SPACE WORLD

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ON THE COVER

The space station Freedom, shown being resupplied by the shuttle Atlantis in this dramatic painting by Cleveland-based artist Paul DiMare, is symbolic of the new age in space. Both an opportunity and a potential liability for space scientists, the space station represents a major national commitment—and a test of the new President's commitment to space. Political activist Thomas Frieling examines the outlook for space under the new administration in his article, which begins on page 7, while veteran *Space World* writers Ray Spangenburg and Diane Moser analyze this role of the space station in their article beginning on page 14.

PHOTO CREDITS: Page 3, U.S. Air Force; Page 6 NASA; Page 9, Mark and Tom Usciak; Page 12, NASA; Page 13, European Space Agency; Pages 14 and 17, Stanford University; Page 15, McDonnell Douglas; Page 16, Boeing; Page 19, Martin Marietta (left) and General Dynamics, Pages 22 and 23, NASA; Page 25, British Aerospace; Page 28, NASA; Page 29, NASA (top) and Jet Propulsion Laboratory; Page 31, Magellan Systems: Page 32, Martin Marietta.

Dialogue

Liftoff!

Space World is experiencing a rebirth with this issue. Now that we are once again publishing an independent magazine, we intend to continue to broaden the coverage of space activities that we pioneered 28½ years ago.

During the past three months we have been involved in a transition. As the National Space Society was putting together its new magazine, which will debut this month, we were reexamining *Space World* to see how we can make it more useful to you, the reader.

We are convinced we have come up with an editorial package that will make the magazine must reading for anyone who is concerned with what is really going on in space. This is the magazine you have come to depend on for all these years, and we are mindful of our responsibility to fulfill your trust.

While *Space World* is the oldest consumer magazine in its field, we like to think it is also the newest. Every issue looks to the future, not to the cliches of the past. Space exploration is a dynamic activity, and blind acceptance of yesterday's answers is inadequate for today's challenges.

We envision *Space World* as an intellectual journey into an exciting, unknown territory—for readers and editors alike. If you want pat answers, I'm afraid we can't help you. But if you want a magazine that raises the questions that stimulate *your* thinking, you've come to the right place.

I see our approach as analogous to what H.L. Mencken had in mind in 1924 when he launched the *American Mercury*, which was to become the most talked-about magazine of its generation. As he described the magazine in a letter to Upton Sinclair the previous year, "it is to be a genuinely first-rate monthly, well printed on good paper.

"I shall try to cut a rather wide swathe in it, covering politics, economics, the exact sciences, etc.," he continued. " . . . it will be, in the main, Tory, but *civilized* Tory."

That last phrase, Tory, but *civilized* Tory, describes *Space World* too. We are not out to overthrow any of the existing space institutions, least of all NASA or the aerospace industry, but we are not apologists for any particular point of view either.

We intend to maintain a steady flow of responsible criticism, conducted at a high level and free of personal invective. Our job is to generate the facts and the ideas to enable *you* to make the decisions—which is the way all news media are supposed to work in a democratic society.

In the final analysis, you will be the judge of whether we have succeeded. You have the opportunity to continue this intellectual journey with us as a subscriber. No magazine can exist without readers, and you can vote us up or vote us down with your checkbook. We think you will like what you see and that you will vote us up.

But we hope your involvement with this magazine won't end there. We need to hear what *you* think. This time I am writing to you to express our views. Now it's your turn.—*Charles E. Spanbauer* ★

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PALMER PUBLICATIONS
318 N. Main St.
Amherst WI 54406
(715) 824-3214
Charles E. Spanbauer, Publisher
Helga Onan, Managing Editor
Judy Statezny, Chris Abbott, Typography
Mary Stanchik, Subscriptions

EDITORIAL OFFICE
150 N. Muhlenberg St.
Woodstock VA 22664
(703) 459-5096
John Rhea, Editor

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Leaders

The New Age

President-elect Bush, like his 40 predecessors, will have a limited ability to leave his mark on American society. Despite the awesome powers of the presidency, there are also countervailing powers, particularly in what seems to be the permanent partisan division between the executive and legislative branches. As a result, he will have to choose his targets carefully and focus major political and economic resources on them in order to achieve lasting accomplishments.

In the tradition of the Truman Doctrine to contain Communism, President Kennedy's Apollo challenge and the civil rights and anti-poverty efforts of President Johnson, President Bush can leave an impressive legacy when he departs the White House. We believe there are compelling reasons why a rejuvenated space program should be on his short list.

May 1960 at Cape Canaveral: The first-ever launch of a Delta on the 13th failed to achieve orbit for an Echo passive communications satellite, but on the 24th an Atlas-Agena successfully launched a Midas satellite for infrared observations of foreign missile tests.

While the conventional wisdom holds that the Bush administration will build on the foundation established by President Reagan, we think President Bush can do better—much better—when it comes to space. As Thomas J. Frieling, executive director of the Campaign for Space, explains in his analysis beginning on page 7, the new President will be severely hampered by the massive budget deficits racked up by an administration that was better at rhetoric (like the space station that was supposed to be in operation in *one* decade) than performance (like the indecision over an orbiter to replace Challenger).

The incoming administration might seek its inspiration from President Eisenhower, who was responsible for the framework that President Kennedy quickly seized to propel this nation into space. One example is illustrative: the F-1 rocket engine originally developed by the Pentagon before the creation of NASA in 1958 proved to be the "pacing item" of the Saturn vehicle that placed the first Americans on the Moon.

An equally important legacy was President Eisenhower's insistence in the face of strenuous objections within his administration that a civilian agency be established to run the nation's space program. Most Americans are at least vaguely aware of the warning that the great hero of World War II issued to his fellow countrymen in his farewell speech of January 18, 1961: "In the councils of government we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex."

What is almost universally overlooked is *another* warning he issued in the same speech: "Yet in holding scientific research and discovery in respect, as we should, we must also be alert to the equal and opposite danger that public policy could itself become the captive of a scientific-technological elite."

Throughout the Reagan years a scientific-technological elite has forced American space activities into the Procrustean bed of the shuttle and the resulting NASA monopoly. We don't think that's what President Eisenhower had in mind when he fended off the military—nor, to his credit, President Reagan, when he belatedly issued his commercial space policy that broke that monopoly.

Now it's President Bush's turn. He has already begun by moving toward a step this magazine has consistently supported: reestablishing the National Space Council to coordinate the increasingly splintered scientific, commercial and military activities in space. That in itself will not usher in the much-desired new age in space, but it should give needed visibility to space within the administration—*if* its chairman, Vice President Quayle, can achieve some degree of the success of such illustrious predecessors as Vice Presidents Johnson and Humphrey.

That still leaves the question of where are today's equivalents of the F-1 engines of 30 years ago? Here President Bush starts with a relatively bare cupboard. An exception is the Air Force's Advanced Launch System, or ALS, which could accomplish what the shuttle failed to do: provide moderately priced, regularly scheduled transportation to space.

As Terri Lehto, an analyst with Jane's Information Group, points out in her article beginning on page 18, ALS has become intertwined with the Strategic Defense Initiative. It shouldn't be. This is a capability that is needed now. Despite President Bush's campaign promise to deploy SDI as soon as it is "viable," the reality is that technical problems and financial constraints will delay that decision past his administration—even if he serves two terms. The best that SDI supporters can hope for in the near term is continuing the SDI research program at about the current funding level of $4 billion a year.

In trying to anticipate the shape of this new age in space that is trying to be born, it is instructive to examine past events that didn't seem impressive at the time but which formed the foundation for today's activities. May 1960, the month this magazine first appeared, is a good example. The United States launched two obscure payloads that month: an Echo balloon passive communications satellite and a Midas satellite to detect missile launches through the use of infrared sensors.

The Echo launch on May 13 was a flop because of failures by the upper stages of a new vehicle being flown for the first time, which was based on the first-generation Thor intermediate-range ballistic missile. Midas was orbited successfully on May 24, but both launches were eventually overshadowed by a nondescript Soviet spacecraft launched on May 14 and enigmatically labeled at the time 1960 Epsilon. Eleven months later, on April 12, 1961, the world found out what 1960 Epsilon was all about: it was a test of the Vostok spacecraft that took the first human into space, Yuri Gagarin.

Ancient history? Not really. The "land-loving Thor," as it was sarcastically called at the time, has been transformed into today's ultra-reliable Delta. It will lead off U.S. commercial launch activities this year, as our Cape Canaveral correspondent, Irene Klotz, explains in her article, which begins on page. 10. Communications satellites (active ones these days, and in geosynchronous orbit) are equally the backbone of the commercial space business. And, yes, the Russians are still busy shuttling cosmonauts back and forth into space.

This is the legacy that President Bush inherits. He will have to build on it if there is to be a new age in space.—*John Rhea* ★

Needed: a National Space Council

President-elect George Bush said in a speech following the October landing of the space shuttle Discovery that the time is ripe to "develop a new comprehensive strategy for space." He added that he intends to create a National Space Council chaired by the Vice President which "will be asked to do two things: make recommendations regarding specific directions for the future, and act as a focal point for international cooperation."

It appears that such a Council will be created—either by executive order or pursuant to legislation. Regardless of the means, it is clear that creation of a National Space Council is a welcome step in the direction of providing a focal point for U.S. leadership in space. For several years, we have attempted to determine space policy through a loosely organized Senior Interagency Group. While that has provided a useful coordination function, what is urgently needed is a leadership and decision-making mechanism. For that principal reason, the Electronic Industries Association enthusiastically endorses the creation of the National Space Council with the Vice President as chairman.

Several cautions and suggestions are in order. First of all, the simple fact of creating the Council will not be a panacea. Leadership does not automatically flow from organizational change. The reality is that such change can facilitate leadership, but only if there is strong commitment—on the part of the President to give the Vice President real authority, and on the part of the Vice President to commit the significant time and energy it will take to make it succeed.

Second, because budget and turf fights have become a way of life in the space program, it is essential that the Council be established very early in the Bush administration—before turf gets reestablished and defensive walls are erected. If we are to have a national space policy, it must be the national interest—not that of some department or agency—which provides the basis for decisions. With space interests that cut across the Pentagon, NASA, the National Oceanic and Atmospheric Administration, the Departments of State, Commerce and Transportation, etc., and with the fiscal reality which our budget deficits force on us, the nation cannot afford to have space policy decided on any basis other than the national interest.

Third, there are some obvious agenda items for the Council to address in addition to (or as a part of) those stated by President-elect Bush. These include establishing budget and program priorities, and dealing with the issues of commercialization, global environment, scientific exploration, the space station, and launch requirements and capabilities. While hardly an exhaustive list, it is indicative of the difficult nature of the issues to be decided—making the need for a decision-making mechanism almost self-evident. When one adds to those the very tough problem of coordinating the civil and military sides of the total U.S. space program, the task becomes awesome.

Finally, as representatives of the nation's electronics industries, with considerable technical expertise, we feel strongly that there is a useful role for us to play. Along with the scientific community, we have been major players in the U.S. space program from its inception. Our history of dedication and technological achievement is well known, making it clear that the National Space Council could benefit from having available the advice of the electronics industry and scientific community. Accordingly, the EIA strongly endorses the establishment of a user advisory panel.

The National Space Council holds great promise, but numerous pitfalls stand in the way of significant success. Realistic and committed leadership is the key. Only time will tell the result, but we at EIA believe the effort must be made if the U.S. space program is to move forward and take maximum advantage of our country's tremendous capabilities.—*Peter F. McCloskey*, president, Electronic Industries Association. ★

Old Whines in New Bottles

Back in the early days of automobiles, when the first horseless carriages were rumbling down America's bumpy roads, somebody noticed a curious thing: some of those early cars had small horizontal iron rings welded to the frame beside the driver's seat. It was not until automobiles had been around for a while that manufacturers realized you didn't need a place to put the buggy whip.

In some ways, today's generation is doing the same thing. No, we're not putting clutch pedals in the shuttle cockpit. But we often resort to "buggy whip" thinking in looking at space policy and economics.

Despite literary and historic parallels with the great epochs of terrestrial discovery and exploration, space travel is a unique endeavor, complete with its own special dangers and rewards. The problems that European and Ming Dynasty explorers faced were severe, but they were basically extrapolations (bigger ships, longer distances, larger crews) from existing operations.

By contrast, the step from flying jumbo jets to launching the space shuttle involves substantially different technologies and environments. Just as it would be ludicrous to try to solve our shuttle problems with airplane technology, it is silly to tackle the economic and technical challenges of space with groundhog solutions (many of which didn't work in the first place.)

A case in point: many libertarian theorists have drawn up magnificent strategies for wholly privatized, nongovernmental space operations. They go back to the dazzling philosophies of the likes of Ayn Rand to come up with some splendid concepts—on paper—for getting Adam Smith into orbit. Upon closer examination, however, their ideas begin to sound like a Dungeons and Dragons rule book: logical, ingenious, 100 percent internally consistent—and bearing little relation to the real world.

The problem was succinctly stated by Stephen L. Gillett, a geologist, industrial consultant and former L5 Society board member: "Why invest in messy, cranky innovators when, with a little financial legerdemain, you can make vast risk-free profits almost overnight? When T. Boone Pickens can make $114 million merely by threatening to take over Mesa Petroleum, the incentive for major investment in risky, long-term, exceedingly capital-intensive ventures like space development is slim indeed."

On the flip side, of course, are the NASA groupies. To them, any suggestion that the National Aeronautics and Space Administration is not the be-all and end-all of space is like strangling mom with the flag and soiling the apple pie. In their insistence on the primacy of government, they are like the fundamentalist Marxists who dutifully shuffle through *Das Kapital* trying to find what Old Whiskers had to say about genetic engineering and nanotechnology.

Space development is to terrestrial development as the transistor is to the vacuum tube: there are some similarities, but a lot more differences. Trying to make the new technologies fit the old templates doesn't cut it. The modern corporation, the joint stock company, came about because the 17th-century Dutch and English voyages of exploration were so costly (for their time) that a new means of financing had to be found. So some bright souls created the limited-liability corporation, in effect an artificial person.

Space launches are also expensive—for our time. Space stations are even more expensive, and only an astrologer or economist—I am told there is a difference between the two—would dare guess what the ante for a space colony will be. The one thing we know for sure is that none of the old paradigms will tell us how to pay for it.

That's the problem: who will create the really new and applicable solutions needed to get a spacefaring civilization off the ground? Probably not the "experts." Their grooves are so deep that they'll never get out of the rut. Almost certainly the innovations will not come from scholars or lawyers: trades based on looking for and applying precedents are not geared toward groundbreaking approaches.

The answer will come instead from that rarest of all critters, the truly original thinker: that person who can tailor new solutions without wasting time trying to fit old patterns.

The biblical writer who penned "Man is born of woman" never heard of test-tube babies, Adam Smith's criteria for the Wealth of Nations did not include information, and Malthus couldn't even imagine hydroponics. Space is a new game and needs a new, erasable rule book—one that doesn't include buggy whip sockets on our starships.—*Jack Kirwan* ★

Orbiting Around

Freedom Under Contract . . .

Final contract negotiations have been completed between NASA and the four major aerospace firms chosen to construct the space station Freedom. The 10-year, $6.7 billion cost-plus-award-fee package covers the design, test and evaluation, and final delivery of the initial Phase 1 version of Freedom.

Boeing Aerospace, Huntsville, Alabama, ($1.6 billion) will work with NASA's Marshall Space Flight Center to develop the U.S. laboratory and habitation module, the environmental control and life support systems, and the internal thermal and communications systems.

McDonnell Douglas Astronautics, Huntington Beach, California, ($2.6 billion), under contract to Johnson Space Center, will design the truss structure, mobile servicing system transporter, airlocks, data management system, navigation and control system, extravehicular activity operations, and the guidance and thermal control systems.

GE Astro-Space Division, Valley Forge, Pennsylvania, and East Windsor, New Jersey, ($895 million) will work with Goddard Space Flight Center to construct the free-flying, unmanned polar-orbiting platform, attach-point hardware, and a pointing system for external scientific instruments on the station.

Rocketdyne Division of Rockwell International, Canoga Park, California, ($1.6 billion), in a project for Lewis Research Center, will provide the 75 kilowatt electrical power and distribution system for Freedom, as well as the power system for the U.S. polar platform.

. . . as Deliveries Begin

Two mockups of the airlocks for the space station Freedom have been delivered to Johnson Space Center by McDonnell Douglas.

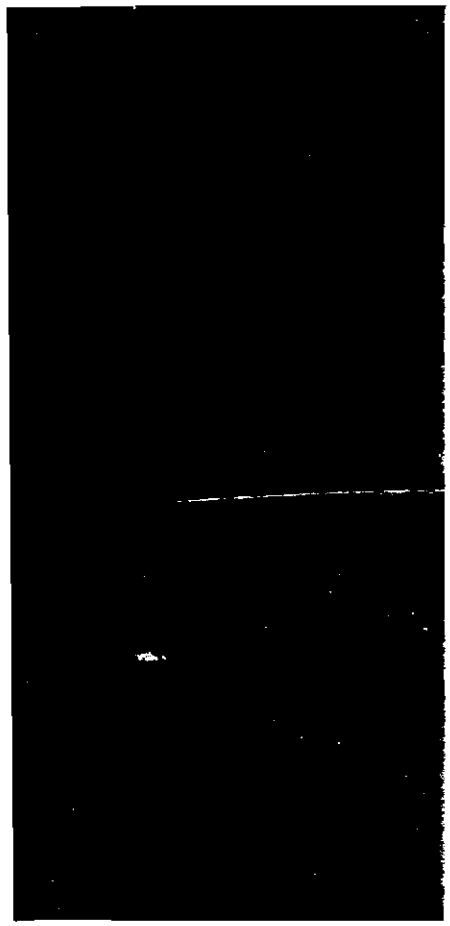
The airlocks, the first station test hardware sent to JSC since the Freedom contract was awarded a year ago, resemble large, hinged oil drums. They are divided into a crew lock and an equipment lock. The mockups feature adjustable compartments that will be tested in the JSC Weightless Training Facility pool to determine the most suitable volume for both pre- and post-extravehicular activity (EVA) for two astronauts.

"The correct sizing of the airlocks is crucial in allowing the astronauts to enter and exit the station," said Wilson Wong, project engineer for McDonnell Douglas. "The more efficient the system is, the more help it will be during assembly and maintenance of the station."

Meanwhile, Lockheed Missiles & Space Company, a major subcontractor on three of the four space station work packages, is building a 16,000-square-foot Life Support Laboratory in Houston. Scheduled for completion this spring, the lab will be the center for Freedom EVA research, and study of crew health, space medicine and biology and future life support challenges, such as a Moon base. Lockheed's EVA-related projects include spacesuit design, propulsion backpacks and on-orbit tools.

Where Am I?

The first hand-held, reasonably affordable marine navigation device has been developed by a Southern California-based firm that takes full advantage of 24 Global Positioning System (GPS) satellites launched into low-Earth orbit by the Defense Department.



LOOK MA, NO MAP: The Magellan GPS NAV 1000 hand-held navigation device.

For about $3,000, commercial and recreational boaters, or anybody who wants to know precisely (within 30 meters) where he is located, can purchase the Magellan GPS NAV

(continued on page 31)

Now it's George Bush's turn.
The space community is watching his lips for clues
—and ought to be.

Promise Versus Reality

by **Thomas J. Frieling**

I am fully committed to the U.S. space program. I am fully and utterly committed to the peaceful exploration of near and far space.—George Bush, October 3, 1988, following Discovery's successful landing.

There are budgetary considerations of course. This is no time to be wasteful.—George Bush, same day, same speech.

NASA traditionally has received a disproportionate share of attention from the media and the public for the relatively small federal agency that it is—one that garners little more than 1 percent of the total federal budget. Sending men to the Moon and robots to the edge of the Solar System and beyond virtually guarantees media coverage. And the fact that our national investment in high technology pays economic dividends doesn't hurt either.

But getting presidential candidates to pay attention to space policy when so many other issues are no less important to the national interest and have bigger constituencies to boot has been harder to pull off.

In the 1988 presidential elections, however, both victor and vanquished made their space policy positions clear throughout the long race. George Bush and Michael Dukakis each released detailed space policy position papers and made major campaign addresses at NASA field centers, taking generally favorable positions on the future of the civil space program. Bush also availed himself of one of the campaign's most dramatic photo opportunities when he greeted Discovery's flag-carrying crew on the lake bed at Edwards Air Force Base, California. (For background on the presidential race, see "Space Race '88," *Space World*, October 1988).

But as George Bush begins his first presidential term, the promises he made during the fall election campaign face their most crucial test as the new President faces the cold realities of Washington. Given the current political and budgetary situation, how will civil space policy fare during the next four years?

During the fall campaign, Bush went on record with support for major NASA programs like the space station; continued unmanned exploration of the Moon, Mars and the outer planets; construction of a shuttle orbiter to replace Challenger; and development of a heavy lift launch vehicle, as well as a fleet of expendable launchers run by private industry. He also endorsed the Mission to Earth goal of the Ride report.

Despite Bush's announced support for these efforts, many space program observers agree that NASA is at a crossroads. Although the shuttle program has successfully recovered from Challenger, a shuttle program does not a space program make. Indeed a recent Congressional Budget Office report makes it clear that major increases to NASA's budget are necessary just to complete the "core program" of approved missions—flying the shuttle fleet, building the space station and completing the space science and planetary exploration missions already awaiting launch.

Supporters of an expanded civil space effort like to point out that, given NASA's small percentage of the total federal budget, either eliminating or doubling NASA's funding would have little impact on reducing the federal deficit, which is expected to weigh in at about $155 billion on inauguration day.

The campaign promises of last fall will soon run headlong into the realities of the federal deficit, where doing all things for all constituencies is manifestly not possible and where tough choices must be made to satisfy the Gramm-Rudman-Hollings Deficit Reduction Act.

The budgetary rules under the Deficit Reduction Act require federal agencies to play a "zero sum" game: if one agency gets a bigger slice of the budget pie, then some other agency necessarily gets a smaller slice. Thus for NASA to continue its current programs—much less to realize any of the visionary new goals outlined in the Ride Report—additional funding must be taken away from one of the space agency's fellow federal departments.

And if those rules weren't bad enough, because of the way Congress handles appropriations bills, NASA must compete at the committee level for its funding against the Department of Housing and Urban Development and the Veterans' Administration, two agencies with large and vocal constituencies.

Obviously, the Bush administration faces tough choices as the fiscal 1990 budget cycle begins. For an incoming President who campaigned on promises of no new taxes and who will be forced by the Deficit Reduction Act to balance the budget, support for increased space spending at the expense of other domestic programs certainly will create a furor in Congress, where both houses are still controlled by Democrats.

Last year's protracted wrangling over the space station budget is just a warm-up for what is expected over the passage of this year's budget. NASA has requested a fiscal 1990 budget of $14 billion—an increase of more than $3 billion over the current fiscal year, which began last October 1. New starts are requested for the long-awaited Comet Rendezvous/Asteroid Flyby mission and the Cassini Saturn orbiter/Titan probe mission. These new planetary missions are widely viewed as essential to maintaining the credibility of the Solar System Exploration Committee's recommended core program aimed at provid-

Let the Experts Speak

George Bernard Shaw once observed that if all the economists in the world were laid end-to-end they wouldn't reach a conclusion. But *Space World* polled several space policy experts and found they had no trouble concluding where the U.S. civil space program should go under the new administration:

"We advocate human exploration of Mars as a goal for the American space program, conducted jointly with the Soviet Union and with other nations on behalf of the human species. This long-range goal would provide short-term direction to the space station program, use of the shuttle, construction of new launch vehicles, the role of the Moon and unmanned exploration of the planets. Without the Mars goal all of these programs will continue to founder."—Louis Friedman, executive director, The Planetary Society.

"Absent a clear political/sociological mandate for a marked increase in our civil space program, our planning should concentrate on deriving the maximum practical and cultural benefits from the present level of resources, namely: full utilization of existing and prospective missions; applicational and scientific work emphasizing ecological and environmental aspects of the Earth on a global basis; scientific work in solar, planetary and stellar astronomy; return to primary reliance on expendable launch vehicles; reduced emphasis on the flight of human crews; and substitution of a much simpler and less expensive space station for the presently planned one."—James A. Van Allen, Carver professor of physics emeritus, University of Iowa.

"The United States should finally recognize it has three civilian space programs, each with its own justification and requirements. Attempts to focus the program on single goals or themes will ultimately be futile. Our space science program ought to be evaluated as one aspect of the country's program of fundamental research, and priorities set in that context. Our space applications program deserves higher priority; the country has not been exploiting the full potential of space technology for providing societal and economic payoffs. Finally, our space exploration program, involving both machines and humans, should be recognized as primarily a cultural and political undertaking, not a scientific one. It is the portion of the space program that commands most public interest and support, and thus deserves top priority in the government's space program."—John M. Logsdon, director, Space Policy Institute, George Washington University.

"No space program will be continued unless it addresses the critical problems of U.S. economic survival and growth in a competitive, clever, hard-working world. All of the space programs now generally in discussion fail to meet that test. Only one space program can make a strong positive contribution to our economic survival. That is the construction in space of satellite solar power stations from lunar materials. Its potential is a $400 billion per year world market. With that as our primary goal, Congress and successive administrations will support an accompanying strong program in space science."—Gerard K. O'Neill, professor of physics emeritus, Princeton University.

"The Aerospace Industries Association holds that space is an investment in tomorrow because it is a driver of scientific and technological advancement, not just in aerospace but across a broad spectrum of productive endeavor. The more challenging the program, the broader the benefits. AIA therefore favors a civil space program with the general goal of expanding human presence in space, to the extent that available resources will allow. An important step is the space station Freedom, an enabling facility for science and technology advances and the centerpiece of the space infrastructure essential to extending human presence beyond earth orbit. We believe it is premature at this time to select goals for the advanced missions of the 20th century; we need at least several years of Project Pathfinder-type technology development to assess the technological requirements and general feasibility of the manned lunar and planetary missions proposed."—Don Fuqua, president, Aerospace Industries Association.—*TJF* ★

ing stability and continuity for NASA's planetary exploration efforts.

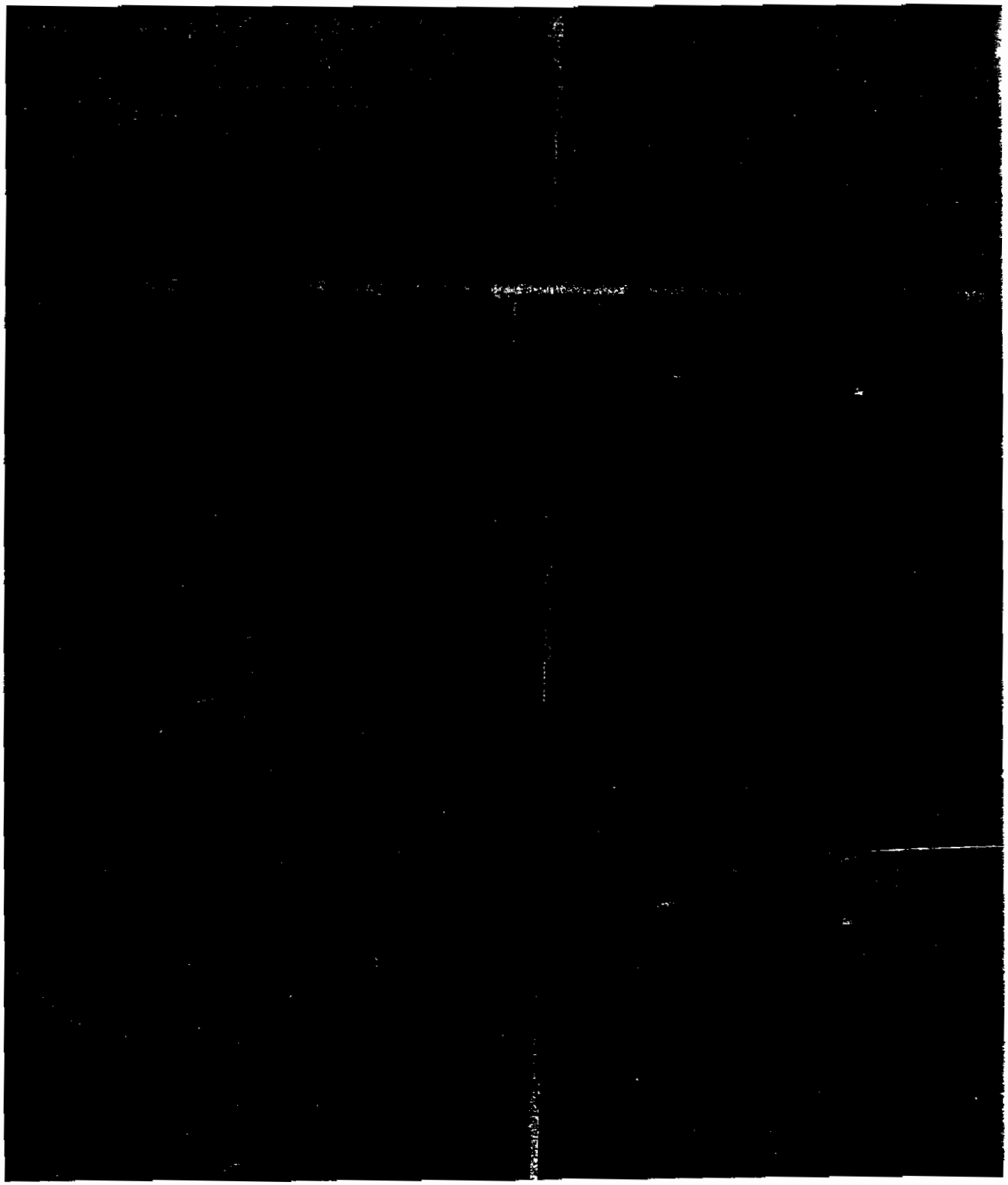
But it is the space station, the linchpin in NASA's manned space flight future, that will provide a measure of President Bush's leadership on—and commitment to—the U.S. civil space program. In the five years since the space station was approved by President Reagan the program has languished, plagued by poor cost estimates, design changes wrought by the Challenger disaster, chronic underfunding and an utter lack of strong presidential support.

The station is now at the make-it-or-break-it stage. Last year's funding level of $900 million must be more than doubled this year to keep the program on track. And of that $900 million approved last year, $515 million is held up by Congress until May 15 to allow the new President to decide for himself whether to proceed with the program.

Bush's past avowal of support for the station makes cancelation unlikely, but allowing the program to limp along with yet another year of inadequate funding will do little to advance the space station program in particular or the space program in general. In short, the coming battle over full space station funding will be viewed by many observers as a test of the new administration's commitment to a strong U.S. civil space program.

The history of the space station program to date, as well as the long list of space program options that have been offered by the various panels of experts, all demonstrate one fact: space policy formulation is a top-down process that requires strong presidential initiative and follow-through. Congress, commissions and NASA advisory panels can analyze space policy and make recommendations, but only a President can initiate specific programs. And strong presidential leadership makes or breaks the programs once they are initiated.

One change promised by President-elect Bush has the potential to strengthen White House leadership on space policy issues. That change is the re-establishment of the National Space Council (see the commentary by the Electronic Industries Association on page 4). Responsible for formulating the nation's space policy from the time of NASA's inception in 1958 until it was abolished during the Nixon administration's executive branch reorganization of 1973, the Space Council provided cabinet-level review and coordination of civil space policy. The council will replace the unwieldy—and largely ineffective—Senior



With the successful STS-26 launch last Sept. 29, America is back in space. Will the new President keep it there?

Interagency Group for Space (SIG-Space) that served as the major policy-making apparatus during the Reagan administration.

With the National Space Council once again providing cabinet-level space policy review, the Bush administration promises to be well positioned as it begins to define its own space policy. But a vision of the space program's future beyond cabinet-level policy reviews is essential if NASA is to lead the nation's space efforts into the 21st century. And only one man can articulate that vision—President George Bush. ★

Thomas J. Frieling, executive director of Campaign for Space, Bainbridge, Georgia, is a senior editor of this magazine.

With six missions set for 1989, the private sector takes aim at foreign and government competitors.

U.S. Firms Book First Commercial Launches

by Irene Klotz

Five years since the United States began paving political highways for commercial launch operations and three years since the Challenger tragedy unveiled a need for those services, private companies are scheduled to place their first customers' satellites into space this year.

Led by long-time rocket manufacturers McDonnell Douglas, General Dynamics and Martin Marietta, a new industry, expected to be worth more than $300 million in 1989, is about to be born. On April 6 a communications satellite for the government of India is scheduled to be orbited from Cape Canaveral Air Force Station. Though the launch will take place from U.S. government property, McDonnell Douglas is handling the service and will pay the Air Force for use of the range. It will be the first commerical satellite launch in the country.

Commercial carriers will launch satellites into orbit six times this year, according to the Department of Transportation, which is responsible for licensing and regulating commercial launches and setting insurance levels.

After the April launch, the schedule looks like this:

In August a McDonnell Douglas Delta will carry a British communications satellite into orbit, and Martin Marietta will piggyback satellites for the Japanese and the British on one Titan launcher.

In September General Dynamics will launch a communications satellite for its first commercial customer, the U.S. Navy.

In October Martin Marietta plans to launch INTELSAT VI, and in December McDonnell Douglas will wrap up the commercial launchers' first year by carrying another international consortium's satellite to orbit.

"We're off to a start," said Bob Cowls, staff director of McDonnell Douglas's Commercial Programs Office. "But let's differentiate between being off to a start, even a good start, and what it might take to say that we're in business for the long term."

For now, governments—the U.S. and others—are virtually the only customers for companies selling rides to space. In the wake of the 1986 Challenger accident and despite a grab for the market by Europe's Arianespace, there is a backlog of satellites needing transportation to orbit. Most of the spacecrafts that have caught commercial launchers' eyes are needed for communication services and weather forecasting.

The worldwide demand for large-capacity launch service over the next decade is 15 to 25 communications, remote sensing, meteorology and science satellites per year, a 1988 Department of Commerce report shows. Of these, Arianespace, which already has signed more than 60 contracts and executed one-third of them, is expected to nab half the world's market. The Russian Proton and the Chinese Long March vehicles also are competing against the U.S. launchers, and the Japanese are expected to begin marketing commercial launch services aboard their H-11 by the early 1990s.

"By the mid- to late '90s, we're going to find ourselves with a glut of launcher supply and then it's going to be a different ball game," Cowls said, in a speech last September at the space commercialization conference in Orlando, Florida.

The worldwide demand for large-capacity launch service over the next decade is 15 to 25 communications, remote sensing, meteorology and science satellites per year.

The expression "creating a level playing field" has become the battle cry of space commercialization advocates. Generically, the term means having the trade officials and policy makers who compete and participate in the worldwide market agree upon, follow and enforce rules of fair trade.

For example, U.S. companies say it is unfair that they have to compete for business with government-subsidized or owned agencies, such as the French-backed Arianespace and China's Great Wall Industry Corporation. The competitors counter that U.S. launchers and launch facilities were developed largely at the government's expense and therefore America's commercial launch industry, too, is in a sense subsidized.

There are no easy answers.

"Protectionist policies do not solve the problem they were set out to correct," said Rick Endres, director of the Commerce Department's Office of Commercial Space Programs. "[The U.S.] didn't become strong by becoming protectionist. We did it by becoming mean and lean."

Launch firms' liability in case of accidents is another sore point among commercial space advocates. Stung by a

NASA Plans Seven Shuttle Missions in 1989

Eager to return to regularly scheduled flights, NASA plans seven shuttle missions in the fleet's first full year of service since the loss of the orbiter Challenger three years ago.

Eventually, the agency would like to fly about once a month, but will build to that level gradually. NASA was criticized after the Challenger accident for having an overly ambitious flight schedule, one that planned to launch the shuttle up to 26 times a year.

The 1989 missions will focus on launching scientific planetary probes and backlogged Department of Defense satellites. NASA says a top priority in determining payload schedules was to take advantage of fixed launch windows for three interplanetary voyages: Magellan's mission to Venus, scheduled for launch in April aboard Atlantis; Galileo's mission to Jupiter, scheduled for launch in October, also aboard Atlantis, and Ulysses to study the Sun, scheduled for launch in 1990.

However, the first payload to be launched by a shuttle crew this year will be a third Tracking and Data Relay Satellite, virtually identical to the one launched in the first post-Challenger flight last September. The TDRS system, as it's known, is used to relay information between ground stations and spacecraft in low Earth orbit.

Not only will TDRS allow shuttle astronauts to remain in continuous communication with mission control, but it will feed information collected by other craft, such as the Hubble Space Telescope, to computers on Earth for processing.

The first TDRS was deployed by shuttle astronauts in 1983. A second was lost aboard Challenger, but a replacement was the primary payload of the September 1988 Discovery mission. The third TDRS, which will complete the system, is scheduled for flight aboard Discovery. Launch date: February 18, 1989.

With TDRS out of the way, NASA will turn to one of its most ambitious science projects, the launch of Magellan. Previously known as the Venus Radar Mapper, Magellan's objective is to study the origin and evolution of Venus using radar. Equipped with an electromagnetic beam, the craft will map at least 70 percent of the planet.

The project began in 1984 and was originally scheduled for launch in April of 1988. Because of mission delays that forced NASA to change the craft's trajectory, Magellan will not reach Venus until August 1990. Also, the cost of the mission has nearly doubled, from $295 million to $514 million, according to congressional reports. Magellan is now scheduled for launch aboard Atlantis. Launch date: April 28, 1989.

Secret DOD payloads are expected to occupy NASA's next two shuttle flights in this year's schedule. The missions involve missile-warning satellites, electronic intelligence spacecraft and reconnaissance ("eye in the sky") satellites. Scheduled launch dates: July 1, 1989, aboard Columbia and August 10, 1989, aboard Discovery.

The July flight will be Columbia's first since Challenger. The orbiter, NASA's oldest, is undergoing renovation at Kennedy Space Center.

With obligations to the military fulfilled, NASA again turns to planetary science with the launch of Galileo. The scientific descendant of the successful Voyager fly-by mission, Galileo will investigate the chemical composition and physical state of Jupiter's atmosphere and moons.

Galileo, delayed for more than seven years, will carry 19 instruments: twelve by the craft and seven by its atmospheric probe. When the project began in late 1977, NASA estimated its costs at $410 million. By October 1987 the cost estimate had climbed to $1.36 billion, primarily because of hardware and mission changes caused by flight delays.

The craft is now scheduled to be launched by Atlantis. Launch date: October 12, 1989.

NASA's sixth shuttle mission will be to deploy a communications satellite and retrieve a Long Duration Exposure Facility, a canister containing experiments. The LDEF, put into orbit in 1984, contains seeds and other materials and was designed to test how the items react to the space environment. Because of orbital decay, the satellite is expected to begin tumbling toward Earth's atmosphere if it is not retrieved by early 1990.

The mission is scheduled aboard Columbia. Launch Date: November 13, 1989.

NASA's final mission for 1989 was expected to deploy another military satellite. However, last October the agency announced that the military payload was being delayed. Instead, NASA will launch its premier scientific mission, the Hubble Space Telescope.

An astronomer's dream come true, the telescope will comb distant stars and galaxies, unobscured by Earth's atmosphere and interference from light.

First scheduled for launch in December 1983, the telescope is costing NASA $7 million to $8 million a month in storage and maintenance fees. It was originally designed at a cost of $1.2 billion, but because of shuttle delays costs have increased by about $435 million. A General Accounting Office report estimates that when the total costs of operations, maintenance and refurbishment are added, the program expenses will be about $2.8 billion.

The space telescope is designed to view objects as far away as 14 billion light years and transmit pictures with 10 times the clarity as had been previously possible. The optics are so powerful that if the technology were deployed on Earth it would be possible to see a match burning in Los Angeles from New York City.

The telescope is scheduled for launch aboard Discovery. Launch date: December 11, 1989.

Several factors may affect NASA's proposed launch manifest, including the availability of crucial propellant and materials, and the success of each previous mission. NASA has allowed extra time between missions to analyze performance data. The schedule will be updated quarterly.—*Irene Klotz* ★

The American challenge in the land of the palm trees: This year U.S. firms will rely on the venerable Delta, launched from Cape Canaveral . . .

string of failed missions and satellite losses, worldwide funds for insurance pools shrank. Ample coverage is once again available, however, and legislation was enacted last year to limit the liability of non-government users of range facilities to $500 million in property damages.

"[The U.S.] didn't become strong by becoming protectionist. We did it by becoming mean and lean."

Foreign competitors, meanwhile, enjoy the sanctity of their governments' indemnification.

Even if the problems could be worked out, fledging U.S. commercial space firms worry about domestic policy flip-flops.

"The problem with space policies is not that they aren't set, but that they are set about every two years," said Joe Allen, with Houston-based Space Industries Inc. "It's very difficult from the point of view of an entrepreneur in this commercial space business to know what the policy is to start with, but mainly to depend and stake a business on it's not changing."

While the Big Three of the U.S. commerical launching industry can thank Uncle Sam for their start—virtually all their rockets' research and development costs were not only picked up by taxpayers, but also the firms have been able to write off fixed expenses of restarting production lines thanks to purchases by the Department of Defense and NASA—they cannot depend on the government for their future.

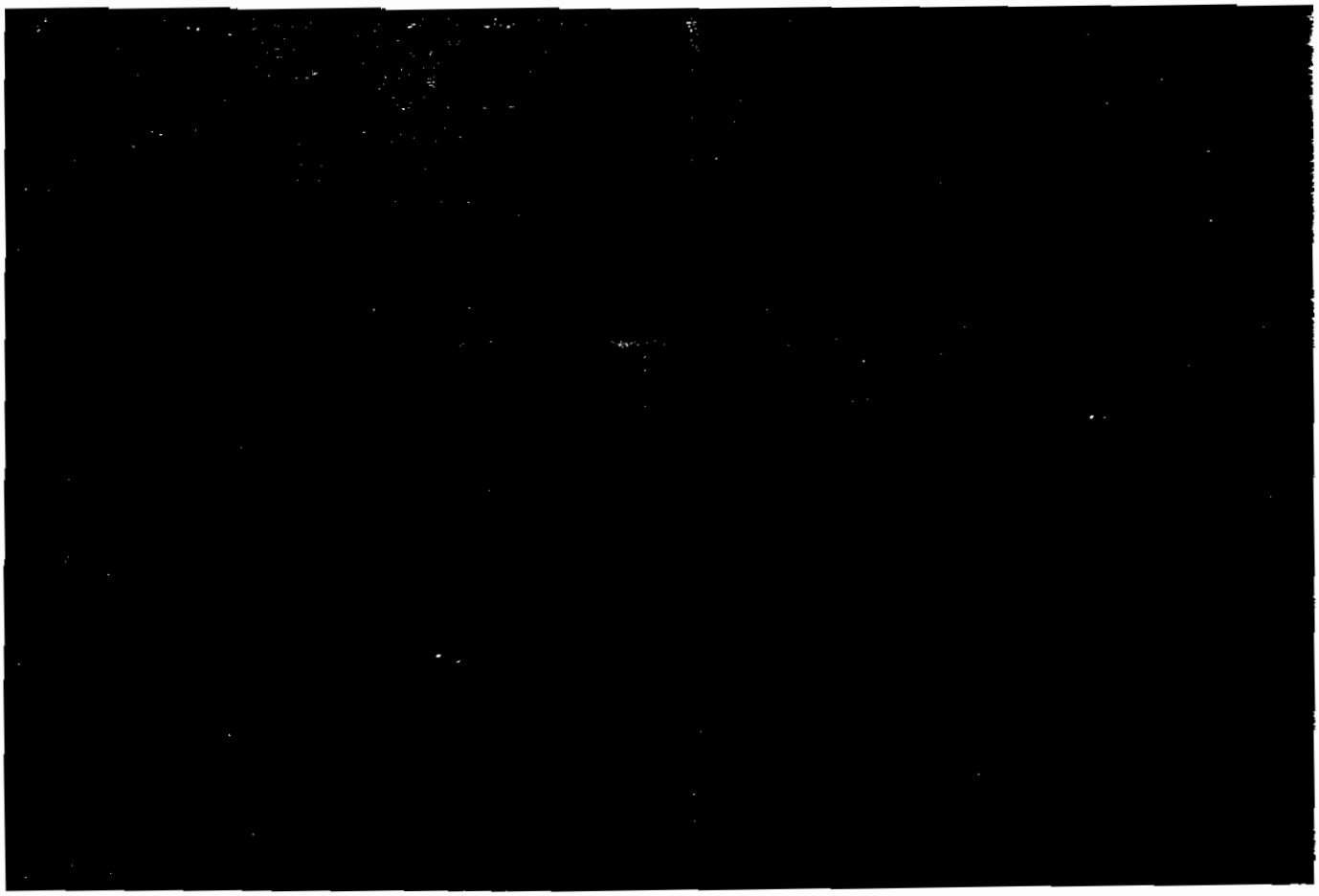
"The very fact that the government decides to get out of a certain arena does not guarantee that new business will fall into the laps of American entrepreuners who are waiting for that policy change," Allen pointed out.

"We are largely the benefactors of events that are outside our control," said McDonnell Douglas's Cowls. "One, we have a service to offer, namely an expendable launch vehicle to give you a ride to orbit, but we have that service . . . because we developed the capability largely through government sponsorship."

Consistent legal and political frameworks are the only ways to get investors to invest in commercial space ventures, said Neil Hosenball, a Washington, D.C. attorney specializing in space issues.

That's where the government comes in.

"Look at space as an underdeveloped country, where you have the Import/Export bank being a source, a lender of last resort," said Stephen Cheston, with Geostar Corporation, a satellite company that buys launch services. "It provides loan guarantees as long as certain organizations meet highly specific criteria. If these loans were focused on the launch industry . . . then the private launch companies would have this line of credit available to them. They could come to the satellite organizations . . . and they would keep our business." In the case of McDonnell Douglas, General Dynamics and Martin Marietta, government



. . . in an attempt to dethrone Arianespace's Ariane 4, launched from Kourou in French Guiana.

support is a double-edged sword: Because their launchers were originally designed and manufactured to meet military missile specifications, customers could be buying a Cadillac for a ride to space, when a pickup truck would do.

"Look at space as an underdeveloped country."

A handful of U.S. entrepreneurs hope to cash in on that fact by selling cut-rate launch vehicles and service. Space Services Inc. of Houston and E'Prime Aerospace Corporation of Titusville, Florida, plan to market various configurations of existing solid-rocket motors, while California-based American Rocket Company has designed and is developing an entirely new launcher based on government-backed technical research on a combination solid-liquid fuel propulsion system.

Another newcomer, Conatec in Lanham, Maryland, plans to send a customer's microgravity research projects on short, suborbital flights. Two launches, from the Army's White Sands, New Mexico, range are scheduled for March.

Although the U.S. commercial launching industry will officially break ground in 1989, issues that will greatly impact its success or failure are still in the air. Among the concerns:

- Distribution of the nation's limited supply of a vital solid-rocket fuel oxidizer. Last year, an explosion leveled one of the nation's two factories, in Nevada, that manufacture the chemical, called ammonium perchlorate. NASA, the Department of Defense and the private sector all need supplies of the chemical to carry out their missions.
- Balancing the national security concerns of the DOD with the timely and reliable launch schedules the private sector must keep to satisfy its customers. Conatec aside, all the commercial launches scheduled between now and 1992 will take place at Cape Canaveral Air Force Station in Florida or Vandenberg Air Force Base in California.
- Wrestling with cumbersome range-use agreements and pay-in-advance policies.

"It's one thing to have seven contracts," Cowls said. "It's another to execute them successfully." ★

Irene Klotz is a business and aerospace writer with Florida Today, *Melbourne, Florida, and a senior editor of* Space World.

Money for space science may be hard to find if NASA spends it all on hardware.

The Space Station, Cannibal or Savior?

by Ray Spangenberg and Diane Moser

With the shuttle flying again, NASA is back in the public eye. And with Americans in space once more, bright visions of the future are reviving. A space station, a Moon base, a manned mission to Mars. A comprehensive "Mission to Earth" to uncover the mysteries of our own planet. Ulysses, Galileo, the Hubble Space Telescope. Life sciences, exciting breakthroughs in materials processing. Name it and someone has a plan, a dream, for it.

But in an era of limited funds, a looming national budget deficit and a zero-sum game for funding, it doesn't take a crystal ball to see that, while visions may not be in short supply, dollars are. The public may be "pro-space," but an election-conscious Congress knows that the same public doesn't part easily with its money. And money fuels the space program.

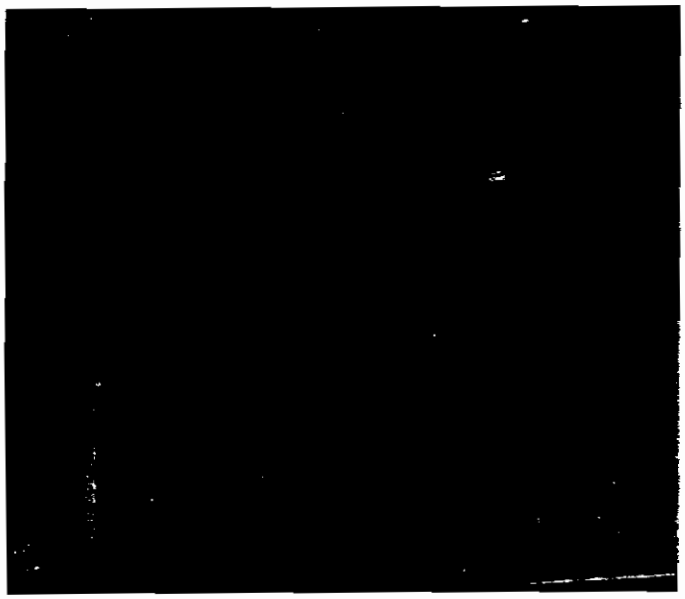
The consensus is that NASA needs a sense of direction again, a "Big Vision" for the public to get behind. And for many that means somehow bringing back the excitement of the Apollo program. A Big Dream. A Major Commitment. In the words of Thomas Paine's National Commission on Space, "To lead the exploration and development of the space frontier . . . from the highlands of the Moon to the Plains of Mars." Space station and beyond.

However, NASA is much more than a "manned space program." It is also a major science program, perhaps one of the most vital and important in American history, and many space scientists fear that NASA's present dominant commitment—the space station Freedom—may turn out to be an overgrown monster, swallowing up all available funds. The result for space science, they say, could be disastrous.

According to renowned physicist James Van Allen of the University of Iowa, who has been involved with NASA since its inception and is an open critic of current policy, the dependence on crew-piloted transportation is a major policy mistake. Although Van Allen has a rueful appreciation for the call of "high adventure" associated with the manned space program and maintains he is a strong supporter of NASA, he thinks NASA's current space station plan is another giant step "on the wrong track."

"I consider the commitment to the huge space station that NASA's promoting is a gross error of general judgment," he says. "If the space station does in fact go ahead, it's going to be a monster, it's going to be voracious in terms of funding." And, Van Allen adds, "unless there is a substantial and progressive augmentation of the NASA budget, it'll be terribly destructive" to every other program the agency has on the books.

Tentatively budgeted in this fiscal year for $900 million, before it's finished the space station's costs could run as high as $30 billion—just for construction of the "raw" station. That's before adding in costs for scientific equipment and operations. As a result, says Van Allen, "I think the overall effect of adopting the space station as the major objective of the agency will be extremely destructive, in fact even murderous, to most of the things the agency should be doing."



Peter Banks

For Van Allen, as for virtually every space scientist in the country, the ideal would be enough funding to do it all. Stanford University's Peter Banks, who chaired an advisory committee to the NASA Task Force on Science Uses of the Space Station, cautions against too narrow a view. "You have to take into consideration those science projects that need to have a manned facility," he points out. Freedom, as well as the shuttle program and its Spacelab facility, will enable scientists to study the effects of prolonged flight on human beings under microgravity conditions. Materials processing and growth of organic crystals, the other major area of science that will benefit, could provide major breakthroughs in development of drugs to fight diseases like AIDS and cancer. Says Van Allen, "I don't disagree with the fact that if you increase the budget $2 billion

Crystal Growth in Space: An Answer for AIDS?

Often touted as an area of science that could benefit from plans for the Freedom space station, does crystal growth really warrant development? It just might.

When Discovery lifted off the launch pad last September 29, it carried with it an experiment package that could provide a key to design and development of better drugs for diseases such as AIDS and cancer.

Put together by biochemist Charles Bugg, X-ray crystallographer Larry DeLucas and other scientists at the University of Alabama at Birmingham, the protein crystal growth experiments on STS-26 included a protein called reverse transcriptase, an enzyme required for viral reproduction, in this case taken from the human immunodeficiency virus (otherwise known as HIV or the AIDS virus).

Crystals grown in microgravity, says DeLucas, are certainly larger and probably more perfect than those grown in a 1-g environment. By applying the techniques of X-ray crystallography to crystals like those grown aboard Discovery, UAB scientists hope to obtain high-resolution, three-dimensional atomic models of these molecules that will provide new insights into their structures and how they work. This kind of insight, says Bugg, "is particularly important if scientists are to design and produce drugs that will interfere with the ability of a virus to replicate itself."

And that could be the first step toward vanquishing the disease itself.—*RS/DM* ★

Artist's concept of Phase 1 Space Station.

or $3 billion a year for four or five years that you can do both. The question is whether that's realistic politically."

NASA clearly is sitting on the horns of a dilemma: limited funds and the necessity of making unwelcome choices. Pointing to the enormous scientific returns of explorer robots like the Pioneers and Voyagers, with comparatively modest program price tags, many scientists feel NASA's dollars would be much better spent doing more of the same.

But not everyone looks at it that way. Says NASA Space Station Deputy Associate Administrator Frank Martin, "Van Allen and some of the other old timers that've been around awhile remember back when it was relatively inexpensive to do some of these missions. If you go back 20 to 25 years you'll find out that most of what we were doing was very preliminary planetary missions and plasma physics missions." Gradually, says Martin, the missions have become more complex, including major Earth sciences programs like the planned Earth Orbiting Satellite (EOS), astronomy missions like the Hubble Space Telescope and the planned Space Infrared Telescope, and planetary missions like Magellan to Venus and Galileo to Jupiter. The price tag has gone up as high as $½ billion to $1 billion apiece.

As NASA's budget has become more constrained for both manned and unmanned programs, he says, numerous new science disciplines have emerged to clamor for support—adding, for instance, materials processing and life sciences to the more traditional "space science" areas of planetary science, Earth science, astronomy and plasma physics. "The opportunities are just so great," he adds, "I'm not sure the budget is keeping pace with them. All the choices both for manned programs and unmanned programs are very difficult."

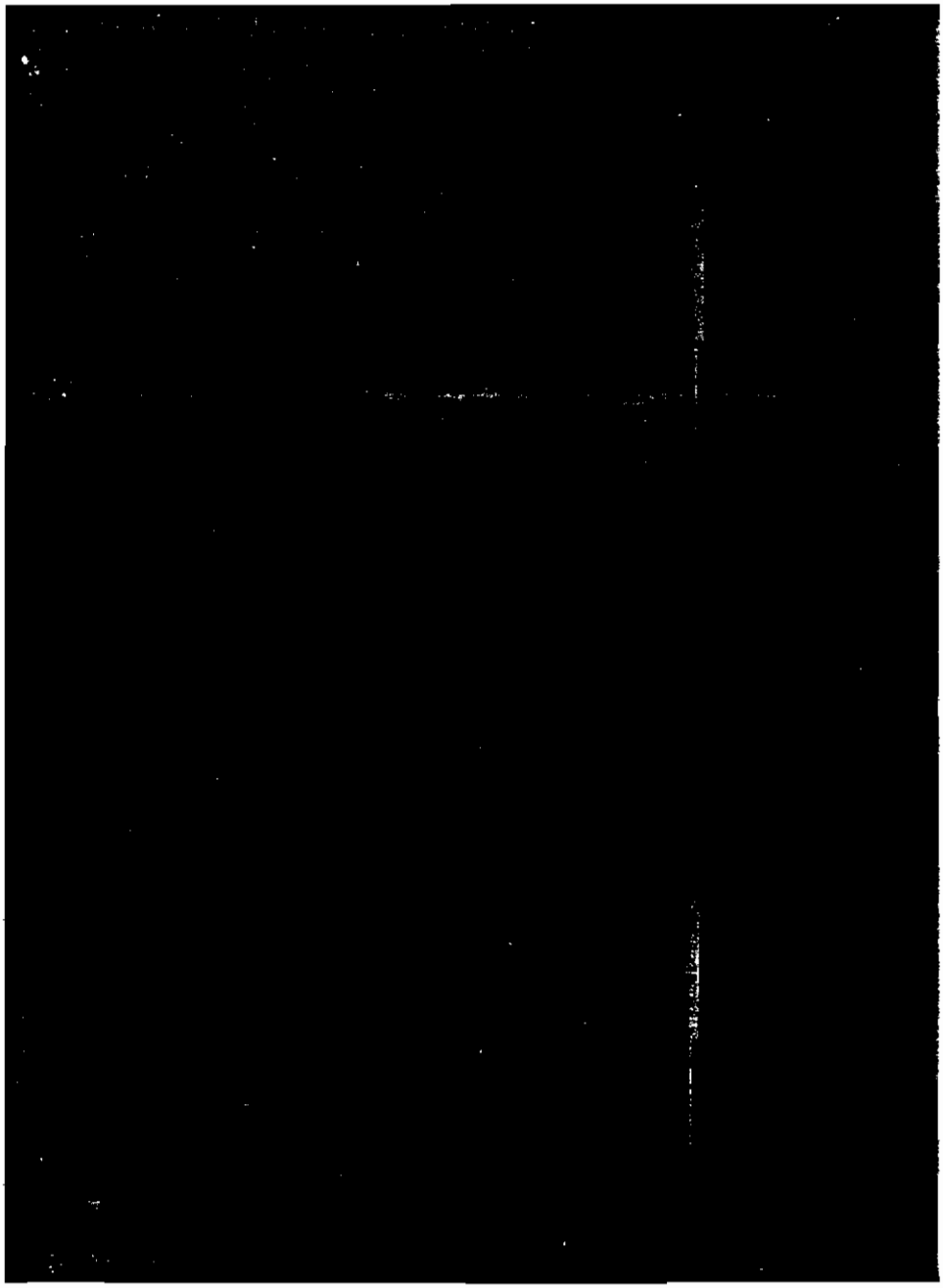
A major driving factor in those decisions, Martin points out, is that "the American public really does want manned presence in space. We don't give ticker-tape parades to robots." Like it or not, most scientists seem to recognize that a human presence in space and a big project such as the space station, followed by a manned lunar base or a piloted mission to Mars, would provide a national goal the country yearns for and worldwide cultural benefits that warrant a strong U.S. commitment.

At the same time major problems confront the space science disciplines that thrived so greatly in the 1960s. Today, says Banks, who heads up Stanford's Plasma

Streamlining a Bottleneck

Quality assurance on the 31,000 tiles that protect the outer skin of the shuttle orbiters has long been a NASA nightmare. During a 90-day orbiter turnaround, the agency has typically had to employ up to 400 man years, with people working around the clock, to get the job done. The procedure developed for checking the critical gap between tiles alone took weeks. A checker on a ladder tested the gap by hand, tile by tile. Too large? Too small? The difference lay in subtle distinctions of friction that required real expertise to differentiate. He called results down to the ground crew below, two individuals who each wrote down the data (redundancy as a cross-check) and were checked by a third, a quality assurance manager who stood by.

Eager to improve their methods, managers at NASA's Kennedy Space Center called for help from Stanford's STAR Laboratory and the aerospace industry, including Lockheed and Rockwell. They got it. Within three weeks they had a rough prototype and within 13 months an integrated prototype for automating the process using laser measurements, voice-recognition computers, computer-aided design graphic displays, a computerized database and state-of-the-art communications equipment. NASA managers were so excited with the results that they used the technique on Discovery and Atlantis and plan to implement it on the new orbiter. More reliable than the old "telephone-game" methods, the new system initially cost only $1.6 million to develop and could end up saving as much as $7 million a month on the budget for orbiter processing.—*RS/DM* ★



Laboratory in space: how soon? how expensive?

Physics Lab as well as the Space Telecommunications and Radio Science (STAR) Laboratory, it's hard to attract new high-quality students. Most scientists who worked on the Galileo project began their work more than 10 years ago. And, after countless delays, when the mission is finally launched in October 1989, it will still be another six years before these researchers will see any data from their work—nearly 20 years after the project began in 1977. But, because of the way the American university system is set up, any university scientist hoping to publish results and achieve the stature needed to acquire tenure must complete that process in seven years or fewer. Galileo is a particularly dramatic example, but most NASA science projects experience repeated delays and inconsistent funding. As a result, attracting new talent to the space science fields has become a losing battle.

Meanwhile, because of waning NASA funds and the uncertain future of the agency, much of the talent within NASA itself is draining away—retiring, moving into other professions or flowing into private industry.

Additionally, says Banks, NASA, with its strong R&D background, consistently pumps several million dollars into development of a spacecraft like Voyager or Galileo and then balks at allocating more than $½ million to analyze the data obtained. Other government agencies such as the National Science Foundation, he says, typically put more dollars into the active production of science. But NASA, whose managers, Van Allen points out, are heavily drawn from the aerospace industry, continues to see itself primarily as a spacecraft builder.

For a problem as convoluted as the ins and outs of Washington bureaucracy itself, can there be any solutions?

Van Allen suggests using a mixed approach to transportation, using both shuttle and expendable launch vehicles, coupled with construction of a smaller space station. Much materials processing, he says, could be done using less

expensive unmanned missions. The Soviets, he adds, "have essentially unmanned launch facilities for sending up materials processing experiments and recovering them and they're shooting one of those off every two to three weeks." And all of the life sciences work and materials processing that require manned missions could be done on a space station the size of Skylab or Mir.

"If the space station does in fact go ahead, it's going to be a monster, it's going to be voracious in terms of funding."

Stanford's Banks possesses a strong appreciation for the visionary, cultural advantages of building the giant Freedom station as a step toward even larger, more ambitious projects like a crewed mission to Mars. But the 1997 version, he says, is "too much, too late." For the interim he proposes a smaller, tended space station. This, he says, could be built quickly with limited funds and available technology, and could be the site of much important scientific research in the meantime. The great danger of this approach, he concedes, is that Congress could get stalled with the smaller station and never allocate funding for the bigger vision. "We're an inconstant lover of space as a nation," he notes.

Michael J. Wiskerchen at Stanford's Center for Aeronautics and Space Information Sciences offers a more basic approach: trim operations costs within all current NASA programs and you could have a lot of funds left over to spend on science. By using state-of-the-art communications systems and up-to-date computer technology, says this former NASA chief scientist for Spacelab 1 and member of the Space Station Operations Task Force, NASA could not only step up efficiency but save millions of dollars. Hundreds of tasks, Wiskerchen thinks, from quality assurance on shuttle tiles to watching over planetary spacecraft, could benefit from a more streamlined approach.

Michael J. Wiskerchen

The Space Station Squeeze

While NASA's budget looks rosier this year than anyone expected, still when the budget for fiscal 1989 finally went into effect on October 1, 1988, Congress had trimmed the administration's request for NASA from $11.5 billion down to $10.7 billion.

Of that total budget, however, space science came up with a comparatively modest appropriation of $1.8 billion, broken down like this: physics and astronomy, $736 million; life sciences, $77 million; planetary exploration, $394 million; and space applications, $616 million.

Pared down from the administration's request by $37 million, the final space science budget reflects severe cuts in some areas. The Advanced X-Ray Astrophysics Facility (AXAF), a new start, was cut by $11 million. The Ocean Topography Experiment (TOPEX) was reduced by $10 million. And Global Geospace Science (GGS) was trimmed by $35 million, one-third of its originally requested funding.

The space science budget isn't the only one with problems, though. For the year, a healthy $900 million (trimmed $67 million by Congress) is earmarked for the space station, but with only $385 million available immediately and the remainder not freed up until May 15, 1989—and that's provided the new administration gives the nod.

Pathfinder, a new-start project to work on technologies required for building a lunar base or sending a manned flight to Mars, was reduced by $60 million, more than half the requested appropriation. Congress also shaved $110 million off the budget for Expendable Launch Vehicles (ELVs) and trimmed $255 million away from the shuttle.—*RS/DM* ★

There may be a problem with the basic assumption, however, warns Martin, that if the money isn't spent one place it will necessarily mean more money for space science. "I don't know whether that's valid or not," he says. "It depends upon how good the project is and how well it's supported." But one thing is sure, if the money isn't there at all it certainly won't be spent on space science, says Stanford's Wiskerchen.

Other, more radical solutions have also been suggested: Let NASA develop the National Aerospace Plane and Freedom, limiting its responsibility to the R&D it's so good at, and split up the rest, with transportation going to the Department of Transportation and all space program operations to the Department of Defense (a solution that assumes that coordination by three bureaucracies is better than the boondoggle of one). Or, shut NASA down altogether and start over with a new agency unencumbered by years of built-up protocol. Basically, however, these two solutions could create more problems than they solve.

But most concerned watchers would like to see Congress (which, Banks points out, continually "cuts NASA off at the knees") out of the business of running NASA on a day-to-day basis. And they'd like to see the scientists who will ultimately use the space station closely involved with shaping its conceptualization. Says Wiskerchen, "If you do design it for utilization, you'll do something exceptional for science." And the best way to accomplish that is to have scientists who will use it involved in the loop at points where they can influence the compromises that certainly will be made in its design and construction. ★

Ray Spangenburg and Diane Moser, freelance science writers in South San Francisco, are senior editors of Space World.

The Air Force's proposed Advanced Launch System looms as a successor to the shuttle, but what happens if 'Star Wars' is axed?

The Next Generation Launch Vehicle

by Terri Lehto

Even before the Challenger tragedy three years ago, pressure had begun building for a post-shuttle launch vehicle capable of orbiting larger payloads at higher reliability, faster turnaround time and, most important of all, lower costs.

Now, with the Strategic Defense Initiative (SDI, or "Star Wars," if you prefer) progressing beyond the paper studies phase, that pressure is becoming intense. Expendable launch vehicles, like the venerable Titans and Deltas, were quickly pressed into service during the three-year hiatus to put up payloads originally scheduled for the shuttle, but it has become obvious that that approach is only an interim solution.

As a measure of SDI's potential impact on U.S. launch needs, Col. William Zersen, a manager at the Air Force's Space Division, has made a "ballpark estimate" that an initial deployment of the anti-missile system could require 600 launches over a three-year period. That works out to one launch every 44 hours!

Furthermore, many of the planned SDI payloads would not fit into the shuttle payload bay. So it's back to the drawing boards in an attempt to put together a new space transportation system that can handle the missions of the future—beginning with SDI and NASA's space station and perhaps later some other missions not even defined at this point.

The heart of that new system is the Air Force's Advanced Launch System, or ALS, which has just entered the second phase of its development program. The Air Force schedule calls for launching the first of this new family of boosters within the next eight years.

The urgency of ALS was spelled out last year by Lt. Gen. James Abrahamson, who retires from the Air Force the first of next month as director of the SDI Organization: "The nation needs in the future, past the mid-1990s, in order to support the space station, to support any SDI deployment in space, and to support many of our civil missions and other military missions, a low cost method of space transportation."

One objective of the ALS is to lift 100,000 to 160,000 pounds into low Earth orbit for a mere $300 per pound. Current expendable launch vehicles can carry up to 32,000 pounds, and the shuttle is capable of up to 65,000 pounds—but at a cost of $3,000 a pound.

In addition to reducing launch costs ten-fold (an order of magnitude in high tech talk), ALS would not necessarily carry a single payload that weighs up to 160,000 pounds. Instead, it would likely carry multiple payloads to achieve an economy of scale. By orbiting several objects at the same time, the launch costs could be reduced significantly.

Initially, a pre-ALS interim booster was planned for deployment in 1994, but the Defense Department cancelled it. The idea now is to build a fleet of heavy launch vehicles that is at first expendable with later versions either fully or partially reuseable.

These later versions will need to have a rapid turnaround: the Air Force's goal is to get them refurbished and back into operation within four months after each use.

ALS is a joint DOD-NASA program headed by an Air Force program manager, Col. John Wormington, and a NASA deputy manager, Harold W. Hallisey. DOD will handle the systems engineering and integration, vehicle logistics and payload module. NASA will manage the engine systems and the underlying technologies. The Pentagon will fund the entire ALS program with the exception of "unique civil requirements," which NASA will fund.

. . . an initial deployment of [SDI] could require 600 launches over a three-year period. That works out to one launch every 44 hours!

The total development cost through 1993 is estimated at $2.5 billion, plus another $200 million to $250 million every year after that to upgrade the technology. First ALS launch is planned for 1996, with the vehicle scheduled to be declared operational by 1998.

Though the principal goal is to reduce launch costs to orbit by a factor of 10, DOD officials have already allowed as how they will be satisfied with a much lesser cost reduction.

The concept definition phase of ALS began with the award of seven design contracts, each worth $5 million, by the Air Force's Space Division on July 10, 1987. They went to Boeing Aerospace, General Dynamics, Hughes Aircraft, Martin Marietta, McDonnell Douglas, Rockwell International and United Technologies' USBI Booster Production Company subsidiary.

Phase 1, which was completed last summer, produced the concepts that are now under development in Phase 2. All these concepts are based on a liquid hydrogen/liquid

oxygen core vehicle with liquid or solid fuel boosters, either partially or fully reusable.

On August 15, 1988, the Air Force announced three contracts for Phase 2 with Boeing, General Dynamics and the team of Martin Marietta and McDonnell Douglas. The contracts have an estimated value of $100 million each and are intended to refine initial concepts, identify the most promising approaches to meeting the project requirements and to conduct preliminary design reviews.

These selections ("down selections" from the original seven contenders in Pentagon parlance) were supposed to initiate Phase 2, but this was delayed to November, when the formal letter authorizing ALS was forwarded from the Pentagon to the Air Force Space Division. The Air Force then awarded the contracts.

Martin Marietta and McDonnell Douglas are studying three designs: (1) four or eight solid rocket boosters with lift capacities of 134,000 and 160,000 pounds; (2) four or eight liquid propellant stages strapped on to an external tank to produce a lift capacity of 105,000 or 160,000 pounds; and (3) one or two reusable liquid propellant stages capable of being flown back (unmanned) aerodynamically and producing a lift capacity of 199,000 or 160,000 pounds.

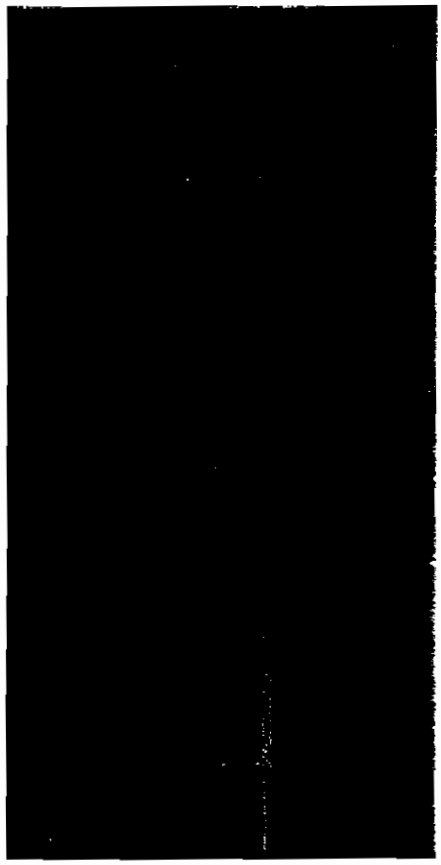
General Dynamics is looking at a design that uses seven non-throttleable main engines in the core vehicle and three engines in the booster so that the launch could still go if one engine failed. The booster propulsion module will be partially reusable. The design has two parallel liquid hydrogen/liquid oxygen systems based on identical, expendable fuel tanks. GD also stresses compatibility with space shuttle facilities at both Cape Canaveral in Florida and Vandenberg Air Force Base in California.

One objective of the ALS is to lift 100,000 to 160,000 pounds into low Earth orbit for a mere $300 per pound.

Boeing is being cagey about its design, but sources say the company is considering an identical core vehicle and boosters, a liquid hydrogen/liquid oxygen system with a specialized burning arrangement. The first stage would have several recoverable engines, not to be used more than four times. The design would use new hardware, but would emphasize low operating costs and high reliability and have an average cost per flight of $45 million.

Upon completion of this phase of the competition, the Air Force will "down select" again to a single prime contractor in November—if the rocket concept again wins the approval of the Pentagon's top procurement decision-making authority, the Defense Acquisitions Board. At this

MARTIN MARIETTA



GENERAL DYNAMICS

BOEING

ALS Contenders: One of Martin Marietta's partially reusable candidates in the competition for the Air Force's Advanced Launch System features a cryogenic core stage with twin liquid boosters capable of being flown back to Earth. General Dynamics is proposing a core vehicle with non-throttleable main engines and a partially reusable booster module. Boeing is not releasing any pictures—and precious little information—of its ALS candidates. Perhaps the company is developing a stealth version.

Ex-Star Warrior Boosts ALS

The big payoff from the Strategic Defense Initiative will be a whole new way of launching payloads into space, according to Dr. James Ionson, former director of the Innovative Science & Technology Branch of the SDI Organization, who scoffs at the other purported SDI spinoffs as so many "laser potato peelers."

Ionson is enthusiastic about the Air Force's Advanced Launch System and what it can do for the future of space exploration—and the U.S. economy.

"ALS can change the world. It can be our railway into space," he says. "The situation is analogous to oil. Today the price of a barrel of oil drives the entire economy. A hundred years from now it will be the price of a barrel of rocket propellant."

The problem, as Ionson sees it, is to pry loose this technology from the governmental labyrinths and out into the real world. "All government bureaucrats tend to do is consolidate abstracts [of scientific research]," he complains. "They've got to get out to the commercial sector."

That's what Ionson has done himself: in the time-honored Washington tradition, he set up his own consulting shop, JDC Enterprises of Bethesda, Maryland, last April to advise the people he used to award contracts to.

His advice to his former Pentagon colleagues is to stop concentrating their efforts on a mixed bag of individual technologies and stress key enabling technologies that will create entire new industries.

His number one candidate industry is space transportation. "The NASA spinoffs were not so much widgets and gadgets as they were access to a place, space," he says.—*JR* ★

point, it is a winner-take-all competition for full-scale engineering development and later production of the ALS.

The issue lurking in the background is what happens to ALS if SDI is killed? Would it die as well? One school of thought holds that ALS, though it would have many potential users, would have no sponsor for funding because no government agency would step forward to assume responsibility.

Realistically, it is possible that the ALS would be dropped under these conditions. Even though the program will likely produce major innovations, the cost could drive supporters away. Furthermore, at that point the program would still be in its early stages and could be halted upon completion of Phase 2 with little trouble. Programs are cancelled all the time; this would be just another to suffer from a lack of a designated user.

The other side argues that the project would continue because the resulting heavy launch vehicle could have other uses. DOD could use an HLV to launch multiple spy or navigation satellites or other military payloads. NASA could use it for the space station or for multiple payloads of any type. Even the National Oceanic and Atmospheric Administration could use ALS for multiple weather or remote-sensing satellites, and the commercial sector could use it for communications satellites if a commercial variation were available.

Concerning the space station, NASA says it has "no requirement during the early timeframe" for a heavy launch vehicle. The shuttle will carry the elements of the station to space during the assembly phase, while ELVs will fly resupply missions. NASA's space station spokesman, Mark Hess, said that if a heavy lift vehicle existed, then NASA would probably use it for space station operations in the future.

Former Air Force Secretary Pete Aldridge sounded a more positive note during a recent congressional hearing: "We see ALS as a national program, not only supporting SDI, but also supporting space station and any future evolving new capabilities, either in the Defense Department or civil or commercial community."

There are also drawbacks to ALS. A problem likely to arise . . . is having all the payloads available for launch at the same time.

There are also drawbacks to ALS. A problem likely to arise when trying to launch multiple payloads at one time is having all the payloads available for launch at the same time. Richard DalBello, a senior analyst in Congress' Office of Technology Assessment, said "a heavy-lift vehicle is not such a good idea; to get 10 payloads and the insurance ready at the same time is not probable, it is ludicrous." His reasoning was that it is hard enough to get one satellite ready for launch, much less 10 at the same time. In addition, the amount of insurance required to support 10 payloads could be staggering.

Then there is the matter of orbits. All payloads launched at one time would need to have similar orbits. The users of the launch service could be hesitant to trust their satellite on a vehicle that could possibly carry nine others because complications could arise.

The technology to come out of the ALS program can be applied to existing boosters. Not only advances in propulsion technology, but also in payload processing, will be explored. Procedures for preparing the booster and launch sites and processing the payloads will be streamlined and automated. Alternative launch sites and facilities are also under consideration. Contractors pursuing the ALS will investigate these and other options for their final proposal.

As Rick Huling, a spokesman at the Air Force Space Division, put it, "This is a whole different mentality and approach to launching. This is not just a new rocket, it is a new technology to launch more cheaply and more reliably." ★

Terri Lehto is a space systems analyst for Jane's Information Group, Alexandria, Virginia. This is her first article for Space World, *although she contributes regularly to various Jane's publications.*

If people are really serious about space colonies it's not too soon to start worrying about the effects of space on human reproduction.

Go Forth and Multiply?

by Lance Frazer

After millions of years of evolution in the gravity of Earth, the human race is now filled with dreams of heading out into space—returning to the Moon (this time as colonists), traveling on to Mars, living for months at a time in orbiting space stations and perhaps someday starting humanity anew in the reaches of outer space.

Certainly, the idea of floating colonies of people who are born, live out their lives and die in outer space is still consigned to the realm of science fiction, but if humanity is indeed serious about finally leaving its "earthly cradle," the issue of whether humans can successfully reproduce in space will have to be addressed.

Serious doubts about whether the human species (or, for that matter, many of the higher species of animals and plants) can reproduce from generation to generation in a microgravity environment were raised in two separate studies done in the late 1970s and early 1980s.

The investigators were George Nace, a biologist at the University of Michigan, who experimented with frog eggs, and Hefzibah Eyal-Giladi, a zoologist at the Hebrew University in Jerusalem, who worked with chicken eggs. The published results of these experiments indicated a strong possibility that, in Nace's words, "the incidence of abnormalities in embryos increases when you interfere with their relationship to gravity."

As anyone who has ever taken Biology 1A knows, mammalian development begins with the union of two cells. In a process that has evolved over millions of years of one-g conditions, what happens next is that, in response to gravity's pull, the egg rotates, allowing the separation of its contents into the proper spatial relationships. Without the gravitational rotation and the resulting separation of contents (producing what is known as "bilateral symmetry"), Nace and others feared that the dividing cells would not be able to form a properly proportioned animal (two eyes, two arms, etc.) and that a resultant organism, if it survived, would be severely deformed.

Since these studies, NASA has conducted experiments, largely with amphibian eggs, on the role of gravity in the development of the egg. One objective has been to determine if microgravity has the same effect on mature, fertilized eggs as it appears to have on recently fertilized eggs. Because the United States has no long-term spaceflight capability, these experiments have been limited to space shuttle missions, where time and research facilities are limited. The results are not conclusive, and that worries a lot of people looking down the long road to space.

Dr. Lynn Wiley is among those concerned over what is seen, in some respects, as a short-sighted approach on the part of the space community. Wiley is an associate professor of obstetrics and gynecology at the University of California at Davis and one of the authors of a National Research Council (NRC) report that is critical of the current level of knowledge of the effects of space travel on the human reproductive system.

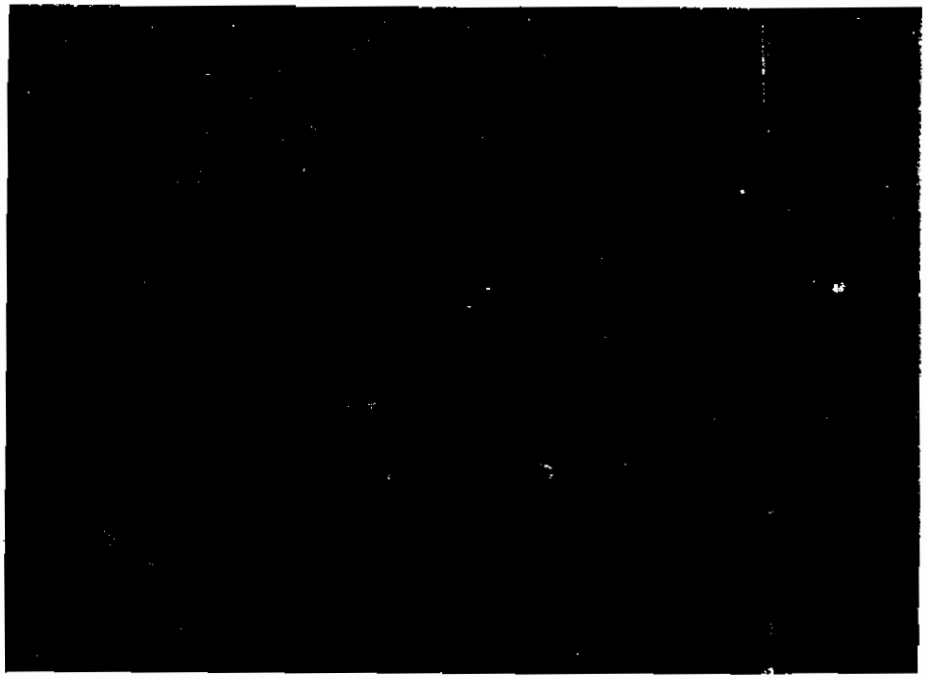
"One of our biggest problems," she says "is that the United States doesn't have a dedicated life sciences space program (unlike our chief rival, the Soviet Union). Life sciences are constantly in competition for valuable space with materials science (microgravity crystal growth, engineering experiments, pharmaceutical experiments, and so on), and we're forced to squeeze our experiments in wherever there is an available locker."

Life sciences experiments are further divided from within, in a manner that Wiley is forced to acknowledge as practical if not satisfying. "Life sciences," she says, "are, understandably, more concerned right now with keeping people alive in space than with seeing if it's possible for them to have families. Survival, the overcoming of life-threatening phenomena such as radiation, the redistribution of plasma and other bodily fluids in microgravity, bone loss, and so on, is a near-term project. Reproduction of the species is a long-term project."

The results are not conclusive, and that worries a lot of people looking down the long road to space.

Current research indicates that there are three factors in space travel that can affect human reproductive function: stress, radiation and the microgravity environment. To the best of existing knowledge, microgravity as such may have no direct, discernible effect on a human egg cell's ability to orient itself and begin cellular division. Since the mammalian embryo develops within, and is thus subject to the effects of stresses on the mammalian female's body, there do appear to be significant grounds for concern over the documented effects of these stresses on human females.

The United States and, more significantly (due to its longer-duration space experience), the Soviet Union have produced a great deal of information concerning the physiological effects of long-term exposure to spaceflight. Phen-



Reproduction in space: In experiments planned for a shuttle mission in July 1991, this pressurized module known as Spacelab J will be flown as part of a cooperative program with Japan . . .

omena such as bone calcium loss, shifts in fluid distribution and the drop in certain hormonal and enzymatic components of body fluid have been documented. There are sound reasons to believe that these changes may have more significant effects on pregnant women.

For instance, in pregnancy the fluid and electrolyte shifts associated with microgravity (especially any changes in sodium and potassium concentrations, as well as levels of prolactin and other hormones) may affect the growth of the developing blastocyst. Of particular concern is the noted drop in plasma potassium. If significant enough, this loss could change cell division rates. And if cell division is delayed and the crucial number of cells is not present at the time of blastocyst formation, an embryo will not develop.

Stress is another possibly dangerous element of spaceflight. The formation of estrogen during pregnancy may accelerate the loss of bone calcium experienced by both men and women participating in spaceflight. In the case of pregnant women, this could possibly lead to severe health consequences in the absence of medical treatment.

The third element, radiation, is being studied more extensively because of its direct relation to crew safety (although a good deal still remains to be done in setting safe radiation exposure standards). According to a report by the National Research Council, "the effect of radiation on male and female reproduction has not been characterized, and even experimental animal work . . . may not be applicable to man because of the marked decreases in sensitivity from not only one species to another but even between strains of the same species."

So it becomes apparent that conception and pregnancy will be no easy matter for long-term space voyagers. The questions are: what remains to be discovered and what are we doing about it? So far, the answers appear to be (1) a lot and (2) not much.

Given the focus of NASA's research into life sciences on the immediate health and safety of the astronauts, the potential problems of creating "space families" are understandably taking a back seat. There are plenty of possible reasons: lack of space (in the shuttle, that is), lack of funds, lack of time, lack of interest, not wanting to come across to the tax paying public as too fanciful or looking too far into the future. Take your pick.

Will the space station help? In its present configuration, yes and no. Yes, because at last there will be a long-term space facility for the United States to use. No, because competition for the facility will be intense and certain design and power needs remain to be worked out.

According to the report by NRC's Committee on the Space Station, the planned space station has been divided into two blocks, or phases. Phase 1, the so-called revised baseline, has been configured for materials and life sciences research. To quote the report, "The Revised Baseline will provide a giant step forward for the life sciences, permitting man, animals and plants to be exposed to microgravity for extended periods."

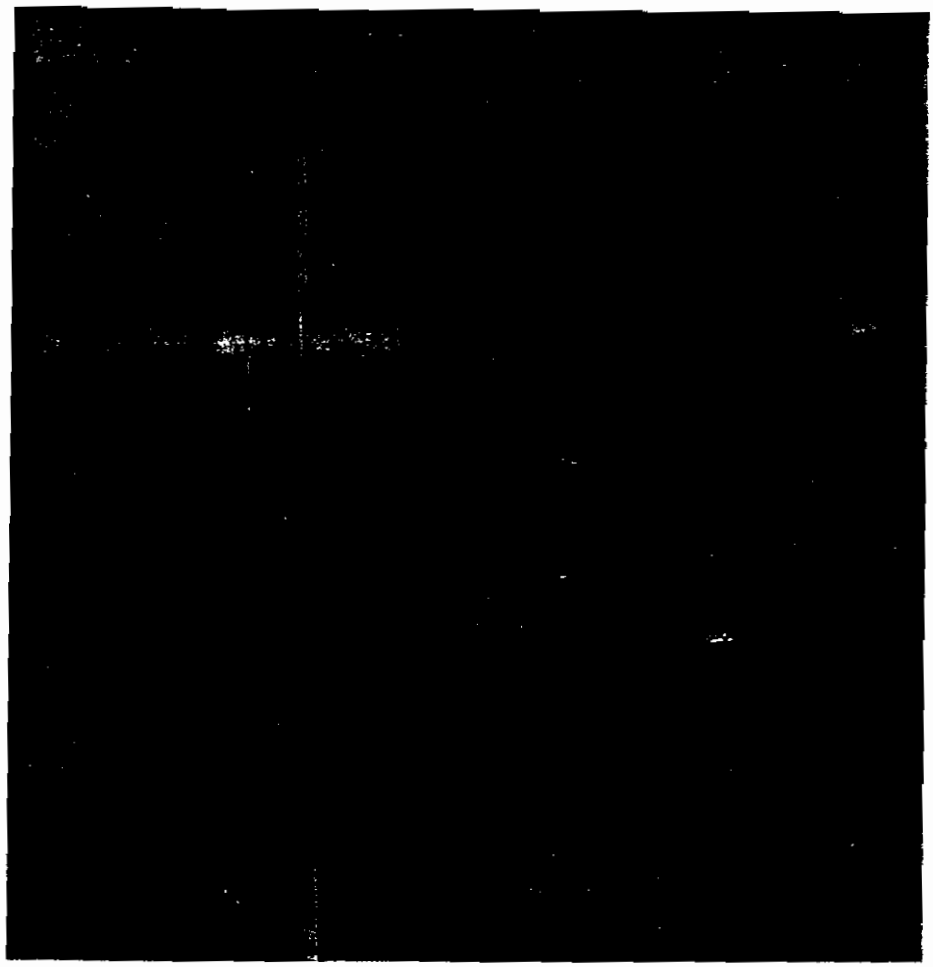
This same report points out that even the revised baseline configuration will not provide a complete life sciences facility. For instance, this configuration is not designed to accommodate large animals, nor would it be easy to install more than a small centrifuge for use in variable gravity research.

Materials scientists also have complaints about the configuration. In the initial space station design, materials and life sciences experiments must be conducted in the same laboratory. But materials science research requires an environment that is as vibration-free as possible, which is difficult in the company of whirling centrifuges and the patter of tiny feet.

Life sciences research also requires greater power, life support maintenance, heat, light, and power requirements that have yet to be worked out. The report concludes that, "If the United States decides to undertake long-duration manned interplanetary missions, a dedicated life sciences module may be a necessary addition to the space station."

Ah, dedicated facilities. Life scientists at NASA have been in pursuit of that "Holy Grail" for years. In the 1960s, three dedicated life sciences satellites were flown as part of the BioSatellite program. The United States has also had a few projects aboard the Soviet Biocosmos satellites, but life sciences is still looking for a home to call its own.

Dr. Thora Halstead, chief of the Space Biology Department of NASA's Life Sciences Division in Washington,



. . . and one 19-inch-wide rack will be devoted to an experiment in which four female clawed frogs (*Xenopus laevis* to biologists) will be inseminated in order to study embryo development under conditions of both microgravity and simulated gravity through the use of a centrifuge.

speaks hopefully of a program called LifeSat, which is currently under study by scientists at NASA's Ames Research Center. She describes the program as "a series of free-flying satellites (the first one scheduled for 1993), which will allow us to perform a series of automated experiments on small invertebrates and plants, and do some tissue culture tests." Later modules will contain experiments on rodents and higher plants.

Planning for LifeSat has completed the initial study phase, and NASA plans to move on to phase B (the design phase) and soon to the combined C and D phase (where the system will actually be built). Not only is interest strong within the U.S. space community, according to Halstead, but "there is a good deal of interest abroad, as the European Space Agency, Japan, Canada and France, as members of the science working group, have all expressed interest in a collaborative effort."

Experiments directed at the possible effects of spaceflight on human reproduction are also planned for future shuttle missions. Dr. Debra Wolgemuth of Columbia University's College of Physicians and Surgeons is the principal investigator on a planned study of the effects of shuttle-duration missions on mice. As explained by Wiley, a co-investigator on the study, "Our plan is to send up two groups of mice bred on the ground. One of the two groups will be sacrificed immediately and the embryos placed into culture. The second group will be sacrificed at various stages throughout the flight, and their embryos will be compared with the ones developing in the culture. Maybe this way we'll be able to get an idea whether the effects of spaceflight are most pronounced through the female or on the actual embryo cells themselves." (A study on frog eggs and their development is also planned for a shuttle mission in July 1991.)

There is a definite feeling among NASA people that the idea of creating and raising families in space is so far off that no one feels comfortable dealing with it. Human reproduction is at the end of a long line of important medical concepts, and now it seems more important to keep astronauts alive, mentally sound and able to perform their duties under the rigors of spaceflight. In that context, there is no arguing with NASA's priorities.

But if there was ever an issue that can't afford to wait until problems arise, this is it. In more immediate terms, no one is confident that someone can travel in space for long periods, return to Earth and then have children. As Halstead puts it, "We have one [female] cosmonaut to base our knowledge on, and that's not a great statistical base."

Over the long term, implications are even greater. Should technology advance to the stage where mankind can send crews to Mars—or other destinations requiring lengthy exposure to the conditions of spaceflight—the risk remains that they may be unable to have children in space or after they return to Earth. Or, if humans attempt to reproduce in space, are malformations or spontaneous abortions a likelihood?

Life in space from the egg to the grave may seem a long way off, but the idea of putting future generations in the role of human guinea pigs is unconscionable. When some NASA projects take as long as 10 years from proposal to flight, there's no such thing as having plenty of time. ★

Lance Frazer is a freelance writer in Santa Rosa, California, who specializes in space science issues.

Letter from Europe

Hotol on Hold

by Clive A. Simpson

The coming year will be critical for the future of Britain's Hotol (horizontal takeoff and landing) space vehicle. Although many of the technical problems to be solved are still daunting, it is perhaps funding that remains the major obstacle to realization of this commercially motivated project.

The British space program has staggered from crisis to crisis in the past two years, largely as a consequence of the actions and inactions of Prime Minister Thatcher's government. Government support for almost any kind of British space involvement has lapsed into deficit, with the European Space Agency (ESA) seriously considering demoting Britain to the embarrassing status of associate member.

Against such an unhealthy backdrop, Hotol emerged last year from a two-year proof of concept study with its major features intact—still a competitor in the stakes for a single-stage-to-orbit spacecraft.

Last July 25, however, Kenneth ("Hurricane") Clarke, trade and industry minister prior to his transfer to the health service, dealt his parting blow to British space hopes: no more government money for Hotol. Clarke's announcement was largely unexpected. The feeling had been that perhaps the government, after refusing to spend more on ESA projects, would be more willing to support this innovative, homespun program.

The two-year concept study, completed in the fall of 1987 at a cost of 3 million pounds ($5.4 millon), had yielded encouraging results with British Aerospace and Rolls-Royce continuing research at their own expense.

Of the original 3 million pounds, half had been put up by the government through the British National Space Center. A definition and initial development phase expected to cost between 4 million and 6 million pounds had been planned to begin last year, and again the government was expected to contribute half the cost. That plan is now dead.

Rolls-Royce, meanwhile, disclosed that it now owned the patents on the reuseable air-breathing engine. The company bought the patent originally taken out by Hotol inventor Alan Bond. Starting last fall, Rolls has been urging the British Ministry of Defense to declassify the engine. This remains a barrier to discussing joint commercial ventures with potential partners, including West German, Japanese and American firms.

Last October the Carroll Group, a privately owned property and investment company in Britain, revealed that it had begun preliminary discussions on the possibility of sharing Hotol funding. Those discussions have yet to be resolved.

Despite these blows, Hotol's developers are convinced the vehicle can reduce launch costs to low Earth orbit to about one-fifth those of conventional launch systems, such as the shuttle, for a typical seven-ton payload. The ability of Hotol to recover satellites and dock with Europe's Columbus and the international space station has also been investigated during these proof-of-concept studies.

Initially, more than 30 different configurations were studied, and it was concluded that for a recoverable, reusable launcher all the expensive hardware (engines, avionics, structure) should be collected into a single vehicle and anything that left the ground—except propellants and payload—should return.

In addition, engineers agreed that as little deadweight as possible should go into space and that turnarounds on the ground would have to be rapid, meaning minimum interfaces with ground facilities. This led to another basic design criterion: single rather than multiple payloads in order to minimize integration problems.

As a result, the concept of the "ideal" launcher emerged: a single-stage-to-orbit vehicle able to operate from a simple launch area with almost airliner-type frequency.

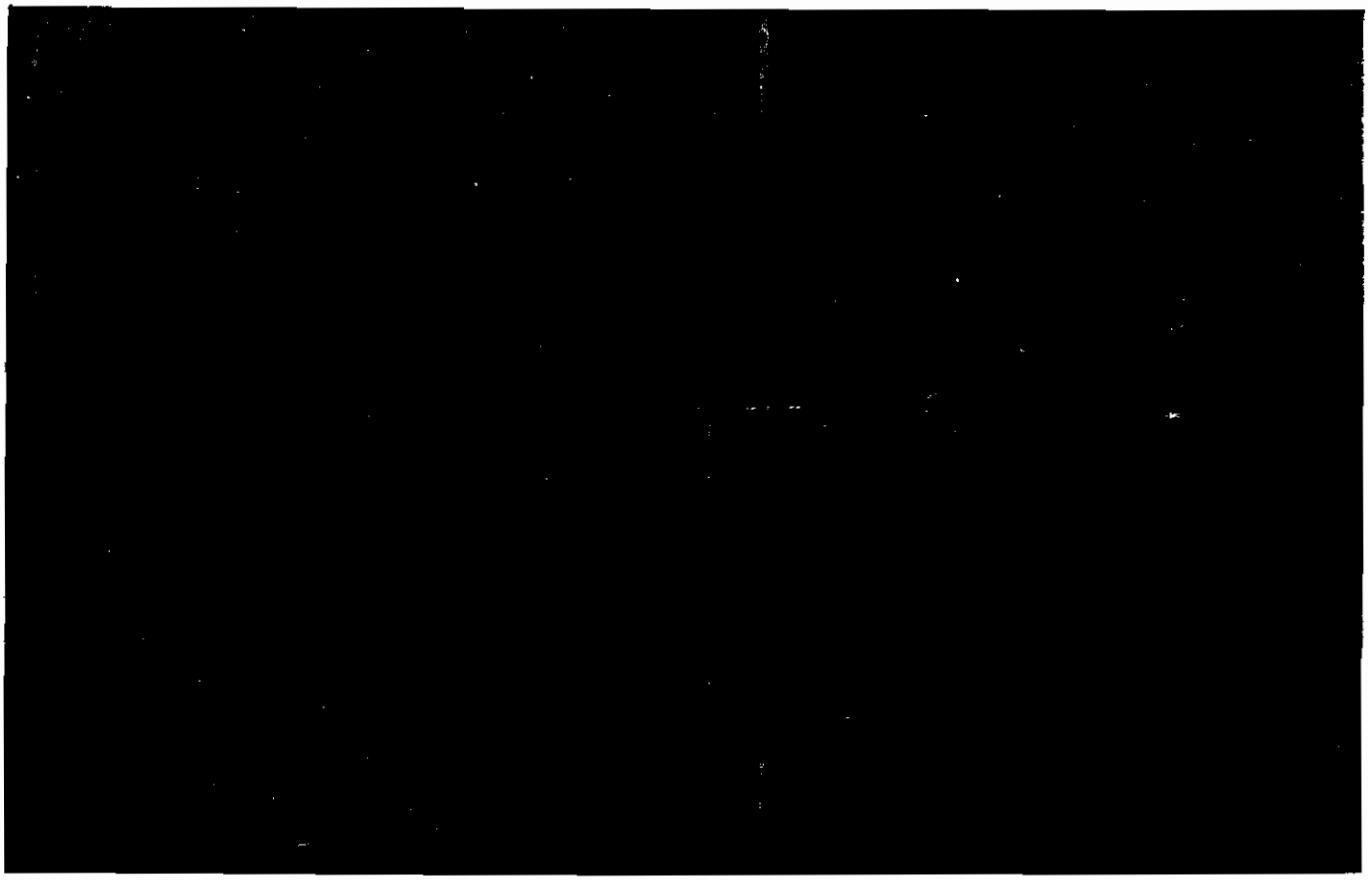
Hotol is based on a new propulsion technique that allows the use of atmospheric oxygen to reduce the onboard propellant mass and wings to optimize the initial flight trajectory after takeoff from a standard runway. The propulsive and aerodynamic characteristics result in a vehicle that is fully recoverable and quickly reusable with minimal refurbishment, preparation and expense.

The vehicle now emerging from the design boards is basically part aircraft and part spacecraft about the size of the Concorde supersonic transport.

Most of Hotol's forward fuselage is occupied by a large pressurized liquid hydrogen fuel tank. At the rear is a liquid oxygen tank for flight outside the atmosphere where air breathing is not possible.

The payload bay, comparable to the diameter of the U.S. shuttle, is between the two tanks, and the layout ensures minimum shifting of the center of gravity during flight. Engines would be conventionally mounted at the rear, and protection for reentry heating would be concentrated largely underneath the fuselage and wing. Takeoff mass would be five times that at landing, as opposed to about twice as much for a conventional aircraft.

A takeoff speed of 290 knots would be achieved with an acceleration of



Hotol soars aloft with an Australian communications satellite—but only if its developers can find the necessary funds.

about half a G force and a run of 2.3 kilometers. Vertical acceleration at liftoff would be 1.15 G with a climb angle of about 24 degrees.

Hotol would go supersonic after two minutes, clearing commercial air lanes (12 km.) after four and a half minutes and reaching Mach 5 after just nine minutes. The fuel burned up to this point would be about 18 percent of takeoff mass, compared to a typical value of 50 percent for a vertical takeoff vehicle.

At the nine-minute point external air-breathing would no longer be possible, and a ballistic trajectory would begin using the main engine. Orbital velocity would be achieved at an altitude of 90 kilometers, at which point the main engine would cut off and Hotol would coast to an operating altitude of around 300 km.

Maximum mission duration would be 50 hours with position and altitude changes achieved by an orbital maneuvering system, or OMS. At the end of the mission the OMS would slow the vehicle and bring the perigee down to about 70 km. in preparation for reentry. Hotol would then reenter the atmosphere at a very high angle (about 80 degrees), reducing that angle as speed falls and beginning a hypersonic glide at an altitude of about 25 km.

Because of its large wing area and low mass, the vehicle would behave much less like a projectile than the U.S. shuttle. Reentry temperatures would thus be lower, and a high-temperature metal alloy skin would be adequate to protect the under surface.

The high hypersonic lift-to-drag ratio of Hotol during reentry (more than twice that of the shuttle) gives a high cross-range capability sufficient for a landing in Europe from an Equatorial orbit. Final approach and landing techniques would be similar to the shuttle but gentler: approach angle of 16 degrees, touchdown speed of 170 knots and ability to stop on a wet runway of 1.8 km.

For purposes of simplicity and economy, the first operational Hotol will be remotely piloted by means of artificial intelligence and robotic systems. From the outset, however, provision will be made for manned operation.

The strategy on manned operations is to include a human crew only when they are needed for orbital or space station operations. A manned module would be situated in the cargo bay, and the crew members would play no role in launch and landing activities.

Manned missions would occur only after the unmanned version of Hotol was fully proved, and the planners anticipate that one vehicle from a fleet of about six would be dedicated solely for manned missions.

The hoped-for economy of operation, coupled with quick reaction and a rapid turnaround time (less than seven days) would enable Hotol to compete for about 75 percent of the commercial satellite-launching market beyond the year 2000, according to its proponents.

In addition. Hotol technology is expected to be upgraded beyond the initial cheap spacecraft launcher. Indeed, a one-hour passenger flight from Europe to Australia is a possibility around the year 2010, and it takes little imagination to identify other uses for such a flying machine. The Hotol developers are already pondering a second-generation version with potential for world-wide sales. ★

Clive A. Simpson, is a science writer in Crowland, Peterborough, England.

Technology Update

Composites: More Strength, Less Weight

Consider the added strength you can achieve by criss-crossing several pieces of strapping tape on a package, instead of just a single piece, and you have an idea of how a composite material achieves its higher strength.

Composite materials are formed by processing two or more materials, such as glass, graphite, continuous fibers or powders, into a base material to produce another material with new or distinctive characteristics. So the final material, like the strapping tape on your package, is a combination of materials adding strength but not as much weight to whatever the product may be.

Composites have been used in everyday products for some time. Two commonly known types of composites are fiberglass for boats and automobiles and strapping tape with glass fiber embedded in the tape. A resin matrix, the most developed of the composites, is also used in golf club shafts and tennis racquets where its function is more one of design and lower weight than resistance to extreme temperatures. Resin matrices are found in rotating components, such as automobile and truck driveshafts.

Composites are currently being used in aerospace applications because they offer the potential of high-strength and low-weight properties that far exceed those of conventional aerospace materials. These characteristics are so vital that the aerospace industry has targeted advanced composites as one of the eight enabling technologies in the Aerospace Industries Association's "Key Technologies for the 1990s" program. Initiated to ensure U.S. competitiveness into the 21st century, the Key Technologies program is a national, cooperative effort that calls for a reordering of priorities and a renewed commitment to technology development from industry, government and academia.

Road maps outlining the stages of development over the next 10 years will be used to guide the technology teams (representatives from industry, government and academia) in their efforts to implement a national technology development plan. The advanced composites road map analyzes four categories of composite materials. In ascending order of temperature resistance they are: resin matrix, metal matrix, ceramic matrix and carbon matrix.

As with the other identified key technologies, advanced composites were selected because of the broad application of this technology and therefore the high payoff potential of its development, factors especially significant to ensuring the U.S. competitive edge in the global marketplace.

Foreign competition is a real and active threat to the United States in this field. Japan and the European community have already shown measured increases in market share in composite materials and hardware. Furthermore, Japan's recently announced plan to develop a superfast commercial aircraft that would rely heavily on advances in composite technology illustrates a new trend: technology development is now a stated priority for the Japanese. At one time Japan was content to capitalize on U.S. technology.

Another dimension to the erosion of U.S. competitiveness is evidenced by U.S. dependence on foreign suppliers for raw materials needed for some composites. Japan and Europe, for example, are the primary suppliers of technical grade ceramic powders and fibrous reinforcements—the raw materials needed for ceramic matrix composites.

The high cost of securing and processing raw materials, the still evolving and complicated manufacturing process, the shortage of skilled engineers trained in advanced composites and inadequate end-product evaluation currently inhibit the more rapid advancement and usage of this key technology. Conventional materials used in aerospace products and systems remain more cost-effective.

Other issues, such as the effects of oxidation on high-temperature composite materials and the development of repair and replacement techniques applicable to composite materials, need further study.

Despite current obstacles, the development of advanced composites technology promises several advantages. Because they are made up of lightweight, structurally efficient reinforcements embedded in lightweight base materials, composite materials significantly reduce weight. Lower structural weight translates into true performance enhancements: increased range, payload, velocity or maneuverability.

Lowering life cycle costs of aircraft, space and weapons systems is an industry priority. Advancements in composite technology could provide composites with greater heat resistance and less vulnerability, thus improving the rate of survivability and maintainability in high-speed aircraft, advanced propulsion systems and other products and systems. Other applications include space structures where the stiffness provided by advanced composites meets a major structural criterion. ★

This is the first in a series of eight technology appraisals to be published under the aegis of the Aerospace Industries Association's "Key Technologies for the 1990s" program and furnished to Space World *by the association. Future articles will deal with very large-scale integrated circuits, advanced software, air-breathing propulsion systems, advanced sensors, optical information processing, artificial intelligence and ultra-reliable electronic systems.*

Starring all your favorite planets and satellites:

Coming Attractions In the Solar System

by Ken Croswell

Stroll down a giant canyon on Mars. Sail across the rings of Saturn. Or set foot on the volcanic plains of Io.

Impossible? For you and me, perhaps, but not for an unmanned space probe. These are just some of the vistas that could await us—*if* the United States renews its once-ambitious program of planetary exploration.

Cheap and productive though it is, planetary exploration has been hard hit by budget cuts, shuttle cost overruns and delays in the space program. During the 1970s the United States launched 10 successful missions to the planets. During the 1980s it has not yet launched a single one.

Even with the shuttle back in business, any would-be planetary mission faces three hurdles before it ever reaches its target: getting through Congress (very difficult), getting off Earth (used to be easy, now it's not) and getting through millions or billions of miles of space (the easy part).

Despite the problems plaguing the planetary program, astronomers are as eager as ever to explore the planets and their satellites. To investigate a new world, scientists have three weapons in their arsenal: the flyby spacecraft, which sails past a planet and gives us a brief glimpse of it; the orbiter spacecraft, which circles a planet again and again for a detailed look; and the lander, which sets down on a planet's surface for a close-up view. Take the planet Mars as a good example of this strategy in action. The United States first sent a flyby spacecraft past Mars in 1965, first placed a spacecraft into orbit around the planet in 1971 and first landed spacecraft on the Martian surface in 1976.

Our exploration of the Solar System, of course, is incomplete. But it is also uneven. We know more about the nearby planets than we do about the distant ones, simply because it's easier to observe the closer planets and it's easier to launch spacecraft toward them. Although American spacecraft have landed on Venus and Mars, they have not even flown by Neptune or Pluto.

Yet at every planet there are gaps in our knowledge, gaps that scientists would love to fill by launching new missions to the worlds of the Solar System. What's ahead for planetary exploration? No one can say for sure; the answer depends more on money and politics than on scientific priorities and celestial mechanics. But here, for the planetary enthusiast, is a possible scenario of coming attractions, rated on the five-star system (in both movies and astronomy, the more stars the better):

Neptune in 1989 ★ ★ ★ ★ Nothing stops Voyager 2. Launched in 1977, Voyager 2 has survived Jovian radiation, the rings of Saturn and even the Reagan administration, which tried to turn the spacecraft off back in 1981. On the night of August 24, Voyager 2 will fly past its final planetary target: Neptune.

Nearly three billion miles from the Sun, Neptune is the most distant of the four giant planets. We know so little about it that almost anything Voyager tells us will be news. Astronomers believe Neptune is similar to Uranus, which Voyager flew by in 1986, but may have more activity in its atmosphere.

Neptune's large moon Triton will be a high point of the Voyager encounter. Organic compounds color Triton orange, and the satellite may have seas of liquid nitrogen on its surface. Voyager will reveal what this far-off moon is like. The spacecraft will also discover new moons around Neptune and tell us whether the planet has rings.

Venus in 1990 ★ ★ ★ With a thick, cloudy atmosphere, Venus is tough to study. You can't see its surface; clouds block the view. Landers have descended through the clouds and sent back pictures, and the 1978 Pioneer Venus mission used radar to look at the surface.

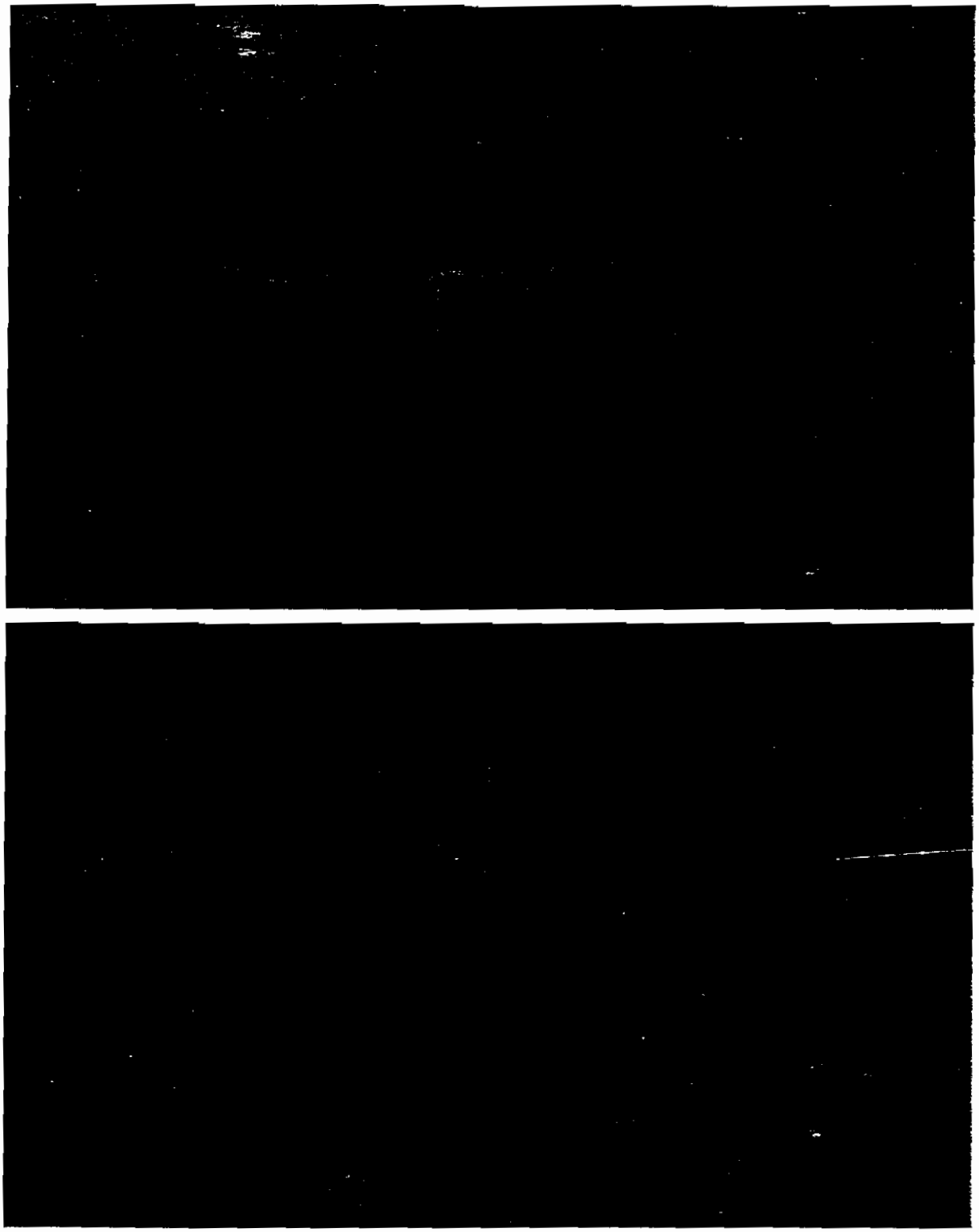
But scientists want to see Venus's surface more clearly. This spring the shuttle will launch Magellan, which will orbit Venus and use radar to map the planet's surface. Magellan will see things a hundred times smaller than Pioneer did. Prime questions that the spacecraft will address include whether the planet has active volcanoes, whether it once had oceans (if so, their basins may still be visible) and whether plate tectonics shape Venus's surface.

Mars in 1993 ★ ★ In 1992 (maybe) the space shuttle (maybe) will launch the Mars Observer. The next year the spacecraft will go into orbit around Mars and study the planet's atmosphere and surface. If this sounds a little boring, well—it is. The Mars Observer represents a retreat from the ambitious Viking program, which in 1976 put two spacecraft into orbit about Mars and sent two landers to the planet's surface.

Jupiter in 1995 ★ ★ ★ ★ ★ Now this is more like it! The Galileo project to Jupiter is extremely ambitious. It will probably be the most exciting planetary project of the 1990s.

There's nothing in the Solar System like Jupiter. More massive than all the other planets combined, Jupiter sports a colorful atmosphere and a giant red spot bigger than Earth. The planet reigns over 16 satellites, four of which are large, lunar-sized objects.

Scheduled to be launched aboard the shuttle late this year, Galileo will reach Jupiter in 1995. Unlike the four other spacecraft that have visited Jupiter, Galileo will orbit the planet. Part of the craft will break off from the mother ship and plunge into Jupiter's atmosphere, sending data



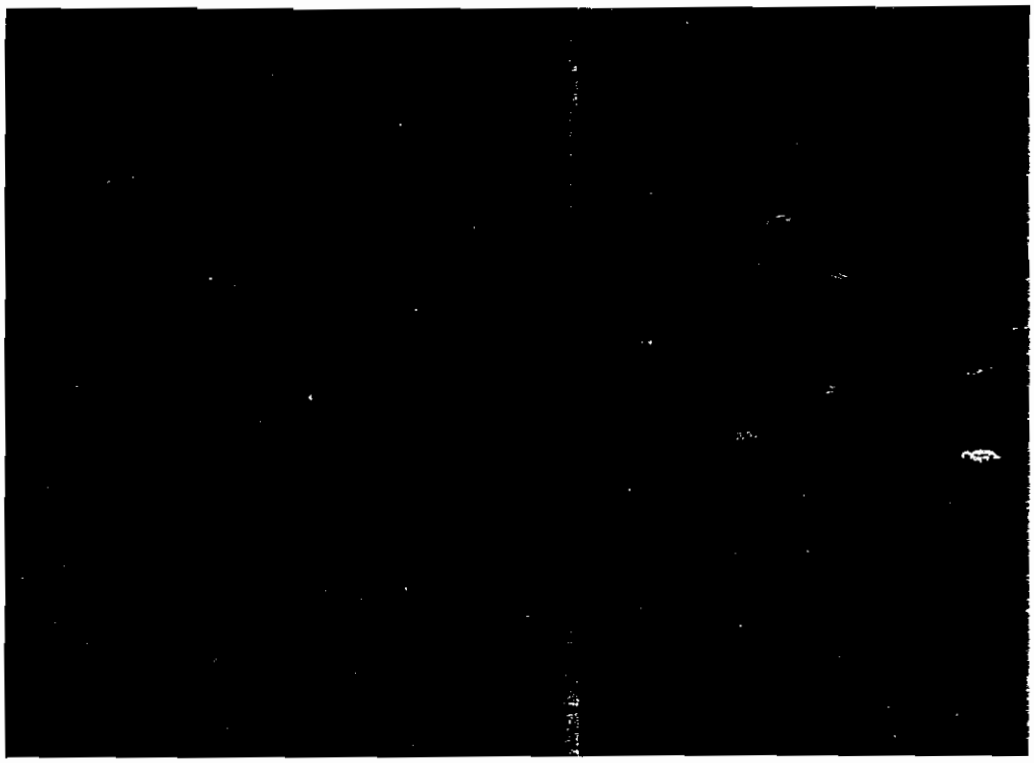
Outward bound in the Solar System: Magellan over Venus (top) and a Galileo probe entering the Jovian atmosphere . . .

back to Earth as the probe dives into the abyss.

The Galileo orbiter will circle Jupiter, studying the planet for many months. It will pass by the four large moons—Io, Europa, Ganymede and Callisto—and take excellent photographs of them. But the spacecraft will also be looking at Jupiter's twelve other moons, only one of which—red, egg-shaped Amalthea—was seen in any detail by Voyager.

Asteroids and a comet around 2000 ★ ★ ★ ★

Although big objects like planets and moons grab the headlines, smaller objects are also important to our understanding of the Solar System. Between Mars and Jupiter circle thousands of asteroids, and every now and then a bright comet approaches Earth and appears in our sky. Asteroids and comets are small, primitive bodies that may not be much changed from the time of their formation. They



. . . and Cassini looking at Saturn's moon Titan (top) and Voyager passing Neptune and its moon Triton.

therefore lend insight into how the Solar System was born.

If it ever gets funded, the Comet Rendezvous and Asteroid Flyby (CRAF) mission will travel through the asteroid belt and photograph an asteroid or two. The spacecraft will then approach a comet and fly alongside it, firing a penetrator that will pierce the comet and sample the comet's composition.

But CRAF has been delayed repeatedly. Each year scientists hope it will get funded, and each year it doesn't. Sort of like Lucy and Charlie Brown and that football she always snaps away from him just as he's about to kick it.

Mars around 2000 ★ ★ ★ ★ ★ In 1976 the very successful Viking project sent two landers to Mars. These landers photographed the surface at two points on Mars, revealing for the first time what Mars looks like at ground level. But what other sights does Mars offer? What lies

Planetary Exploration

Planet	Number of successful U.S. missions	Planet	Number of successful U.S. missions
Mercury	1	Saturn	3
Venus	5	Uranus	1
Mars	6	Neptune	0
Jupiter	4	Pluto	0

beyond the horizons of the Viking photographs?

A mobile lander could tell us. Roaming all over the planet, such a lander could travel to more interesting places than Viking set down in. Both Viking spacecraft deliberately landed in safe, boring regions to avoid coming down on boulders that could topple them. A mobile lander could land in a safe, boring region but then travel to more dangerous—and more exciting—places. It could check out the Martian volcanoes, look into what may be ancient river beds, and travel up to the polar caps, taking photographs and searching for signs of life along the way.

Venus around 2000 ★ ★ ★ The soon-to-be-launched Magellan spacecraft will look at Venus's surface, but what about the planet's atmosphere? Full of clouds and carbon dioxide, Venus's atmosphere invites the sort of study Magellan will not give it. Another orbiter could be sent to the planet to investigate Venus's atmosphere.

Saturn around 2002 ★ ★ ★ ★ ★ The ringed planet is undeniably the most beautiful world in the Solar System. It rules 17 moons and thousands of rings. Of great interest is the planet's giant moon Titan, which has organic compounds and a thick nitrogen atmosphere. Unfortunately, since Titan is covered with haze, even Voyager couldn't tell us what Titan's surface is like. But scientists speculate that seas of liquid ethane and methane may cover part or all of the satellite and believe that Titan may resemble the way Earth was billions of years ago.

To study Saturn in the same intensive way that Galileo will investigate Jupiter, scientists have proposed a mission called Cassini that will place a spacecraft into orbit around Saturn. The spacecraft will examine the planet, the moons and the rings thoroughly. The mission will also send a probe to Titan that will penetrate the satellite's clouds and photograph a bit of the moon's surface.

Mercury around 2005 ★ ★ ★ It's easy to forget this crater-pocked world so close to the Sun. But scientists want to see more of Mercury since the only previous Mercury mission, Mariner 10, imaged less than half the planet's surface. A spacecraft in orbit around Mercury could study the entire planet better than Mariner did, investigating Mercury's geology, surface composition and magnetic field.

Mars around 2005 ★ ★ ★ ★ We've got Moon rocks. Why not Mars rocks too? A spacecraft could land on Mars, scoop up some rocks and return them to Earth. Scientists could then scrutinize the rocks far better than automated landers have done.

Io and Europa around 2005 ★ ★ ★ ★ ★ These are Jupiter's most interesting satellites. Voyager gave us good looks at both, discovering erupting volcanoes on Io and an ice-covered surface on Europa. The Galileo project of the 1990s will look at the pair closely.

But now imagine something even more daring than Galileo. Imagine sending a lander or two to Io, to explore the volcanoes, lava streams and lava lakes. And then imagine sending landers to Europa to investigate the icy surface. Some scientists believe oceans of liquid water may lie beneath Europa's ice layer, and where there's liquid water, there may be life. Europan landers could check out this intriguing possibility.

Asteroids around 2010 ★ ★ ★ ★ There are thousands of asteroids out there, and the proposed CRAF mission will image only one or two of them. If a spacecraft were sent through the asteroid belt, it could dart from one asteroid to another, examining asteroids of different sizes, shapes and colors.

Venus around 2010 ★ ★ ★ ★ ★ Venus is both the best of worlds and the worst of worlds. Since it's the planet closest to Earth, Venus is the easiest place to send a spacecraft. But with a temperature of 900 degrees F and an atmosphere 90 times thicker than Earth's, it's a tough place for a spacecraft to survive. Landers that manage to reach the surface last no more than an hour or two.

Nonetheless, picture placing a "superprobe" on Venus—a mobile craft that could withstand the planet's heat and pressure for months rather than minutes. The lander could roam all over Venus, taking samples of the soil and photographs of the landscape. No doubt this mission would be extremely difficult, but no doubt it would also be extremely rewarding.

Uranus around 2010 ★ ★ ★ ★ Although Voyager 2 successfully flew past Uranus in 1986, it was not really designed to study planets beyond Saturn. Scientists would like to place a more sophisticated spacecraft into orbit around Uranus. Such a mission would be analogous to the Galileo mission to Jupiter and the Cassini mission to Saturn. A prime target of this mission would be the small moon Miranda, whose strange surface Voyager first revealed.

To get to Uranus fast, the spacecraft must fly by Jupiter, which will accelerate the craft to Uranus. The next launch opportunity occurs around the turn of the century; the craft would then take 10 years or so to make it out to the distant planet.

Neptune around 2012 ★ ★ ★ ★ ★ While we're at it, why not mount a similar mission to Neptune? An orbiter could examine the planet thoroughly and investigate Neptune's moons and any rings the planet has. Until Voyager flies past Neptune this summer, it's hard to say what the top priority of a Neptune orbiter would be. One possibility: send a lander to Neptune's satellite Triton.

Pluto around 2015 ★ ★ ★ ★ Everyone likes Pluto. The tiny world huddles in darkness at the edge of the Solar System, its only companion its one moon. We know very little about Pluto. Only in 1978 did astronomers find its satellite, Charon, and only in the past couple years have they accurately determined Pluto's size. Although astronomers think Pluto may have polar caps, we know little else about its appearance. A spacecraft to Pluto would give us a first look at this distant world.

Missions like these are difficult and complex, but the challenges they present are ones scientists and engineers are ready to meet. The question is not whether we *can* embark on such missions but whether we *will*, and the answer depends on whether the United States will reinvigorate its program of unmanned planetary exploration, a program that has been cheap, ambitious and—above all—enormously successful. ★

Ken Croswell is a graduate student at Harvard University and has written articles for magazines such as Air & Space, Astronomy, Astronomy Now, Odyssey *and* Star Date. *He is also a contributing author to Time-Life Books' new astronomy series,* Voyage Through the Universe. *He is a senior editor of* Space World.

Capsules (continued from page 6)

1000, a portable battery-powered device which is able to read and process position and time data from three or four GPS satellites to produce a readout of latitude and longitude. This information can then be manipulated to compute velocity, travel distance and even estimated time of arrival.

Produced by Magellan Systems Corporation, Monrovia, California, the GPS NAV 1000 weighs just 1.5 pounds, and can also be used on land.

Now, if only somebody would market that wrist telephone we've heard about for years . . .

Farthest Out

An international group of astronomers at the Space Telescope Science Institute has discovered the most distant galaxy yet seen.

At an estimated distance of 15 billion light years, the galaxy is more than 90 percent of the way to the edge of the visible universe. Since its light has taken so long to travel to Earth, this object is being seen only a few billion years after the date that scientists now place the Big Bang, which marks the beginning of the observable universe.

Ken Chambers, graduate student at Johns Hopkins University, George Miley, Professor of Astronomy at Leiden University in the Netherlands, and Wil van Breugel, an astronomer at the University of California at Berkeley, formed the team that made the discovery, one of several distant galaxies they have found using a technique they developed that combines the enormous power and unique optical spectrum of a galaxy's radio emission.

The Space Telescope Science Institute, operated for NASA by the Association of Universities for Research in Astronomy Inc., is located at Johns Hopkins University, Baltimore.

NASA Minority Contractors

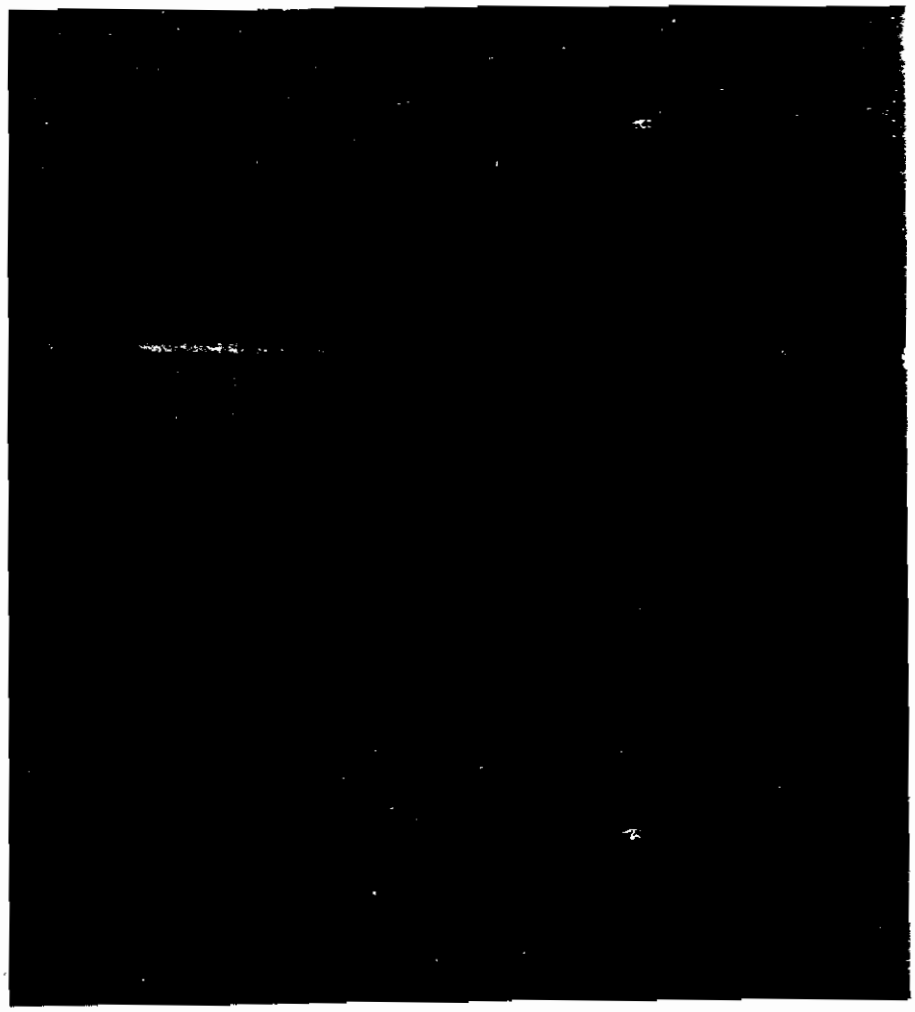
Two companies were named by NASA's Office of Small and Disadvantaged Business Utilization as its minority contractors of the year.

Communications Electronics International, Orlando, Florida, was honored for its fabrication of a wiring assembly that featured 12,908 connections found to be 100 percent error-free.

New Technology, Inc., Huntsville, Alabama, was selected for its hardware and software engineering support of NASA's Marshall Space Flight Center in Huntsville over the past eight years.

Contractors are recommended for the award based on such criteria as the firm's contract and internal management, financial stability, historical growth and contract performance.

Optical Assist



HEADS UP: Transparent helmet-mounted displays may provide future spacewalkers with timely information crucial to construction and operation of the space station Freedom. Under development at Johnson Space Center since 1984, the view screen projected onto the astronaut's visor could contain important spacesuit readings, work checklists, schematics and perhaps even low-quality videotape via a link to computers on the space station or on the ground. In addition to a transparent screen, features may include partially voice-activated controls. The frequent EVAs required by space station operations demand some alternate method of getting relevant, updated data to the astronaut. ★

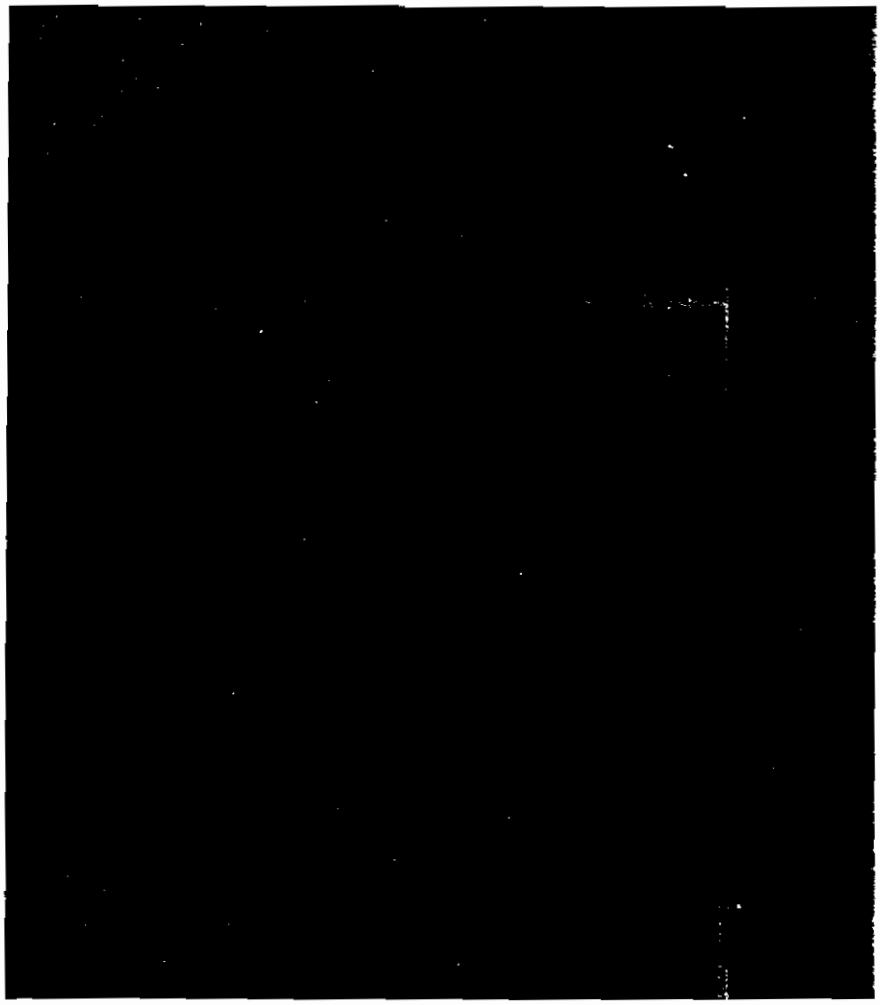
Future Freedom Residents?

Sixth and seventh grade students in Jackson, Mississippi, got the chance to simulate a four-day space station visit when they participated in "Mission 88-A," the first flight of the Davis Planetarium Student Space Station. Nine students climbed into the 12 by 43-foot prototype space station to conduct space-related experiments using computers and other testing equipment, while 21 other students served as flight controllers and mission directors—all with the help of NASA technicians.

Various corporations and organizations supplied the materials to outfit the empty petroleum tank modified to serve as the space station, including fiberglass insulation from Manville Corporation, Denver, Colorado, similar to that used in the space shuttle crew cabin.

The mission was preceded by almost two weeks of space science studies and a trip to the Johnson Space Center in Houston.

Giant Steps



BROBDINGNAGIAN MARTIANS: Martin Marietta scientists use this 16-foot-square model of the Martian surface to develop artificial intelligence techniques to enable a spacecraft to choose a safe landing site as it descends through the Martian atmosphere at 200-400 feet per second. Because of the 40-minute time lag for instructions to be received from Earth, the spacecraft will have to make instantaneous decisions on its own. The company is studying Mars landing approaches under a NASA contract.

No Stamp Necessary

NASA, which pioneered satellite communications, is breaking new ground in terrestrial communications with a sophisticated electronic network of its own.

Since 1982, the agency has used NASAMail, provided by the Telemail service of Telenet Communications Corporation, Reston, Virginia, to connect 7,500 authorized NASA and contractor personnel with each other to send messages, post bulletins, and exchange updates and reports. In that time, data communications usage at the agency has more than tripled, according to Sandra Bates, program manager for NASA's Program Support Communications Network.

In December 1987, NASA added an extensive video teleconferencing capability, which now covers 11 of its 16 network centers and is scheduled at the rate of three to eight teleconferences a day, according to Sherry Paul, video teleconference center coordinator at Marshall Space Flight Center.

This heavy information traffic is predicted to increase even more when Telenet finishes incorporating NASA's other electronic mail programs with NASAMail.

All of this saves time, money and hassle, various NASA managers said. NASA even has its own command and control center for its data network, one of few government agencies to do so.

This is not the greatest news for another communications-oriented government agency—the U.S. Postal Service.

Next Month

The February issue of *Space World* will focus on the international scene. San Francisco-based writers Ray Spangenburg and Diane Moser examine the emerging space activities around the Pacific Rim. Clive Simpson, former assistant editor of the British Interplanetary Society's magazine *Spaceflight*, looks at the situation in Europe—particularly as it will be impacted by the planned integration of the European Community in 1992. And there will be features on other international programs by your favorite *Space World* writers.

But that's not all! We'll take a journey to Mercury with Harvard University astronomer Ken Croswell. The Mensa society, which is looking for a few good men and women with IQs in the 98th percentile, has a special interest group on astronomy and space. We'll show you how you can become a member.

All of this and more are coming in the February issue of *Space World*, the independent magazine of the space age. ★

Who's Got the Mass?

Unresolved questions about the origins of the universe and its "missing mass" may be refined when the Cosmic Background Explorer (COBE) is orbited in 1990.

COBE will examine uniform diffuse background radiation, which cannot be explained by current scientific theory except as a remnant of the Big Bang. As with many other astronomical phenomena, this radiation is difficult to study from beneath Earth's absorbing atmosphere.

Originally scheduled for launch from the space shuttle but now slated for a Delta expendable launch vehicle, COBE will examine the entire sky twice in the course of its year-long mission. With the help of a special long-life cryogenic liquid helium tank developed by Ball Aerospace, COBE's instruments will create a detailed map of the cosmic background radiation, and will search for radiation from the first galaxies.

Call To Arms

Saying that "The United States civilian space program is at a crossroads," three of the leading U.S. scientific and engineering societies have called for "a restored commitment to space" by the government.

A joint statement signed by the presidents of the American Astronautical Society (AAS), the American

Institute of Aeronautics and Astronautics (AIAA), and the Institute of Electrical and Electronics Engineers (IEEE), the report states that NASA is "neither sufficiently understood nor adequately supported" by Congress as the "critical" time approaches to set NASA's funding future.

After detailing the numerous contributions that the early space program made to the nation—boosting technical education, economic development, knowledge of the Earth and Solar System, and general scientific theory, and ultimately leading to man's more philosophical perspective about life—the paper alludes to the Congressional Budget Office report *The NASA Program in the 1990s and Beyond*, and states that the agency's budget must soon grow in order to fully exploit the technology and societal vigor created by NASA.

"The space frontier is no less significant to our future than our terrestrial boundaries," the statement concludes, and the leadership of the United States must act now to rectify the current lack of adequate financial and bureaucratic resources for NASA.

Space Station Update

The work force employed to make the space station Freedom a reality now numbers 6,000—at a cost of $52 million a month—according to James M. Sisson, NASA's deputy director of the program.

Speaking at a November 1 briefing on the space station for industry at Tyson's Corner, Virginia, Sisson said that, although Freedom is still in an early design stage, the systems have undergone extensive trade-off studies by NASA and such outside organizations as the National Research Council.

Sisson, who worked on both the Apollo and space shuttle, said the space station is at a more mature level of development than those programs were at similar points in their history.

The NASA official also emphasized that the full fiscal 1990 funding request of $2.1 billion must be made available to sustain the present program momentum, and that NASA is committed to making Freedom a permanently manned facility despite recent efforts to scale it down to a merely man-tended outpost.

Also speaking at the meeting, Frank DiBello of Peat Marwick, a consulting firm that is working with Boeing to promote non-governmental use of the station, said he was encouraged by recent detailed NASA guidelines for commercial technical proposals for use of Freedom. He called this the biggest development of recent months.

A call for patience was issued, however, by Fred Haise, former Apollo astronaut who now heads Grumman's space station support office in Reston, Virginia. He reminded the audience that Freedom will be a "multi-decade" operation, with many evolving and unforeseen opportunities for private business participation. The briefing was the second in an annual series of updates sponsored by the American Electronics Association.—*Doug Isbell* ★

Careers

NASA Wants You!

by Suzanne Montgomery

If you're a graduate student eager to begin your career in aerospace research, you have until February 1 to apply for a NASA grant for the 1989-90 academic year. If you're no longer a student, but a university and college faculty member in science and engineering, the same deadline applies to apply for a NASA-funded 10-week summer fellowship.

As a student, you can receive up to $18,000 a year (with potential for renewed funding for two additional years) from the NASA Graduate Student Researchers Program (GSRP). You may apply at any time during your graduate career or before you receive your B.S. degree.

This year the space agency will award about 80 individual grants to promising U.S. graduate students whose research interests mesh with NASA's programs in space science and aerospace technology.

Selections are made on the basis of competitive evaluation of your academic qualifications, your proposed research plans or plan of study and your plan to use NASA research facilities. Decisions on fellowships are usually made in March or April.

Of the 80 fellowships awarded each year, 40 are sponsored by the NASA Headquarters Office of Space Science and Applications (OSSA) in the fields of astrophysics, Earth science, life sciences, solar system exploration, space physics and microgravity science. OSSA fellows carry out their research at their home universities and gather once during the year for a seminar at NASA Headquarters.

The remaining 40 fellowships are distributed among NASA's field centers. Those selected for a center fellowship must spend some time in residence at the center. This gives them the opportunity to work with the installation's research facilities and personnel.

For a copy of the brochure and application form, contact the Educational Affairs Division, Office of External Relations, NASA Headquarters, Washington, D.C. 20546. You can also contact Jackie Counts, GSRP Program Administrator, on (202) 453-8344.

University and college faculty also have their chance at winning NASA's brass ring. Every year, the Summer Faculty Fellowship Program gives some 250 experienced faculty members an opportunity to carry out research at one of 12 NASA facilities. The program, now in its 25th year, is jointly sponsored by NASA and the American Society for Engineering and Education.

Selected fellows for the 10-week program are awarded a stipend ($8,000 in 1987) and a travel allowance. More than half the past fellows have returned by invitation for a second year's research.

NASA officials point out that competition for the program is fierce. In the past, applications have exceeded fellowship slots by more than 3:1, and most of those selected have doctorate degrees and a professorship.

Although fellowships are available in more than 35 different teaching disciplines, odds are apparently better for those in engineering, physics, mathematics/statistics and chemistry. NASA notes that nearly 75 percent of former faculty fellows have taught in these disciplines. Additional information on these programs is also available from Jackie Counts.

Employment Up—Slightly

Scientists and engineers make up the steadiest growing segment of the U.S. aerospace industry, although the rate apparently dipped somewhat last year. The Washington-based Aerospace Industries Association (AIA), which surveys the health of the industry, predicted a 2.2 percent increase in the number of scientists and engineers for 1988. This follows a 2.8 percent growth in 1987.

The dip was based primarily on anticipated decline in federal spending for military aircraft, according to AIA. Employment in the missile and space sector, which grew by 1 percent in 1987, was expected to remain level in 1988.

Job Listings

Hiring was brisk in the federal work force as the year drew to a close. Here's a sampling of some of the jobs available, according to Federal Career Opportunities, an independent federal job listing published by Federal Research Service:

NASA Headquarters in Washington needed procurement analysts, electronics engineers (GS-15 or approximately $60,000 a year), computer systems analysts and program analysts (up to GS-12 or $35,000) and administrative support personnel.

- At nearby Goddard Space Flight Center, recruiters were looking for budget analysts, supervisory financial systems analysts at several grade levels, and a facilities management specialist for assignment to NASA's Wallops Island (Virginia) facility.
- The Defense Intelligence Agency was looking for a GS-13/14 aerospace engineer with a knowledge of Soviet ballistic missile systems and a GS-14 supervisory intelligence office (aerospace engineer).
- The Air Force was recruiting for aerospace engineers for positions at Los Angeles Air Force Station and Norton Air Force Base in California and Kirtland Air Force Base in New Mexico. ★

Suzanne Montgomery is an editor at Federal Research Service, Vienna, Virginia.

Reflections

Putting the Universe in a Dentist's Chair

by Peter Jedicke

What comes to mind when you think of X-rays? Your latest visit to the dentist may be a fresh (and perhaps painful) memory, but there are plenty of other places in the universe where X-rays are found.

Astronomers have been studying X-rays for most of this century for clues about the nature of the universe, beginning with instruments carried aboard balloons before World War I and continuing into the 1940s and '50s with rockets. Since the instruments have to be placed above the Earth's atmosphere, which absorbs the X-rays, the advent of Earth-orbiting satellites came as a godsend.

Now, there's a new spacecraft under development that should tell the astronomers as much about distant galaxies and supernovas as your dentist's X-ray machine reveals about the condition of your teeth. It's called the Advanced X-Ray Astrophysics Facility (abbreviated to AXAF and pronounced "ax-aff"), and last August TRW beat Lockheed for the NASA contract to develop it.

AXAF, which is due to to be launched in 1995 by either a shuttle or a Titan 4 expendable launch vehicle, builds on previous NASA successes during the 1970s with the X-ray sensors on its Einstein High Energy Astronomical Observatory and the Uhuru, Ariel and Astronomical Netherlands cooperative satellite programs with the United Kingdom and the Netherlands.

There's a lot more to be learned about X-rays, however, and that's what AXAF is intended to do. In fact, there was some early controversy about the nature of X-rays, but it was soon established that they are high-energy photons of electromagnetic radiation. Since this means that X-rays are a form of light, it should come as no surprise that most objects in the universe emit them.

Electromagnetic radiation owes its existence to the ubiquitous presence of electric charge (or vice versa, but we'll let the philosophers stew about that). Whenever such a charge changes its speed or the direction of its motion, a "ripple" of energy is sent out. Quantum physics lets you think of this ripple either as a particle or a wave; this is why the words "photon" and "radiation" are both commonly used.

An X-ray photon has thousands of times more energy than a photon of visible light, and this is an important difference. Not only must there be a source capable of providing such energy, but there must be a mechanism to make that energy come out as an X-ray rather than in the form of a thousand photons of visible light. (Sorry about that, Mr. Bush.)

It is these mechanisms that interest astronomers. The most basic of them is thermal radiation, which results from enormous numbers of collisions between atoms and molecules as they jostle about. Part of the energy of these collisions is transformed into photons, but, although the collisions take place randomly, photons with certain wavelengths are more likely to be produced than others.

According to the imposing "blackbody equation" formulated by the great physicist Max Planck, the more energetic photons are produced in greater quantities when the temperature of the molecules or atoms is higher. In fact, thermal X-rays are insignificant unless the temperature is in the hundreds of thousands of degrees. At such incredible temperatures, collisions among the atoms tear off the outer electrons, and the gas becomes a plasma—a very hot collection of ionized atoms and free electrons with a neutral charge.

In a plasma, atoms of the more complex elements can hold their more tightly bound electrons, while the simplest atoms—such as hydrogen—are stripped completely. How many electrons remain bound depends on the type of atom, the density and the actual temperature of the plasma. For example, a very common X-ray emission which astronomers observe is due to iron atoms with half of their 26 electrons removed.

The free electrons whizzing through the plasma are veritable fountains of electromagnetic radiation, since they are nothing more than fast-moving electric charges. Any effect that causes the electrons to change speed or direction will cause them to emit radiation. When an electron collides with an ionized atom and decelerates drastically, its energy is transferred into a photon. The energy of such electrons often corresponds to the energy of an X-ray, so X-rays are produced in prodigious quantities.

There are plenty of X-rays out there to observe. The hottest plasmas are at the centers of stars, however, where X-rays are immediately blocked by the rest of the star. So instead of viewing them directly, astronomers observe X-rays from plasmas outside stars—in the corona around the Sun, for example, or in the matter torn from one star by a super-dense companion in a binary system, or even surrounding whole clusters of galaxies.

All of which will give you plenty to think about the next time you are in the dentist's chair waiting to be exposed to X-rays of your own. ★

Peter Jedicke is a physics instructor at Fanshawe College, London, Ontario, and a prominent Canadian amateur astronomer.

Reviews

Reaching for the Stars

THE INTERNATIONAL ENCYCLOPAEDIA OF ASTRONOMY
edited by Patrick Moore
Orion Books, 464 pages, $40

The time will come when what lies beyond our atmosphere is not our neighborhood, but our extended family. We are concerned about space, and thus we need to know as much about it as we can. Edited by well-known astronomy educator Patrick Moore, *The International Encyclopaedia of Astronomy* is a good source for that education.

More than just an encyclopaedia, this book features a collection of seven major articles, of which I found three especially important for people concerned with the future of space exploration. The first is a philosophical essay by *Sky and Telescope* magazine's Leif Robinson called "A Family Named Universe" that summarizes not just what we know, but what remains unknown until we can venture outward to find out, both from ground-based and space-based telescopes.

Nowhere in this book's 464 pages will we find the answer to the question of whether the Universe will expand forever or whether it will begin to contract. Robinson succinctly points out that the answer is "of no practical consequence," but that it is something basic that we should know. The answer is lost for now because we don't know how much mass there is in the Universe; there is a certain threshold beyond which the Universe's gravity will stop expanding and bring the pieces back together again.

In "Exploring Space," David Morrison of the University of Hawaii offers a concise history of the events and goals of the U.S. space program. Although this history emphasizes this country's space efforts at the expense of the Soviet, European and Japanese programs, it does offer the perspective of a writer whose life is devoted to studying the Solar System. "Mars looms as a clear and obvious target," Morrison concludes, "if humanity chooses to leave the confines of the Earth (and low-Earth orbit) and seek a future among the planets of our own system."

The third essay that I found unusual and enticing is simply entitled "Moons." Written by Joseph Veverka of Cornell University, this essay points out just how special planetary satellites have become in our understanding of the neighborhood. True, we have nine major planets, four of which are huge, swirling gas giants, but we also can study at least 54 satellites that offer clues to a complex history of our Solar System.

I think an essay like this makes an "encyclopaedia" different and special: the book doesn't just give us what we want to know; it offers special papers on what its editor thinks we need to know.

If the soul of this book is contained in the major essays, the heart is in the more than 2,500 entries that cover most aspects of astronomical thought. It is surprisingly thorough; I found entries on Coggia's Comet of 1874, a comet I haven't lost sleep over since I studied it for a historical paper years ago, and comet wine, which was bottled around the time of the Great Comet of 1811.

For $40, you get a progress report on "A Family Named Universe." It's an excellent buy.—*David Levy*

FUTURE MAGIC
by Robert L. Forward
Avon, 230 pages, $3.95 (paperback)

Bob Forward's imagination is like a Japanese fireworks display: it sparkles with new and amazing patterns and never seems to quit. Perhaps more than any other futurist, Forward sees the biggest pictures furthest down the road. *Future Magic* is a collection of his boldest extrapolations.

The title, as *Space World* readers will know, is derived from Arthur C. Clarke's Third Law: "Any sufficiently advanced technology is indistinguishable from magic." Forward does not concern himself with ideas that basically require solving engineering problems (like space stations and lettuce-picking robots), but with "Things that are theoretically possible, but so far from our present technical capabilities that they seem almost magical."

As a physicist by trade, Forward's thinking, even when it seems to skirt the edges of pure fantasy, is always tethered to the theoretically possible.

In his chapter on Magic Starships, for instance, Forward ponders the problem of interstellar travel. Fantasy stuff like the warp drive of *Star Trek* and Isaac Asimov's hyperspace have blunted our realization of how far away the stars really are. But Forward, by number-crunching the distances, brings us back to reality—for a moment. Then, having presented the seemingly insoluble problem, he offers a whole smorgasbord of solutions, including interstellar ramjets, solar lightsails and beam-powered propulsion (among others.)

"It is difficult to go to the stars," writes Forward, "But it is not impossible. There are . . . many, many future magic technologies, all under intense development for other purposes, that, if suitably modified and redirected, can give the human race a magic starship that will take us to the stars. And go we will."

Future Magic is an exciting, optimistic look at the infinite potentials of the human race. On a scale of one to ten, it ranks in double digits. Read it and do a lot of mind flexing. —*Jack Kirwan.* ★

Software

The Stars: My Destiny

by Vincent R. DeNardo

STAR SAGA: ONE, BEYOND THE BOUNDARY, *for the Apple II, IIGS or IBM PC; $79.95; published by MasterPlay, Tampa, Florida.*

It's 2815 A.D., and the majority of the human race is afraid to travel into space, so they're cloistered in the Nine Worlds (Earth and its eight colonies) located in the Galactic Fringe. Even though the invention of the hyperdrive has made space travel practical, mankind's attempt to colonize space ended when it was ravaged by the "Space Plague," a gargantuan epidemic that wiped out more than half of humanity. Its cause? An organism of alien origin.

Now, a Space Patrol enforces the "Boundary," the one-way border around the Nine Worlds. Anyone may leave and go "Beyond the Boundary," but no one may return. So far, the Boundary has been an effective deterrent, and humanity has been safe for the last three centuries.

Of course, with safety comes stagnation: no new discoveries; no new challenges; a comfortable, dull numbness. Yet, something is slightly amiss. Things are too quiet. Everything runs a little too smoothly. And there are six people preparing to do something about it.

Star Saga: One, Beyond The Boundary is the first science fiction, role-playing, adventure game in a planned trilogy, and it is a genre-buster. It can be compared to no other game on the market.

The best way to describe Star Saga's playing experience is to compare it to participating in Isaac Asimov's Foundation series. We're talking grand scale adventure here, folks.

From one to six can play and each human player takes on the role of one of the six characters in the game. Each character comes with his own individual history, goals and possessions. Their paths cross, sometimes clash and often overlap.

The game is non-graphic and driven by text in booklet form. The computer acts as a gamemaster throughout by moderating combat, keeping track of players' locations, handling trade transactions and updating personal possessions. It also directs the players to the proper paragraphs to read, depending on their situation.

The game plays smoothly and quickly, although it takes 60-80 hours to complete. On each turn a player has the option to pilot his ship through space, land and explore planets, trade cargo at planetary commodity exchanges, meet with players to exchange cargo or secret information, or interact with any non-player characters that he may meet on various planets.

The player inputs orders into the computer and is, in turn, directed to the appropriate paragraph to read. These paragraphs may lead to further options and paragraphs or may cause the player's turn to end, sometimes prematurely. (Meeting a space pirate who cleans out your cargo hold does put an unexpected crimp in that shopping spree you were going to have on Rialla!). Each character starts the game with a set of goals to accomplish. This usually sends everyone out into the void in different directions seeking separate destinies. As they explore and gain information, there is a need to trade and interact with the other players.

In addition to exploration, there is an economic subgame that runs through the main plot. Each player starts the game with three cargo bays filled with goodies. It is up to him to determine what and when to trade. Most of the planets to be discovered will trade their products for items they can't naturally produce. Sometimes, they'll trade three for one (if you've got what they need). Knowing what planetary exchanges offer, and what they need, is one of the most valuable pieces of information in the game.

When you start the game your ship is basically the stripped down, economy model. Your personal armor and weapons consist of clothes and hands. So to emulate the bug-busting marines in the movie *Aliens*, you'll need to upgrade bit. Fortunately, there are several space docks and weapons emporiums located in the galactic fringe. Of course, finding them is another matter. The combat subgame is handled completely by the computer. It determines the combat situations you encounter and picks the weapons and armor you will use.

A total score of 100 is needed for success when attacking or defending, so it is possible to successfully defend against an opponent's attack, yet fail to press your own attack home. This can result in no harm to you, but an equally undaunted foe.

The prose is as well-written as anything you'll find in the science fiction section of your local bookstore and the story line is tight and well-plotted. Each player is free to do anything he wants all through the game, yet behind it all is a gently guiding hand that makes sure everyone gets where they should eventually go.

I've played the game completely through twice and will probably run through once more before the sequel comes out. Unfortunately, that won't be until next year. Waiting will be very difficult. ★

Vincent DeNardo is assistant editor and art director of Computer Gaming World *magazine, Anaheim, California.*

FYI

Events

January 8-12
American Institute of Aeronautics and Astronautics (AIAA) 27th Aerospace Sciences Meeting and Exhibit, Bally's, Reno, Nevada. For more information call (202) 646-7463.

January 14-19
American Association for the Advancement of Science Annual Meeting, San Francisco. This year's conference features the exhibit "Science in San Francisco," a joint venture with the American Association of Physics Teachers and American Physical Society, both of which are hosting their joint winter meetings in conjunction with the show. For more AAAS information, call (202) 326-6462. For more AAPT/APS information, call (301) 345-4200.

January 23

War and Peace in the Nuclear Age, a 13-week documentary series, debuts on public television at 8 p.m. (Eastern Time). The series reveals how nuclear politics and technology have influenced international relations and contemporary thought. The series was produced by WGBH in Boston and Central Independent Television in England in association with NHK, the national network of Japan. A companion book by John Newhouse, also titled *War and Peace in the Nuclear Age*, will be published this month by Alfred A. Knopf. For information on college credit, call 1-800-LEARNER.

January 24
"Future Explorations," NASA video conference, Oklahoma State University, Stillwater, Oklahoma. The second of four educational programs planned for the 1988-89 school year, transmitted on Westar 4. Teachers can write to NASA Aerospace Education Services Project, Videoconference Site, 200 North Cordell, Oklahoma State University, Stillwater OK 74078-0422 or call (405) 744-7015 to register and receive announcements, publications and other supplemental materials. The final conference, "Technology for Your Classroom," will be held on March 21.

February 14-16
American Institute of Aeronautics and Astronautics Aerospace Engineering Conference and Show, Los Angeles Airport Hilton, Los Angeles. For more information call (202) 646-7463.

March 5-10
Symposium on Space Commercialization: Roles of Developing Countries, Nashville, Tennessee. For more information call Jami Dickinson, (615) 455-0631.

Resources

The Space Business Research Center, a joint research program established by NASA and the University of Houston at Clear Lake, has published a study titled *Space Business* that analyzes the current state of the U.S. space industry, and the effects of the Japanese and European competition upon it. Call Gary Hamel, 1-800-243-1533.

Attention, computer whizzes! *Shareware* magazine, which focuses on non-copy-protected software, has made an offer you may not be able to refuse. For a $20 pre-paid subscription and a note to Managing Editor-in-Chief Mark Barnes mentioning where you heard about the deal, you'll get a year's worth of the bimonthly magazine, a free copy of the PC-SIG Fourth Edition Directory (a $12.95 value) listing more than 700 Shareware titles and two free Shareware disks of your choice. The address is 1030 E. Duane Ave., Suite D, Sunnyvale CA 94086.

Some new American Astronautical Society publications are available:

Soviet Space Programs 1980-1985—Sequel to Handbook of Soviet Lunar and Planetary Exploration, 1979, and Handbook of Soviet Manned Space Flight, 1980. Vol. 66 of Science and Technology Series, by Nicholas L. Johnson, 1987, 298 pages, hardcover $55, softcover $45.

Astrodynamics 1987—Annual ASS/AIAA conference notes, Vol.65 of Advances in the Astronautical Sciences series, 1774 pages, hardcover $180, softcover $150, microfiche supplement $70.

Guidance and Control 1988—Latest AAS Rocky Mountain conference, Vol. 66 of Advances in the Astronautical Sciences series, 576 pages, hardcover $75, softcover $10, microfiche supplement, $10.

For any of the above or a complete list of AAS publications write to: Horace Jacobs, Univelt Inc., PO Box 28130, San Diego CA 92128 or call (619) 746-4005. AAS members receive a 25 percent discount.

The video musical adventure, *Voyage to the Outer Planets and Beyond,* featuring rare NASA and Jet Propulsion Laboratory footage set to classical music and hosted by the inimitable Isaac Asimov, is available in VHS or Beta for $39.95 plus $4.50 postage from Today Home Video, PO Box 310, San Fernando CA 91341, or call 1-800-544-7557. The package includes a full-color NASA brochure titled *A Look at the Planets,* and a space almanac of astronomical events through 2001. ★

Milestones

A retrospective look at the successes and failures of mankind's first faltering steps into space—as reported by Space World *when they occurred:*

January 1967

With the flight of Gemini XII the Gemini program has been completed. It can be stamped "successful" and the record books placed along side the Mercury records. Next step—Apollo and three men to the Moon. From blastoff at 3:46 p.m., November 11 from Cape Kennedy to splashdown in the Atlantic at 2:20 p.m., November 15 the mission proceeded with almost monotonous success . . . Astronaut Edwin (Buzz) Aldrin stood up in the open hatch for 2 hours and 29 minutes on Saturday for a record exposure in space.

January 1970

The prime Moon-landing site for the Apollo 12 mission scheduled for launch from the Kennedy Space Center November 14 is located in the western portion of the Moon's front side . . . This is in the lunar feature named Oceanus Procellarum . . . [near] where the NASA Surveyor 3 soft-landed April 19, 1967 . . . If Apollo 12 astronauts Charles Conrad Jr. and Alan Bean can land close enough to Surveyor so that they can walk to it, remove some of its parts and bring them back to Earth, that hope [of recovering the spacecraft] will be realized.

January 1971

A major part of General Electric's space station work with North American Rockwell has been to determine the facilities needed and the support requirements for each experiment on NASA's candidate list . . . Integral laboratories, built into the space station, are the preferred method of operating experiments. Attached and detached laboratory modules will be brought to the station on the proposed space shuttle and attached to the station by docking ports . . . A new kind of space vehicle with a flair for rugged usefulness is on the drawing boards at Lockheed Missiles & Space Co. Known as an OOS—an orbit-to-orbit shuttle, or space tug—the new concept is a do-anything spacecraft which will be the mortar among the bricks in the national space program in the late 1970s and 1980s.

January 1972

A wide variety of the natural resources of Earth and man's management of them will be studied by an initial group of scientists tentatively chosen by NASA to analyze data to be gathered by two Earth-orbiting spacecraft. The spacecraft are the first Earth Resources Technology Satellite (ERTS-A) and the manned Skylab which will carry an Earth Resources Experiment Package (EREP) . . . A French meteorological satellite—Eole, the French name for the God of Winds in mythology—is being prepared for launch from Wallops Station, Virginia . . . The mission of Eole is to collect information on winds, temperatures and pressures from instrumented balloons.

January 1975

NASA's Earth Resources Technology Satellite (ERTS-1) is rapidly becoming an important tool for hydrologists as more and more data are returned from the spacecraft and analyzed in relation to present water resource management practices which man uses to extract water economically from only about 0.01 percent of the total global supply.

January 1980

Solar cell arrays, the power-producing workhorses of our near-Earth space efforts, are expanding their horizons toward the outer planets. So reports Don Rockey, a member of the technical staff in the JPL technology group that apparently has found a way to channel the relatively feeble sunlight of space into a practical source of spacecraft electrical power. He and his colleagues . . . have determined that large mirrors and conventional silicon solar cells could concentrate and collect what little sunlight is available, thereby increasing the power output of solar arrays. These [arrays] are being evaluated for use on Solar Polar, Galileo (the Jupiter orbiter with probe) and other missions.

January 1983

The space shuttle can deliver on time. That was the message driven home by the flight and ground crews of the STS-5 mission who put two communications satellites on targets as planned as Columbia made its first operational mission . . . NASA is planning a unique subsatellite that it hopes will bridge the gap between short, cheap experiments aboard sounding rockets and larger, more elaborate ones aboard the space shuttle . . . The subsatellite is known as Spartan . . . The basic concept [is to] attach a sounding rocket science package to a small bus that will be carried into orbit by the shuttle, release it to operate alone for up to 40 hours, then retrieve it with the remote manipulator system. ★