

2. PLANNING OF SCIENTIFIC AND TECHNICAL EXPERIMENT

PAYLOADS FOR AAP

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GILL: We will now go into the second talk by Dr. T. A. George. Dr. George deals with experiments in the Earth orbital mission studies.

GEORGE: The purpose of this presentation is to cover the present status of our experiments program, including a discussion of how manned space-flight experimentation has evolved over the years, finally resulting into the concept of the Apollo Applications Program (AAP). Also, I propose to discuss some of the management problems which we face in organizing a major program of this type, together with some of the tentative solutions arrived at. I wish to emphasize the word "tentative," because in view of the formative stage which the AAP is in at present, none of our solutions are frozen. I will avoid engineering details of the Apollo hardware, which have already been covered by Mr. Taylor and, also, I will avoid the specific details of bioscience experiments under consideration by NASA, a subject which will be discussed by Dr. Gerathewohl in a later paper.

As you are all aware, the purpose of AAP is to conduct experiments in space. This is a broad statement which really does not convey a clear picture; consequently I would like to elaborate. The experiments which we visualize for AAP fall into three general categories: science, technology, and operations. The scientific experiments will be aimed at advancing our knowledge of the laws of nature, and the composition and history of the universe, with special emphasis on the Earth and our solar system. We visualize important byproducts resulting from this effort, including a better utilization of natural resources. Technological experiments will serve to obtain a quantitative understanding of the influence of the space environment on materials and functional components, and for testing advanced developments under actual space-flight conditions. Further, to develop through precursory experiments the space technology required in direct support of scientific experiments. Operational experiments will be aimed at building up the operational capability of the manned spacecraft complex in direct support of technological experiments. These are the general categories. Now let us go into the specific experiment areas.

The list below is a breakdown of the general categories into individual disciplines for which we are considering experiments. Also, NASA is always prepared to provide assistance to other agencies and departments. On the last line, a category for requests from the Department of Defense has been reserved.

Our present plans for conducting experiments in space as part of the Apollo Applications Program are strongly influenced by the capabilities of the AAP system to support such experiments, by our past experience in conducting experiments, and by the overall evolutionary processes in space exploration. First, let us examine how the capability has changed, since the days of Mercury, into the projected AAP system some 10 years later.

Space science and application:

Astronomy/Astrophysics

Bioscience

Physical science

Atmospheric science

Communications and navigation

Earth science and resources

Lunar surface exploration

Lunar orbit

Advanced research: Advanced technology and supporting research

Manned space flight:

Biomedicine/behavior

Extravehicular engineering

Operations techniques

Advanced subsystems

DOD: All types of supporting experiments

Table I includes some of the more important features which affect the spacecraft capability for conducting useful experiments. However, table I does not tell the complete story. For example, we might recall from Mr. Taylor's paper that with the help of the Apollo system it will be possible to place substantial payloads into polar and synchronous Earth orbits as well as into lunar orbits—and finally onto the lunar surface.

Briefly let us review what has been accomplished in the realm of experiments carried out by manned spacecraft. This is synonymous with describing our experience with manned space experimentation. However, first, I would like to give you a feel of our prediction as to how this effort will grow.

Table I. —Comparison of Spacecraft Capabilities for Conducting MSF Experiments

Program	Standard spacecraft payload (lb)	Volume		Power, kw-hrs	Astronaut man-hours for experiments ⁴	Maximum duration, days
		Pressurized, (ft ³)	Unpressurized, (ft ³)			
Mercury	<100	<1	<1	16.5	25	3
Gemini	340	<1	~150	12.8	260	14
Apollo	3000-70 000	CM ---- 3	0	⁵ 1000	390	14
		SM ---- 0	210			
		LEM --- 20	17			
		Total -- 23	227			
Apollo application	3000-70 000	CM ---- ¹ 50	0	⁵ 3200	³ 1250	45
		SM ---- 0	210			
		LEM ---247	1500			
		Total --297	² 1710			

¹With a crew of 2.²May be as high as 5000 ft³ if LEM is omitted.³Based on crew of 3.⁴Based on 40 percent of total time for experiments.⁵Does not include 1500-W reserve fuel cell.

Table II is a statistical breakdown of past and future experiments. The Mercury experiments have, of course, been completed already. In the case of Gemini, some of the experiments have been completed while others are scheduled for future missions. In the case of Apollo, approximately one-half of the proposed experiments identified so far have received formal approval. As far as the AAP experiments are concerned, we must recognize that they are all still in the very early development phase. In fact, some have not progressed beyond the preliminary concept stage.

Table III includes a list of experiments completed during Mercury, and the degree of success attributed to each. Unfortunately, time will not allow me to go into more detail on these experiments. In fact, when we reach the AAP plan, it would not be meaningful to list all of the titles. However, you should be aware that detailed information about completed experiments has been published in most instances, and as far as the biological experiments planned for the future, these will be discussed by other speakers.

Table IV shows the experiments completed to date as part of the Gemini program. I should mention at this point that it is our intention to hold symposia covering the results of experiments as soon after each flight as possible. The first such symposium was held in October and covered the experiments on board GT-3 and -4. These papers were published in a single volume which is available to you upon request to NASA.¹

Table V shows the experiments still scheduled for future Gemini flights.

¹"Manned Space Flight Experiments Symposium, Gemini Missions III and IV," NASA. Held in Washington, D. C., Oct. 18-19, 1965; 236 pp.

Table II. —MSF Experiment Program by Area

Experiment area	Mercury	Gemini	Apollo	Apollo application
Astronomy/astrophysics	3	4	8	12
Bioscience	0	4	2	18
Physical science	2	9	4	26
Atmospheric science	1	2	1	14
Communications and navigation	0	3	0	9
Earth sciences and resources	3	1	1	24
Lunar surface explorations	0	0	16	65
Lunar orbit	0	0	0	20
Advanced technology and supporting research	4	2	0	38
Biomedicine/behavior	5	8	13	23
Extravehicular engineering	0	0	0	18
Operations techniques	0	0	1	12
Advanced subsystems	0	0	1	6
DOD support	0	15	2	0
Total	18	48	49	285

Table III. —NASA Mercury Experiments Program

Experiments	Flown on No.	Success	Astronaut man-hours required
Tethered balloon	7 and 9	partial	0.2
Flashing light	9	yes	0.7
Radiation level measurement	8 and 9	yes	1.6
Micrometeoroid study	9	yes	
Terrain photography	8 and 9	yes	2
Weather photography	7, 8, and 9	yes	2
Horizon definition photography	7 and 9	yes	3
Zodiacal light photography	9	no	3
Ablation materials	8	yes	
Zero-G water ball	7	yes	
Airglow green filter	6	yes	
UV photography	6	no	
Orbital speed reentry	6	yes	
Observation of ground lights	7, 8, and 9	yes on 1 flight	0.3
Xylose absorption test	6	yes	0.05
Calibrated exercise	6-9	yes	0.1
Tilt-table studies with flack test	9	yes	
Evaluation of hormonal output (steroids, catecholamines)	6-9	partial	

Following is a list of experiments approved by MSFEB for Apollo.

Subcritical cryogenic storage	In-flight nephelometer
Radiation in spacecraft	Cardiovascular conditioning
Simple navigation	In-flight phonocardiogram
Synoptic terrain photography	Bioassays body fluids
Synoptic weather photography	Bone demineralization
Frog otolith function	Calcium balance study
Zero G—single human cells	Human otolith function
Trapped particles assymetry	Cytogenetic blood studies
X-ray astronomy	Exercise ergometer
Micrometeorite collection	Metabolic rate measurement
UV stellar astronomy	Pulmonary function
UV/X-ray solar photography	Lower body negative pressure

As indicated previously, this represents only about one-half of those contemplated for the entire Apollo program.

Now to move on to the AAP. Instead of listing all the experiment titles, table VI shows a breakdown of the number of experiments being considered in each discipline, together with the present status of these experiments. What I hope this table will convey is that the AAP experiment program is still in the early stage of development. Relatively few of the experiments have reached the design phase. In fact, NASA would welcome any additional proposals or general ideas as to experiments which should be taken into consideration for future AAP space missions.

Now to delve into some of the management planning aspects of the AAP experiment program. First, I should state that it is our firm intention to treat each and every experiment as an independent entity. That means that each experiment will have a principal investigator

Table IV. —NASA Gemini Experiments Program (Conducted)

Experiment	Flown on No.	Success
Astronomy/astrophysics:		
2-color Earth's limbs photos	4	yes
Zodiacal light photography	5	yes
Bioscience:		
Sea urchin egg growth	3	no
Visual acuity	5	incomplete
Radiation zero G on blood	3	yes
Physical science:		
Electric charge	4 and 5	yes
Triaxis magnetometer	4	yes
Proton electron spectrometer	4	yes
Atmospheric science:		
Synoptic weather photography	4 and 5	yes
Cloud top spectrometer	5	incomplete
Earth sciences and resources:		
Synoptic terrain photography	4 and 5	yes
Communications and navigation:		
Reentry communication	3	yes
Biomedicine/behavior:		
Cardiovascular conditioning	5	partial
Bone demineralization	4 and 5	yes
Inflight exerciser	4 and 5	yes
Human otolith function	5	yes
Inflight phonocardiogram	4 and 5	yes
DOD support:		
8 DOD support experiments		

who will be in direct contact with all aspects of the experiment from its initiation through to completion. This approach is not contradictory to the concept of a centralized flight laboratory capable of serving the needs of several experimenters simultaneously. The objective of the experiment is to obtain data under carefully controlled conditions specified by the experimenter so that he and his associates can study these data and arrive at meaningful conclusions. But this requirement does not imply that the same instrument or set of instruments cannot secure data which would be equally useful to several independent investigators.

I will give an example of this situation which arose during the Gemini flights. Numerous photographs were taken which were of equal interest to oceanographers, geologists, and geographers. Obviously, a single camera was sufficient to satisfy these multiple requirements. It is NASA's responsibility to insure that all these interested groups receive the data which are relevant to their fields of research. At the same time we must insure efficient and economical management of the entire program. Early recognition of equipment commonality is an essential element to meet these objectives. To handle this problem and to prevent incompatibilities between experiments, a carefully planned integration process will be established as stated by Mr. Taylor. As part of this effort, it will be necessary to identify all equipment requirements for the various experiments as early as possible. This will allow prompt identification of equipment commonality and prevent unnecessary expenditures and redundant equipment development. Figure 1 is a dramatic example of how expenses can be

Table V. —NASA Gemini Experiments Program (Planned)

Experiment	To be flown on flight No.
Astronomy/astrophysics:	
Zodiacal light photography	8, 9, and 10
Airglow horizon photography	9, 11, and 12
UV astronomical camera	10, 11, and 12
Bioscience:	
Frog egg growth	8
Visual acuity	7
Physical science:	
Triaxis magnetometer	7, 8, and 12
Bremsstrahlung spectrometer	10 and 12
Micrometeorite collection	9 and 10
Proton electron spectrometer	7
Beta spectrometer	10 and 12
Nuclear emulsion	8 and 11
Ion wave measurement	9 and 10
Atmospheric science:	
Synoptic weather photography	6, 7, 10, and 12
Cloud-top spectrometer	8 and 12
Communication and navigation:	
Optical communication	7
Manual navigation sightings	12
Earth sciences and resources:	
Synoptic terrain photography	6, 7, 10, and 12
Advanced technology and supporting research:	
Color patch photography	10
Landmark contrast measurements	7 and 10
Biomedicine/behavior:	
Cardiovascular conditioning	7
Bioassays body fluids	7-12
Inflight sleep analysis	7 and 9
Inflight exerciser	7
Bone demineralization	7
Human otolith functions	7
Inflight human phonocardiogram	7
Calcium balance study	7

reduced. The number of experiments appear on the abscissa, while the corresponding weight of the integrated payload shows on the ordinate. There is a gross correlation between cost and weight of payload, and consequently the ordinate might equally well represent funding requirements. The importance of figure 1 is that the equipment commonality curve approaches asymptotically a maximum weight/cost figure, whereas the curve which disregards commonality continues to rise indefinitely as the number of experiments increases. Furthermore, the commonality curve indicates a lower funding requirement at all levels of experimentation, including those missions with only a few experiments on board.

Table VI. —Present Status of Apollo Application Experiments

Experiment area	Stage				Total
	Concept	Preliminary definition	Design and development	Operation	
Astronomy/astrophysics	2	8	2	0	12
Bioscience	0	15	2	1	18
Physical science	4	16	5	1	26
Atmospheric science	3	9	2	0	14
Communications and navigation	3	5	1	0	9
Earth sciences and resources	0	19	5	0	24
Lunar surface exploration	2	55	8	0	65
Lunar orbit	0	20	0	0	20
Advanced technology and supporting research	1	24	13	0	38
Biomedicine/behavior	4	10	5	4	23
Extravehicular engineering	3	12	3	0	18
Operations techniques	1	7	4	0	12
Advanced subsystems	0	4	2	0	6
Total	23	204	52	6	285

The experiment planning process followed internally within NASA is quite complex. However, there are a few points worth mentioning. We visualize all experiments going through a sequence of phases: first, conceptual; second, definition and feasibility; third, hardware development. The conceptual studies are generally of short duration and intended to establish the scientific/technical merit of the experiments. The second phase, definition and feasibility, will carry the experiment from concept to breadboarding, and may include simulation studies and special equipment development. The experiment definition study should result in an experiment program plan, including detailed equipment description, specifications, and hardware development. The third phase, hardware development, should cover design, mockup, prototype, flight hardware testing, and delivery of flight-rated equipment.

Let us now briefly consider the experiment approval process. The idea for an experiment may originate at a university or at an industrial organization; it may be conceived by a member of the NASA staff, or some other Government technical agency. Irrespective of how the experiment originates, it will require a sponsor in one of the NASA program offices.

Each of the offices in figure 2 has an experiment review and approval process. After the experiment has cleared this step, it is ready to be funded through the conceptual, and definition and feasibility phases. If the experiment still shows promise after passing this stage of development, a decision must be made as to whether to proceed with hardware development and procurement. This decision is made by the Manned Space Flight Experiments Board, which is under the chairmanship of Dr. George E. Mueller, Associate

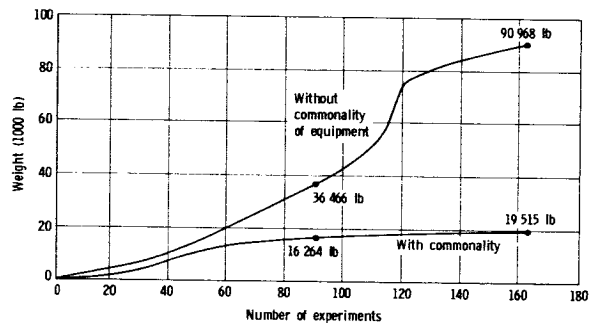


Figure 1. —Effect of equipment sharing.

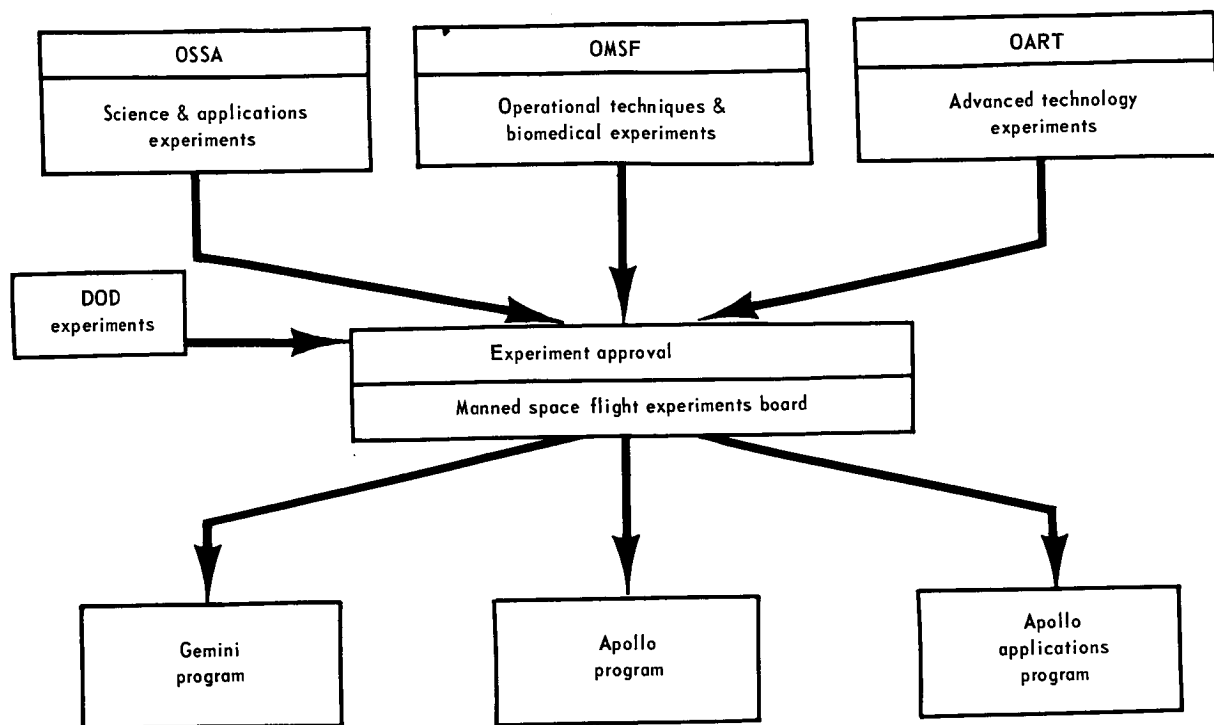


Figure 2. —MSF experiment program.

Administrator for Manned Space Flight. Other members of the Board include the heads of the other program offices, a Department of Defense representative, and several other NASA officials. The Board decides whether the experiment will be continued, and, if so, to which program office it will be assigned.

Now in conclusion let me try to convey the overall objectives of the manned space flight program. The list below breaks these objectives into four separate areas. Category 4 could perhaps be included in IE or IIA. However, in my opinion it is of sufficient importance to merit a separate place in our list of objectives.

- I. Use of space:
 - A. Improved communications capability
 - B. Better weather forecasting
 - C. Real-time Earth resource inventory
 - D. Worldwide traffic monitoring
 - E. Expanded scientific and technological capability
 - F. Support DOD
- II. Exploration of space:
 - A. Expanded knowledge of the universe
 - B. Improved space operations capability
 - C. Increased international prestige
- III. Operations through space:
 - A. Improved long-range Earth transportation systems
- IV. Life in space:
 - A. Increased knowledge of life processes
 - B. Improved understanding of behavioral processes