SECRET

244

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A National Space Program

The purpose of this paper is to suggest what the goals of the United States space science and exploration program should be for the next decade, and to determine how the United States can best organize its resources to achieve these goals. We exclude from consideration the strictly military aspects of space technology, on the assumption that these will be pursued by the appropriate military departments.

In order to determine how the program should be organized, we first outline the more promising scientific and technological opportunities (Section I), then we outline a sample program in space science and exploration designed to exploit these opportunities, and attempt to list the major developments along with their costs and time scales which are needed to carry out such a program (Section II). Section III then describes an idealized operating organization for carrying out the program, listing the various functions it must perform and suggesting how it should do them. Section IV then discusses the organization at the governmental level which seems most appropriate to the program.

I. Outline of Goals of a National Space Program.

1. The Scientific Uses of Space Vehicles. The following are the scientific opportunities that look most promising and interesting at this time, arranged on a rough time scale:

a. Early Opportunities (1 - 2 years): Heat balance in insolation and terrestrial radiation; solar ultra-violet and x-ray activity; ionospheric physics and low frequency radio astronomy; pioneer cloud survey; earth's magnetic field; special cosmic ray experiments.

b. A Little Later (2 - 5 years): Astronomical observations with a satellite-borne telescope, including ultra-violet stellar spectroscopy and high resolution photography of planets; continuous global meteoralogical survey; serious moon investigations, including close-up photography, lunar magnetism, possibly lunar seismology; generalyrelativity test; minimal Mars probe; reaction of living organisms to weightlessness.

c. Still Later (5 - 15 Years): Manned lunar exploration; lunar observatory; better measurements of everything listed above, serious automated exploration of planets, new horizons which cannot be anticipated at this time.

Comments: In terms of scientific value, some of the biggest gains may be expected early, rather than late --in the 2 - 5 year period roughly. Also, the early part of the program, developing naturally out of the IGY program, offers excellent opportunities for international collaboration.

2. Practical Peaceful Uses of Space Vehicles. In the short run these benefits, at least, can be foreseen with some confidence:

a. Communication relay via satellites.

b. Global meteorological observations with consequent improvement in forecasting.

c. Indirect benefits flowing from increase in knowledge which scientific exploitation of space vehicles will bring. (For example, a better understanding of terrestrial effects of solar activity.)

3. Astronautical Science. In addition to the central problem of propulsion, the development of astronautics poses challenging problems in applied science, of which the following are representative:

a. Soft landing and recovery techniques.

b. Complex problems of terminal guidance.

c. Power supplies.

d. Adaptation of the environment to the human and vice-versa.

e. Eventually, astrobiology (astrobotany, etc.).

Comments: We here take for granted the development into human space flight, although it plays no significant role in the early stages of the scientific exploration of space. Note that problems a through e would remain, even without human space travel as a goal. They are common to all advanced space technology, and illustrate the importance in the whole program of advanced electronics and fundamental components development. Compared to these, indeed, "space medicine" looks like a relatively simple problem.

4. Military Uses of Space Vehicles: The present paper is intended to deal only with those aspects of space science and technology which are not primarily of military interest. However, for completeness, we also include here our views regarding what the strictly military uses of space vehicles are. Ground to ground ballistic missiles aside, the foreseeable important uses are the following:

[redacted]

b. Communication, and, possibly, jamming.

Comments: It may turn out that there are military uses now unforeseen. All explicit proposals we have examined, such as armed satellite patrol, satellite vs. satellite warfare, and a military outpost on the moon, dissolve on close and quantitative examination into something of very little use. Note that both 3a and 3b closely parallel developments under 1 and 2.

SECRET

SECTION II

The following is intended as a sample National Space Science and Exploration Program. It is designed to serve as a guide for determining the problem areas which must be worked on in order to furnish a basis for outlining the type organization needed to accomplish the program. Included at the end are a very brief statement of costs, and a list of possible first dates for various achievements.

SECRET

<u>Phase I</u> - Scientific Earth Satellite Vehicles (100-500#)

<u>Carriers</u>

Juno II (100-200# sat.)
Juno III (300-500# sat.) 100# lunar hit

Costs: 10R & D, 20 Operational 100 M
Availability - 1958/59

<u>Payloads</u>

Satellites, Simple Lunar Payload 20-40 M
Flight schedule - 58/59/60

<u>Phase II</u> - Intermediate Space Science Projects
(lunar hits, lunar circumnavigation, larger satellites)

<u>Carriers</u>

1) Juno III - 3 lunar hits 10 M
2) 3 lunar circu. 10 M
flights - 59/60
2) Alternate carriers (do one or two)
Atlas/117 L - sat.
lunar hit
lunar landing
Availability - 59 (crash)

Titan/15000# O_2 engine
sat.
lunar hit
lunar landing

costs: (15K O_2 engine) 5-10 M
availability - 59/60 (crash)
60/61 (normal)

Titan/15,000# F_2 engine
sat.
lunar hit
lunar landing

Development costs: 15,000# F_2 engine 40-60 M
Availability - 1960 (crash)
61/62 (normal)

Phase II (continued)

Terminal Stages Dev. Costs

Terminal motors	0- 10 M
Terminal guidance & control	5- 15 M
System Integration	5- 15 M

Flight Costs and Schedules

Satellite Flights
Costs:
carriers 3 M each) x 16 65 M
instruments 1 M each)

Flight period 60/61/62

Lunar Flights (hard landing or circumlunar)
Costs:
carriers 3 M each) x 10 40 M
instruments 1 M each)

Flight period 60/61/62

Lunar Flights (soft landing)
Costs:
carriers 3 M each) x 10 45 M
instruments 1-2 M each)

Flight period 61/62/63

Phase III - Initial Manned Space Flight

Carriers
Atlas or Titan, plus extra motors as in Phase II

Reentry equipment
Ballistic System
Development cost, incl 10 animal flights 45-70 M
flights w/animals 61/62 (crash)

Manned Research Flights
carriers 2 M each) x 10 50 M
re-entry 1 M each)
flights 62/63 (crash)

Phase III - (continued)
Re-entry equipment (continued)
Airplane-like system
Development cost ?
Research flight cost, each ?
Flight schedule ?

Phase IV

Carrier Alternatives (do 1 or 2)

1. Super (400K first stage, 110K F_2 second stage, 15 K F_2 third)

(9200# sat. 4000# lunar hit, 1400# lunar loading)
Engine and system development cost including 20 R & D missiles 200 M
Carrier availability 61 (crash)
62/63 (normal)

2. Improved versions of Best Vehicles used in Phase II. Long range payloads about half of above.

Notes: Mars satellite weight is between lunar hit and landing weight.
Mars aerodynamic landing weight is somewhat larger than lunar landing weight in net payload.

Terminal Equipment Development

Terminal motors	developed by use in Phase II lunar flights	0-10 M
Martian guidance and control		10-100 M
Martian communications		10-100 M
Martian satellite instrumentation		10-20 M
Martian landing equipment		5-50 M
Power plant		5-50 M

Available two years after first larger Phase II flights -
61/62 (crash)
62/64 (normal)

Phase IV (continued)

Flight costs and Schedules

Scientific Satellites, 1/2 per month for four years (62-65) carriers 3-5 M/each, instruments 0-5 M/each	x 24	130-180 M
10 Lunar flights (1962-1965) carriers 3-5 M/each, instruments 0-5 M/each	x 10	55-75 M
20 Mars flights (1963-1965) carriers 3-5 M/each, payload 2-7 M/each	x 20	150-200 M

Notes: for Super Titan case, Mars satellite payload would be about 2000#, and aerodynamic landing on Mars would have about same net, after deducting for re-entry heat sink and parachutes.

Phase V - Extraterrestrial exploration.

Carriers Alternatives (do one)

1. Large Military Satellite Vehicle (LMSV)
   70,000# sat., 36,000# lunar hit, 16,000# lunar landing, also about 18,000# net martian aerodynamic landing, and 3000# to 6000# rocket retro-fire martian landing.

2. Super Jupiter
   33,000# satellite, 10,000# lunar hit, 3500# hit lunar landing.

Development cost of either 1 or 2 would be about (incl. 30 R&D flights) 500-1000 M

Available 1963 (crash) ??
1965/66 (normal)

Phase V (Continued)

Terminal Equipment

landing rockets and deceleration equipment	100-300M	200-650 M
assemblable solid propellant rockets for return flight	50-250 M	
ground exploration equipment	50-100 M	

Exploration

Alternate A (with LMSV only)

Build cache on Moon (Mars) 5-20 flights LMSV @ 10 M each	50-200 M	
Manned rockets to cache (2-10 men ea) 1-3 flights LMSV @ 15 M each	15-45 M	
Assemblable rocket for return trip	10 M	
Exploration equipment	20 M	
3 to 8 such expeditions, starting in 1965		1000-2000 M

Alternate B (for Super Jupiter or LMSV)

Establish 150 ton space station (1965)
(10-20 man station)

R & D and establishment (10 flights Super Jupiter)	350-500 M	1250-1950
Maintain for 6 years	400-450 M	
Staged exploration of moon from station (3 men) (1967) (100 flights Super Jupiter, 50 LMSV)	500-1000 M	

Alternate C (Super Jupiter or LMSV)

Establish 500 ton space station (1968)
(50 man station)

R&D and establish	800-1200 M	2300-3800
Maintain for six years	500-600 M	
Moon landing and exploration, stage from 500 ton station (1970) (300 flights Super Jupiter, 150 flights LMSV)	1000-2000 M	

Cost Summary

1) Phases I - IV for first 8 years: 500 M/yr

(includes cost of supporting R&D, and an overhead estimate. Not good to better than a factor of 2)

2) Adding large scale effort in Phase V in 1965, costs per year would rise to 1000 M/yr if full scale program of Phase III and IV space science is continued. This figure also very uncertain.

3) Costs during Phases I-IV are very roughly divided as follows:

15% - big booster development
20% - big booster procurement and firing
25% - terminal equipment of all sorts
30% - supporting R&D

Time Summary

Event	Crash (?)	Normal	Without/O F_2
100# sat		58	
500# sat	58	59	
100# lunar hit	59 (perhaps late '58)	59	
3000-6000# sat	59/60	61/62	
700# lunar hit	60		
*2000# lunar hit	60/61	61/62	1000"
200# lunar landing	60		
* 750# lunar landing	60/61	61/62	400"
Manned reentry	62	63	
*Mars probes (2000-4000#)	61/62	62/64	500"
Men on moon	65	68/75	
Men on Mars	67	70/80	
Space Platforms (150-500 tons)	65	70/80	

* require the use of one or more large super fuel engines for weights given.

III. Institute for Space Science and Exploration:

Organization and Functions

1. <u>Basic Organization Pattern</u>

We propose that there be set up an Institute whose purpose is to direct and carry out a space program of the kind outlined above in Section II, and that this Institute be operated by a private contractor under a contract with the appropriate government agency. The contractor should be of the non-profit institution type, such as a major University or, for example, the Carnegie Institution. The contractor should have a degree of authority and responsibility similar to that of the AEC weapons laboratories. The Institute should consist of several laboratories, all of which might be operated by the prime contractor, or some of which might be operated by further subcontractors. It is essential that among these laboratories be at least one, and very preferably two, which are already in the field: the two which fit the program needs best being JPL and ABMA.

2. <u>Functions of the Institute</u>

The following is an outline of the major programmatic functions of the ~~Institute~~ Institute.

a. Buys its required large booster rockets fromthe USAF or the USAF's contractors, arranges with the USAF for launch site services, assembles and fires the completed rocket system.

SECRET

b. Arranges (by contractoor otherwise) for the development of new advanced boosters, either through the USAF or directly with the airframe and rocket engine contractors.

c. Carries out largely in-house but partly through sub-contractors, the basic development of all of the special components and techniques needed in space science and exploration (except, as noted above, for the boosters) such as terminal ~~propulsion~~ propulsion, hypersonic aerodynamic landing methods, terminal and midcourse guidance and control, power sources (solar, chemical, nuclear) methods of telemetry, data storage and ~~handling~~ handling, communications, design, weightless structures

d. Carries out basic research in fields related to the program, such as in advanced propulsion methods (chemical, ionic, plasma jet, etc.), advanced guidance methods, hypersonics, electronics, automation, communications, power sources (solar, nuclear, etc.), physics, astronomy, chemistry, and mathematics, space medicine and biology.

d. Provides a service to the scientific community so that the best scientists of the US and other countries can play a direct part in the planning and performing of

SECRET

the basic experiments to be done in the satellites and other space vehicles. The point here is that many of the best ideas with regard to what ought to be measured and how to measure it will probably come from the general scientific community, (particularly the Universities), but, in general, these scientists will not have the capability of building apparatus capable of performing successfully in the satellite environment, and some system must be devised for integrating this important source of the ideas with the engineering capability which the Institute would possess. This integration can perhaps be best performed through NAS or NSF channels such as were used for the IGY satellite program.

f. Coordinates the general program of the Institute with related and corollary programs in other government agencies where control through subcontract is not possible, such as AEC, NACA, USAF. Each of these has special talents and programs of special interest to the national space program: the AEC in its nuclear rocket (Rover) program; the NACA in its hypersonics research, its X-15 and X-15 follow-on programs, etc; the USAF in its space medicine program (booster development is considered separately in b., above).

IV. Choice of Government Agency

The most important consideration in selecting which government agency should have the program is that of whether or not the agency in question can and will set up an operating organization of the type mentioned in Section III. To be sure, there are other considerations of some importante also, but this one is deemed to be overriding.

The agencies usually considered for this job are the AEC, the ARPA of the DOD, the NACA, or a new agency specifically established for this purpose. At present it would seem that any of these, with the possible exception of the NACA, could ~~and~~ set up contractor organizations of the type described above. In the case of NACA, this would be a somewhat unusual circumstance for two reasons: first, the NACA is primarily a collection of civil service type laboratories, and establishing such a contractor organization would be amajor departure from its present modus operandi, and second, it appears that the total rate of expenditure required for the space program (sec. II) is several times the present rate of expenditure of NACA and the new program would thus completely dominate the old one; in fact, giving the space program to NACA would be tantamount to setting up a new agency and having it take over the NACA.

With regard to the other three possibilities, the following observations seem pertinent:

1. DOD/ARPA - The advantages of having APRA run the National Space Program are the following:

(a) Coordination with the USAF and/or its contractors in the procurement of boosters, development of new boosters, and use of existing launching sites would be ~~easier~~ easier and simpler; disagreements ~~x~~ could be resolved at the DOD level rather than at a still higher level.

(b) Transfer of laboratories, such as JPL and/or ABMA, from the services to the new Institute would certainly be simpler if the new Institute were also in the DOD.

(c) Much of the ~~R~~ research done by the Institute ~~m~~ will be of great value to the military missile and satellite programs, and vice versa. Again, cross-fertilization of the ~~various~~ various R&D groups, and transfer of information and know-how between the groups would be simpler if all groups involved were in DOD.

As for the disadvantages, the following have been mentioned:

(a) The DOD is responsible for so many diversified activities already, that little attention to this program from the top levels can be expec ted.

(b) It is important that this program acquire an international aspect in that the peaceful ~~xxxxx~~ development of ~~x~~ space science and exploration should be carried out for the benefit of all mankind and with international participation, especially as regards scientific observation and measurements. In this connection, it has been said that, because of its primarily military role, there is a "stigma" attached to the DOD which will make international cooperation difficult or impossible. We believe that, if the program is carried out by a private institutional contractor, as described in Section III, with a minimum of military interference and redtape, that this supposed stigma will be largely removed.

2. <u>AEC</u> - It has been sometimes erroneously thought that, the AEC's nuclear rocket program is an essential element in space science and exploration. It is true that nuclear propulsion may eventually be superior to chemical propulsion, but it is not true that an important beginning in the exploration and exploitation of space cannot be made without nuclear propulsion. Nuclear propulsion is at least ten years off as a practical method for space travel and there is so much that can and should be done in the meantime that there seems little point in tying the two together at this time because of a possible future connection, however important. However, considered as a system of scientific and technical management, the AEC has some definite virtues, in that the basic organizational pattern for the proposed Institute is very

SECRET

similar to that used in some parts of the AEC program and thus could be easily applied to the space program if it were under AEC management. Further, AEC has a good record in carrying forward joint programs with the DOD.

On the other hand, the space program is of such a different nature than the AEC's present programs that adding it to AEC would probably result in a considerable dilution of the energies now going into its nuclear research and development programs.

3. A New Space Agency - A new Agency could no doubt be established for the purpose of serving as the governmental agency which holds the contract for the Institute described above, and for carrying out that coordination which will be necessary at the government level with the other agencies involved (DOD, NACA, AEC, BOB, etc.) and the Congress. It would have the initial disadvantage of making it more difficult to transfer to the Institute and the space programs the already existing DOD laboratories (JPL, ABMA) which as stated above, are absolutely essential as a means for starting the program in a vigorous manner, and as a nucleus around which to expand further activities.

Recommendation - In consideration of the above, and in the light of recent Congressional action, we recommend that:

SECRET

1) National Space Program, along the lines described in Section II, be promptly initiated within the ARPA of the DOD.

2) That ARPA set up for this purpose an Institute under a private contractor as outlined in Section III.

3) That JPL and ABMA (or a part thereof) and perhaps parts of other service laboratories as may be later determined, be transferred to the Institute as soon as practicable after its formation.

4) That ARPA proceed in such a manner as not to preclude transfer of the/executive agency Institute and its program to another at a later date, if deemed advisable or if so ordered by Congress.

5) That the AEC nuclear propulsion program be left as is, and that the various NACA programs in the space field be left as is, with these programs to be coordinated with the main space program by such procedures as may be jointly agreed to by the agencies involved.

6) After 1 year.