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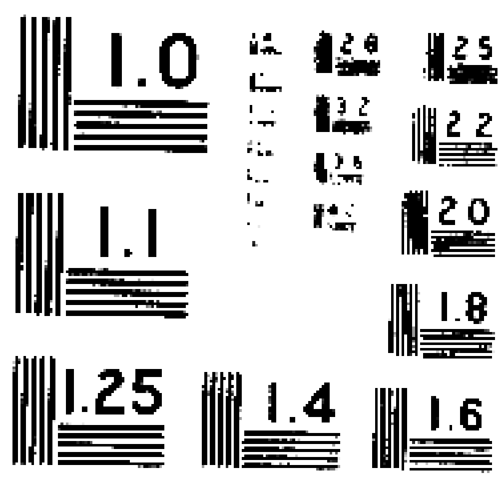

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO PROGRAM

FLIGHT SUMMARY REPORT

(NASA-TM-X-70154) APOLLO PROGRAM FLIGHT SUMMARY REPORT: APOLLO MISSIONS AS-201 THROUGH APOLLO 16, REVISION 11 (NASA) 132 p HC $9.75 CSCL 22C

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APOLLO MISSIONS

AS-201 through APOLLO 16

JUNE 1972

OFFICE OF MANNED SPACE FLIGHT

APOLLO PROGRAM OFFICE

APOLLO PROGRAM

FLIGHT SUMMARY REPORT

APOLLO MISSIONS
AS-201 THROUGH APOLLO 16

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OFFICE OF MANNED SPACE FLIGHT
APOLLO PROGRAM OFFICE

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SUMMARY

APOLLO/SATURN FLIGHTS

Mission	Launch Date	Launch Vehicle	Payload	Description
AS-201	2/26/66	SA-201	CSM-009	Launch vehicle and CSM development. Test of CSM subsystems and of the space vehicle. Demonstration of reentry adequacy of the CM at earth orbital conditions.
AS-203	7/5/66	SA-203	LH_2 in S-IVB	Launch vehicle development. Demonstration of control of LH_2 by continuous venting in orbit.
AS-202	8/25/66	SA-202	CSM-011	Launch vehicle and CSM development. Test of CSM subsystems and of the structural integrity and compatibility of the space vehicle. Demonstration of propulsion and entry control by G&N system. Demonstration of entry at 28,500 fps.
APOLLO 4	11/9/67	SA-501	CSM-017 LTA-10R	Launch vehicle and spacecraft development. Demonstration of Saturn V Launch Vehicle performance and of CM entry at lunar return velocity.
APOLLO 5	1/22/68	SA-204	LM-1 SLA-7	LM development. Verified operation of LM subsystems: ascent and descent propulsion systems (including restart) and structures. Evaluation of LM staging. Evaluation of S-IVB/IU orbital performance.
APOLLO 6	4/4/68	SA-502	CM-020 SM-014 LTA-2R SLA-9	Launch vehicle and spacecraft development. Demonstration of Saturn V Launch Vehicle performance.

APOLLO/SATURN FLIGHTS

Mission	Launch Date	Launch Vehicle	Payload	Description
APOLLO 7	10/11/68	SA-205	CM-101 SM-101 SLA-5	Manned CSM operations. Duration 10 days 20 hours.
APOLLO 8	12/21/68	SA-503	CM-103 SM-103 LTA-B SLA-11	Lunar orbital mission. Ten lunar orbits. Mission duration 6 days 3 hours. Manned CSM operations.
APOLLO 9	3/3/69	SA-504	CM-104 SM-104 LM-3 SLA-12	Earth orbital mission. Manned CSM/LM operations. Duration 10 days 1 hour.
APOLLO 10	5/18/69	SA-505	CM-106 SM-106 LM-4 SLA-13	Lunar orbital mission. Manned CSM/LM operations. Evaluation of LM performance in cislunar and lunar environment, following lunar landing profile. Mission duration 8 days.
APOLLO 11	7/16/69	SA-506	CM-107 SM-107 LM-5 SLA-14 EASEP	First manned lunar landing mission. Lunar surface stay time 21.6 hours. Mission duration 8 days 3 hours.
APOLLO 12	11/14/69	SA-507	CM-108 SM-108 LM-6 SLA-15 ALSEP I	Second manned lunar landing mission. Demonstration of point landing capability. Deployment of ALSEP I. Surveyor III investigation. Lunar surface stay time 31.5 hours. Two dual EVA's (15.5 manhours). 89 hours in lunar orbit (45 orbits). Mission duration 10 days 4.6 hours.
APOLLO 13	4/11/70	SA-508	CM-109 SM-109 LM-7 SLA-16 ALSEP III	Planned third lunar landing. Mission aborted at approximately 56 hours due to loss of SM cryogenic oxygen and consequent loss of capability to generate electrical power and water.
APOLLO 14	1/31/71	SA-509	CM-110 SM-110 LM-8 SLA-17 ALSEP 14	Third successful lunar landing mission. Landing at Fra Mauro site. Deployment of ALSEP. Extensive geology traverse. Lunar stay time 34.5 hours. Two dual EVA's of 4 hr. 49 min. and 4 hr. 28 min. Mission duration 9 days 2 min.

APOLLO/SATURN FLIGHTS

Mission	Launch Date	Launch Vehicle	Payload	Description
APOLLO 15	7/26/71	SA-510	CM-112 SM-112 LM-10 SLA-19 ALSEP 15 LRV-1	Fourth successful lunar landing mission. Exploration at Hadley-Apennine site. Extensive geology traverses with first lunar roving vehicle (27.9 km) Deployment of ALSEP Lunar stay time 66.9 hours. Three dual EVA's totaling 18.6 hours. 145.3 hours in lunar orbit (74 orbits). Mission duration 12 days 7.2 hours.
APOLLO 16	4/16/72	SA-511	CM-113 SM-113 LM-11 SLA-20 ALSEP 16 LRV-2	Fifth successful lunar landing mission. Exploration at Descartes site. Deployment of ALSEP and other experiments. Three extensive geology traverses on LRV. Three dual EVA's totaling 20.3 hours. Lunar stay time 71 hours. Second use of scientific instrument module for orbital science. 126.1 hours in lunar orbit (64 orbits). Mission duration 11 days 1.8 hours.

AS-201 FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Objectives Accomplished)

1. Demonstrate structural integrity and compatibility of the launch vehicle and confirm launch loads.
2. Test the separation of:
   a) S-IVB stage, instrument unit (IU), and spacecraft from S-IB stage.
   b) Launch escape system (LES) and boost protective cover from command/service module (CSM) and launch vehicle.
   c) CSM from S-IVB stage, IU, and service module-LM adapter (SLA).
   d) Command module (CM) from service module (SM).
3. Obtain flight operation information on the following subsystems:
   a) Launch vehicle: propulsion, guidance and control, and electrical systems.
   b) Spacecraft: CM heat shield (adequacy for entry from low earth orbit); service propulsion system (SPS) (including restart); environmental control system (ECS) (pressure and temperature control); communications; CM reaction control system (RCS); SM RCS; stabilization control system (SCS); earth landing system (ELS); and electrical power system (EPS).
4. Evaluate performance of the space vehicle emergency detection system (EDS) in an open-loop configuration.
5. Evaluate the CM heat shield at a heating rate of approximately 200 Btu/ft.^{2}/sec. during entry at approximately 28,000 fps.
6. Demonstrate the mission support facilities and operations required for launch, mission conduct, and CM recovery.

DETAILED TEST OBJECTIVES (All Objectives Accomplished)

PRINCIPAL OBJECTIVES

Launch Vehicle:

1. Demonstrate compatibility and structural integrity of the space vehicle (SV) during S-IB stage-powered flight and confirm structural loads and dynamic characteristics.

2. Demonstrate structural integrity and compatibility of S-IVB and space vehicle during powered phase and coast.

3. Demonstrate separation of:

   a) S-IVB from S-IB.

   b) CSM from S-IVB/IU/SLA.

4. Demonstrate S-IVB propulsion system including program mixture ratio shift and determine system performance parameters.

5. Demonstrate S-IB propulsion system and evaluate subsystem performance parameters.

6. Demonstrate launch vehicle guidance system, achieve guidance cutoff, and evaluate system accuracy.

7. Demonstrate LV control system during S-IVB-powered phase, S-IVB coast phase, and S-IB-powered phase, and evaluate performance characteristics.

8. Demonstrate LV sequencing system.

9. Evaluate performance of the space vehicle EDS in an open-loop configuration.

10. Demonstrate the mission support facilities required for launch, mission operations and CM recovery.

Spacecraft:

1. Determine performance of the SCS and determine its adequacy for manned orbital flight.
2. Verify SPS operation for a minimum of 20 seconds after at least 2 minutes in space environment and verify restart capability.
3. Determine performance of the CM RCS and SM RCS to determine their adequacy for manned orbital flight.
4. Determine long duration (approximately 200 seconds) SPS performance including shutdown characteristics.
5. Obtain data on SPS engine firing stability.
6. Determine performance of ECS (pressure and temperature control) and its adequacy for manned orbital flight.
7. Determine performance of the EPS and determine its adequacy for manned orbital flight.
8. Determine performance of the communication system and determine its adequacy for manned orbital flight.
9. Demonstrate compatibility and structural integrity of CSM/Saturn IB.
10. Determine structural loading of SLA when subjected to the Saturn IB launch environment.
11. Demonstrate separation of the S-IVB from the S-IB, the LES and boost protective cover from the CSM, the CSM from the S-IVB/IU/SLA, and the CM from the SM.
12. Determine CM adequacy for manned entry from low earth orbit.
13. Evaluate the CM heat shield ablator at a high heating rate of approximately 200 Btu/ft.^{2}/sec. during entry at 28,000 fps.

14. Demonstrate operation of the parachute recovery subsystem and recovery aids following entry.

15. Evaluate space vehicle EDS in the open-loop configuration.

16. Demonstrate the mission support facilities required for launch, mission operations, and CM recovery.

SECONDARY OBJECTIVES

Launch Vehicle:

1. Confirm LV-powered flight external environment.

2. Evaluate LV internal environment.

3. Evaluate IU/S-IVB inflight thermal conditioning system.

4. Demonstrate adequacy of S-IVB residual propellant venting system.

UNUSUAL FEATURES OF THE MISSION

1. First flight of the Saturn IB Launch Vehicle with both the S-IB first stage and the S-IVB second stage.

2. First non-orbital flight separation of the launch vehicle and spacecraft in the Saturn IB configuration.

3. First CM recovery.

4. First SPS burn and restart.

5. First flight test of a Block I Apollo Spacecraft.

6. First employment of the Mission Director concept in Apollo.

7. First employment of Mission Control Center - Houston (MCC-H) for Apollo mission control.

GENERAL INFORMATION

Spacecraft: CSM-009

Launch Vehicle: SA-201

Launch Complex: 34

Launch Time: 11:12 a.m. EST, February 26, 1966

Launch Azimuth: 105°

Sub-orbital Flight - Maximum Altitude: 266 NM

Mission Duration: 37 minutes 19 seconds

Time of Landing: 11:49 a.m. EST

SPACE VEHICLE AND PRE-LAUNCH DATA

Spacecraft delivered to Cape Kennedy: October 1965

Launch vehicle delivered to Cape Kennedy:

First stage (S-IB): September 1965

Second stage (S-IVB): September 1965

Instrument unit (IU): October 1965

Spacecraft launch weight: 45,900 lb.

Space vehicle weight at liftoff: 1,317,900 lb.

Spacecraft differences from "operational" Block I configuration:

* A developmental Block I heat shield was added.
* The guidance and navigation system was omitted.
* An open-loop EDS for the LES was added.
* Couches, space suits, and crew provisions were omitted.
* Batteries were substituted for fuel cells in the EPS.

* Biomedical instrumentation was omitted in the instrumentation system.

* Certain displays and controls related to astronaut operation were omitted.

* A CM control programmer and attitude reference system was added.

* Additional research and development (R&D) instrumentation was included.

The SA-201 Launch Vehicle was a standard Saturn IB design with the following exceptions:

* R&D instrumentation was included.

* An open-loop EDS was added.

* R&D structure was used in the S-IB stage.

RECOVERY DATA

Recovery Area: Atlantic Ocean

Landing Coordinates: 8°56'S., 10°43'W.

Recovery Ship: USS Boxer

Spacecraft Recovery Time: 2:13 p.m. EST, February 27, 1966

AS-203 FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Objectives Accomplished)

1. Evaluate the S-IVB LH_2 continuous venting system.
2. Evaluate S-IVB engine chilldown and recirculation system.
3. Determine S-IVB tank fluid dynamics.
4. Determine heat transfer into liquid hydrogen (LH_2) through tank wall, and obtain data required for propellant thermodynamic model.
5. Evaluate S-IVB and IU checkout in orbit.
6. Demonstrate orbital operation of the launch vehicle attitude control and thermal control systems.
7. Demonstrate the ability of the launch vehicle guidance to insert a payload into orbit.
8. Demonstrate operational structure of the launch vehicle.
9. Demonstrate the mission support facilities and operations required for launch and mission control.

DETAILED TEST OBJECTIVES (All Objectives Accomplished)

PRINCIPAL OBJECTIVES

Launch Vehicle:

1. **Evaluate the J-2 engine LH_2 chilldown and recirculation system, and ullage requirements for simulated engine restart.**
2. Determine cryogenic liquid/vapor interface configuration and fluid dynamics of propellants in near zero-g environment.
3. Demonstrate the S-IVB auxiliary propulsion system operation and evaluate performance parameters.

4. Demonstrate the adequacy of the S-IVB/IU thermal control system.

5. Demonstrate the launch vehicle guidance system operation, achieve guidance cutoff, and determine system accuracy.

6. Demonstrate the structural integrity of the launch vehicle and determine its dynamic characteristics.

SECONDARY OBJECTIVES

Launch Vehicle:

1. Evaluate the launch vehicle-powered flight external environment.

2. Verify the launch vehicle sequencing system operation.

3. Evaluate performance of the EDS in an open-loop configuration.

4. Evaluate separation of S-IVB/IU/nosecone from S-IB.

5. Verify launch vehicle propulsion systems' operation and evaluate system performance parameters.

6. Evaluate the MSC subcritical cryogenic experiment.

UNUSUAL FEATURES OF THE MISSION

1. Simulated S-IVB engine restart in orbit.

2. Use of hydrogen continuous vents to accelerate payload in orbit for settling S-IVB LH_2.

3. First orbital flight for S-IVB stage.

4. Insert most weight to date in orbit by the United States (28 tons).

5. Television feedback on behavior of LH_2 under orbital conditions.

6. First flight for redesigned, lighter weight S-IB stage.

GENERAL INFORMATION

Launch Vehicle: SA-203

Launch Complex: 37

Launch Time: 9:53 a.m. EST, July 5, 1966

Launch Azimuth: 72°

Apogee: 101.8 NM

Perigee: 101.6 NM

Revolutions: 4 (Vehicle broke up during pressure test above design value.)

Vehicle recovery was not planned.

SPACE VEHICLE AND PRE-LAUNCH DATA

No spacecraft was carried on this mission. An aerodynamic fairing (nosecone) weighing 3700 lb. was attached to the instrument unit and contained an MSC subcritical cryogenic experiment.

Launch vehicle delivered to Cape Kennedy:

First stage (S-IB): April 1966

Second stage (S-IVB): March 1966

Instrument unit (IU): April 1966

Space vehicle liftoff weight: 1,187,000 lb.

Total weight in orbit: 58,500 lb.

The SA-203 Launch Vehicle differed from the SA-201 vehicle as follows:

* The S-IB stage weight was decreased by 28,500 lb.
* The S-IB stage had a redesigned propellant container, barrel assembly, outriggers and gaseous oxygen interconnect and vent system.
* The S-IB stage outboard engine skirt was removed.

AS-202 FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Objectives Accomplished)

1. Demonstrate structural integrity and compatibility of the launch vehicle and spacecraft and confirm launch loads.

2. Demonstrate separation of:

   a) S-IVB/IU/Spacecraft from S-IB.

   b) LES and boost protective cover from CSM/launch vehicle.

   c) CSM from S-IVB/IU/SLA.

   d) CM from SM.

3. Verify operation of the following subsystems:

   a) Launch vehicle: propulsion, guidance and control, and electrical systems.

   b) Spacecraft: CM heat shield (adequacy for entry from low earth orbit); SPS (including multiple restart); guidance and navigation, environmental control system; communications; CM reaction control system; SM reaction control system; stabilization control system; earth landing system; and electrical power system.

4. Evaluate performance of the space vehicle EDS in closed-loop configuration.

5. Evaluate the heat shield at high heat load during entry at approximately 28,000 fps .

6. Demonstrate the mission support facilities and operations required for launch, mission conduct, and CM recovery.

DETAILED TEST OBJECTIVES (All Objectives Accomplished)

PRINCIPAL OBJECTIVES

Launch Vehicle:

1. Demonstrate structural integrity and compatibility of the space vehicle during S-IB stage-powered

flight and confirm structural loads and dynamic characteristics.

2. Demonstrate structural integrity and compatibility of the space vehicle during S-IVB stage-powered flight and coast.

3. Demonstrate S-IVB propulsion system operation including program mixture ratio shift and evaluate system performance parameters.

4. Demonstrate S-IB propulsion system operation and evaluate system performance parameters.

5. Demonstrate launch vehicle guidance system operation, achieve guidance cutoff, and evaluate system accuracy.

6. Demonstrate launch vehicle control system operation during S-IB-powered phase, S-IVB-powered phase, and S-IVB coast phase; and evaluate performance characteristics.

7. Demonstrate launch vehicle sequencing system operation.

8. Demonstrate the inflight performance of the S-IB and S-IVB secure range command systems.

Spacecraft:

1. Determine performance of guidance and navigation subsystem and its adequacy for a manned orbital mission.

2. Evaluate guidance and navigation performance during boost and closed-loop entry.

3. Determine performance of the SCS and determine its adequacy for manned orbital flight.

4. Demonstrate multiple SPS restart (at least three burns of at least three-second duration at ten-second intervals.)

5. Evaluate performance of the CM RCS and the SM RCS to determine their adequacy for manned orbital flight.

6. Verify SPS standpipe fix (minimum of 198 seconds of SPS burn required.)

7. Determine long duration (approximately 200 seconds) SPS performance including shutdown characteristics.

8. Obtain data on SPS engine firing stability.

9. Determine performance of ECS and its adequacy for manned orbital flight.

10. Determine performance of the EPS and determine its adequacy for manned orbital flight.

11. Determine performance of the communication system and determine its adequacy for manned orbital flight.

12. Verify S-band communications operations for turn-around ranging mode and downlink modes.

13. Demonstrate compatibility and structural integrity of CSM/Saturn IB.

14. Determine separation of the S-IVB/IU from the S-IB, the LES and boost protective cover (BPC) from the CSM/SLA/LV (nominal mode), the CSM from the S-IVB/IU/SLA, and the CM from the SM.

15. Determine CM adequacy for manned entry from low earth orbit.

16. Verify astrosextant thermal protection subsystem.

17. Evaluate the heat shield at high heat load during entry at approximately 28,000 fps , including the thermal protection of the CM heat shield ablator during a high heat load (20,000 Btu/sq. ft.) entry.

18. Demonstrate operation of the parachute recovery subsystem and recovery aids following reentry.

19. Evaluate the space vehicle EDS in closed-loop configuration.

20. Demonstrate the mission support facilities required for launch, mission operations, and CM recovery.

SECONDARY OBJECTIVES

Launch Vehicle:

1. Confirm launch vehicle-powered flight external environment.
2. Evaluate IU/S-IVB inflight thermal conditioning system.
3. Verify adequacy of S-IVB residual propellant venting.
4. Evaluate the S-IVB common bulkhead reversal test.

UNUSUAL FEATURES OF THE MISSION

1. First use of fuel cells in the service module on an Apollo/Saturn flight.
2. First flight of the emergency detection system in closed-loop configuration.
3. First recovery of Apollo spacecraft in Pacific area.
4. First test of unified S-band communications.
5. Repeat of the second stage (S-IVB) common bulkhead pressure test.
6. "Black Out" communication test.
7. First flight of Apollo guidance and navigation system.

GENERAL INFORMATION

Spacecraft: CSM-011

Launch Vehicle: SA-202

Launch Complex: 34

Launch Time: 12:15 p.m. EST, August 25, 1966

Launch Azimuth: 105°

Apogee: 617.1 NM

No Orbital Insertion Planned.

Mission Duration: 1 hour 33 minutes

Time of Landing: 1:48 p.m. EST

SPACE VEHICLE AND PRE-LAUNCH DATA

Spacecraft delivered to Cape Kennedy: April 1966

Launch vehicle delivered to Cape Kennedy:

First stage (S-IB): February 1966

Second stage (S-IVB): January 1966

Instrument unit (IU): February 1966

Spacecraft launch weight: 56,900 lb.

Space vehicle weight at liftoff: 1,312,300 lb.

Spacecraft 011 differences from the "operational" Block I configuration:

* A developmental Block I heat shield was added.
* Couches, space suits, and crew provisions were omitted.
* A tie-bar to replace a lunar module was added.
* The S-band in the communication system was omitted.
* Biomedical instrumentation was omitted in the instrumentation system.
* Certain displays and controls related to astronaut operation were omitted.
* A CM control programmer and attitude reference system was added.
* Additional R&D instrumentation was included.

The SA-202 Launch Vehicle differed from the standard Saturn IB design as follows:

* R&D instrumentation was included.

* R&D structure for S-IB stage was included.
* TV camera was included in the IU to view CSM separation

RECOVERY DATA

Recovery Area: Pacific Ocean

Landing Coordinates: 16°7'N., 168°54'E.

Recovery Ship: USS Hornet

Spacecraft Recovery Time: 10:10 p.m. EST, August 25, 1966

APOLLO 4 (AS-501) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Objectives Accomplished)

1. Demonstrate the structural and thermal integrity and compatibility of the launch vehicle and spacecraft. Confirm launch loads and dynamic characteristics.

2. Demonstrate separation of:

   a) S-II from S-IC (dual plane).

   b) S-IVB from S-II.

3. Verify operation of the following subsystems:

   a) Launch vehicle: propulsion (including S-IVB restart), guidance and control, and electrical system.

   b) Spacecraft: CM heat shield, (adequacy of Block II design for entry at lunar return conditions); and selected subsystems.

4. Evaluate performance of the space vehicle EDS in an open-loop configuration.

5. Demonstrate mission support facilities and operations required for launch, mission conduct, and CM recovery.

DETAILED TEST OBJECTIVES

PRINCIPAL OBJECTIVES

Launch Vehicle:

1. Demonstrate the S-IVB stage restart capability.

2. Demonstrate the adequacy of the S-IVB continuous vent system while in earth orbit.

3. Demonstrate the capability of the S-IVB auxiliary propulsion system during S-IVB-powered flight and orbital coast periods to maintain attitude control and perform required maneuvers.

4. Demonstrate the S-IVB stage propulsion system, including the propellant management systems, and determine inflight system performance parameters.

5. Demonstrate the S-II stage propulsion system, including programmed mixture ratio shift and the propellant management system, and determine inflight performance parameters.

6. Demonstrate the S-IC stage propulsion system, and determine inflight system performance parameters.

7. Demonstrate S-IC/S-II dual plane separation.

8. Demonstrate S-II/S-IVB separation.

9. Demonstrate the mission support capability required for launch and mission operations to high post injection altitudes.

10. Demonstrate structural and thermal integrity of the launch vehicle throughout powered and coasting flight, and determine inflight structural loads and dynamic characteristics.

11. Determine inflight launch vehicle internal environment.

12. Demonstrate the launch vehicle guidance and control system during S-IC, S-II, and S-IVB-powered flight; achieve guidance cutoff; and evaluate system accuracy.

13. Demonstrate launch vehicle sequencing system.

14. Evaluate the performance of the emergency detection system in an open-loop configuration.

15. Demonstrate compatibility of the launch vehicle and spacecraft.

16. Verify prelaunch and launch support equipment compatibility with launch vehicle and spacecraft systems.

Spacecraft:

1. Verify operation of the guidance and navigation system after subjection to the Saturn V boost environment.

2. Verify operation of the guidance and navigation system in the space environment after S-IVB separation.

3. Verify operation of the guidance and navigation/SCS during entry and recovery.

4. Gather data on the effects of a long duration SPS burn on spacecraft stability.

5. Demonstrate an SPS no-ullage start.

6. Determine performance of the SPS during a long duration burn.

7. Verify operation of the CM RCS during entry and throughout the mission.

8. Verify operation of the heat rejection system throughout the mission.

9. Verify operation of the EPS after being subjected to the Saturn V launch environment.

10. Verify operation of the primary guidance system (PGS) after being subjected to the Saturn V launch environment.

11. Verify operation of the EPS in the space environment after S-IVB separation.

12. Verify operation of the PGS in the space environment after S-IVB separation.

13. Verify operation of the EPS during entry and recovery.

14. Demonstrate the performance of CSM/MSFN S-band communications.

15. Demonstrate satisfactory operation of CSM communication subsystem using the Block II-type VHF omnidirectional antennas.

16. Obtain data via CSM-ARIA communications.

17. Demonstrate CSM/SLA/LTA/Saturn V structural compatibility and determine spacecraft loads in a Saturn V launch environment.

18. Determine the dynamic and thermal responses of the SLA/CSM structure in the Saturn V launch environment.

19. Evaluate the thermal and structural performance of the Block II thermal protection system, including effects of cold soak and maximum thermal gradient when subjected to the combination of a high heat load and a high heating rate representative of lunar return entry.

20. Verify the performance of the SM RCS thermal control subsystem and engine thermal response in the deep space environment.

21. Verify the thermal design adequacy of the CM RCS thrusters and extensions during simulated lunar return entry.

22. Evaluate the thermal performance of a gap and seal configuration simulating the unified crew hatch design, for heating conditions anticipated during lunar return entry.

23. Perform flight test of low density ablator panels.

24. Determine the force inputs to the simulated LM from the SLA at the spacecraft attachment structure in a Saturn V launch environment.

25. Obtain data on the acoustic and thermal environment of the SLA/simulated LM interface during a Saturn V launch.

26. Obtain data on the temperature of the simulated LM skin during launch.

27. Determine vibration response of LM descent stage engine and propellant tanks in a Saturn V launch environment.

28. Evaluate the performance of the spacecraft emergency detection system in the open-loop configuration.

29. Verify operation of the ELS during entry and recovery.

30. Measure the integrated skin and depth radiation dose within the CM up to an altitude of at least 2000 NM.

31. Determine the radiation shielding effectiveness of the command module.

32. Determine and display, in real time, Van Allen Belt radiation dose data at the Mission Control Center.

33. Obtain motion pictures for study of entry horizon reference, boost protective cover jettison, and orbit insertion; obtain photographs for earth landmark identification.

SECONDARY OBJECTIVES

Launch Vehicle:

1. Determine launch vehicle-powered flight external environment.

2. Determine attenuation effects of exhaust flames on RF radiating and receiving systems during main engine, retro and ullage motor firings.

UNUSUAL FEATURES OF THE MISSION

1. First space vehicle launch from LC-39.
2. First flight of Saturn V Space Vehicle.
3. First flight of S-IC launch vehicle stage.
4. First flight of S-II launch vehicle stage.
5. First flight of a lunar module test article (LTA).
6. First orbital restart of S-IVB stage.
7. First SPS no-ullage start.
8. First simulated Block II heat shield.
9. First lunar return velocity CM reentry.
10. First command and communication system flight test.
11. First use of Apollo Range Instrumentation Aircraft (ARIA).
12. First use of Apollo-configured ships.

GENERAL INFORMATION

Spacecraft: CSM-107, LTA-10R

Launch Vehicle: SA-501

Launch Complex: 39A

Launch Time: 7:00:00 a.m. EST, November 9, 1967

Launch Azimuth: 72°

Apogee: 9767 NM

Perigee: 100 NM

Revolutions: 3

Mission Duration: 8 hours 37 minutes 08 seconds

Time of Landing: 3:38:09 p.m. EST, November 9, 1967

SPACE VEHICLE AND PRE-LAUNCH DATA

Spacecraft delivered to KSC:

Command/service module: December 1966

Lunar module test article: September 1966

Launch vehicle delivered to KSC:

First stage (S-IC): September 1966

Second stage (S-II): January 1967

Third stage (S-IVB): August 1966

Instrument unit (IU): August 1966

Spacecraft weight at liftoff: 93,700 lb.

Space vehicle weight at liftoff: 6,121,466 lb.

Spacecraft differences from previous Block I flights:

* The EDS system operated in open-loop configuration.
* Block II thickness, thermal coating, and manufacturing technique for the CM heat shield ablator was used.
* A simulated Block II umbilical was added on CM in addition to active Block I umbilical.
* An Apollo Mission Control Programmer with special interface equipment for operation with CSM subsystems was installed in CM in place of crew couches.

* All S-band transmissions and receptions were performed by four S-band omnidirectional antennas modified to reflect Block II configuration.

* Flight qualification tape recorder and associated equipment for R&D measurements were added.

* Couches, crew restraints, crew provisions, instrument panel (partial), SCS (partial), and ECS (partial) were deleted from Block I configuration.

* CM hatch window was replaced with instrumentation test panel containing simulations of flexible thermal seals designed for the developmental quick operating hatches.

* Selected ECS water-glycol joints were armor-plated to evaluate their behavior during a space vehicle launch.

* The CM cabin was filled with gaseous nitrogen (GN_2) at liftoff to preclude the possibility of cabin fire.

* CM underwent extensive inspection and rework of its wiring to provide better wiring protection.

The lunar module test article (LTA-10R)was a "boiler-plate" LM test article instrumented to measure vibration, acoustics, and structural integrity at 36 points in the spacecraft-LM adapter (SLA). Data was telemetered to the ground stations during the first 12 minutes of flight. The LTA-10R used a flight-type descent stage without landing gear. Its propellant tanks were filled with water/glycol and freon to simulate fuel and oxidizer, respectively. The ascent stage was a ballasted aluminum structure containing no flight systems.

Launch vehicle differences from lunar mission configuration:

* The second stage (S-II) did not have the light weight structure to be used for the lunar mission.

* The F-1 and J-2 engines were not uprated versions.

* The EDS system was in open-loop configuration.

* The O_2H_2 burner, used as helium heater on S-IVB, was not installed.

RECOVERY DATA

Recovery Area: Pacific Ocean

Landing Coordinates: 30°N., 172°W.

Recovery Ship: USS Bennington

Spacecraft Recovery Time: 5:52 p.m. EST, November 9, 1967

APOLLO 5 (SA-204/LM-1) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Primary Objectives Accomplished)

1. Verify operation of the following LM subsystems:

   Ascent propulsion system and descent propulsion system (including restart), and structure.

2. Evaluate LM staging.

3. Evaluate the S-IVB/IU orbital performance.

DETAILED TEST OBJECTIVES

PRINCIPAL AND MANDATORY OBJECTIVES

Spacecraft:

1. Verify descent engine gimballing response to control signals. (Accomplished)

2. Demonstrate PGNCS thrust vector control and attitude control capability and evaluate the performance of the DAP and IMU in a flight environment. (Partially Accomplished)

3. Determine DPS and APS start, restart and shutdown characteristics in a space environment. (Accomplished)

4. Verify DPS thrust response to throttling control signals. (Partially Accomplished)

5. Determine that no adverse interactions exist between propellant slosh, vehicle stability, engine vibration and APS/DPS performance. (Partially Accomplished)

6. Determine that no vehicle degradation exists which would affect crew safety during APS burn to depletion. (Partially Accomplished.)

7. Verify the operation of the DPS propellant feed and pressurization sections. (Partially Accomplished)

SECONDARY OBJECTIVES

Launch Vehicle:

1. Evaluate the launcn vehicle attitude control system operation and maneuvering capability. (Accomplished)

2. Verify the S-IVB LH_2 and LOX tank pressure rise rates. (Accomplished)

3. Demonstrate nosecone separation from the S-IVB/IU/SLA. (Accomplished)

4. Evaluate the operational adequacy of the launch vehicle systems, including guidance and control, electrical, mechanical, and instrumentation. (Accomplished)

Spacecraft:

1. Verify satisfactory operation of portions of the LM ECS equipment. (Accomplished)

2. Evaluate the performance of the spacecraft jettison controller (SJC) and pyrotechnical devices in the execution of nose cap separations, SLA panel deployment and LM/SLA separation functions. (Accomplished)

3. Verify performance of portions of the LM S-band communications subsystem and its compatibility with MSFN. (Accomplished)

4. Evaluate the performance of the instrumentation subsystem during boost and LM propulsion subsystem operations. (Accomplished)

5. Demonstrate the operation of the explosive devices. (Accomplished)

UNUSUAL FEATURES OF THE MISSION

1. First flight to verify operation of LM subsystems.

2. First firing in space of LM descent engine.

3. First firing in space of LM ascent engine.

4. First test of LM fire-in-the-hole (FITH) staging capability.

GENERAL INFORMATION

Lunar Module: LM-1

Launch Vehicle: SA-204

Launch Complex: 37B

Launch Time: 5:48:08 p.m. EST, January 22, 1968

Launch Azimuth: 72°

Apogee: 519 NM

Perigee: 88 NM

Mission Duration: 7 hours 50 minutes

SPACE VEHICLE AND PRE-LAUNCH DATA

Spacecraft delivered to KSC:

Lunar module (LM): June 1967

Spacecraft-LM Adapter (SLA): October 1966

Launch vehicle delivered to KSC:

First stage (S-IB): July 1966

Second stage (S-IVB): August 1966

Instrument unit (IU): August 1966

Spacecraft launch weight: 31,700 lb.

Space vehicle weight at liftoff: 1,285,400 lb.

Lunar module differences from future LM's:

* An LM mission programmer (LMP) was added to perform control functions normally accomplished by the flight crew. The LMP received commands from the LM guidance computer (LGC), ground controller or its component program reader assembly (PRA). The PRA contained 64 taped contingency programs to be used in event of LGC failure. The digital command assembly (DCA) provided an uplink capability for

routing of ground signals to the LGC for the PRA. The program coupler assembly (PCA) provided coupling of the LGC and PRA commands to the subsystems.

* Developmental flight instrumentation (DFI) was within the LM-1 to supply operational data for flight conditioning electronics, modulation packages, VHF transmitters, and C-band beacons.

* The lunar mission erectable S-band antenna was not used.

* The mission did not employ a tape recorder for either systems, data, or voice.

* Cable and reel assemblies were used to verify and evaluate (post-flight) the ascent/descent stage separation.

* No EVA equipment was used or tested.

* LM guidance was active at liftoff. Normally, this is crew-initiated in a later flight phase. Because this equipment was active at liftoff, the cooling system was also active.

* This mission employed a spacecraft-LM adapter (SLA) umbilical. The LM and SLA were closed out several hours before launch.

* Because LM guidance was activated at liftoff, a guidance reference release signal (GRRS) was transmitted from MCC at approximately T-3 minutes (before automatic countdown sequencing).

* Landing gear was not attached.

* No crew provisions were included.

* Partial deletions were made in the environmental control system (ECS).

* The rendezvous radar was inoperative.

* The two LM cabin windows and the overhead docking window were replaced by aluminum panels.

The SA-204 Launch Vehicle was similar to the previous Saturn IB vehicles.

RECOVERY DATA

No recovery was planned.

REMARKS

An unscheduled hold of 3 hours 48 minutes occurred during the countdown at T-2 hours 30 minutes. The hold was caused by two problems: a failure in the freon supply in the ECS ground support equipment, and a power supply failure in the DDAS.

The flight of the SA-204 Launch Vehicle was according to plan. The LM-1 spacecraft also performed according to plan until the time of the first descent propulsion engine burn. The engine started as planned but was shut down after slightly more than four seconds by the LM guidance subsystem when the velocity did not build up at the predicted rate. The problem was analyzed and was determined to involve guidance software only, and the decision was made to go to an alternate mission plan that provided for accomplishing the minimum requirements necessary to meet the primary objectives of the mission. The major difference between the planned and alternate missions was the deletion of a long (12-minute) DPS burn and the substitution of program reader assembly (PRA) control for primary guidance control during the propulsion burns. During all burns conducted under PRA control, there was no attitude control; only rate damping was provided. The alternate plan was successfully executed by the flight operations team.

Although not all spacecraft detailed test objectives were fully accomplished, sufficient data were obtained to proceed with the mission schedule.

APOLLO 6 (AS-502) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES

1. Demonstrate the structural and thermal integrity and compatibility of the launch vehicle and spacecraft. Confirm launch loads and dynamic characteristics. (Partially Accomplished)

2. Demonstrate separation of:

   a. S-II from S-IC (dual plane). (Accomplished)

   b. S-IVB from S-II. (Accomplished)

3. Verify operation of the following launch vehicle subsystems: propulsion (including S-IVB restart), guidance and control (optimum injection), and electrical system. (Partially Accomplished)

4. Evaluate performance of the space vehicle EDS in a closed-loop configuration. (Accomplished)

5. Demonstrate mission support facilities and operations required for launch, mission conduct, and CM recovery. (Accomplished)

DETAILED TEST OBJECTIVES

PRINCIPAL AND MANDATORY OBJECTIVES

Launch Vehicle:

1. Demonstrate structural and thermal integrity of launch vehicle throughout powered and coasting flight, and determine inflight structural loads and dynamic characteristics. (Partially Accomplished)

2. Determine inflight launch vehicle internal environment. (Accomplished)

3. Verify pre-launch and launch support equipment compatibility with launch vehicle and spacecraft systems. (Accomplished)

4. Demonstrate the S-IC stage propulsion system and determine inflight system performance parameters. (Accomplished)

5. Demonstrate the S-II stage propulsion system, including programmed mixture ratio shift and the propellant management systems, and determine inflight system performance parameters. (Partially Accomplished)

6. Demonstrate the launch vehicle guidance and control system during S-IC, S-II, and S-IVB-powered flight. Achieve guidance cutoff and evaluate system accuracy. (Partially Accomplished.)

7. Demonstrate S-IC/S-II dual plane separation. (Accomplished)

8. Demonstrate S-II/S-IVB separation. (Accomplished)

9. Demonstrate launch vehicle sequencing system. (Accomplished)

10. Demonstrate compatibility of the launch vehicle and spacecraft. (Partially Accomplished)

11. Evaluate performance of the emergency detection system (EDS) in a closed-loop configuration. (Accomplished)

12. Demonstrate the capability of the S-IVB auxiliary propulsion system during S-IVB-powered flight and orbital coast periods to maintain attitude control and perform required maneuvers. (Accomplished)

13. Demonstrate the adequacy of the S-IVB continuous vent system while in earth orbit. (Accomplished)

14. Demonstrate the S-IVB stage restart capability. (Not Accomplished)

15. Demonstrate the mission support capability required for launch and mission operations to high post-injection altitudes. (Partially Accomplished)

16. Demonstrate the S-IVB stage propulsion system including the propellant management system, and determine inflight system performance parameters. (Partially Accomplished)

Spacecraft:

1. Evaluate the thermal and structural performance of the Block II thermal protection system, including effects of cold soak and maximum thermal gradient when subjected to the combination of a high heat load and a high heating rate representative of lunar return entry. (Accomplished)

2. Evaluate the thermal performance of a gap and seal configuration simulating the unified crew hatch design for heating conditions anticipated during lunar return entry. (Accomplished)

3. Demonstrate CSM/SLA/LTA/Saturn V structural compatibility and determine spacecraft loads in a Saturn V launch environment. (Partially Accomplished)

4. Determine the dynamic and thermal responses of the SLA/CSM structure in the Saturn V launch environment. (Accomplished)

5. Determine the force inputs to the simulated LM from the SLA at the spacecraft attachment structure in a Saturn V launch environment. (Accomplished)

6. Evaluate the performance of the spacecraft emergency detection subsystem (EDS) in the open-loop configuration. (Accomplished)

7. Obtain data on the acoustic and thermal environment of the SLA/simulated LM interface during a Saturn V launch. (Accomplished)

8. Determine vibration response of LM descent stage engine and propellant tanks in a Saturn V launch environment. (Accomplished)

9. Demonstrate an SPS no-ullage start. (Accomplished)

10. Verify the performance of the SM RCS thermal control subsystem and engine thermal response in the deep space environment. (Accomplished)

11. Verify the thermal design adequacy of the CM RCS thrusters and extensions during simulated lunar return entry. (Accomplished)

12. Verify operation of the heat rejection system throughout the mission. (Accomplished)

13. Measure the integrated skin and depth radiation dose within the command module up to an altitude of at least 2000 nautical miles. (Accomplished)

14. Determine performance of the SPS during a long duration burn. (Accomplished)

15. Demonstrate the performance of CSM/MSFN S-band communications. (Partially Accomplished)

SECONDARY OBJECTIVES

Launch Vehicle:

1. Determine launch vehicle-powered flight external environment. (Accomplished)

2. Determine attenuation effects of exhaust flames on RF radiating and receiving systems during main engine, retro, and ullage motor firings. (Accomplished)

Spacecraft:

1. Determine and display, in real time, Van Allen belt radiation dose rate and integrated dose data at the Mission Control Center, Houston, Texas. (Accomplished)

2. Verify operation of the PGS in the space environment after S-IVB separation. (Accomplished)

3. Demonstrate satisfactory operation of CSM communication subsystem using the Block II-type VHF omnidirectional antennas. (Accomplished)

4. Verify operation of the G&N/SCS during entry and recovery. (Accomplished)

5. Verify operation of PGS after being subjected to the Saturn V launch environment. (Accomplished)

6. Gather data on the effects of a long duration SPS burn on spacecraft stability. (Accomplished)

7. Verify operation of the CM RCS during entry and recovery. (Accomplished)

8. Verify operation of the ELS during entry and recovery. (Accomplished)

9. Verify operation of the electrical power system in the space environment after S-IVB separation. (Accomplished)

10. Verify operation of the G&N system after subjection to the Saturn V boost environment. (Accomplished)

11. Verify operation of the electrical power system during entry and recovery. (Accomplished)

12. Verify operation of the G&N in the space environment after S-IVB separation. (Accomplished)

13. Verify operation of the EPS after being subjected to the Saturn V launch environment. (Accomplished)

14. Determine the radiation shielding effectiveness of the CM. (Accomplished)

15. Obtain data on the temperature of the simulated LM skin during launch. (Accomplished)

16. Obtain data via CSM-ARIA communications. (Accomplished)

UNUSUAL FEATURES OF THE MISSION

1. First flight of the emergency detection system (EDS) in a closed-loop configuration.

2. First mission where flight controllers were not deployed to remote sites.

3. First flight of CM unified hatch.

GENERAL INFORMATION

Spacecraft: CM-020, SM-014, LTA-2R

Launch Vehicle: SA-502

Launch Complex: 39A

Launch Time: 7:00:00 a.m. EST, April 4, 1968

Launch Azimuth: 72°

Apogee: 12,010 NM (highest)

Revolutions: 3

Mission Duration: 9 hours 57 minutes

Time of Landing: 4:57 p.m. EST, April 4, 1968

SPACE VEHICLE AND PRE-LAUNCH DATA

Spacecraft delivered to KSC:

Command/service module (CSM): November 1967

Lunar module test article (LTA): February 1967

Launch vehicle delivered to KSC:

First stage (S-IC): March 1967

Second stage (S-II): May 1967

Third stage (S-IVB): February 1967

Instrument unit (IU): March 1967

Spacecraft weight at liftoff: 93,885 lb.

Space vehicle weight at liftoff: 6,108,128 lb.

Spacecraft changes from Apollo 4:

* The emergency detection system (EDS) was flown in its normal or "closed-loop" configuration with automatic abort capability.
* The command module contained the new unified, quick operating crew hatch.
* Entry batteries A and B in the CM each had a redundant battery added in parallel in order to eliminate a single-point failure mode.

* On the CM, the thermal coating used on Apollo 4 was replaced with a high emissivity paint in order to simulate the structural temperatures that will be encountered on a lunar mission.

* The micrometeoroid protection windows were removed from the CM.

* Five of the seven operational Block II EVA handrails were installed on the CM. Only two handrails were installed on Apollo 4.

* Five test samples of low-density ablative heat shield materials were flown to test materials which may result in weight savings on future Block II CM's. Three samples were mounted in place of the left side window and two samples were mounted in the simulated Block II umbilical cavity.

* A 16mm movie camera was added to the CM, positioned to sight out the left rendezvous window to record LES jettison, and to determine visibility of the horizon, window degradation, and plasma brilliance during entry. The 70mm sequence camera used on Apollo 4 was relocated to sight out the crew hatch window for earth landmark photography.

* Dosimeters were added in the CM to provide evaluation of the operational system for determining crew radiation dose rate and displaying this data in real time at the Mission Control Center.

* A microphone was installed to determine the noise level in the CM during Saturn V launch with the unified crew hatch installed.

* The CM postlanding vent valve was replaced with the Block II valve.

* The ECS 2.40 controller was replaced with an improved unit having reduced EMI susceptibility, improved potting, and circuitry changes for increased reliability.

* The instrumentation signal mechanical commutators used on Apollo 4 were replaced with solid state commutators having a higher reliability.

* Electrical bonding straps were installed across the CM/SM and LTA/SLA interfaces to provide electrical bonding without special preparation of mating structural surfaces.

* The SM aft bulkhead was strengthened to have a safety factor of 1.5 at 4.58 g.

* The SPS propellant tank skirt in the SM was strengthened.

* The titanium lines connected to the cryogenic hydrogen tanks in the SM were replaced with stainless steel line and bi-metallic adapters.

* The Block I SM RCS engines in Quad B were replaced with Block II engines.

* The SM had the standard Block I white paint whereas the Apollo 4 SM was painted with the Block II aluminized paint.

* The LTA had the landing gear installed permanently in the retracted position.

Launch vehicle differences from the lunar configuration:

* The second stage (S-II) did not have the lightweight structure which will be used with the lunar configuration.

* Neither the F-1 nor the J-2 engine was the uprated version.

* The O_2H_2 burner used as a helium heater on the S-IVB was not installed.

* R&D instrumentation was installed on all stages.

* The S-IC had two TV cameras looking at the F-1 engines.

* Recoverable cameras were mounted on the S-IC and S-II stages.

RECOVERY DATA

Recovery Area: Pacific Ocean

Landing Coordinates: 27°40'N, 157°59'W.

Recovery Ship: USS Okinawa

Spacecraft Recovery Time: 5:55 p.m. EST, April 4, 1968

REMARKS

During the first stage burn a propulsion structural longitudinal coupling (POGO effect) was noted. At approximately 134 seconds GET all LTA instrumentation showed a sudden unexpected change in dynamic characteristics and airborne lightweight optical tracking system (ALOTS) photos showed debris coming from the SLA area. The S-IC/S-II dual plane separation occurred normally.

Approximately 260 seconds after S-II ignition, engines #2 and #3 cut off prematurely. The remaining engines maintained vehicle control through the subsequent portion of the S-II burn. This malfunction caused the S-II stage to burn approximately 58 seconds longer than the nominal time. The S-IVB/S-II separation therefore occurred approximately 59 seconds later than nominal. The first S-IVB burn was approximately 29 seconds longer than nominal due to the S-II malfunction and the subsequent automatic attempt to achieve the proper orbit conditions. Despite the unplanned usage of propellants during the first S-IVB burn, the vehicle loading had sufficient margin that the planned full duration translunar injection burn was still possible. The S-IVB restart sequence was initiated at the end of the second revolution, but the stage failed to complete the ignition sequence.

Due to the failure of the S-IVB to reignite, an alternate mission was selected. This mission consisted of firing the service propulsion system (SPS) to attain the planned apogee of approximately 12,000 NM. To achieve this altitude a burn duration of 445 seconds was required, leaving residuals sufficient for a second burn of only 23 seconds. Because of this low propellant quantity, the planned second burn was not performed. The command module landed within 50 miles of the onboard targeted landing point and was recovered in good condition by USS Okinawa.

APOLLO 7 (AS-205) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Primary Objectives Accomplished)

1. Demonstrate CSM/crew performance.
2. Demonstrate crew/space vehicle/mission support facilities performance during a manned CSM mission.
3. Demonstrate CSM rendezvous capability.

DETAILED TEST OBJECTIVES

PRINCIPAL AND MANDATORY OBJECTIVES

Launch Vehicle:

1. Demonstrate orbital safing of the S-IVB. (Accomplished)
2. Demonstrate launch vehicle attitude control. (Accomplished)
3. Qualify J-2 engine augmented spark ignition (ASI) line modification. (Accomplished)

Spacecraft:

1. Obtain data on the environmental control system primary radiator thermal coating degradation. (Accomplished)
2. Obtain data on the Block II forward heat shield thermal protection system. (Accomplished)
3. Perform an inertial measurement unit orientation determination and a star pattern daylight visibility check. (Accomplished)
4. Perform inertial measurement unit alignments using the sextant. (Accomplished)
5. Perform guidance navigation control system-controlled SPS and RCS velocity maneuvers. (Accomplished)
6. Demonstrate guidance navigation control system automatic and manual attitude-controlled RCS maneuvers. (Accomplished)

7. Evaluate the ability of the guidance navigation control system to guide the entry from earth orbit. (Accomplished)

8. Demonstrate the stabilization control system automatic and manual attitude-controlled RCS maneuvers. (Accomplished)

9. Demonstrate CSM stabilization control system velocity control capability. (Accomplished)

10. Verify the life support functions of the environmental control system throughout the mission. (Accomplished)

11. Demonstrate the water management subsystems operation in the flight environment. (Accomplished)

12. Monitor the entry monitoring system during SPS velocity changes and entry. (Accomplished)

13. Perform star and earth horizon sightings to establish an earth horizon model. (Accomplished)

14. Obtain data on all command/service module consumables. (Accomplished)

15. Demonstrate fuel cell water operations in a zero-g environment. (Accomplished)

16. Perform a service propulsion system performance burn in the space environment. (Accomplished)

17. Demonstrate the performance of the command/service module - Manned Space Flight Network S-band communication system. (Accomplished)

18. Verify the adequacy of the propellant feed line thermal control system. (Accomplished)

19. Obtain inertial measurement unit performance data in the flight environment. (Accomplished)

20. Demonstrate the service propulsion system minimum impulse burns in a space environment. (Accomplished)

21. Perform onboard navigation using the technique of the scanning telescope landmark tracking. (Accomplished)

22. Obtain data on the stabilization control systems capability to provide a suitable inertial reference in a flight environment. (Accomplished)

23. Verify automatic pressure control of the cryogenic tank systems in a zero-g environment. (Accomplished)

24. Obtain data on thermal stratification with and without the cryogenic fans of the cryogenic gas storage system. (Accomplished)

25. Demonstrate S-band updata link capability. (Accomplished)

26. Obtain crew evaluation of intravehicular activity in general. (Accomplished)

27. Obtain data on operation of the waste management system in the flight environment. (Accomplished)

28. Operate the secondary coolant loop. (Accomplished)

29. Perform a command/service module-active rendezvous with the S-IVB. (Accomplished)

30. Accomplish the backup mode of the gyro display coupler-flight director attitude indicator alignment using the scanning telescope in preparation for an incremental velocity maneuver. (Accomplished)

31. Demonstrate the postlanding ventilation circuit operation. (Accomplished)

32. Perform optical tracking of a target vehicle using the sextant. (Accomplished)

33. Perform a command/service module - S-IVB separation, transposition and simulated docking. (Accomplished)

34. Perform a manual thrust vector control takeover. (Accomplished)

35. Monitor the primary and auxiliary gauging system. (Accomplished)

36. Demonstrate a simulated command/service module overpass of the lunar module rendezvous radar during the lunar stay. (Accomplished)

SECONDARY OBJECTIVES

Launch Vehicle:

1. Evaluate launch vehicle orbital lifetime. (Accomplished)

2. Demonstrate CSM manual launch vehicle orbital attitude control. (Accomplished)

Spacecraft:

1. Obtain data on initial coning angles when in the spin mode as used during transearth flight. (Accomplished)

2. Demonstrate command/service module VHF voice communications with the Manned Space Flight Network. (Accomplished)

3. Obtain data on the service module reaction control subsystem pulse and steady state performance. (Accomplished)

4. Obtain data on propellant slosh damping following SPS cutoff and following reaction control subsystem burns. (Accomplished)

5. Verify that the launch vehicle propellant pressure displays are adequate to warn of a common bulkhead reversal. (Accomplished)

6. Obtain photographs of the command module rendezvous windows during discrete phases of the flight. (Accomplished)

7. Evaluate the crew optical alignment sight for docking, rendezvous and proper attitude verification. (Accomplished)

8. Perform manual out-of-window command/service module attitude orientation for retro fire. (Accomplished)

9. Monitor the guidance navigation control systems and displays during launch. (Accomplished)

10. Obtain data via the command/service module - Apollo Range Instrumentation Aircraft communications systems. (Accomplished)

11. Perform crew-controlled manual S-IVB attitude maneuvers in three axes. (Accomplished)

12. Obtain data on the spacecraft-LM adapter deployment system operation. (Accomplished)

13. Obtain command/service module vibration data. (Accomplished)

14. Obtain selective, high quality photographs with color and panchromatic film of selected land and ocean areas. (Accomplished)

15. Obtain selective, high quality, color cloud photographs to study the fine structure of the earth's weather system. (Accomplished)

UNUSUAL FEATURES OF THE MISSION

1. First manned Apollo flight.

2. First flight of Block II Apollo Spacecraft.

3. First flight of the Apollo space suits.

4. First flight with full crew support equipment.

5. First live national TV from space during a manned space flight.

GENERAL INFORMATION

Spacecraft: CM-101, SM-101

Launch Vehicle: SA-205

Launch Complex: 34

Flight Crew:	Commander (CDR)	Walter M. Schirra, Jr.
	Command Module Pilot (CMP)	Donn F. Eisele
	Lunar Module Pilot (LMP)	Walter Cunningham

Launch Time: 11:02:45 a.m. EDT, October 11, 1968

Launch Azimuth: 72°

Apogee: 245 NM

Perigee: 90 NM

Revolutions: 163

Mission Duration: 10 days 20 hours

Time of Landing: 7:11 a.m. EDT, October 22, 1968

SPACE VEHICLE AND PRE-LAUNCH DATA

Spacecraft delivered to KSC: May 1968

Launch vehicle delivered to Cape Kennedy:

First stage (S-IB): March 1968

Second stage (S-IVB): April 1968

Instrument Unit (IU): April 1968

Spacecraft weight at liftoff: 45,374 lb.

Space vehicle weight at liftoff: 1,277,742 lb.

Significant spacecraft changes from Block I:

* A unified hatch assembly was incorporated.
* S-band equipment was added.
* Unitized crew couches were incorporated.
* Flight qualification and operational instrumentation were increased.
* Full crew support systems were incorporated.
* Usage of non-metallic materials was modified and decreased.

* A 60% oxygen/40% nitrogen cabin environment was used during pre-launch and early boost phases of the mission.
* There was an increased use of stainless steel tubing in place of aluminum.
* Armoring of solder tubing joints was increased.
* Fire extinguisher and emergency oxygen masks were incorporated in the CM.
* An onboard TV camera was added.
* The capabilities of components of the earth landing system were improved.
* Communication system modifications were incorporated.
* A redesigned cobra cable was incorporated.

RECOVERY DATA

Recovery Area: West Atlantic Ocean

Landing Coordinates: 27°33'N., 64°04'W. (Stable II)

Recovery Ship: USS Essex

Crew Recovery Time: 8:08 a.m. EDT, October 22, 1968

Spacecraft Recovery Time: 9:03 a.m. EDT, October 22, 1968

REMARKS

All primary Apollo 7 Mission objectives were successfully accomplished. In addition, all planned detailed test objectives plus three that were not originally scheduled were satisfactorily accomplished.

As part of the effort to alleviate fire hazard prior to liftoff and during initial flight, the command module cabin atmosphere was composed of 60% oxygen and 40%

nitrogen. During this period the crew was isolated from the cabin by the suit circuit, which contained 100% oxygen. Shortly after liftoff, the cabin atmosphere was gradually enriched to pure oxygen at a pressure of 5 psi.

Hot meals and relatively complete freedom of motion in the spacecraft enhanced crew comfort over previous Mercury and Gemini flights. The service module SPS main engine proved itself by accomplishing the longest and shortest manned SPS burns and the largest number of inflight restarts. The SPS engine is the largest thrust engine to be manually thrust vector-controlled. Manual tracking, navigation, and control achievements included full optical rendezvous, daylight platform realignment, optical platform alignments, pilot attitude control of launch vehicle, and orbital determination by sextant tracking of another vehicle by the spacecraft. The Apollo 7 Mission also accomplished the first digital auto pilot-controlled engine burn and the first manned S-band communications.

All launch vehicle systems performed satisfactorily throughout their expected lifetime. All spacecraft systems continued to function throughout the mission with some minor anomalies. Each anomaly was countered by a backup subsystem, a change in procedures, isolation, or careful monitoring such that no loss of system support resulted. Temperatures and consumables usages remained within specified limits throughout the mission.

APOLLO 8 (AS-503) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Primary Objectives Accomplished)

1. Demonstrate crew/space vehicle/mission support facilities performance during a manned Saturn V mission with CSM.

2. Demonstrate performance of nominal and selected backup lunar orbit rendezvous (LOR) mission activities, including:

   a. Translunar injection;

   b. CSM navigation, communications, and midcourse corrections;

   c. CSM consumables assessment and passive thermal control.

DETAILED TEST OBJECTIVES

PRINCIPAL AND MANDATORY OBJECTIVES

Launch Vehicle:

1. Verify the capability of the launch vehicle to perform a free-return translunar injection (TLI). (Accomplished)

2. Demonstrate the capability of the S-IVB to restart in earth orbit. (Accomplished)

3. Verify the modifications made to the J-2 engine since the Apollo 6 flight. (Accomplished)

4. Confirm the J-2 engine environment in the S-II and S-IVB stages. (Accomplished)

5. Confirm the launch vehicle longitudinal oscillation environment during the S-IC stage burn. (Accomplished)

6. Verify that the modifications incorporated in the S-IC stage since the Apollo 6 flight suppress low frequency longitudinal oscillations (POGO). (Accomplished)

7. Demonstrate the operation of the S-IVB helium heater repressurization system. (Accomplished)

8. Verify the capability to inject the S-IVB/IU/LTA-B into a lunar "slingshot" trajectory. (Accomplished)

9. Demonstrate the capability to safe the S-IVB stage in orbit. (Accomplished)

10. Verify the onboard command and communication system (CCS) and ground system interface and the operation of the CCS in a deep space environment. (Accomplished)

Spacecraft:

1. Perform a guidance, navigation, and control system (GNCS)-controlled entry from a lunar return. (Accomplished)

2. Perform star-lunar horizon sightings during the translunar and transearth phases. (Accomplished)

3. Perform star-earth horizon sightings during translunar and transearth phases. (Accomplished)

4. Perform manual and automatic acquisition, tracking, and communication with MSFN using the high-gain CSM-S-band antenna during a lunar mission. (Accomplished)

5. Obtain data on the passive thermal control system during a lunar orbit mission. (Accomplished)

6. Obtain data on the spacecraft dynamic response. (Accomplished)

7. Demonstrate SLA panel jettison in a zero-g environment. (Accomplished)

8. Perform lunar orbit insertion SPS GNCS-controlled burns with a fully loaded CSM. (Accomplished)

9. Perform a transearth insertion GNCS-controlled SPS burn. (Accomplished)

10. Obtain data on the CM crew procedures and timeline for lunar orbit mission activities. (Accomplished)

11. Demonstrate CSM passive thermal control (PTC) modes and related communication procedures during a lunar orbit mission. (Accomplished)

12. Demonstrate ground operational support for a CSM lunar orbit mission. (Accomplished)

13. Perform lunar landmark tracking from the CSM in lunar orbit. (The intent of this objective was to establish that an onboard capability existed to compute relative position data for the lunar landing mission. This mode will be used in conjunction with the MSFC state-vector update.) (Partially Accomplished)

14. Prepare for translunar injection (TLI), and monitor the GNCS and LV tank pressure displays during the TLI burn. (Accomplished)

15. Perform translunar and transearth midcourse corrections. (Accomplished)

SECONDARY OBJECTIVES

Spacecraft:

1. Monitor the GNCS and displays during launch. (Accomplished)

2. Obtain IMU performance data in the flight environment. (Accomplished)

3. Perform star-earth landmark sighting navigation during translunar and transearth phases. (The intent of this objective was to demonstrate onboard star-earth landmark optical navigation.) (Partially Accomplished)

4. Perform an IMU alignment and a star pattern visibility check in daylight. (Accomplished)

5. Perform SPS lunar orbit insertion and transearth injection burns and monitor the primary and auxiliary gauging systems. (Accomplished)

6. Obtain data on the Block II ECS performance during manned lunar return entry conditions. (Accomplished)

7. Communicate with MSFC using the CSM S-band omni-antennas at lunar distance. (Accomplished)

8. Demonstrate the performance of the Block II thermal protection system during a manned lunar return entry. (Accomplished)

9. Perform a CSM/S-IVB separation and a CSM transposition on a lunar mission timeline. (Accomplished)

10. Obtain data on CSM consumables for a CSM lunar orbit mission. (Accomplished)

11. Obtain photographs during the transearth, translunar and lunar orbit phases for operational and scientific purposes. (Accomplished)

12. Obtain data to determine the effect of the tower jettison motor, S-II retro and SM RCS exhausts and other sources of contamination on the CM windows. (Accomplished)

UNUSUAL FEATURES OF THE MISSION

1. First manned Saturn V flight.
2. First manned flight to the lunar vicinity.
3. Highest velocity yet attained by man - 36,228 fps.
4. First live TV coverage of the lunar surface.
5. Deepest penetration of space by a manned spacecraft.
6. First space flight on which man escaped earth's gravity.

GENERAL INFORMATION

Spacecraft: CM-103, SM-103, LTA-B

Launch Vehicle: SA-503

Launch Complex: 39A

Flight Crew:	Commander (CDR)	Frank Borman
	Command Module Pilot (CMP)	James A. Lovell, Jr.
	Lunar Module Pilot (LMP)	William A. Anders

Launch Time: 7:51:00 a.m. EST, December 21, 1968

Launch Azimuth: 72°

Earth Orbit: Apogee 103.3 NM, Perigee 98.0 NM

Lunar Orbit: Initial Apocynthion 168.5 NM, Pericynthion 59.7 NM

Circularized Apocynthion 60.7 NM, Pericynthion 59.7 NM

Mission Duration: 146 hours 59 minutes 49 seconds

Time of Landing: 10:50:49 a.m. EST, December 27, 1968

SPACE VEHICLE AND PRE-LAUNCH DATA

Spacecraft delivered to KSC:

Command/service module (CSM): August 1968

Lunar module test article (LTA): January 1968

Launch vehicle delivered to KSC:

First stage (S-IC): December 1967

Second stage (S-II): June 1968

Third stage (S-IVB): December 1967

Instrument unit (IU): January 1968

Space vehicle weight at liftoff: 6,133,880 lb.

Weight placed in earth orbit: 282,237 lb.

Weight placed in lunar orbit: 46,743 lb.

Significant spacecraft differences from Apollo 7:

* Forward hatch was modified to a combined forward crew hatch.
* The SM aft bulkhead structure was modified to assure a 1.4 factor of safety.
* The CM-SM tension tie thickness was increased.
* The SM/SLA interface was redesigned to install bolts from outside.

* Couch strut load/stroke criteria were reduced and lockouts added.
* A change to foldable crew couches was incorporated.
* The spacecraft ground intercom was converted from a two-wire to a four-wire system.
* An S-band high-gain antenna was included.
* A high-gain antenna automatic reacquisition system was added.
* The ECS radiator flow proportioning valve was redesigned.
* Aluminum CO_2 absorber elements were added.
* The Collossus onboard software was installed.
* A change to jettisonable SLA panels was incorporated.
* The Van Allen Belt dosimeter was added.
* POGO instrumentation was added.
* A nuclear particle detection system was added.
* The right-hand crewman's right-hand arm rest was deleted.
* A redundant launch vehicle attitude error display was added.

Significant launch vehicle changes from Apollo 6:

* The ASI's in the J-2 engine were modified.
* The S-IC stage was modified to suppress low frequency longitudinal oscillations.

RECOVERY DATA

Recovery Area: Pacific Ocean

Landing Coordinates: 165°1'W. 8°8'N. (Stable II)

Recovery Ship: USS Yorktown

Crew Recovery Time: 12:20 p.m. EST, December 27, 1968

Spacecraft Recovery Time: 13:20 p.m. EST, December 27, 1968

REMARKS

All primary Apollo 8 mission objectives were completely accomplished. Every detailed test objective was accomplished as well as four which were not originally planned.

The AS-503 Space Vehicle featured several configuration details for the first time, including: a Block II Apollo Spacecraft on a Saturn V Launch Vehicle, a manned spacecraft on a Saturn V Launch Vehicle, an O_2H_2 gas burner on the S-IVB for propellant tank repressurization prior to engine restart, open-loop propellant utilization systems on the S-II and S-IVB stages, and jettisonable SLA panels.

For this first Apollo flight to the lunar vicinity, Mission Operations successfully coped with lunar launch opportunity and launch window constraints and injected the S-IVB into a lunar "slingshot" trajectory to prevent recontact with the spacecraft or impact on the moon or earth. Apollo 8 provided man his first opportunity to personally view the backside of the moon, view the moon from as little as 60 NM away, view the earth from over 200,000 NM away, and reenter the earth's atmosphere through a lunar return corridor at lunar return velocity.

All launch vehicle systems performed satisfactorily throughout their expected lifetimes. All spacecraft systems continued to function satisfactorily throughout the mission. No major anomalies occurred. Those minor discrepancies which did occur were primarily procedural and were corrected in flight with no mission impact. All temperatures and consumables usage rates remained within normal limits throughout the mission.

APOLLO 9 (AS-504) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Primary Objectives Accomplished)

1. Demonstrate crew/space vehicle/mission support facilities performance during a manned Saturn V mission with CSM and LM.
2. Demonstrate LM/crew performance.
3. Demonstrate performance of nominal and selected backup LOR mission activities, including:
    a. Transposition, docking, LM withdrawal;
    b. Intervehicular crew transfer;
    c. Extravehicular capability;
    d. SPS and DPS burns;
    e. LM-active rendezvous and docking.
4. CSM/LM consumables assessment.

DETAILED TEST OBJECTIVES

PRINCIPAL AND MANDATORY OBJECTIVES

Launch Vehicle:

1. Demonstrate S-IVB/IU attitude control capability during transposition, docking, and LM ejection (TD&E) maneuver. (Accomplished)

Spacecraft:

1. Perform LM-active rendezvous. (Accomplished)
2. Determine DPS duration effects and primary propulsion/vehicle interactions. (Accomplished)
3. Verify satisfactory performance of passive thermal subsystem. (Accomplished)

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4. Demonstrate LM structural integrity. (Accomplished)

5. Perform DPS burn including throttling, docked; and a short duration DPS burn, undocked. (Accomplished)

6. Perform long duration APS burns. (Accomplished)

7. Demonstrate environmental control system (ECS) performance during all LM activities. (Accomplished)

8. Obtain temperature data on deployed landing gear resulting from DPS operation. (Accomplished)

9. Determine electrical power system (EPS) performance, primary and backup. (Accomplished)

10. Operate landing radar during DPS burns. (Accomplished)

11. Perform abort guidance system (AGS)/control electronics system (CES)-controlled DPS burn. (Accomplished)

12. Perform primary guidance, navigation, and control system (PGNCS)/digital auto pilot (DAP)-controlled long duration APS burn. (Accomplished)

13. Demonstrate RCS control of LM using manual and automatic PGNCS. (Accomplished)

14. Demonstrate S-band and VHF communication compatibility. (Partially Accomplished)

15. Demonstrate RCS control of LM using manual and automatic AGS/CES. (Accomplished)

16. Demonstrate CSM attitude control, docked, during SPS burn. (Accomplished)

17. Demonstrate LM-active docking. (Accomplished)

18. Demonstrate LM ejection from SLA with CSM. (Accomplished)

19. Demonstrate CSM-active docking. (Accomplished)

20. Demonstrate CSM-active undocking. (Accomplished)

21. Verify inertial measurement unit (IMU) performance. (Accomplished)

22. Demonstrate guidance, navigation, and control system (GNCS)/manual thrust vector control (MTVC) takeover. (Accomplished)

23. Demonstrate LM rendezvous radar performance. (Accomplished)

24. Demonstrate LM/Manned Space Flight Network (MSFN) S-band communications capability. (Partially Accomplished)

25. Demonstrate intervehicular transfer (IVT). (Accomplished)

26. Demonstrate AGS calibration and obtain performance data in flight. (Accomplished)

27. Perform LM IMU alignment. (Accomplished)

28. Perform LM jettison. (Accomplished)

29. Obtain data on reaction control system (RCS) plume impingement and corona effect on rendezvous radar performance. (Accomplished)

30. Demonstrate support facilities performance during earth orbital missions. (Accomplished)

31. Perform IMU alignment and daylight star visibility check, docked. (Accomplished)

32. Prepare for CSM-active rendezvous with LM. (Accomplished)

33. Perform IMU alignment with sextant (SXT), docked. (Accomplished)

34. Perform landing radar self-test. (Accomplished)

35. Perform extravehicular activity. (Accomplished)

SECONDARY OBJECTIVES

Launch Vehicle:

1. Verify S-IVB restart capability. (Accomplished)
2. Verify J-2 engine modification. (Accomplished)
3. Confirm J-2 engine environment in S-II stage. (Accomplished)
4. Confirm launch vehicle longitudinal oscillation environment during S-IC stage burn period. (Accomplished)

5. Demonstrate O_2H_2 burner repressurization system operation. (Accomplished)

6. Demonstrate S-IVB propellant dump and safing. (Not Accomplished)

7. Verify that modifications incorporated in the S-IC stage suppress low-frequency longitudinal oscillations. (Accomplished)

8. Demonstrate 80-minute restart capability. (Accomplished)

9. Demonstrate dual repressurization capability. (Accomplished)

10. Demonstrate O_2H_2 burner restart capability. (Accomplished)

11. Verify the onboard command and communications system (CCS)/ground system interface and operation in the space environment. (Accomplished)

Spacecraft:

1. Obtain exhaust effects data from launch escape tower (LET), S-II retro, and SM RCS on CSM. (Accomplished)
2. Evaluate crew performance of all tasks. (Accomplished)
3. Perform navigation by landmark tracking. (Accomplished)
4. Perform unmanned APS burn-to-depletion. (Accomplished)
5. Obtain data on DPS plume effects on visibility. (Accomplished)
6. Perform CSM/LM electromagnetic compatibility test. (Accomplished)

UNUSUAL FEATURES OF THE MISSION

1. Largest payload yet placed in orbit.
2. First launch of Saturn V/Apollo Spacecraft in lunar mission configuration.
3. First demonstration of S-IVB second orbital restart capability.
4. First CSM-active docking.

5. First manned LM systems performance demonstration.

6. First inflight depressurization and hatch opening of LM and CM.

7. First Apollo extravehicular activity.

8. First intervehicular transfer between docked interface of two vehicles in shirt sleeve environment.

9. First docked SPS burns with CSM guidance and docked DPS burns with LM guidance.

10. First demonstration of lunar module TV camera (black and white).

11. First LM TV.

12. First LM-active rendezvous and docking.

13. First time one spacecraft was configured from another spacecraft for an unmanned burn.

GENERAL INFORMATION

Spacecraft: CM-104, SM-104, LM-3

Launch Vehicle: SA-504

Launch Complex: 39A

Flight Crew:	Commander (CDR)	James A. McDivitt
	Command Module Pilot (CMP)	David R. Scott
	Lunar Module Pilot (LMP)	Russell L. Schweickart

Launch Time: 11:00:00 a.m. EST, March 3, 1969

Launch Azimuth: 72°

Apogee: 271.8 NM (Highest)

Perigee: 97.8 NM (Lowest)

Mission Duration: 10 days 01 hour 53 seconds

Time of Landing: 12:00:53 p.m. EST, March 13, 1969

SPACE VEHICLE AND PRE-LAUNCH DATA

Spacecraft delivered to KSC:

Command/service module (CSM): October 1968

Lunar module (LM): June 1968

Launch vehicle delivered to KSC:

First stage (S-IC): September 1968

Second stage (S-II): May 1968

Third stage (S-IVB): September 1968

Instrument unit (IU): September 1968

Space vehicle weight at liftoff: 6,397,055 lb.

Weight placed in earth orbit: 292,091 lb.

Significant spacecraft differences from Apollo 8 (LM-3 is compared with LM-1 which was flown on Apollo 5):

Command Module

* Forward hatch emergency closing link was added.
* A general purpose timer was added.
* A precured RTV was added to side and hatch windows.
* The S-065 camera experiment equipment was added.
* Docking probe, ring, and latches were added.
* An RCS propulsion burst disc was added.
* A solenoid valve was added to the RCS propellant system.
* The S-band power amplifier configuration was changed to 0006 configuration.
* The flight qualification recorder was deleted.

Lunar Module

* First operational flight of oxygen supply module.
* First operational flight of water control module.
* First flight of VHF transceiver and diplexer.
* First flight to use exterior tracking light.
* First flight to use ascent engine arming assembly.
* First operational flight of the abort guidance section.
* First operational flight of the rendezvous radar.
* First flight of the landing radar electronic and antenna assembly.
* First flight using thrust translation controller assembly.
* First flight to use orbital rate drive.
* The CO_2 partial pressure sensor was modified to correct EMI, vibration, and outgassing problems.
* A high-reliability transformer was added for use with the S-band steerable antenna.
* A pressure switch was added to the RCS.
* Thermal insulation was modified in the rendezvous radar antenna assembly.
* Landing gear was installed.
* High-efficiency reflective coated cabin and docking windows were added.
* A split AC bus was added.
* A more reliable signal processor assembly was added.
* Manual trim shutdown was added to descent engine control assembly.

* Stabilization and control assembly No. 1 was modified to eliminate single failure point.

* Fire preventive and resistive materials were added.

* A TV camera was added.

Spacecraft-LM Adapter

* The SLA panel charges were redesigned.

* A spring ejector for LM separation was added.

* The LM separation sequence controllers were added.

* The POGO instrumentation was deleted.

Significant launch vehicle changes from Apollo 8:

S-IC Stage

* The film camera system was deleted.

* The R&D instrumentation was reduced.

* A redesigned F-1 engine injector was installed.

* Television cameras were removed.

* Propulsion performance was increased.

* Weight was reduced by removal of forward skirt insulation and revising "Y" rings and skin taper in propellant tanks.

S-II Stage

* First flight of lightweight structure.

* Separation planes tension plates were redesigned.

* The J-2 engines were uprated.

* The thrust structure was reinforced.

* The propellant utilization (PU) system was changed to closed loop.

S-IVB Stage

* Instrumentation battery capacity was reduced.

* The anti-flutter kit was deleted.

* The J-2 engine was uprated.

Instrument Unit

* The methanol accumulator was enlarged.

* Networks to disable spacecraft control of launch vehicle were changed.

* One instrument battery was removed.

* The S-band telemetry was deleted.

RECOVERY DATA

Recovery Area: Atlantic Ocean

Landing Coordinates: 67°56'W, 23°13'N. (Stable I)

Recovery Ship: USS Guadalcanal

Crew Recovery Time: 12:50 p.m. EST, March 13, 1969

Spacecraft Recovery Time: 2:13 p.m. EST, March 13, 1969

REMARKS

A mild virus respiratory illness which infected all of the Apollo 9 crew members was the primary factor in the decision to reschedule the launch from February 28 to 11:00 EST, March 3, 1969. This decision to reschedule was made February 27, 1969 in order to assure the full recovery and good health of the astronauts. The countdown was accomplished without any unscheduled holds and was the fourth Saturn V on-time launch.

The Apollo 9 launch was the first Saturn V/Apollo Spacecraft in full lunar mission configuration and carried the largest payload ever placed in orbit. Since Apollo 9 was the first manned demonstration of lunar module systems performance, many firsts were achieved. These were highlighted by CSM- and LM-active rendezvous and docking, the first Apollo EVA, and intervehicular transfer in shirt sleeve environment. This flight also contained the first demonstration of S-IVB second orbital restart capability.

In the third day of the mission, LMP Schweickart was struck by nausea and this illness caused a small delay from the normal timeline in the donning of pressure suits and in the transfer to the LM. It also caused shortening of the proposed EVA plan. Later the next morning, CDR McDivitt assessed LMP Schweickart's condition as excellent and with ground control concurrence decided to extend his EVA activities.

The Apollo 9 crew had remarkable success in sighting objects using the crewman optical alignment sight (COAS). Their success seems to confirm the thesis that the visual acuity of the human eye is increased in space. One example is their sighting of the Pegasus II Satellite at a range of approximately 1,000 miles.

All primary objectives were successfully accomplished on the Apollo 9 flight. All mandatory and principal detailed test objectives were accomplished, except two, and these two were partially accomplished. One secondary detailed test objective, the S-IVB propellant dump and safing, was not accomplished.

All launch vehicle systems performed satisfactorily throughout their expected lifetimes with the exception of inability to dump propellants following the third S-IVB burn. All spacecraft systems continued to function satisfactorily throughout the mission. No major anomalies occurred. Those minor discrepancies which did occur were primarily procedural and were corrected in flight with no mission impact, or involved instrumentation errors on quantities which could be checked by other means. Temperatures and consumables usage rates remained generally within normal limits throughout the mission.

APOLLO 10 (AS-505) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Primary Objectives Accomplished)

1. Demonstrate crew/space vehicle/mission support facilities performance during a manned lunar mission with CSM and LM.

2. Evaluate LM performance in the cislunar and lunar environment.

DETAILED TEST OBJECTIVES

PRINCIPAL AND MANDATORY OBJECTIVES

Spacecraft:

1. Demonstrate CSM/LM rendezvous capability for a lunar landing mission. (Accomplished)

2. Perform manual and automatic acquisition, tracking, and communications with MSFN using the steerable S-band antenna at lunar distance. (Accomplished)

3. Perform lunar landmark tracking from the CSM while in lunar orbit. (Accomplished)

4. Perform lunar landmark tracking in lunar orbit from the CSM with the LM attached. (Accomplished)

5. Operate the landing radar at the closest approach to the moon and during DPS burns. (Accomplished)

6. Obtain data on the CM and LM crew procedures and time-line for the lunar orbit phase of a lunar landing mission. (Accomplished)

7. Perform PGNCS/DPS undocked descent orbit insertion (DOI) and a high thrust maneuver. (Accomplished)

SECONDARY OBJECTIVES

Launch Vehicle:

1. Verify J-2 engine modifications. (Accomplished)

2. Confirm J-2 engine environment in S-II and S-IVB stages. (Accomplished)

3. Confirm launch vehicle longitudinal oscillation environment during S-IC stage burn period. (Accomplished)

4. Verify that modifications incorporated in the S-IC stage suppress low frequency longitudinal oscillations. (Accomplished)

5. Confirm launch vehicle longitudinal oscillation environment during S-II stage burn period. (Accomplished)

6. Demonstrate that early center engine cutoff for S-II stage suppresses low frequency longitudinal oscillations. (Accomplished)

Spacecraft:

1. Demonstrate LM/CSM/MSFN communications at lunar distance. (Partially Accomplished)

2. Communicate with MSFN using the LM S-band omni-antennas at lunar distance. (Accomplished)

3. Obtain data on the rendezvous radar performance and capability near maximum range. (Accomplished)

4. Obtain supercritical helium system pressure data while in standby conditions and during all DPS engine firings. (Accomplished)

5. Perform an unmanned AGS-controlled APS burn. (Accomplished)

6. Obtain data on the operational capability of VHF ranging during an LM-active rendezvous. (Accomplished)

7. Obtain data on the effects of lunar illumination and contrast conditions on crew visual perception while in lunar orbit. (Accomplished)

8. Obtain data on the passive thermal control mode during a lunar orbit mission. (Partially Accomplished)

9. Demonstrate CSM/LM passive thermal control modes during a lunar orbit mission. (Accomplished)

10. Demonstrate RCS translation and attitude control of the staged LM using automatic and manual AGS/CES control. (Accomplished)

11. Evaluate the ability of the AGS to perform an LM-active rendezvous. (Accomplished)

12. Monitor PGNCS/AGS performance during lunar orbit operations. (Accomplished)

13. Demonstrate operational support for a CSM/LM lunar orbit mission. (Accomplished)

14. Perform a long duration unmanned APS burn. (Accomplished)

15. Perform lunar orbit insertion using SPS GNCS-controlled burns with a docked CSM/LM. (Accomplished)

16. Obtain data to verify IMU performance in the flight environment. (Accomplished)

17. Perform a reflectivity test using the CSM S-band high-gain antenna while docked. (Accomplished)

18. Perform CSM transposition, docking, and CSM/LM ejection after S-IVB TLI burn. (Accomplished)

19. Perform translunar midcourse corrections. (Accomplished)

20. Obtain AGS performance data in the flight environment. (Accomplished)

21. Perform star-lunar landmark sightings during the transearth phase. (Accomplished)

22. Obtain data on LM consumables for a simulated lunar landing mission, in lunar orbit, to determine lunar landing mission consumables. (Accomplished)

UNUSUAL FEATURES OF THE MISSION

Provided these first-time inflight opportunities:

1. Lunar orbit rendezvous.

2. Docked lunar landmark tracking.

3. Lunar module steerable antenna operation at distances greater than those of low earth orbit enabling its evaluation under conditions for which it was designed.

4. Descent propulsion system (DPS) engine burn in the lunar landing mission configuration and environment.

5. Lunar landing mission profile simulation (except for powered descent, lunar surface activity, and ascent).

6. Low level (47,000 feet) evaluation of lunar visibility.

7. Docked CSM/LM thermal control in the absence of earth albedo and during long periods of sunlight.

8. Lunar module omni-directional antenna operation at lunar distance.

9. Abort guidance system (AGS) operation during an APS burn over the range of inertias for a lunar mission.

10. VHF ranging during a rendezvous.

11. Landing radar operation near lunar environment where the reflected energy from the lunar surface is detected.

12. Transposition, docking, and LM ejection in daylight after the S-IVB burn where the S-IVB is in inertial hold attitude and while the spacecraft is moving away from the earth.

13. Translunar midcourse correction with a docked CSM/LM.

14. Lunar module digital uplink assembly first flight (replaces digital command assembly used on LM-3).

15. First launch from Pad B of launch complex 39.

16. Largest payload yet placed in earth orbit.

17. Largest payload yet placed in lunar orbit.

18. Demonstration of color TV camera.

19. Manned navigational, visual, and photographic evaluation of lunar landing sites 2 and 3.

20. Manned visual and photographic evaluation of range of possible landing sites in Apollo belt highlands areas.

21. Acquisition of major quantities of photographic training materials for Apollo 11 and subsequent lunar landing missions.

22. Acquisition of numerous visual observations and photographs of scientific significance.

GENERAL INFORMATION

Spacecraft: CM-106, SM-106, LM-4

Launch Vehicle: SA-505

Launch Complex: 39B

Flight Crew:		
	Commander (CDR)	Thomas P. Stafford
	Command Module Pilot (CMP)	John W. Young
	Lunar Module Pilot (LMP)	Eugene A. Cernan

Launch Time: 12:49 p.m. EDT, May 18, 1969

Launch Azimuth: 72°

Earth Orbit:

Apogee: 102.6 NM

Perigee: 99.6 NM

Lunar Orbits:

Initial Apocynthion/Pericynthion (LOI-1): 170.4 NM x 59.6 NM

Circularized Apocynthion/Pericynthion (LOI-2): 61.5 NM x 58.9 NM

LM Descent Orbit Insertion: 61.2 x 8.4 NM

LM Phasing Maneuver: 190 NM x 11.2 NM

LM Insertion Maneuver: 45.3 NM x 11.2 NM

Final LM/CSM Separation: 63.2 NM x 55 NM

Mission Duration: 192 hours 3 minutes 23 seconds

Time of Landing: 12:52:23 EDT, May 26, 1969

SPACE VEHICLE AND PRE-LAUNCH DATA

Spacecraft delivered to KSC:

Command/service module (CSM): November 1968

Lunar module (LM): October 1968

Launch vehicle delivered to KSC:

First stage (S-IC): November 1968

Second stage (S-II): December 1968

Third stage (S-IVB): December 1968

Instrument unit (IU): December 1968

Space vehicle weight at liftoff: 6,412,250 lb.

Weight placed in earth orbit: 294,947 lb.

Weight placed in lunar orbit: 69,429 lb.

Significant spacecraft differences from Apollo 9:

Command Module

* The VHF ranging capability was added as a backup to CSM/LM rendezvous radar (RR).

Lunar Module

* The VHF ranging capability was added as an RR backup.
* The CM to LM power transfer capability after LM stage separation was incorporated to extend hold capability between docking and final LM/CSM separation.
* The CM/LM power transfer redundancy was provided as a power transfer backup.
* The EVA antenna was deleted because there was no EVA planned for Apollo 10.
* Digital uplink voice output (up to 20 db) was increased because it was required for lunar distance communication.
* Landing gear deployment mechanism protective shield was added to prevent possible malfunction due to DPS plume impingement.

* Ascent stage plume heat blanket and venting was added to improve thermal control.

* A separate power source for utility/floodlight was added to prevent simultaneous loss of both lights.

* An APS muffler was added to prevent APS regulator loss.

* RR and VHF bus isolation was provided to prevent simultaneous RR and VHF loss.

* The TV camera was deleted.

* Luminary 1 (LM onboard program) was used for the first time (Sundance for LM-3).

Significant launch vehicle changes from Apollo 9:

S-II Stage

* Center engine early cutoff was planned as a means of eliminating longitudinal oscillations.

S-IVB Stage

* A redesigned helium regulator valve was substituted to correct an SA-504 malfunction.

Instrument Unit

* Instrument unit network change (software) was incorporated to enable SC control of LV during the launch phase and translunar injection.

* Insulation and damping compound were added to improve vibration damping and IU load-carrying capability.

RECOVERY DATA

Recovery Area: Southwest Pacific Ocean

Landing Coordinates: 15°S., 165°W. (Stable I)

Recovery Ship: USS Princeton

Crew Recovery Time: 1:31 p.m. EDT, May 26, 1969

Spacecraft Recovery Time: 2:22 p.m. EDT, May 26, 1969

REMARKS

The most complex mission yet flown in the Apollo Program was performed in the full lunar landing configuration, paralleling as closely as possible the lunar landing mission profile and timeline. Extensive photographic coverage of candidate lunar landing sites provided excellent data and crew training material for subsequent missions. This was the fifth on-time Saturn V launch.

Nineteen color television transmissions (totaling 5 hours 52 minutes) of remarkable quality provided a world audience the best exposure yet to spacecraft activities and spectacular views of the earth and the moon. The LM pericynthion of 47,000 feet was the closest man had come to the moon, and the crew reported excellent visual perception of the proposed landing areas.

The mission was nominal in all major respects. Translunar and transearth navigational accuracy was so precise that only two of seven allocated midcourse corrections were required, one each during translunar and transearth coast periods. Significant perturbations in lunar orbit, resulting from differences in gravitational potential, were noted. Subsequent mission LOI burns can be biased to compensate for these effects. All launch vehicle systems performed satisfactorily during their expected lifetimes. Spacecraft systems generally performed satisfactorily throughout the mission. One exception was the No. 1 fuel cell which had to be isolated from the main bus, but work-around procedures made it available for load sharing, if required. Another problem was the occasional difficulty with direct LM-earth communications. Two incidents of unexpected motion occurred prior to and during LM staging. Data indicates unscheduled transfer of the abort guidance system mode from "Attitude Hold" to "Automatic."

A number of minor discrepancies occurred which were either primarily procedural and were corrected in flight with no mission impact, or which involved instrumentation errors on quantities that could be checked by other means. Two cameras that malfunctioned were returned to earth for failure analysis. All detailed test objectives were met, except for two secondary spacecraft objectives that were partially accomplished. Five other major activities not defined as detailed test objectives were fully accomplished.

Flight crew performance was outstanding. Their health and spirits remained excellent throughout the mission. Unexpected bonuses from the mission were several sightings of individual SLA panels long after TD&E, three sightings of the jettisoned descent stage as it orbited the moon at low altitude, and a few sightings of the receding S-IVB stage with the naked eye, once from nearly 4000 miles as it tumbled and flashed in the sunlight.

APOLLO 11 (AS-506) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVE (Accomplished)

Perform a manned lunar landing and return.

DETAILED OBJECTIVES AND EXPERIMENTS

1. Collect a contingency sample. (Accomplished)
2. Egress from the LM to the lunar surface, perform lunar surface EVA operations, and ingress into the LM from the lunar surface. (Accomplished)
3. Perform lunar surface operations with the EMU. (Accomplished)
4. Obtain data on effects of DPS and RCS plume impingement on the LM and obtain data on the performance of the LM landing gear and descent engine skirt after touchdown. (Accomplished)
5. Obtain data on the lunar surface characteristics from the effects of the LM landing. (Accomplished)
6. Collect lunar Bulk Samples. (Accomplished)
7. Determine the position of the LM on the lunar surface. (Accomplished)
8. Obtain data on the effects of illumination and contrast conditions on crew visual perception. (Accomplished)
9. Demonstrate procedures and hardware used to prevent back contamination of the earth's biosphere. (Accomplished)
10. Deploy the Early Apollo Scientific Experiments Package (EASEP) which included the following:
    a. S-031, Passive Seismic Experiment. (Accomplished)
    b. S-078, Laser Ranging Retro-Reflector. (Accomplished)

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11. Deploy and retrieve the Solar Wind Composition Experiment, S-080. (Accomplished)

12. Perform Cosmic Ray Detector Experiment (helmet portion), S-151. (Accomplished)

13. Perform Lunar Field Geology, S-059. (Partially Accomplished)

14. Obtain television coverage during the lunar stay period. (Accomplished)

15. Obtain photographic coverage during the lunar stay period. (Accomplished)

UNUSUAL FEATURES OF THE MISSION

1. First manned lunar landing and return.
2. First lunar surface EVA.
3. First seismometer deployed on moon.
4. First laser reflector deployed on moon.
5. First solar wind experiment deployed on moon.
6. First lunar soil samples brought to earth.
7. Largest payload yet placed in lunar orbit.
8. First lunar module test in total operational environment.
9. Acquisition of numerous visual observations, photographs, and television of scientific and engineering significance.
10. First operational use of the mobile quarantine facility (MQF) and the lunar receiving laboratory (LRL).

GENERAL INFORMATION

Spacecraft: CM-107, SM-107, LM-5

Launch Vehicle: SA-506

Launch Complex: 39A

Flight Crew: Commander (CDR) — Neil A. Armstrong
Command Module Pilot (CMP) — Michael Collins
Lunar Module Pilot (LMP) — Edwin E. Aldrin, Jr.

Launch Time: 9:32 a.m. EDT, July 16, 1969

Flight Azimuth: 72°

Earth Orbit: 102.9 x 103.7 NM

Lunar Orbits and Events:

Initial Apocynthion/Pericynthion (LOI-1): 168.6 NM x 61.2 NM

Circularized Apocynthion/Pericynthion (LOI-2): 65.7 NM x 53.8 NM

LM Descent Orbit: 57.2 NM x 8.5 NM

Landing Site Coordinates: 0.647°N. latitude, 23.505° E. longitude (Tranquility Base)

Lunar Landing Time: 4:17:40 p.m. EDT, July 20, 1969

First Step on Lunar Surface: 10:56:19 p.m. EDT, July 20, 1969

LM Liftoff from Lunar Surface: 1:54:00 p.m. EDT, July 21, 1969

Lunar Insertion Orbit: 45.2 NM x 9.0 NM

Final LM/CSM Separation Orbit: 62.6 NM x 54.8 NM

Mission Duration: 195 hours 18 minutes 35 seconds

Time of Landing: 12:50:35 p.m. EDT, July 24, 1969

SPACE VEHICLE AND PRE-LAUNCH DATA

Spacecraft delivered to KSC:

Command/service module: January 1969

Lunar module: January 1969

Launch vehicle delivered to KSC:

First stage (S-IC): February 1969

Second stage (S-II): February 1969

Third stage (S-IVB): January 1969

Instrument unit (IU): February 1969

Space vehicle weight at liftoff: 6,398,325 lb.

Weight placed in earth orbit: 297,848 lb.

Weight placed in lunar orbit: 72,038 lb.

Significant spacecraft differences from Apollo 10:

Command/Service Module

* The blanket type insulation was removed from the forward hatch.

Lunar Module

* A VHF antenna was added for extravehicular activity (EVA) coverage.
* A liquid cooling garment (LCG) heat removal subsystem was added.
* The ascent engine was replaced with a lighter weight engine.
* The base heat shield on the descent stage was modified by the removal of H-film.
* Reaction control system (RCS) plume deflectors were added for each of the lower four RCS thrusters.
* The landing gear thermal protection was increased.
* The descent propulsion system (DPS) engine gimbal drive actuators were modified by the removal of the polarizer and armature and by the installation of new brake material.
* An erectable S-band antenna was carried on the descent stage.
* The Early Apollo Scientific Experiments Package (EASEP) was carried in the descent stage.

a result of Apollo 10 lunar orbit experience, the LOI-2 burn was biased to achieve a slightly eccentric orbit (65.7 x 53.8 NM). It was anticipated that this would compensate for variations in lunar gravity effect and that the CSM orbit would become circular by the time of LM rendezvous. Subsequent measurements showed that this effect did not occur as rapidly as expected and that the CSM orbit did not become circular.

The LM powered descent initiation maneuver was performed on time at pericynthion on the descent orbit; however, this position was about 4 NM downrange from the planned point apparently due to an accumulation of uncoupled attitude maneuvers during the last two revolutions prior to PDI. This resulted in the landing point being shifted downrange about 4 NM.

During the final approach phase, the crew noted that the LM was headed for the general area of a large, rugged crater, filled with boulders of 5 to 10 feet in diameter. The CDR took manual attitude control and translated the LM to a landing point approximately 1000 feet farther downrange.

The crew adapted quickly to the lunar environment and conducted the lunar surface activities as planned, including the collection of two lunar core samples and a considerable amount of discretely selected surface material. The LMP had to exert a considerable force to drive the core tubes an estimated 6 to 8 inches deep. The crew spent a total of 5 manhours of EVA on the lunar surface. The total lunar stay time was 21 hours 36 minutes. Approximately 46 pounds of lunar samples were returned to earth.

All launch vehicle systems performed satisfactorily throughout their expected lifetimes and all spacecraft systems continued to function satisfactorily throughout the mission. No major anomalies occurred. New biological isolation procedures and post-recovery operations were executed successfully.

Flight crew performance was outstanding and all three crew members remained in excellent health.

APOLLO 12 (AS-507) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Primary Objectives Accomplished)

1. Perform selenological inspection, survey, and sampling in a mare area.
2. Deploy and activate the Apollo Lunar Surface Experiments Package (ALSEP).
3. Develop techniques for a point landing capability.
4. Develop man's capability to work in the lunar environment.
5. Obtain photographs of candidate exploration sites.

DETAILED OBJECTIVES AND EXPERIMENTS

PRINCIPAL (All Principal Detailed Objectives Accomplished)

1. Collect a contingency sample.
2. Perform lunar surface EVA operations.
3. Deploy ALSEP I, which included the following:
   a. S-031, Passive Seismic Experiment.
   b. S-034, Lunar Surface Magnetometer Experiment.
   c. S-035, Solar Wind Spectrometer Experiment.
   d. S-036, Suprathermal Ion Detector Experiment.
   e. S-058, Cold Cathode Ionization Gauge Experiment.
   f. M-515, Lunar Dust Detector.
4. Collect selected samples.
5. Recharge the portable life support systems.
6. Perform Lunar Field Geology, S-059.
7. Obtain photographic coverage of candidate exploration sites.

8. Obtain data on the lunar surface characteristics from the effects of the LM landing.

9. Obtain data on the effects of illumination and contrast conditions on crew visual perception.

10. Determine the position of the LM on the lunar surface.

11. Perform selenodetic reference point update.

12. Deploy and retrieve the Solar Wind Composition Experiment, S-080.

13. Perform Lunar Multispectral Photography Experiment, S-158.

SECONDARY

1. Investigate and obtain samples for earth return from the Surveyor III spacecraft. (Accomplished)

2. Obtain photographic coverage during the lunar stay period. (Accomplished)

3. Obtain television coverage during the lunar stay period. (Partially Accomplished)

UNUSUAL FEATURES OF THE MISSION

1. First use of the S-IVB stage to perform an evasive maneuver.

2. First use of a hybrid trajectory.

3. Largest payload yet placed in lunar orbit.

4. First demonstration of a point landing capability.

5. First use of two lunar surface EVA periods (about 4 hours each).

6. First ALSEP deployed on the moon.

7. First deployment of the erectable S-band antenna.

8. First recharge of the portable life support system.

9. First documented samples returned to earth.

10. First use of geologists to plan a lunar surface traverse in real time.

11. First double core-tube sample taken.

12. First return of samples from a prior lunar landed vehicle (Surveyor III).

13. Longest distance yet traversed on the lunar surface.

14. First multispectral photography from lunar orbit.

15. Longest lunar surface stay to date.

16. Longest lunar mission to date.

17. Largest payload yet returned from the lunar surface.

GENERAL INFORMATION

Spacecraft: CM-108, SM-108, LM-6

Launch Vehicle: SA-507

Launch Complex: 39A

Flight Crew:	Commander (CDR)	Charles Conrad, Jr.
	Command Module Pilot (CMP)	Richard F. Gordon, Jr.
	Lunar Module Pilot (LMP)	Alan L. Bean

Launch Time: 11:22 a.m. EST, November 14, 1969

Launch Azimuth: 72°

Earth Orbit: 102.5 x 99.9 NM

Lunar Orbit and Events:

Initial Apocynthion/Pericynthion (LOI-1): 168.8 NM x 62.6 NM

Circularized Apocynthion/Pericynthion (LOI-2): 66.1 NM x 54.3 NM

LM Descent Orbit: 60.6 NM x 8.1 NM

Landing Site Coordinates: 3.036° S. latitude, 23.418°W. longitude

Lunar Landing Time: 01:54:35 a.m. EST, November 19, 1969

LM Liftoff from Lunar Surface: 09:25:47 a.m. EST, November 20, 1969

Lunar Insertion Orbit: 46.3 NM x 8.8 NM

Ascent Stage Impact on Lunar Surface: 5:17:16 p.m. EST, November 20, 1969

Ascent Stage Impact Coordinates: 3.95°S. latitude, 21.17°W. longitude

Ascent Stage Impact Velocity: 5502 fps

Ascent Stage Impact Weight: 5254 pounds

Mission Duration: 244 hours 36 minutes 24 seconds

Time of Landing: 3:58 p.m. EST, November 24, 1969

SPACE VEHICLE AND PRE-LAUNCH DATA

Spacecraft delivered to KSC:

Command/service module: March 1969

Lunar module: March 1969

Launch vehicle delivered to KSC:

First stage (S-IC): May 1969

Second stage (S-II): May 1969

Third stage (S-IVB): May 1969

Instrument unit (IU): May 1969

Space vehicle weight at liftoff: 6,484,780 lb.

Weight placed in earth orbit: 300,056 lb.

Weight placed in lunar orbit: 72,212 lb.

Significant spacecraft differences from Apollo 11:

Command/Service Module

* Experiment S-158 was incorporated and the side hatch window pane was changed for lunar multi-spectral photography.

* The reaction control system (RCS) engine arc was suppressed.

* An inertial measurement unit (IMU) power switch guard was added.

* Stowage was modified to provide for return of Surveyor III samples and increased lunar surface samples.

Lunar Module

* The display and keyboard assembly (DSKY) table and support were modified to enhance actuation and release from the stowed to the operating position.

* The ascent stage propellant tanks were redesigned to an all-welded configuration.

* Stowable hammocks were added for increased crew sleeping comfort.

* The bacteria filter was deleted from the forward hatch valve.

* Stowage was modified to provide for return of Surveyor III samples and increased lunar surface samples.

* Landing gear and plume deflector thermal insulation was reduced.

* Extravehicular activity (EVA) equipment stowage was modified.

* Apollo Lunar Surface Experiments Package (ALSEP) was installed to replace the Early Apollo Scientific Experiments Package (EASEP).

Significant launch vehicle changes from Apollo 11:

S-IVB Stage

* The telemetry system for the S-IVB stage was changes by adding one SSB/FM link to provide increased acoustic and vibration measurements.

RECOVERY DATA

Recovery Area: Mid-Pacific Ocean

Landing Coordinates: 15°47'S., 165°11'W. (Stable II)

Recovery Ship: USS Hornet

Crew Recovery Time: 4:58 p.m. EST, November 24, 1969

Spacecraft Recovery Time: 5:49 p.m. EST, November 24, 1969

REMARKS

Launch vehicle performance was satisfactory throughout its expected lifetime except for the S-IVB slingshot maneuver. The spacecraft systems functioned satisfactorily during the entire mission except for the perturbations caused by an electrical anomaly which occurred shortly after liftoff. Communications were very good except for occasional problems with the high gain antenna (HGA).

The spacecraft and launch vehicle were involved in two electrical potential discharges during the first minute of the flight. The first, at 36.5 seconds after liftoff, was from the clouds to earth through the vehicle and was visible to launch site observers. The second occurred at 52 seconds with the vehicle in the clouds.

The discharge at 36.5 seconds disconnected the fuel cells from the spacecraft buses and damaged nine instrumentation measurements. The discharge at 52 seconds caused tumbling of the spacecraft inertial platform. Both discharges caused a temporary interruption of spacecraft communications. Many other effects were noted on instrumentation data from the launch vehicle, which apparently sustained no permanent malfunctions from the discharges.

The S-IVB slingshot maneuver was initiated on schedule but, due to IU state vector errors, the slingshot maneuver did not achieve the desired heliocentric orbit but rather a highly eccentric geocentric orbit.

Lunar orbit insertion (LOI) was performed in two separate maneuvers, LOI-1 and LOI-2, using the service propulsion system (SPS). The LOI maneuver resulted in a CSM/LM position some 4 to 5 NM north of the expected ground track prior to descent orbit insertion (DOI). This crossrange error was known prior to DOI and was corrected during the powered descent maneuver.

The guidance computer was updated during powered descent to compensate for indications that the trajectory was coming in 4200 feet short of the target point. The initial crossrange distance was continuously reduced throughout the braking phase. At entry into the approach phase the spacecraft's trajectory was very close to nominal. Redesignations were incorporated during the approach phase. The crew took over manual control at about 370 feet, passed over the right side of the target crater, then flew to the left for landing. The commander reported extensive dust obscuring his view during final descent. The actual landing point is determined to be about 600 feet from the Surveyor III spacecraft.

The ascent stage deorbit retrograde burn was initiated and burned slightly longer than planned. This resulted in lunar impact about 36 NM short of the target point. Impact occurred about 39 NM southeast of Surveyor III.

On several occasions during the mission, communications with the CSM experienced some degradation due to inability of the HGA to hold lock. Two special HGA tests were conducted during the transearth coast to attempt to identify the cause of the anomaly. Results indicate that the problem appears to be associated with the dynamic thermal operation of the antenna, probably in the microwave circuitry in the narrow beam mode.

The Apollo 12 crew performance was outstanding throughout the mission. All scheduled lunar surface scientific activities were performed as planned within the allotted time periods. During the first EVA the ALSEP experiments were deployed and began transmitting scientific data. Real-time planning for the geological traverse of the second EVA was accomplished jointly by the crew and earth-based scientists.

All planned Surveyor activities were performed and, in addition, retrieval of the Surveyor scoop containing a surface sample was accomplished. Approximately 75 pounds of samples were collected during the two 2-man EVA's which totaled 7 hr. 45 min. The traverse distance was approximately 2 km.

APOLLO 13 (AS-508) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (None Accomplished)

1. Perform selenological inspection, survey, and sampling of materials in a preselected region of the Fra Mauro Formation.

2. Deploy and activate an Apollo Lunar Surface Experiments Package (ALSEP).

3. Develop man's capability to work in the lunar environment.

4. Obtain photographs of candidate exploration sites.

DETAILED OBJECTIVES

LAUNCH VEHICLE Secondary Objectives - Both Accomplished

- Impact of the expended S-IVB/IU on the lunar surface within 350 km of the targeted impact point of 3°S., 30°W. under nominal flight profile conditions to excite ALSEP I.

- Post-flight determination of actual S-IVB/IU point of impact within 5 km, and time of impact within 1 second.

SPACECRAFT AND LUNAR SURFACE (None Accomplished)

1. Contingency Sample Collection.

2. Deployment of the Apollo Lunar Surface Experiments Package (ALSEP III), which included the following:

   a. S-031 Lunar Passive Seismology.

   b. S-037 Lunar Heat Flow.

   c. S-038 Charged Particle Lunar Environment.

   d. S-058 Cold Cathode Ionization Gauge.

   e. M-515 Lunar Dust Detector.

3. Selected Sample Collection.
4. Lunar Field Geology (S-059).
5. Photographs of Candidate Exploration Sites.
6. Evaluation of Landing Accuracy Techniques.
7. Television Coverage.
8. EVA Communication System Performance.
9. Lunar Soil Mechanics.
10. Selenodetic Reference Point Update.
11. Lunar Surface Closeup Photography (S-184).
12. Thermal Coating Degradation.
13. CSM Orbital Science Photography (Includes S-182).
14. Transearth Lunar Photography.
15. Solar Wind Composition (S-080).
16. EMU Water Consumption Measurement.
17. Gegenschein From Lunar Orbit (S-178).
18. Dim Light Photography.
19. CSM/LM S-Band Transponder Experiment (S-164).
20. Downlink Bistatic Radar Experiment (VHF Portion Only) (S-170)

UNUSUAL FEATURES OF THE MISSION

1. Use of backup CM pilot.
2. First aborted Apollo Mission.
3. First impact of the S-IVB/IU on the lunar surface.
4. First use of lunar module to provide emergency propulsion and life support after loss of service module systems.

GENERAL INFORMATION

Spacecraft: CM-109, SM-109, LM-7

Launch Vehicle: SA-508

Launch Complex: 39A

Flight Crew:

Commander (CDR)	James A. Lovell, Jr.
Command Module Pilot (CMP)	John L. Swigert, Jr.
Lunar Module Pilot (LMP)	Fred W. Haise, Jr.

Launch Time: 2:13 p.m. EST, April 11, 1970

Launch Azimuth: 72°

Earth Orbit: 100.2 x 98.0 NM

Closest Approach to the Lunar Surface: 142.8 NM

S-IVB/IU Lunar Impact:

Time: 8:09:40 p.m. EST, April 14, 1970

Velocity of Impact: 8465 fps

Angle of Impact: Approx. 80° to the horizontal

Lunar Location: 2.4°S., 27.9°W.

Energy Equivalent: 11.5 tons of TNT

Mission Duration: 142 hours 54 minutes 41 seconds

Time of Landing: 1:07:41 p.m. EST, April 17, 1970

SPACE VEHICLE AND PRE-LAUNCH DATA

Spacecraft delivered to KSC:

Command/service module: June 1969

Lunar module: June 1969

Launch vehicle delivered to KSC:

First stage (S-IC): June 1969

Second stage (S-II): June 1969

Third stage (S-IVB): June 1969

Instrument unit (IU): July 1969

Space vehicle weight at liftoff: 6,421,259 lb.

Weight placed in earth orbit: 296,463 lb.

Significant spacecraft differences from Apollo 12:

None significant to mission flown

Significant launch vehicle differences from Apollo 12:

A fourth battery was added to the instrument unit to extend command communications systems tracking to assist S-IVB/IU lunar impact trajectory and corrections.

RECOVERY DATA

Recovery Area: Mid-Pacific Ocean

Landing Coordinates: 21°38'24" S., 165°21'42" W. (Stable I)

Recovery Ship: USS Iwo Jima

Crew Recovery Time: 1:53 p.m. EST, April 17, 1970

Spacecraft Recovery Time: 2:36 p.m. EST, April 17, 1970

REMARKS

The Apollo 13 Mission was planned as a lunar landing mission but was aborted enroute to the moon after about 56 hours of flight due to loss of service module cryogenic oxygen and consequent loss of capability to generate electrical power, to provide oxygen and to produce water in the command/service module. Shortly after the anomaly, the command/service module was powered down and the remaining flight, except for entry, was made with the lunar module providing all necessary power, environmental control, guidance and propulsion.

Launch vehicle performance was satisfactory through first stage (S-IC) boost and into second stage (S-II) boost until the S-II center engine shut down approximately

132 seconds early. Low frequency oscillations (14 to 16 hertz) were experienced on the S-II stage and resulted in the early shutdown. To compensate for the early center engine cutoff the remaining four engines burned approximately 34 seconds longer than initially planned. Resultant S-II stage cutoff velocity was 223 feet per second (fps) lower than planned. As a result, the S-IVB orbital insertion burn was approximately 9 seconds longer than predicted with cutoff velocity within about 1.2 fps of planned. Total launch vehicle burn time was approximately 44 seconds longer than predicted. At termination of the orbital insertion burn, a greater than 3-sigma probability of meeting translunar injection cutoff conditions existed with remaining S-IVB propellants. The TLI burn was nominal.

The planned S-IVB evasive maneuver and the subsequent LOX dump and Auxiliary Propulsion System (APS) burn were accomplished as planned. The S-IVB/IU impacted the lunar surface at 77:56:40 GET (08:09:40 p.m. EST, April 14) at 2.4°S., 27.9°W. and the seismometer deployed during the Apollo 12 mission successfully detected the impact as a seismic signal 20 to 30 times larger and four times longer than that caused by the impact of the Apollo 12 LM ascent stage. The target impact point was 110 NM from the seismometer. The actual impact point was approximately 35 NM from the target point and about 85 NM from the seismometer.

Spacecraft systems performance was nominal until the fans in cryogenic oxygen tank 2 were turned on at 55:53:18. About 2 seconds after energizing the fan circuit, a short was indicated in the current from fuel cell 3, which was supplying power to cryogenic oxygen tank 2 fans. Within several additional seconds, two other shorted conditions occurred.

Electrical shorts in the fan circuit ignited the wire insulation, causing temperature and pressure increases within cryogenic oxygen tank 2. When the pressure reached the cryogenic oxygen tank 2 relief valve full-flow conditions of 1008 psia, the pressure began decreasing for about 9 seconds, at which time the relief valve probably reseated, causing the pressure to rise again momentarily. About 1/4 second later, a vibration disturbance was noted on the command module accelerometers.

The next series of events occurred within a fraction of a second between the accelerometer disturbances and the data loss. A tank line burst, because of heat, in the vacuum jacket pressurizing the annulus and, in turn, caused the blow-out plug on the vacuum jacket to rupture. Some mechanism in bay 4 combined with the oxygen buildup in that bay to cause a rapid pressure rise which resulted in separation of the outer panel. The panel struck one of the dishes of the high-gain antenna. The panel separation shock closed the fuel cell 1 and 3 oxygen reactant shut-off valves and several propellant and helium isolation valves in the reaction control system. Data were lost for about 1.8 seconds as the high-gain antenna switched from narrow beam to wide beam, because of the antenna being hit and damaged.

Following recovery of the data, the vehicle had experienced a translation change of about 0.4 fps, primarily in a plane normal to bay 4. Cryogenic oxygen tank 2 pressure indication was at the lower limit readout value. The cryogenic oxygen tank 1 heaters were on, and the tank 1 pressure was decaying rapidly.

Fuel cells 1 and 3 operated for about 2-1/2 minutes after the reactant valves closed. During this period, these fuel cells consumed the oxygen trapped in the plumbing, thereby reducing the pressure below minimum requirements and causing total loss of fuel cell current and voltage output from these two fuel cells. Fuel cell 2 was turned off about 2 hours later because of the loss of pressure from cryogenic oxygen tank 1.

As a result of these occurrences, the CM was powered down and the LM was configured to supply the necessary power and other consumables.

The CSM was powered down at approximately 58:40 GET. The surge tank and repressurization package were isolated with approximately 860 psi residual pressure (approximately 6.5 pounds of oxygen total). The primary water glycol system was left with radiators bypassed.

The first maneuver following the incident was made with the descent propulsion system at approximately 61:30 GET and placed the spacecraft once again on a free-return trajectory, with the altitude of closest lunar approach raised to 143 miles. A maneuver that was performed with the descent engine 2 hours after passing pericynthion reduced the transearth transit time from about 76 hours to 64 hours and moved the earth landing point from the Indian Ocean to the South Pacific. Two small transearth midcourse corrections were required prior to entry; the first occurring at about 105:18 GET using the descent propulsion system and the second at approximately 137:40 GET using the lunar module reaction control system.

All LM systems performed satisfactorily in providing the necessary power and environmental control to the spacecraft. The requirement for lithium hydroxide to remove carbon dioxide from the spacecraft atmosphere was met by a combination of CM and LM cartridges since the LM cartridges alone would not satisfy the total requirement. The crewmen, with direction from Mission Control, built an adapter for the CM cartridges to accept the LM hoses.

The service module was jettisoned at approximately 138 hours GET, and the crew observed and photographed the bay-4 area where the cryogenic tank anomaly had occurred. At this time, the crew remarked that the outer skin covering for bay-4 had been severely damaged, with a large portion missing. The lunar module was jettisoned about 1 hour before entry, which was performed nominally using the primary guidance and navigation system.

The performance of the flight crew was excellent throughout the mission. Their ability to implement the new procedures developed and tested by the flight operations team was exceptional. Similarly, performance of ground based personnel, both NASA and contractor, in analyzing the problem, developing new procedures and in running the extensive tests and simulations required to verify them was outstanding.

APOLLO 14 (AS-509) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Accomplished)

1. Perform selenological inspection, survey, and sampling of materials in a preselected region of the Fra Mauro Formation.
2. Deploy and activate ALSEP.
3. Develop man's capability to work in the lunar environment.
4. Obtain photographs of candidate exploration sites.

DETAILED OBJECTIVES AND EXPERIMENTS

LAUNCH VEHICLE (Both Accomplished)

- Impact the expended S-IVB/IU or the lunar surface under nominal flight profile conditions.
- Post-flight determination of actual S-IVB/IU point of impact within 5 km, and time of impact within 1 second.

SPACECRAFT AND LUNAR SURFACE

1. Contingency Sample Collection (Accomplished)
2. Apollo Lunar Surface Experiment Package (Apollo 14 ALSEP) which included the following: (Accomplished)
   a. Lunar Passive Seismology (S-031)
   b. Lunar Active Seismology (S-033)
   c. Suprathermal Ion Detector (S-036)
   d. Low Energy Solar Wind (S-038)
   e. Cold Cathode Ionization Gauge (S-058)
   f. Lunar Dust Detector (M-515)

3. Lunar Geology Investigation (S-059) (Accomplished)
4. Photographs of Candidate Exploration Sites (Accomplished)
5. Laser Ranging Retro-Reflector (S-078) (Accomplished)
6. Soil Mechanics (S-200) (Accomplished)
7. Portable Magnetometer (S-198) (Accomplished)
8. Visibility at High Sun Angles (Accomplished)
9. Mobile Equipment Transporter Evaluation (Accomplished)
10. Selenodetic Reference Point Update (Accomplished)
11. Bistatic Radar (S-170) (Accomplished)
12. CSM Orbital Photographic Tasks (Accomplished)
13. Assessment of EVA Operation Limits (Accomplished)
14. CSM Oxygen Flow Rate (Accomplished)
15. Solar Wind Composition (S-080) (Accomplished)
16. Thermal Coating Degradation (Accomplished)
17. EVA Communication System Performance (Not Accomplished)
18. Gegenschein From Lunar Orbit (S-178) (Accomplished)
19. S-Band Transponder (Accomplished)

<u>IN-FLIGHT DEMONSTRATIONS</u> (All Accomplished)

Electrophoretic Separation
Heat Flow and Convection
Liquid Transfer
Composite Casting

<u>UNUSUAL FEATURES OF THE MISSION</u>

1. First SPS DOI maneuver.
2. First use of the mobile equipment transporter.
3. Longest total EVA time to date.
4. Longest distance yet traveled on the lunar surface.

5. Largest weight of lunar samples returned to date.

6. First use of short rendezvous.

7. First use of the In-flight Demonstrations

GENERAL INFORMATION

Spacecraft: CM-110, SM-110, LM-8

Launch Vehicle: SA-509

Launch Complex: 39A

Flight Crew:		
	Commander (CDR)	Alan B. Shepard, Jr.
	Command Module Pilot (CMP)	Stuart A. Roosa
	Lunar Module Pilot (LM)	Edgar D. Mitchell

Launch Time: 4:03 p.m. EST, January 31, 1971

Launch Azimuth: 75.56°

Earth Orbit: 100.2 x 99.2 NM

S-IVB/IU Lunar Impact:

Time: 1:01 a.m. EST, February 4, 1971

Velocity of Impact: 8,350 fps

Lunar Location: 7.81°S. latitude 26.00°W. longitude

Impact Weight: 30,836 lb..

Lunar Orbit and Events:

Initial Apocynthian/Pericynthian (LOI): 169 x 58.4

Descent Orbit (DOI) 58.8 x 9.6 NM

CSM Circularization: 63.9 x 56.0 NM

Landing Site Coordinates: 3.66°S. latitude 17.48°W. longitude

Lunar Landing Time: 4:18 a.m. EST, February 5, 1971

LM Liftoff from Lunar Surface: 1:49 p.m. EST, February 6, 1971

Ascent Stage Impact on Lunar Surface: 7:46 p.m. EST, February 6, 1971

Ascent Stage Impact Coordinates: 3.42°S. latitude 19.66°W. longitude

Ascent Stage Impact Velocity: 5500 fps

Ascent Stage Impact Weight: 5067 lb.

Mission Duration: 216 hours 01 minutes 57 seconds

Time of Landing: 4:05 p.m. EST, February 9, 1971

SPACE VEHICLE AND PRELAUNCH DATA

Spacecraft delivered to KSC:

Command/Service Module: November 1969

Lunar Module: November 1969

Launch Vehicle delivered to KSC:

First Stage (S-IC) January 1970

Second Stage (S-II) January 1970

Third Stage (S-IVB) January 1970

Instrument Unit (IU) May 1970

Space Vehicle Weight at Liftoff: 6,420,491 lb.

Weight Placed in Earth Orbit: 302,626 lb.

Weight Placed in Lunar Orbit: 71,702 lb.

Significant spacecraft differences from Apollo 13:

Command/Service Module

* The SM cryogenic oxygen tanks were redesigned to remove the fans; to eliminate, as far as possible, flammable materials; to improve the design for fabrication and assembly; and to replace teflon insulated conductors with stainless steel sheathed conductors.

* A third cryogenic oxygen tank with its associated piping was added in SM bay 1 to provide backup to existing two tanks.

* A solenoid isolation valve was added to isolate the third oxygen tank from the other two.

* An auxiliary battery was added in SM bay 4 to provide electrical power backup if fuel cell power should become unavailable.

* Water bags having a 40# capacity were added to provide return enhancement for the CSM water system.

Lunar Module

* Anti-slosh baffles were added to the descent stage propellant tanks to improve PQGS flight performance and decrease propellant level uncertainty.

* Wiring was added to enhance power transfer capability from LM ascent stage to CSM.

* Modifications were made to the LM batteries to prevent any free KOH from causing short circuits.

* Modifications were made to descent stage Quads I and II structure to provide for stowage of laser ranging retro reflector and the lunar portable magnetometer.

Significant launch vehicle (POGO). from Apollo 13:

S-II Stage

* A center engine LOX feedline accumulator was added to alleviate potential 16 Hz structural/propulsion oscillations (POGO).

* A backup center engine cutoff system was provided to eliminate possibility of high g loads developing to destructive levels.

* Two position mixture ratio control valves were incorporated to simplify propellant mixture control system by eliminating the interface with the IU computer.

S-IVB Stage

* Two position mixture control valves were incorporated to simplify the propellant mixture control system.

Other significant configuration changes from Apollo 13:

Crew Systems

* **The buddy secondary life support system (BSLSS) was incorporated to provide capability to supply cooling water to an astronaut with a failed portable life support system (PLSS) from a working PLSS.**

RECOVERY DATA

Recovery Area: Mid-Pacific Ocean

Landing Coordinates: 27°0'S., 172°39'30"W. (Stable I)

Recovery Ship: USS New Orleans

Crew Recovery Time: 4:53 p.m. EST, February 9, 1971

Spacecraft Recovery Time: 5:55 p.m. EST, February 9, 1971

REMARKS

Apollo 14 was launched at 4:03 p.m. EST on January 31, 1971 after an unscheduled 40 minute hold occurred at T-8 minutes and 2 seconds, due to high overcast clouds and rain.

All launch vehicle systems performed satisfactorily throughout the expected lifetime. Following orbital insertion, all major systems were verified, preparations were completed and the S-IVB second burn was carried out as planned to insert the spacecraft into a translunar trajectory. Difficulties were encountered in the docking of the CSM and LM and a successful "hard dock" was not accomplished until the sixth attempt. Other aspects of the translunar journey were nominal and only one midcourse correction was made.

The S-IVB stage impacted the moon's surface, as planned. The Apollo 12 passive seismometer located 169 km northwest of the impact point recorded the event 37 seconds later.

LM separation and descent were as planned and it was reported that the LM landed on an 8 degree slope about 30 to 60 feet short of the planned target in the Fra Mauro area. Minor communications difficulties delayed the start of the first extra vehicular activity (EVA) period 49 minutes. During EVA-1, the Apollo lunar surface experiments package (ALSEP) was deployed approximately 500 feet west of the LM and the laser ranging retro-reflector an additional 100 feet west of the ALSEP. The laser ranging team at the MacDonald Observatory in Texas reported high quality "returns" from the retro-reflector shortly after deployment. All ALSEP experiments are now functioning as expected. EVA-1 was terminated after 4 hours and 49 minutes.

Following a rest period, the second EVA was started 2 hours and 27 minutes ahead of schedule. The LM crew set out on a geology traverse, using the mobile equipment transporter (MET), to carry tools, cameras, and the lunar portable magnetometer. Lunar samples were also collected.

During the geology traverse, various samples, photographs and terrain descriptions were obtained. Two measurements were made with the portable magnetometer to determine variations in the moon's magnetic field. Difficulty encountered in traversing the rough terrain resulted in the furthermost point of the traverse being established short of the rim of Cone Crater in order to allow sufficient time for completing all mandatory scientific tasks in EVA-2. EVA-2 was terminated after a total of 4 hours 28 minutes. Approximately 169 pounds of samples were collected, and the total traverse distance for the two EVA's was 3.3 km.

During the LM lunar surface stay various astronomic and lunar photographic tasks were performed from the CSM in lunar orbit. Ascent of the LM from the lunar surface, rendezvous and docking with the CSM were performed as planned. No docking problems were encountered but the docking probe was brought back to earth for post flight analysis. The LM ascent stage was impacted on the moon and signals were recorded by both the Apollo 12 and Apollo 14 ALSEPs.

During the return flight from the moon four inflight technical demonstrations of equipment and processes designed to illustrate the use of the unique condition of zero-gravity in space were performed.

Only one midcourse correction was required during the transearth flight. The CM and SM separation, reentry and splashdown were carried out according to plan. The CM landed in the Pacific Ocean approximately 675 miles south of Samoa and about 4 nautical miles from the prime recovery ship USS New Orleans.

APOLLO 15 (AS-510) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Accomplished)

1. Perform selenological inspection, survey, and sampling of materials and surface features in a preselected area of the Hadley-Apennine region.

2. Emplace and activate surface experiments.

3. Evaluate the capability of the Apollo equipment to provide extended lunar surface stay time, increased EVA operations, and surface mobility.

4. Conduct in-flight experiments and photographic tasks from lunar orbit.

DETAILED OBJECTIVES AND EXPERIMENTS

LAUNCH VEHICLE (Both Accomplished)

- Impact the expended S-IVB/IU on the lunar surface under nominal flight profile conditions.

- Post-flight determination of actual S-IVB/IU point of impact within 5 km, and the time of impact within one second.

LUNAR SURFACE (All Accomplished)

1. Contingency Sample Collection

2. Documented Sample Collection (Apennine Front)*

3. Apollo Lunar Surface Experiment Package (Apollo 15 ALSEP), which included the following:

   a. Lunar Passive Seismology (S-031)
   b. Lunar Tri-Axis Magnetometer (S-034)
   c. Medium Energy Solar Wind (S-035)
   d. Suprathermal Ion Detector (S-036)
   e. Cold Cathode Ionization Gauge (S-058)
   f. Lunar Heat Flow (S-037)
   g. Lunar Dust Detector (M-515)

* Part of Lunar Geology Investigation (S-059)

4. Drill Core Sample Collection*

5. Laser Ranging Retro-Reflector (S-078)

6. Lunar Geology Investigation (S-059)

7. LRV Evaluation

8. EVA Communications with LCRU/GCTA

9. EMU Assessment of Lunar Surface

10. LM Landing Effects Evaluation

11. Solar Wind Composition (S-080)

12. Soil Mechanics (S-200)

* Part of Lunar Geology Investigation (S-059)

<u>IN-FLIGHT</u>

1. Gamma-Ray Spectrometer (S-160) (Accomplished)

2. X-Ray Flourescence (S-161) (Accomplished)

3. SM Orbital Photographic Tasks

   a. 24" Panoramic Camera (Accomplished)
   b. 3" Mapping Camera (Accomplished)
   c. Laser Altimeter (Partially Accomplished)

4. Subsatellite (Accomplished)

   a. S-Band Transponder (S-164)
   b. Particle Shadows/Boundary Layer (S-173)
   c. Magnetometer (S-174)

5. Bistatic Radar (S-170) (Accomplished)

6. S-Band Transponder (CSM/LM) (S-164) (Accomplished)

7. Alpha-Particle Spectrometer (S-162) (Accomplished)

8. Mass Spectrometer (S-165) (Accomplished)

9. UV Photography - Earth and Moon (S-177) (Accomplished)

10. Gegenschein from Lunar Orbit (S-178) (Partially Accomplished)

11. CM Photographic Tasks (Accomplished)

12. SIM Thermal Data (Accomplished)

13. SIM Bay Inspection During EVA (Accomplished)
14. SIM Door Jettison Evaluation (Accomplished)
15. Visual Observation from Lunar Orbit (Accomplished)
16. Visual Light Flash Phenomenon (Accomplished)

OTHER (All Accomplished)

- LM Descent Engine Performance
- Apollo Time and Motion Study
- Bone Mineral Measurement (M-078)
- Total Body Gamma Spectrometry (M-079)
- Apollo Window Meteoroid (S-176)

UNUSUAL FEATURES OF THE MISSION

1. First Apollo use of 90-NM earth parking orbit.
2. First use of direct, minimum energy trajectory to the moon.
3. First use of scientific instrument module (SIM).
4. Largest spacecraft payload yet put in lunar orbit. (74,522 lb.)
5. Highest lunar orbit inclination (28.9°) during a manned mission.
6. First LM landing using 25° descent trajectory.
7. First use of stand-up EVA on the lunar surface.
8. Establishment of sensor networks by deployment of third station for the lunar passive seismometer and laser reflector experiments.
9. First use of extended capability CSM, LM, space suits, and PLSS's.
10. First use of manned lunar roving vehicle and lunar surface navigation devices.
11. First use of lunar communications relay unit and ground commanded TV assembly.

12. Longest total EVA time to date (18.6 hr.).

13. Longest distance yet traveled on the lunar surface (27.9 km).

14. Largest weight of lunar sample material returned to date (Approx. 169 lb.)

15. Deepest core sample of lunar material yet obtained (7 ft. 6 in.).

16. First scientific exploration of lunar mountain and rille areas.

17. First TV observation of LM ascent from the lunar surface.

18. First launch of a subsatellite in lunar orbit.

19. Longest manned duration in lunar orbit (74 orbits).

20. First EVA from CM in deep space.

21. First in-flight TV and photos of moon during solar eclipse.

22. First lunar landing mission with no post-mission quarantine requirements.

GENERAL INFORMATION

Spacecraft:	CM-112, SM-112, LM-10	
Launch Vehicle:	SA-510	
Launch Complex:	39A	
Flight Crew:	Commander (CDR)	David R. Scott
	Command Module Pilot (CMP)	Alfred M. Worden, Jr.
	Lunar Module Pilot (LMP)	James B. Irwin
Launch Time:	9:34 a.m. EDT, July 26, 1971	

Launch Azimuth: 80.088°

Earth Orbit: 91.5 x 92.5 NM

S-IVB/IU Lunar Impact:

Time: 4:59 p.m. EDT, July 29, 1971

Velocity of Impact: 8455 fps.

Lunar Location: 1°S. latitude, 11.87°W. longitude

Impact Weight: 30,786 lb.

Lunar Orbits and events:

Initial Apocynthian/Pericynthian (LOI): 170x58 NM

Descent Orbit (DOI): 58.5 x 9.2 NM

DOI Trim: 59.9 x 9.6 NM

CSM Circularization: 64.7 x 53 NM

Landing Site Coordinates: 26°05'N. latitude, 3°39'E. longitude

Lunar Landing Time: 6:16 p.m. EDT, July 30, 1971

LM Liftoff from Lunar Surface: 1:11 p.m. EDT, August 2, 197

Ascent Stage Impact on Lunar Surface: 11:04 p.m. EDT, August 2, 1971

Ascent Stage Impact Coordinates: 26.22' N. latitude, 0°15'E. longitude

Ascent Stage Impact Velocity: 5562 fps

Ascent Stage Impact Weight: 5259 lb.

Subsatellite Launch: 4:13 p.m., EDT, August 4, 1971; 76.3 x 55.1 NM, 28.7° inclination

Mission Duration: 295 hours 11 minutes 53 seconds

Time of Landing: 4:46 p.m. EDT, August 7, 1971

SPACE VEHICLE AND PRELAUNCH DATA

Spacecraft delivered to KSC:

Command/Service Module: January 1971

Lunar Module: November 1970

Lunar Roving Vehicle: March 1971

Launch Vehicle Delivered to KSC:

First Stage (S-IC): July 1970

Second Stage (S-II): May 1970

Third Stage (S-IVB): June 1970

Instrument Unit (IU): June 1970

Space Vehicle Weight at Liftoff: 6,407,758 lb. (107,142 lb. payload)

Weight Placed in Earth Orbit: 309,330 lb.

Weight Placed in Lunar Orbit: 74,522 lb.

Significant spacecraft differences from Apollo 14:

Command/Service Module

* A third SM cryogenic O_2 tank and associated plumbing were added for increased electrical power capability.

* A Scientific Instrument Module with a jettisonable door was added to bay IV of the SM, with associated controls in the CM, to increase the in-flight science capability by the operation of on-board sensors and a long-duration subsatellite in lunar orbit.

* A scientific data system was added to collect and transmit SIM experiment and camera data, with the capability for real-time data transmission simultaneously with tape recorder playback of lunar farside data.

* THE CM environmental control system was modified to provide for in-flight EVA by the CMP to retrieve film from the SIM bay cameras, and external handholds and a foot restraint were also added for the EVA.

Lunar Module

* The descent stage propellant tanks were enlarged to provide for increased LM landing weight and landing point selection through longer powered descent burns.

* The descent engine specific impulse was increased by the addition of a quartz liner and a ten-inch nozzle extension.

* A GOX tank, a water tank, a descent stage battery, and a new waste container were added to increase the lunar stay time to 68 hours.

* Stowage provisions were incorporated for the LRV in quad I and for the LRV-carried equipment pallet in quad III.

Crew Systems and Lunar Mobility

* Provided A7L-B spacesuit with improved mobility and durability to increase the lunar surface EVA efficiency and staytime, including increased drinking water and fruit bar provisions in the CDR and LMP suits and in-flight EVA capability for the CMP suit.

* Modified the life support system (PLSS) to increase O_2, H_2O, and LiOH quantities and battery power to increase the range and efficiency of lunar surface operations by extending the maximum EVA time to seven hours.

* Added the lunar roving vehicle to increase the range and scientific return of lunar surface traverses.

* Added a lunar communications relay unit (LCRU), carried either on the LRV or by an astronaut, to enhance uplink and downlink telemetry, voice, and TV communications during lunar surface traverses.

* Added a ground commanded TV assembly (GCTA) to provide earth-controlled color TV monitoring of lunar surface activities through the LCRU, including LM ascent and post-liftoff lunar surveys.

Significant launch vehicle changes from Apollo 14:

S-IC Stage

* Increased payload capability approximately 500 lb. by increasing the outboard engine LOX depletion time.

* Increased payload capability approximately 100 lb. by removing four of eight retro-rocket motors.

* Increased payload capability 600 lb. by reorficing the F-1 engines to provide greater thrust.

S-II Stage

* Eliminated single engine failure points and increased payload capability approximately 90 lb. by removing four ullage motors.

* Improved reliability and payload capability approximately 210 lb. by replacing LH_2 and LOX ullage pressure regulators with fixed orifices.

Instrument Unit

* Improved power supply reliability by adding redundant + 28 volt power for the ST-124 stabilized platform system.

* Modified the launch tower avoidance yaw maneuver which increased tower clearance assurance and reduced launch wind restrictions.

* Increased the accuracy of TLI burn cutoff in the event of IU platform failure by modifying the CM computer to provide backup burn cutoff capability.

RECOVERY DATA

Recovery Area: Mid-Pacific Ocean

Landing Coordinates: 26°07'N., 158°09'W. (Stable I)

Recovery Ship: USS Okinawa

Crew Recovery Time: 5:26 p.m. EDT, August 7, 1971

Spacecraft Recovery Time: 6:20 p.m. EDT, August 7, 1971

REMARKS

Apollo 15 was launched on time after an exceptionally smooth countdown. All launch vehicle systems performed nominally, except that the S-IVB J-2 engine delivered greater than predicted thrust, which had no adverse effects on the mission.

TLI was performed as predicted and CSM separation, turnaround, and docking accomplished without problems. Spacecraft separation from the S-IVB/IU/SLA was accomplished shortly thereafter.

Two S-IVB APS burns were performed to accomplish the targeted S-IVB/IU lunar impact. The actual impact was 188 km northeast of the Apollo 14 site and 355 km northeast of the Apollo 12 site. The impact provided seismic data to depths of 50-100 km vs. 30 km from previous impacts.

Shortly after docking, during translunar coast, both telemetry and cabin indications identified an electrical short in service propulsion system (SPS) control circuitry and troubleshooting isolated the problem to the **delta V** thrust A switch or adjacent wiring. Special SPS burn procedures developed and conducted for the MCC-2 maneuver indicated that SPS bank A could be operated satisfactorily in the manual mode for subsequent firings, all of which were performed successfully.

The SIM bay door was successfully jettisoned into a heliocentric orbit 4.5 hours before LOI. The SIM experiment and cameras were initiated successfully after LOI.

Because the high orbital inclination established a flight path over the major lunar mascons, the orbital decay rate was greater than anticipated. A DOI trim burn was performed with the SM RCS to change the orbit from 59 x 7.1 NM to 59.9 x 9.6 NM. CSM/LM undocking and separation were delayed 25 minutes because of a loose umbilical connector, after which the CSM "circularized" its orbit to 64.7 x 53 NM.

After the LM landed at the Hadley-Apennine site, sightings performed by the Commander during his 35 minute stand-up EVA in the top hatch and sightings from the CSM fixed the landing site about 600 meters north-northwest of the target point. The first EVA traverse was conducted to the Apennine mountain front immediately after deploying the lunar roving vehicle (LRV).

After the 10.3-km LRV traverse on EVA-1 the ALSEP was deployed and activated. One 150-cm probe of the Heat Flow Experiment was emplaced; however, the second probe was not completed until EVA-2 because of drilling difficulties with the battery-powered Apollo Lunar Surface Drill (ALSD). All ALSEP units operated normally and good data was received. The 300-cube Laser Ranging Retro-Reflector was deployed and has been acquired with greater ease than was possible with the previous smaller (100 cube) units. EVA-1 was terminated at 6 hr. 33 min. due to higher than normal O_2 usage by the Commander, whose usage rate was normal on subsequent EVA's.

The LRV traverse on EVA-2 was 12.5 km, during which speeds of 12-13 kph were achieved and excellent LRV controllability and slope-climbing capability were demonstrated. Lunar samples were collected at the Apennine front and the secondary crater complex to the south, and final station tasks were performed back at the ALSEP site. The EVA-2 duration was 7 hr. 12 min.

EVA-3 featured a 5.1 km LRV traverse to the terrace area of Hadley Rille, and samples, photography, and geologic descriptions were obtained. The 2.4-meter core tube drilling was completed, which produced a core sample of 58 distinct layers of various sized soil and rock materials. The 4 hr. 50 min. EVA was completed after positioning the LRV to monitor LM ascent with the LCRU/GCTA. The ascent stage lift-off was observed on TV; however, the LCRU unexpectedly stopped responding to signals on August 3rd, before the lunar sunset and solar eclipse could be observed.

The new and improved lunar surface equipment, combined with the geologic training of the crew, produced outstanding scientific achievements. The LRV averaged 9.2 kph during its 3 hr. 2 min. riding time with good navigational accuracy, yet consumed only half the expected battery power. The enhanced mobility of the spacesuits was quite evident on TV as the crew performed difficult tasks with increased dexterity.

Linear patterns in the mountain slopes and the Hadley Rille wall structure were reported by the crew and extensively photographed, including 500 mm Hasselblad photographic surveys. Seventy documented samples, core tubes, trench samples, and comprehensive samples amounted to about 169 pounds of lunar material returned to earth.

Of equal scientific significance was the performance of the in-flight geochemical experiments and CMP tasks during the six-day period in lunar orbit. The gamma-ray-spectrometer detected higher levels of radioactivity on the lunar farside, and lower average levels than that measured in the Fra Mauro samples. X-ray spectrometer data indicates richer abundance of aluminum in the highlands, especially on the farside, yet greater concentrations of magnesium in the maria. The alpha-particle spectrometer data indicates that radon diffusion on the moon is three orders of magnitude less than on earth. The mass spectrometer detected an unexpected population of molecules in lunar orbit.

Although the velocity/height sensor was erratic, almost all of the panoramic camera's 6500 feet of film is usable as high resolution stereo photography. The mapping camera achieved excellent results with all 4700 feet of its film. Laser altimeter performance started to degrade during revolution 26 and was inoperative after revolution 38; however, initial results were very significant in that the moon's center of mass was found to be offset.

The subsatellite particles and fields sensors returned excellent initial data, including detection of a new mascon near the east limb and indications that mascons vary in their intensity. The 76.3 x 55.1 NM lunar orbit is designed to give the subsatellite a lifetime of at least one year.

All CM photographic tasks were successfully accomplished except for the Gegenschein experiment. Visual observations by the CMP achieved important sightings, such as a rille within another rille, potential worthwhile landing sites, volcanic cone structures, and previously undetected details of major crater structures.

During transearth coast, the CMP performed a 38-min. in-flight EVA to retrieve the panoramic and mapping film cassettes. He made a third excursion to inspect the SIM bay and to investigate the V/H malfunction, the mapping camera extend/retract mechanism failure, and the mass spectrometer boom position. TEI burn accuracy was such that no midcourse correction was required until MCC-7.

CM separation and atmospheric entry were normal; however, one of three main parachutes partially collapsed during descent and a slightly harder than planned landing occurred about one NM from the planned point (285 NM north of Hawaii) and 5.5 NM from the prime recovery ship. The astronauts were flown to Hickman AFB, Hawaii the next day, and thence to Ellington AFB, Texas.

Spacecraft and crew systems performance were near nominal throughout the mission. All anomalies were rapidly analyzed and either resolved or safely dispositioned by workaround procedures developed with effective ground/flight coordination. The flight crew performance was outstanding throughout the mission.

APOLLO 16 (AS-511) FLIGHT SUMMARY

MISSION PRIMARY OBJECTIVES (All Accomplished)

1. Perform selenological inspection, survey, and sampling of material and surface features in a preselected area of the Descartes region.
2. Emplace and activate surface experiments.
3. Conduct in-flight experiments and photographic tasks.

DETAILED OBJECTIVES AND EXPERIMENTS

LAUNCH VEHICLE (Partially Accomplished)

° Impact the expended S-IVB/IU in a preselected zone on the lunar surface under nominal flight profile conditions to simulate the ALSEP passive seismometers.

° Post-flight determination of actual S-IVB/IU point of impact within 5 km, and the time of impact within one second.

LUNAR SURFACE

1. Documented Sample Collection* (Accomplished)

   Apollo Lunar Surface Experiment Package (Apollo 16 ALSEP), which included the following:

2. Lunar Heat Flow (S-037) (Not Accomplished)
3. Lunar Tri-Axis Magnetometer (S-034) (Accomplished)
4. Lunar Passive Seismology (S-031) (Accomplished)
5. Lunar Active Seismology (S-033) (Accomplished)
6. Drill Core Sample Collection* (Accomplished)
7. Lunar Geology Investigation (S-059) (Accomplished)
8. Far UV Camera/Spectroscope (S-201) (Accomplished)
9. Solar Wind Composition (S-080) (Accomplished)

* Part of Lunar Geology Investigation (S-059)

10. Soil Mechanics (S-200) (Accomplished)

11. Portable Magnetometer (S-198) (Accomplished)

12. Cosmic Ray Detector (Sheets) (S-152) (Accomplished)

13. Lunar Roving Vehicle Evaluation (Accomplished)

IN-FLIGHT

1. Gamma-Ray Spectrometer (S-160) (Accomplished)

2. X-Ray Fluorescence (S-161) (Accomplished)

3. SM Orbital Photographic Tasks

   a. 24" Panoramic Camera (Accomplished)
   b. 3" Mapping Camera (Accomplished)
   c. Laser Altimeter (Accomplished)

4. Subsatellite (Partially Accomplished)*

   a. S-Band Transponder (S-164)
   b. Particle Shadows/Boundary Layer (S-173)
   c. Magnetometer (S-174)

5. S-Band Transponder (CSM/LM)(S-164) (Accomplished)

6. Alpha-Particle Spectrometer (S-162) (Accomplished)

7. Mass Spectrometer (S-165) (Accomplished)

8. UV Photography - Earth and Moon (S-177) (Accomplished)

9. Gegenschein from Lunar Orbit (S-178) (Accomplished)

10. Visual Light Flash Phenomenon (Accomplished)

11. Microbial Response in Space Environment (M-191) (Accomplished)

12. CM Photographic Tasks (Accomplished)

13. Visual Observations from Lunar Orbit (Accomplished)

* The CSM shaping burn prior to subsatellite ejection was not performed, as described under Remarks. As a consequence, the subsatellite's orbit was such that it impacted the lunar surface on May 30 after a number of low altitude passes. All experiments performed as planned and significant low altitude data was acquired during the vehicle's life.

14. Bistatic Radar (S-170) (Accomplished)

15. Skylab Contamination Study (Partially Accomplished)

16. Improved Gas/Water Separator (Accomplished)

17. Body Fluid Balance Analysis (Accomplished)

18. Subsatellite Tracking for Autonomous Navigation (Not Accomplished)

19. Improved Fecal Collection Bag (Accomplished)

20. Skylab Food Package (Accomplished)

OTHER (All Accomplished)

- Voice and Data Relay
- Apollo Time and Motion Study
- Bone Mineral Measurement (M-078)
- Apollo Window Meteoroid (S-176)
- Biostack (M-211)

IN-FLIGHT DEMONSTRATION

- Electrophoretic Separation (Accomplished)

UNUSUAL FEATURES OF THE MISSION

1. Largest spacecraft payload yet put in lunar orbit.

2. First scientific exploration of lunar highlands and Cayley formation.

3. First use of the moon as an astronomical observatory.

4. Longest total lunar surface EVA time to date (20.3 hr.).

5. Largest weight of lunar sample material returned to date (Approx.213 lb.)

6. Longest lunar stay time to date (71 hr. 2 min.).

APOLLO 16

GENERAL INFORMATION

Spacecraft: CM-113, SM-113, LM-11

Launch Vehicle: SA-511

Launch Complex: 39A

Flight Crew: Commander (CDR) John W. Young

Command Module Pilot (CMP) Thomas K. Mattingly, II

Lunar Module Pilot (LMP) Charles M. Duke, Jr.

Launch Time: 12:54 pm EST, April 16, 1972

Launch Azimuth: 72°

Earth Orbit: 95 x 90 NM

S-IVB/IU Lunar Impact:

Time: 4:02 p.m. EST., April 19, 1972

Velocity of Impact: 8711 fps. (Est.)

Lunar Location: 2.1°N. latitude, 24.3°W. longitude (Est.)

Impact Weight: 30,805 lb. (Est.)

Lunar Orbits and events:

Initial Apocynthian/Pericynthian (LOI): 170.3 X 58.1 NM

Descent Orbit (DOI): 58.5 x 10.9 NM

Initial CSM Separation: 59.2 x 10.4 NM

CSM Circularization: 68 X 53.1 NM

Landing Site Coordinates: 9°N. latitude, 15°31'E. longitude

Lunar Landing Time: 9:24 p.m. EST, April 20, 1972

LM Liftoff from Lunar Surface: 8:26 p.m. EST, April 23, 1972

Ascent Stage Jettison: 3:54 p.m. EST, April 24, 1972

Subsatellite Launch: 4:56 p.m. EST, April 24, 1972
66.6 X 52.8 NM

Mission Duration: 265 hours 51 minutes 05 seconds

Time of Landing: 2:45 p.m. EST, April 27, 1972

SPACE VEHICLE AND PRELAUNCH DATA

Spacecraft delivered to KSC:

Command/Service Module: July 1971

Lunar Module: May 1971

Lunar Roving Vehicle: September 1971

Launch Vehicle Delivered to KSC:

First Stage (S-IC): September 1971

Second Stage (S-II): July 1971

Third Stage (S-IVB): July 1971

Instrument Unit (IU): September 1971

Space Vehicle Weight at Liftcff: 6,439,605 lb. (107,158 lb. payload)

Weight Placed in Earth Orbit: 308,734 lb.

Weight Placed in Lunar Orbit: 76,109 lb.

Significant spacecraft differences from Apollo 15:

Command/Service Module

* The time delay in the RCS control box was increased from 42 seconds to 61 seconds for mode IA aborts to reduce possible land landing hazards with pressurized propellant tanks.

* Installed transparent Teflon shields to strengthen meter glass and to retain glass particles in case of breakage.

* Installed Inconel parachute links in place of nickel plated links to reduce probability of parachute riser link failures due to flaws.

* Replaced selected early series switches with 400 series switches to reduce the possibility of switch failure.

Lunar Module

* Descent stage batteries were improved to prevent case cracking and to increase electrical capacity.

* Added glycol shutoff valve to increase battery temperature, if required, to maximize electrical capacity.

* Added an exterior glass doubler to the range/range rate meter window to reduce stress. Added tape and particle shield as required to other meters.

SLA

* Changed ordnance adhesive in pyro train to avoid a lead acetate reaction.

Crew Systems and Lunar Mobility

* New LRV seat belts were installed to eliminate adjustment and latching problems.

* Swage fittings in the pressure garment assembly were modified to provide greater mobility and reliability, and gloves were reinforced for greater wearability.

Lunar Surface Equipment

* The ground commanded TV assembly incorporated new clutch assemblies, a new elevation drive motor, and temperature control modifications to preclude previous flight problems.

Significant launch vehicle changes from Apollo 15:

S-IC Stage

* Four retro-rocket motors were added (8 total) to improve S-IC/S-II separation characteristics.

S-II Stage

* Structure was modified to increase safety factors and to improve POGO stability.

* Several single-point relay failure modes were eliminated in the engine start/cutoff circuitry.

S-IVB Stage

* Fuel and LOX feedline bellows were changed from stainless steel to 2-ply solar duct.

Instrument Unit

* The LVDC was modified to distinguish between failures of upper and lower engines for proper abort guidance programming.

* Redesigned command decoder by adding solder joint stress relief to eliminate solder joint cracks for improved reliability.

RECOVERY DATA

Recovery Area: Mid-Pacific Ocean

Landing Coordinates: 0°43'S., 156°13W. (Stable II)

Recovery Ship: USS Ticonderoga

Crew Recovery Time: 3:20 p.m. EST, April 27, 1972

Spacecraft Recovery Time: 4:45 p.m. EST, April 27, 1972

REMARKS

Apollo 16 was launched on time after a countdown with no unscheduled holds. All launch vehicle systems performed nominally in achieving an earth parking orbit of 95 x 90 NM. A nominal translunar injection (TLI) burn was performed after one and a half orbits.

During CSM/LM docking, particles were noticed coming from the area of a LM close-out panel. The crew entered the LM early, at 8:17 GET, to determine system status. All systems were normal, and it was later determined that the particles were flakes of thermal protection paint, the loss of which would have no adverse effect on LM operations.

The first S-IVB APS burn for lunar impact was nominal. Because of APS module No. 1 helium depletion due to external leakage, the APS-2 maneuver was not performed. Tracking of the S-IVB/IU was lost at 27:10 GET due to signal loss from the IU command and communications system. Lunar impact was detected by the Apollo 12, 14,and 15 seismometers and was approximated at 75:08 GET and 260 km NE of the targeted impact point.

Spacecraft operations were close to nominal until the CSM prepared for the SPS circularization burn on the lunar farside. A problem was detected in the secondary yaw actuator servo loop which drives the SPS gimbal in backup mode. The burn was not performed as scheduled and the LM PDI burn on Rev. 13 was delayed. The CSM maneuvered to station-keeping position with the LM while trouble shooting was performed. Analysis concluded that the secondary system was operable and the landing could proceed. To minimize the remaining SPS engine firings, lunar orbit plane change 2 and the subsatellite shaping burn were deleted. Subsequently, it was decided to shorten the mission one day. Circularization was performed on Rev. 15, and LM PDI was accomplished on Rev. 16.

The landing in the Descartes area was only 230 meters NW of the planned target point. Because of the almost 6-hour delay in landing caused by the SPS control problem, EVA-1 was rescheduled to follow a full crew rest period. Before performing the traverse to Flag Crater, the crew deployed and activated the Apollo lunar surface experiments package (ALSEP) and other experiments. During ALSEP deployment, the Commander inadvertently pulled the heat flow experiment cable loose at its central station connector and that experiment was abandoned. Approximately 42 pounds of samples were collected during the 7-hr. 11-min. EVA and total distance travelled by the LRV was 4.2 km.

The second 11.4-km traverse took the crew about half way up 500-meter high Stone Mountain, 4.1-km south of the LM. The lunar roving vehicle provided excellent mobility and stability, achieving eleven to fourteen kilometers per hour (kph) over rocky, pock-marked surfaces and easily climbing to 15- to 20-degree slopes at about 7 to 8 kph. Extensive sampling was accomplished, and about 71 pounds were collected during the 7-hr. 23-min. EVA. The extension of the 7-hr. EVA was possible because PLSS consumables usage was lower than predicted.

The EVA-3 duration of 5 hr. 40 min. was judged adequate to meet objectives while holding the ascent and rendezvous work day to an acceptable length. The LRV traverse was 4.5 km to North Ray Crater, the biggest yet explored on an Apollo mission. Very interesting rocks were sampled, one about house-size, another with permanent shadowed area in the lee of the sun line and interesting "drill-holes" normal to its surface. Polarimetric photography was accomplished and additional portable magnetometer readings were obtained. At one point during the downslope return to the LM the LRV recorded about 18 kph. Approximately 100 pounds of samples were collected during the 11.4-km traverse. The film cassette from the far UV camera was retrieved after 51 hours recording 11 planned celestial targets.

The 71-hour stay in the Descartes area featured excellent experiment, LRV, TV, and crew systems operation; revised theories of Cayley formation; less evidence of volcanism than expected, and the highest recordings of local magnetic field of any Apollo landing site. 1809 frames of 70 mm film and 4 1/2 magazines of 16 mm film were exposed during the 20-hour 15-minute total EVA time. One hundred eleven documented samples totaled approximately 213 pounds. LM ascent, rendezvous, and docking were normal. However, after jettison from the CSM the LM ascent stage lost attitude control and began tumbling at about 3° per second, probably because of an open circuit breaker in the primary guidance and navigation system, and it could not be deorbited as planned. The ascent stage is expected to stay in lunar orbit approximately a year before impacting the surface.

Lunar orbital science and photographic tasks were successfully conducted throughout most of the 64 CSM orbits. The subsatellite was launched 4 hr. 20 min. before transearth injection; however, because of the decision not to perform the orbit shaping burn its lifetime was much shorter than the planned one year.

To maintain the orbital time line after the delayed CSM circularization event, a GET clock update of 11 min. 48 sec. was made at 118:06:31. To minimize checklist changes during transearth coast, another GET adjustment of 24 hr. 34 min. 12 sec. was made at 202:25, after the transearth injection maneuver.

The spacecraft was depressurized for 1 hr. 23 min. during trans-earth coast for the CMP's EVA to retrieve mapping and panoramic camera film cassettes. He also inspected the SIM bay to report on experiment conditions, and the microbial response in space environment was conducted for 10 minutes outside the open hatch.

Two small midcourse corrections were made during transearth coast. Final detailed objectives were completed, and an 18-min. TV press conference was conducted. CM separation, entry, and descent were normal, with water landing 0.3 from the target point and 3.5 NM from the primary recovery ship (PRS). The CM was righted from the stable II position, and the crew was greeted aboard the PRS 35 minutes later.

The crew's health was excellent throughout the flight. Because of the in-flight arrhythmias experienced by the Apollo 15 crew, special pre-flight procedures, in-flight dietary supplements, and longer scheduled rest periods were instituted for the Apollo 16 crew. The post-flight adaptation periods were less than those experienced after Apollo 15.

Numerous "glitches" and system anomalies were rapidly analyzed by the support/flight controller/crew team and were effectively resolved to minimize the mission impact.

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