ASTRONOMY FROM THE MOON: A LOGISTIC APPRAISAL

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ABSTRACT

A methodology is available for quantitatively evaluating the implications of superimposing scientific requirements on an existing or planned supply support system for space operations. For one application, a detailed scenario was prepared for an astronomical research program that culminates in the establishment of a lunar-based observatory. The scientific requirements of this scenario were then added to the basic requirements for the construction and operation of a manned lunar base over an eight-year period. The numerical results indicate that such a research program is logistically feasible and could be conducted during the next decades. Further analysis suggests that future scientific space missions, in other disciplines as well as in astronomy, can fruitfully be planned in terms of weights and dimensions orders of magnitude larger than those of today.

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In a recent study (1), a mathematical model of space operations was utilized to investigate the logistic feasibility of establishing an astronomical observatory on the moon. The model (2) is a remarkably flexible tool for planning and critically evaluating the logistic requirements and constraints of conducting various space missions. It can be programmed to find and describe a realistic operation schedule, taking into consideration such diverse aspects as capabilities of launch vehicles, delivery of equipment in the required sequence during a desired time span, shielding weights and storage provisions for perishable supplies, and many, many more. One of its unique applications is the possibility of comparing quantitatively such alternatives as attaining a specific scientific objective by means of a lunar base or with an orbiting laboratory, by means of manned operations or with unmanned spacecraft.

In this report, we present a brief analysis of those results of our earlier study that pertain to the conduct of a program of astronomical research on the moon. To utilize fully the inherent capabilities of the space-base supply-system model, the scientific program to be evaluated had to be developed in realistic terms. For this purpose, a detailed scenario provided for a possible time sequence of events, starting with the present pre-Apollo period of space research, continuing with circumlunar Apollo flights and landings, and eventually culminating in a semi-permanent lunar base which includes an astronomical observatory of substantial research capabilities.

The scenario had to specify in detail--and in a reasonable time sequence--the basic astronomical equipment, instrumentation, and supplies, needed to conduct a meaningful scientific program during and beyond this period. These scientific/requirements were then superimposed on a supply support system that provided for the establishment and operation of a manned lunar base over an extended period, commencing at some unspecified future date in the 1970's.

We shall limit our discussion to an analysis of the results of one specific computer run that had the following input characteristics: Starting with year zero, the time of the first landing of personnel for permanent occupancy, a manned lunar base was to be established and maintained for an eight-year period by a personnel compliment of six people. All supplies needed to support the base were specified in terms of supply modules compatible with the Saturn V launch system. These modules included such items as shelters, roving vehicles, power units, engineering maintenance equipment, food, water, clothing, hygiene, and similar life-support units. A set of some 150 astronomical modules was added that contained all the equipment and instrumentation designated by the scenario. This astronomical equipment ranged from simple occultation devices, chronometers, and recording instruments to all the equipment and supplies necessary for the operation of major astronomical facilities of increasing complexity, called for by the scenario.

The output of the mathematical model provided a detailed launch and delivery schedule for getting the supplies to the lunar base in the right sequence within the required times, with the specified vehicles, subject to such limitations as weight and volume capacity of each vehicle, rate of supply, number of available launch pads, and maximum and minimum permissible intervals between launches. Iterations could be continued by varying various requirements until a suitable schedule was found for the desired plan of operations. The basic logistic result of the computer run analyzed here is schematically summarized in Fig. 1. Equipment and supplies with a total weight of 555,000 pounds were landed on the moon within a period of seven years. Of this total, 106,000 pounds consisted of astronomical modules containing equipment and instrumentation, 38,000 pounds represented expendable scientific supplies, and 6,000 pounds were reserved for unspecified instrumentation. The derived schedule demanded 23 launch vehicles to perform this task. A comparative computer run indicated that this was 7 vehicles more than required to maintain and operate the manned base without astronomical equipment over the same eight-year period.

This launch operations schedule does not include the additional man-rated vehicles to transport the base personnel to and from the moon. However, the uneven rate of equipment delivery, noticeable in Fig. 1, is related to provisions for personnel safety and desirable personnel rotation requirements.

Let us now see what this logistic expenditure would provide for in terms of scientific research. The potential value of the moon as a site from which to perform astronomical research has received considerable attention in recent years (3). On the other hand, there have been frequent discussions of the advantages and disadvantages of a lunar observatory compared to existing earth-based and potential earth-orbiting observatories. These arguments will not be repeated here.

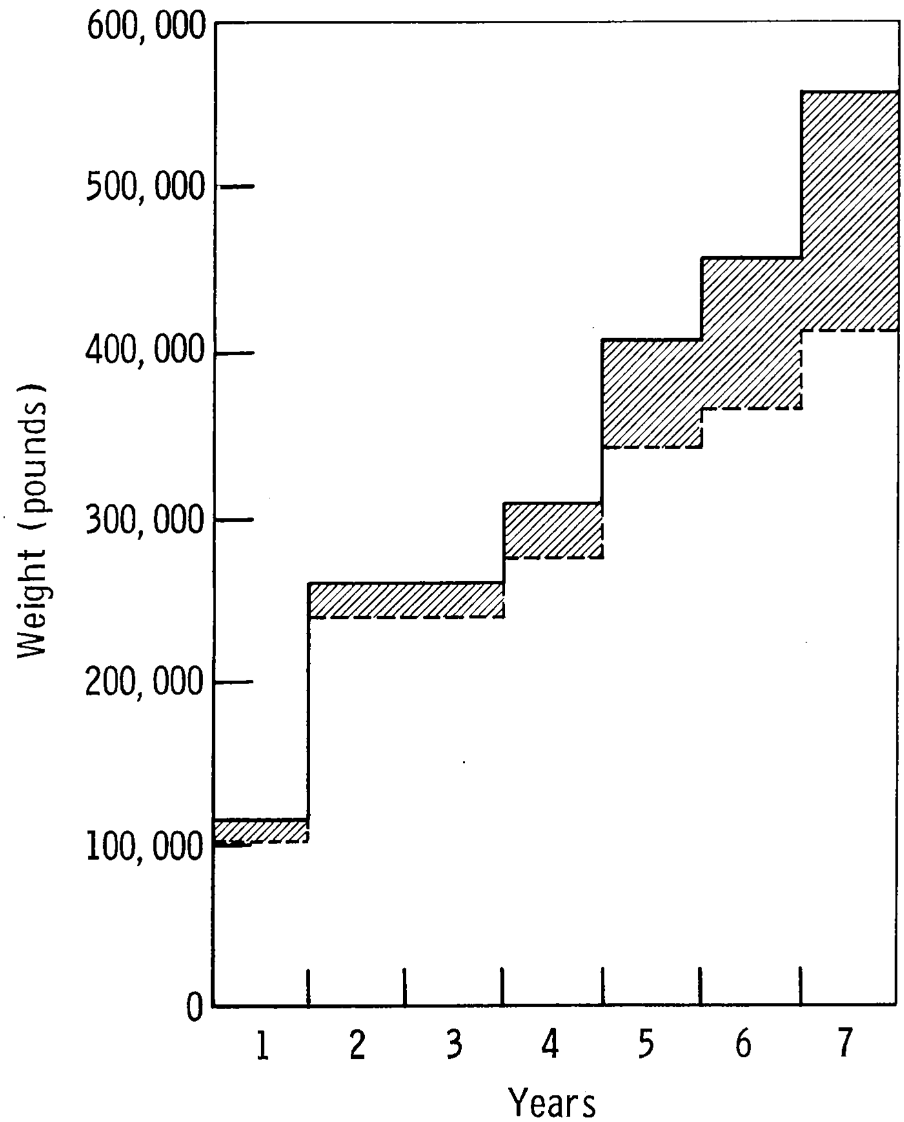

Fig. 1 -- Cumulative delivery of equipment and supplies at a lunar base in years after time of first landing of personnel for permanent occupancy. Total weight provides for construction and operation over an eight-year period with a six-man staff in residence. The shaded portion represents astronomical equipment, instrumentation, and scientific supplies.

Since we are dealing with long-range planning rather than with the instrumental details and scientific objectives of a single payload, it would appear more important to look at the potentialities of advancing the science of astronomy as a whole (4). Hence, we did not pre-plan in our scenario the discoveries to be made by a program of astronomical research on the moon (5). Rather, we concentrated on an examination of the basic instruments and facilities that could be erected advantageously on the moon, thereby allowing for maximum freedom of choice for the actively interested experimenter to conduct, or have conducted, the astronomical studies he wishes to pursue--for years in the future.

An indication of the research opportunities thus provided is given in Table 1, which is a chronological listing of the arrival times of some of the major astronomical equipment at the lunar base. In addition to the listed items, a complete array of supplementary equipment such as measuring engines, blink comparator, image converters, and dark-room facilities, was contained in the astronomical supply modules. With this computer run, however, we did not examine the assembly restraints imposed by the lunar environment in conjunction with the number of persons available for construction. Thus, operation and full use of all the available instrumentation will realistically start only sometime after assembly and testing have been completed. For example, operation of such major pieces of equipment as the 60-inch reflector telescope and the large parabolic radio dish will depend on research plans for the lunar base beyond the initial eight-year period considered here.

Table 1

DELIVERY TIMES OF MAJOR ASTRONOMICAL EQUIPMENT AT LUNAR BASE

Equipment	Year*
Meridian transit circle	1
Reflecting telescope, 10"	1
Schmidt camera	1
Coronagraph	1
Radio astronomy net	1
Reflecting telescope, 36"	2
Infrared spectrometer	2
Coudé spectrograph	4
Astrograph, 10"	5
Solar telescope, 40"	5
Spectroheliograph	5
Infrared telescope	5
Parabolic radio dish, 28'	7
Large reflector, 60"	7

*Year of base operations during which the last part needed to make the equipment complete is delivered. Note that partial assembly can commence earlier, but full activation and use will realistically start only sometime after assembly has been completed.

For the initial question asked, namely the logistic feasibility of astronomy from the moon, the study provided a clear answer: Such a scientific program culminating in the construction of a lunar-based observatory is well within the constraints imposed by the logistics of presently planned spacecraft, boosters, and launching facilities. Further, such an observatory could be established, without any unrealistic logistic requirements, as part of a semi-permanent, manned lunar base during the 1970's and 1980's.

Still, the numerical results, mentioned here only briefly, should not be interpreted as though they represented a proposed program of research. Rather, they must be viewed primarily as one application of a methodology that permits quantitative comparisons of the logistical aspects of alternative or complementary space missions of the future. On the other hand, our analysis revealed important implications for future space research in general.

For example, one may argue the relative scientific merit of doing astronomy from a lunar observatory, from a 200-inch telescope in earth orbit, or at earth-based facilities (6). Yet prior to our study, we were not able to estimate even remotely whether a 60-inch telescope on the moon was a logistically realistic task for this century or for the next.

In a wider sense, the specific astronomical program opportunity investigated clearly indicates that space missions of the future will present scientists of all disciplines with a different set of operational parameters. Whereas today we deal in ounces and inches when designing instrumentation for the exploration of the solar system with space probes and satellites, the launch vehicle systems of tomorrow will permit thinking in terms of scientific equipment that may weigh tons and measure yards.

For years to come, of the equipment conceivably called for, by any scientific discipline, to be placed in space, that called for by astronomy is probably the bulkiest. As we have shown, even a large lunar-based astronomical observatory could be established within the next decades. To obtain an indication as to whether similar scientific desires in other disciplines are compatible with logistic and economic realities, the methodology employed here should be a useful tool.

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