For the Advisory Committee
on the Future of the U.S.
Space Program
19 November 1990
[Slightly revised version 12/10/90]

On the Future of Space Science and Applications

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Introduction

Recently I have read David DeVorkin's book entitled "Race to the Stratosphere—Manned Scientific Ballooning in America". The author's point of departure is the 1931 balloon flight of the Belgian aeronaut Auguste Piccard to an altitude of nearly 16 kilometers. This flight generated widespread public interest both in Europe and elsewhere and was hailed as opening up a vast new frontier of human adventure and exploration. The sheer romance and public visibility of high altitude ballooning were Piccard's central motivations. But he felt it necessary to exalt his aspirations by wrapping them in the cloak of scientific objectives.

However, his own attempts to achieve such objectives were feeble and inconclusive, being severely compromised by his necessary preoccupation with his life support system and the mechanics of the flight.

Manned ballooning to high altitudes enjoyed a brief revival in America after World War II. But it became overwhelmingly evident that automated equipment on unmanned balloons provides a greatly superior technique for scientific measurements within the atmosphere.

At the present time, scores of unmanned balloon flights are made each year for scientific and practical purposes but manned ballooning survives only as an adventurous sport at low altitudes.

Most of the modern history of scientific ballooning falls within my direct personal knowledge as does the entire history of space flight. On many occasions I have compared the two histories. This theme of historical parallelism is developed by DeVorkin in a richly detailed and persuasive way.

With the benefit of over three decades of experience in space flight, it is now clear (a) that the conduct of scientific and applicational missions in space by human crews is of very limited value and (b) that justification for future manned space missions must rest on other considerations—those of a general cultural nature such as inspiration, high adventure under exotic and perilous circumstances, human record-setting, and the like. It would be refreshing to hear a prominent political leader make such statements, assess the motives for manned space missions in the context of their significance and costs, and not obfuscate the issue with a plethora of false analogies and unsupported claims.

The post World War II epoch was characterized in the United States by intense "cold war" rivalry with the Soviet Union and by a notably optimistic and expansionistic public mood. But as of 1990, our citizenry is much more preoccupied by societal, financial, and environmental distress and by the threat of active warfare in the middle-East. Hence, I consider it futile to attempt to replay the Apollo paradigm during the 1990s. Rather, we should restructure our plans to match our extensive experience and the political realities of the current epoch.

Any attempt to visualize the future of the U.S. space program must consider the relative roles of manned and unmanned spacecraft. The route of easy virtue is to declare in favor of a "balanced" program. But such a simple declaration is, of course, meaningless. It becomes meaningful and discussable only if one specifies a quantitative ratio of the respective efforts and explains the rational basis for such a ratio. Otherwise, advocacy of a balanced program is what my father would have called a platitudinous pomposity.

The issue of balance is a fundamental one. It will not go away. It can not be waved aside. It is already an acute issue in the U.S. and the U.S.S.R. and is prospectively so in other countries.

I will now offer my own attempt to assess this issue.

Space Science

A proper description of the scientific advances that have been achieved by space techniques is far too voluminous for a short talk. Many basic geophysical and astronomical discoveries are made each year and the total volume of original work is truly staggering. Let me list a few examples.

Knowledge of the composition, structure, and dynamics of the Earth's atmosphere and ionosphere has been greatly expanded and clarified. Corresponding but less comprehensive studies of the atmospheres and ionospheres of seven other planets of the solar system have been conducted on planetary missions. The results of these planetary studies have intrinsic interest and add depth to our attempts to better understand the Earth system.

The full electromagnetic spectrum of solar emissions, from gamma rays to radio waves, has been observed as have the sporadic solar emission of energetic particles and solar influences on the intensity and composition of cosmic rays out to great distances from the Sun. A much improved understanding of the dynamics of the quiescent and disturbed Sun and the consequences at the Earth has been achieved. Of special interest is the solar coronal plasma (or solar wind) which flows outward through the solar system and has now been observed out to radial distances of over seven billion kilometers. The influence of the solar wind on the physical properties of the planets has become an important feature of the broad subject called solar-planetary relationships.

Knowledge of distant astronomical objects, the interstellar medium, and the origin of the universe has been extended greatly by space-based observations in the gamma ray, x-ray, ultraviolet, infrared, and short-wavelength radio regions of the spectrum, and by improved angular resolution.

The Earth's magnetosphere has been studied in great detail and it has become the prototype for the magnetospheres of the other planets and for analogous plasma physical phenomena of pulsars and large astronomical systems.

Oceanography, geodesy, and geology have also profited importantly by space-based techniques. Such advances together with those in atmospheric science undergird long term forecasts of the future of the Earth as a habitat for life.

Planetary and cometary exploration has produced dramatic advances in understanding the full nature of our solar system, of its many elements, of its rich variety of current phenomena, and of its probable evolutionary history. Many current research papers discuss the detailed geology of the Moon, the planets Mercury, Venus, and Mars, and the planetary satellites of Mars, Jupiter, Saturn, Uranus, and Neptune. The character of the rings of the outer planets and the solar wind's interaction with cometary gas and dust are also subjects of special interest. The spacecraft Pioneer 10 passed a heliocentric distance of 50 astronomical units about two months ago and continues to be the most remote man-made object in the universe, still transmitting scientific data continuously. Pioneer 10, its companion spacecraft Pioneer 11, and the two later spacecraft Voyagers 1 and 2 are all on solar system escape trajectories. There is a reasonable hope that at least one of these four will continue to operate and transmit data as it passes from the heliosphere into the interstellar medium—a classical objective of space science.

In the realm of biological science, the most significant findings have come from the Viking landers on Mars. Their remotely controlled assays of surface material revealed an essentially complete absence of any biological material. These findings do not conclusively preclude the presence of biological material elsewhere on Mars or on some other non-terrestrial body in the solar system but do make such a possibility much less likely.

I recognize that the foregoing survey of the current status of space science is incomplete but I believe that it provides representative examples and suggests the future of the subject.

Nearly all the great advances in space science have been achieved by unmanned automated spacecraft, controlled and monitored by teams of scientists and engineers from the comfort of resourceful terrestrial laboratories.

In the company of many others I served on a panel of scientists who prepared a recent report entitled "Space Science in the Twenty-First Century—Imperatives for the Decades 1995 to 2015". The two-year study was conducted under the auspices of the U.S. National Academy of Sciences. Our report comprises one overview volume and six other volumes with the following subtitles:

(1) Fundamental Physics and Chemistry

(2) Astronomy and Astrophysics

(3) Life Sciences

(4) Mission to Planet Earth

(5) Planetary and Lunar Exploration

(6) Solar and Space Physics

These documents summarize the rich agenda of our aspirations for the future. Aside from studies of human physiology and psychology under prolonged free-fall (or weightless) conditions, very little need for manned space vehicles emerged.

Space science throughout the world is supported almost entirely by governments, i.e., by tax-paying citizens. A tough minded politician is therefore entitled to question the appropriateness of any proposed level of effort.

One form of answer, of course, is to cite the long history of pure science in laying the foundations for innumerable technical developments and their contributions to human welfare, and to further cite specific examples.

Also, I have no difficulty in defending the intellectual quality of astronomical science, for example. But I would not like what I see in a mirror if I were to claim that knowledge of the magnetic moment of Saturn is of any immediate practical importance. Nor do I attempt to do so. In such matters, I think that our best move is to fall back on the general public perception of "worthwhileness". Worthwhileness is a collective judgment which is quantified by the political process as a kind of equilibrium between advocates and skeptics. So it is with space science.

It is well known that scientists have a virtually unlimited capacity for planning new programs. The challenges of space research are noteworthy for spawning expansive thinking. I have often remarked that I can think of a one-billion dollar space project before breakfast any day of the week, or a two-billion dollar project before breakfast on Sunday. This is easy to do. Yet we must not delude ourselves by what has been called a triumph of hope over experience in formulating our programs.

Space Applications

Space applications is a short term for the use of space flight technology to provide direct and tangible human benefits of a utilitarian nature. Such applications are sometimes called "spin-offs". But I personally deplore the use of this term, which implies that they are incidental and without conscious intent. On the contrary, space applications are the result of purposeful and highly competent effort directed toward clear needs.

In some cases, they are derived from fresh knowledge gained by space scientists but more usually they have a much broader scientific and technological base. Some have commercial potential. Others lie primarily in the realm of governmental services.

The most prominent of space applications is the use of satellite relays for rapid domestic and international telecommunications. This is the only application of space technology that has achieved true commercial status in the non-governmental market place. Communication satellites serve an immense variety of civilian and military purposes and are a pervasive element of modern civilization. Their use continues to grow but they now have formidable competition in high-traffic point-to-point communication by way of optical fiber cables, especially transoceanic ones.

Another prominent space application is represented by satellites for the continuous monitoring of the Earth's weather on a global basis and for monitoring solar emissions. Special applications of meteorological satellites in surveying the ozone content of the upper atmosphere and the distribution of other minor but important components of the atmosphere are of increasing importance in assessing both natural and anthropogenic fluctuations and trends. Also research satellites are of importance in clarifying the dynamics of the atmosphere and ionosphere, matters which mix pure science and applications to human welfare.

Another major area is that called remote sensing, typified by Landsat and Spot satellites for the sophisticated, multi-spectral survey of the surface and near surface features of the Earth and its oceans on a global basis. Again, such satellites have both civilian and military purposes. There is significant commercial potential for their observations but most continue to fall in the broad area of governmental services and there is no reasonable expectation that this situation will change markedly in the near future.

Networks of satellites provide the basis for navigation on land, at sea, and in the air with unprecedented accuracy and also have important applications to geodesy and geology.

My roster of examples of space applications is, of course, incomplete but illustrative of modern developments. It is a matter of regret that their importance in everyday life is so little appreciated by the general public including the news media, industry, and commerce which, ironically, are increasingly dependent on them in their daily operations.

All important applications of space technology utilize unmanned, commandable spacecraft, most of which have useful lifetimes of many years. There is little or no justification for claiming that human crews in space have had or will have importance in the field of space applications.

Concerning the Space Flight of Human Crews

I now turn to some remarks on the future role of human crews in space from the perspective of our collective experience over the past three decades. I will use the common term manned flight but do so with the full recognition of the roles of both men and women.

In common with millions of others, I shared in the vicarious thrill of the Apollo landings on the Moon, including especially the TV coverage of Neil Armstrong lumbering down the short ladder from the Apollo capsule and setting his heavy boots on the lunar surface. This was on 20 July 1969, now over twenty-one years ago.

Significant scientific results were obtained by the Apollo and Skylab programs but at no time has manned flight been truly essential to any important scientific or utilitarian purpose despite the fact that, in the United States, it has consumed over two-thirds of the resources of our civilian space program.

It can be and has been argued that the United States can afford expenditures of such magnitude purely for lofty cultural goals and high adventure. But in the face of our massive societal distress, typical taxpayers and their representatives in the Congress do not have a manned mission to Mars among their national priorities.

Worse yet, presidential rhetoric emphasizing such remote possibilities does a great disservice to the many worthy, much less costly, and readily achievable scientific and utilitarian objectives of a thoughtful program of space exploration with unmanned spacecraft. The latter objectives, as mentioned earlier, include environmental monitoring of the Earth on a global basis and important contributions to assuring the health and welfare of future generations of its human inhabitants. I suggest that NASA may profit by studying the nature of the National Institutes of Health, a federal agency of comparable size ($8.3 B vis-a-vis $13.9 B, FY91 budgets), devoted to basic biological-medical research and its applications to alleviating human disease. It is important to note that over 62% of the budget of NIH (or about $5 B annually) flows to university training and research programs—the well springs of new ideas, basic discoveries, and future professionals in its field. Such foresight is much less evident in NASA's planning.

Conclusions

On the basis of the foregoing perceptions, I now offer some specific conclusions and recommendations.

- NASA and its associated contractors and grantees, despite despair following the Challenger accident, continue to have high competence and constitute a unique national asset. Much of the recent criticism of the agency is, at least in part, unfair. But it reflects, I believe, a much deeper disenchantment of the public and the Congress with NASA's heavy emphasis on manned flight, with its excessive claims for same, and its notorious underestimation of the costs and difficulties of major undertakings.

- For almost all scientific and utilitarian purposes a human crew in space is neither necessary nor significantly useful and the shuttle is the most expensive and least robust of available launching techniques.

- The civil space program of the United States must return to <u>primary</u> reliance on unmanned launch vehicles, as the communications industry and the Department of Defense already have.

- The planned U.S./International space station is on such a huge scale as to be grossly incommensurate with its clearly identified usefulness (cf. MIR, Skylab).

- The bright promise of future space science and applications programs (NASA and NOAA) must not be held hostage to the manned flight program (shuttle and/or space station). Such programs should have quasi-independent authority to make coherent long range plans and to procure appropriate launch services (as part of their budgets). The "balance" of NASA's efforts should be adjusted markedly in order to increase emphasis on things that work and to diminish emphasis on things that do not.

- Improved understanding of the Earth's environment on a global scale should be made a substantial element of NASA's direct response to public welfare (perhaps analogous to that of the National Institutes of Health); but the program should be developed incrementally and should not be overrepresented as a panacea to the world's environmental distress.

- The space flight of human crews may well be a worthy cultural objective in its own right (high adventure under exotic circumstances, inspirational, prestigious) for a wealthy nation, but advocates should acknowledge the realistic risks and costs and should not bewilder the issue with patently false claims and analogies.

- Apart from the flourishing telecommunication industry, the true "commercialization of space", free of essential governmental subsidy, is a wan hope and hence a wrongheaded basis for policy.

- The Human (Space) Exploration Initiative of the present Administration (permanently manned station on the Moon and manned expedition to Mars) is on such a long time scale and such a high level of cost as to be incompatible with realistic expectations of public support. Emphasis on such objectives does the entire space program a disservice.

- International collaboration in space should be cultivated in a natural way, as in the past, but should not be driven by political objectives.