

CHAPTER 1 THE LUNAR QUARANTINE PROGRAM

by

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Introduction

In 1963, a special subcommittee of the Space Science Board of the National Academy of Sciences was convened to consider the general problem of handling material and personnel returned from flights to the moon. The subcommittee recommended that NASA establish a quarantine program to ensure that the Earth and its ecology would be protected from any possible hazard associated with the return of lunar material.

The development of the requirements, the philosophy, and the guidelines which resulted in the Apollo quarantine program were the joint responsibility of NASA and a newly-formed Interagency Committee on Back-Contamination (ICBC). Those federal agencies responsible for protecting public health, agriculture, and other living and natural resources had representatives on the ICBC. Included on the Committee were members of the National Academy of Sciences and representatives from the U.S. Public Health Service, U.S. Department of Agriculture, and U.S. Department of Interior.

The charter of the Committee defined its purpose as follows:

1. To protect the public's health, agriculture, and other living resources.
2. To protect the integrity of the lunar samples and the scientific experiments.
3. To ensure that the operational aspects of the program were least compromised.

An interagency agreement, which served as a basis for the development of the quarantine program, was developed and approved. Implementation of the program

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was the responsibility of NASA. The Committee served only as an advisory body to review and approve plans proposed by NASA.

The quarantine objectives of the Apollo Program included biological containment of the crewmen, lunar samples, and other lunar-exposed material until released from quarantine, and biological assessment of the returned lunar materials to ensure that safe release could be effected.

The Apollo Back-Contamination Program was divided into three phases (figure 1). The first phase was concerned with procedures to be followed by the crewmen while inflight to eliminate the return of lunar-surface contaminants in the Command Module (CM). The second phase included spacecraft and crew recovery and the provisions for isolation and transport of the crewmen, spacecraft, and lunar samples to the Lyndon B. Johnson Space Center (JSC). The third phase encompassed the quarantine operations in the Lunar Receiving Laboratory (LRL).

In order to meet the ICBC requirements, NASA began to plan special quarantine facilities, equipment, and operational procedures. The facilities and procedures made necessary by the quarantine program were often well beyond the state of the art. Quarantine represented a major impact on the Apollo Program. It meant that the crew, the Command Module, and the lunar material had to be isolated from the moment of arrival back on Earth.

Specific physical science and biomedical requirements for the collection, return, and examination of lunar samples were formulated. Whereas the primary concern of the physical science advisory groups was to ensure that procedures and equipment were developed that would minimize the possibility of the contamination of the lunar samples by terrestrial organic and inorganic material, the primary concern of the biomedical advisory groups was to ensure that equipment and procedures were developed that would minimize the possibility of introducing the lunar material into the biosphere. Although the possibility of discovering an existing life system was considered remote, it could not be ignored. Consequently, appropriate quarantine precautions were required for both the crewmen and the lunar samples.

Program Description

Quarantine Requirements

By observation of plant and animal diseases, it was determined that most terrestrial disease agents were capable of invading a host and causing evident disease symptoms within 21 days after exposure of the host. Most disease agents capable of causing epidemic or rapidly spreading diseases were sufficiently virulent to be transmitted in less than 21 days. The ICBC decided that a crew quarantine period of at least 21 days should be required after each Apollo mission.

Intensive medical examinations of the flight crewmembers during quarantine determined if any medical problems existed as a result of exposure to lunar material. The returned lunar samples and equipment were evaluated to ensure that release of these items to an investigation team did not represent a hazard. To

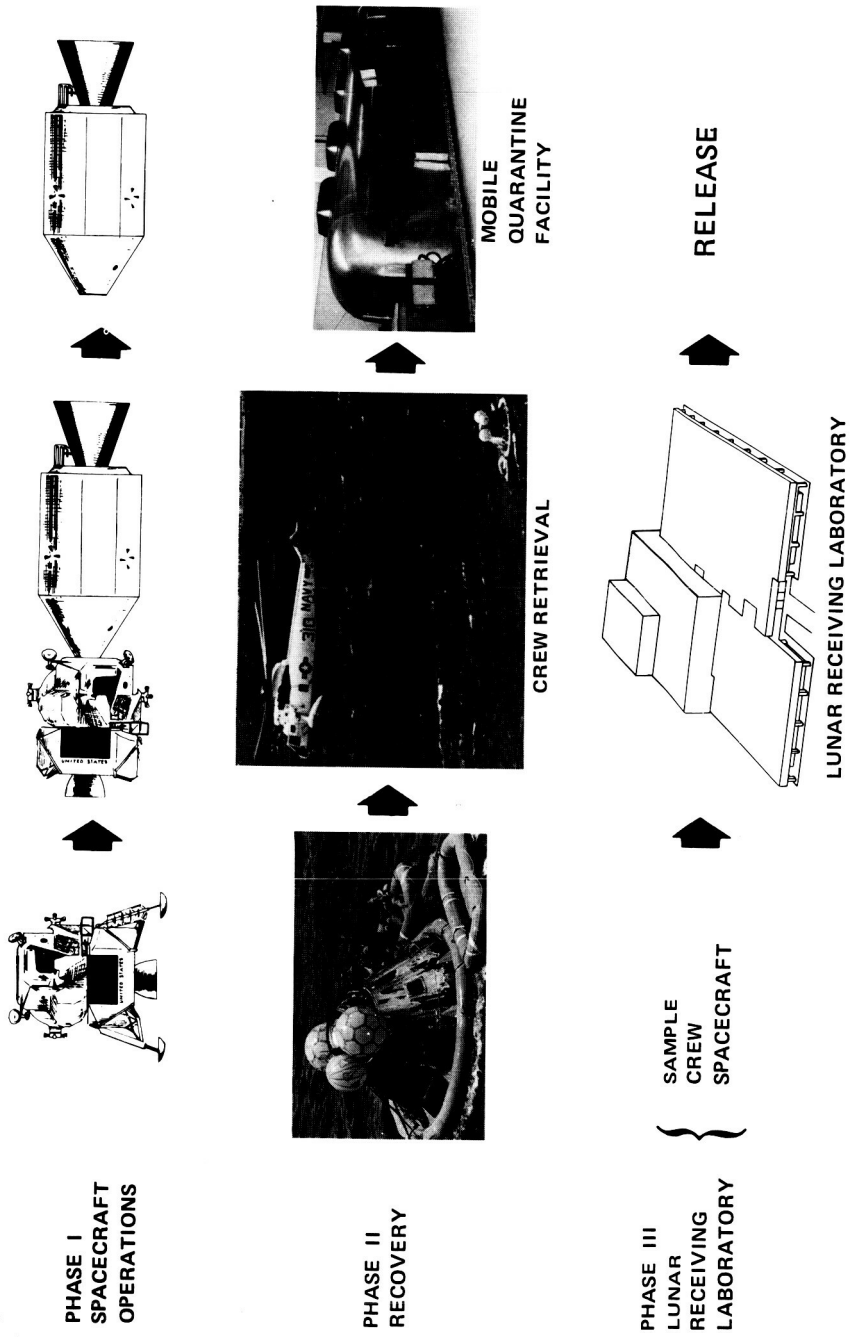


Figure 1. Apollo Back-Contamination Program.

accomplish this and other functions, the Lunar Receiving Laboratory was constructed at the Johnson Space Center to serve in the following manner:

1. As a quarantine facility for returning Apollo crewmembers, spacecraft, equipment, and lunar samples.
2. As an isolation facility where specific biomedical evaluations of the lunar samples could be performed to determine whether the samples contained any hazardous replicating microorganisms.
3. As an isolation facility where time-critical physical science investigations could be performed. (Time-critical investigations were those for which data would be lost or seriously degraded if the experiments were not initiated during the quarantine period.)
4. As a facility for lunar sample preparation and distribution to outside principal investigators for detailed scientific analyses.

Quarantine Assumptions and Guidelines

The coordination of the multidisciplinary, and often contradictory, requirements presented a unique series of problems, many of them associated with the hypothetical nature of an unknown lunar hazard. If precise scientific and technical decisions were to be made, basic assumptions and guidelines had to be followed. Those established for development of the Lunar Quarantine Program (LQP) were as follows:

1. The existence of hazardous, replicating microorganisms on the moon would be assumed.
2. The preservation of human life should take precedence over the maintenance of quarantine.
3. Biological containment requirements should be based on the most stringent means used for containment of infectious terrestrial agents.
4. The sterilization requirement should be based on methods needed for the destruction of the most resistant terrestrial forms.
5. Hazard detection procedures should be based on an alteration of the ecology and classical pathogenicity.
6. The extent of the biological test protocol would be limited to facilities approved by the Congress, to well-defined systems, and to biological systems of known ecological importance.

Together, guidelines 1 and 2 provided the basis for the Lunar Quarantine Program; that is, although the probability that life existed on the moon was extremely low, the risk was sufficiently high that a quarantine program was justified. However, this risk was not considered great enough to permit an otherwise avoidable injury and/or loss of human life just to maintain the integrity of the program.

Many critical decisions, especially those involving emergency procedures, could not have been made without the establishment of the second guideline. Typical examples

were emergency procedures for escape of crewmembers should the Command Module begin to sink after splashdown, and emergency exit procedures should a major fire occur in the LRL living quarters for quarantined personnel. The third guideline became the basic criterion for the design and operation of the required containment systems. Again, the dilemma was that procedures and equipment had to be designed, fabricated, and operated to contain microbial agents that were assumed to exist on the moon and about which no characteristics were known. It was decided that the biological containment requirements should be based on the most stringent means used at that time to contain infectious terrestrial agents. The fourth guideline established that sterilization requirements should be based on the method needed for destruction of the most resistant terrestrial life forms. Terrestrial spore-forming microorganisms were used as models in providing design criteria for equipment and guidelines for sterilization procedures.

The fifth guideline concerned the detection of hazards assumed to be present. The term "hazard" had to be defined before a method of detection could be developed. Procedures were limited to those capable of detecting an agent that would exhibit classical pathogenicity to some terrestrial life form or that could establish itself in a terrestrial environment and thereby alter the ecology. This guideline limited the search to the detection of replicating microorganisms. Parameters such as toxicity were eliminated; even if the lunar samples were highly toxic, the toxicity characteristics would be self-limiting and non-propagating.

The sixth guideline dealt with methods to be used for the detection of replicating microorganisms that could cause disease or establish and replicate themselves in some terrestrial environment. The guidelines made a first level of decision possible in that the efforts of the biological test program were directed toward the specific detection of hazards to the biosphere. Because the program was focused on hazards to the terrestrial environment, only terrestrial environmental conditions were acceptable as test systems.

Three limitations were set for the biological test protocols in support of the quarantine program. Test systems for which little or no baseline or background information was available were not considered. Systems of known ecological importance were stressed. Lastly, the size of the facility and the scope of activities were determined for planning purposes.

The period of quarantine for spacecraft, crew, and lunar samples was considered to have begun as soon as the Apollo crewmen left the moon. Isolation was accomplished by containing men and equipment first in the Mobile Quarantine Facility (MQF) located on the hangar deck of the recovery ship, and, later, the Lunar Receiving Laboratory at the Johnson Space Center. A crew surgeon and recovery engineer joined the crew in the MQF and remained with them throughout the period of quarantine.

Boxes containing samples of lunar rocks and soil from early missions were opened at JSC in a unique vacuum chamber. The chamber was designed to ensure sample sterility and to provide a method for preliminary examination without compromising sample integrity by exposure to air. The vacuum simulated lunar pressure.

The quarantine program was carried out with minimal breaks. There were a few instances in the LRL operations when technicians had to be quarantined because of leaks in vacuum chamber gloves while personnel were handling the lunar material or when

similar faults in the other protective devices occurred. These instances were infrequent. In no instance was the biological containment of the crewmen, lunar samples, and/or any other exposed material compromised.

Equipment and Facilities

Equipment

Spacecraft Equipment. The Apollo spacecraft carried equipment specifically to maintain cleanliness and to reduce the quantity of lunar dust in the spacecraft environment. This equipment included vacuum brushes, lunar equipment stowage bags, and other items to maintain spacecraft cleanliness.

Recovery Equipment. A Mobile Quarantine Facility (MQF) was designed and fabricated to house and transport the Apollo crewmen from the recovery ship to the Lunar Receiving Laboratory. The MQF was equipped to house six people for a period of ten days and provided a lounge, galley, and sleeping and toilet facilities. It was powered through several systems to interface with various ships, aircraft, and transportation vehicles. Quarantine was assured in the MQF through the maintenance of negative internal pressure and by filtration of effluent air.

Waste water from washing and showers was chemically treated and stored in special containers. Body wastes (urine and feces) were stored in special tanks in the Mobile Quarantine Facility. Items were passed in or out through a submersible transfer lock. The MQF could be serviced with utilities (power, communications, alarm system) from shipboard, aircraft, and/or trucks. Redundant power systems and fans assured maintenance of a negative pressure. Specially packaged and controlled meals could be passed into the facility to be prepared in a microwave oven. Medical equipment was also provided for use in immediate postlanding crew examinations and tests.

Biological isolation garments were used in Apollo 11 to isolate the crew from the Earth's environment and from contact with recovery personnel. These garments were constructed from a fabric which effectively isolated microorganisms from the crewman's body. The garment was donned in the spacecraft before the helicopter hoist operation and was worn until the crew entered the MQF aboard the primary recovery ship. The suit was fabricated of nylon. A respirator was worn with the garment. It featured an air-inlet flapper valve and high efficiency air-outlet filter to biologically filter expired gas. The Apollo 11 crew used a heavier biological isolation garment, but this was discarded as an unnecessary precaution after the initial lunar landing flight. On later missions, a lightweight overgarment was used when transferring from the Command Module to the MQF.

Special containers were fabricated for return of the medical and lunar samples, films, and data tapes from the recovery area to the LRL.

Lunar Receiving Laboratory

The final phase of the Apollo back-contamination program was completed in the JSC Lunar Receiving Laboratory (figures 2 and 3). The LRL, housed in Building 37 at JSC,

covers 7700 m² (83 000 ft²) of floor space and includes several distinct areas. These are: the Crew Reception Area (CRA), Vacuum Laboratory, Sample Laboratories (Physical and Bio-Science), and an administrative and support area. Special building systems were employed to maintain airflow into sample-handling areas and the Crew Reception Area to sterilize liquid waste and to incinerate contaminated air from the primary containment systems.

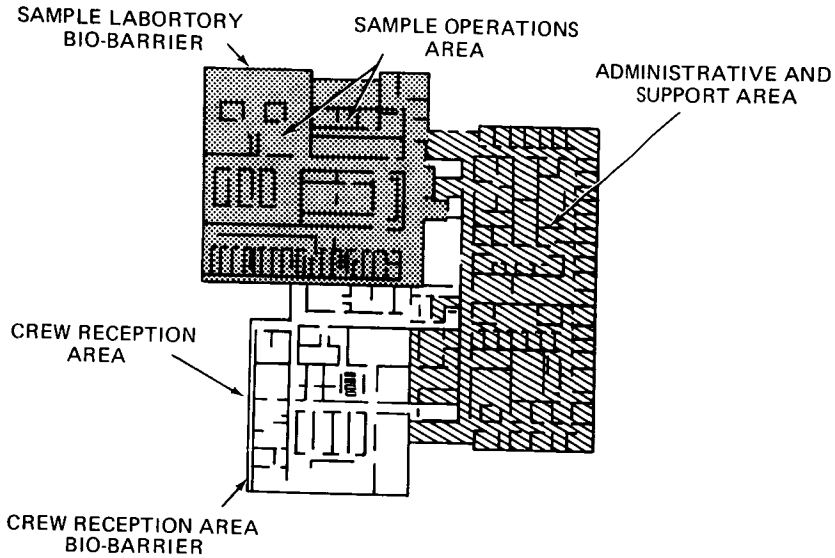


Figure 2. Functional area floor plan.

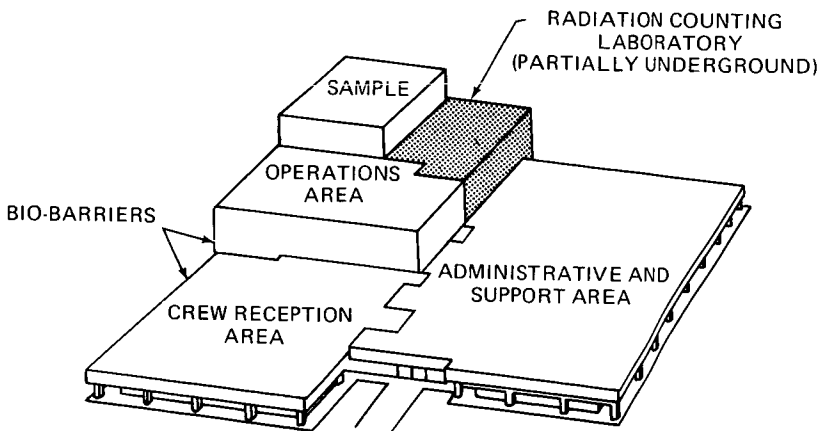


Figure 3. Perspective view of functional areas.

Biological containment in the Lunar Receiving Laboratory relied on a primary and secondary barrier system. The primary biological barrier consisted of the vacuum complex and Class III biological cabinets. A secondary barrier was maintained in the Crew Reception Area and the sample laboratory by maintaining the areas at negative pressure with respect to the atmospheric pressure external to the building. Within these two barriers the postmission work on returned lunar samples was performed. The design and operational features for the primary and secondary barriers are described below.

The need for a central facility to carry out the foregoing functions was identified early in 1964. A series of studies preceded the construction of the building, which began in July 1966. The test system equipment was developed and installed during the period from mid-1966 until approximately September 1968.

The Lunar Receiving Laboratory was built to meet the most stringent biological containment requirements of the U.S. Army Biological Laboratories, Fort Detrick. This was a unique facility in many respects. It contained a vacuum chamber which permitted scientists to manipulate and examine lunar samples without breaking the vacuum or risking contamination of the samples or themselves. It had a low-level radiation counting facility and could safely accommodate a large variety of biological specimens.

Primary Biological Barrier.

The Vacuum Complex. The vacuum complex was the area in which sample containers were opened and processing of the lunar material was initiated. This system was sterilized before return of the containers to ensure lunar samples would not be contaminated with terrestrial microorganisms. All materials entering the vacuum complex after premission sterilization were sterilized using peracetic acid. All items leaving the complex during the quarantine period were either placed in vacuum-tight containers, the exteriors of which were sterilized with peracetic acid, or were directly sterilized with the acid. Effluent gases from the vacuum chamber pumps were passed through absolute biological filters, incinerated, and filtered again prior to venting to the outside environment. All lunar samples left the vacuum complex in sterilized vacuum-tight containers. The containers were placed in sealed plastic bags for handling within the sample laboratory.

Biological Cabinets. Biological and physical/chemical testing of the lunar samples was performed within biological cabinets. These cabinets were gastight enclosures through which all manipulations were performed using neoprene gloves. Air or nitrogen entered the cabinets through absolute biological filters, was incinerated, and was filtered again before being vented to the outside. All material entering the cabinets was sterilized. The cabinets were operated at a pressure negative with respect to the laboratory to ensure that any leak that developed would be directed into the cabinets rather than into the laboratory.

Secondary Biological Barrier. The rooms in which the cabinets were housed were also maintained at a pressure negative with respect to the adjacent corridors. This guaranteed that any escaping lunar material would be contained. The secondary biological barrier

which surrounded the sample laboratory included facility systems and operational procedures. Tight building construction was used and all penetrations were sealed. The sample laboratory had a single-pass air conditioning supply and exhaust system which maintained the area at a pressure negative with respect to the outside air. Inlet air was filtered, and air exited through absolute biological filters. All liquid waste coming from the sample laboratory area was sterilized with steam before being transported to the JSC sewage treatment plant. All solid materials including waste, clothing, and trash were sterilized. The sample laboratory area received supplies during quarantine operations through ultraviolet-lighted airlocks.

Procedures

Lunar and Command Module Operations

The Apollo crewmembers represented the prime source of contamination to the lunar surface. Three other sources of contamination were: (1) waste products such as feces, urine, and residual food; (2) viable terrestrial microorganisms released during Lunar Module depressurization; and (3) microorganisms present in the LM waste water system. Procedures were defined to eliminate massive contamination of the lunar surface from these three sources. Of the three, waste products were the chief source of potential contamination. To minimize the thrust required for lift-off from the lunar surface, waste products had to be removed from the ascent stage of the LM. All waste products were stored in the equipment bays of the descent stage. Even if the storage bags had leaked or the integrity of the containers had been violated, microbial contamination would have been contained within the descent stage of the LM and not deposited on the lunar surface.

The primary quarantine-related concern in collecting lunar samples was to minimize their contamination with viable terrestrial microorganisms. Such contamination would have complicated interpretation of biological findings. Lunar samples were collected with sterile tools and returned to the Lunar Receiving Laboratory in a sterile environment. The types of materials used for fabricating tools and other items that came in contact with lunar material were severely limited by the physical scientific contamination requirements and by weight restrictions. A high-temperature bakeout under vacuum conditions was considered the best method for removing volatile terrestrial contaminants from the hardware. This treatment, at a sufficient temperature for a sufficient period of time, also satisfied the sterilization requirements for the hardware.

The procedures and the hardware necessary for the stowage of collected lunar samples were considered next. Because the lunar material had existed for millions of years in an almost perfect vacuum, the physical scientists decided that the lunar samples should be transported to Earth under environmental conditions as near to those on the moon as technically feasible. This decision necessitated the design and fabrication of a pressure vessel that could be filled with lunar samples and sealed on the lunar surface, and in which the internal environment could be maintained throughout the sample transfer from the lunar surface to the LRL. Because the pressure vessel had to be an ultraclean,

gastight container, no additional requirements were necessary in terms of quarantine control.

The Lunar Module was designed to include a bacterial filter system to prevent contamination of the lunar surface when the cabin atmosphere was released at the start of lunar exploration. Before reentering the LM, the crewmen brushed any lunar surface dust or dirt from their space suits. They scraped their feet on the LM footpad and kicked the LM ladder while ascending to dislodge any particles on their boots.

After cabin repressurization, the LM was launched from the lunar surface and docked with the Command Module. The CM tunnel was pressurized and checks made to ensure that an adequate pressurized seal had been made. The crewmen then vacuumed the Lunar Module, their space suits, and the lunar surface equipment. To prevent dust particles from being transferred from the Lunar Module atmosphere to the Command Module, provisions were made to ensure a positive CM pressure relative to the LM.

The Apollo Lunar and Command Modules had separate environmental control systems that removed dirt particles continually from the spacecraft atmosphere. In normal operation, the environmental control-space suit systems were used to condition the cabin atmosphere. Cabin gas was drawn into the system, and, as it passed through the lithium hydroxide canister, nearly all dirt particles were filtered from the atmosphere. This cleansing action reduced the amount of airborne lunar dust in the LM at the time of docking with the Command Module. The 63-hour operation of the CM environmental control system had the capability to virtually remove all lunar dust from the atmosphere which had been transferred from the Lunar Module during docked operations.

The vacuuming system allowed material as small as 0.3 micron to be trapped in the lithium hydroxide canisters. Visible liquids were removed by the liquid dump system. The crewmen used towels to wipe surfaces clean of liquids and/or dirt particles. The three suit hoses were located at random positions around the spacecraft for positive ventilation and cabin atmosphere filtration.

Recovery

The general requirements of the recovery quarantine operation were as follows:

1. *Crew Safety.* To provide a safe method for the retrieval and return of crew and spacecraft.
2. *Biological Isolation.* To provide isolation during the recovery operation and during the movement of the crew and equipment from the recovery area to the LRL.
3. *Sustenance Provisioning.* To provide eating, sleeping, and hygienic facilities for the crew and technical personnel during the return phase.
4. *Medical and Debriefing Provisioning.* To provide some limited medical facilities and interfaces during the recovery and transportation phases.
5. *Transportation.* To provide suitable hardware for the transportation of the crew, CM, and hardware by ship, aircraft, and truck.

The quarantine phase of the recovery operation began as soon as the Command Module had been located and the flotation collar installed by swimmers. The swimmers were instructed to withdraw upwind from the immediate vicinity of the Command Module after installing the collar. An additional swimmer, dressed in a protective garment, was then delivered by helicopter to the raft attached to the flotation collar on the spacecraft. The spacecraft hatch was opened momentarily and three protective garments and masks were passed to the crew.

After the crewmen had donned the garments in the spacecraft, they closed the postlanding ventilation system valves. The hatch was then opened and they egressed into the raft which contained a decontaminant solution. The hatch was closed immediately after egress, and the swimmer who had provided the crew with their garments and masks sponged them off with a solution of organic iodine, an antibacterial agent. The spacecraft hatch was also washed down with the solution (figure 4).

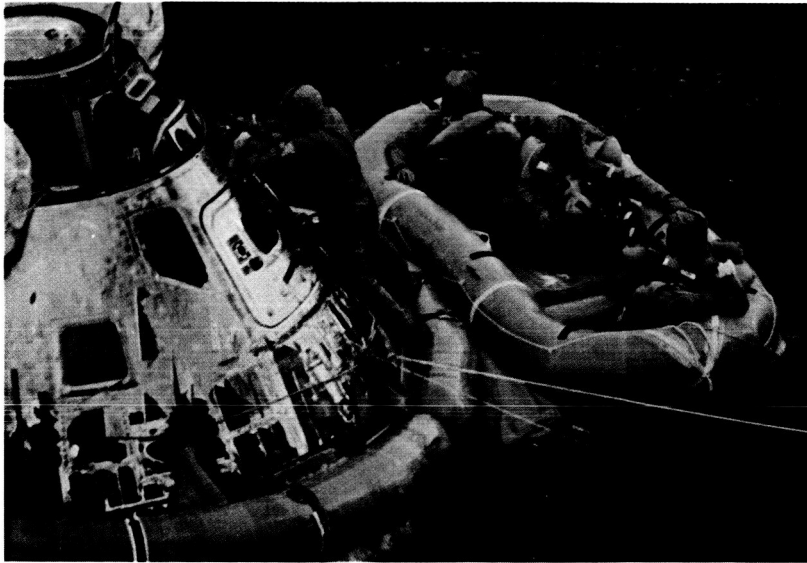


Figure 4. Apollo Crewmen in biological isolation garments egressing their spacecraft.

The Command Module crew was retrieved by helicopter and delivered to the aircraft carrier. The helicopter was then towed to the immediate vicinity of the Mobile Quarantine Facility where the crew left the helicopter and immediately entered the Mobile Quarantine Facility. Following crew egress, the swimmer decontaminated the Command Module, the collar, the raft, and his own protective garment with an antibacterial agent. When the Command Module exterior had been decontaminated, all decontamination equipment and the liferafts used by the Apollo crewmen were sunk at sea.

The Command Module was retrieved by the ship, towed to the immediate vicinity of the MQF, and coupled to it with a plastic tunnel. The recovery engineer from the MQF entered the Command Module via the tunnel, removed samples and data, and completed Command Module shutdown procedures. The Command Module hatch was resealed and remained sealed until it was placed in the Lunar Receiving Laboratory in Houston.

The biomedical samples and lunar sample containers, film, data, etc., from the CM were packaged and decontaminated for return to the Johnson Space Center. The Mobile Quarantine Facility with the astronauts, one crew surgeon, and one recovery engineer was transported by the recovery ship to Hawaii where it was placed aboard an aircraft for the flight to Houston. In Houston, the MQF was taken to the Johnson Space Center and coupled to the Lunar Receiving Laboratory for transfer of crew, associated personnel, and equipment. The MQF was then sealed and placed in quarantine as authorized.

The Command Module was also subjected to reaction control system decontamination and pyro-safing in Hawaii. The CM was then transported to the Johnson Space Center where it arrived approximately five days after the astronauts.

Quarantine of Personnel

The final phase of the Apollo back-contamination program was completed in the Lunar Receiving Laboratory. The sequential flow of crewmen, spacecraft, and lunar samples is shown in figure 5. The crewmen and spacecraft were quarantined for a minimum of 21 days and were released after the completion of certain prescribed tests. The lunar sample was quarantined for a period of 50 to 80 days, depending on the results of extensive biological tests. In addition to the three Apollo crewmembers, other personnel quarantined in the LRL were two crew surgeons, a recovery engineer, medical laboratory technicians, cooks, and stewards.

During the quarantine period, the crew and their immediate contacts underwent daily medical examinations. Basic observations consisted of recording oral temperature and pulse rate, and a brief interview by the crew surgeon. Biological specimens were obtained from the crew on the twelfth and eighteenth days after lunar departure, and the crew underwent another complete physical examination on the twenty-first day. Selected microbiologic and immunologic examinations were also conducted at several points in the quarantine. The purpose of the latter examinations was to provide diagnostic information in the event of clinical illness.

Provisions were made to treat routine illness and minor injuries within the Crew Reception Area. Equipment and a small working pharmacy were available. Serious illness and injury were also to be treated onsite so far as possible. But, had any of the Apollo crewmen or support personnel become critically ill or injured, the quarantine would have been broken and the individual transported to the nearest appropriate medical facility.

In the event of a serious crew illness, a quarantine Medical Advisory Panel was available for consultation. This panel consisted of experts in various aspects of infectious disease empowered to provide diagnostic information pertinent to any release recommendation.

Release recommendations for the crew and support staff were developed by the medical staff. The medical status of both the crew and the support personnel exposed to

the crew and/or to the lunar mission equipment was taken into consideration. Technically, release of the Apollo crews might have been delayed because of illness among the support staff. This, however, never occurred.

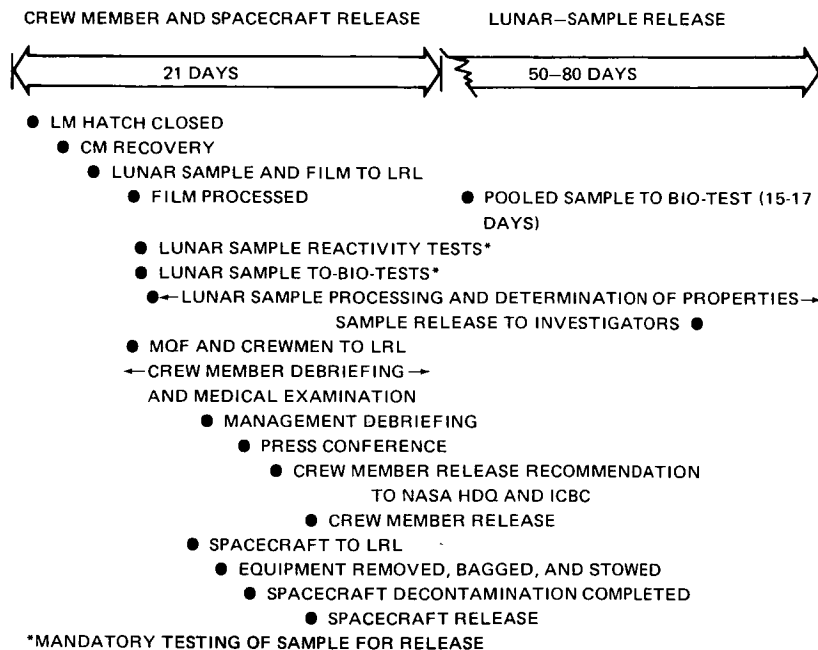


Figure 5. Apollo Back-Contamination flow chart, phase III.

To safeguard the health of LRL personnel, every worker was subjected to extensive medical examinations before each Apollo lunar mission. Because of the potential hazard of working with lunar material, a requirement was established that pregnant employees, all persons taking medication, and those requiring medical aids such as crutches, braces, or hearing aids would not be permitted to enter the secondary biological barrier. In addition, serum pools were collected from each individual who might be exposed to lunar material. The stored samples would serve as a baseline for analysis of any medical complications that might arise in the years following the exposure.

The quarantine program was in effect for the crews of Apollo 11, 12, and 14. Procedures differed very little for the three flights. The quarantine of the Apollo 11 crew was uneventful. No signs or symptoms of infectious disease related to lunar exposure became apparent in any of the crewmen or support staff. No microorganisms attributable to an extraterrestrial source were recovered from the crewmen or the spacecraft. Release of crew, equipment, and lunar samples took place on schedule.

No variations of the quarantine procedure occurred during recovery and return of the Apollo 12 crew. However, the biological isolation garments used for Apollo 11 were not

used for Apollo 12 or 14 since they proved to be uncomfortably hot during recovery operations. They were replaced with lightweight coveralls and biological masks which filtered exhaled air. No significant trends were noted in any biochemical, immunological, or hematological parameters in either the flight crew or support personnel.

The only change in quarantine procedures for the Apollo 14 mission was the use of two MQFs and two helicopter transfers of the crew and support personnel. This procedure was implemented to return the crew to the Lunar Receiving Laboratory five days earlier than on the previous lunar landing missions. No signs of illness or significant trends related to lunar material exposure were reported, and again, release took place on schedule.

Quarantine of the Spacecraft

There was no plan to decontaminate the spacecraft unless anomalies occurred during a mission that might have indicated the need for an early spacecraft release. Provisions were made, however, for spacecraft decontamination, if required. Before installing the biological barrier (door panels) on the CM, the exterior was photographed, and preparations were made for connecting the decontamination equipment. These activities were performed by non-quarantined personnel, who did not deal with "contaminated" systems. These persons then left the room in which the spacecraft was located and biological barriers were installed.

The spacecraft room contained all equipment required for decontamination of the Command Module. There were also communications and closed circuit television for monitoring and supporting cleanup and decontamination activities. Personnel from the Crew Reception Area were trained to open the Command Module hatch and remove the double-bag stowed equipment, including lithium hydroxide canisters, fecal bags, food bags, and space suits. The individual working inside the CM doffed shoe covers upon egress. All persons then reentered the CRA and showered. Thus the likelihood of contaminating the Crew Reception Area and space suit room was minimal.

Formaldehyde decontamination of the Command Module cabin and suit circuit was accomplished without reopening the hatch. Following a minimum 24-hour kill period, the hatch was opened and the cabin exhausted through the room air conditioning system. The water and waste management systems were also decontaminated with aqueous formaldehyde (formalin) for 24 hours. Spore strips were placed at random locations in the CM to verify decontamination effectiveness.

Quarantine of the Lunar Sample

The returned lunar sample was processed through a sequence of steps which resulted in the following:

1. Data upon which to base a release decision.
2. Preliminary scientific data upon which to base a sample distribution plan.
3. Portions of the lunar sample packaged for distribution to principal investigators.
4. Portions of the lunar sample sealed and protected for future experiments.
5. Time-critical experiments.

The incoming lunar material was contained in two sample return containers and one contingency bag. A portion of the sample was lunar "rock," documented as to location of collection. The bulk of the sample, however, was loose surface material, predominantly below 1 cm (.40 in.) in size. Lunar sample operations are summarized in figure 6.

On arrival at the Lunar Receiving Laboratory, sample boxes were moved through an airlock and through three decontamination chambers to sterilize the outside of the containers. They were then sent into a vacuum chamber where a technician punctured a diaphragm to draw off any gases. The sample was then passed on to a mass spectrometer to determine (1) if the interior of the boxes had been contaminated by the Earth's atmosphere, and (2) if any gases could be identified as being of lunar origin.

The boxes were opened in an environment free of terrestrial organisms. The nominal mode of operation called for opening the sample boxes in the special chamber described earlier which operated at a vacuum of 1.33×10^{-4} N/m² (10^{-6} mm Hg). An alternate mode employed the same chamber but with an atmosphere of sterile nitrogen at a pressure slightly below atmospheric. A contingency mode was to open the containers in a Class III biological cabinet. Each lunar rock and portion of fine material was examined, photographed from six different angles, and observed visually through glass ports and through microscopes. A representative sample was committed to quarantine testing. Small chips of each rock were examined for physical and chemical properties. Selected specimens were subjected to special tests, radioactivity determination. The balance of the material was sealed and protected for later use.

The preponderance of scientific work on the lunar sample was done by some 150 to 200 principal investigators throughout the world. Each investigator received a type and amount of lunar material suitable for his work and returned the residues to the Lunar Receiving Laboratory for further use by other researchers. A few of the principal investigators performed their experiments in the LRL during quarantine because of the time-critical nature of the data being sought.

Release of lunar samples was contingent upon meeting either one of the following:

1. Biological safety tests upon representative portions of the samples. These tests included: bacteriology, mycology, virology-mycoplasma, mammalian animals, botanical systems, invertebrate/lower vertebrate systems.
2. Sterilization of the sample by the use of dry heat during the quarantine period.

All protocols were designed to be completed within 30 days from the introduction of the sample to the laboratories. This was to be increased to 60 days in the event significant numbers of microbial contaminants were found in the sample. By 60 days, sufficient data would have been available to evaluate the requirement for second order testing.

Quarantine of Flight Equipment

All flight equipment exposed to lunar surface materials was placed under quarantine restrictions. The equipment included films, data tapes, logs, and other flight equipment.

Procedures for quarantine and release of the equipment were as follows:

Flight Film. Flight film was received in the Crew Reception Area and, after appropriate preparation, was passed out for processing. Film from the Apollo 11 mission

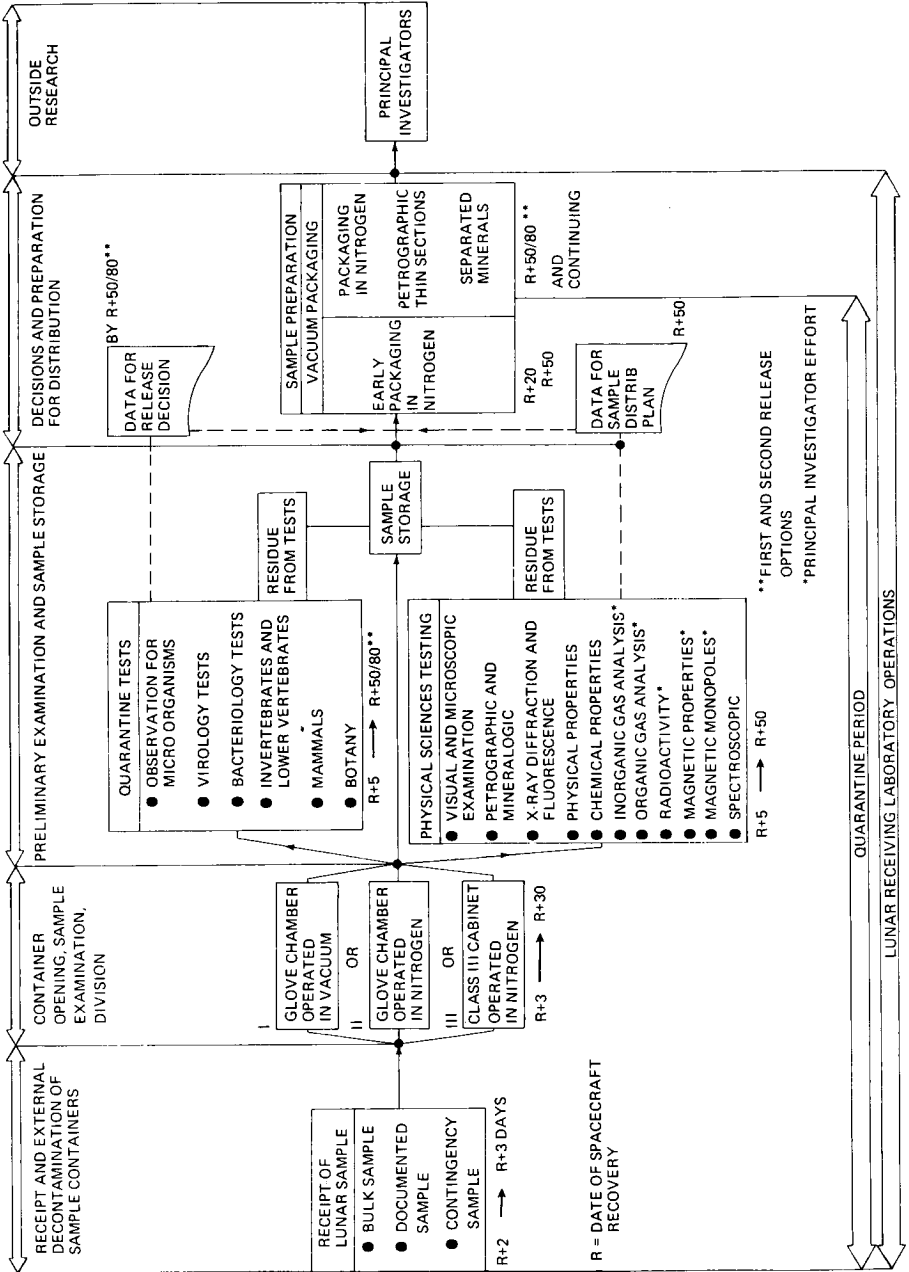


Figure 6. Lunar sample operations.

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was sterilized with ethylene oxide. After the Apollo 11 mission, sterilization of flight film was not required.

Data Tapes. Data tapes were received in the CRA and, after appropriate preparation, were sterilized using ethylene oxide gas and passed through the biological barrier. The tapes were then handled using normal procedures.

Other Spacecraft Equipment. All other items were either held in approved biological containers until the release of lunar samples or were processed using the procedures outlined in figure 7. Requirements for early release were kept to a minimum.

CRA EQUIPMENT RELEASE CRITERIA

Item	Example	Treatment
Material exposed to lunar surface or Equipment concentrating lunar material or LM equipment	Pressure suits LiOH canisters Logs	Hold until sample release or Steam sterilization or Dry heat sterilization or Peracetic acid or Hypochlorite dunk or Formaldehyde
CM Hardware (not concentrating lunar material)	Food bags Fecal bags dse recorder	As above or Ethylene oxide and release with crew
Special Cases: Data Tape Flight Film Surveyor Equipment		Ethylene oxide and release with (spore strip controls included with film/tape) Sterilization not required See text.

Figure 7. Crew Reception Area equipment release criteria.

Summary

The crews of Apollo 11, 12, and 14 experienced no health problems as a result of their exposure to lunar material. The test species, plant and animal, which were exposed to and injected with lunar material showed no adverse alterations or ill effects from exposure. Since exhaustive studies of the astronauts and returned lunar samples from Apollo 11 and 12 indicated there was no hazard to Earth's biosphere, the Interagency Committee on Back-Contamination, in January of 1970, concurred in NASA's

recommendation that stringent quarantine rules be abandoned for future Apollo missions to the moon.

To ensure that lunar material represented absolutely no danger to the Earth's environment, the quarantine program remained in effect for the Apollo 14 flight and was then abandoned. Although the formal quarantine for the crew, spacecraft, and lunar samples was over, procedures for handling lunar material and protecting it from contamination remained in effect for the Apollo 15, 16, and 17 missions. This guaranteed that scientists performing tests on the material would have uncontaminated samples.