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General Accounting Office  
Washington, D.C. 20548

National Security and  
International Affairs Division

B-282682

June 30, 1999

The Honorable F. James Sensenbrenner, Jr.  
Chairman  
The Honorable George E. Brown, Jr.  
Ranking Minority Member  
Committee on Science  
House of Representatives

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Subject: Space Station: Status of Efforts to Determine Commercial Potential

In 1998, Congress declared that a priority goal of constructing the International Space Station was the economic development of Earth's orbital space and directed the National Aeronautics and Space Administration (NASA) to assess the station's commercial potential.<sup>1</sup> NASA is doing so as part of its commercial development plan for the space station.<sup>2</sup>

As requested, we are providing information on whether space-station-related commercial activities could generate revenue capable of reducing the station's annual cost of operations, which NASA estimates will average \$1.3 billion, or \$13 billion over a 10-year mission life after the space station is fully assembled in 2004.<sup>3</sup>

We are also providing information on funding issues associated with the proposed x-ray crystallography facility for the space station because it may have some potential commercial use. One intended purpose of this facility would be to support the design of new drugs, which may be of possible interest to pharmaceutical companies. Uncertainty over funding of the facility brings to the forefront the issue of who should pay to develop station-based commercial facilities.

RESULTS IN BRIEF

On the basis of available information such as commercialization proposals and opinion surveys, we concluded that many businesses are skeptical of the station's commercial usefulness. However, commercial interest in the station may increase as the station's assembly nears completion and its capabilities grow. NASA is developing an independently conducted market study of potential commercial interest in the station, as required by the Commercial Space Act, and is implementing a commercial development plan for the station. When NASA completes these tasks, it should be in a better position to understand how

<sup>1</sup> Commercial Space Act of 1998 (P.L. 105-303 sec. 101, Oct. 28, 1998).

<sup>2</sup> Commercial Development Plan for the International Space Station, NASA (Nov. 16, 1998).

<sup>3</sup> We will provide the Committee with an evaluation of this estimate in a separate report.

businesses perceive the station's commercial potential. Until then, NASA will be unable to estimate whether commercial activity would eventually reduce the space station's cost of operations.

NASA has not yet decided whether to pay to develop an x-ray crystallography facility primarily intended for commercial use aboard the space station. Drug design companies have not agreed to pay for this facility, although some firms said they could use it if its on-orbit capabilities were sufficiently well demonstrated. Other firms remained skeptical of the facility's commercial usefulness compared with the usefulness of competing ground-based facilities.

### BACKGROUND

NASA and its partners—Canada, the European Space Agency, Japan, and Russia—are building the space station as a permanently orbiting laboratory to conduct materials and life sciences research, Earth observation, commercial operations, and related activities under nearly weightless conditions. Each partner is providing hardware and crew members and is expected to share operating costs and use of the station. The Boeing Company, the prime contractor, is responsible for development, integration, and on-orbit performance.

The Commercial Space Act declared that the use of free market principles in operating, servicing, allocating the use of, and adding capabilities to the station would create demand for commercial providers and users and would thereby reduce the station's cost of operations (See encl. I for P.L. 105-303 sec. 101, Commercialization of Space Station). NASA's commercial development plan endorsed a similar view (see encl. II). The plan's short-term objective is to begin the transition from public to private investment to offset the space shuttle's and station's operating costs through commercial enterprise and open markets.

The x-ray crystallography facility aboard the space station would be a comprehensive protein crystallography laboratory. NASA began to sponsor space-based protein crystal growth through its commercial space center for macromolecular crystallography in 1985. Since then, research has shown that in the absence of gravity, protein crystals are sometimes larger and/or have better-ordered internal structure than their Earth-grown counterparts. When returned to Earth, some of these crystals yield better data compared with Earth-grown crystals when exposed to x-ray radiation, but reentry through the atmosphere, which involves acceleration and vibration, can damage the crystals.

Knowledge of a crystal's structure could be helpful in creating drugs that can stop the spread of a virus from cell to cell.<sup>4</sup> Aboard the space station, protein crystals would be grown, harvested, mounted, frozen, and bombarded with x-rays in order to create a diffraction pattern that would be transmitted to ground-based researchers to determine a protein's structure.<sup>5</sup> NASA believes that a major justification for the x-ray facility includes the ability to

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<sup>4</sup> W. Graeme Laver, et. al., "Disarming Flu Viruses," *Scientific American* (Jan. 1999).

<sup>5</sup> Generally, as x-ray radiation passes through protein crystals, it interacts with or bounces off atoms, changing direction and energy. These interactions are recorded by a special detector attached to a computer. Software interprets the data so it can be analyzed.

characterize crystals being grown so that new experiments can be immediately designed in an attempt to optimize the crystallization conditions. If it decides to build this facility, NASA currently plans to put the x-ray facility on the station in September 2003.

INITIAL ESTIMATE OF STATION'S  
COMMERCIAL POTENTIAL IS NOT YET POSSIBLE

An initial estimate of the station's commercial potential could be made after NASA implements its commercial development plan, submits all the reports required by the Commercial Space Act, and assembles more parts of the station. However, currently available information suggests that businesses are skeptical of the station's commercial usefulness.

Implementation of the Commercial Development Plan

NASA's commercial development plan defines NASA's role in commercializing the space station. The plan describes generic types of possible commercial activities, or "pathfinders,"<sup>6</sup> and the types of barriers that might prevent commercialization (for example, policies that might make some forms of advertising unacceptable).<sup>7</sup> The plan, adopted in November 1998, also includes a model of a nongovernmental organization that would manage the station and a proposed procedure to more efficiently review proposals and offers from industry to use the station for commercial purposes.<sup>8</sup> According to a NASA official, industry is responsible for demonstrating commercial interest in the station. Accordingly, NASA plans to assess potential barriers in the context of specific proposals.

Specifically, NASA's strategy to define its commercialization role and thereby determine whether the station's cost of operations could be reduced by commercialization calls for

- contracting an independent market study, required by the Commercial Space Act, to clarify current business attitudes about the space station's potential for commercialization;
- selecting specific commercial pathfinder offers that could help NASA identify barriers to, and define acceptable types of, commercial activities aboard the space station, especially for nontraditional activities such as advertising, sponsorship, and entertainment;
- establishing a pricing options policy for commercial development of the space station that would make it possible for NASA to evaluate the effects of moving from a cost-based to a value-based pricing policy;
- developing a single point of entry in NASA to streamline and discipline its review of commercial proposals and offers; and

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<sup>6</sup> These include communications, brand names in public service sponsorship, consumer goods, payload accommodation auctions, imagery, and in-space educational experiments. These examples do not represent specific proposals.

<sup>7</sup> The potential types of barriers identified are NASA policy, culture, and process; regulations; statutes; and international agreements. The plan did not identify specific statutes, regulations, and agreements.

<sup>8</sup> NASA distinguishes between "unsolicited proposals" for the purpose of obtaining a contract and "entrepreneurial offers" for the purpose of creating value-added products or services for sale in private markets.

- implementing a variation of a proposed model of a nongovernmental organization to manage the U.S. part of the space station's scientific, technological, and commercial research and development programs.

NASA has started to implement this strategy. According to a NASA official, the market survey required by the Commercial Space Act and pricing options study should be finished by July 1999. He also said that, as of May 17, 1999, NASA had received seven offers that could be used as commercial pathfinders. Two of the offers potentially involve investments of over \$100 million. Other offers are smaller, including one that could be applied to writing pens and would involve flying a few ounces of gold. NASA has not yet established a clearinghouse for commercial proposals and offers.

The Commercial Space Act requires the NASA Administrator to identify and report on opportunities for commercial providers to play a role in station activities, including operation, use, servicing, and augmentation. He is also required to report the potential cost savings to be derived from having commercial providers play a role in each of these activities. The Administrator submitted his report on May 14, 1999, and stated that it is not possible to identify potential cost savings, revenues, or reimbursements without specific formal commercial offers in hand with which to perform a credible life-cycle cost analysis. He also stated that NASA will prepare "comparative life-cycle cost statements" in conjunction with offers but will seek to avoid imposing burdensome analysis requirements that could serve as a disincentive or barrier to commercial development.

#### Nongovernmental Organization

The idea of creating a nongovernmental organization to manage the space station grew out of a 1995 NASA proposal to establish an orbital research institute for the station. At that time, the Space Telescope Science Institute, which was responsible for the science-related operations of the Hubble Space Telescope, was discussed as a possible model for an orbital research institute.<sup>9</sup> However, unlike with the Hubble Space Telescope, the space station's partners will support a wide range of unrelated scientific investigations<sup>10</sup> as well as engineering development and commercial activities. If a stationwide nongovernmental organization is established, one of its main challenges will be to manage diverse uses of the station. To review management options for the station, NASA contracted with the National Research Council to evaluate options by October 1999. According to a NASA official, the intent of a nongovernmental organization would be to replace government bureaucracy, not add to it. But, he also said, a nongovernmental organization initially would be publicly funded, and its board of directors therefore would likely be government officials. He further noted that the government would not turn the space station over to a nongovernmental organization without providing strategic direction and oversight.

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<sup>9</sup> The Association of Universities for Research in Astronomy manages the institute under a contract with NASA. The Lockheed Missiles and Space Company operates the satellite under contract with NASA at its Goddard Space Flight Center.

<sup>10</sup> These include, biotechnology, combustion science, fluid physics, fundamental physics, gravitational biology and ecology, and materials science.

Available Data Indicates Businesses Are  
Skeptical of Station's Commercial Potential

Currently, industry generally does not see the space station as a place to do business. Although the market study required by the Commercial Space Act and proposals for commercial pathfinders may reveal a different outlook, the limited data currently available indicates that industry is skeptical of the space station's commercial potential.

In May 1998, a major aerospace company told NASA that most respondents to its market study showed (1) a lack of understanding of the space station's capabilities, (2) an indifference to microgravity<sup>11</sup> as a condition for research, and (3) an inability to transfer space-based research to spaced-based manufacturing. Respondents also expressed concerns about the cost of accessing space, the lack of predictable launch schedules, and the absence of a regulatory framework, including rules to protect intellectual property.<sup>12</sup> According to respondents, the lack of a regulatory framework means that businesses cannot readily determine the cost of doing business on the space station. Of particular relevance, in view of NASA's long-term support of protein crystal growth in microgravity, was the fact that 7 out of 10 respondents from the pharmaceutical industry stated they were not interested in doing research in microgravity. According to the survey, the most promising areas for generating revenue in the short term are advertising, sponsorship, and entertainment.

The results of the survey were consistent with a 1998 survey of pharmaceutical company attitudes conducted for NASA's commercial space center for macromolecular crystallography.<sup>13</sup> The 1998 survey asked questions about the proposed x-ray crystallography facility for the space station. According to the contractor that conducted the survey, most respondents did not see the utility of a station-based x-ray capability and believed that power constraints and the absence of a trained crystallographer aboard the space station would limit its usefulness. On the other hand, many respondents were reportedly "intensely" interested in the x-ray facility's robotic crystal preparation and handling capability because it could be used by their laboratories on the ground. Funding issues associated with this facility are discussed later in this report.

The Commercial Space Act requires NASA to report the number of proposals it received in 1997 and 1998 regarding commercial operation, servicing, utilization, or augmentation of the space station and the number of agreements NASA made in response to these proposals. NASA reported its findings on May 14, 1999. According to the report, the agency received four unsolicited proposals in 1997 and one in 1998. Of these, one resulted in an agreement to establish a commercial space center for engineering at Texas A&M University,<sup>14</sup> and one resulted in an agreement with a company to provide a cargo carrier for a space shuttle flight.

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<sup>11</sup> Microgravity is a condition of free-fall within a gravitational field in which the weight of an object is significantly reduced compared to its weight at rest on Earth.

<sup>12</sup> Respondents were from the pharmaceutical, electronics, remote sensing, materials processing, and advertising industries. Seventy-three companies were contacted, and about 60 percent responded.

<sup>13</sup> The center's contractor contacted 41 firms, 30 of which responded. Nine respondents were affiliated with the center in 1997.

<sup>14</sup> The center's mission is to advance engineering research on and foster commercial use of the space station.

Additionally, the space station's prime contractor, Boeing, has signed agreements with two unidentified potential customers for the station. A company official told us that one customer, comprising a university and a multimedia company, submitted an offer to NASA on April 14, 1999. Depending on NASA's reaction to this offer, a second offer, involving advertising and sponsorship aboard the station, could follow.

X-RAY CRYSTALLOGRAPHY FACILITY HIGHLIGHTS  
ISSUE OF WHO SHOULD PAY TO DEVELOP  
STATION-BASED COMMERCIAL FACILITIES

Although an x-ray crystallography facility aboard the space station would be intended primarily for drug designers, companies in the field have not agreed to fund the development of such facility. However, according to NASA, some companies have said they would use the x-ray facility for difficult proteins if real results were possible. Funding issues surrounding the x-ray facility highlight the problem of deciding whether NASA should fund the development of a station-based commercial facility if industry abstains from doing so.

Space-Based Protein Crystal Growth Program  
Is Well Established but Controversial

Protein crystal growth/x-ray crystallography researchers are sharply divided over the space-based crystal growth program's usefulness to drug design. In 1995, the National Research Council concluded that "protein crystal growth experiments conducted aboard the shuttle have provided persuasive evidence that improvements can, in fact, be realized for a variety of protein samples" and that such crystal growth "can be crucial to success in protein structure determination." But the Council also noted that such experiments have not shown that protein crystals uniformly display improved properties when grown in microgravity. Nevertheless, it also concluded that "an expanded program of protein crystal growth experiments deserves support."<sup>15</sup>

On the other hand, in July 1998 a "blue ribbon" committee of the American Society for Cell Biology described the space station as the "most expensive and inflexible research laboratory ever built." The committee specifically criticized NASA's space-based crystallography program and concluded: "No serious contributions to knowledge of protein structure or to drug discovery or design have yet been made in space."<sup>16</sup> The committee recommended that no further funds be spent on crystallization of proteins in space.

Development of the X-ray Crystallography Facility

In April 1995, NASA funded the Center for Macromolecular Crystallography to study the feasibility of an x-ray crystallography facility aboard the space station. On the basis of the positive results of the study, in September 1996 NASA authorized the center to build a ground-based prototype of the x-ray facility to validate and verify key technologies. To be

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<sup>15</sup> Microgravity Research Opportunities for the 1990s, National Research Council (1995).

<sup>16</sup> The committee's report did not state the basis of its conclusion but, according to a committee member, it was primarily based on a review of six scientific journal articles.

useful aboard the station, such a facility would have to be relatively lightweight and use low power. To date, the center has demonstrated a 25-watt, 50-pound x-ray generator with a beam intensity comparable to a 5,000-watt, 2-ton ground-based x-ray system. In June 1998, NASA approved additional funding of \$1.5 million for prototype development and required surveys of commercial and research interest in the facility. The surveys were completed in September 1998 and a tabletop version of the proposed x-ray facility was successfully demonstrated in February 1999. NASA's decision on whether to proceed with full-scale development of the x-ray facility for the station could take place by the end of fiscal year 1999. This decision will be based on a revised cost estimate and successful integration of the x-ray facility in a space-station-type rack. The x-ray facility would cost about \$50 million to complete, according to NASA.

#### Industry Skeptical of X-Ray Crystallography Facility's Commercial Potential

The contractor who performed the survey for NASA's commercial space center for macromolecular crystallography summarized the pharmaceutical companies' comments as follows:

- Costs for current ground-based crystallography research vary substantially depending on the protein being studied, but a higher-power source of x-rays such as synchrotrons allows the use of smaller, lower-quality crystals, and the widespread use and availability of synchrotrons is lowering the cost of x-ray analysis.
- Proteins that are easily crystallized on the ground are not candidates for microgravity-related research.
- As a result, growing crystals in microgravity is limited only to relatively high-priority proteins whose structure is difficult to determine and for which ground-based methods are still inadequate. Such instances are considered rare.

Aside from commercial use, NASA believes that the x-ray facility could be used for research not associated with drug design. A decision on whether to fund the x-ray facility would have to take this into account. To help make this decision, NASA's Marshall Space Flight Center in Huntsville, Alabama, surveyed principal investigators in its microgravity science program.<sup>17</sup> None of the researchers in the survey said that x-ray analysis aboard the space station was mandatory for macromolecular crystal growth generally or for experiments they planned to propose. Seventy-nine percent thought space-station-based x-ray analysis was highly desirable or desirable, and 21 percent said it was not required. With respect to their planned experiments, 58 percent of the researchers said space-based x-ray analysis was desirable, and 42 percent said it was not required.

NASA's commercial space center for macromolecular crystallography is discussing investment options in the x-ray facility with at least two companies. According to a NASA official, initial commercial investment interest centers on the facility's crystal preparation and

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<sup>17</sup> Thirty researchers were contacted, and 24 replied. Also, The University of Alabama (Birmingham) and the commercial space center for macromolecular crystallography surveyed 39 domestic and international investigators not covered by other surveys. According to NASA, researchers who responded indicated an interest in a station-based x-ray diffraction facility if its on-orbit capabilities were successfully demonstrated.

handling unit, which could be used with x-ray diffraction systems on the ground. A NASA official told us that NASA's Marshall and Johnson field centers are expected to make a recommendation on a funding option for the x-ray facility by October 1999 as part of the fiscal year 2001 budget cycle. For now, the question remains unanswered as to whether the agency would pay to develop all or part of a facility that commercial users are so far unwilling to support financially and for which they have indicated only a limited need.

### CONCLUSIONS

There is insufficient information at this time to estimate whether commercial activity would eventually reduce the space station's cost of operations. On the basis of available evidence, we found that industry is uncertain about the station's commercial potential. While the reasons for this uncertainty vary, the business community overall is unclear about the station's capabilities and concerned about the lack of a regulatory framework and pricing policy. Even if these concerns are alleviated, it is uncertain whether the current low level of interest in commercializing the station will increase enough to allow future commercial activity to make a significant difference in operating costs. In any case, NASA's reporting under the Commercial Space Act and its implementation of the commercial development plan could help clarify industry's perception of the station's commercial potential in the near term.

One public policy issue raised by the station-based x-ray crystallography facility concerns whether NASA should pay the full-scale development costs of the station's commercial facilities if industry remains uncertain about the facilities' commercial value. This is an issue that NASA could face repeatedly as it considers various commercial efforts aboard the space station. Accordingly, NASA's decision on the x-ray facility may assume an importance that is larger than the issue of whether to spend \$50 million for this one specific facility.

### AGENCY COMMENTS AND OUR EVALUATION

In written comments on a draft of our report, NASA stated that industry's initial skepticism concerning the x-ray facility is understandable in light of the new technology involved and of the fact that the facility has not yet been demonstrated on orbit. According to NASA, once this demonstration takes place and the facility is working, the x-ray facility's advantages will be obvious and its commercial use will pay for its operations costs.

NASA also provided technical comments which we incorporated where appropriate. NASA's comments are reprinted in enclosure III.

### SCOPE AND METHODOLOGY

To accomplish our objectives, we obtained documents from and interviewed officials at NASA headquarters in Washington, D.C.; NASA's Marshall Space Flight Center, Huntsville, Alabama; and Johnson Space Center, Houston, Texas.

To evaluate whether commercial activities could generate revenue capable of reducing the space station's cost of operations, we interviewed officials about the development of NASA's commercial development plan and its reporting under the Commercial Space Act. We also attended meetings of NASA's Commercial Advisory Subcommittee and Space Station Utilization Advisory Subcommittee. We reviewed the results of station-related market



surveys conducted by an aerospace company and for one of NASA's commercial space centers.

To evaluate funding issues associated with the proposed x-ray crystallography facility, we reviewed the basis of a report on NASA's protein crystal growth program by the American Society of Cell Biology and interviewed officials of a NASA-sponsored commercial space center, the Center for Macromolecular Crystallography, Birmingham, Alabama. We performed our work between July 1998 and May 1999 in accordance with generally accepted government auditing standards.

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Unless you publicly announce its contents earlier, we plan no further distribution of this report until 14 days from its issue date. At that time, we will send copies to the Honorable Daniel S. Goldin, Administrator, NASA and the Honorable Jacob J. Lew, Director, Office of Management and Budget. We will also make copies available to others upon request.

If you or your staff have any questions, please contact me at (202) 512-4841 or Mr. Jerry Herley, Assistant Director, at (202) 512-7609 or Mr. Tom Mills, Evaluator-in-Charge, at (202) 512-4339.



Allen Li  
Associate Director,  
Defense Acquisitions Issues

Enclosures - 3

COMMERCIAL SPACE ACT OF 1998  
SECTION 101

PUBLIC LAW 105-303—OCT. 28, 1998

112 STAT. 2845

43 **TITLE I—PROMOTION OF COMMERCIAL  
SPACE OPPORTUNITIES**

**SEC. 101. COMMERCIALIZATION OF SPACE STATION.**

42 USC 14711.

(a) **POLICY.**—The Congress declares that a priority goal of constructing the International Space Station is the economic development of Earth orbital space. The Congress further declares that free and competitive markets create the most efficient conditions for promoting economic development, and should therefore govern the economic development of Earth orbital space. The Congress further declares that the use of free market principles in operating, servicing, allocating the use of, and adding capabilities to the Space Station, and the resulting fullest possible engagement of commercial providers and participation of commercial users, will reduce Space Station operational costs for all partners and the Federal Government's share of the United States burden to fund operations.

(b) **REPORTS.**—(1) The Administrator shall deliver to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate, within 90 days after the date of the enactment of this Act, a study that identifies and examines—

(A) the opportunities for commercial providers to play a role in International Space Station activities, including operation, use, servicing, and augmentation;

(B) the potential cost savings to be derived from commercial providers playing a role in each of these activities;

(C) which of the opportunities described in subparagraph (A) the Administrator plans to make available to commercial providers in fiscal years 1999 and 2000;

(D) the specific policies and initiatives the Administrator is advancing to encourage and facilitate these commercial opportunities; and

(E) the revenues and cost reimbursements to the Federal Government from commercial users of the Space Station.

(2) The Administrator shall deliver to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate, within 180 days after the date of the enactment of this Act, an independently conducted market study that examines and evaluates potential industry interest in providing commercial goods and services for the operation, servicing, and augmentation of the International Space Station, and in the commercial use of the International Space Station. This study shall also include updates to the cost savings and revenue estimates made in the study described in paragraph (1) based on the external market assessment.

(3) The Administrator shall deliver to the Congress, no later than the submission of the President's annual budget request for fiscal year 2000, a report detailing how many proposals (whether solicited or not) the National Aeronautics and Space Administration received during calendar years 1997 and 1998 regarding commercial operation, servicing, utilization, or augmentation of the International Space Station, broken down by each of these four categories, and specifying how many agreements the National Aeronautics and Space Administration has entered into in response to these proposals, also broken down by these four categories.