ROLE OF THE SCIENTIST-ASTRONAUT

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To describe the role of a scientist-astronaut will require at least a few words describing who these people are, and to suggest that they are not the "fish-out-of-water" some may mistakenly believe. The Astronaut Office has two groups of astronauts selected primarily on the basis of their past experience in scientific or medical research and practice. Of these 13 men (who comprise about 25 percent of the Office) only one was jet qualified at the time of selection. The other twelve completed the standard Air Force pilot training program, and the first group now has jet time in excess of the minimum requirement for selection as a pilot-astronaut. The second group will pass this 1,000 hour mark in the next year or so. All medical and proficiency standards are the same for all members of the Office.

Their experience prior to joining NASA has been in areas important to the manned space program. Four are M.D.'s, with special interests in human physiology, body chemistry and flight medicine. Others are Ph.D.'s, trained in geology and in geophysics with emphasis on lunar studies, or astronomy, engineering, and physics, the latter being areas of major Skylab experimental activity.

Most of my time will be devoted to describing the work assigned to scientist-astronauts and to illustrations of its value to the manned space flight program. Some of these tasks are similar to those undertaken by any other astronaut. In particular, the hardware design reviews of the very large and complex space systems for Skylab to assure manned compatibility and adequacy have taken many hundreds of hours in the schedule of each of the 20 astronauts now working on the program. However, there are many tasks in both the mainline Apollo program and in Skylab in which previous medical or scientific experience has been a major asset.

For example, in the flight planning and training for every lunar flight, our geologist and geophysicist have made important contributions to the mission, made possible by their familiarity with both the scientific objectives and the capabilities and limitations of the crewmen.

We (meaning one or more of the scientist-astronauts) have been closely involved in the pre-flight training for lunar site inspection and photography and for landmark identification during the final phases of powered descent. A new concept, developed to focus crew and mission control training efforts, was to pre-plan and study several standard traverses around the intended landing sites. The precision landing which was accomplished by Apollo 12 allowed the use of one such traverse, so that their brief time spent on the surface was utilized most efficiently for the objectives of field geology and sampling.

It was also established that the Command Module Pilot in solo orbit for almost 48 hours would have adequate time and an excellent opportunity to make additional lunar observations. Our geologist played a leading role in the development of an "Orbital Science Program" to take advantage of this opportunity. In fact, the major responsibility for the development and management of all science training has rested with the scientist-astronauts since specific mission training for Apollo 8 began.

As the number of scientific experiments began to grow, the impact on crew operations correspondingly increased. First, a "single point-of-contact" was established in our office, through which all scientific requirements on the crew were channeled. This grew into the post of "Mission Scientist," whose responsibilities included acting for and representing both Flight Crew and Science Directorates in their contacts with the science community. His responsibilities extend to assuring that all approved scientific objectives are met through training, hardware development, and flight planning. We believe that this led to a significant improvement in our working relationship with the science experimenters and will allow us to better accomplish the objectives of the experiments assigned to flight.

The qualification of men for long duration space flight is one of NASA's principal objectives, and the medical profession is closely involved in this effort. The traditional reserve observed between the medical and piloting professions leads to some difficulty in designing the experiments necessary to establish the effects of a long term zero-g environment on man without unduly constraining either the body or the time of the flight crewman. Having within our office several qualified medical doctors has allowed us to critique proposed procedures from a professional standpoint, and at the same time, given us additional confidence that the final protocol is necessary and valuable to the scientific objectives. A few examples are:

a. Efforts to secure improved electrodes for vector-cardiogram measurements, so that they can be donned and doffed quickly and easily and not permanently attached to the subject.
b. A convenient and simple device to measure the body mass, based on the principal of timing the period of oscillation of a body-spring assembly. One of our group has conceived and acted as Principal Investigator for this experiment.
c. Exercise devices are currently in work to help maintain muscular as well as cardiovascular condition during long exposure to zero-g.
d. New methods of establishing changes in protein and mineral balance based on simple pre- and post-flight examination only, rather than difficult and time consuming measurements in-flight of all food intake and waste product quantities.
e. After the Apollo fire in 1967, a launch atmosphere had to be identified which minimized flammability, was physiologically safe, and required minimum crew procedures after launch. One of us served as a member of the team which identified the optimum gas mixture (60 percent O_2, 40 percent N_2), the procedures,

and then tested these procedures in the Apollo thermal vacuum test spacecraft (2TV-1).

Let's turn for a few minutes to the areas of experimentation in Skylab. They can be conveniently grouped into four categories: medical, solar astronomy, earth resources, and smaller, individual experiments, which we have called "corollary" experiments.

Within the medical category, a major objective is to establish the way in which zero-g affects the mineral balance and body chemistry. Loss of calcium from the bones is of particular concern. Daily body mass determinations will provide an excellent, real-time estimate of changes in body fluid volumes. Shifts in body fluid volumes contribute significantly to the "deconditioning" seen in zero-g.

A bicycle ergometer will be on board to measure the variations in heart rate required to deliver a specified rate of work, simultaneously measuring the O_2 consumption and CO_2 production rates. Another experiment uses a "Lower Body Negative Pressure" device to draw a slight negative pressure (less than 50mm Hg) on the lower half of the body to simulate the effects of a gravity field. In this way, any cardiovascular deconditioning may be discovered while still in flight; prevention or corrective measures could be taken, if found to be necessary. Other major medical objectives include establishing the effects of zero-g on the inner ear or "vestibular function" and the recording of vector-cardiograms during certain activities. The full scope of medical experimentation is clearly far larger than it has been possible to undertake within the Gemini or Apollo space flights. Our medically trained astronauts have had the responsibility of following the development of hardware and in-flight procedures for all these experiments.

The second major area of research in Skylab is Solar Astronomy. Mounted within a large canister called the ATM (for Apollo Telescope Mount) are eight individual telescopes, nearly ten feet long, intended to examine the sun in fine detail at nearly all wavelengths between the visible region and X-ray. In the visible range, it will be possible to examine the surface details of the chromosphere (a layer just above "white" disk visible to the eye) with greater resolution than from the earth's surface, where the variable refraction in our atmosphere blurs the image and incidentally also produces a star's twinkling. Also, we will see the sun's corona out to about six solar radii, a far better view than from the earth, even at times of a solar eclipse. Three other instruments explore the extreme ultra-violet radiation, which is responsible for the production of the ionospheric layers essential to high frequency radio communications circuits. Two other instruments extend the observations to shorter X-ray wavelengths to examine radiation from active regions in the solar atmosphere and the sudden bursts of energy produced by "flares" which may disrupt our communications circuits and even fill the interplanetary medium with potentially dangerous energetic protons.

The size of these instruments allows the sun to be examined with far better spatial resolution than has been possible before. A resolution of two to five arc seconds is expected with several telescopes, which will be an improvement by greater than a factor of ten over previous observations. Most important, there will be a period of five months in which man can exercise his judgment in the operation and evaluation of data collection. There are several transient solar phenomena (flares, eruptive prominences, filament motion, perhaps coronal changes) in which real-time decisions will be essential to the successful conduct of the experiments.

We have had a great deal to do with the interface between these instruments and the flight crew. For example, we now have a means of viewing the corona on a television image, which was not originally included in the experiment. It will allow the operator to examine the corona for interesting detail prior to the expenditure of film to record the view and to assure that no contamination products from the spacecraft are spoiling the photography. We have added a radio noise monitor to assist the crew in establishing that a significant solar flare is underway, before any expenditure of the very limited (in some cases) amount of film. Perhaps most important is the Controls and Displays panel itself, which has involved the efforts of almost everyone in the Skylab Office, but especially those most familiar with the scientific objectives.

While looking at this panel, it is important to note that half of the electrical power system (fed from the ATM solar array) and the entire attitude control system for the Skylab is controlled from this panel. Perhaps sadly, you may note there are no hand-controllers; only switches, meters, and a computer key board with which to control vehicle attitude. It seems very likely that virtually all future space stations will rely on momentum wheels for basic attitude control, and these are our first steps in that direction.

The third major area of experimentation on Skylab is in Earth Resources. One experiment examines the appearance of crops, forests, varied terrain, and water conditions in a variety of spectral ranges. Other experiments will examine the IR "signatures" of a number of specific locations for comparison with ground and aircraft data. Radar "scatterometer" measurements are also included. Astronauts with previous experience in physics and earth-sensing experimentation have been particularly effective in monitoring the crew interface with these experiments, assuring that we will be able to accomplish the scientific objectives in the available time.

The fourth major area is that of the smaller, individual "corollary" experiments. I'll not have time to discuss each of these, but should point out that there are over 30 to be performed on Skylab and, in most cases, one of the scientist-astronauts has the Office responsibility for following its development.

Finally, it is appropriate to comment on the time available for the conduct of these experiments on the Skylab flights. I hope I have left you with the impression that medical, technological, and scientific research is the major goal of our Skylab activities. To meet a major goal requires a corresponding commitment of crew time. Very roughly each man will spend about eight hours/day sleeping, eight hours/day in eating, housekeeping, and systems monitoring, and the remaining eight hours/day in activities related to the experiments I have discussed above. This is a very substantial commitment and a far larger one than it has been possible to make to medicine and science in any previous manned flight program.

Although I have stressed here the ways in which their experience prior to NASA selection has enabled scientists to contribute most effectively to the manned space flight program, it is equally important to be aware of the extensive cross-training accomplished by all members of the Astronaut

Office. Not only do all the scientist-astronauts maintain flight proficiency and class-one medical standards, but all members of the Office participate in hundreds of hours of lectures, briefings, and field trips concerning the scientific objectives of their flights. After five years or more of working together in preparation for a flight, the degree of homogeneity across the Office may be at least as remarkable as the individual differences in background training.

Summarizing briefly, scientist-astronauts have filled almost all posts within our office, including support crew and back-up crew assignments, Mission Scientist, and Cap Comm for main-line Apollo flights; they have acted as Principal Investigator or Co-Investigator on various scientific and medical experiments to be performed on Skylab missions. They have made use of their previous experience in contributing to the design of Skylab electrical and attitude control systems, medical experimentation, and in the design of the manned interface to the major scientific instruments such as the ATM solar telescopes. The one major omission in this list is that of a prime flight crew assignment, and we are waiting anxiously, if not very patiently, to fill this slot as well.