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THE SPACE TELESCOPE: OUT WHERE THE STARS DO NOT TWINKLE

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The NASA Space Telescope is designed to answer questions like: How big is the universe? How old is it? Did it have a beginning? Will it have an end? Will observations of black holes or quasars reveal new laws of physics? What kinds of undiscovered things are there in outer space? How are stars formed? Are there other planetary systems like our own?

The Space Telescope can provide new information on these fundamental questions because it will be located outside the earth's atmosphere in a stabilized observatory. The earth's atmosphere is a partially opaque curtain between us and the rest of the universe. Only a very narrow band of colors is transmitted unimpeded by the atmosphere. The images we do see here on earth are also blurred because of the irregular motions of cells of air in the earth's atmosphere. Thus terrestrial observations through the atmospheric curtain are limited to visual colors and twinkling (blurry) stars.

The Space Telescope, by being outside the earth's atmosphere, will enable us to see images that are ten times smaller (or less fuzzy) than with ground-based optical telescopes. This tenfold increase in resolution will permit us to study nearby known objects in much greater detail or to detect stellar counterparts at about ten times greater distances than is possible from earth. If the universe had a beginning, we should be able to detect objects all the way back to between 75% to 95% of the beginning of time. The Space Telescope will allow us to observe light over the entire range from the far ultraviolet to the far infrared (from approximately 1100 Angstroms to about 1mm = 10,000,000 Angstroms). This will increase the color-range over which we can "see" (or photograph) the universe by a factor of more than a thousand.

The Space Telescope will be a National Observatory in long-term orbit around the earth. It will be launched by the NASA Space Shuttle and will be the first permanent national astronomical observatory in space. The availability of the shuttle will allow in-orbit repair and replacement of equipment by shuttle crewmen and return to earth when necessary for a refurbishment of the entire system. The spacecraft facility is a cylinder of about 14 meters in length (46 feet) and 4.3 meters (14 feet) in diameter, weighing about 9000 kg (10 tons). The mirror size will be 2.4 meters (94 inches), comparable to some of the largest ground-based telescopes. This size was fixed as a result of detailed studies, requested by the Congress, that established 2.4 meters as an optimal compromise among the conflicting objectives of maximum resolving power and speed, with minimum cost and technological risk. The mirror is sufficiently large that experiments requiring large light-gathering power can be done with this telescope that would be impossible with the smaller predecessors that NASA has been able to orbit previously.

The optical design is similar to conventional ground-based reflecting telescopes (technically: an F/24 Cassegrain, Ritchey-Chretien optics). The mirrors will be made from light-weight ultra-low expansion fused silica. There will be several versatile scientific instruments to carry out a wide range of kinds of observations (possibly including a wide field camera, a faint-object spectrograph, an infrared photometer, and a faint-object camera). The in-orbit maintenance capability provided by the Space Shuttle insures the successful initial operation of the scientific instrumentation and will permit the replacement of failed or outdated equipment at a small fraction of the cost of a new scientific mission. Thus the Space Telescope can be operated with the best scientific instruments as they become available. Data will be transmitted to earth, and the telescope controlled, via the NASA Tracking and Data Relay Satellite System. One of the ultimate products will be pictures of the universe in wavelengths (colors) that the unaided eye could not "see."

The National Academy of Sciences study "Opportunities and Choices in Space Science, 1974" [1] described the Space Telescope as "...an exciting major step in the history of observational astronomy, observational cosmology, and the understanding of the universe." There have been many detailed studies, over the past twelve years, of the fundamental advances that may be anticipated in astronomy from the application of the Space Telescope to known problems. These include a better understanding of planetary atmospheres and meteorology, the search for other planetary systems like our own, studies of clouds where stars like our sun are now being formed, a search for massive black holes and compact white dwarfs inside the globular star clusters, a measurement of the size of the universe, the investigation of the nuclei of active galaxies and many more. However, the history of science suggests, despite this impressive list of foreseeable problems, that the greatest discoveries will probably be unanticipated, involving objects that are now hidden by the earth's atmospheric curtain. For purposes of illustration, I will describe in a little more detail below just one problem on which the Space Telescope can certainly provide crucial new information.

Quasars are the most distant and most energetic objects known in the universe. They produce enormous amounts of energy, 100 times that from a bright galaxy of 10 billion stars, in a very small region of space. No one knows for sure how quasars manage to produce such great amounts of energy; there are many theories and speculations but observational tests of these ideas are prevented in large part by the earth's atmospheric curtain. Many of the speculations can be categorized as "sick-galaxy" theories of quasars, i.e., they suppose that quasars are some sort of disease or transient event in an otherwise normal galaxy, a sort of cosmical cancer. To test these ideas one needs to observe quasars with the Space Telescope to find out whether or not these bright point-objects, quasars, are surrounded by fainter, more diffuse light of galaxies. One may also be able to determine if being a quasar is a disease of the young, or the old, galaxies; this is a fundamental question that is currently inaccessible to us because of the fuzziness of the images received by earth-based telescopes.

It is conceivable that an understanding of the way quasars produce energy could lead to improved laws of physics or even some practical applications. As an historical example, we recall that the inspiration for this country's controlled thermonuclear fusion program came from the realization, by astronomers and physicists working in pure research, that the sun shines on the basis of hydrogen fusion.

It is also possible that frequent and precise observations of other planets will lead to a better general understanding of planetary atmospheres and meteorology. This basic knowledge might help us to an improved comprehension of the processes that control the earth's atmosphere and weather. Just as it is sometimes easier to understand the behavior of your own children if you observe someone else's offspring from a distance, it may be that our studies of other planets will lead to discoveries that may improve conditions on earth.

Granting that the Space Telescope can make significant scientific contributions of widespread interest, the important questions of timing and priority remain. Budgetary pressures and our social problems are urgent. It is natural that under these circumstances those in Congress who are responsible for deciding which programs have priority should ask: Why send up the Space Telescope now? Will not the laws of physics and astronomy be the same five or ten years from now? Could we not delay this program and come back to it equally well when the economic and social situations are improved? These questions have been put to me in the past by Congressional friends of science who were enthusiastic about the program but were concerned about priorities. They deserve serious, quantitative answers in the same concerned spirit in which the questions were asked. The scientific laws and phenomena will indeed be the same in future years, but there are at least four logical and economic reasons to go forward with the Space Telescope program this year.

First, many United States and foreign astronomers have participated in the Space Telescope feasibility and design studies over the past five years. About 45 academic scientists were under direct contract to the NASA, representing some 25 major astronomical research groups in the U.S., Canada and Europe, as well as some additional 30 scientists who worked for the program in various non-contract, supporting roles. There were probably about an equal number of NASA personnel directly involved in the planning and testing. If the Space Telescope were delayed now, these expert teams would dissolve and the individual scientists would turn to other areas of research. If the Space Telescope were delayed and then restarted in the future, years of retraining and duplication of scientific studies would be required.

Second, a number of outstanding industrial firms have invested heavily of their own internal research and development funds, and the time of some of their most skilled personnel, to provide NASA with the best possible preliminary design. (The principal contractors include Boeing, Itek, Lockheed, Martin-Marietta, and Perkin-Elmer; important contributions have also been made by Aerospace Corp., Ball Bros., Bendix, Corning Glass, IBM and others.) These companies have spent some 15 million dollars of their internal research and developments funds in the design studies, compared to the about 5 million dollars paid to them by NASA. These skilled industrial teams would be dissolved if there were a significant delay in the program; they would have to be reactivated and retrained in the event of a postponement. The design of an intricate system such as a space satellite is not a static problem; much of the design work would have to be redone and integrated with new components if there were to be a long delay. I am not sure that one could persuade the qualified industrial companies that five years from now the Space Telescope would again be a worthwhile financial investment. This is especially true if the argument for postponement now were that the laws of physics are unchanging and astronomical investigations may be delayed whenever convenient, an argument that could easily be applied again in another five years.

Third, as a result of Congressional initiatives, the European Space Agency (ESA) and the NASA have formulated a Memorandum of Understanding regarding the formal aspects of European support and participation in the Space Telescope program. The ESA voted in October 1976 to spend 80 million accounting units (approximately 88 million dollars) for their participation in the Space Telescope. This is a very significant commitment on their part; it amounts to approximately 18 percent of their total Fy 1977 budget (or close to two years equivalent of their science budget). The ESA is composed of ten member nations that have participated with NASA on several previous joint programs and are now building the Spacelab for the Space Shuttle. The member nations represent the majority of Western European astronomers and would form a strong supplement to the United States scientific team. Naturally the commitment of ESA to the Space Telescope is based on the signing of the Memorandum of Understanding between NASA and ESA (under which ESA scientists would receive an amount of observing time commensurate with their agency's financial contribution) and of course the support by the United States Congress of the Space Telescope in the NASA budget. If there were a significant delay in the program, European scientists would presumably turn their interests to other areas and ESA would redirect its funds to more exclusively European projects.

Fourth, the Space Telescope is the logical and economical successor to the previous NASA program of short-lived individual space astronomy experiments. The availability of the Space Shuttle enables NASA to maintain and update a single observatory in space for a period of many years at a fraction of the cost of sending up a series of duplicate spacecraft. The Space Telescope will be the first major astronomical application of the full potentialities of the Space Shuttle.

The immediate predecessor of this committee, the Senate Aeronautics and Space Science

Committee, issued the following instruction in its report on the NASA Authorization Bill for FY'77: "...the committee requests that NASA in formulating its FY'77 budget request make the initiation of the Space Telescope project the item of the highest priority." In a recent NASA symposium [2] on the technical design and performance of the Space Telescope, J.A. Downey pointed out: "More time and resources have been expended on definition of the Space Telescope than in the planning of any previous NASA scientific mission." The Space Telescope is ready to go. American scientists and industrial people are eager to begin. Our European colleagues are anxious to participate. Now is the time to start.

I would like, if I may, to close on a purely personal note. Many astronomical discussions of the Space Telescope [3–6] are presented in terms of the commonly accepted Big Bang theory of the universe in which everything began some 10 billion years ago. In this cosmology, the universe began as pure hydrogen gas at enormous temperature and density and has been expanding rapidly ever since in a way that is determined exactly by a few elegant equations. I have refrained from describing the potentialities of the Space Telescope in the conventional cosmological terms because I do not personally want to believe that we already know the equations that determine the evolution and fate of the universe; it would make life too dull for me as a scientist. Instead I prefer to be mindful of the many cultures in the past who believed they had a comprehensive account of the cosmos: for example, the ancient Hindus who believed the universe is a round egg, covered with seven concentric shells composed of different elements or the ancient Hebrews who believed in a flat, disc-shaped earth that rests on pillars beneath the solid firmament, which is the heavens. More detailed astronomical observations made these cosmologies appear incomplete or even incorrect. I am probably among a small minority of scientists when I say that I hope, and believe, that the Space Telescope might make the Big Bang cosmology appear incorrect to future generations, perhaps somewhat analogous to the way that Galileo's telescope showed that the earth-centered, Ptolemaic system was inadequate. My own speculations and beliefs are, of course, unimportant. What is significant is that the Space Telescope has the potentiality for answering fundamental questions in which all of us are interested.

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