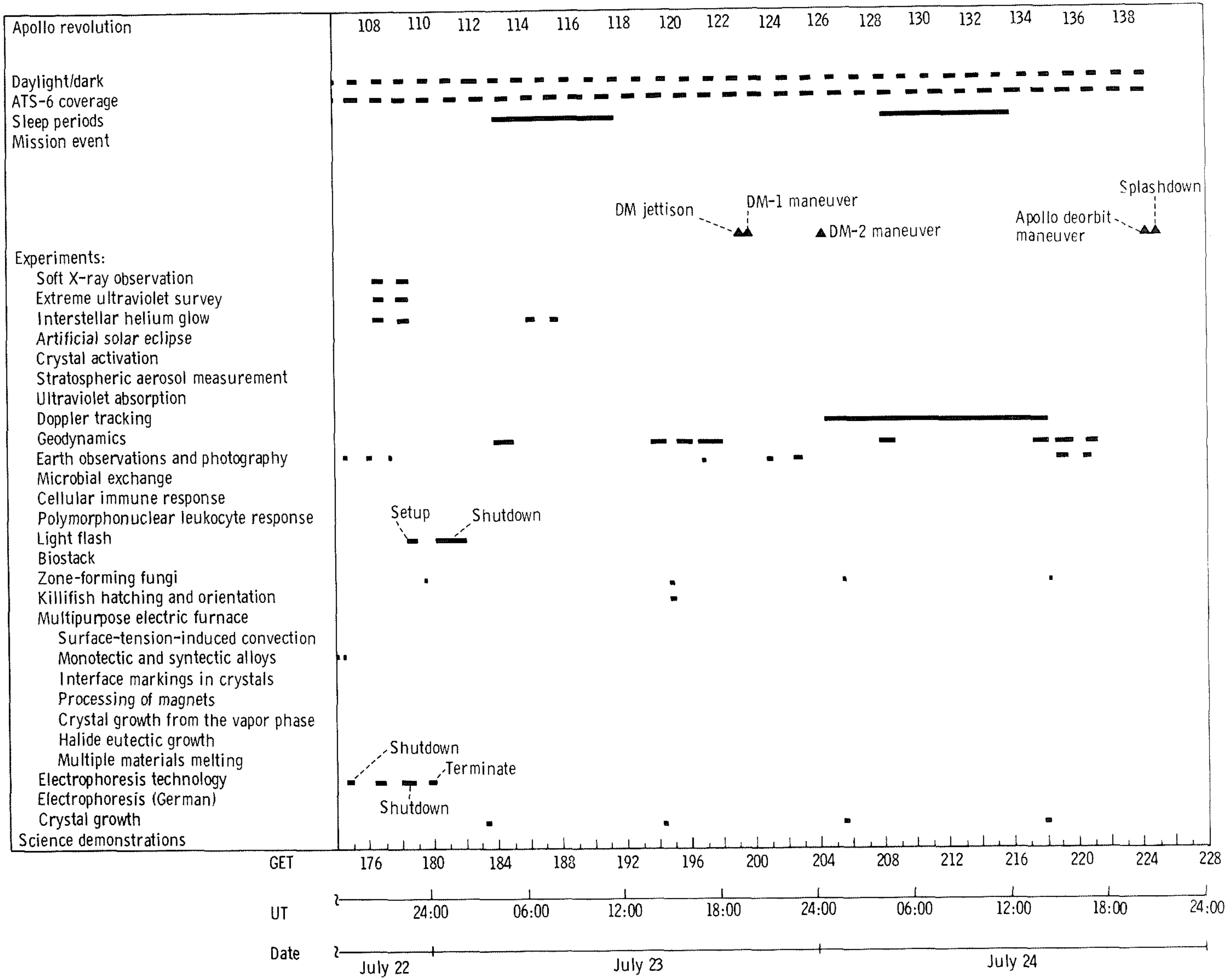

FIGURE 2-7.—Concluded.

Apollo out-of-plane data was obtained and a spacecraft test roll maneuver of 360° was performed to measure resonant fluorescence background and ambient atmosphere gas pileup. The experiment was shut down at 107:07 GET.

The multipurpose furnace zero-g processing of magnets was concluded at 106:50 GET, and the Halide Eutectic Experiment was initiated in the furnace at 109:20 GET. In the interim, zone-forming fungi photographs and Earth observations were made; the Crystal Growth Experiment (CGE) was initiated; and a raster scan for the extreme ultraviolet survey was made. After several Geodynamics Experiment data takes and several Earth observations, the extreme ultraviolet experiment was started. The Crystal Growth and Zone-Forming Fungi Experiments were then examined and photographed before the Helium Glow Experiment scans were made. Helium glow data-take periods consisted of sweeping the 15° field of view across regions of the celestial sphere by rolling the Apollo spacecraft about the longitudinal axis. Several excellent roll scan data takes were made. The killifish observations were again made during this period.

Extreme ultraviolet and helium glow scans, Earth observations, geodynamics data takes, and crystal growth and zone-forming fungi observations were continued at intervals; the multipurpose furnace Crystal Growth From the Vapor Phase Experiment was conducted; and the Biostack III Experiment was turned on at 132:00 GET. The Electrophoresis Technology Experiment was initiated at 147:30 GET and was shut down at 152:10; it was started again 18 hours later. The Stratospheric Aerosol Measurements (SAM) Experiment operations were initiated at 154:30 GET, and shutdown occurred at 158:00 GET. The multipurpose furnace Interface Marking in Crystals Experiment was also conducted during this period, as was the Monotectic and Syntectic Alloys Experiment.

During revolution 109, an extreme ultraviolet finding of special significance was made when an intense EUV source was discovered. This discovery was the first known detection of a cosmic source of extreme ultraviolet radiation. The Light Flash Observations Experiment was also initiated during revolution 109. The unmanned portion of this experiment started at 179:13 GET, and the manned portion was initiated during the following revolution. These times were selected so that the two data-take periods would include passage through the South Atlantic Anomaly and would be descending passes (i.e., from northwest to southeast) to provide data at the maximum available geomagnetic latitude and to provide South Atlantic Anomaly data. Periodic zone-forming fungi, geodynamics, crystal growth, Earth observations, helium glow, killifish experiment, soft X-ray, and electrophoresis technology operations were also conducted during this period.

The docking module was jettisoned at 199:27 GET to prepare for the Doppler Tracking Experiment, which required a 300-km separation of the command and service module from the docking module. After jettison, the Apollo crew photographed the docking module and then maneuvered the command and service module to the same orbit as the docking module at a range of 300 km. The data-take period began at 204:20 GET and continued for approximately 14 hours with intentional command and service module attitude changes during the interim. During these 14 hours, periodic crystal growth, zone-forming fungi, geodynamics, and Earth observations operations were continued.

Apollo Deorbit and Landing

After several minor changes in orbit (during the joint phase and the orbit continuation phase) due to decay and maneuvers, the final Apollo orbit was a nominal 213 km with a 13-km difference between apogee and perigee. The Apollo deorbit maneuver was performed at 224:17 GET; and, after a flight of 217 hours 28 minutes, the command module landed approximately 1.3 km from the target point. The time of splashdown was 21:18 UT on July 24, 1975. The command module assumed the stable II attitude for approximately 4.5 minutes after splashdown. The crew remained in the command module during recovery operations and were onboard the U.S.S. *New Orleans* approximately 41 minutes after splashdown.

After shipboard ceremonies, during which the crewmen appeared to be in good condition, it was learned that they had been exposed to oxidizer vapors for several minutes when an arming function and a manual backup function were overlooked during the entry phase of the mission. The crewmen were immediately given intensive medical care. The necessary changes in medical examination schedules and the therapy given the crew potentially affected the Cellular Immune Response Experiment and the Polymorphonuclear Leukocyte Response Experiment. These experiments were complementary experiments that were conducted by preflight and postflight blood sampling and analysis. Despite this impact, scientifically useful results were obtained in these experiments.