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The thesis of Deborah L. Naylor entitled

Building the International Space Station: Exploring Issues of Public Policy and Technology

submitted in partial fulfillment of the requirements for the degree of Bachelor of Arts in Liberal Studies in the School for Summer and Continuing Education of Georgetown University has been read and approved.

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BUILDING THE INTERNATIONAL SPACE STATION:

EXPLORING ISSUES OF PUBLIC POLICY AND TECHNOLOGY

A Thesis
submitted in partial fulfillment of the
requirements for the degree of
Bachelor of Arts
in Liberal Studies

By

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Washington, D.C.
April 30, 1999

BUILDING THE INTERNATIONAL SPACE STATION:

EXPLORING ISSUES OF PUBLIC POLICY AND TECHNOLOGY

Deborah L. Naylor

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ABSTRACT

In 2004, the *International Space Station*, an orbiting tribute to Man's spirit of diplomacy, tenacity and tolerance, will be christened. Consisting of parts gathered from over the globe, it is the most ambitious engineering project ever undertaken. The ability to complete the *International Space Station* rests squarely on the shoulder of its political partners. A diplomatic pact binds 16 nations to the project: the United States, Russia, Canada, Japan, Brazil and 11 nations of the European Space Agency (Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom).

The *International Space Station* (ISS) will be a permanent space platform. Predominantly a space laboratory, the primary research experiments will be aimed at conquering the illnesses associated with long term space travel. The primary technology experiments will be searching for a more powerful propulsion method. These two problems stand between NASA and their future goal, sending space explorers to Mars

Dubbed a "city in space," the *International Space Station* will be the size of two football fields and will be covered in an acre of power-supplying solar panels. Orbiting 250 miles above the Earth, the station will have a breathtaking observation of 85 percent of the globe and over flight of 95 percent of the population.[1] It will shine as bright as Venus, making it visible to the eye.

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[1] NASA Facts, "The International Space Station: An Overview," January 1999 [database on-line]; available from http://station.nasa.gov/spacenews/factsheets/index.html#overviews; Internet; accessed 23 February 1999.

America is too great for small dreams.... We can follow our dreams to distant stars, living and working in space for peaceful, economic and scientific gain. Tonight, I am directing NASA to develop a permanently manned space station, and to do it within a decade.... We want our friends to help us meet this challenge and share in the benefits. NASA will invite other countries to participate, so we can strengthen peace, build prosperity and expand freedom for all who share our goals.

- President Ronald Reagan
State of the Union Address
January 25, 1984

CHAPTER 1

Evolution of the ISS Project

In 2004, the *International Space Station*, an orbiting tribute to Man's spirit of diplomacy, tenacity and tolerance, will be christened. Consisting of parts gathered from over the globe, it is the most ambitious engineering project ever undertaken. The ability to complete the *International Space Station* rests squarely on the shoulder of its political partners. A diplomatic pact binds 16 nations to the project: the United States, Russia, Canada, Japan, Brazil and 11 nations of the European Space Agency (Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom).

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The decision to go forward with the *International Space Station* project involved the blending of complex political, economic and scientific factors. This paper will consider the issues brought to the forefront, from the U.S. perspective, by the U.S. decision to lead a consortium of nations in the construction of a permanent science laboratory in space. Consideration will be given to questions such as: could this joint venture affect other key international relations decisions? What is the economic impact of this multibillion dollar project? Is there a significant scientific advantage to experiments performed in space?

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[1] NASA Facts, "The International Space Station: An Overview," January 1999 [database on-line]; available from http://station.nasa.gov/spacenews/factsheets/index.html#overviews; Internet; accessed 23 February 1999.

From Sputnik to Mir

Like the people they serve, governments are prideful, competitive, ambitious and dignified. Countries are not inanimate objects but living entities. To better appreciate the complex relationship between the U.S. and Russia, the two major international partners, it is necessary to remember the past.

The space programs for both the United States and Russia began in the late 1950's. On October 4, 1957, the Soviet Union launched the world' first artificial satellite, *Sputnik 1*. Less than four months later the United States launched its first satellite, *Explorer 1*. The two countries began a competitive space race towards the next milestone.

On April 12, 1961, Yuri Gagarin, of the Soviet Union, became the first human to travel into space. The Soviet Union held onto a strong lead in the space by successfully deploying satellites and probes before the U.S. It took over eight years, but on July 20, 1969, the United States eclipsed the previous Soviet achievements, by landing men on the Moon.

Both the Soviet Union and the U.S. experimented with temporary space platforms. The Soviet Union launched a number of orbital space stations called *Salyut*, using Soyuz spacecraft to ferry supplies. The U.S. launched *Skylab* in May, 1973. It was made from the third stage of a leftover Saturn V rocket. Three separate three-man crews collected scientific data aboard the floating laboratory for from 28, 52 and 84 days, respectively. *Skylab* was abandoned in 1974 and burned up re-entering the Earth's atmosphere in 1979.

On July 18, 1975, during a brief time of detente, the U.S. Apollo spacecraft docked with a Soviet Soyuz space craft while in earth's orbit. This was the first international manned spaceflight.

Mir

In the late 1970's the paths of U.S. and Russian space programs began to diverge. The Soviet Union decided it wanted a permanent presence in space. They launched a modular space station called Mir. In 1986, Soyuz spacecraft transported the first cosmonauts to Mir and the Soyuz continues to be used as a supply craft. These were exuberant times for the Russian people. They were justifiable proud of accomplishments of their space program. By 1996, Mir had grown to capacity with its six docking and sealing rings filled with different modules and had out-lived its intended life expectancy of five years.

The Space Shuttle

Elated after the Moon landing, NASA next wanted to press ahead with two major projects. These projects would require major funding. NASA wanted a permanent space platform, that would be supplied by a reusable shuttle craft. President Nixon had little use for the space program and public interest had also waned after the Lunar landing. NASA's budget was cut and they were forced to choose between the two projects. NASA threw its energy and financing into the space shuttle project.

Up until that time NASA's launch vehicles had been expendable. After each stage of an Apollo rocket, for instance, burned out it dropped into the sea or became space debris. The reusability of the shuttle was a novel approach. It showed enormous forward thinking on the part of NASA.

In reality the shuttle is only partially reusable. The orbiter returns and the two solid rocket boosters parachute back to the ocean. They are recovered and refurbished. The external tank which supplies fuel during launch is not retrievable. It is released and usually lands in the Indian Ocean or burns up.[2]

Recently, NASA sheepishly ask the U.S. Space and Rocket Center museum to return two solid rocket boosters that had been donated to the museum's full-size shuttle display. Though they were damaged NASA now believes they can be resurrected, saving three years wait and the $5-10 million cost of new ones.[3]

The shuttle has had its amazing successes and spectacular failures. The 1993 capture of the Hubble Telescope and the spacewalk that repaired its unfocused optical lens held thousands riveted to their televisions.

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[2] Paul S. Hardsen, *The Case for Space : Who Benefits from Explorations of the Last Frontier. Vol. 3.* (Shrewsbury, MA.: ATL Press. 1997), 135.

[3] Associated Press, "NASA Reclaims Parts from Museum Exhibit," [database on-line]; available from http://www.cnn.com/TECH/space/9902/15/nasa.museum/index.html; Internet; accessed 23 February 1999.

It gave NASA a public relations boost that was badly needed. The Challenger disaster in 1986, touched the heart of the world. It opened the facade of NASA to investigation and revealed the chaos within.

All shuttle missions were halted until 1988, while the tragedy was investigated and new safety policies implemented. When the space shuttle began flying again, the missions were oriented more towards life science research.

As the ISS comes together, the shuttle role will again change to that of a transport and supply ship. The shuttles are expected to fly 34 of the 43 missions needed to build the space station. Every shuttle flight costs taxpayers approximately $500 million.[4]

Space Station Design

In 1984, NASA's future brightened when President Ronald Reagan announced his support for a permanent manned space station. James Beggs, was NASA's administrator and responsible for obtaining the President's support. Reagan

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[4] Walter P. Kistler, "Humanity's Future in Space," *The Futurist*, (January 1999): 43.

also asked the European, Japanese and Canadian space agencies to join NASA in this endeavor.

The Agency saw the international collaboration as both a blessing and a curse. With other nations involved, their funding was more secure. Alternately, the management of widespread project would be a nightmare, not to mention the loss to U.S. aerospace contractors. Beggs traveled abroad to visit the other agencies encouraging them to think of ways they could use the space station once it was built. Each space agency had the same considerations and ambitions as NASA. There was a hungry, global aerospace industry to be fed. Each country wanted to be involved in the design and construction of the space station.[5]

NASA had a preliminary model and plans for the space station, which carried the stirring, patriotic name, *Freedom*. Beginning in 1984, the initial time line called for a budget of $8 billion to be spent over a development

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[5] Piers Bizony, *Island in the Sky : Building the International Space Station* (London: Aurum Press,1996), 46.

period of eight years.[6] Unable to define a purpose for the space station, arguments broke out. The Marshall Space Center in Alabama had previous experience with the Skylab project. Marshall also had collaborative experience, having worked closely with the European Space Agency (ESA) on Skylab. They wanted the space station to be primarily used for scientific experimentation. The prior experience in Texas at the Johnson Space Center lay in their controlling of Apollo flights and shuttle missions. They saw the space station as an outpost for continued space exploration.[7]

NASA's budget requests are reviewed on a yearly basis by a series of congressional committees. The NASA budget is always heavily scrutinized and an easy target for cutbacks. There are always needy social programs that could immediately benefit Americans caught in desperate straits. Even members of Congress, whose home state depended on aerospace contracts, were finding it increasingly difficult to turn away from public need and promote the seemingly purposeless space station. It was

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[6] Ibid., 53.

[7] Ibid., 56.

the foreign participation that continued to keep the space station alive. Canada, Japan and the European Space Agency had contributed over $2 billion, towards the space station. Funding continued to be renewed but by smaller and smaller margins.

In 1992, George Bush named Daniel Goldin as NASA's Administrator. Goldin began to streamline the agency's operations. The NASA motto became, "Faster, Better, Cheaper". Goldin ruthlessly cut contracts, contractors and NASA personnel. While his management style may be objectionable, the need for more cost control cannot be argued.

Upon entering office, President Bill Clinton was immediately embroiled in federal budget battles. In 1993, the new Administration demanded that the space station costs be slashed. Keeping Daniel Goldin in his job, they gave NASA 90 days to come back with three new designs for the space station. The choices were to be based on three options; Option A, a $5 billion design, Option B, a $7 billion design and Option C, a $9 billion design.[8]
NASA met the challenge but eventually all the designs were

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[8] Ibid., 68.

rejected because they were unrealistic. The Clinton Administration acknowledged that to have a truly functional space station, the purse strings would have to be opened wider.

Choosing an amalgamated design of Option A and Option B, yet another space station design was created. The name *Freedom* was dropped in favor of the more generic, *Alpha*. The estimated cost had grown to $20 billion.
"Currently the agency is spending a total of $14 billion annually. President Clinton wants that reduced by 30 percent before the year 2000, space station, shuttle and all. His support for NASA is dependent on such a commitment."[9]

Enter the Russians

President Clinton invited the Russians to become a partner in the building the new space station. This overture saved the space station from cancellation by Congress. NASA's budget request passed through Congress

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[9] Ibid., 66.

by one vote.[10] *Alpha* was quickly renamed the *International Space Station*.

The Russian Space Agency (RSA) headed by Uri Koptev, was contracted to build one-third of the space station hardware. "The station would now become a significant tool of East-West relations--a stabilizing factor between the old superpowers and a means of easing tensions."[11]

Despite its near bankrupt economy, Russia had a lot in terms of experience and expertise, it could share with the other member nations. Not only was there a political purpose served but it was hoped, a practical one. With the Russian knowledge base, the project should move faster. The United States also had a great deal of respect for Russia's scientist and wanted them to remain employed by Russian rather than risk the selling of missile-making knowledge to volatile regimes.

Phase 1: Shuttle-Mir

The *International Space Station* project was divided into three phases. In 1994, the United States and Russia

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[10] Ibid., 70.

[11] Ibid., 78.

signed an agreement that would put U.S. astronauts aboard Mir. This was a major step in joint cooperation. Each space agency had to learn to communicate and work towards a common goal. The NASA paid $400 million in rent to the Russians for their stay on Mir. This helped to subsidize the bankrupt Russian Space Agency. Several near catastrophic disasters, in 1997 aboard Mir, caused Congress to question the value and safety of the U.S. personnel on Mir. NASA insists the scientific and operational knowledge gained was worth the expense. Phase 1 ended in May, 1998 without tragedy.

Phase 2: Construction

On December 13, 1998, the crew of the space shuttle Endeavor returned to the ground, after successfully joining the Russian built module *Zarya* and the U.S. built module *Unity*. The next milestone will be the arrival of the Russian built service module, in November, 1999.

Phase 3: Operating the Space Station

The space station is expected to be fully operational and staffed in March, 2004.

CHAPTER 2

Economic Implications of the ISS Project

The economic issues involving the design, creation, launch and maintenance of the ISS are at the same time relatively simplistic, extremely complex and hugely controversial. As well, the addition of Russia's role adds a political component that can not be ignored. There are, of course, proponents and detractors to each side. And looking strictly at the monetary statistics of the project, the nays currently have the stronger petition.

While proponents of the ISS project argue for the future, the reality of the enormous expenditures of the past and present bear a terribly practical burden.

History Recap

NASA's first viable space station study, in 1975, projected a $200 billion cost for a huge, Star Wars-type station that would house 10,000 individuals existing in a nearly (economically) self-supporting environment. Profits would be produced by the construction of solar satellites.[1]

In 1984, President Ronald Reagan charged NASA with planning and building a space station. The goal was for an $8 billion expenditure, and launch and establishment by 1994. Its purpose was to be scientific experimentation on weightlessness which results would enable a subsequent flight to Mars.

By 1993, the station had become an international partnership, including European, Canadian, Japanese, and Russian participation. The price tag rose to $17.4 with a projected completion date of 2002. Russia's participation promised to decrease costs by $2 billion owing to its own lower costs in technology and space launches.[2] This situation was made all the more attractive due to NASA's previous $10 billion expenditure on space station design.

When the bottom fell out of the Russian economy last year, the U.S. injected $60 million in exchange for most of Russia's research privileges on the ISS, and announced a plan to pay the country $660 million over the next four

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[1] Mark Alpert, "The Best Use of Space," Scientific American, March 1999 [journal on-line], available from www.sciam.com/1999/0399space/0399alpert.html; Internet; accessed 5 April 1999.

[2] Ibid.

years (this in addition to approximately $700 million that has been paid to Russia over the short life of its participation. Russia is charged with building the service module critical to the project's viability.

On April 2, 1999, the U.S. offered Russia $100 million for the lifeboat project that is also its responsibility as an incentive to keep the project on its schedule (now 17 months late). With this expenditure, the U.S. is also buying leverage to force the Russians to retire the Mir, which is competing for Russia's non-existent space dollars.

What Costs So Much?

As easy as it is to discuss millions and billions of dollars, it is hard to conceive of the actual expenditures. Besides the obvious high cost of the best professional and technological equipment and experience, the most expensive item is, simply, the launch.

Escaping Earth's gravity is expensive. The cost is between $10,000 and $20,000 *per kilogram launched.*[3] NASA is investigating several means to use cheaper launches,

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[3] Ibid.

and considering the delay in the ISS launch, there may realitistically be time for it to develop, build or buy better launch projects that will help to keep costs down.

The Expenditures

ISS detractors need only present a simplified spreadsheet of actual and projected expenditures to argue its position that the project is a colossal waste. The figures, which change on a daily basis, follow:

U.S. Contribution to date:
$11.4 billion in industrial contracts
$ 700 million to Russia for ISS/Mir development and maintenance

Non-U.S. Contributions:	$1 billion (Canada) $3.7 billion (ESA) $3.1 billion (Japan) $.6 billion (Italy) $.2 billion (Brazil)
Total Actual Contributions:	$20.7 billion
Projected Future Costs:	$14.4 billion to fund 36 flights to ISS $ 5.3 billion for station operation (maintenance) $ 3.6 billion for On-Board research $ 8 billion for Initial Operations

Total Projected Costs in future: $31+ billion

Detractors point to the uncertain success and usefulness of the project. And usefulness has grown to be the key to the debate.

What Benefits will ISS Provide?

Obviously, there must be a plan for the Earth's future, and that plan, equally obviously, can not take place exclusively on Earth. We are overcrowded and running out of resources. The ISS will help "propel us toward our future, and [provide] real-world products and life-saving technologies to make our lives better...."[4] Of more immediate importance is ISS's role in promoting international cooperation and hastening nuclear disarmament.

Economic sources emphasize that, although overblown, the space station project is, proportionately, not as big a waste as detractors make it out to be. They compare it to the $5.8 trillion expenditure that the U.S. poured into

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[4] Linda Billings, "Despite Problems, Space Station project deserves support," 6 October, 1998, Knight-Ridder/Tribune News Service.

nuclear weapons programs[5], and maintain that less than one percent of U.S. tax dollars is devoted to the space program.[6]

They state further that bringing Russia into the project was not a bad decision--that Russia's contribution to construct key components and to launch many of the missions has value enough to sustain its participation.

ISS advocates also point to the contractors who have spent so much of the money. The General Accounting Organization reported that Boeing, for instance, had cost overruns in June 1997 that had reached $300 million. At the same time, Boeing's performance rating was 0 out of 100.[7] And sometime prior to January 1998, its sub-contractors held contracts totaling $2109 million, with Boeing itself contracting for $4891 million.[8]

Arguments for ISS' enhancement of improvements in

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[5] Ibid.

[6] Jim Lovell, "Upcoming International Space Station Will Boost Economies Here on Earth," *Knight-Ridder/Tribune News Service*,7 November 1997.

[7] Anthony Lawler, "Senate Raps NASA on Cost Overruns," *Science,* 27 June 1997, 19.

[8] Chris Bulloch, "ISS: the Flying Ham," *Interavia Business & Technology,* January 1999, 41.

industry and technology in the U.S. are uplifting. However, "even NASA officials admit that commercial interest has been cool."[9]

To date, the construction of solar-power satellites, which was the most productive use of the space station envisioned in 1975, is still the most promising of all proposed commercial functions of the station. Also, there appears to be more real interest in Space Tourism than in any industrial business that may take place aboard the ISS.

Space tourism is one of the entrepreneurial areas being developed by new companies trying to stick their feet in the space industry's door. Other areas being explored for profit are the development of "low-cost launch vehicles, . . . [and] planning lunar and deep-space missions." However, Wall Street is basically uninterested in the commercial space industry as it currently exists. The risks are too large, and investors too nervous.

Two suggestions have been put forth for alternate

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[9] Mark Alpert, "The Best Use of Space," Scientific American, March 1999 [journal on-line], available from www.sciam.com/1999/0399space/0399alpert.html; Internet; accessed 5 April 1999.

funding for this new group of space industrialists. One is that whatever results more research-oriented companies produce can be sold to NASA, and they can thereby earn their profits on the back end. Second, is that NASA should privatize a portion of the space industry, including the space shuttle and the space station, and indeed, there is now a Commercial Space Act, passed by Congress in 1998, which paves the way for privatization and launch vehicle licensing.[10]

Conclusion

It is difficult to sympathize with Russia, a nation that seems to continually have their hand out. It must be remembered that this is not entirely a free ride. Russia is selling or bartering all of its privileges aboard the space station, to other member countries. It is technically possible that the completion of the space station will mean the completion of Russian contact with it.

There is no arguing that the cost of the *International Space Station* has reached behemoth

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[10] Ibid.

proportions. No one wanted this to happen not NASA, not Congress, not the member nations. Despite the expense there can be no turning back, no waiting for a another time. Labor will not get cheaper, economic conditions will not improve enough that nations can swallow this size debit and not notice. We must forge ahead now, while there is momentum. This is the most painful phase. Once the space station is running, there will be dozens of windows of opportunity to repay the world for the sacrifices. It will one day pay for itself with phenomenal discoveries that will benefit humanity. We must give ourselves those opportunities.

CHAPTER 3

Scientific Ramifications of the ISS Project

The *International Space Station* will be a permanent laboratory for long term research for life and material sciences. The venue, high above Earth's gravitational pull, make the environment fertile with Nobel Prize possibilities. NASA received hundreds of research proposals for experiments aboard the *International Space Station*. There will be a wide variety of opportunities for exploration of the physical, chemical and biological mysteries.

Desiring to reach Mars one day, study of the long term effects of space travel on humans will be one of NASA's primary scientific goals for the ISS program. Physiological and psychological studies, which were begun on previous shuttle missions and on Mir during Phase I will continue. In addition, research will be conducted on commercial product development and environmental changes affecting Earth.[1]

NASA scientists believe that hidden processes might be revealed by studying common phenomenon, such as fire, without the pressure of Earth's gravity. Unlocking these processes

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[1] CNN, "Space Station Will Take Wing One Piece at a Time," [database on-line] (posted 18 November 1998); available from http://www.cnn.com/SPECIALS/space/station/news/overview; Internet; accessed 18 March 1999.

could lead to new treatments for diseases, better materials and alloys, and even more efficient use of fuels.[2]

There will be six laboratory modules on the completed station: one from the United States, Europe and Japan; two from Russia; and a sixth module, built in Japan and operated by NASA. The module supplied by the Japanese Space Agency is designed with a "back porch," an outside attachment for experiments that need to be exposed to space. The astronauts will use a robotic arm and hand, contributed by the Canadian space agency, to lift experiments onto the porch from an air lock.

Earth & Atmospheric Sciences

Earth scientists are excited the hardware being supplied by the Brazilian Space Agency. It is contributing a Window Observational Research Facility which will use sophisticated cameras and remote sensors to take advantage of the space station's unique position to study the Earth's ecology. It will be possible to track natural events like hurricanes and volcanic eruptions. Data surrounding the deforestation of the rainforest, global climate changes, rainfall, ozone depletion,

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[2] Mariette DiChristina, "Weird Science; Space Station Research," *Popular Science*, May 1998, 76.

etc. can be collected and studied for predictable trends.[3]

Engineering & Technology

The strongest reason for moving scientific research to a space platform is to reach a better understanding of zero gravity. On Earth we take for granted the gravity that will cause a flame to flicker upward; in zero gravity, fire expands in all directions at the same speed, creating a flame that looks like a burning ball.[4] This familiar element takes on new properties, becoming a more mobile and lethal hazard.

A stunning reminder of the dangers inherent in zero gravity happened in February, 1997 when a fire erupted on board the space station Mir. As practiced as the cosmonauts were, they were unprepared for the ferocity and speed of the blaze. Fortunately, the crew of Mir was able to extinguish the flame before it ruptured the hull, making an emergency evacuation necessary.

Improving fire safety on space missions is essential. Experiments on the ISS will include the use of a special

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[3] Boeing Space Systems, "International Space Station-Optical Window Rack Facility," [database on-line]; available from http://www.boeing.com/defense-space/space/spacestation/s4-windonw.html; Internet; accessed 18 December 1998.

[4] Bryan Burrough, *Dragonfly, NASA and the Crisis Aboard Mir* (New York; HarperCollins Publishers, 1998), 127.

breadbox size chamber to burn a spray of fuel, similar to the way fuel is burned in automotive diesel engines. Combustion researchers on Earth will downlink the data, examining the flame patterns, so they can develop better burners.[5]

Biotechnology

The most promising medical experiments in space have been the growth of protein crystals. A protein is involved in a way in every human illness and understanding the structure of protein crystals can help unlock new disease therapies.

Lawrence DeLucas, head of NASA's space development center, explains the process this way: "When you grow a crystal in Earth's gravity, lighter material floats upward while heavier material sinks. In space, the weight doesn't exist, so the molecules may have more time to arrive at the best orientation in the crystal. The crystals grow bigger and more perfectly, making it easier to analyze them with X-rays to determine their structure."[6] Crystals grown aboard space shuttle missions have already helped locate the key areas of the proteins that enable influenza to spread in the body. A new strand of drugs has been designed to block the disease.

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[5] DiChristina, "Weird Science," 77.

[6] Ibid.

Life & Biomedical Sciences

Astronauts will be guinea pigs for experiments as well as conducting them. Before travel to Mars can begin the detrimental effects of microgravity on human immune systems, tissue, bone and muscle mass have to be resolved. Towards that end, John Glenn, at the age of 77, returned to space aboard the Space Shuttle Discovery, in October, 1998. As a test subject for many age-related experiments, Glenn's personal hope was to assist in finding a cure for Osteoporosis. This is a disease that occurs mainly in the elderly, characterized by fragile and porous bones. Bone calcium is lost ten times faster in space.[7]

Norm Thaagard was the first American to live aboard the space station Mir. His 111 days broke all American long duration records. In an interview with Bob McDonald of National Magazine, Thagaard detailed the toll those four months took on his body:

> I had a 20 percent loss of muscle from the calf muscles, about 10 percent from the thigh muscles. I lost about 12 percent of bone mineral from the head of the femur. I lost about 20 percent of red cell mass, so I had a pretty good anaemia when I returned.[8]

More than two years after the flight Thaagard has still not

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[7] Ibid.

[8] Bob McDonald, "Just How Will Human Beings Live in Space," The National Magazine.[database on-line] (posted 15 April 1998); available from http://www.tv.cbc.ca/national/pgminfo/space/livingspace.html; Internet: accessed 21 November 1998.

completely recovered from the mineral loss.

The damage is done to the human systems when there is no pressure on the skeleton. A person will take approximately 4000 steps a day on Earth. It is that weight on the lower body that keeps bones and muscles strong and the blood flowing to the feet. Working out on exercise bikes and treadmills provides resistance for the muscles and works the cardiovascular system. Exercise helps to combat the effects of weightlessness but muscle conditioning is not the total answer. Much more research will need to be done by NASA because despite having over twenty-five years of experience on Mir, the Russians have little published data to share.

The psychology of space travel as a science is beginning to gain more respect from NASA. There is still a lot to be learned. In the short term, NASA offers astronauts what high-tech relief it can from the stresses of a working in space. Frequent contact with ground control and family via email and voice communication helps to push back the feeling of isolation. Computer games and videos also fill the void. NASA is hoping to include virtual reality capabilities on the space station, something not readily available on earth yet.

Also, special attention is being paid to interior design. The weightless of space makes every part of the ship, easy to reach and usable operational surface. Station design became a classic case of "because you can, doesn't always mean you should." The astronauts aboard Skylab, lived a topsy-turvy existence and the unnecessary emotional stress had an adverse effect on their ability to work. Humans have a basic need for orientation, to know top from bottom, ceiling from floor.

"The color scheme will be brighter and more cheerful, with an inherent bias towards 'up' and 'down'. The ceilings will contain strip lighting, while the floors will have dark-colored panels to differentiate them. Airlocks and hatchways will be marked with a 'top' and 'bottom'."[9] Unlike the cramped space on Mir, the passageways will be wider and the wires and toolboxes will be tucked behind panels, so the astronauts are not always bumping into equipment.

Material Research

Investigation of metallurgical alloys will be conducted on the ISS. A special furnace facility and fast action photography will be used to study the transition from liquid to solid metal. On Earth, dendrites, the microscopic parts of metals that solidify, can cool unevenly, becoming brittle and less valuable. Without the pull of gravity to cause separation

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[9] Piers Bizony, *Island in the Sky : Building the International Space Station* (London: Aurum Press,1996), 104.

in the metal, it is hoped a stronger, purer bond can be formed.

For every scientist enthused about the possibilities there are two detractors. Worldwide arguments erupt daily over the Internet and in science journals. Microgravity research in the current target of dissension. Many scientists think the research will prove to have little impact on the solution to long term space travel issues and find the enormous cost to outweigh the benefits.

As research dollars become more scarce, supporters of projects other than those promoting space travel have formed strong congressional lobbies. This, however, has not always meant success.

Not long before approving the space station budget, Congress had voted against funding of the Superconducting Supercollider (SSC) project, a technology rival to the *International Space Station*. For $8 billion dollars, the Superconducting Supercollider project, was considered a bargain. The SSC was to have been the most powerful particle accelerator in the world. Physicists expected that by mimicking the conditions thought to exist in the primordial plasma of the early universe, the supercollider would reveal new and exotic species of particles, thereby providing significant insight into the fundamental structure of matter.[10]

Wrathful, those engaged in "pure" science cover the ISS project in a blizzard of denouncements. Every delay in the ISS schedule and cost increase, supplies more ammunition for the bitterness of the SSC supporters, which gets spewed into editorial pages and Internet chat rooms across the nation.

Disparaging publicity will continue but the detractors' points can be only theoretical now. The decisions have been made and the ISS scientific goals are established. The positive ramifications for science from space station experimentation will open exciting avenues of possibility and discovery.

[10] Jeff Bowers, "A Particular Passion (Energy Physics)," *MIT's Technology Review,* August-September 1997, 51.

CHAPTER 4

Future of the ISS Project

In yet another blow to the ISS project, the Russians announced on April 12, 1999 an additional two month delay for the service module. The Russian made service module, the third component of ISS, is crucial to the project. It will provides not only the living quarters for the crews of astronauts and cosmonauts but also flight control, data processing, power distribution and communications.[1] The launching of the service module was originally targeted for April, 1998. In January, 1999, the Russians acknowledged a slip in the fabrication and testing of the service module, publicly admitting to letting their partners down.

NASA has no backup plan or substitute part for the mission critical component. The entire project is on hold until the Russians complete the service module. The Russians say that financial difficulties have kept them

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[1] Mark Carreau, "*Another Delay Slams Space Station Module*," Houston Chronicle, 12 April 1999, [newspaper on-line]; available from http://www.chron.com/content/interactive/space/station/stories/1999/990412.html; Internet; accessed 12 April 1999.

chronically behind schedule. Their partners look at the dollar figures and think of "black holes."

Frustration over the Russians inability to keep the project on track and the constant funding drain may have been behind the recent resignations of NASA's top two space station managers. The loss of these decision makers will undoubtably cause additional delays.

Putting aside the financial problems, there is the additional question of Mir. The United States is insisting that Mir be abandoned and that Russia direct all its attention to ISS. For the Russian people, Mir is a great source of pride. They are slow to abandon it.

Moscow would like to keep Mir in orbit until the space station is operational, then have the shuttle take scavenged parts from Mir to the space station. In another possible scenario, the Russians are still looking for a underwriter, an "angel" to use a theatre term, to absorb the cost of running Mir, so it can remain active. The cost is approximately $200 million a year. It looked, at one time, as if an investor had come forth but the deal fell through. The subject of Mir will continue, growing into a deal-breaking issue. As time and dollars continue to flow, the Russians must make commit to the difficult, and for them, huge gesture and bring Mir down. It needs to pacify their critics and keep harmony with its partners.

In recent weeks, the world has seen fragility of the bonds between nations. NATO countries have joined to bomb the Republic of Yugoslavia for its invasion of Kosovo and the genocide of the ethnic Albanian people. Russia warned that it was prepared to unite with Yugoslavia and create a European war, if the bombing did not stop. They went so far as to insinuate that nuclear missiles could once again be directed to the United States. President Boris Yeltsin later denied these threats to President Clinton but the situation remains tenuous. Any military action against by the Russians against NATO, could easily destroy the *International Space Station* project. This is a situation that bears watching.

Conclusion

We are a world of limited resources. The possibilities are not endless any longer. For the sake of our children and our children's children we must explore space. Building the infrastructure is expensive and costly. The odds are very high that there will loss of life, as the construction project advances. We cannot be deterred. The space station may not be the perfect answer but is a beginning. We must start.

Before traveling and establishing colonies on Mars or the Moon, illnesses caused by long exposure to microgravity must be halted. Also, a more powerful and sustained propulsion systems will needed.

In many ways the *International Space Station* project is akin to the Year 2000 (Y2K) projects going on across the world. While we go about our everyday lives, we are too busy to be bothered with what might happen in the year 2000. There must be a group that sets itself apart from the day to day and anticipates NASA insists the scientific and operational knowledge gained was worth the expense. the future. Whether we recognize it or not we are expecting that if a crisis occurs, there will already be a plan of action. Fixing the Y2K problems are incredibly expensive now, but imagine the cost of the disasters if there was no one designing, building and operating to alleviate the possible problems of tomorrow.

The *International Space Station* will become a beacon to earthbound dreamers; those who envisage touching the face on Mars or putting divots in the moon's surface while aiming to the right of the water, or maybe just standing tall, on strong bones, at their ninetieth birthday party.

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