NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 13 MISSION
5-DAY REPORT

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

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SUMMARY

The Apollo 13 mission, planned as a lunar landing in the Fra Mauro area, was aborted because of the abrupt loss of service module cryogenic oxygen pressure at approximately 56 hours. After entering the lunar module and powering up the lunar module systems, the crew shut down all command and service module systems not required for the abort mission. A circumlunar profile was executed as the most efficient means of earth return, with the lunar module providing power and life support until transfer to the command module just prior to entry.

The space vehicle, with a crew of James A. Lovell, Commander; Fred W. Haise, Jr., Lunar Module Pilot; and John L. Swigert, Jr., Command Module Pilot; was launched from Kennedy Space Center, Florida, at 2:13:00 p.m. e.s.t. (19:13:00 G.m.t.) April 11, 1970. Three days before launch the Command Module Pilot, as a member of the Apollo 13 backup crew, was substituted for his prime crew counterpart, who was exposed and found susceptible to rubella (German measles). The only unexpected occurrence during launch was an early shutdown of the S-II inboard engine, with no appreciable effect on the flight. The activities during earth orbit checkout, translunar injection, and initial translunar coast were similar to those of Apollo 11 and 12. Soon after the spacecraft was ejected, the S-IVB was maneuvered using the auxiliary propulsion system to impact at a preselected point on the lunar surface. This impact, which occurred at about 78 hours, provided valuable seismological data from the passive seismometer deployed during Apollo 12.

The first midcourse correction, performed at about 30 hours 41 minutes using the service propulsion system, inserted the spacecraft into a non-free-return trajectory with a pericynthian altitude close to the planned value of about 60 miles. At approximately 56 hours, the pressure in cryogenic oxygen tank 2 began to rise at an abnormally high rate, and soon thereafter, the tank abruptly lost pressure. The pressure in tank 1 also dropped but at a rate sufficient to maintain fuel cell 2 operational for approximately 2 hours. Fuel cells 1 and 3 lost power soon after the oxygen pressure began to drop. This was attributed to the oxygen flow valves closing. The loss of primary power in the command module led to aborting the mission shortly thereafter. A mode of operation was established by the ground to safely return the crew.

The first maneuver following the incident was made with the descent propulsion system at 61 hours 30 minutes and placed the spacecraft once again on a free-return trajectory, with the altitude of closest lunar approach raised to 137 miles. A maneuver that was performed with the descent engine 2 hours after passing pericynthian 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 105 hours 18 minutes using the descent propulsion system and the second at 137 hours 40 minutes using the lunar module reaction control system.

The service module was jettisoned at 138 hours, 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 1 hour before entry, which was performed nominally using the primary guidance and navigation system. Landing occurred at 142:54:41 and was within sight of the recovery ship USS Iwo Jima, which reported the touchdown point as 21 degrees 38 minutes 24 seconds south latitude and 165 degrees 21 minutes 42 seconds west longitude. The crew were in good condition when they were retrieved by a recovery helicopter, and they were aboard the recovery ship within 45 minutes after landing.

LOSS OF CRYOGENIC OXYGEN PRESSURE

An abrupt loss of pressure in cryogenic oxygen tank 2 occurred at 55:54:53, followed by an abnormal pressure decay from oxygen tank 1. The significant events prior to these pressure losses are summarized in the following table.

Time, hr:min:sec	Event
55:53:20	Oxygen tank 2 fan cycle
55:53:23	11.5-ampere spike from fuel cell 3
55:53:36	First indicated pressure rise from tank 2 to 891 psia from a recent low of 887 psia.
55:53:38	11.3-volt drop on ac bus 2
55:53:41	23-ampere spike from fuel cell 3
55:53:45	First indication of temperature increase in tank 2
55:54:44	Tank 2 pressure at relief-valve cracking value
55:54:45	Tank 2 pressure at maximum recorded value of 1008 psia
55:54:53	Significant spacecraft momentum changes
57:46:00	Fuel cell 2 taken off line when tank 1 pressure decreased to 60 psia

Immediately after the tank 2 peak pressure was reached, a data drop-out of 1 or 2 seconds was experienced. When data resumed, the pressure had decreased to below the telemetry threshold, and the pressure in tank 1 dropped nearly 500 psi in about 1 minute. Although the oxygen flowmeter readings for fuel cells 1 and 3 were zero, both fuel cells continued to operate for over 2 minutes 30 seconds. When fuel cells 1 and 3 ceased to operate, the total bus A load was was assumed by fuel cell 2, which showed a curren increase to 60 amperes. This fuel cell continued to supply current until the pressure in oxygen tank 1 had decayed to 60 psia at approximately 57 hours 46 minutes.

After the service module was jettisoned at 4 hours 39 minutes prior to entry, the crew observed and photographed the bay-4 area of the service module where the failure had occurred. The crew remarked that damage to the structure was evident in this area and that the associated outer skin panel was missing.

TRAJECTORY

The trajectory was very close to the nominal flight plan up to the time of abort. As on Apollo 12, the S-IVB was targeted for a high-pericynthian free-return profile, with the first major spacecraft maneuver intended to lower the pericynthian to the planned orbital altitude of 60 miles. Upon execution of this maneuver, the spacecraft was intentionally placed on a non-free-return trajectory. The achieved pericynthian altitude at translunar injection was 415.8 miles. The accuracy of the translunar injection maneuver was such that the option for the first planned midcourse correction was not exercised. The velocity change required at the second planned midcourse option point, intended as the time for entering the non-free-return profile, was 23.2 ft/sec. A sequence of pertinent flight events is contained in table I, and a summary of all major maneuvers is presented in table II.

For Apollo 13, the discarded S-IVB stage was targeted for a lunar impact at 3 degrees south latitude and 30 degrees west longitude. The S-IVB maneuver to achieve lunar impact was initiated at 6 hours. The firing duration using the auxiliary propulsion system was 217 seconds and produced a velocity change of 28 ft/sec. The impact point was 73 miles from the Apollo 12 seismometer.

The accuracy of the first midcourse correction was such that a maneuver was not required at the third planned option point. Because of the cryogenic system anomaly, a 38-ft/sec midcourse maneuver was performed at 61 hours 30 minutes using the descent propulsion system to return the spacecraft to a free-return trajectory.

Two hours after passing the free-return pericynthian point; a second descent propulsion maneuver, to provide an additional 860 ft/sec, was performed to reduce the transearth trip time and to move the earth landing point to the South Pacific. The landing time was thereby reduced from 155 to about 143 hours. At 105 hours 18 minutes, a 15-second descent propulsion maneuver was performed for a midcourse correction and produced a velocity change of about 7.8 ft/sec to correct the entry flight path angle.

Because of the unusual spacecraft configuration, new procedures in preparation for entry were developed and verified. The resulting timeline called for a final midcourse correction 5 hours before entry, jettison of the service module 4 hours 39 minutes before entry, and jettison of the lunar module at 1 hour 15 minutes before entry. The final midcourse correction was successfully accomplished using the lunar module reaction control system and resulted in a predicted entry flight path angle of minus 6.49 degrees, which was very close to the desired value.

Landing occurred at 142:54:41 in the mid-Pacific Ocean at approximately 21 degrees 36 minutes south latitude and 165 degrees 24 minutes west longitude, or about 800 yards from the target point, as determined by the recovery ship.

COMMAND AND SERVICE MODULE PERFORMANCE

This section presents only those aspects of the command and service module performance which are significant to the mission. The systems that are not discussed performed essentially as intended, except for the service module component failures presented previously.

Structural and Mechanical

Structural loads during the prelaunch and boost phases of flight were within acceptable limits. Command module structural oscillations of less than 0.1g at 16 hertz in all directions were measured during a period of S-II longitudinal oscillations (POGO) prior to center engine cutoff. The levels of these oscillations were comparable to those measured on previous Apollo missions. The structural oscillations reported during the translunar injection firing were less than 0.1g at 15 hertz in all directions. These oscillations were also comparable to those measured on previous Apollo missions. Preliminary command module accelerometer and rate data at the time oxygen tank 2 lost pressure, indicate a high frequency oscillation which damped out in less than 0.2 second. After service module separation, crew observations indicated extensive damage to the service module shell in the bay 4 area.

Thermal

The thermal control system of the command and service modules performed nominally until about 56 hours. Because of the powered-down condition from 56 hours until the service module was jettisoned, the command module temperatures dropped about as predicted to the 40° F range. Service module temperatures also dropped gradually during this time period, although temperature responses from the reaction control and service propulsion systems indicated that a reasonable passive thermal control was maintained.

Cryogenic Storage

Cryogenic storage was satisfactory until 46:40:09 when the quantity indication was lost for cryogenic oxygen tank 2. At about 56 hours, the pressure in oxygen tank 2 went to zero and oxygen tank 1 pressure began to decay rapidly until cryogenic oxygen was lost. This anomaly is discussed in a previous section of this report.

Electrical Power

The electrical power distribution and sequential system, except for the fuel cells, operated as expected until the sudden loss of pressure in cryogenic oxygen tank 2.

Fuel cell 3 condenser exit temperature varied periodically, as observed on Apollo 10 during lunar orbit. Analysis and tests subsequent to Apollo 10 showed that the oscillations were not detrimental to the performance or life of the fuel cells. Soon after the loss of the oxygen supply, there was a loss of power from fuel cells 1 and 3. A main bus B undervoltage alarm was triggered and ac bus 2 power was lost as a result of loss of fuel cell power. Therefore, the fuel cells were shut down.

All batteries performed nominally throughout the mission. Following the cryogenic oxygen anomaly, battery A was twice placed on main bus A to support mission requirements. At 58 hours 40 minutes, batteries A and B were placed on open circuit. Batteries A and B were charged a total of three times during the flight, the last charge being on power from the lunar module.

Pre-entry procedures were conducted with the lunar module supplying power to the command module main bus B through the command and service module/lunar module umbilical and with the command module batteries supplying power to main bus A. This configuration was maintained from 6 hours 30 minutes prior to entry interface until 2 hours 30 minutes prior to entry interface. At entry interface minus 2 hours 30 minutes, the lunar module batteries were disconnected and all electrical power loads were met by the command module batteries.

Instrumentation

The instrumentation system performed satisfactorily, and only three minor discrepancies were noted. The cryogenic oxygen tank 2 quantity measurement unexpectedly changed to a 100-percent indication at 46:40:09. Prior to this time, the reading had been 82 percent, which was nominal. For about 18 seconds during the cryogenic oxygen tank anomaly, the measurement indicated 74 percent, which appeared to be correct.

The suit pressure measurement indicated 0.5 psi below cabin pressure until powerdown of the command module. The measurement indicated correct values upon command module activation at 123 hours.

The potable water quantity measurement operated erratically for a brief period early in the mission. This type of erratic operation has been noted on previous missions.

Communications

The communications system and network supported the mission using the normal and back-up modes. The uplink and downlink signal strengths corresponded to preflight predictions. Communications system management, including antenna switching, was satisfactory.

Prior to the television broadcast at about 55 hours, some difficulty was experienced in acquiring with the high-gain antenna. After changing the spacecraft attitude, acquisition was attained.

The communications system was powered down at about 56 hours. It was powered up twice between 56 hours and entry interface minus 2 hours for a total of 16 minutes to obtain high-bit-rate data on the command module systems.

Service Propulsion

The service propulsion system was used for one midcourse correction at about 31 hours. This firing was 3.5 seconds in duration, and all parameters were nominal. At approximately the time of the loss of cryogenic oxygen, the oxidizer storage tank skin temperature dropped from 75° to 65° F; however, the tank pressure did not show a corresponding decrease.

Service Module Reaction Control

The service module reaction control system performance and parameters were normal during the operational period. Just before the system was powered down, the propellant remaining was 1093 pounds, 43 pounds more than preflight predictions. Immediately prior to power-down, the crew reported several indications of the isolation valves being closed. These resulted from a combination of loss of power on bus B and the shock from the cryogenic oxygen tank anomaly physically closing some valves. After the anomaly, heavy engine activity was noted as the crew attempted to null the effects of propulsive venting. This activity was reflected in high package temperatures and high propellant usage rates, except on quad C. The quad C package temperature dropped, and apparently there was no propellant usage, thus indicating that all propellant isolation valves were closed and the heaters disabled. After the anomaly, all parameters were normal and showed no evidence of damage, except that the quad C isolation valves were closed. All parameters were normal when checked at 102 hours and at 123 hours.

Command Module Reaction Control

The command module reaction control system operated nominally throughout entry. All parameters were nominal at system activation and the crew reported satisfactory check firings on all engines. Engine injector temperatures, which were as low as 10° to 14° F prior to activation, required that the engines be preheated. The lowest injector temperature prior to lunar module jettison was 23° F. Both systems were used briefly at lunar module separation; then system 1 only was used for the duration of the entry. Until the time of blackout, approximately 10 to 13 pounds of propellant had been used. The propellant dump was observed after main parachute deployment.

Guidance, Navigation, and Control

The guidance, navigation, and control system performance was satisfactory throughout the mission. Attitude and translation control, platform alignment, and midcourse navigation were all nominal. An abnormal fluctuation of the optics shaft, when in "zero" optics mode, was noted at 40 hours. A test at 49 hours indicated that the conditions were the same as those on Apollo 12 and that the system performed properly in operating modes.

Environmental Control

The environmental control system performed normally throughout the mission and no significant anomalies were noted. After the loss of cryogenic oxygen, a total storage of 6.5 pounds of gaseous oxygen remained in the command module. The water tanks were periodically repressurized to allow the crew to fill food bags with potable water for drinking.

LUNAR MODULE PERFORMANCE

This section presents only the lunar module performance aspects which are significant to this mission. Systems not discussed performed essentially as intended.

Electrical Power

The electrical power system performed all functions as required. The pyrotechnic batteries performed as expected. At lunar module jettison, the descent batteries had delivered 1434.7 amp-hr of a nominal total capacity of 1600 amp-hr and the ascent batteries had delivered 200 amp-hr of a nominal total of 592 amp-hr. The lunar module initial power-down configuration was consuming electrical energy at the average rate of 900 watts (30 amperes). After the second descent propulsion firing, the lunar module was further powered-down to about a 360-watt (12 amperes) rate. At approximately 111 hours 30 minutes, the lunar module started to provide power to the command module at a rate of 7 amperes for approximately 15 hours of command module battery charging. The command module was also powered from the lunar module at an 11-ampere rate for a brief period to power the reaction control heaters. The estimated total energy transfer to the command module was 129 amp-hr.

Instrumentation

The instrumentation system performed nominally. The caution and warning electronics and signal conditioning electronics exhibited no problems while the lunar module was powered up. Two transducer anomalies were experienced. At the time of initial reaction control thrusting, a thrust chamber pressure switch failed closed. Later, a sensor in either battery 2 or the electrical control assembly falsely indicated either a battery 2 overtemperature (greater than 145° F) or a reverse current. As a result of this anomalous indication, numerous nuisance master alarms occurred.

Communications

The S-band communications were nominal from turn-on at approximately 58 hours through the time of lunar module jettison. Except for short periods of time when high-bit-rate data and improved voice were required, low power transmissions and omnidirectional antennas were used in order to conserve electrical power. The S-band power amplifier was turned off to provide the higher modulation index for the pulse code modulation telemetry. The primary communications mode was low power, low-bit-rate telemetry, and backup voice on base band. High-bit-rate data were attempted with the 210-foot dish during this mode. Except for regular intervals of data dropout due to vehicle attitude changes, the data remained good. The updata link was used when required and performed nominally. After 82 hours 25 minutes, only one audio center was used to conserve power.

Descent Propulsion

At 55 hours, the crew entered the lunar module to monitor the supercritical helium tank pressure on the cabin display for a suspected abnormally high pressure rise rate. The pressure reading at that time indicated that an approximate 7 psi/hr rise rate had occurred since launch, and this was about the same value as experienced on previous missions. At 61 hours 30 minutes, the descent propulsion system was pressurized and performed a 31-second firing to place the vehicle on a free return trajectory. Subsequent to the firing, the supercritical helium rise rate increased to 11.5 psi/hr. This rise rate was abnormally high and is suspected to be the result of condensible contaminates in the supercritical helium tank vacuum jacket. At 79 hours 28 minutes, a second descent propulsion system firing permitted a Pacific landing site and a more rapid transearth return. The supercritical helium tank rise rate, after the second firing, increased to 33 psi/hr. At 105 hours 18 minutes, a third descent propulsion system firing was conducted for a midcourse correction. At 108 hours 54 minutes, the supercritical helium tank vented at 1940 psi, within the burst disc range.

Reaction Control

The reaction control system was activated at 58 hours 30 minutes. System performance throughout the mission was nominal. Total propellant consumption was 467 pounds.

During the passive thermal control periods, the cluster heaters were turned off to conserve electrical power and the reaction control engines were inhibited. The final midcourse correction was performed with the plus-X reaction control engines at approximately 137 hours 40 minutes.

Guidance, Navigation, and Control

The guidance, navigation, and control systems performed satisfactorily throughout the abort mission. Attitude and translation control of the docked configuration was maintained using both the primary and abort guidance systems. Two docked descent-engine maneuvers were performed using the digital autopilot portion of the primary system in an automatic mode. The last descent firing was controlled manually in pitch and roll, with the abort guidance system controlling yaw and providing reference; all functions were satisfactory. Passive thermal control during coast phases was initiated and maintained for the first time from the lunar module.

Environmental Control

At approximately 58 hours 40 minutes, the lunar module was configured to provide life support. Checkout and activation were completed with all parameters nominal. At the time the crew entered the lunar module, the oxygen and water supply was 53 and 330 pounds, respectively. Because of judicious power management, including transferring of power to the command module, the water reserve at lunar module jettison was 54 pounds. The oxygen reserve at lunar module jettison was 20 pounds. Due to the low power level, the lunar module cabin temperature averaged about 54° to 60° F.

To provide supplemental carbon-dioxide removal capability to the lunar module, four command module lithium hydroxide cartridges were improvised into the oxygen supply loop using command module hoses, liquid-cooled-garment bags, and tape (fig. 1). This arrangement proved extremely successful since the partial pressure of carbon dioxide never exceeded 7.6 mm Hg while using command module cartridges.

BIOMEDICAL EVALUATION

The preflight physical examination 5 days prior to launch revealed that the Command Module Pilot in the prime crew had no immunity to rubella (German measles), to which he had been exposed by a member of the backup crew. Consequently, the Command Module Pilot was replaced by the backup Command Module Pilot 3 days before launch. Brief physical examinations conducted on launch day certified that all crewmen were fit for flight.

In the period following the cryogenic oxygen tank anomaly, crew heart rates increased from about 60 beats/min to well over 100 beats/min. Physiological data for the remainder of the mission were very scant. Because of the requirement to conserve electrical power, the lunar module was powered down and biomedical data were not received.

The major medical concern was initially the buildup of carbon dioxide in both cabin atmospheres. However, modified use of the command module lithium hydroxide cartridges maintained satisfactory carbon dioxide levels when required.

The crew was significantly fatigued at landing because of the heavy workload and the inability to sleep in the cold and noisy lunar module cabin; estimated sleep after the incident was 11, 13, and 18 hours for the Commander, Command Module Pilot, and Lunar Module Pilot, respectively.

MISSION SUPPORT PERFORMANCE

Flight Control

The operational support provided by the flight control team was satisfactory and timely in safely returning the Apollo 13 crew. Only the inflight problems which influenced flight control operation, and their resultant effects on the flight plan, are discussed.

A master caution and warning alarm at 38 hours indicated the hydrogen tank pressures were low. After crew wakeup, the heaters in hydrogen tank 2 were turned off so that the tank 1 heaters could control hydrogen pressure at a higher increment above the caution-and-warning setting.

The problem experienced with the two cryogenic oxygen tanks at about 56 hours resulted in the following decisions:

a. Abort the primary mission and attempt a safe return to earth as rapidly as possible.

b. Shut down all command and service module systems to conserve consumables for entry.

c. Advise the crew to use the lunar module for life support and any propulsive maneuvers.

The plan for earth return required an immediate descent engine firing to a free return trajectory for landing at 155 hours in the Indian Ocean. The optimum plan then included a pericynthian-plus-2 hour maneuver to expedite the landing to about 142 hours 30 minutes at a mid-Pacific location. Only essential life support, navigation, instrumentation, and communication systems were operated to conserve electrical power and cooling water. A procedure was developed and used by the crew to allow use of the command module lithium hydroxide cartridges for carbon dioxide removal.

A major concern, in addition to maintaining acceptable consumable quantities, was to determine new procedures for entry. The established procedures, verified in a simulator prior to advising the crew, called for remaining on lunar module environmental control and power as long as possible using the umbilical between modules.

Recovery

The Apollo 13 crew and spacecraft were successfully recovered in the Pacific Ocean at about 21 degrees 38 minutes 24 seconds south latitude and 165 degrees 21 minutes 42 seconds west longitude by the primary recovery ship, USS Iwo Jimo. The following table is a list of significant recovery events on April 17, 1970.

Event	Time, G.m.t.
Visual contact	1803
Command module landing (142:54:41)	1808
Flotation collar installed	1824
Command module hatch open	1835
Crew in raft	1836
Crew aboard helicopter	1842
Crew aboard USS Iwo Jima	1853
Command module aboard USS Iwo Jima	1936

The spacecraft landed approximately 4 miles from the recovery ship and remained in the stable I position. Weather and sea-state conditions were moderate in the recovery area, with a 6-knot wind and a scattered cloud cover. Recovery helicopters were able to retrieve one main parachute and the apex cover.

Network

The Mission Control Center and the Manned Space Flight Network provided excellent support throughout the mission. Minor problems occurred at different sites around the network, but all were corrected with no consequence to flight control.

EXPERIMENTS

S-IVB Impact

The S-IVB stage of the Saturn launch vehicle was maneuvered to impact on the lunar surface. The effects of the impact on the lunar surface of the 30 700-pound S-IVB stage were indicated by the Apollo 12 experiment package. The impact occurred at 77:56:40 at Lansberg B crater approximately 73 miles west-northwest of the Apollo 12 experiment package site and was sensed by the passive seismic experiment, starting at about 30 seconds after impact and continuing for about 3 hours 30 minutes. Peak intensity, occurring 5 minutes after the first signal, was 25 times the peak of the Apollo 12 lunar module ascent stage impact. An expanding gas cloud from the S-IVB was sensed by the lunar ionosphere detector about 22 seconds after impact and lasted 70 seconds.

Experiment Equipment

Impact of the radioisotope thermoelectric fuel capsule and cask assembly was in the open sea between Samoa and New Zealand, at 25 degrees 34 minutes south latitude and 176 degrees 7 minutes west longitude. Surveillance aircraft were in the impact area, and no abnormal radiation levels were detected.

Scientific Photography

During the initial period of translunar coast, the crew took numerous photographs of the earth to be analyzed for meteorological data. A special high-resolution camera, intended to have been mounted on the command module hatch window for lunar photography, was not used because of the aborted mission. The majority of 70-mm photographic coverage was of targets of opportunity as the spacecraft circumnavigated the moon. The 70-mm camera was then used primarily to photograph the damaged service module after its separation just prior to entry.

TABLE II.- MANEUVER SUMMARY

Maneuver	System	Duration, sec	Velocity change, ft/sec
Translunar injection	S-IVB	351.00	10 437.1
First midcourse correction	Service propulsion	3.37	23.1
Second midcourse correction	Descent propulsion	30.40	37.8
Transearth injection	Descent propulsion	263.40	860.5
Third midcourse correction	Descent propulsion	15.38	7.8
Fourth midcourse correction	Lunar module reaction control	22.40	2.9

TABLE I.- SEQUENCE OF EVENTS

Event	Time, Hr:min:sec
Range zero - 19:13:00 G.m.t., April 11, 1970	
Lift-off	00:00:00.6
S-IC outboard engine cutoff	00:02:44
S-II engine ignition (command)	00:02:45
Launch escape tower jettison	00:03:21
S-II engine cutoff	00:09:53
S-IVB engine ignition (command)	00:09:54
S-IVB engine cutoff	00:12:30
Translunar injection maneuver	02:35:46
S-IVB/command and service module separation	03:06:39
Docking	03:19:08
Spacecraft ejection	04:01:03
S-IVB separation maneuver	04:18:01
First midcourse correction (SPS)	30:40:50
Cryogenic oxygen tank anomaly occurred	55:54:53
Second midcourse correction (DPS)	61:29:44
S-IVB lunar impact	77:56:40
Transearth injection (DPS)	79:27:39
Third midcourse correction (DPS)	105:18:28
Fourth midcourse correction (LM RCS)	137:39:49
Command module/service module separation	138:02:00
Undocking	141:30:00
Entry interface	142:40:46
Landing	142:54:41

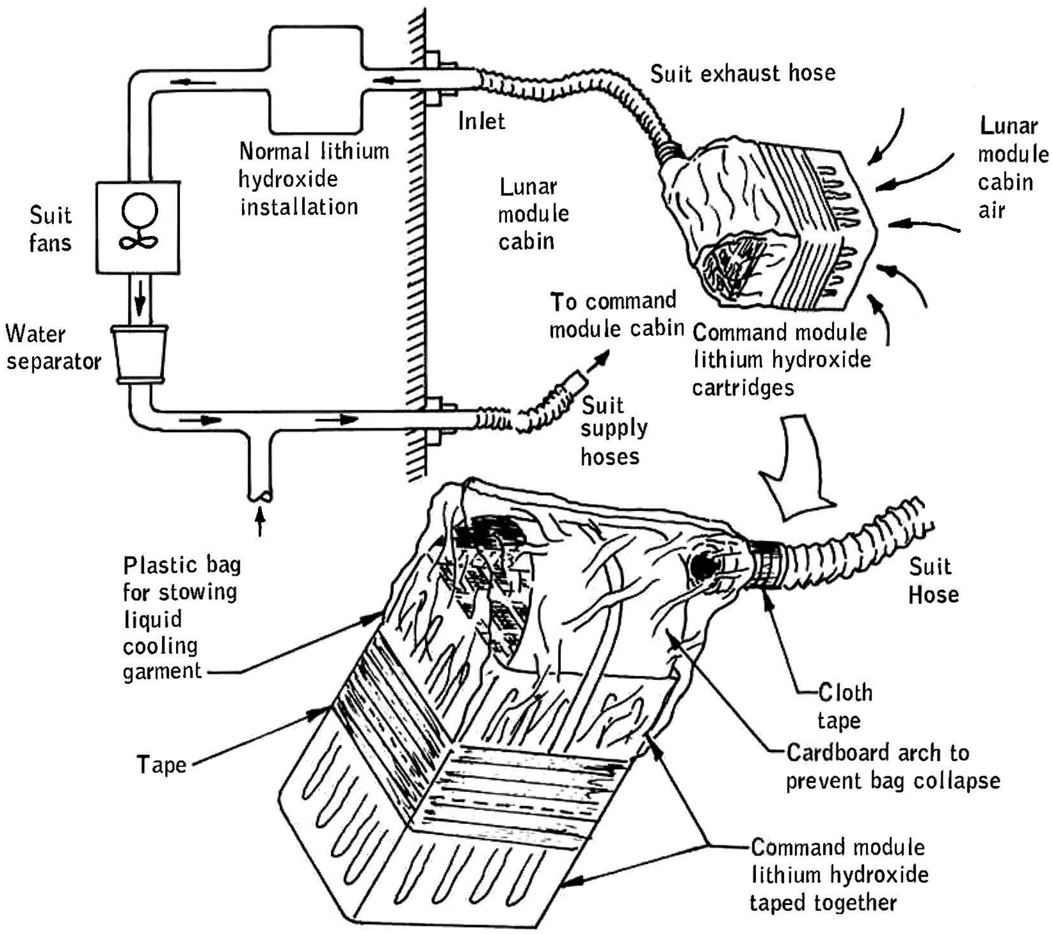

Figure 1.- Supplemental carbon dioxide removal system.