

APPENDIX A: LITERATURE REVIEW OF ISS-RELATED DOCUMENTS

LITERATURE REVIEW OF ISS-RELATED DOCUMENTS CONTENTS:

- ISS – Position Documents
- ISS – In the Press

The contents of this appendix are focused on the ISS technical, political or programmatic issues, with a number of documents on issues of commercial space that may be tangentially related to the ISS. The documents listed in this appendix are neither intended to provide market forecasts nor to support a particular political position on the ISS. Rather, they are intended to give the reader a sense of the discussions that have taken place over the period of 1995 to present.

Brief summaries and/or abstracts of the following publications are provided as representative samples of the documentation reviewed and do not represent the entire body of work reviewed during the course of this study.

In addition, several of the documents do not adhere strictly to our study guidelines but were noted, due to their unique contribution, to the overall report. The papers are presented in approximate reverse chronological order, from 1999 to 1995.

ISS POSITION DOCUMENTS

The following reports and publications represent some of the more substantial ISS-related documents reviewed during this study. They were used primarily to provide a background for the research regarding the issues and opinions surrounding the ISS and its commercialization potential. This list provides a good representative sampling from which our findings and conclusions were derived.

AIAA 96-4471 Advanced Space Processing Concepts: From the International Space Station to the Lunar Territory, John L. Anderson, Advanced Concepts Office NASA, December 11, 1999.

"The commercial use of space has been the evolving theme of the space age since the Space Act of 1958. Since the establishment of Commercial Space Centers in 1985, space processing for research, development and eventual production of commercial products and processes has received increasing emphasis. Successes to date have been impressive and continued plans for Space Shuttle (STS) and the early stages of the International Space Station (ISS) should complete a broad base of data for commercial demonstration validation and application. Beyond that, two categories of space processing will emerge: 1) products resulting from using the unique conditions of space - largely projections of the currently perceived markets and capabilities and 2) operational capabilities to meet the unique requirements of large-scale space development."

Commercializing the International Space Station: Current US Thinking, John M. Logsdon Space Policy Institute, George Washington 1998 pp 239-246.

"This article provides an overview of NASA's plans to encourage commercial use of the International Space Station (ISS). It examines the reasons driving such commercialization and highlights those private companies currently most interested in undertaking profit-making operations on the station, as well as discussing those activities most likely to be seen as commercial possibilities. The steps NASA is taking to stimulate private interest are enumerated. Various unresolved issues are raised, such as the legal issues associated with commercial research, charging policy for in-orbit operations and "metering" of in-orbit resources. It is noted that the international dimension of the ISS has thus far received little consideration in the USA."

NASA Commercial Development Plan for the International Space Station, Final Draft, November 16, 1998.

"Objective: Long-Term: To establish the foundation for a marketplace and stimulate a national economy for space products and services in low-Earth orbit, where both demand and supply are dominated by the private sector.

Short-Term: To begin the transition to private investment and offset a share of the public cost for operating the space shuttle fleet and space station through commercial enterprise in open markets.

"Strategy: In partnership with the private sector, initiate a set of pathfinder business opportunities which can achieve profitable operations over the long run without public subsidies. Employ these businesses to break down market barriers in the near term and open the path for economic expansion. Initialize the process through the internal NASA study of pathfinder candidates, as a point-of-departure, with emphasis on pushing the envelope in terms of both public and private sector policies, procedures and cultural predisposition."

NASA Internal Study: Potential Pathfinder Areas for Commercial Development of the International Space Station, Discussion Draft, October, 1998.

"An internal study was undertaken to identify pathfinder business enterprises with the potential to illuminate the commercial development of the International Space Station (ISS) and break down any perceived barriers to such development. The process used to identify the opportunities for commercialization, as well as potential pathfinders to evaluate these opportunities, is described in this report. The study concentrated on delineating the scope of potential commercial opportunities associated with the ISS, as well as evaluating, from the NASA perspective, several pathfinder areas of potential interest to the private sector. The NASA approach, evaluation criteria and results are provided in the following study report. As the plan for commercial development proceeds, it is anticipated that new business concepts will emerge and move to the forefront as private industry becomes involved. These concepts may be related to the pathfinders identified in this study, or they may represent entirely new and innovative space products or services. In either case, NASA intends to proceed with the most effective set, as determined by the new Government-industry partnership."

NASA Reference Model: A Non-Governmental Organization for Space Station Utilization Management,
Discussion Draft, October, 1998.

"The purpose of this reference model is to initiate a discussion of a new management approach to R&D in low-earth orbit consistent with the present and future constrained budget challenges.

The objective is to create a non-government organization (NGO) for accomplishing an aggressive science, technology and commercial development program while simultaneously limiting government functions to policy and oversight. The ultimate success of the orbital R&D program depends equally on the efficient operation of the space and ground assets (laboratories, spacecraft, space station) and on the optimal utilization of the assets by the R&D and business communities. The utilization component must be managed in a manner which ensures productivity of the space station and other future ground and space assets. A NGO would serve as the interface between users and operators, in order to maximize the range of productive uses, as well as minimize the cost and schedule associated with conducting user operations in low-Earth orbit.

The framework for a NGO should be based on a management structure that is representative of, and responsive to, a broad base within the utilization community. This management structure must possess a high degree of stability that will permit it to undertake and complete an integrated program over the expected life of the space station and associated assets."

NASA Strategic Plan: Discussion Draft, October, 1998.

"We seek to bring the frontier of space fully within the sphere of human activity to build a better future for all humankind. Imagine new products based on space research, such as high-quality protein crystals to allow the design of new drugs for treating disease. Envision school children learning their lessons by telepresence instruction from the Moon. Imagine commerce flourishing in space, with solar power satellites, or a Martian powerplant to permit a permanent colony. These images are part of the Human Exploration and Development of Space (HEDS) Enterprise. The mission of the Enterprise is to open the space frontier by exploring, using and enabling the development of space and to expand the human experience into the far reaches of space."

Microgravity and Space Processing, Robert Gustafson, AIAA, December, 1998.

"This year marked an important transition from conducting microgravity experiments on the Space Shuttle to preparing for experiments on the International Space Station (ISS). Despite some delay in the ISS assembly schedule, the NASA Microgravity Research Division continued to identify the scientific experiments that will be conducted on board the station once utilization flights begin. During the first three such flights, hardware facilities will be available in the areas of biotechnology, combustion science and fluid physics. The process of assigning experiments to the flights is nearing its final stages. In the interim, the ground-based research program continued to increase the number of investigators."

New Space Industries for the Next Millennium, Compiled by D.V. Smitherman Jr. Marshall Space Flight Center, Marshall Space Flight Center, December 3, 1998.

"New Space Industries for the Next Millennium is a final report of the finding from the New Space Industries Workshop held in Washington D.C. in February 1998. The primary purpose of this workshop was to identify what must be done to develop new markets, and to generate plans, milestones and new organization relationships designed to facilitate the goal of space development."

Commercial Space Business Parks: Final Report of Task Order #TOF-021 to Contract #NAS8-50000, Boeing Defense and Space Group, April 7, 1997.

"The study started with the results of the Commercial Space Transportation Study (CSTS), which was performed by six aerospace companies in 1993 and 1994. The CSTS identified a number of promising markets for commercial space transportation, provided that the transportation costs can be reduced to an acceptably low level.

Case studies were developed for commercial microgravity production, satellite servicing, entertainment and tourism. These case studies identified potential market size and helped to determine cost thresholds required for market development. They were further used to identify the required infrastructure and some of the critical policy-related issues that must be addressed before commercial space business parks can evolve. A rough schedule has been assembled to enable the market infrastructure, and policy resolution to move forward at a rate comparable to the low-cost space transportation development rate."

Large-Scale Commercial-Industrial Business in the Human Space Flight Area: Using the Space Station and its Support Program to Do So, T.F. Rogers, April 15, 1997.

"Commercial-Industrial business in the space information area -- communications, navigation, position-fixing and remote sensing -- is large and surging; nearly \$10 billion per year including satellite launching and growing at a 10-12% rate.

But, having spent \$100s of billions in the human space flight area over four decades, there is still essentially no private commercial business going on therein.

If we are serious about seeing the human space flight area opened up to private sector business creation and growth, then we must now begin the "gear-change" of moving from "cooperation" to "competition" in a free enterprise context, and from a complete dependence upon the long-term R&D process to seeing our entrepreneurial forces becoming directly engaged as well. The government roles are: to open up the ISS "frontier" with its presence there; to offer related markets to meet its own needs there in a way that will spur imaginative and aggressive risk-reward entrepreneurs to meet these market needs; and to develop/demonstrate further-out, lower cost, basic infrastructure that offers even greater promise if the financial-operational costs and risks can be reduced sufficiently..."

The International Space Station Commercialization (ISSC) Study, Potomac Institute for Policy Studies, March 20, 1997.

"The present Administration, Congress, NASA, and the general public have all voiced support of commercialization of human space flight. The issues are who should do it, how it should be done, and how quickly.

The purpose of the study was to address the three questions stated below. Its findings rested upon the assumption that the International Space Station (ISS) will be deployed by NASA within the next six years.

- *Are there compelling potential benefits from commercialization of human orbital space flight?*
- *Are there viable areas of opportunity and plausible commercial ventures?*
- *What, if any, should the government's role in fostering commercialization?"*

AIAA 97-0106 Planning for Microgravity Science Research on the International Space Station, J. Robey
NASA Headquarters, January 1997.

"The microgravity research program for the International Space Station (ISS) is a key element of the strategic planning of the Microgravity Science and Applications Division (MSAD) at the National Aeronautics and Space Administration (NASA) headquarters. With limited logistics and operation resources anticipated for the early ISS, multi-user science instrument facilities are planned to support the needed capabilities for microgravity research.

This multi-user concept reduces the amount of hardware that must be launched to and returned from the orbiting Space Station. These microgravity research facilities focus on MSAD's five major science disciplines; biotechnology, combustion science, fluid physics, fundamental physics and materials science."

On Research Facilities Planning for the International Space Station, Space Studies Board, National Research Council, July 8 1997.

On July 8, 1997, Dr. Claude R. Canizares, chair of the Space Studies Board, Dr. Mary Jane Osborn, chair of the Committee on Space Biology and Medicine, and Dr. Martin E. Glicksman, chair of the Committee on Microgravity Research, sent the following letter to NASA Administrator Daniel S. Goldin.

"Among the challenges currently facing the space station program, those imposed by its flat development funding profile are clearly among the most demanding. It is the Board's understanding that, of the \$2.1 billion yearly program budget, a substantial share of resources that had originally been intended for development of research facilities and outfitting is being allocated to development of the vehicle itself. As a result, key microgravity research facilities such as the furnace and the combustion and fluid science facilities that were to have been launched and put into operation in 2000 will now be delayed until 2002. Availability of gravitational biology habitat facilities will slip from 1999 to 2001, and the life sciences centrifuge will be delayed until at least the end of 2002. As a result, most of this research equipment will not be available to investigators until approximately five years from today."

Microgravity Research Opportunities for the 1990s, Space Studies Board, National Research Council, July 8 1997.

"Microgravity research is concerned with the effects of reduced gravitational forces on physical, chemical and biological phenomena. The scientific disciplines affected by gravity include fundamental physics, fluid mechanics and transport phenomena, materials science, biological sciences and biotechnology and combustion. It is especially noteworthy that these disciplines are laboratory sciences that inherently use controlled, model experiments. Many experiments require constant attention and frequent intervention by the experimenter, which distinguishes microgravity research from the observational space sciences. Microgravity research also spans both fundamental and applied sciences."

Space Commercialization: An AIAA Information Paper, Prepared by the Public Policy Committee, American Institute of Aeronautics and Astronautics, January 1996.

"This paper summarizes the background and current status of commercial space activities, identifies the major problems (or barriers) faced by the U.S. in expanding and broadening these activities in the current changing global environment, and suggest actions to help resolve the problems and improve the environment for successful U.S. commercialization of space technologies."

Historical Analogies Potentially Applicable to the Commercialization of Space Activities, G Harry Stine, 1996.

"Historical precursors and analogs are often invoked in an attempt to forecast or justify commercial space endeavors. This is especially true when space advocates attempt to make the case of getting government out of space and letting private space enterprise take over.

However, history reveals that government participation in a technologically-based activity has benefits as well as disadvantages. Therefore, it may be well to proceed with caution when invoking historical examples as justifications. This calls for occasional sanity checks, particularly with regard to the current attempt to commercialize space activities. Keep in mind that the record shows that once a system is put into practice it rarely changed and then only with great difficulty, travail and often negative consequences."

Private Sector Involvement in the Space Station Program, IEEE United States Activities Board, June, 1996.

"Consistent with the 'Space Privatization Activities' goals endorsed by IEEE-USA, the Space Station program is expected to serve as a hub for private activities. The private sector should be encouraged to provide the goods and services needed by ISSA over a transitional interval as our space industry moves from being government-supported to being driven by a free enterprise economy. Consequently, IEEE-USA recommends the following:

- **Promotion:** The White House, Congress, NASA and members of U.S. industry should promote private sector involvement in ISSA through widely-publicized joint meetings and conferences which highlight the unique attributes of the space station environment. Private sector involvement will benefit our country through the ingenuity of U.S. industry leading to expanded commerce for space-based business founded on advance applied research.
- **Involvement:** The resulting private sector involvement will both enhance the U.S. benefits from the space station program and encourage private industry contributions to related research and development
- **Business Development:** The White House, Congress and NASA should help the private sector obtain and use engineering information about ISSA in order to open up new business opportunities in low-earth orbit and, ultimately, on the moon and beyond.
- **Cooperation:** Cooperation among industry, government and academia should be encouraged and fostered by the U.S. Government to help ISSA create larger economic markets for private-sector space developments and hasten space-related economic growth."

AIAA 96-4297 An Integration Strategy for Worldwide Research Operations on the International Space Station, M. Uhran NASA, J. Sullivan SAIC, September 1996.

"The International Space Station, in its fully assembled configuration, will include over fifty payload sites capable of accommodating up to three hundred individual payload elements from around the world. Planning and scheduling research operations of this magnitude is unprecedented in the history of space flight. The physical and functional characteristics of the projected payload population have been analyzed from a statistical perspective, and operational models have been developed which employ recursive linear programming (r-LP) techniques.

Because research operations are relatively non-repetitive, and have uncertain predictability over time, standard operations research techniques, such as r-LP, are of limited utility. Instead, the search for the most effective planning and scheduling technique has led to a unique multistage method, employing heuristic search techniques to achieve an approximate solution."

Bid Me Up, Scotty, John O. Ledyard, Caltech Social Science Faculty Profiles, 1999.

Description of Adaptive User Selection Mechanism (AUSM) using demand-based pricing as a means of allocating ISS payload resources (e.g. weight, volume, electrical power, manpower etc.)

"Ledyard, who in 1983 joined a group studying pricing policies at the Jet Propulsion Laboratory (JPL), thinks there is a better way. 'Any economist knows that pricing policy and the allocation of resources are intimately linked.' Those benefiting the most from a scarce resource will pay the most to secure its use, so auction it off. Assuming the bidders have some idea of their potential benefits, the bids become proxies for the payloads' real worth. The winning bids reflect the 'opportunity cost' of the payloads that don't fly --- the benefits lost to the unsuccessful bidders. Such a system is called 'demand-based' pricing."

International Space Station Teleconference: Make it Your Business, WHR/ NASA, 1999, 1998, 1997 etc.

Teleconference video tapes reviewed provided coverage of a number of issues surrounding space station commercialization including:

- Space Station Partnerships
- Discoveries in Fundamental Physics
- Discoveries in Fundamental Science
- Research Profile: Bristol-Myers Squibb
- Commercial Space Policy
- Investments in Space
- Commercial Impact of Combustion Research
- Research Profile: Taking Diabetes Research to Market

Consideration of Adding a Commercial Module to the International Space Station, J. Friefeld, D. Fugleberg, J. Patel, G. Subbaraman, Space Studies Board, The Boeing Company, 1999.

"The National Aeronautics and Space Administration (NASA) is currently assembling the International Space Station in Low Earth Orbit. One of NASA's program objectives is to encourage space commercialization. Through NASA's Engineering Research and Technology Development program, Boeing is conducting a study to ascertain the feasibility of adding a commercial module to the International Space Station. This module (facility) that can be added, following on-orbit assembly, is described. The facility would have the capability to test large, engineering scale payloads in a space environment. It would also have the capability to provide services to co-orbit space vehicles as well as gather data for commercial terrestrial applications. The types of industries to be serviced are described as are some of the technical and business considerations that need to be addressed in order to achieve commercial viability."

GEODE - Commercial Space Production Facility, Mark L. Holderman, 1999.

"The allure of utilizing External Tanks (ET) for on-orbit space platforms has existed for well over a decade. For this vision to be realized it must first be understood that the ET is already an integral element of a proven, validated and precisely balanced man-rated space delivery system. Excursions or departures from the certified (flight experience) design database, via extreme engineering changes to the baseline, must be avoided. Safety, predictable performance and the benefits of a successful Operations/Integration program are to be viewed as major accomplishments and not be subjected to unnecessary or potentially deleterious design perturbations."

ISS IN THE PRESS

The following are representative news and periodical articles that provide a variety of perspectives and opinions on the ISS, both pro and con.

Making Money in Space, Tim Beardsley, Scientific American, March 1999.

"Exploring the solar system turns out to be the easy part. The next great challenge will be creating profitable space enterprises."

The International Space Station, if it is ever completed, will hold only seven crew members and generate negligible income, certainly not enough to cover its \$40-billion construction cost. NASA still hopes to strike partnerships with companies interested in manufacturing in zero gravity; the agency is trying to sell research modules on the space station to pharmaceutical, biotechnology and electronics companies. But even NASA officials admit that commercial interest has been cool. So far the only space industry that has proved to be arousing success is the satellite communications business."

ISS: The Flying Ham, Chris Bulloch, Interavia Business & Technology, January 1, 1999

"The world's space industry has cause to be glad of the International Space Station. Noone is asking the scientists what they think."

The first two components of the International Space Station are finally in orbit -- the Russian (Khrunichev) - built and US-financed propulsion and power module 'Zarya', launched by Shuttle on December 3. Ironically, the Shuttle already had to carry up a spare battery for Zarya. It will now be virtually impossible to get the project cancelled."

Castle in the Air?, Randolph Fillmore, Beagle, January 22, 1999.

"The International Space Station is up and running, although it will be more than a year before the biological research facilities are in place. There's still plenty of controversy over whether a space station is necessary or cost-effective for much of the proposed research."

Lots of Money, Lost in Space; Station will mean lost opportunities on Earth, Jack Uldrich, Star Tribune, December 11, 1998.

"According to the National Aeronautics and Space Administration (NASA), 'the mission of the International Space Station is to enable long-term exploration of space and provide benefits to people on Earth.

A laudable and worthy mission to be sure. Unfortunately, the International Space Station (ISS) is a \$100 billion boondoggle that threatens the very mission it seeks to accomplish."

10 Reasons Why This is a Winner: The Space Station's Place in History, Michael Martin-Smith, The Straits Times (Singapore), December 12, 1998.

"The foundation was laid for the \$98-billion International Space Station with the docking of a Russian and a US module this week. Although the project will not stand up to a cost-benefits analysis just yet, Michael Martin-Smith, a British doctor and writer with a keen interest in space development, argues why it is important for our common future. Nearly 15 years after it was proposed by US President Ronald Reagan, the International Space Station project is finally underway, 400 km above our heads."

Space is the Place, Martin Burkey, Arkansas Democrat-Gazette, November 29, 1996.

"A 17,000-mph chase ends with a slow-motion ballet and a remarkably gentle bump as a 115-ton spaceship glides silently through airless space and docks with a 507-ton space station. Deceptively simple in appearance, yet devilishly complex to execute, the International Space Station is a symbol of exploration much like the effort that created it."

New Millennium, New Frontier, David Lore, The Columbus Dispatch, November 29, 1998.

"What did the witnesses feel when the Egyptians built the first pyramid or the Chinese laid the first stone of the Great Wall?

Unless something goes wrong, the human race will pass another such milestone next Sunday as orbital assembly of the International Space Station begins."

A Black Hole in the Sky, The Economist, November 14, 1998.

"Fourteen years and more than \$20 billion after its conception, the first part of the International Space Station is about to be launched. Unfortunately, there is precious little for it to do once it is up there."

Critics Praise NASA Plan to Privatize Space Station, Rick Tumlinson, Space Frontier Foundation, November 20, 1998.

"The Space Frontier Foundation praised a new plan by NASA to hand over operations of the International Space Station (ISS) to the private sector, and called for its immediate implementation. The "Commercial Development Plan for the International Space Station" recommends ISS be managed by a "non-governmental organization" to handle operations and deal with both government and commercial users of the facility, acting as landlord and station manager."

Making Privatization Happen, Letter to the Editor Rep. Dana Rohrabacher, Space News, December 7-13, 1998.

"With the launch of the first two pieces of the international space station, America and its partners will be fully committed - in the sense of having jumped off the diving board - to the assembly and operation of the International Space Station. The only question will be whether we execute a pretty dive, or a costly and painful belly-flop."

NASA Begins Countdown for Shuttle Launch That Will Put the First American Piece of the International Space Station in Orbit, Anchor Bob Edwards, Reporter Richard Harris, National Public Radio, December 1, 1998.

"The largest construction project in the history of space exploration is set to get underway this week. On Thursday, NASA plans to launch the first U.S. component of the international space station. Astronauts aboard the shuttle Endeavor will join the component to a Russian component already in orbit. Ultimately the orbiting facility is supposed to be as roomy as a 747 with enough living space for seven astronauts"

Space Station Experiments have a Practical Payoff, John M. Shaw, *The Plain Dealer*, December 10, 1998.

"With the first assembly operation of the space station completed just a few days ago, now seems a good time to look again at what the space station will do for Americans, why we are building it and how Lewis Research Center will connect Cleveland to this tremendous scientific resource.

The clear goal of the space station is a better standard of living for all Americans. That will come about, in part, because of research that will be done in a very special environment: sustained microgravity. By examining materials and processes in space, we will know how to make and do things better on Earth. And that's the main purpose of any research: to add usefully to the sum of human knowledge, thus improving the human condition."

The Space Business Heats Up, Erick Schonfeld, *Fortune*, November 24, 1997.

"There is a new breed of entrepreneurs who think of space less as a scientific frontier than as a place to make money."

Station Science Unprecedented, But Debate Will Rage On, Joseph Anselmo, *Aviation Week and Space Technology*, December 8, 1997.

"The scientific potential of the International Space Station is a point of great debate, but it is clear the project will provide the largest and most advanced space laboratory ever available to mankind. The amount of research on the station will be just a tiny fraction of that performed on Earth, but NASA says the microgravity environment on the facility could provide the key to unlock mysteries in areas such as biotechnology, combustion science and biomedical research."

Science in the Sky, Tim Beardsley, *Scientific American*, June 1996.

"The International Space Station will be the most expensive object ever built. Although many scientists oppose the grandiose scheme, its political momentum now appears unstoppable.

Commercial interest, too, is cool, even though the National Aeronautics and Space Administration has provided substantial incentives for businesses to conduct research and to manufacture high-tech products in space. To date, no large companies are planning major research or manufacturing efforts on the space station."

The New Celestial Capitalists, Sharon Begley, Newsweek.

"With plans for floating spaceports, lunar rovers and missions to asteroids, business is viewing the heavens as the final (profit-making) frontier."

Global Space Station's 'Dawn' is Set to Rise, Richard C. Paddock, Los Angeles Times.

"The United States and Russia are preparing to launch the first piece of the most ambitious space project ever attempted: a multinational station that will take astronauts six years to assemble and will grow to nearly the size of two football fields."