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Ground Based Work Speeds Moon Flight

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THE TRAGEDY THAT took the lives of Astronauts Grissom, White, and Chaffee on 27 January 1967 led the National Space Agency into a period of major modification of the Apollo Spacecraft with a relentless determination to "right the wrongs" and once again place this nation's lunar landing program into high gear.

The months that followed were filled with frustration, delays, disappointments and success, culminated by the almost textbook flights of Apollo 7 and Apollo 8, which performed to all expectation with only minor exceptions. The long hours of hardware redesign, procedural changes and crew training, made even more difficult by budget "belt tightening", had paid off in tangible evidence that Apollo Spacecraft had made the difficult transition from developmental to operational status and stood poised on the threshold of being put to the rigid test of a lunar landing mission.

A Major Role

The Medical Research and Operations Directorate has played a major role in redesign of the major life support systems within the Apollo spacecraft. The basic requirements for these systems have been defined in terms of human tolerance envelopes for the environmental control system, crew couch and restraint and associated subsystems of food, water and waste management, bioinstrumentation and onboard medical supplies.

Additionally, we have defined certain medical objectives which operationally support the program goals while providing for the inclusion of medical tests which will enable us to continue to evaluate man's performance in the environment of space. Although the Apollo program is primarily operational and, therefore, not oriented toward elaborate medical experimentation, one must not lose sight of the many opportunities to gather meaningful biomedical data from carefully selected preflight, inflight and postflight evaluations on the flight crew and associated life support systems. The medical objectives for the Apollo Program are:

- To insure crew safety from a medical standpoint. The intent of this objective is to insure that, within the scope of its responsibilities, we will recognize and identify potential hazards and propose measures to eliminate or minimize them.
- To improve the probability of mission success by providing the medical information necessary for mission management. It is the intent of this objective to insure that sufficient information is available to provide the medical management necessary to attain mission objectives.
- To prevent back contamination from the lunar surface. The intent of this objective is to protect the earth's animal and plant resources from contamination by lunar exposed material and lunar samples and to insure that the duration of crew, spacecraft and sample quarantine is minimal.
- To continue to further the understanding of the biomedical changes incident to space flight. The intent of this objective is to further the understanding of biomedical changes incident to space flight and to insure that such changes as occur are detected, understood, and documented.

After careful consideration of a number of pre- and postflight medical evaluations, only those were chosen which would uphold the major medical objectives and were in keeping with the general ground rule of "non-interference with operational objectives."

The inflight biomedical data consist of one lead of electrocardiogram and respiration rate—via impedance pneumograph—from each crewman. This inflight biomedical monitoring is supplemented by voice communication and periodic crew status reporting on food and water intake, exercise periods, sleep periods and radiation dosimetry readings.

During the "hard look" redesign period in late 1967 and early 1968, a number of challenging problems of biomedical interest were uncovered.

Because of the greater complexity of the Apollo systems, the variety and quantities of nonmetallic materials used in the Apollo spacecraft are far greater than those found in either the Mercury or the Gemini spacecraft. Each of these materials was evaluated concerning its toxicological potential.

The approach to materials selection for spacecraft use has been an engineering one. Proposed materials have been offgassed at 155 degrees Fahrenheit for 72 hours in 100 per cent oxygen, the quantities of carbon monoxide and total organics released measured and a material considered acceptable if it did not release more than 20 ppm by weight of carbon monoxide and 100 ppm by weight of total hydrocarbons. This approach is gross, of course, and does not define specific potentially hazardous compounds, nor does it account for lot-to-lot and manufacturers' variations.

Over 200 Apollo materials have been examined by heating various combinations of random samples and evaluating the toxicological effects of the resulting offgassing products on mice and rats.

Craft Checked Out

Ethylene glycol, used as a heat-exchange fluid, has been studied for its toxicological effects in the event of a leak in the cooling system. After extensive animal testing to establish basic parameters for safety, human volunteers were exposed to the glycol aerosol and vapors. These volunteers were closely followed for gross effects, changes in blood chemistry indicating renal damage, personality changes, and psychomotor changes. On the basis of these observations, we were able to establish safety and abort conditions for the Apollo missions.

Finally, to minimize the potential hazard resulting from lot variations, late changeouts, and possible inadvertent use of an unsatisfactory material, the medical directorate had required evaluation of the atmosphere of the completed spacecraft during the unmanned and manned testing in the altitude chambers prior to mating the spacecraft with the vehicle. To date, three spacecraft have been checked out successfully. Although as many as 42 contaminants have been detected, their levels have been extremely low (parts per billion) and do not constitute a toxicological hazard.

A decision was made to reduce the probability of fire on the pad by diluting the 100 per cent oxygen atmosphere under slight over pressure to a 60 per cent oxygen, 40 per cent nitrogen environment for the command module, with 100 per cent oxygen supplied to the suit loop only. While the data indicated that a nitrogen enriched environment lessened the chance of uncontrollable fire, it also introduces the medical concern of possible decompression sickness with cabin pressure reduction if the crew is exposed to the nitrogen. There is a medical requirement for the crew to prebreathe 100 per cent oxygen for a minimum of three hours prior to launch in order to accomplish denitrogenation to a point which would eliminate or reduce the probability of decompression sickness when the cabin pressure is reduced from 14.7 psia, even if an emergency should result in a pressure drop to 3.75 psia—the emergency pressure provided to the space suits. Denitrogenation is specific to individuals and the time required to denitrogenate is dependent on body mass, age and body lipid content. Recent studies have indicated that three hours prebreathing of 100 per cent oxygen covers a broad range and eliminates sufficient nitrogen to reduce the probability of bends to an acceptable level.

Oxygen Purge

From the launch environment of 60-40, the cabin bleeds down through the cabin dump valve and the waste management valve during ascent to orbital insertion with shutoff at a cabin pressure of 5.8 psia. A constant purge of 100 per cent oxygen will allow cabin replenishment in a pre-determined time. In Apollo 7 the crew was able to doff helmets and gloves in 45 minutes after launch and totally remove the suit some eight hours later.

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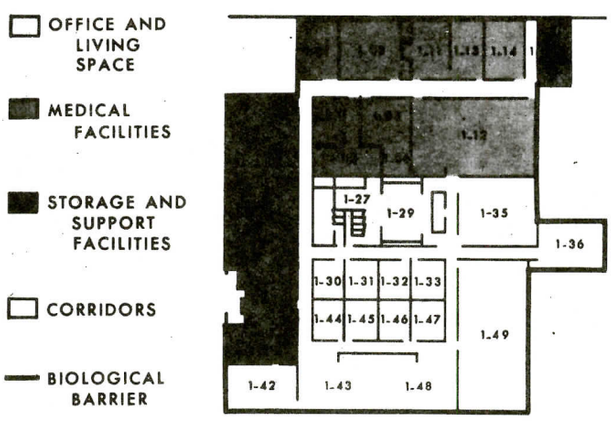
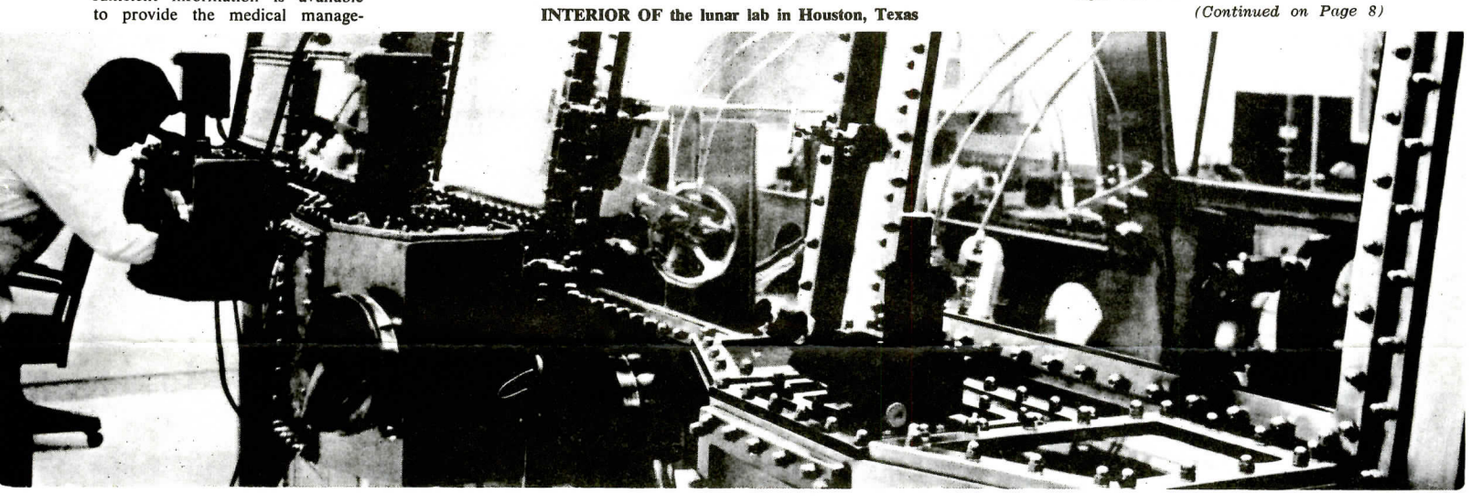


RETURNING LUNAR astronauts will use the crew reception area depicted above.

INTERIOR OF the lunar lab in Houston, Texas



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In order to prevent bacterial contamination of the potable water by migration of bacteria from the waste water system through interconnecting valving, a syringe injection system is incorporated to provide for daily injection of chlorine. The chlorination procedure is so designed as to insure a minimum of 0.5 mg/1 chlorine residual in the water at the end of each 24-hour period. The maximum chlorine concentration expected from this dosage schedule is about 6 mg/1. There is a medical requirement within the program to provide the crew with sterilized water. Before the launch, water is loaded into the spacecraft, the entire water management system is thoroughly flushed with deionized, microbially filtered water containing 20 parts per million chlorine.

'G' Force Tolerance

Man's tolerance to G forces has been defined in the Apollo program as nominal (those levels where no performance decrement or injury is expected) and emergency (those levels with no resulting decrement in pilot performance). In the case of a launch abort, it is expected that the G-loads in all directions would be within the emergency limits. The principal concern for human tolerance to dynamic force rests with impact loads. If the couch strut attenuation system performs to specification, the impact G-loads should stay within the nominal limits.

Prior to our first manned launch, analyses indicated that a "worst case" condition of failures could produce a 1 per cent probability of the crew's experiencing impact forces in the emergency limit zone. Data indicate that even in this 1 per cent probability area, man would have a better than 50 per cent chance of survival. The Apollo impact limits closely approximate those established for ejection seats in high performance jet aircraft.

Since two separate couch systems have been designed for use in the command module, continuing analysis of impact loads is necessary.

It should be noted that the Apollo 7 where some injury can be expected).

Measurement of G forces from unmanned tests have shown that under normal launch and ascent to altitude the G forces on a crew will be well within the human tolerance envelope crew reported an almost ideal impact with minimal G forces resulting and have even characterized it as a water landing rather than water impact.

21-Day Quarantine

Based upon the requirements developed by the National Academy of Sciences, the returning lunar crewmen, the lunar samples and certain flight hardware items will be subjected to quarantine during the postflight period. This requirement is to assure that the lunar crew and sample materials will not adversely affect our terrestrial life forms. For the crew members, this quarantine will be for 21 days, beginning with the time of ascent from the lunar surface. From the prime recovery vessel, the crew members will enter a mobile quarantine facility for transport to the Lunar Receiving Laboratory where they will enter the crew reception area which serves as quarters for the crew and alternate physicians and technicians. Additionally, the lunar samples will undergo extensive analysis to assure that they contain no infectious disease agent for man, plant or animal.

The planning and staffing for the LRL has created some new and interesting challenges in logistics as well as evaluation procedures to assure that a returning lunar crew will have no potential for infecting the terrestrial life forms with disease agents.

The successful Apollo 7 flight has provided the first step in a long awaited flight program. Its degree of success has been measured, and considered adequate in committing the second manned flight to the most ambitious space mission ever undertaken by man, a lunar orbit mission. The medical community at NASA continues to build a level of confidence in its understanding of man's ability to perform in the space environment which one day 'ere long' will permit us to give a "go" for the lunar landing mission.