ACADEMY PANEL PROPOSES BOLD COURSE FOR SPACE SCIENCE IN 21st CENTURY

STEVE BENSON/MEDIA TRIBUNE SERVICES

When the cheering stopped for the near-perfect four-day flight of the space shuttle Discovery in early October, NASA's science program was still sitting on the launch pad. The flight of the reusable Discovery revived the nation's dreams of heroic astronauts exploring the solar system, but it did not restore the hopes of scientists that their space experiments will soon be in space. For NASA officials and the public, the televised scenes of the fiery launch, the astronauts clowning in flight and the smooth touchdown could be summed up with the buttons picturing the blastoff and bearing the phrase "Back to the Future." For space scientists, however, the future remains on hold.

NASA Administrator James C. Fletcher hailed Discovery's flight as "the first step into a new era." Those words were not lost on scientists, who welcome the end of the frustrating 32-month gap since the Challenger explosion and anticipate the beginning of exciting revelations about the Earth and the universe. But after heaving a sigh of relief, most researchers were still left scratching their heads.

One problem is the large backlog of reconnaissance payloads the Defense Department has on the priority list for shuttle flights. DOD had no choice other than the shuttle in placing its satellites into orbit. The Challenger calamity confirmed what critics in the Pentagon had warned Congress about in the early 1980s: It is folly for the US to put all its trust and cargoes in the shuttle. The long wait and the repeated delays in the flight of Discovery have caused several military missions to be bumped—notably, reconnaissance satellites and the Strategic Defense Initiative's Starlab, which is biding time for a critical test of the effectiveness of lasers in space. In consequence of these setbacks, DOD wangled appropriations from Congress to build 11 Titan 34–D rockets for military launches.

Casualties of Challenger

Scientists, by contrast, consider themselves among the casualties of Challenger. Only in recent months did NASA give in to the arguments of scientists that alternatives to the shuttle need to be found for their experiments. The Cosmic Background Explorer, originally planned for the shuttle, and future planetary missions will be flown from Delta rockets. But other, older scientific missions are still stuck with the shuttle. Hence, deadlines have been missed for launches of the Magellan (which is designated to map the surface of Venus), the joint US–West German Galileo mission (which is to survey Jupiter and its moons) and Ulysses (to conduct studies from a polar orbit around the sun). Then there is the plight of the Hubble Space Telescope. Once in space, it is virtually certain to revolutionize astronomy by extending the view to the edges of the universe. But it is in cold storage in a clean room at Lockheed in Sunnyvale, California.

Anticipating Discovery's success, NASA issued a launch manifest a few weeks before the shuttle flight (see box, page 85). In the event that Magellan misses its 20-day takeoff window, it will have to wait 18 months for Venus to come into correct alignment for another launch date. Galileo would wait 13 months for another chance at Jupiter. While they fretted over the Space Telescope, which had lost its place in line for a 1989 launch date and got pushed into 1990, astronomers were happy to learn in November that it had suddenly moved up the launch list to December 1989. The schedule change occurred when the Pentagon asked NASA to postpone placing a classified satellite in orbit.

"NASA's list of space shots," says Alex Roland, a professor of military history and technology at Duke University, "suggests that we're not entering a new era at all. What NASA is planning to do is return to the pre-Challenger era—that is, to run a space program based primarily on the shuttle. This strategy calls for building a space station and moving on from that to a manned Mars mission, which is the same era that NASA has been planning since the end of the Apollo moon landings."

John Logsdon, director of the Space Policy Institute of George Washington University, insists that NASA is simply returning to "the vision that has guided pioneers like Tsiolkovsky, Goddard and Oberth, who believed we humans would some day leave Earth and venture to the moon and Mars. NASA is simply returning to the steps necessary to act out that vision."

According to Congressional analysts, the total cost of the Challenger accident comes to at least $20 billion—though Logsdon puts the figure closer to $30 billion if the bill includes the impact on the military, on delayed scientific missions and on lost commercial satellite business.

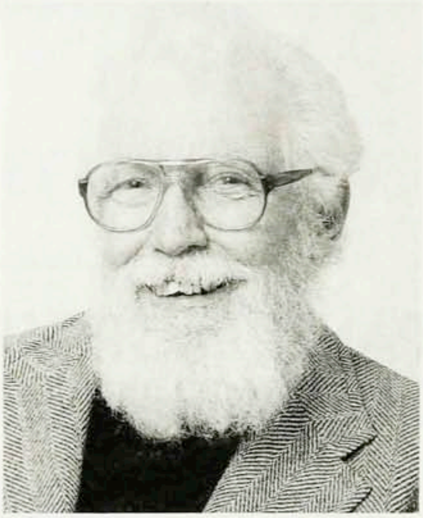
Although the shuttle is likely to be a safer way of reaching space than before the Challenger disaster, it is an even more expensive, complex and vulnerable vehicle than ever. "It's more susceptible to delays than any other vehicle in the world and, as such, it's less capable of being the workhorse of NASA's program," says Roland. He thinks it unlikely that NASA can hold to its relatively modest schedule of 18 more flights between now and the end of 1990.

"I don't disagree," declares Logsdon, "but it also happens to be all we've got for human exploration and scientific research in space. We always need to remember that popular and political support for a space program comes from the value of enabling humans to push out the space frontier."

Appeal of astronauts

Roland admits that astronauts are what "sells the whole space program." Nonetheless, he adds, "the balance needs changing. My major concern is that the entire NASA program is built around manned space flight. Since Apollo, two-thirds of NASA's budget goes for piloted missions. But the real payoff comes from automated spacecraft—from scientific probes, reconnaissance and meteorological payloads and communication satellites. I'd like to see the human program reduced and most of the funding for space be given to those activities that give us a real return on our investment."

Since the Challenger debacle, public support for the nation's space program has been increasing. *New York Times*–CBS News polls taken in



Donahue: Will wishing make it so?

January 1987 and again a year later indicated that 66% of the adults questioned said they thought the shuttle was "worth continuing." Following Discovery's flight, public support for the shuttle went up to 73%, even, as the question put it, "given the costs and risks involved in space exploration." In that same sampling, 33% said the government is spending too much money on space exploration, 19% said too little and 37% claimed funding is just about right.

To the surprise of many within NASA, who had braced for cuts in the fiscal 1989 budget, Congress last August reduced some social and environmental programs to give $10.7 billion for the space program—just about $1 billion less than the Reagan Administration's request. The appropriation kept hope alive for space research.

Only a few weeks earlier, the Senate had cut funding for the space station to $200 million for the year. Senator Bennett Johnston, a Louisiana Democrat who wields enormous power on the appropriations committee, moved to transfer $600 million from DOD to NASA , thereby sending a signal to other members about the importance of the station. In the House, Representative Edward Boland, a Massachusetts Democrat who heads NASA's appropriations subcommittee, convinced colleagues that a minimum of $900 million was needed if the station was to be built at all.

In a House–Senate conference, Senator William Proxmire, a Democrat from Wisconsin, who is an opponent of the space station, joined Boland in voting for the NASA appropriation, which won by a narrow 7-6 vote. The space station faces an even tougher fight next year when the funding request will leap to $2.1 billion and Congress will need to lop spending to meet the Gramm–Rudman–Hollings requirement of a $100 billion deficit limit in fiscal 1990. "The pressure to make cuts everywhere will be fierce," says a Congressional staffer. "But the President-elect [George Bush] is on record as dedicated to the space station. It's not clear what he thinks the station would be used for. It's also not clear what he thinks the shuttle would be useful for."

Pride of Presidents

Four presidents have made the shuttle the fulcrum of the US space program. The accident all but wiped out what was left of the shuttle's original rationale: that it could do all of America's work in space both reliably and economically. Now there is no new consensus within NASA or Congress about the shuttle's future or, by extension, about what the agency will do in human exploration and scientific research.

Indeed, many researchers argue that although science is frequently used to justify NASA's budget, it seems to be the first to get cut back when budgets are tight or priority questions arise. John N. Bahcall, an astrophysicist at the Institute for Advanced Study in Princeton, New Jersey, says that space science is secondary to NASA's main job of transporting astronauts and satellites into orbit. "Sooner or later, science will come back as dessert or entertainment," he observes, "but it's not clear it plays a major role."

Logsdon thinks otherwise. "American technology enjoys pride and prestige because of our manned space program. Space flight inspires us to excellence and creativity. The motivation to study science and engineering, the sense of common accomplishment that pulls millions of people into the National Air and Space Museum and attracts them to space topics at movies and on television comes from the involvement of humans," he says. "Those are all intangible but equally important payoffs."

In *The Heavens and the Earth: A Political History of the Space Age* (Basic Books, 1985), Walter McDougall argues that the space shuttle was not the product of a policy but the excuse not to have a policy. During the Apollo period "vagueness became the pattern," writes McDougall, "when the costs of new programs were unpredictable and sure to seem excessive in the Vietnam–Great Society era. Inevitable tinkering with long-range plans might also make NASA appear to be confused or fishing for big money." For the next few years NASA officials, the agency's advisory panels and the President's Science Advisory Committee disagreed on what to do beyond the moon landings. In the late 1970s, with the launching of the Soviet Salyut VI (a "salute" to Yuri Gagarin's first human flight in space) and a European satellite from an Ariane rocket, the US monopoly on space expertise appeared to be in relative decline.

Also in the late 1970s, beset with production delays and budget overruns, the shuttle program was saved from cancellation by the Carter Administration because DOD needed it to launch satellites vital to national security. Since Challenger, the military has moved to end its dependence on the shuttle as rapidly as possible by redesigning satellites and ordering expendable launchers—a state of affairs that is reckoned to cost about $12 billion.

NASA will continue to rely on the

Missions on the NASA manifest

Space scientists whose research projects were grounded for at least three years after the Challenger calamity on 28 January 1986 continue to be frustrated. Despite the successful voyage of the Discovery shuttle last October, NASA has only one more flight this year—the Atlantis, which is set to carry a Defense Department reconnaissance satellite equipped with high-resolution optics and radar. The agency has 50 scientific and military payloads, all told, queued up through 1993.

From the start of shuttle operations in 1982, the Pentagon has been entitled to preempt any NASA missions on the grounds of national security—though it rarely exercised this right. The Titan III and 34–D rockets that DOD uses to launch satellites have had a run of troubles. Until the Pentagon can obtain a reliable launch capability with a fleet of expendable rockets, it must rely almost entirely on NASA shuttles.

To be sure, NASA has a squadron of three reusable orbiters, but almost all heavy lifting can be done by only two—Atlantis and Discovery. The third, Columbia, is both older than the others and heavier by 4 tons. As such, Columbia lacks the performance capability needed for the Hubble Space Telescope and the planetary probes, as well as for most of the Pentagon's classified missions. Lennard A. Fisk, chief of NASA's Office of Space Science and Applications, argued long and hard to place the space telescope into one of the Pentagon's slots for next summer. But in the ensuing battle to move up the line, neither Fisk nor the Space Telescope Science Institute could muster the necessary allies within the agency, White House and Congress to win out.

The delay came with some benefits. As viewed by Riccardo Giacconi, director of the telescope institute, the postponement allows for further tests to be made on hardware and software, along with time to make some improvements. In one change, NASA installed new solar cells, which were developed by the European Space Agency to upgrade power levels by about 15%; another alteration allowed NASA to switch from nickel–cadmium to nickel–hydrogen batteries, thereby improving energy storage and cycling capabilities. In addition, the delay has enabled astronomers at the institute to improve their ability to use at the same time two of the telescope's five instruments, such as its wide-field planetary camera and its faint-object spectrograph.

Until last October, the space telescope was set for launch in February 1990. But when DOD asked to postpone a military reconnaissance satellite reserved for flight in December 1989, NASA proposed that the classified mission swap dates with the space telescope, and the Pentagon agreed.

The schedule through 1989 includes two interplanetary probes that NASA calls "window-sensitive"—meaning that if each is not launched in a relatively narrow period it will have to be postponed a year or more to await the correct planetary alignment. During the 32-month hiatus between shuttle flights, the agency ran into trouble preparing Columbia for its return to space. The shuttle had been expected to be ready for launch next February. It is now pushed back to July. NASA counts on Columbia for the first long flight in March 1992, when it is slated to carry a microgravity laboratory on a mission that is expected to last for about two weeks.

Here is NASA's current flight sequence:

▷ 1 December 1988, Atlantis—Classified military mission.

▷ 18 February 1989, Discovery—Launch of a Tracking and Data Relay Satellite (TDRS–4), which will operate in conjunction with TDRS–3, placed in geosynchronous orbit by Discovery last September. With two of these in full operation, NASA can maintain radio contact with a scientific satellite or shuttle as much as 85% of each orbit of Earth, thus making it unnecessary to use the agency's worldwide network of aging ground stations, which are in constant need of maintenance. The first of these communications satellites, TDRS–1, encountered difficulties soon after it was launched in 1983. TDRS–2 was destroyed in the Challenger.

▷ 28 April 1989, Atlantis—Flight will carry the Magellan radar mapper. The spacecraft is designed to orbit Venus, exploring the surface with a sophisticated radar.

▷ 1 July 1989, Columbia—Classified military mission.

▷ 10 August 1989, Discovery—Classified military mission.

▷ 12 October 1989, Atlantis—Launch of Galileo interplanetary probe, a cooperative project with West Germany to survey Jupiter and its moons.

▷ 13 November 1989, Columbia—Military communications satellite. This mission also calls for retrieving a scientific satellite left in orbit in 1984 that will fall back to Earth unless it is recovered sometime soon. The satellite has been testing the effects of weightlessness, radiation and cold on organic and inorganic materials.

▷ 11 December 1989, Discovery—Hubble Space Telescope, the complex $1.4 billion instrument that was originally scheduled to go up on the shuttle mission just after Challenger. The space telescope costs $7.3 million per month just to keep it operational while in storage in a dust-free hangar at the Lockheed Corporation's research center in Sunnyvale, California.

Other scientific highlights in the manifest:

▷ February 1990, Atlantis—Classified military mission.

▷ March 1990, Columbia—Astro–1, the first of two missions involving university experiments designed to collect ultraviolet radiation from various regions of space. Until the latest NASA launch schedule, Astro–1 had been listed for November 1989.

▷ April 1990, Discovery—Gamma Ray Observatory.

▷ October 1990, no shuttle designated—Ulysses, a cooperative project with the European Space Agency to investigate the properties of the sun.

▷ December 1991, no shuttle designated—Astro–2, postponed from January 1991 on an earlier manifest.

—IRWIN GOODWIN

shuttle for flying astronauts and for servicing its space station. During the Presidential campaign, both candidates endorsed the station, more or less, though neither provided any ideas about paying its price. Nevertheless, the candidates also darkly hinted that budgetary constraints are likely to impede ambitious projects such as sending people to Mars or building a base on the moon—both goals usually voiced for building the space station.

To carry out the "core program" now on NASA's books—space station, second generation shuttle, robot science missions and so forth—would require the agency's annual budget to almost double by the year 2000 to $16.4 billion (in 1988 values), according to a report issued last May by the Congressional Budget Office. The CBO report calculates that operating the current fleet of shuttles along with conventional rocket services and an unmanned cargo carrier using the shuttle propulsion system would cost as much as $3.1 billion per year by 1996. Running the space station is likely to add another $1.5 billion annually beginning in 1999. A tracking and data network for both low Earth orbit and deep space would cost another $1 billion per year.

The core program's space science and applications projects include four "Great Observatories"—the Advanced X-Ray Astronomy Facility and the Space Infrared Telescope Facility, both to be functioning in the 1990s, as well as the Hubble Space Telescope and the Gamma Ray Observatory. When operating, these four will give US scientists an observing capability in all major wavelengths. The science program also calls for new planetary missions such as CRAF (the code name for the Comet Rendezvous–Asteroid Flyby), the Cassini probe to Titan (Saturn's principal moon) and an Earth Observation System. All told, the science projects might total $2.2 billion per year by 1995, says CBO. What's more, CBO figures that the research and program management from 1989 through 2000 could account for another $2.3 billion per year.

Of course, such estimates do not take into consideration major accidents, cost overruns and new projects. Worse yet, CBO did not figure in any of the far-out initiatives suggested by the 1986 Presidential commission headed by Thomas O. Paine, a former NASA administrator, or a year later by Sally Ride, the former astronaut now practicing physics at Stanford. The Paine and Ride reports call for a more aggressive space program that includes such options as an odyssey to Mars, a lunar colony and a vigorous unmanned exploration of the solar system (see PHYSICS TODAY, October 1987, page 64). Carrying all these out could more than triple NASA's budget by the year 2000.

Perhaps the most imaginative set of space science activities was revealed at a two-day symposium last July to mark the 30th anniversary of the National Research Council's Space Science Board. On the occasion at the National Academy of Sciences, the board released its report on *Space Science in the Twenty-First Century*, which had been originally commissioned four years earlier, long before the Challenger episode. In describing the report, the board's chairman, Thomas M. Donahue of the University of Michigan, listed two caveats: First, the timetable suggested by the subtitle, "Imperatives for the Decades 1995 to 2015," really means "the two decades or so after the currently planned missions are finally flown." Second, the recommendations are not a ranking of priorities. Without having information from space projects not yet launched, said Donahue, board members could see no reasonable way of setting such priorities. Nor could the board calculate the costs. The proposed missions are so far off and so broadly defined that the estimates would be little more than guesses.

Opportunities in six fields

The Donahue Report lays out a panoply of possibilities in six fields:

Earth sciences. The Space Science Board recommends continued emphasis on studying the planet as a global system—a high-priority theme that is dramatized by recent international concerns about chlorofluorocarbons and carbon dioxide in the atmosphere, depletion of the ozone layer and last summer's devastating drought in the Midwest. In the 21st century the board would like NASA to deploy at least two of a set of five global monitoring satellites in geosynchronous orbit; a set of two to six platforms with an extensive array of sensors to provide global coverage at lower altitudes from polar orbit and thus complement the higher altitude satellites; a worldwide network of ground sensors, possibly using NASA satellite technology for autonomous data acquisition operation in remote locations; and advanced computer systems for analyzing the flood of data collected by the sensors and for acquiring better theoretical models of Earth–atmosphere interactions.

Planetary and lunar exploration. Here the board calls for better understanding of the origin and evolution of the entire solar system to understand planet Earth. It therefore proposes surface rovers and sensor networks for the Moon and all the inner planets of the solar system—Mercury, Venus and Mars—and that samples be returned from all but Mercury; orbiters and atmospheric probes for all the gaseous giants of the outer solar system—Jupiter, Saturn, Uranus and Neptune—as well as an orbiter for Pluto; landers for Jupiter's moon Io and Saturn's moon Titan; and rendezvous and sample-return voyages to a variety of comets and asteroids. In parallel with this, the board proposes special emphasis on Mars as the most Earth-like planet in the solar system. Mars, says the Donahue Report, should be the subject of extensive investigation and perhaps even human exploration, but only as a supplement to the baseline program, not as a substitute. "The recommendations put forward here, if implemented, will advance our understanding of the solar system on the broad front that is needed to progress toward answering some of mankind's long-standing questions about the cosmos," the report asserts.

Solar system space physics. In this field the board proposes a program to advance understanding of the sources and processes of the sun's magnetized plasma. Among its recommendations are high-resolution x-ray and ultraviolet telescopes to study small-scale phenomena that are thought to play a critical role in producing solar flares and the solar wind; a solar probe to carry sensors to within 2 million kilometers of the sun's surface; a high-speed interstellar mission that would approach the edge of the sun's magnetosphere within 10 years; and new instrumentation for large-scale monitoring of the Earth's magnetosphere.

Astronomy and astrophysics. "The universe we perceive today," says the report, "appears much more complex in its design and more mysterious in its ways than anyone could have predicted in generations past." So, the board is naturally intrigued by questions about the large-scale structure of the universe, dark matter, gravitational forces and the formation of planetary systems, stars and galaxies. To try to answer such conundrums, it proposes a program involving large imaging interferometers in which orbiting arrays of optical, infrared or radiotelescopes would operate in parallel to provide images of distant galaxies and quasars that are hundreds of times sharper than those likely to come from the Hubble Space Telescope. The program includes separate telescopes with vast collecting areas—an 8- to 16-meter optical telescope, say, or a gamma-ray telescope for energies above 2 MeV—that would gather scarce photons by the bushel. The board also calls for a new high-resolution cosmic-ray spectrometer using superconducting magnets for research in particle astrophysics, and for a vigorous exploration program carried out by Explorer-class satellites to provide a baseline for future studies.

Fundamental physics and chemistry. The board sees exciting opportunities for high-sensitivity tests of general relativity and gravitational waves, using such techniques as a laser observatory to detect gravitational radiation at frequencies below 10 Hz from space and a hydrogen maser clock on board a spacecraft that could measure the gravitational redshift to second order. It also suggested the possibility of studying the behavior of matter under conditions of weightlessness—the materials processing research that NASA has advanced as an important reason for building the space station. While the board agreed that interesting work could be done in this subject, it says little is known about the basic scientific questions. "Until these are answered," the report states matter-of-factly, "there does not seem to be any way to structure a rational program of materials processing in space."

Life sciences. Among the most vexing unanswered questions are those involving the origin and evolution of global biota in space and interactions with life on Earth. In addition, if the US eventually decides to go ahead with a colony on the Moon or an expedition to Mars, human life in space demands a better understanding of how weightlessness degrades bone and muscle, what kind of shielding astronauts would need in the interplanetary environment and what it would take to develop a reliable ecosystem for recyling wastes on flights extending for months or years.

In the penultimate chapter, the board admits it had difficulty determining which scientific projects, other than those in space medicine, "compel the presence of humans in space. In fact, there may be no others." Board members clearly know that humans can function in support of science in space, but "at present we lack enough information to judge where the balance between manned and unmanned missions should lie."

Collaboration or competition

The concluding section seems to say the board prefers international cooperation to world rivalry in space science. It is careful to point out that the US needs to be wary about disruptions that result from "unanticipated changes in the relationship that may be imposed for reasons that are outside the scientific programs.

In a letter sending the Donahue Report to NASA Administrator Fletcher, Frank Press, president of the National Academy of Sciences, writes that the findings and recommendations "probably constitute, in aggregate, a much larger space science program than can be realistically anticipated in the period of time examined in the study." Press acknowledges that the board members are aware of this, particularly in light of the painful lessons of the past few years.

For its part, the board urges NASA to make science "an objective no less central to the space program of the US than any other." The message is clear but unstated: If NASA is bent on taking on spectacular feats of engineering for the sake of national pride and prestige, or to further military and commercial causes, it may be best to separate scientific research from the rest. This topic, however, was hardly discussed at the symposium.

Nevertheless, in his remarks at the symposium, Donahue emphasized that the program the board outlined for the coming decades heralds a true golden age of understanding and advancement. The justification for the huge investment in space science, he says, has its own intrinsic worth: It provides answers to some of the most fundamental questions in nature; it contributes to the scientific and technological prowess of the nation; it stirs mankind's imagination and broadens perspectives.

—Irwin Goodwin

DEFENSE SCIENCE BOARD URGES PRESIDENT TO COORDINATE MILITARY WITH ECONOMIC PLANS

Throughout the long and often caustic 1988 Presidential campaign, the issues heard most—patriotism, family values, crime, prison parole—were matters of personal and state responsibility, not those the new Administration can do much about. By contrast, in the transition between the Reagan and Bush periods, many of the transcending realities facing the government are up for debate: the budget deficit, economic competition, industrial innovation, scientific preeminence. All of these problems are discussed in a report of fewer than 65 pages, issued two days after the election by a task force of the Defense Science Board. The report is directed at measures the President should take to reverse "an increasing loss of technological leadership to both our allies and adversaries."

Designated to examine conditions in the defense technology and industrial base, the task force found that push has come to shove. "The days of Fortress America are past," it asserts. The evidence suggests that military research and production are in decline, with far-reaching consequences. Persistent deterioration of the nation's technology and dependence on foreign suppliers for such critical components in weapons systems as semiconductors, machine tools and precision optics have "diminished the credibility of our deterrent," the report declares.

Woes of defense business

The 28-member panel, headed by Robert A. Fuhrman, chairman, president and chief operating officer of Lockheed Corp, argues that the US defense industry has not made sufficient long-term investment because of a propensity for the Defense Department to adopt short-term goals. To be sure, says the Fuhrman Report, blame for this can be placed on fluctuations in Federal funding and equivocations in Pentagon procurements. The panel also is concerned about the perception of investors and contractors of the disparity between the risks of weapons production and the rewards for defense business.

The science board report comes as many in the Pentagon, Commerce Department and Congress worry about US dependence on foreign manufacturers and suppliers for advanced military technologies. A decline in US industrial competitiveness had been decried as a national security issue in reports by the Congressional