the coastal waters were 1° or 2° cooler than sea-water temperatures farther west in the Arabian Sea.

Experiment S007, Spectrophotography of Clouds.—The objective of Experiment S007, Spectrophotography of Clouds, was to measure cloud-top altitudes. The experiment was first flown during Gemini V, and was also scheduled for Gemini VIII. Because of the early termination of the Gemini VIII flight, however, the experiment could not be accomplished. As a result, the National Environmental Satellite Center has designed a second-generation weather satellite that can measure cloud-top altitude and cloud thickness.

Experiment S051, Sodium Cloud Photography.—Experiment S051, Sodium Vapor Cloud, was flown on Gemini XII. The purpose of the experiment was to measure the daytime wind-velocity vector of the high atmosphere as a function of altitude between 62 and 93 miles. The measurements were to be obtained from the deformation of a rocket-made vertical sodium cloud. During the Gemini XII mission, two rockets were launched from Algeria. Although the second launching was easily visible from the ground, the sodium release was not seen by the flight crew. Even though they did not have visual sighting, the pilots photographed the region of the firing using a 70-mm still camera with a wide-angle lens. Unfortunately, shutter difficulties with the camera spoiled the exposed film. The experiment will be rescheduled for the Apollo Program.

Biological Experiments

Experiment S004, Synergistic Effects of Radiation and Zero-g on Blood and Neurospora.—Experiment S004, Synergistic Effect of Zero-g on White Blood Cells, was first carried during Gemini III, and was continued on Gemini XI with the addition of neurospora. A refrigeration unit was added to preserve the blood during the 4-day mission of Gemini XI. Gemini III was a three-orbit flight, and the blood could be recovered for analysis within 24 hours; therefore, refrigeration was not required.

An identical experimental package was established as a control in a laboratory at Cape Kennedy. It was activated simultaneously with the package in the spacecraft and was maintained under similar temperature conditions. Air-to-ground communications from the flight crew verified that the experiment was proceeding through the various stages exactly as planned.

The experiment was successfully conducted on the Gemini XI mission. The leukocyte-chromosome analysis of the blood showed no increase in the chromosome-deletion frequency in the flight samples over the ground control samples. The result does not confirm the preliminary results found on Gemini III. Preliminary results from the neurospora portion of the experiment carried on Gemini XI indicate no increase in the frequency of mutations in the flight samples. This part of the experiment analysis will require more time, but there now appears to be no observable synergism between radiation and space flight on white blood cells.

Experiment S003, Frog Egg Growth Under Zero-g.—The objectives of Experiment S003, Frog Egg Growth Under Zero-g, were to determine the effect of weightlessness on the ability of the fertilized frog egg to divide normally, and to differentiate and form a normal embryo. The experiment was performed in one package mounted on the right hatch in the spacecraft. The package had four chambers containing frog eggs in water with a partitioned section containing a fixative. Handles were provided on the outside of the package so the flight crew could activate the experiment.

During Gemini VIII, early cleavage stages were successfully obtained; however, the short duration of the flight did not permit formation of the later cleavage and developmental stages. During Gemini XII, the experiment was completely successful from a mechanical standpoint, and later embryonic stages were obtained. The 10 embryos in the fixation chambers appeared to be morphologically normal. The five embryos which were unfixed were live, swimming tadpoles when the chamber was opened on board the recovery ship. Three of the embryos were morphologically normal; two were abnormal (twinning). The abnormalities, however, were not inconsistent with the controls, and no abnormalities can be ascribed to the flight at this time. The five surviving tadpoles died several hours after recovery, and were fixed for histological sectioning. The reason for death has not yet been ascertained; however, all the eggs will be sectioned for histological study to determine more conclusive results.

Visual Acuity Experiment

Experiment S008, Visual Acuity.—The ability of the flight crew to visually detect and recognize objects on the surface of the Earth was tested during Gemini V and VII in Experiment S008, Visual Acuity. Data from an inflight vision tester used during these flights showed no change in the visual performance of the crews. Results from the flight-crew observations of the ground site (fig. 19-6) near Laredo, Tex., confirm that visual performance during space flight was within the statistical range of the preflight visual performance, and that there was no degradation of the visual perception during space flight.

Astronomical Photography Experiments

Experiment S001, Zodiacal Light and Airglow Photography.—A series of excellent photographs for Experiment S001, Zodiacal Light Photography, was obtained during the Gemini IX–A flight. A photograph of the zodiacal light and the planet Venus is shown in figure 19–7. The apparent curvature of the airglow layer is due to the nature of the lens. The presence of Venus points out that the zodiacal light lies in the ecliptic plane. After sunset, a ground observer can see the zodiacal light. However, he must wait for twilight in order to see the dim-sky phenomena; even then the view is never free of the airglow, and not often of the glare from city lights. The photograph clearly distinguishes the cone-shaped zodiacal light from the narrow airglow layer visible just above the moonlit Earth. Heretofore, only an artist's drawing has been able to represent the zodiacal light as it would appear to a ground observer without the visual distractions of city lights, airglow, and faint sources of celestial light.

Experiment S011, Airglow Horizon Photography.—Experiment S011, Airglow Horizon Photography, was conducted during Gemini XI and XII as well as Gemini IX–A. The crews used the 70-mm general-purpose still camera in the f/0.95 configuration to photograph the night airglow layer with the Earth's limb. The camera was mounted so that exposures of 2 to 50 seconds could be obtained through the right hatch window. The objective was to obtain worldwide measurements of airglow altitude and intensity.

The camera filter system registered the spectral regions of 5577 angstroms (oxygen green) and 5893 angstroms (sodium yellow) side by side but separated by a vertical dividing line. Filter bandwidths were 270 and 380 angstroms, respectively. In figure 19–8, an example of the split-field photography taken during Gemini IX–A is shown. This is a 5-second exposure looking west. The corresponding star field is shown in figure 19–9, and the bright stars Procyon and Sirius are visible in the airglow layer. The pictures are being analyzed for possible height variations in the two layers.

During Gemini XI, an additional 6300-angstrom (red) filter with a bandwidth of 150 angstroms was provided to obtain photographs in a higher orbit; however, no photographs were obtained because of a camera malfunction. On Gemini XII, the split-field filter was removed, and the entire field was exposed with 40-angstrom-wide filters in alternate green and yellow bands. The 6300-angstrom filter was not used during Gemini XII because a high-altitude orbit could not be achieved. Much more work remains on airglow research, but the results obtained from Experiment S011 have demonstrated several useful lines of approach.

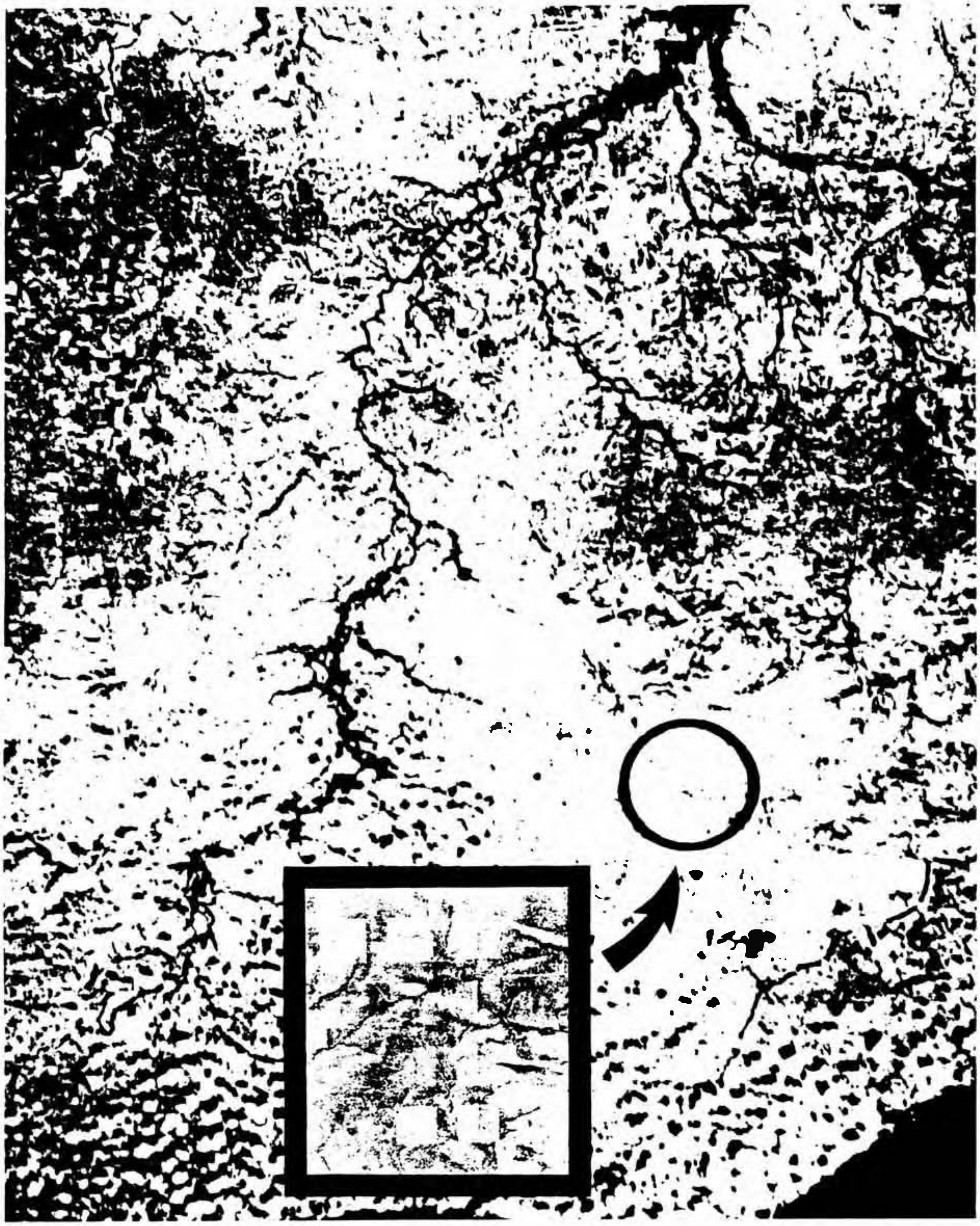

FIGURE 19-6.—Experiment S008 visual acuity ground pattern near Laredo, Tex. The inset area is an aerial photograph of the ground pattern.

FIGURE 19-7.—Zodiacal light and planet Venus. Airglow is seen as a narrow band above the moonlit Earth.

FIGURE 19-8.—Star field seen in airglow split-field filter photography.

Experiment S030, Dim Sky Photography/Orthicon.—Experiment S030, Dim Sky Photography/Orthicon, was conducted during Gemini XI. The image orthicon system of Experiment D015, Night Image Intensification, was used to obtain 415 pictures of airglow in a 360° sweep. At times, the image orthicon sensitivity was so great that these pictures were almost overexposed. There is some indication of a splitting of the airglow into two layers. The system had an automatic gain control with the sensitivity varying constantly; this makes calibration of the pictures difficult and time consuming. Figure 19-10 shows two sample frames. In figure 19-10 (b), the blot above the airglow is due to the cathode tube.

Experiment S029, Libration Regions Photography.—The purpose of Experiment S029, Libration Regions Photography, was to investigate by photographic techniques the libration points of the Earth-Moon system to determine the possible existence of clouds or particulate matter orbiting the Earth in these regions. The Gemini XII mission was the first mission on which any libration region was available for photography. The 70-mm still camera with a wide-angle

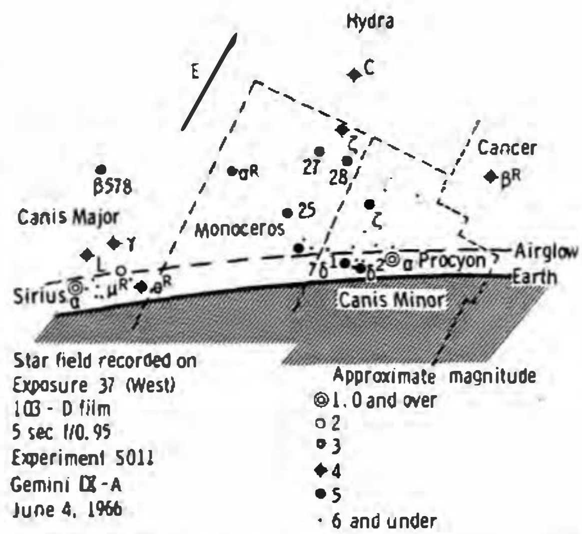

FIGURE 19-9.—Split-field filter photography showing Procyon and Sirius (from Norton's Atlas, maps 7 and 8).

lens was used and the results are not immediately obvious, but appear to be less than satisfactory. Isodensitometry will be run on several exposures, but at this time the study is not expected to yield positive results.

Micrometeorite, Cosmic Ray, and Ion Wake Experiments

Experiment S010, Agena Micrometeorite Collection.—As part of Experiment S010, Agena Micrometeorite Collection, a package for recording micrometeorite impacts was installed on the Gemini VIII target vehicle.

FIGURE 19-10.—Airglow photographs obtained from image orthicon system. (a) Near Canopus; (b) Near Arcturus.

After approximately 4 months in orbit, the package was recovered by the Gemini X flight crew. Optical scanning at the Dudley Observatory of the four stainless-steel slides on the outside of the box (protected from launch) have revealed at least four craters larger than 4 microns; these appear to be hyperballistic. Figure 19-11 shows one crater which has a diameter of 200 microns, a depth of 35 microns, and a lip height of 25 microns. This crater has been named Crater Schweickart for the astronaut who suggested that there be an outside collection area on the micrometeorite package on which micrometeorites could impact, even though the pilot did not open the package during extravehicular activity. The Dudley Observatory has installed a stereoscan electron microscope which will permit scanning the surface in the original form, thus minimizing sample contamination. Results of this work are not yet known.

During the Gemini XII mission, the extravehicular pilot opened the package on the Gemini XII target vehicle and exposed the sensitive collection plates to the space environment. The package was intended to be retrieved during some future mission; however, it is expected that the target vehicle will reenter the Earth's atmosphere before the package can be recovered.

Experiment S012, Gemini Micrometeorite Collection.—The package for Experiment S012, Gemini Micrometeorite Collection, was successfully recovered from the Gemini IX-A spacecraft adapter section after an exposure of over 16 hours. For comparison, another package was exposed for 6 hours during the Gemini XII flight (fig. 19-12). This experi-

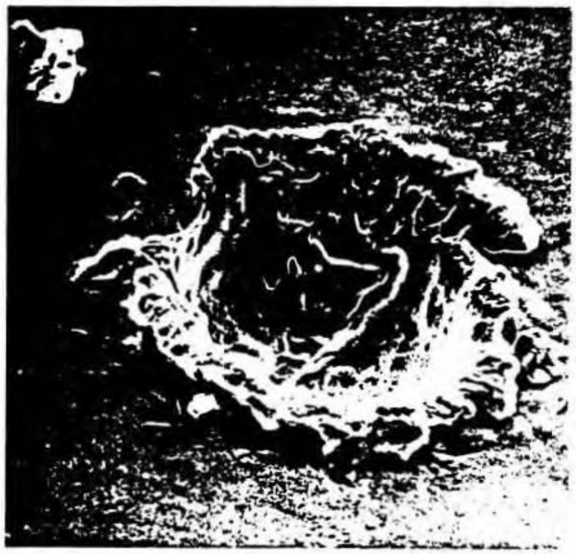

FIGURE 19-11.—Micrometeorite impact crater.

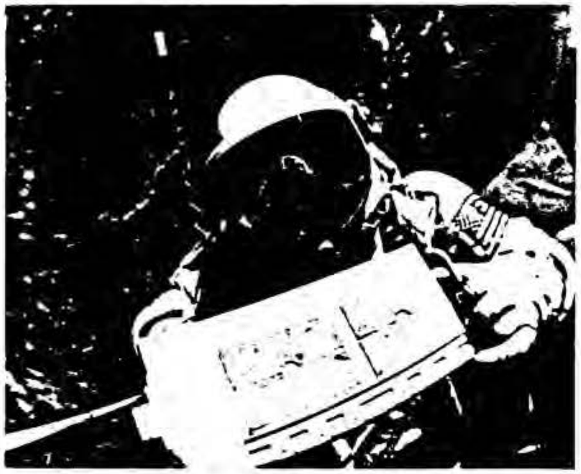

FIGURE 19-12.—Gemini XII pilot retrieving micrometeorite collection package.

ment had a number of guest investigators from the United States and abroad. A full report of the results can be made only after the impact craters have been carefully scanned with the electron microscope. A preliminary examination of 1 square centimeter of the surface of the Gemini XII package has revealed no impacts. Much work remains to be done to complete the analysis of this experiment.

Experiment S009, Nuclear Emulsions.—During the extravehicular activities of the Gemini XI mission, the pilot retrieved the package for Experiment S009, Nuclear Emulsions, from the exterior surface of the spacecraft adapter section. The Naval Research Laboratory has finished the initial scan of about one-fourth of the emulsion stacks, and has found about 700 tracks which must be sorted according to origin (either inside or outside the spacecraft) during activation of the experiment. It is estimated that about 200 of these tracks will belong to the experiment. If this percentage can be used throughout the analysis of the experiment, then it may be expected that between 1000 and 2000 usable tracks will have been recorded.

At the present time, the experimenters are performing a special kind of scan to obtain information on the appearance of the tracks in order that a preliminary report can be prepared on this aspect. Later, a detailed scanning, which is expected to require 1 to 2 years to complete, will provide information on the light nuclei. The experiment group at the Goddard Space Flight Center is concentrating on detailed scanning of the emulsion stacks in order to make progress on the analysis of the light nuclei, the main objective of the experiment.

Experiment S026, Gemini Ion Wake Measurement.—Experiment S026, Ion Wake Measurement, was conducted during Gemini X and XI. A great deal of ambient data were obtained during Gemini X, and all requested modes were performed during Gemini XI. Reduction of the data will be a rather painstaking task that will necessitate coordination of all available records of times and activities during the operation. It is believed that this experiment can result in a very useful method for mapping the actual wake of a vehicle.

Ultraviolet Photography Experiments

Experiment S064, Ultraviolet Dust Photography.—Experiment S064, Ultraviolet Dust Photography, was designed to provide ultraviolet photographs of dust in the Earth atmosphere, and was carried on Gemini XII. The experiment used black-and-white film in the 70-mm still camera with an ultraviolet lens. A series of sunrise photographs was made in the ultraviolet region; however, due to the many electrostatic marks in the film, very little information has been determined.

Experiment S013, Ultraviolet Astronomical Photography.—Experiment S013, Ultraviolet Astronomical Photography, used the 70-mm general-purpose still camera with an ultraviolet lens. Similar but less severe trouble was experienced with the electrostatic marks as on Experiment S064. An ultraviolet spectrum of the bright star Sirius was obtained on the Gemini XII mission (fig. 19-13). The Balmer series of hydrogen appears at the right. The Mg II doublet at 2800 angstroms and several other weak, sharp lines of Fe II appear at the left. The exposure was 20 seconds. Figure 19-14, a spectrum of

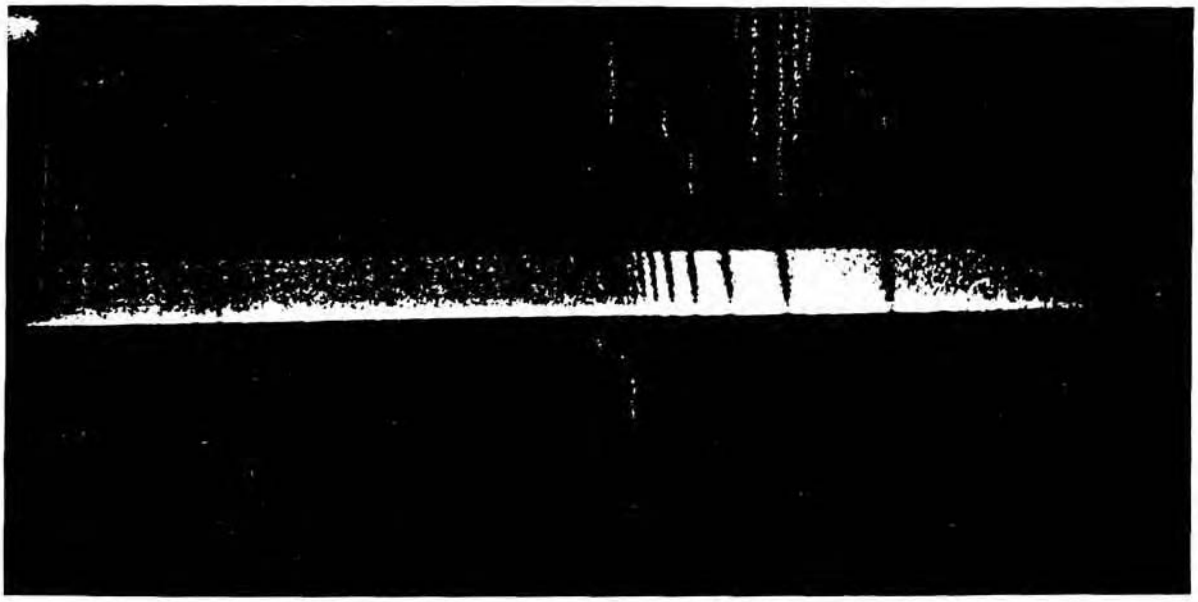

FIGURE 19-13.—Grating ultraviolet spectrum of Sirius.

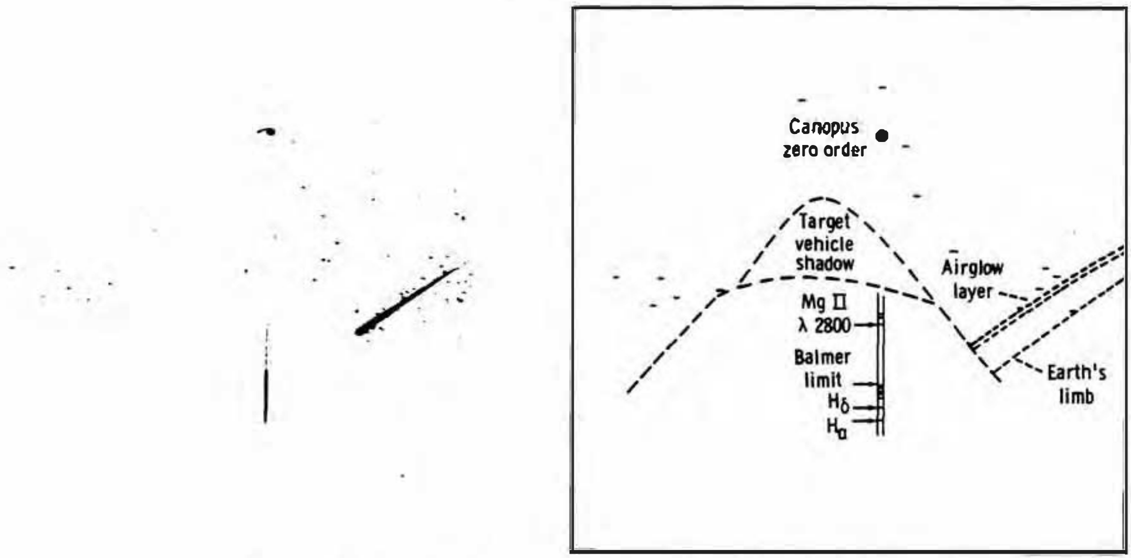

FIGURE 19-14.—Grating ultraviolet spectrum of Canopus.

the solar-type star Canopus, was obtained from Experiment S013, Gemini XI, frame 98, Dearborn Observatory, Northwestern University. This spectrum was especially useful for calibration purposes when compared with the solar spectra obtained from rockets.

In addition to the two remarkable grating spectrograms, several prism spectrograms were obtained. The prism resulted in a lower dispersion, but provided significant information on a large number of stars. The photographs recorded stars of fainter magnitude than was anticipated, and there will be work to be done on the ultraviolet energy curves for many months as a result of the photographs. Figure 19–15 is a reproduction of a

FIGURE 19–15.—Prism ultraviolet spectrogram of Cygnus region. The spacecraft shadow is on the left.

prism spectrogram of Cygnus and is typical of the exposures obtained during this experiment.

Since the spacecraft windows did not admit ultraviolet light, the experiment would not have been possible without the extravehicular capability of the pilot. Thus far, it has been possible to obtain only a few ultraviolet stellar spectra from rocket flights. During the three trials of this experiment during the Gemini Program, considerable ultraviolet information was obtained and should be especially useful in planning future ultraviolet experiments for manned flights.

Concluding Remarks

Significantly, Gemini experience has shown much about what can be done in the area of experiments for manned operations, and has uncovered some of the pitfalls. In summary, it seems clear that the same attention must be paid to all details of the experiments, crew procedures, and crew training that has been devoted to spacecraft operation. When this is possible, the return of new scientific information will increase. It is safe to say that scientific information has increased exponentially since Project Mercury, and is expected to continue to follow an upward curve. The interest the flight crew and the engineers have shown in the experiments has nearly matched the keen interest of the investigators, and will continue to be a large factor in future manned space-flight experiments.

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20. DOD/NASA GEMINI EXPERIMENTS SUMMARY

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Introduction

The DOD/NASA Gemini Experiments Program consisted of 15 experiments, sponsored by several development agencies of the Department of Defense. Experiments were selected which could be accomplished with minimum effect on the Gemini Program, and which would contribute to the solution of the evaluation of space technical development problems of interest to DOD. Participation in the experiments program provided a means for DOD elements to acquire data and operations experience for evaluation of the ability of man to accomplish missions in space, and provided a mechanism for the timely flow of manned space-flight development information between NASA and DOD.

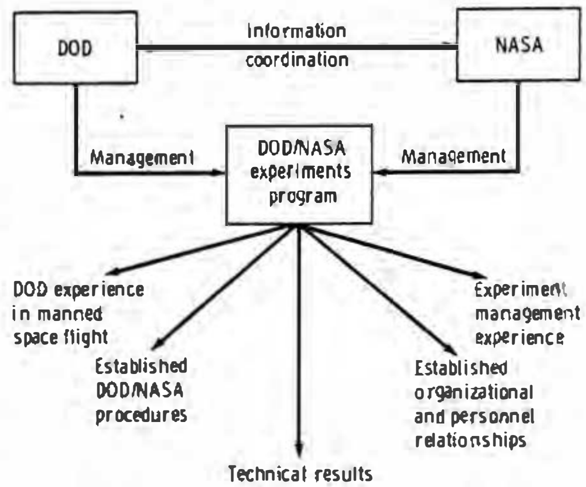

FIGURE 20-1.—DOD/NASA Gemini experiments program results.

Program Accomplishments

Although the technical result outwardly appeared to be the major program accomplishment, several other results of equal importance were obtained during the joint DOD/NASA implementation of the experiments program (fig. 20-1).

DOD Experience in Manned Space Flight

Through the experiments program, DOD participation was broadened to include experience in spacecraft, crew, and operational activities in addition to the experience acquired through program responsibilities for the Gemini Launch Vehicle, the Gemini Agena Target Vehicle, and the DOD Range Support. The direct working association with the Gemini Program permitted DOD development agencies at all levels to gain practical experience in manned space-flight development.

Procedures and Experience

Implementation of the DOD/NASA Gemini Experiments Program required the designation of responsibilities and development procedures for joint management. Organizational elements and procedures have been established for future joint activity, and experience has provided a better understanding of such joint activity for future planning.

Establishment of Organizational and Personnel Relationships

One of the most significant results of DOD participation in the Gemini Program was the development of organization knowledge and the establishment of personnel relationships which facilitate the flow of manned space-flight development information between DOD and NASA agencies. Active participation in the Gemini Program provided a working-level insight which facilitated the recognition

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of information significant to DOD programs; and provided personnel and organizational rapport which expedited NASA/DOD support. The established relationships have been most beneficial in liaison with the Apollo and Apollo Applications Programs.

Experiment Management Information

The program has developed some specific conclusions related to management of experiments conducted as secondary objectives of a basic program. Although the following conclusions are of secondary importance as experiment program results, they are considered significant for future management planning.

Each experiment should be scheduled on at least two flights. The probability of successful attainment of experiment objectives on a single attempt is too low to risk high experiment development cost. Because experiments were considered as secondary mission objectives, successful experiments were highly dependent on the accomplishment of primary mission objectives. Occasions of higher-than-nominal fuel usage, of reduced electrical power, and of other mission problems resulted in the curtailment of experiment activities and the inability to obtain experiment objectives. A second experiment flight was essential to success in these cases.

The experiment interface with the spacecraft should be minimized. A simplified interface will generally result in higher reliability, in lower integration cost, in greater operational flexibility, and in reduced effect of basic spacecraft hardware change.

Colocation of the experiment manager with the agency accomplishing the basic program management provides a significant advantage for all experiments, and is essential for those experiments which have complex interfaces with the basic program. Experiments are developed concurrently and interact with the basic program development, and the experiment managers must develop detailed awareness of basic program effects and constraints to efficiently integrate the experiments. In dynamic development programs, this awareness can be developed only through day-to-day contact with the management personnel accomplishing the basic program.

The experimenter must emphasize the support of flight-crew training. The crew must represent the experimenter at a crucial point in what is normally an advanced experimental process; therefore, the crew must possess maximum understanding of experimental objectives and procedures. Training simulations using equipment identical to flight hardware are highly desirable. Direct contact between the experimenter and the crew during experiment training is essential.

Careful consideration should be given to scheduling the secondary experiments which require a large amount of crew operational time. Because such experiments have a greater probability of being affected by primary program contingencies, they have a lesser probability of success.

Technical Results

Program technical results were good. Of the 15 programed experiments, 11 were successfully completed (table 20–I). The four remaining experiments were carried on Gemini missions, but flight tests were not completed. Although flight test objectives of these four experiments were not completely attained, valuable data and experience were acquired during experiment development.

Experiments D001, D002, and D006, Basic Object, Nearby Object, and Surface Photography.—Photography accomplished during Project Mercury was oriented to a broad area of coverage with no specific pointing or tracking requirements. Experiments D001, D002, and D006 were designed to investigate the ability of man to acquire, track, and photograph objects in space and on the ground on a preplanned basis using photographic equipment with a small field of view. Acquisition of preplanned photographs of the Moon, planets, and points on the surface of the Earth clearly demonstrated the capability. The photograph of Love Field, Dallas, Tex. (fig. 20–2), is representative of the data acquired.

TABLE 20-I.—*DOD/NASA Gemini Experiments*

Experiment no.	Title	Flight	Result
D001	Basic Object Photography	V	Complete
D002	Nearby Object Photography	V	Incomplete
D003	Mass Determination	VIII, XI	Complete
D004	Celestial Radiometry	V, VII	Complete
D005	Star Occultation Navigation	VII, X	Complete
D006	Surface Photography	V	Complete
D007	Space Object Radiometry	V, VII	Complete
D008	Radiation in Spacecraft	IV, VI-A	Complete
D009	Simple Navigation	IV, VII	Complete
D010	Ion-Sensing Attitude Control	X, XII	Complete
D012	Astronaut Maneuvering Unit	IX-A	Incomplete
D013	Astronaut Visibility	V, VII	Complete
D014	UHF/VHF Polarization Measurements	VIII, IX-A	Incomplete
D015	Night Image Intensification	VIII, XI	Complete
D016	Power Tool Evaluation	VIII, XI	Incomplete

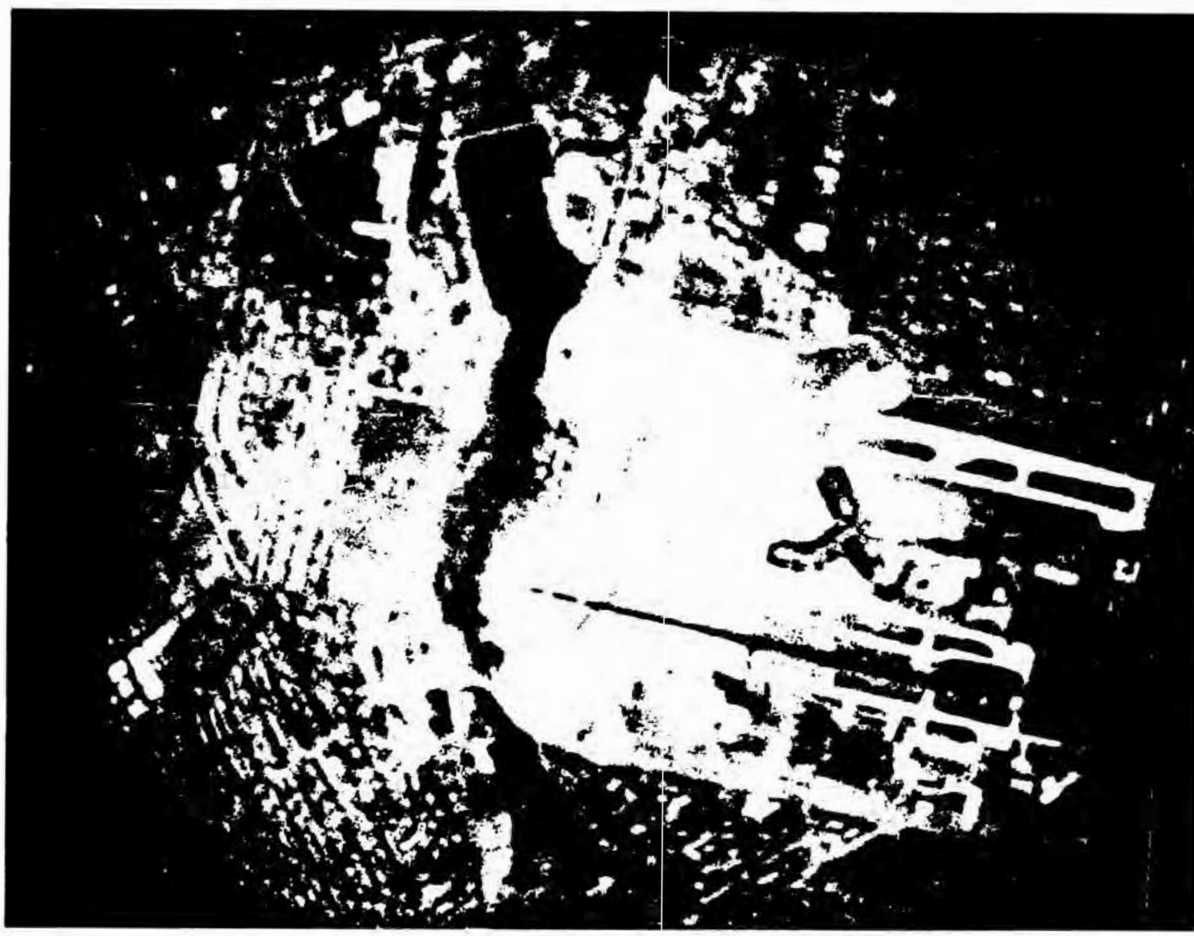

FIGURE 20-2.—Love Field, Dallas, Tex. Photograph taken during the Gemini V mission.

Experiment D003, Mass Determination.—Experiment D003 demonstrated the feasibility and the accuracy of determining the mass of an orbiting object by thrusting on it with a known thrust and measuring the resulting change in velocity. The experiment was conducted during the Gemini XI mission and used a Gemini Agena Target Vehicle as the orbiting object. The mass as determined from the experiment procedure was compared with the target-vehicle mass as computed from known launch weight and expendable usage to determine the accuracy of the method.

Experiment D003 investigated two methods of data acquisition. The Telemetry Method was based upon the telemetry data from the spacecraft computer and Time Reference System. The Astronaut Method was based upon data displayed by the spacecraft Manual Data Insertion Unit and the event timer, and recorded by the flight crew. In both cases, spacecraft thrust was determined from a calibration firing of the spacecraft propulsion system with the spacecraft and target vehicle undocked. Resulting spacecraft thrust F_c was computed from

$$F_c = \frac{M_G \Delta V}{\Delta t}$$

where

M_G—mass of spacecraft, slugs
ΔV—measured incremental velocity, ft/sec
Δt —measured thrusting time interval, sec

Data from the calibration and mass-determination firings for each method investigated are shown in figures 20–3 and 20–4, and in table 20-II. Using these data, the mass of the target vehicle was computed from

$$M_{A_c} = \frac{F_c(\Delta t)}{\Delta V} - M_{G_c}$$

where

M_{A_c}—target-vehicle mass, slugs
F_c —maneuvering thrust of the spacecraft, lb
Δt —measured thrusting time interval, sec
ΔV —measured incremental velocity, ft/sec
M_{G_c}—spacecraft mass, slugs

TABLE 20–II.—*Manually Observed Data, Astronaut Method*

Experiment operations	Time, sec	Velocity change, ft/sec
Calibration maneuver	11	9.8
Mass determination maneuver	7	2.94

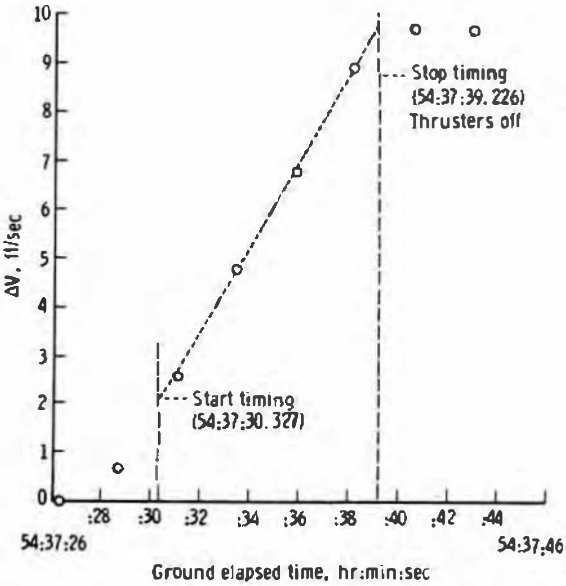

FIGURE 20–3.—Calibration maneuver. Experiment D003, Mass Determination, telemetry method.

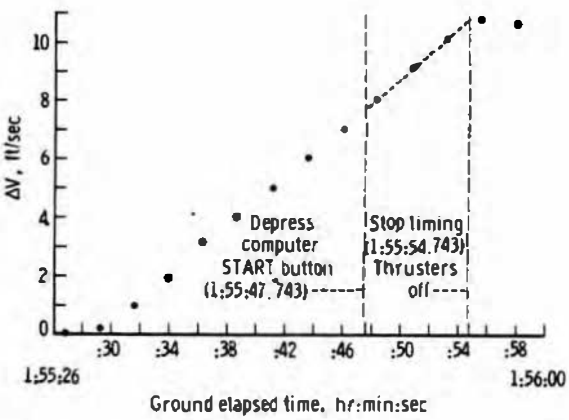

FIGURE 20–4.—Experiment D003, mass determination maneuver, telemetry method.

Comparison with target-vehicle mass as computed from launch weight and known expendables indicated a variation in results of 4.9 percent for the Telemetry Method and 7.6 percent for the Astronaut Method (table 20-III).

Experiment D004/D007, Celestial Radiometry/Space Object Radiometry.—Experiment D004/D007 was conducted during the Gemini V and VII missions. The spacecraft carried two interferometer spectrometers and a multichannel spectroradiometer for measurements of selected sources in the bands indicated in figure 20-5. Equipment characteristics are shown in tables 20-IV, V, and VI. Discrete measurements were made on 72 subjects such as the following:

(1) Gemini VI-A spacecraft thruster plume
(2) Rendezvous Evaluation Pod
(3) Gemini Launch Vehicle second stage
(4) Moon
(5) Stars
(6) Sky background
(7) Space void
(8) Star-to-horizon calibration
(9) Horizon-to-Earth nadir calibration
(10) Large ground fire
(11) Night and day, land and water subjects
(12) Sunlit cloudtops
(13) Moonlit cloudtops
(14) Lightning
(15) Missile-powered flight

TABLE 20-III.—*Weight of Target Vehicle Determined by Experiment D003*

Method	Actual weight, lb [a]	Calculated weight, lb	Variation in weight, lb	Percent
Telemetry	7268	6912	—356	—4.9
Astronaut	7268	7820	552	7.6

[a] Computed from launch weight and usage of consumables.

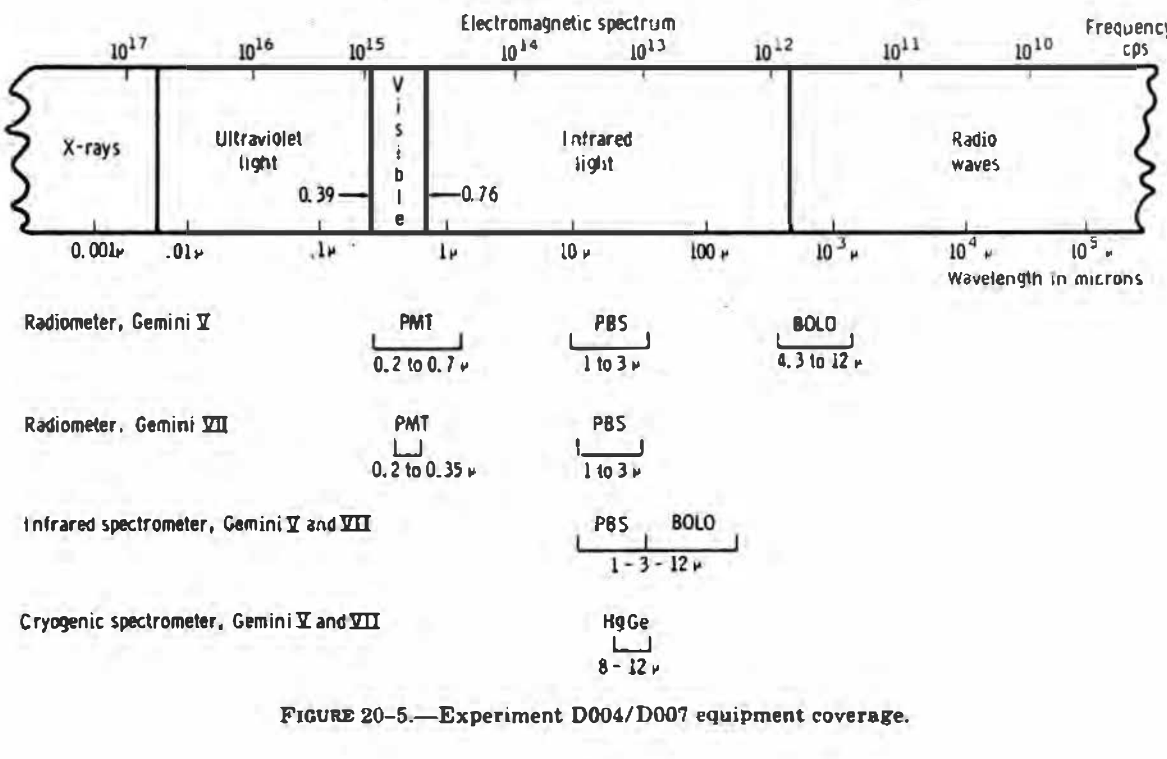

FIGURE 20-5.—Experiment D004/D007 equipment coverage.

TABLE 20-IV.—*Radiometer Instrument Parameters*

Weight, lb	17.5		
Power input, watts	14		
Field of view, deg	2		
Optics, in. Cassegrain	4		
Detectors, Gemini V	**Photomultiplier tube (IP 28)**	**Lead sulfide**	**Bolometer**
Spectral band, μ	0.2–0.6	1.0–3.0	4–15
Nominal filter width, μ	0.03	0.1	0.3
Filters used, μ	.22	1.053	4.30
	.24	1.242	4.45
	.26	1.380	6.00
	.28	1.555	8.0
	.30	1.870	9.6
	.35	2.200	15.0
	.40	2.820	
	.50		
	.60		
Dynamic range	10^5 in 4 discrete steps	10^3 log compressed	10^3 log compressed
Detectors, Gemini VII	**Photomultiplier tube (ASCOP 541 F-05M)**	**Lead sulfide**	**Bolometer**
Spectral band, μ	0.2–0.35	1.0–3.0	
Nominal filter width, μ	0.03	0.1	
Filters used, μ	.2200	1.053	
	.2400	1.242	
	.2500	1.380	
	.2600	1.555	
	.2800	1.870	
	.2811	1.900	
	.2862	2.200	
	.3000	2.725	
	.3060	2.775	
		2.825	
Dynamic range	10^5 in 4 discrete steps	10^3 log compressed	

TABLE 20-V.—*Parameters of the Cryogenic Interferometer/Spectrometer*

Weight (with neon), lb	33.5
Power input, watts	6
Field of view, deg	2
Optics, in. Cassegrain	4
Detector	Mercury-doped germanium
Spectral band, microns	8 to 12
Dynamic range	10^3 automatic gain changing
Coolant	Liquid neon

TABLE 20-VI.—*Parameters of the Infrared Spectrometer*

Weight, lb	18.5
Power input, watts	8
Resolution, cm^{-1}	40
Field of view, deg	2
Optics, in. Cassegrain	4

Detectors	Lead sulfide	Bolometer
Spectral band, μ	1–3	3–15
Dynamic range	10^3 automatic gain changing	10^3 automatic gain changing

The measurements on items (2), (3), (5), (7), and (8) were accomplished with the cryogenic-neon-cooled spectrometer which was successfully used in orbit for the first time during this experiment. New information was obtained on the development and the use of cryogenically cooled sensor systems for space application. Included in the experiment results were the first infrared measurements of a satellite made by a manned spacecraft outside the atmosphere (fig. 20–6). The experiment demonstrated the advantages of using manned systems to obtain basic data with the crew contributing identification and choice of target; choice of equipment mode; ability to track selectively; and augmenting, validating, and correlating data through on-the-spot voice comments.

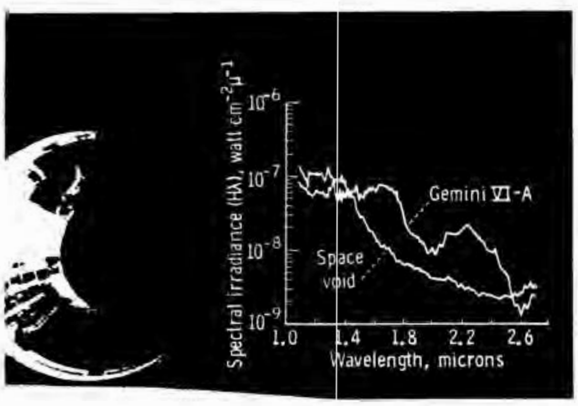

FIGURE 20–6.—Experiment D004/D007 measurement of Gemini VI–A in Earth-reflected sunlight.

Experiment D005, Star Occultation Navigation.—Experiment D005 was conducted to determine the usefulness of star occultation measurements for spacecraft navigation, and to establish a density profile for updating atmospheric models for horizon-based systems. Data analysis has not yet been completed; but preliminary evaluation indicates that the atmospheric density profile is sufficiently stable to provide photometer data for determining spacecraft position with an accuracy of ±1 nautical mile. Typical occultation data are shown in figure 20–7. The photometer developed and tested during this experiment is available for future applications.

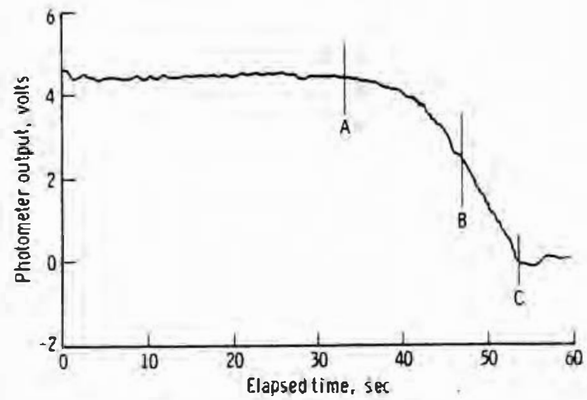

FIGURE 20–7.—Experiment D005, Gemini X. Measurement of Vega occultation.

Experiment D008, Radiation in Spacecraft.—Experiment D008 provided an active tissue equivalent ionization chamber system and passive dosimeters including thermoluminescent devices, film-emulsion packs, and activation foils to record cosmic and Van Allen belt radiation within the Gemini spacecraft. Excellent agreement was found between data from the active and the passive dosimetry. The active dosimeter incorporated a portable sensor to measure radiation dose rate at various points within the spacecraft and about the body of each crewman. The measurements indicated that the total dose received on the Gemini IV mission was 82 millirads; the major portion was Van Allen belt radiation. On Gemini VI–A, a total dose of only 20 millirads was computed. The integrated dose per pass through the South Atlantic anomaly is shown in table 20–VII. On Gemini IV, the instantaneous dose rate reached a level of 107 millirads/hour during revolution 7 (fig. 20–8); the highest dose rate recorded on Gemini VI–A was 73 millirads/hour during a pass through the inner Van Allen belt. Typical cosmic radiation levels for the Gemini orbits are shown in figure 20–9.

The spacecraft shielding influenced dose levels by more than a factor of 2 on both

TABLE 20–VII.—*Radiation Dose Experienced During South Atlantic Anomaly Passes*

Mission	Revolution	Integrated dose per anomaly revolution, mrad
Gemini IV	6	3.0
	7	8.4
	8	10.45
	9	3.5
	21	2.87
	22	7.10
	23	[a]6.0
	24	[a]3.0
	36	3.32
	37	5.90
	38	3.26
	39	2.50
	51	1.72
	52	2.26
	53	[a]2.0
	54	2.0
Total		67.28
Gemini VI–A	5	[a]1.0
	6	6.0
	7	5.5
	8	2.5
	9	1.5
Total		16.5

[a] These data are not measured, but are extrapolated from dose-rate plots of similar type revolutions.

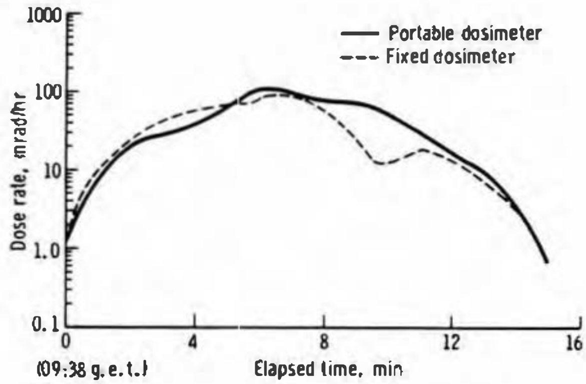

FIGURE 20-8.—Dose rate, South Atlantic anomaly pass, Gemini IV, revolution 7.

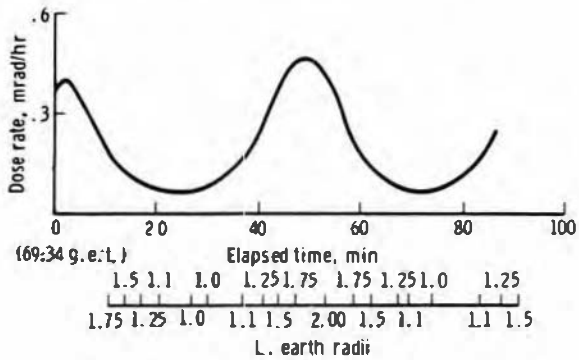

FIGURE 20-9.—Cosmic radiation dose levels within Gemini IV as a function of orbital time and *L*-values for revolution 45.

missions. Film-emulsion data, coupled with special shielding experiments conducted using the active dosimeters, show that the doses received on the Gemini IV and VI–A missions were predominantly a result of the energetic proton component of the inner Van Allen belt: although radiation levels were well within acceptable limits, the data indicated the problems of manned operations deeper in the radiation belts. Equipment developed and tested during this experiment is available for future space applications.

Experiment D009, Simple Navigation.—Experiment D009 developed data on observable phenomena and procedures which can be used for manual spacecraft navigation. A space sextant was developed and tested; the use of the sextant in an autonomous navigation system proved feasible. The observable horizon for sextant measurements was determined to average 14.9 miles above the mean Earth horizon. Typical errors in star coaltitude determination were less than 0.10°. Measurements of angles to 51° were made with ease. Table 20–VIII compares some Gemini VII essential orbital elements computed from ground track data and from sextant data. The calculated uncertainty for the position determined from sextant sightings was 10.1 nautical miles along the track, and 6.3 nautical miles across the track. This compared favorably with the accuracy of the

TABLE 20-VIII.—*Orbit Parameter Comparison for Experiment D009*

Star set no.	Inclination, deg		Right ascension of ascending node, deg	
	Ground track	Sextant	Ground track	Sextant
4	28.90	28.71	192.03	191.85
8	28.90	29.03	192.06	192.37
12	28.87	28.92	192.01	192.20
16	28.90	28.72	192.02	191.84

spacecraft position computed from radar tracking data. **A** flight-qualified sextant is available for future operational use.

Experiment D010, Ion-Sensing Attitude Control.—Experiment D010 developed and tested equipment which used specially adapted ion sensors to indicate spacecraft yaw and pitch angles relative to the flight path. The flight crew confirmed that the system provided an excellent indication of attitude. Data from the ion sensors are compared with data from the Gemini X spacecraft inertial sensor in figures 20-10 and 20-11. The system has excellent possibilities for future attitude indication/control applications.

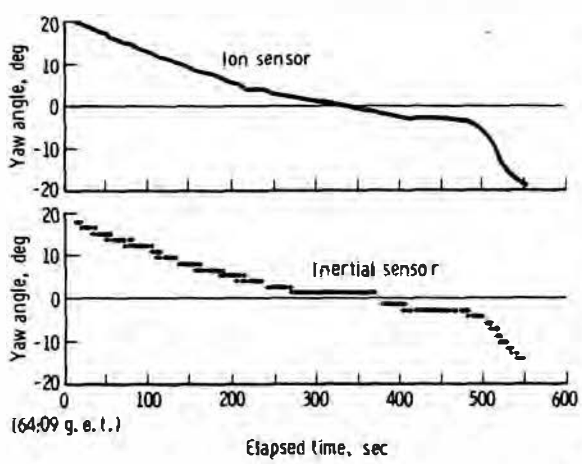

FIGURE 20-10.—Comparison of ion sensor and inertial system yaw-angle measurements, Gemini X.

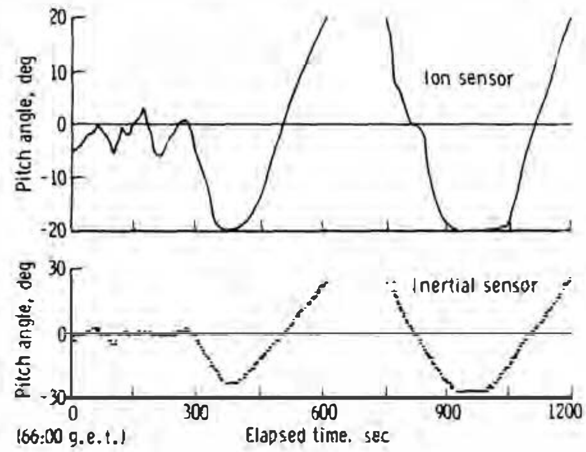

FIGURE 20-11.—Comparison of ion sensor and inertial system pitch-angle measurement, Gemini X.

Experiment D012, Astronaut Maneuvering Unit.—Experiment D012 was not completed due to the inability to accomplish the planned flight tests on Gemini IX-A and XII. The Astronaut Maneuvering Unit was carried in the Gemini IX-A spacecraft, but flight testing was terminated prior to separation of the Astronaut Maneuvering Unit when visor fogging obstructed the vision of the extravehicular pilot. Preparation of the Astronaut Maneuvering Unit for donning demonstrated for the first time that extravehicular work tasks of significant magnitude could be accomplished, and that adequate astronaut restraint provisions were required to maintain the workload within acceptable levels. Extravehicular activity evaluation through Gemini XI indicated that progress of extravehicular activity development was less than desired. Therefore, the final Gemini XII extravehicular activity was devoted to investigation of basic extravehicular activity tasks rather than to testing of the Astronaut Maneuvering Unit. Although flight tests were not completed, the experience and data acquired during design fabrication, testing, and training will be valuable in the planning and future development of personal extravehicular maneuvering units. The Astronaut Maneuvering Unit, the Gemini space suit, and the

Extravehicular Life-Support System (chest pack) are shown in figure 20-12.

FIGURE 20-12.—The Astronaut Maneuvering Unit, Gemini space suit, and Extravehicular Life-Support System.

Experiment D013, Astronaut Visibility.—In conjunction with the scientific visual acuity experiment (S008) which investigated the effects of the space environment on visual acuity, Experiment D013 confirmed a technique for predicting capability of the flight crew to discriminate small objects on the surface of the Earth in daylight. In the experiment, the crew observed and reported ground rectangles of known size, contrast, and orientation as shown in the photograph of the array at Laredo, Tex. (fig. 20-13). Simultaneous measurements were taken of light scattering caused by the spacecraft window and of conditions over the array. The crew reported correctly on the rectangles that earlier predictions indicated they should see.

Experiment D014, Ultrahigh-Frequency/Very High-Frequency Polarization Measurements.—The flight test of Experiment D014 was not completed. The experiment was scheduled for the Gemini VIII and IX-A missions. The experiment was not attempted during Gemini VIII due to control problems which forced early termination of the mission. The experiment was accomplished on Gemini IX-A, but the number of measurements was limited because of other experiments and mission constraints. The success of the experiment required a representative number of measurements; since only a limited number were acquired, objectives were not completely attained. Experiment equipment operation was satisfactory, and experiment technique was successfully demonstrated.

Experiment D015, Night Image Intensification.—In Experiment D015 image intensification equipment was used for the first time on a manned spacecraft to view the Earth in darkness. The crew reported that geographic features (bodies of water, coastlines, and rivers) were observed under starlight conditions, with no Moon. Cloud patterns were especially prominent, indicating a possibility for mapping weather patterns at night. The experiment results provided a basis for evaluating future applications of image intensification equipment in space flight.

Experiment D016, Power Tool Evaluation.—Experiment D016 was not completed due to the inability to complete the planned flight tests. Spacecraft control problems of the Gemini VIII mission prevented evaluation of the minimum-reaction power tool (fig. 20-14). Pilot fatigue necessitated early termination of extravehicular activity during Gemini XI, and evaluation of the power tool was not attempted. Although flight testing was not completed, development and testing of the power tool provided experience and data of value to future development of space maintenance activities.

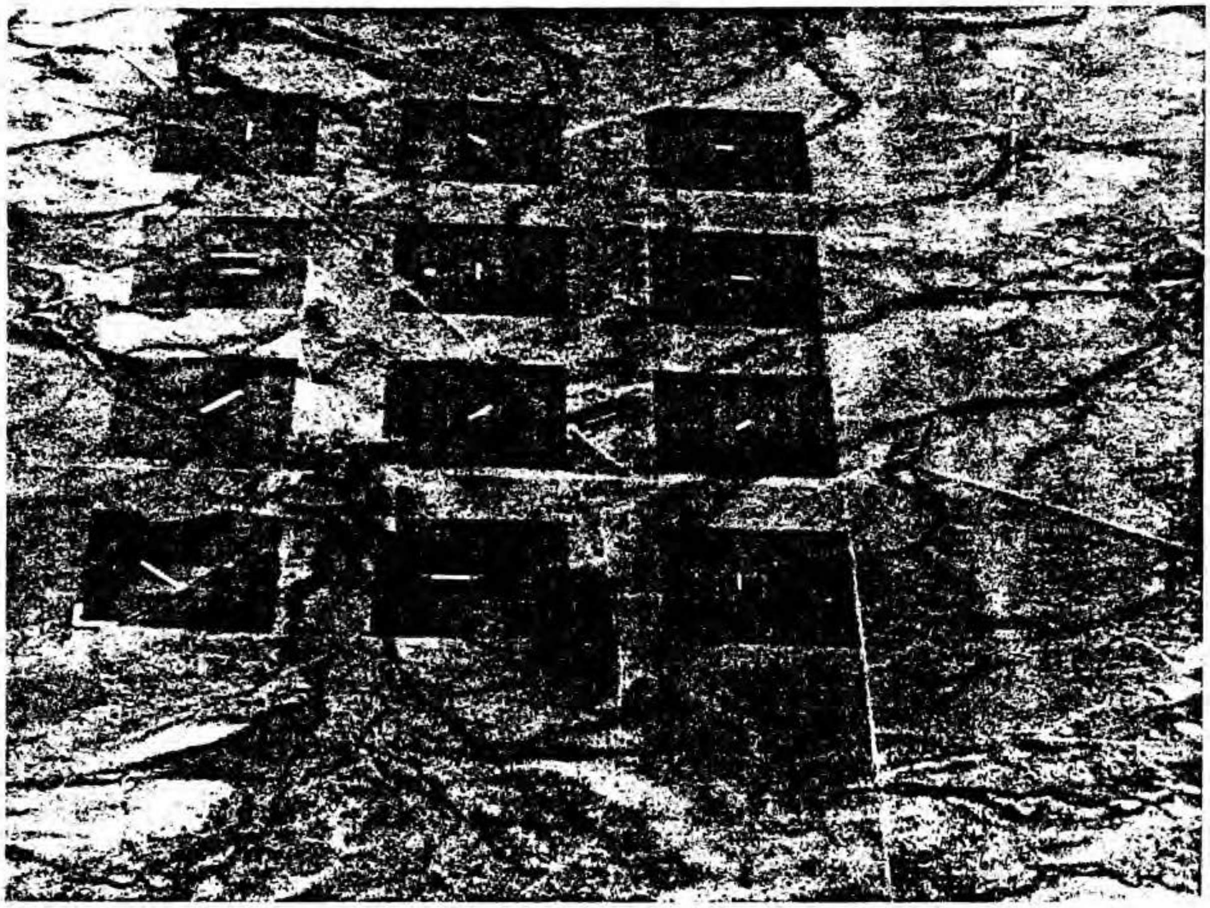

FIGURE 20-13.—Aircraft photograph of Experiment D013, ground array, Laredo, Tex.

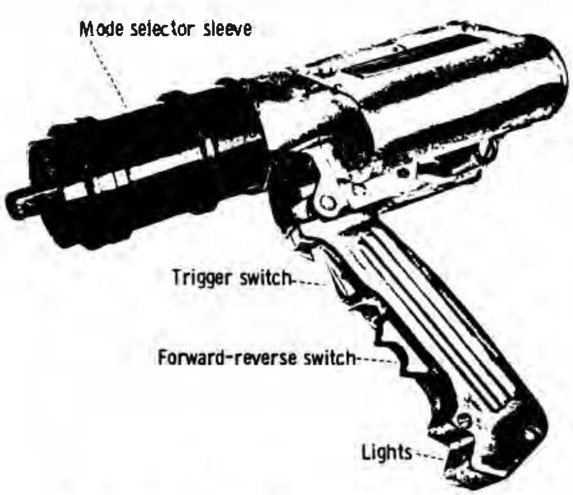

FIGURE 20-14.—Experiment D016, minimum reaction power tool.

Conclusion

Overall evaluation of the DOD/NASA Gemini Experiments Program indicates that the program was successful. Some basic capabilities of man in space which were unknown or uncertain at the beginning of the experiments program are now understood in specific terms. Such understanding will be valuable in the planning of future manned space systems.

GEMINI SUMMARIZATION

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21. ASTRONAUT FLIGHT AND SIMULATION EXPERIENCES

By THOMAS P. STAFFORD, *Astronaut, Astronaut Office, NASA Manned Spacecraft Center*; and CHARLES CONRAD, JR., *Astronaut, Astronaut Office, NASA Manned Spacecraft Center*

Summary

This presentation will be a discussion of the flight simulations and of the actual flight experiences of the Gemini Program. The program has proven that precise flight-crew responses during orbital flight is critically dependent upon the fidelity of the simulation training received prior to flight. All crews utilized a variety of simulators in preparing for their specific missions. Flight experiences have shown that the majority of the simulators were of a high fidelity and that, in most cases, the simulators produced accurate conditions of the actual flight. The few minor discrepancies between the responses, controls, and displays in the simulator and in the actual spacecraft had no noticeable effect on flight-crew performance.

Introduction

The presentation will be categorized into specific areas of the missions, and will compare the fidelity of flight simulations with actual flight experience. The areas will be discussed in the chronological sequence in which they occurred during flight.

Launch

The launch phase encompassed powered flight from lift-off through orbital insertion. The first phase of training for the launch sequence was conducted by the flight crew in the Dynamic Crew Procedures Simulator located at the Manned Spacecraft Center, Houston. The simulator provided sound, motion, and visual cues to the crew (figs. 21–1 and 21–2). During this phase of training, all launch and abort procedures were exercised and revised when necessary. After completing initial practice runs in the Dynamic Crew Procedures Simulator, the crew practiced the launch phase of flight at the start of each Gemini Mission Simulator Session. The initial training was conducted in a shirt-sleeve environment and later with each crewman wearing a full pressure suit. The Gemini Mission Simulator was of the exact configuration of the spacecraft to be flown, and provided both visual displays and sound cues (figs. 21–3 and 21–4).

As the training progressed, launch-abort simulations were practiced with the Gemini Mission Simulator integrated with the Mission Control Center. During these simulations, the Mission Control Center was manned by the mission flight controllers. The majority of the later runs were conducted with the crew suited in either training or flight suits. A final series of runs in the Dynamic Crew Procedures Simulator was conducted approximately 3 weeks prior to launch.

The data displayed in the Dynamic Crew Procedures Simulator and in the Gemini Mission Simulator proved very realistic when compared with the data experienced in flight. Quantitative statistical data and qualitative flight-crew debriefings all correlated this fact. A comparison of Gemini Mission Simulator and actual flight data from the powered-flight phase of the Gemini VI–A mission is shown in figures 21–5 to 21–8. An analysis of the plots indicates a close agreement between the two sources of data. During the debriefing sessions after each flight, the crews have indicated that the response of the simulator controls and displays had an extremely close correlation with the responses observed in flight.

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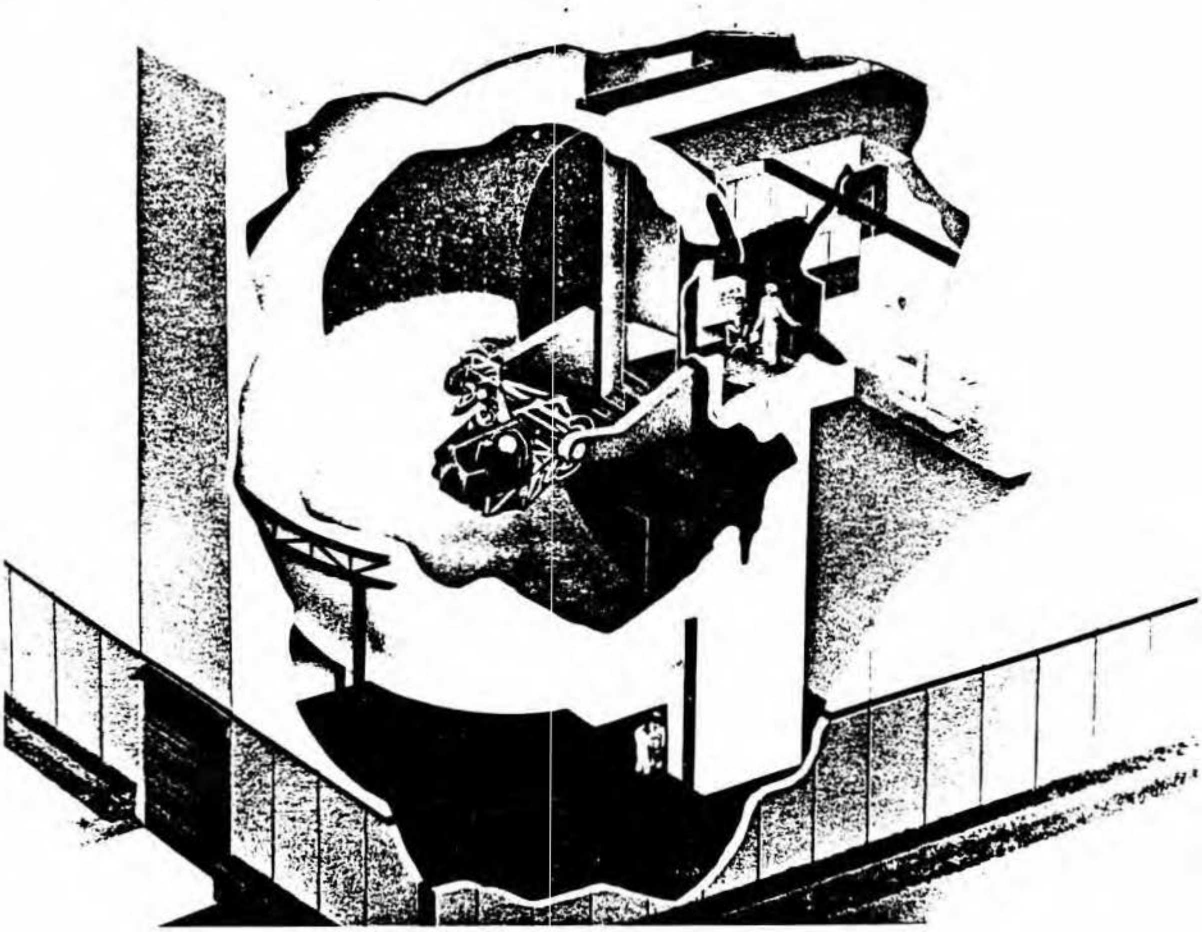

FIGURE 21-1.—Cutaway view of the Dynamic Crew Procedures Simulator.

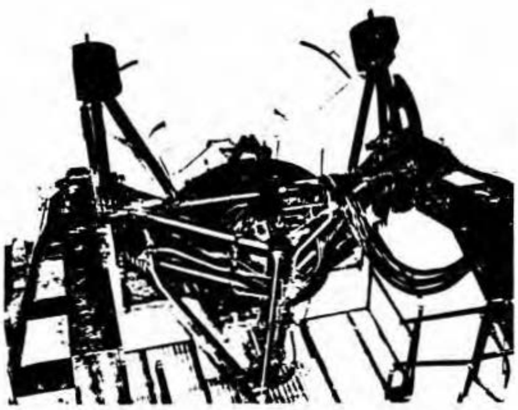

FIGURE 21-2.—Dynamic Crew Procedures Simulator.

FIGURE 21-3.—Gemini Mission Simulator console area.

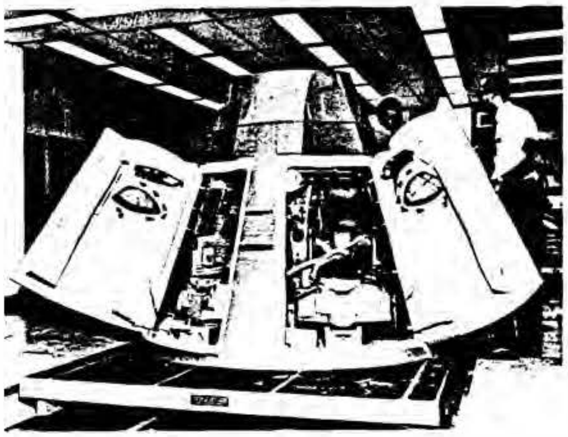

FIGURE 21-4.—Gemini Mission Simulator crew station.

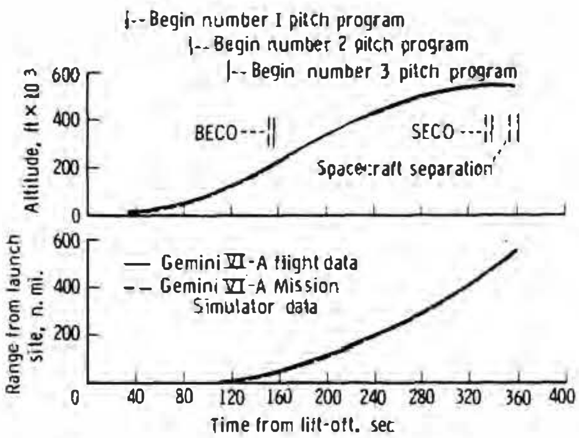

FIGURE 21-5.—Time history of altitude and range during launch phase.

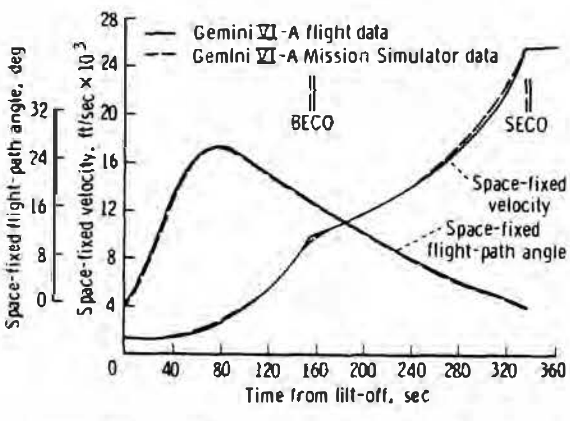

FIGURE 21-6.—Space-fixed velocity and flight-path angle.

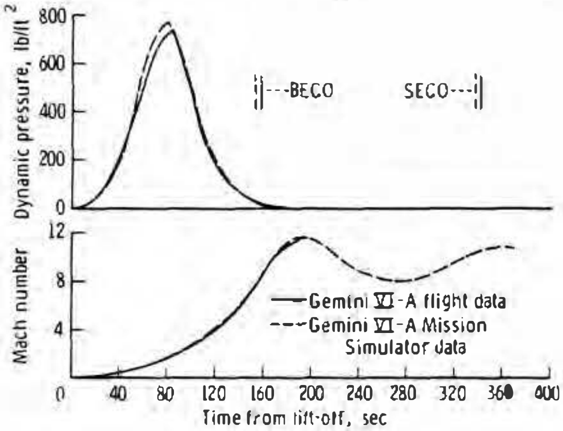

FIGURE 21-7.—Dynamic pressure and Mach number.

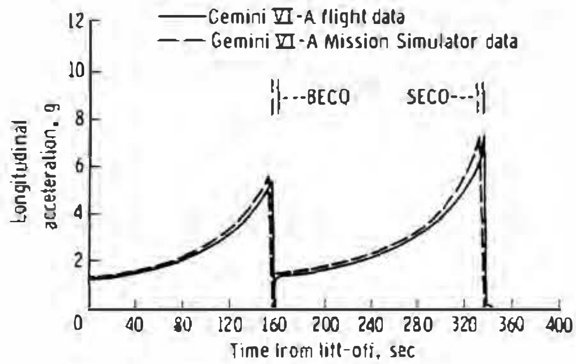

FIGURE 21-8.—Comparison of longitudinal acceleration.

One simulation problem that continually recurred during the early phases of the Gemini Program was that of providing guidance and control functions that were accurate and repeatable. The Gemini III crew received a reentry simulation that approached the flight computer outputs only 2 weeks prior to flight. This situation slowly improved and the Gemini VI crew received accurate launch and reentry data approximately 1 month prior to flight. The Gemini VIII and subsequent crews were provided with accurate guidance and navigation simulations for the entire training period.

Rendezvous

The initial phase of the training for rendezvous operations was conducted on the

Hybrid Simulator at the spacecraft contractor facility. The simulator contained the flight controls and displays of the spacecraft Guidance and Control System and of the Propulsion System, with a mockup for the remainder of the cockpit (figs. 21-9 and 21-10). Procedures for normal, backup, and failure modes were developed during the early part of the training period. The crews performed this phase of rendezvous training in a shirt-sleeve environment. Various instructors were able to stand alongside the simulator to observe and make comments during the run. The Hybrid Simulator visual display had a random star-field background

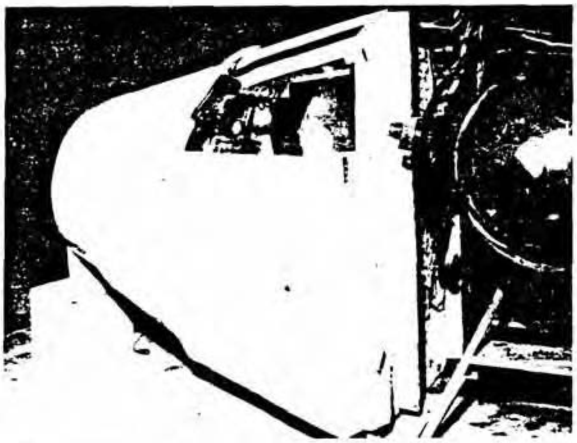

FIGURE 21-9.—Exterior view of Hybrid Simulator.

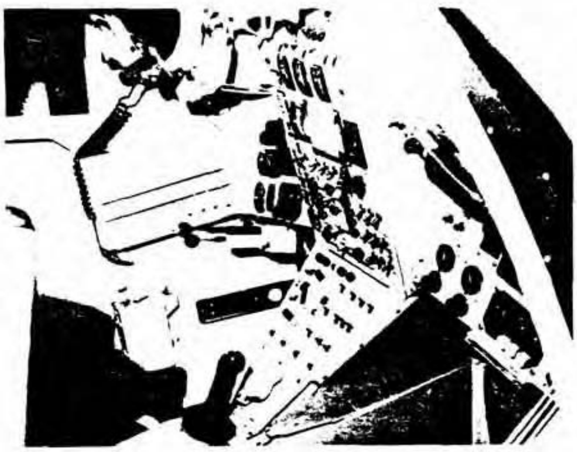

FIGURE 21-10.—Hybrid Simulator crew station.

which provided a satisfactory inertial reference for this phase of training. Accurate data on attitude and maneuver fuel were obtained, and indicated a close correlation with the inflight data.

The training progressed to the Gemini Mission Simulator at the Kennedy Space Center where the total spacecraft configuration was available. The runs were conducted first in a shirt-sleeve environment and later progressed to the suited condition. Approximately 20 percent of the simulator runs during the later phase of rendezvous training were conducted with the crew wearing training suits and then flight suits. The rendezvous phases of the flight plans were also refined during the runs. The third orbit ($M=3$) and the first orbit ($M=1$) rendezvous missions required that considerable effort be expended in practicing unstowage of gear, and in cockpit configuration management. This was a significant item in obtaining a smooth work flow during a time-critical period.

After the predicted launch date and time were determined, the simulator optical system was programed to provide the precise star and constellation field. The day/night cycle was also included in this part of the program. Flight experience indicated that the visual simulations were extremely accurate with respect to the celestial field, but somewhat lacking with respect to the magnitude and sharpness of the acquisition lights on the Gemini Agena Target Vehicle. Starting with the Gemini VI-A mission, the Gemini Mission Simulator and the Mission Control Center were integrated for rendezvous network simulations; however, not until the Gemini IX simulations could a satisfactory rendezvous be achieved on a target generated by the Mission Control Center. While wearing space suits, the flight crew performed all of the network rendezvous simulations and unstowed equipment in the same manner as they would in flight. To facilitate the rendezvous phase of the mission, the information obtained from the network rendezvous simulations frequently resulted in minor changes in the stowage configuration.

Basic failure modes of the guidance and navigation system were presented to the crew during training, and the knowledge acquired by the crew contributed to their confidence in performing the entire rendezvous maneuver. Several reset points were available for specific parts of the maneuver; for example, the period after the completion of the final midcourse maneuver through the entire braking routine. These runs were used to perfect the pilot techniques required for specific maneuvers.

The Gemini Mission Simulator provided accurate trajectory and fuel data for mission planning. Figures 21–11 and 21–12 compare the simulator and flight data for the Gemini VI–A rendezvous mission. Figure 21–13 compares hybrid simulation, Gemini mission simulation, and flight data for the Gemini IX–A mission. The hybrid simulation and the Gemini mission simulation were conducted at 15 nautical miles differential altitude. The flight was conducted at 12.1 nautical miles differential altitude. The hybrid simulation incorporated system errors. The Gemini mission simulation was nominal.

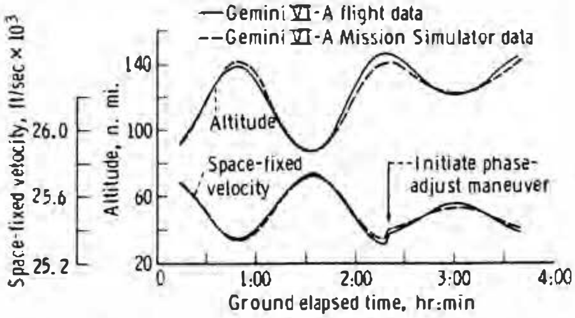

FIGURE 21–11.—Altitude and space-fixed velocity during orbit.

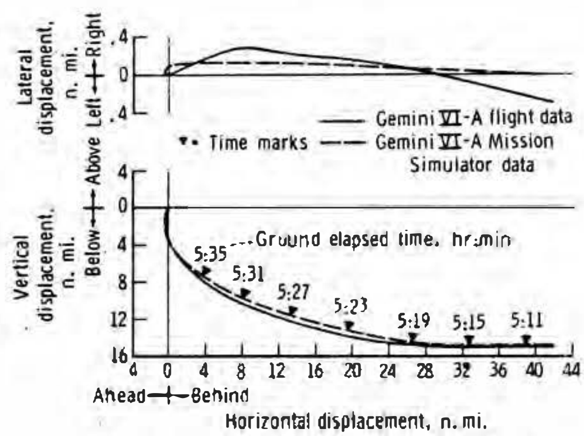

FIGURE 21–12.—Relative trajectory profile during terminal phase.

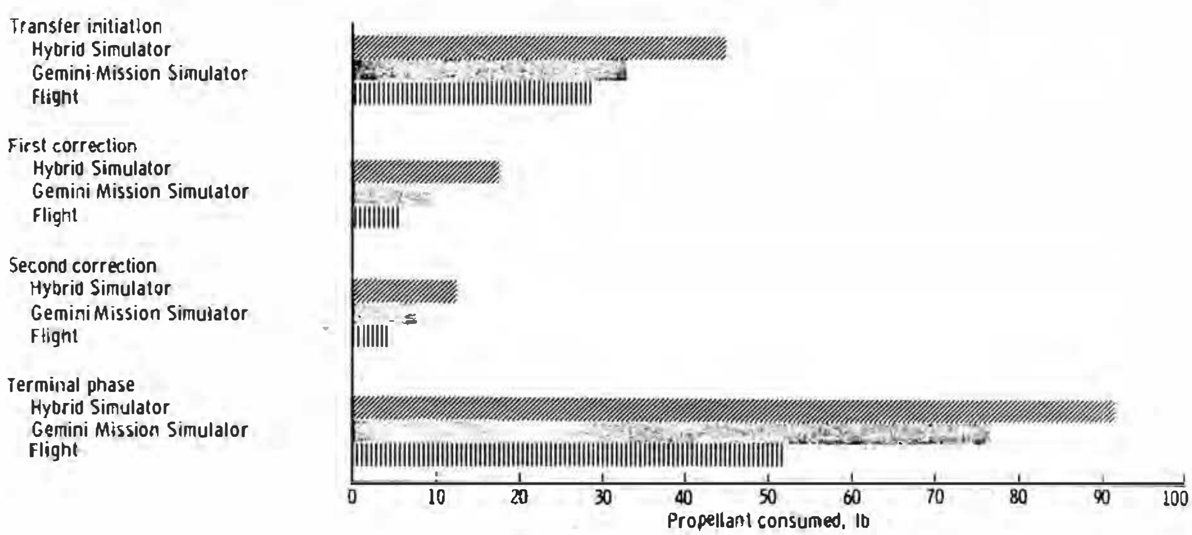

FIGURE 21–13.—Gemini IX–A rendezvous propellant comparison.

Special Tasks

Experiment Training

Training equipment identical to the actual flight hardware was provided for each Gemini experiment. The individual pieces of experiment hardware were first used for training in the spacecraft mockups at the spacecraft contractor facility and at the Manned Spacecraft Center. Later, the same hardware was used for training in the Gemini Mission Simulators. Camera equipment and other experiment hardware were often used by the Gemini flight crews while flying T–33 and T–38 aircraft. Operating the specific gear in this environment provided excellent training in the use of the individual pieces of hardware. To accomplish specific tasks for individual experiments that required precise tracking, spacecraft pointing commands and nulling of attitude rates were practiced. Flight experience indicated that the time lines and control tasks were very similar to those experienced in the Gemini Mission Simulator. The required updating and engineering changes of the experiment equipment frequently resulted in the flight crew not having the training hardware at a specified time to complete training. In certain isolated instances, the actual experiment hardware was not received until just prior to launch. This placed a difficult workload on the crew in trying to concentrate on new hardware and procedures in the last few days prior to flight.

Gemini Agena Target Vehicle Training

The Gemini VIII through XII missions were scheduled to include docking and various maneuvers involving the Gemini Agena Target Vehicle. The Gemini Mission Simulator provided a visual target vehicle that responded to commands from the Gemini crew station and from the simulator instructor station. All target-vehicle commands in both the docked and the undocked configurations were available. Commands were initiated for practicing attitude maneuvers as well as maneuvers with the target-vehicle Primary and Secondary Propulsion Systems. The response of the simulated target vehicle to the input commands accurately simulated the response of the actual target vehicle during flight. Target-vehicle failure modes were included during certain training periods to provide the crew with the maximum available training for systems malfunction.

The Gemini docking trainer, located at the Manned Spacecraft Center, provided the majority of the actual docking-sequence training. All control modes of the spacecraft and of the target vehicle were simulated in this facility. The lighting configuration was varied to simulate the conditions that were encountered during flight. All flight crews indicated that the final contact and docking-engage maneuver was somewhat easier than that experienced in the simulator. The control task difference was explained by the difficulty in simulating a dynamic 6-degree-of-freedom motion precisely equal to the orbital flight condition.

Tether Dynamics

The Dynamic Crew Procedures Simulator at the Manned Spacecraft Center was configured to provide a realistic simulation of the tethered-vehicle evaluations performed during the Gemini XI and XII missions. The basic time lines and control task for the tether maneuver were developed on this facility. The ability of the crew to cope with the large attitude excursions can be directly attributed to simulation training. The tether evaluation again demonstrated that an exercise could be generated with only a specific task involved; the use of this technique contributed greatly to the success of many of the Gemini missions.

Systems Operation

The flight-crew training for normal and emergency engineering procedures was first practiced on the Gemini Mission Simulator in conjunction with spacecraft systems briefings at the Manned Spacecraft Center. After the crew moved to the Kennedy Space Center, practice for the normal procedures was emphasized; and less emphasis was placed on emergency procedures in order to concentrate on the planned mission. Final systems briefings were conducted at the Kennedy Space Center, and training in the operation of all spacecraft systems was accomplished in the Gemini Mission Simulator. Network simulations involving the Mission Control Center provided practice for all types of system failures, and provided vehicle training for both ground and flight crews. A few minor simulator discrepancies were noted in the display responses when a system condition was changed. The differences between the simulator display and the actual spacecraft responses were small and did not produce any noticeable effect on the training program or the crew reaction in flight.

Reentry-Phase Training

The training for the reentry phase was conducted initially at the Manned Spacecraft Center on the Gemini Mission Simulator, and later at the Kennedy Space Center. Two types of reset points were available for training, one just prior to retrofire, and the other at an altitude of 400 000 feet. The reset points provided the crew considerable flexibility in perfecting procedures and techniques for the retrofire and reentry sequence.

The exact constellation position for the night retrofire sequence was programed for each mission. This feature of the Gemini Mission Simulator provided excellent training for the actual mission. The Mission Control Center simulations were performed in both the shirt-sleeve and the suited configurations.

The computer updates for reentry were performed by updata link and by voice link. The exact procedures used in flight were practiced many times in the simulator by the flight crews and in the Mission Control Center by the flight controllers during network reentry simulations.

The Gemini Mission Simulator data and the actual flight data for the Gemini VI–A mission are shown in figure 21–14. The curve shows a close correlation between simulation and flight data. Any variances between actual flight data and simulation data were considered insignificant for crew training.

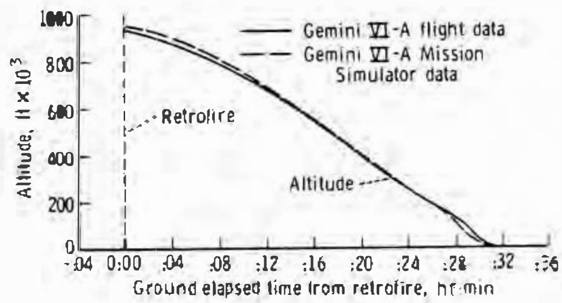

FIGURE 21–14.—Altitude during reentry.

Concluding Remarks

The variety of simulations available to the Gemini flight crews produced conditions that closely approximated those encountered in flight. Certain simulators were of the hybrid design and encompassed only specific systems. However, the simulation of the spacecraft operation of the individual systems produced excellent flight-crew training to accomplish specific tasks such as launch, rendezvous and docking, and reentry. The few discrepancies between simulator and actual spacecraft systems had no noticeable effect on the overall training program or orbital performance. The success with which the flight crews accomplished each Gemini mission was a direct result of high-fidelity simulation training.

Thus it can be concluded that the wealth of knowledge gained in the Gemini Program will provide the simulation and training guidelines for the Apollo Program. High-fidelity Apollo simulations and adequate flight-crew training can allow us to complete the lunar landing mission with a minimum number of actual space flights. The only phase of the lunar mission that has not been previously experienced to a great degree in the

Gemini Program is that of the lunar descent and landing. This phase cannot be experienced in flight until the actual landing takes place. Thus we can extrapolate from present knowledge that an accurate simulation can be provided to give the flight crews a realism that will closely approximate the actual lunar landing.

22. GEMINI RESULTS AS RELATED TO THE APOLLO PROGRAM

By WILLIS B. MITCHELL, *Manager, Office of Vehicles and Missions, Gemini Program Office, NASA Manned Spacecraft Center;* OWEN E. MAYNARD, *Chief, Mission Operations Division, Apollo Spacecraft Program Office, NASA Manned Spacecraft Center; and* DONALD D. ARABIAN, *Office of Vehicles and Missions, Gemini Program Office, NASA Manned Spacecraft Center*

Introduction

The Gemini Program was conceived to provide a space system that could furnish answers to many of the problems in operating manned vehicles in space. It was designed to build upon the experience gained from Project Mercury, and to extend and expand this fund of experience in support of the manned lunar landing program and other future manned space-flight programs. The purpose of this paper is to relate some of the results of the Gemini Program to the Apollo Program, and to discuss some of the contributions which have been made.

The objectives of the Gemini Program applicable to Apollo are: (1) long-duration flight, (2) rendezvous and docking, (3) post-docking maneuver capability, (4) controlled reentry and landing, (5) flight- and ground-crew proficiency, and (6) extravehicular capability. The achievement of these objectives has provided operational experience and confirmed much of the technology which will be utilized in future manned programs. These contributions will be discussed in three major areas: launch and flight operations, flight-crew operations and training, and technological development of subsystems and components. While there is obvious interrelation among the three elements, the grouping affords emphasis and order to the discussion.

Launch and Flight Operations

Gemini experience is being applied to Apollo launch and flight operations planning and concepts. Probably the most significant is the development and understanding of the rendezvous and docking process. The Apollo Program depends heavily upon rendezvous for successful completion of the basic lunar mission. The Lunar Module, on returning from the surface of the Moon, must rendezvous and dock with the Command and Service Module. In addition, the first Apollo mission involving a manned Lunar Module will require rendezvous and docking in Earth orbit by a Command and Service Module placed in orbit by a separate launch vehicle. During the Gemini Program, 10 rendezvous and 9 docking operations were completed. The rendezvous operations were completed under a variety of conditions applicable to the Apollo missions.

The Gemini VI-A and VII missions demonstrated the feasibility of rendezvous. During the Gemini IX-A mission, maneuvers performed during the second re-rendezvous demonstrated the feasibility of a rendezvous from above; this is of great importance if the Lunar Module should be required to abort a lunar-powered descent. During the Gemini X mission, the spacecraft computer was programed to use star-horizon sightings for predicting the spacecraft orbit. These data, combined with target-vehicle ephemeris data, provided an onboard prediction of the rendezvous maneuvers required. The rendezvous was actually accomplished with the ground-computed solution, but the data from the onboard prediction will be useful in developing space-navigation and orbit-determination techniques.

The passive ground-controlled rendezvous demonstrated on Gemini X and XI is important in developing backup procedures for equipment failures. The Gemini XI first-orbit rendezvous was onboard controlled and provides an additional technique to Apollo planners. The Gemini XII mission resulted in a third-orbit rendezvous patterned after the lunar-orbit rendezvous sequence, and again illustrated that rendezvous can be reliably and repeatedly performed.

All of the Gemini rendezvous operations provided extensive experience in computing and conducting midcourse maneuvers. These maneuvers involved separate and combined corrections of orbit plane, altitude, and phasing similar to the corrections planned for the lunar rendezvous. Experience in maneuvering combined vehicles in space was also accumulated during the operations using the docked spacecraft/target-vehicle configuration when the Primary Propulsion System of the target vehicle was used to propel the spacecraft to the high-apogee orbital altitudes. During the Gemini X mission, the Primary Propulsion System was used in combination with the Secondary Propulsion System to accomplish the dual-rendezvous operation with the passive Gemini VIII target vehicle. These uses of an auxiliary propulsion system add another important operational technique.

In summary, 10 rendezvous exercises were accomplished during the Gemini Program, including 3 re-rendezvous and 1 dual operation (fig. 22-1). Seven different rendezvous modes were utilized. These activities demonstrated the capabilities for computing rendezvous maneuvers in the ground-based computer complex; the use of the onboard radar-computer closed-loop system; the use of manual computations made by the flight crew; and the use of optical techniques and star background during the terminal phase and also in the event of equipment failures. A variety of lighting conditions and background conditions during the terminal-phase maneuvers, and the use of auxiliary lighting devices, have been investigated. The rendezvous operations demonstrated that the com-

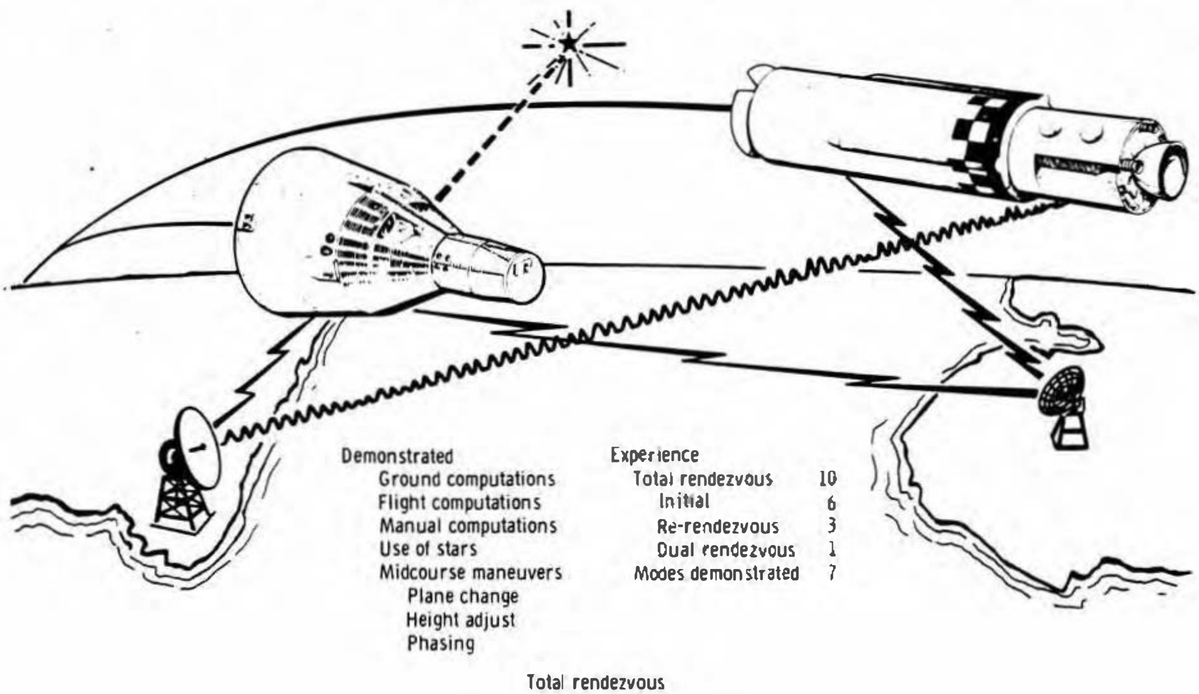

FIGURE 22-1.—Rendezvous.

putation and execution of maneuvers for changing or adjusting orbits in space can be performed with considerable precision.

The nine docking operations during Gemini demonstrated that the process can be accomplished in a routine manner, and that the ground training simulation was adequate for this operation (fig. 22–2). The Gemini flight experience has established the proper lighting conditions for successful docking operations. Based on the data and experience derived from the Gemini rendezvous and docking operations, planning for the lunar-orbit rendezvous can proceed with confidence.

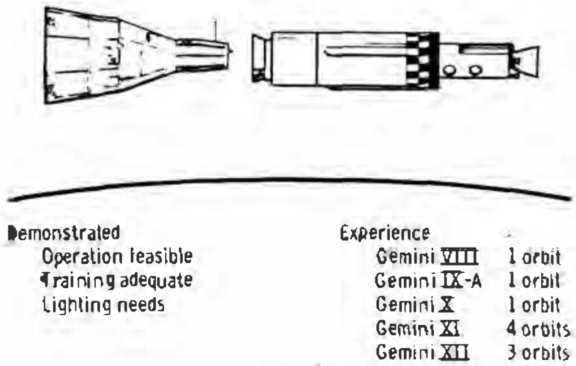

FIGURE 22–2.—Docking.

Extravehicular Activity

Extravehicular activity was another important objective of the Gemini Program. Although extensive use of extravehicular activity has not been planned for the Apollo Program, the Gemini extravehicular experience should provide valuable information in two areas. First, extravehicular activity will be used as a contingency method of crew transfer from the Lunar Module to the Command Module in the event the normal transfer mode cannot be accomplished. Second, operations on the lunar surface will be accomplished in a vacuum environment using auxiliary life-support equipment and consequently will be similar to Gemini extravehicular operations. For these applications, the results from Gemini have been used to determine the type of equipment and the crew training required. The requirements for auxiliary equipment such as handholds, tether points, and handrails have been established.

Controlled Landing

From the beginning of the Gemini Program, one of the objectives was to develop reentry flight-path and landing control. The spacecraft was designed with an offset center of gravity so that it would develop lift during the flight through the atmosphere. The spacecraft control system was used to orient the lift vector to provide maneuvering capability. A similar system concept is utilized by the Apollo spacecraft during reentry through the Earth atmosphere.

After initial development problems on the early Gemini flights, the control system worked very well in both the manual and the automatic control modes. Spacecraft landings were achieved varying from a few hundred yards to a few miles from the target point (fig. 22–3). The first use of a blunt lifting body for reentry control serves to verify and to validate the Apollo-design concepts. The success of the Gemini guidance system in controlling reentry will support the Apollo design, even though the systems differ in detail.

Launch Operations

The prelaunch checkout and verification concept which was originated during the Gemini Program is being used for Apollo. The testing and servicing tasks are very similar for both spacecraft, and the Gemini test-flow plan developed at the Kennedy Space Center is being applied. The entire mode of operation involving scheduling, daily operational techniques, operational procedures, procedures manuals, and documentation is similar to that used in the Gemini operation. Much of the launch-site operational support is common to both programs; this includes tracking radars and cameras, communications equipment, telemetry, critical power,

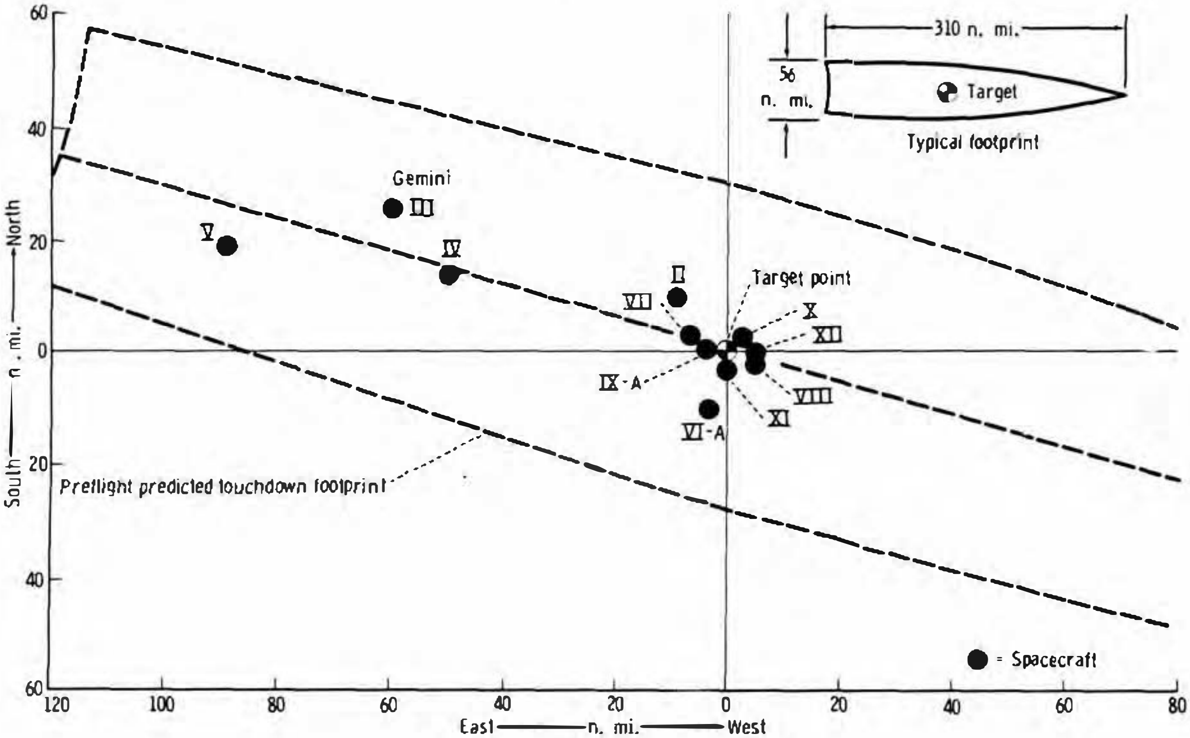

FIGURE 22-3.—Demonstration of landing accuracy.

and photography. The requirements for this equipment are the same in many cases, and the Gemini experience is directly applicable. The Apollo Program will use the same mission operations organization for the launch sequence that was established during Project Mercury and tested and refined during the Gemini Program.

Mission Control

The Gemini mission-control operations concepts evolved from Project Mercury. These concepts were applied during the Gemini Program and will be developed further during the Apollo missions, although the complexity of the operations will substantially increase as the time for the lunar mission nears. The worldwide network of tracking stations was established to gather data concerning the status of the Mercury spacecraft and pilots. The Mercury flights, however, involved control of a single vehicle with no maneuvering capability.

The Gemini Program involved multiple vehicles, rendezvous maneuvers, and long-duration flights, and required a more complex ground-control system capable of processing and reacting to vast amounts of real-time data. The new mission-control facility at the Manned Spacecraft Center, Houston, was designed to operate in conjunction with the Manned Space Flight Network for direction and control of Gemini and Apollo missions, as well as of future manned space-flight programs. Much of this network capability was expanded for Gemini and is now being used to support the Apollo missions. Gemini has contributed personnel training in flight control and in maintenance and operation of flight-support systems. As the Gemini flights progressed and increased in complexity, the capabilities of the flight controllers increased, and resulted in a nucleus of qualified control personnel.

The development of experienced teams of mission-planning personnel has proved extremely useful in the preparation for future manned missions. Mission plans and flight-crew procedures have been developed and exercised to perform the precise inflight maneuvers required for rendezvous of two vehicles in space, and to perform flights up to 14 days in duration. The techniques which were evolved during Gemini have resulted in flight plans that provide the maximum probability of achieving mission objectives with a minimum usage of consumables and optimum crew activity. The development of satisfactory work-rest cycles and the acceptance of simultaneous sleep periods are examples of learning which will be carried forward to the Apollo planning. The mission planning procedures developed for Gemini are applicable to future programs, and the personnel who devised and implemented the procedures are applying their experience to the Apollo flight-planning effort.

Flight-Crew Operations and Training

Crew Capability

The results of the Gemini Program in the area of flight-crew operations have been very rewarding in yielding knowledge concerning the Gemini long-duration missions. The medical experiments conducted during these flights have demonstrated that man can function in space for the planned duration of the lunar landing mission. The primary question concerning the effect of long-duration weightlessness has been favorably answered. Adaptation to the peculiarities of the zero-g environment has been readily accomplished. The results significantly increase the confidence in the operational efficiency of the flight crew for the lunar mission.

The Apollo spacecraft is designed for cooperative operation by two or more pilots. Each module may be operated by one individual for short periods; however, a successful mission requires a cooperative effort by the three-man crew. The multiple-crew concept of spacecraft operation was introduced for the first time in the United States during the Gemini Program and cooperative procedures for multipilot operations were developed.

The Gemini Program has established that man can function normally and without ill effect outside the spacecraft during extravehicular operations.

Crew Equipment

Most of the Gemini technology regarding personal crew equipment is applicable to Apollo. The Block I Apollo space suit is basically the same as the Gemini space suit. The Block II Apollo space suit, although different in design, will have familiar Gemini items such as suit-design concepts, locking mechanisms for connectors, and polycarbonate visors and helmets. The Gemini spacesuit support facilities at the Manned Spacecraft Center and at the Kennedy Space Center, plus the ground-support equipment, will be fully utilized during Apollo.

A considerable amount of personal and postlanding survival equipment will be used for Apollo in the same configuration as was used for Gemini. Some items have minor modifications for compatibility, others for improvements based upon knowledge resulting from flight experience. Specific examples include food packaging, water dispenser, medical kits, personal hygiene items, watches, sunglasses, penlights, cameras, and data books.

Many of the concepts of crew equipment originated in Gemini experience with long-duration missions and recovery: food and waste management; cleanliness; housekeeping and general sanitation; and environmental conditions such as temperature, radiation, vibration, and acceleration. Although the Apollo approach may differ in many areas, the Gemini experience has been the guide.

Flight-Crew Training

The aspects of crew training important to future programs include preflight preparation of the crews for the mission and the reservoir of flight experience derived from the Gemini Program. Apollo will inherit the training technology developed for the Gemini flight crews. The technology began with Project Mercury, and was developed and refined during the training of the Gemini multiman crews. There now exists an organization of highly skilled specialists with a thorough understanding of the training task. Adequate crew preparation can be assured in all areas, from the physical conditioning of the individual crewmembers to the most complicated integrated mission simulation.

One highly developed aspect of flight-crew training is the use of simulators and simulation techniques. A significant result of the Gemini rendezvous experience was the verification of the ground simulation employed in flight-crew training. The incorporation of optical displays in the Gemini simulations was an important step in improving the training value of these devices. Using high-fidelity mission simulators to represent the spacecraft and to work with the ground control network and flight controllers was instrumental in training the pilots and ground crew as a functional team that could deal with problems and achieve a large percentage of the mission objectives.

The Gemini Program resulted in an accumulated total of 1940 man-hours of flight time distributed among 16 flight-crew members. This flight experience is readily adaptable to future programs since the Gemini pilots are flight qualified for long-duration flights and rendezvous operations, and are familiar with many of the aspects of working in the close confines of the spacecraft. This experience is of great value to future training programs. The experience in preparing multiman crews for flight, in monitoring the crew during flight, and in examining and debriefing after flight will facilitate effective and efficient procedures for Apollo.

Technological Development of Systems and Components

Gemini and Apollo share common hardware items in some subsystems; in other subsystems, the similarity exists in concept and general design. The performance of Gemini systems, operating over a range of conditions, has provided flight-test data for the verification of the design of related subsystems. These data are important since many elements of Apollo, especially systems interactions, cannot be completely simulated in ground testing. The Apollo Spacecraft Program Office at the Manned Spacecraft Center, Houston, has reviewed and analyzed Gemini anomalous conditions to determine corrective measures applicable to Apollo. The Apollo Program Director has established additional procedures at NASA Headquarters to promote rapid dissemination and application of Gemini experience to Apollo equipment design.

The Gemini missions have provided background experience in many systems such as communications, guidance and navigation, fuel cells, and propulsion. In addition, a series of experiments was performed specifically for obtaining general support information applicable to the Apollo Program.

In the communications systems, common items include the recovery and flashing-light beacons; similar components are utilized in the high-frequency and ultrahigh-frequency recovery antennas. Reentry and postlanding batteries and the digital data uplink have the same design concepts. The major Apollo design parameters concerned with power requirements and range capability have been confirmed.

In the area of guidance and navigation, the use of an onboard computer has been demonstrated and the Gemini experience with rendezvous radar techniques has been a factor in the selection of this capability for the Lunar Module. The ability to perform inplane and out-of-plane maneuvers and to determine new space references for successful reentry and landing has been confirmed by Gemini flights. The control of a blunt lifting body during reentry will also support the Apollo concept.

In the electrical power supply, the use of the Gemini fuel cell has confirmed the applicability of the concept. The ability of the cryogenic reactant storage system to operate over a wide range of off-design conditions in flight has verified the design, which is similar for Apollo. The performance of the Gemini system has provided a better understanding of the system parameters over an operating range considerably in excess of the range previously contemplated. The design of the cryogenic servicing system for Apollo was altered after the initial difficulties experienced by early Gemini flights. Consequently, a fairly sophisticated system now exists which will eliminate the possibility of delays in servicing. The ability to estimate the power requirements for the Apollo spacecraft equipment is enhanced by the Gemini operational data.

In the propulsion area, the ullage control rockets of the Apollo-Saturn S–IVB stage are the same configuration as the thrusters used for the Gemini spacecraft Orbital Attitude and Maneuver System; the thrusters of the Apollo Command Module Reaction Control System are similar. Steps have been taken to eliminate the problems which occurred in the development of the Gemini thrusters, such as the cracking of the silicon-carbide throat inserts, the unsymmetrical errosion of the chamber liners, and the chamber burnthrough. The tankage of the Reaction Control System is based upon the Gemini design, and employs the same materials for tanks and bladders. The propellant control valves were also reworked as a result of early problems in the Gemini system.

The Lunar Module ascent engine also benefited from the Gemini technology: the contractor for this engine also manufactured the engines for the Gemini Agena Target Vehicle. Following the inflight failure of the target-vehicle engine during the Gemini VI mission, a test program verified the inherent danger in fuel-lead starts in the space environment. Consequently, the Lunar Module ascent engine and the Gemini target-vehicle engine were changed so that the oxidizer would enter the engine before the fuel. The problem had been indicated during ascent-engine testing, but was not isolated until the required definitive data were furnished by Project Sure Fire on the target-vehicle engine.

In addition to medical experiments, several other types of experiments were conducted during Gemini and have supplied information and data for use by the Apollo Program. The experiments included electrostatic charge, proton-electron spectrometer, lunar ultraviolet spectrometer, color-patch photography, landmark contrast measurements, radiation in spacecraft, reentry communications, manual navigation sightings, simple navigation, radiation and zero-g effects on blood, and micrometeorite collection. Although the direct effects of these experiments on Apollo systems are difficult to isolate, the general store of background data and available information has been increased.

Concluding Remarks

The Gemini Program has made significant contributions to future manned space-flight programs. Some of the more important contributions include flight-operations techniques and operational concepts, flight-crew operations and training, and technological development of components and systems. In the Gemini Program, the rendezvous and docking processes so necessary to the lunar mission were investigated; workable procedures were developed, and are available for operational use. The capability of man to function in the weightless environment of space was investigated for periods up to 14 days. Flight crews have been trained, and have demonstrated that they can perform complicated mechanical and mental tasks with precision while adapting to the spacecraft environment and physical constraints during long-duration missions.

Additionally, the development of Gemini hardware and techniques bas advanced spacecraft-design practices and has demonstrated advanced systems which, in many cases, will substantiate approaches and concepts for future spacecraft.

Finally, probably the most significant contributions of Gemini have been the training of personnel and organizations in the disciplines of management, operations, manufacturing, and engineering. This nucleus of experience has been disseminated throughout the many facets of Apollo and will benefit all future manned space-flight programs.

23. CONCLUDING REMARKS

By GEORGE M. LOW, *Deputy Director, NASA Manned Spacecraft Center*

With the preceding paper, one of the most successful programs in our short history of space flight has ended. The Gemini achievements have been many, and have included long-duration flight, maneuvers in space, rendezvous, docking, use of large engines in space, extravehicular activity, and controlled reentry. The Gemini achievements have also included a host of medical, technological, and scientific experiments.

The papers have included discussions of many individual difficulties that were experienced in preparation for many of the flight missions and in some of the flights. The successful demonstration that these difficulties were overcome in later missions is a great tribute to the program, to the organization, and to the entire Gemini team.

A period of difficulty exists today in the program that follows Gemini, the Apollo Program. Yet, perhaps one of the most important legacies from Gemini to the Apollo Program and to future programs is the demonstration that great successes can be achieved in spite of serious difficulties along the way.

The Gemini Program is now officially completed.

APPENDIXES

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APPENDIX A

NASA CENTERS AND OTHER GOVERNMENT AGENCIES

This appendix contains a list of Government agencies participating in the Gemini Program.

NASA Headquarters, Washington, D.C., and the following NASA centers:
- Ames Research Center, Moffett Field, Calif.
- Electronics Research Center, Cambridge, Mass.
- Flight Research Center, Edwards, Calif.
- Goddard Space Flight Center, Greenbelt, Md.
- Kennedy Space Center, Cocoa Beach, Fla.
- Langley Research Center, Langley Station, Hampton, Va.
- Lewis Research Center, Cleveland, Ohio
- Manned Spacecraft Center, Houston, Tex.
- Marshall Space Flight Center, Huntsville, Ala.

Department of Defense, Washington, D.C.:
- Department of the Army
- Department of the Navy
- Department of the Air Force

Department of State, Washington, D.C.

Department of Commerce, Washington, D.C.

Department of the Interior, Washington, D.C.

Department of Health, Education, and Welfare, Washington, D.C.

Department of the Treasury, Washington, D.C.:
- U.S. Coast Guard

Atomic Energy Commission, Washington, D.C.

Environmental Science Services Administration, Washington, D.C.

U.S. Information Agency, Washington, D.C.

APPENDIX B

CONTRACTORS, SUBCONTRACTORS, AND VENDORS

This appendix contains a listing of contractors, subcontractors, and vendors that have Gemini contracts totaling more than $100 000. It represents the best effort possible to obtain a complete listing; however, it is possible that some are missing, such as those supporting activities not directly concerned with Manned Spacecraft Center activities. These contractors, subcontractors, and vendors are recognized as a group.

Contractors

Acoustica Associates, Inc., Los Angeles, Calif.
Aerojet-General Corp., Sacremento, Calif.
Aerojet-General Corp., Downey, Calif.
Aerospace Corp., El Segundo, Calif.
AiResearch Manufacturing Co., division of Garrett Corp., Torrance, Calif.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Analytical Mechanics Associates, Westbury, N.Y.
Arde-Portland, Inc., Paramus, N.J.
Avco Corp., Stratford, Conn.
Bechtel Corp., Los Angeles, Calif.
Beckman Instruments, Inc., Fullerton, Calif.
Bell Aerosystems Co., division of Bell Aerospace Corp., Buffalo, N.Y.
Bissett-Berman Corp., Santa Monica, Calif.
Burroughs Corp., Paoli, Pa.
CBS Labs, Inc., Stamford, Conn.
David Clark Co., Inc., Worcester, Mass.
Cook Electric Co., Morton Grove, Ill.
Cutler-Hammer, Inc., Long Island, N.Y.
Electro-Optical Systems, Inc., Pasadena, Calif.
Farrand Optical Co., Inc., Bronx, N.Y.
Federal Electric Corp., Paramus, N.J.
Federal-Mogul Corp., Los Alamitos, Calif.
General Dynamics/Astronautics Division, San Diego, Calif.
General Dynamics/Convair Division, San Diego, Calif.
General Dynamics/Convair Division, Fort Worth, Tex.
General Electric Co., Syracuse, N.Y.
General Motors Corp., Milwaukee, Wis.
General Precision, Inc., Link Division, Binghamton, N.Y.
General Precision, Inc., Pleasantville, N.Y.
B. F. Goodrich Co., Akron, Ohio
Honeywell, Inc., Minneapolis, Minn.
Honeywell, Inc., West Covina, Calif.
Hughes Aircraft Co., Culver City, Calif.
International Business Machines Corp., Owego, N.Y.
International Business Machines Corp., Bethesda, Md.
Ling-Temco-Vought, Inc., Dallas, Tex.
Lockheed Missiles & Space Co., Sunnyvale, Calif.
Martin Co., division of Martin-Marietta Corp., Baltimore, Md.
Martin Co., division of Martin-Marietta Corp., Denver, Colo.
J. A. Maurer, Inc., Long Island City, N.Y.
McDonnell Aircraft Corp., St. Louis, Mo.
Melpar, Inc., Falls Church, Va.
D. B. Milliken, Inc., Arcadia, Calif.
North American Aviation, Inc., Rocketdyne Division, Canoga Park, Calif.
North American Aviation, Inc., Space and Information Systems Division, Downey, Calif.
Philco Corp., Philadelphia, Pa.
Philco Corp., WDL Division, Palo Alto, Calif.
Razdow Lab., Newark, N.J.
Scientific Data Systems, Inc., Santa Monica, Calif.

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Space Labs, Inc., Van Nuys, Calif.
Sperry Rand Corp., Sperry Phoenix Co. Division, Phoenix, Ariz.
Sperry Rand Corp., Washington, D.C.
Texas Institute for Rehabilitation and Research, Houston, Tex.
Thiokol Chemical Corp., Elkton, Md.
Thompson Ramo Wooldridge, Inc., Redondo Beach, Calif.
Todd Shipyards Corp., Galveston, Tex.
Western Gear Corp., Lynwood, Calif.
Whirlpool Corp., St. Joseph, Mich.

Subcontractors and Vendors

ACF Industries, Inc., Paramus, N.J.
ACR Electronics Corp., New York, N.Y.
Advanced Technology Laboratories, division of American Radiator & Standard Corp., Mountain View, Calif.
Aeronca Manufacturing Corp., Baltimore, Md.
AiResearch Manufacturing Co., division of Garrett Corp., Torrance, Calif.
American Machine & Foundry Co., Springdale, Conn.
Argus Industries, Inc., Gardena, Calif.
Astro Metallic, Inc., Chicago, Ill.
Autronics Corp., Pasadena, Calif.
Avionics Research Corp., West Hempstead, N.Y.
Barnes Engineering Co., Stamford, Conn.
Beech Aircraft Corp., Boulder, Colo.
Bell Aerosystems Co., Buffalo, N.Y.
Bendix Corp., Eatontown, N.J.
Brodie, Inc., San Leandro, Calif.
Brush Beryllium Co., Cleveland, Ohio
Brush Instrument Corp., Los Angeles, Calif.
Burtek, Inc., Tulsa, Okla.
Cadillac Gage Co., Costa Mesa, Calif.
Calcor Space Facility, Inc., Whittier, Calif.
Cannon Electric Co., Brentwood, Mo.
Cannon Electric Co., Phoenix, Ariz.
Captive Seal Corp., Caldwell, N.J.
Central Technology Corp., Herrin, Ill.
Clevite Corp., Cleveland, Ohio
Clifton Precision Products Co., Clifton Heights, Pa.
Collins Radio Co., Cedar Rapids, Iowa
Comprehensive Designers, Inc., Philadelphia, Pa.
Computer Control Co., Inc., Framingham, Mass.
Consolidated Electrodynamics Corp., Monrovia, Calif.
Cook Electric Co., Skokie, Ill.
Cosmodyne Corp., Hawthorne, Calif.
Custom Printing Co., Ferguson, Mo.
Day & Zimmerman, Inc., Los Angeles, Calif.
De Havilland Aircraft, Ltd., Downsview, Ontario, Canada
Dilectrix Corp., Farmingdale, N.Y.
Douglas Aircraft Co., Inc., Tulsa, Okla.
Douglas Aircraft Co., Inc., Santa Monica, Calif.
Eagle-Picher Co., Joplin, Mo.
Edgerton, Germeshausen & Grier, Inc., Boston, Mass.
Electro-Mechanical Research, Inc., Sarasota, Fla.
Electronics Associates, Inc., Long Branch, N.J.
Emerson Electric Co., St. Louis, Mo.
Emertron Information and Control Division, Litton Systems, Inc., Newark, N.J.
Engineered Magnetic Division, Hawthorne, Calif.
Epsco, Inc., Westwood, Mass.
Explosive Technology, Inc., Santa Clara, Calif.
Fairchild Camera & Instrument Corp., Cable Division, Joplin, Mo.
Fairchild Controls, Inc., division of Fairchild Camera & Instrument Corp., Hicksville, N.Y.
Fairchild Hiller Corp., Bay Shore, N.Y.
Fairchild Stratos Corp., Bay Shore, N.Y.
General Electric Co., Pittsfield, Mass.
General Electric Co., West Lynn, Mass.
General Electric Co., Waynesboro, Va.
General Precision, Inc., Link Division, Binghamton, N.Y.
General Precision, Inc., Little Falls, N.J.
Genistron, Inc., Bensenville, Ill.
Giannini Controls Corp., Duarte, Calif.
Goodyear Aerospace Corp., Akron, Ohio
Gray & Huleguard, Inc., Santa Monica, Calif.
Gulton Industries, Inc., Hawthorne, Calif.

Hamilton-Standard, division of United Aircraft Corp., Windsor Locks, Conn.
Hexcel Products, Inc., Berkeley, Calif.
Honeywell, Inc., Minneapolis, Minn.
Honeywell, Inc., St. Petersburg, Fla.
Hurletron Corp., Wheaton, Ill.
Hydra Electric Co., Burbank, Calif.
International Business Machines Corp., Owego, N.Y.
Johns-Mansville Corp., Mansville, N. J.
Kinetics Corp., Solvana Beach, Calif.
Kirk Engineering Co., Philadelphia, Pa.
Leach Corp., Compton, Calif.
Leach Relay Corp., Los Angeles, Calif.
Lear-Siegler, Inc., Grand Rapids, Mich.
Linde Co., Whiting, Ind.
Lion Research Corp., Cambridge, Mass.
Maffett Tool & Machine Co., St. Louis, Mo.
Marotta Valve Corp., Boonton, N.J.
Meg Products, Inc., Seattle, Wash.
Missouri Research Laboratories, Inc., St. Louis, Mo.
Moog, Inc., Buffalo, N.Y.
Motorola, Inc., Scottsdale, Ariz.
National Water Lift Co., Kalamazoo, Mich.
North American Aviation, Inc., Rocketdyne Division, Canoga Park, Calif.
Northrop Corp., Ventura Division, Newbury Park, Calif.
Northrop Corp., Van Nuys, Calif.
Ordnance Associates, Inc., South Pasadena, Calif.
Ordnance Engineering Associates, Inc., Des Plaines, Ill.
Palomar Scientific Corp., Redmond, Wash.
Pneumodynamics Corp., Kalamazoo, Mich.
Pollak & Skan, Inc., Chicago, Ill.
Powerton, Inc., Plainsville, N.Y.
Radcom Emerton, College Park, Md.
Radiation, Inc., Melbourne, Fla.
Raymond Engineering Laboratory, Inc., Middletown, Conn.
Reinhold Engineering Co., Santa Fe Springs, Calif.
Rocket Power, Inc., Mesa, Ariz.
Rome Cable Corp., division of Alcoa, Rome, N.Y.
Rosemount Engineering Co., Minneapolis, Minn.
Servonics Instruments, Inc., Costa Mesa, Calif.
Space Corp., Dallas, Tex.
Sperry Rand Corp., Tampa, Fla.
Sperry Rand Corp., Torrance, Calif.
Speidel Co., Warwick, R.I.
Talley Industries, Mesa, Ariz.
Teledyne Systems Corp., Hawthorne, Calif.
Texas Instruments, Inc., Dallas, Tex.
Thiokol Chemical Corp., Elkton, Md.
Union Carbide Corp., Whiting, Ind.
Vickers, Inc., St. Louis, Mo.
Weber Aircraft Corp., Burbank, Calif.
Westinghouse Electric Corp., Baltimore, Md.
Whiting-Turner, Baltimore, Md.
Wyle Laboratories, El Segundo, Calif.
Yardney Electric Corp., New York, N.Y.
H. L. Yoh Co., Philadelphia, Pa.

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GEMINI SPACECRAFT FLIGHT HISTORY

MISSION	DESCRIPTION	LAUNCH DATE	MAJOR ACCOMPLISHMENTS
Gemini VIII	Manned 3 days Rendezvous and dock Extravehicular activity	Mar. 16, 1966	Demonstrated rendezvous and docking with Gemini Agena Target Vehicle, controlled landing and emergency recovery, and multiple restart of Gemini Agena Target Vehicle in orbit. Spacecraft mission terminated early because of an electrical short in the control system.
Gemini IX	Manned 3 days Rendezvous and dock Extravehicular activity (Canceled after failure of Target Launch Vehicle)	May 17, 1966	Demonstrated dual countdown procedures.
Gemini IX-A	Manned 3 days Rendezvous and dock Extravehicular activity	June 3, 1966	Demonstrated three rendezvous techniques, evaluated extravehicular activity with detailed work tasks, and demonstrated precision landing capability.
Gemini X	Manned 3 days Rendezvous and dock Extravehicular activity	July 18, 1966	Demonstrated dual rendezvous using Gemini Agena Target Vehicle propulsion for docked maneuvers, and demonstrated removal of experiment package from passive target vehicle during extravehicular activity. Evaluated feasibility of using onboard navigational techniques for rendezvous.
Gemini XI	Manned 3 days Rendezvous and dock Tether evaluation Extravehicular activity	Sept. 12, 1966	Demonstrated first-orbit rendezvous and docking, evaluated extravehicular activity, demonstrated feasibility of tethered station keeping, and demonstrated automatic reentry capability.
Gemini XII	Manned 4 days Rendezvous and dock Tether evaluation Extravehicular activity	Nov. 11 1966	Demonstrated rendezvous and docking, evaluated extravehicular activity, demonstrated feasibility of gravity-gradient tethered-vehicle station keeping, and demonstrated automatic reentry capability.