The Political Context of Technology Transfer: NASA and the International Space Station

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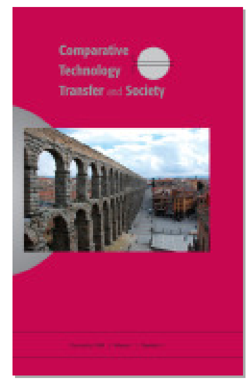

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The Political Context of Technology Transfer

NASA and the International Space Station

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THE INTERNATIONAL SPACE STATION (ISS) is the largest, most expensive, and most complex civilian international science and technology project in history. An orbiting scientific laboratory and potential manufacturing facility, ISS will be the size of a football field when finally completed. The project was launched by President Ronald Reagan in 1984 and has been maintained by each of his successors. In 1984, the National Aeronautics and Space Administration (NASA) projected a cost of $8 billion with completion a decade later. However, the cost to the United States thus far has been approximately $35 billion and the completion date is still some years away. With its long history, the space station has been shaped in turn by Cold War, post–Cold War, and globalization issues. Yet perhaps the most interesting aspect of the Station is the involvement of 16 nations in its construction. As a U.S.-led, multinational project, it serves as a potential model (for both positive and negative lessons) for large-scale international research and development (R&D) projects in the early 21st century.

For those interested in the political context of technological development projects including technology transfer—the flow of hardware and techniques from one entity to another—ISS stands out. It illuminates virtually all issues associated with science and technology in the contempo-

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rary era. The ISS has been a focus of debate since its inception. Domestic political forces pro and con have sought to influence its course; the Station has undergone several cost-cutting technical redesigns and survived numerous termination attempts. In addition to being influenced by domestic politics, the Station has also been affected heavily by international security concerns. The evolution of the ISS reveals much about how these external political forces can shape huge research and development projects. ISS also demonstrates the sometimes surprising ways that concerns about technology transfer contribute to the politics that shape the direction and pace of large projects.

APPROACH

This essay seeks to examine how political forces shaped ISS and the role that technology transfer questions have played in the debates that often surrounded the entire project. Politics sometimes has limited the opportunities for technology movements, and always has complicated the efforts to develop and manage the station. Whereas technology transfer, as an issue, has sometimes been obscured by larger concerns, it has been a fairly constant factor, one way or another, in decision making. Looking at the space station thus provides an opportunity to explore the role technology transfer issues can play in the outcome and direction of big technical projects with international dimensions. This should be seen as an exploratory essay, largely based on secondary sources, aiming to illuminate a terrain. This is not a definitive study of technology transfer and the space station. That history has yet to be written. Instead, this essay uses the space station as a vehicle for indicating the complexities of technology transfer in projects where huge domestic and international forces hold sway.

Among the questions examined here are these: Who have been the advocates and detractors of the space station? How have the international partners been recruited to the project despite concerns about controlling the transfer of apparently sensitive or special technologies? What has sustained the interest of domestic and international actors? Where does Russia fit into the history of the project? What strategies has NASA used along the way? How did technology transfer questions come into play?

To get at these questions, it is useful to track the history of ISS and how it has evolved over time as a technology development project. We suggest at least eight stages in the research and development process and a ninth of utilization. The first was an agenda-setting stage, when the space station appeared on the U.S. national policy agenda and stayed there. Relative permanence as an issue is important, because the idea of a station had long been discussed among space supporters but had moved on and off NASA's formal agenda. This agenda-setting stage was followed by a presidential adoption stage, marked by the Reagan administration's decision to build a space station. The third stage involved the enlistment of international partners as the United States brought Europe, Japan, and Canada into the project. The fourth stage was one of early implementation, followed by stage five, presidential re-adoption and Russian entry into the project. In this period, President William Clinton not only directed a major reorientation in technological design, but also made the space station an important element in his administration's post–Cold War national security policy. The sixth step involved implementation of the U.S.–Russian space station. The seventh stage, in which the project is currently situated, focuses on achieving *Core Complete*, meaning that the main crew quarters are sufficiently complete so that astronauts can live and work on the Station and the U.S. contributions are largely accomplished. This is then followed by *Assembly Complete*, in which all the other participating nations have their modules attached. There will be at least one stage after this point, *post-R&D*, when the space station moves to routine utilization. That stage is years away, although some limited scientific operations have already commenced. Needless to say, the movement toward "assembly complete" has been slowed by the *Columbia* shuttle disaster. This listing of stages reflects the length, turbulence, and complexity of the project's history.

A multiplicity of actors shaped the ISS and the technology transfer policies. However, this essay focuses on one particular actor—NASA. NASA has played the key role because it is the leader, or policy entrepreneur, behind the project. It interacts with other space agencies, including the European Space Agency (ESA), itself an amalgam of European nations that have joined to share the cost;[1] and the space agencies of Japan, Canada, Russia, and Brazil. Our interest is in NASA's role in steering the space station project and dealing with issues of technology transfer. NASA built a political coalition (domestic and international) to undergird the space station. In doing so, it found issues related to technology transfer were of continuing concern. The issue came up in at least three ways: (1) as a national security issue that at one point in the space station history constrained the project and at another facilitated it; (2) as an economic opportunity that attracted partners who foresaw potential commercial gain from participation, but simultaneously made everyone wary of possible competitors; and (3) as a strictly space policy concern related to the technical process of efficiently building the facility.

If space policy were the only interest involved, NASA might well have

[1]ESA has 15 members but only 11 have supported ESA participation in ISS.

tried to build the station unilaterally. Similarly, if NASA needed partners for their technical and financial contributions, it might well have engaged the minimal number necessary and sought to control a cohesive team, forming a virtual organization. In the real world, however, security and economic interests significantly affected technical designs. Compromises have been and continue to be made for political reasons, even as large-scale projects require big coalitions to get resources to carry them out. Yet big coalitions are hard to assemble, and even harder to maintain. Instead of seeking autonomy, NASA has fostered interdependence when it has joined with others.[2] Whether such large-scale projects can be managed in any technically efficient way when the interests of many participants are aggregated is an interesting question, worthy of much research. The space station is, after all, still incomplete after 20 years. That it has taken this long to create is due more to the politics of technology than technological challenges per se. Among the most intriguing political issues are those associated with technology transfer.

LITERATURE

This essay draws its approach from various strands of academic literature. One is the literature on space and technology transfer. A survey of the technology transfer literature reveals that most of the literature consists of case studies. Much of it deals with practical how-to questions, and is not associated with theory. To the extent the transfer literature has theoretical strength, it is found mainly in studies of the impacts of technology on the economy. There is a space technology transfer literature that examines spin-offs of technology from space to commercial endeavor (Amesse, Cohender, Poirer, & Choinard, 2002; Bach, Cohender, & Schenk, 2002; Hertzfeld, 2002; Pankova, 2002). Surprisingly, there is little published discussion of the political aspects of technology transfer, a gap the present essay hopes to narrow to some degree.

Another strand is the public administration literature that deals with domestic or public sector organizational cooperation and conflict (Bardach, 1998; O'Toole, 1997; Provan & Milward, 2001). In addition, there are a growing number of analyses that focus on international alliances (Levinson & Asahi, 1995; Narula & Dunning, 1998), and in particular, international strategic technical alliances (Chan & Wang, 1994; Das Somnath, Pradyot, & Sengupta, 2003). The technology transfer literature has

[2]On interdependence and globalization, see Keohane & Nye (2001).

also begun to address the role of learning through strategic technical alliances (Aranitis & Vonortas, 2000). This essay adds to the growing literature by highlighting the benefits and hurdles associated with building an international alliance to construct the ISS. Again, the present essay builds on this literature by showing that the decisions to bring the original international partners and Russia aboard the project were not just technical and administrative, but very much political. They were made with an eye to domestic political support, but also involve international political interests. The decisions made in regard to the ISS have carried with them a price: some loss of U.S. control over the project and a need for increased coordination across space agencies in a number of different countries.

A third strand of relevant literature addresses the dynamics of international relations among countries in space. In particular, much of this literature deals with the costs associated with cooperative development and implementation of space technologies. Krige, for example, has argued that "any collaborative venture involves a partial loss of sovereignty for a nation. Inevitably, the question arises as to whether the benefits accruing from working with others outweigh the costs" (1997, p. 4). A large literature has emerged that examines the U.S.–European relationship (Launius, 1995; Logsdon, 1984, 1991; Pedersen, 1992; Shaffer & Shaffer, 1980). This body of literature highlights the complicated relationships that emerge between countries as they combine resources and exchange technology in an effort to push the boundaries of space exploration.

Last, this essay contributes to the growing tendency within the sociological and historical literature on technological development to argue that technology is socially constructed, that is, shaped significantly by society (Bijker, Hughes, & Pinch, 1987; Bijker & Law, 1992; MacKenzie & Wajcman, 1999). Specifically, this essay builds on much of this previous work by emphasizing the political construction of technology (Lambright, 1994). We argue that the space station is a prime example of how large R&D projects in the 21st century are shaped by social forces, and how an agency charged with leadership of a complex endeavor copes with the political requirements of that construction, including those of technology transfer.

AGENDA SETTING, 1981–1993

In 1981, President Reagan appointed James Beggs as NASA administrator. Beggs identified getting the shuttle operational and then obtaining a presidential decision to launch the space station project as his top priorities.[3] Beggs realized that NASA's Space Shuttle was close to completion in terms of development and moving toward operational status. NASA was an R&D agency that needed a new and substantial project to sustain its position as the world's leading space agency. The agency had other efforts in the works, but NASA's identity, budgets, and personnel were linked to vast engineering projects in manned space. The space station—a facility for science, manufacture, and a possible staging ground for space exploration—had been on NASA's drawing board since the inception of the agency in 1958. However, President Richard Nixon had rejected a NASA proposal for a space station following the *Apollo* program, and instead selected the space shuttle. For NASA, the space shuttle's central purpose was to serve a space station. Beggs called the space station the "next logical step" (McCurdy, 1990, p. 1).

Beggs also identified international cooperation as a means of realizing a space station. Joint efforts were not more efficient; indeed, one agency in total control probably achieved greater economic efficiency. Rather, the space station NASA envisioned was large, complex, multipurpose, and most importantly very expensive. Given the mood of the country in the early 1980s, NASA could not expect enough money from Congress to do what it deemed necessary technically. International partners could help to pay for the station as well as promote the project. Also, they had advanced technically over the years and could provide certain technical benefits. The international dimension, NASA realized, might also make it harder for Congress to kill the project.

However, these international linkages also complicated NASA's effort to build domestic support for a space station. In the midst of the Cold War, the Department of Defense (DOD) and intelligence agencies saw international projects as more likely to allow U.S. technologies to diffuse to other nations in ways that could hurt U.S. national and economic security interests. Officials from those agencies tended to view such transfers of technology with skepticism and opposed the space station during executive branch deliberations (Logsdon, 1998). Technology transfer concerns at this stage threatened to undermine the entire project.

PRESIDENTIAL ADOPTION, 1984

Ultimately, Beggs, with the help of an ally on the White House staff, made an end-run around DOD and other opponents of the space station,

[3]For a book-length study of how the space station project was launched, see McCurdy (1990).

and secured the support of President Reagan (McCurdy, 1990). The president viewed the space station in the context of great power rivalry. He understood that the Soviet Union had built and deployed space stations. Reagan believed that the United States, if it was to lead in space, had to have a station that was bigger and better. The space station for Reagan was a geopolitical project, not an R&D endeavor. Reagan personally backed the space station, and became the all-important centerpiece of the political coalition Beggs was constructing.

Because Reagan's decision initially framed the station as a national leadership project, the possibility of including international partners was not at first discussed. After the decision, as the discussion shifted to the public announcement in an upcoming State of the Union Address, Beggs broached the prospect of international partners, bringing technology transfer concerns back into consideration (McCurdy, 1990). The president agreed to the notion of including international partners, and in his public address indicated he would ask other countries to join in the project. In response to concerns about maintaining control over technology transfer, NASA officials emphasized that, despite international participation, the space station would be a U.S.-led project.

INTERNATIONAL PARTNER ENLISTMENT, 1985–1988

A key reason the issue of national control was so emphasized in presidential decision making was the concern about controlling technology transfer voiced by various members of the Reagan administration. These officials in the State and Commerce Departments and in the Pentagon consistently sought more rigid export controls on sensitive advanced technologies in an effort to throttle technology flows to Eastern Europe and the Soviet Union (McIntyre & Papp, 1986; Perry & Pfaltzgraff, 1987). NASA officials therefore adopted the strategy of attracting international partners without losing control of the direction and shape of the station, thereby minimizing the risk of technology seepage. The concept Reagan approved projected a cost of $8 billion in U.S. expenditures and deployment in a decade (McCurdy, 1990). However, it soon became clear the design in question would not work out for technical and budgetary reasons. Then, in 1986, the *Challenger* disaster set NASA back in every way. *Challenger* showed that the space shuttle was not as operational as assured, and could not be launched frequently enough to routinely put men and women in space, much less assemble a space station within the original time frame.

The concerns regarding technology transfer, meanwhile, had not gone away and contributed to lengthy negotiations between the United States and its international partners. In 1985, the ESA, Japan, and Canada had agreed in principle to participate in the space station, but it took three years (1985–1988) for final agreements to be reached. In the view of at least one observer, "technology transfer concerns almost torpedoed negotiations in the 1987 time period."[4]

One factor that helped NASA in the negotiations was the imbalance in expertise and funding between NASA and the international partners, at least in terms of building *Freedom*, the name now given to the space station. The other countries were anxious to be part of such a prestigious space endeavor. NASA was definitely the managing partner and the other countries were junior partners, although no one used such rhetoric. Decisions were to be reached by consensus, but in the event of disagreement, the U.S. view would govern (Yakovenko, 1999).

The project's technical structure also seemed to minimize the danger of technology transfer from the United States to foreign nations. NASA alone would build the basic frame or core of the space station. This approach would lead to a viable station in its own right where a crew could live and work. The international partners would provide enhancements with their own modules for scientific and/or manufacturing research. Only Canada, with its robotic arm for assembly, seemed intrinsically connected to the core apparatus.

NASA's goal was to build an optimal space station, from a technical standpoint. The agency's strategy was to maintain as much technical control as possible, and in doing so avoid technology transfers detrimental to the United States, either in terms of national security or economic competitiveness. This approach won support domestically. Strategies included sequencing (first the U.S. base, then the foreign additions); compartmentalization (each country built its own modules); and minimal, clean interfaces (the equipment would come together in space, much as a Lego set, and the United States and its partners would transfer only that information necessary to connect the parts). Finally, NASA officials agreed to keep the export control bureaucracy in the State and Commerce Departments informed of cooperative technical activities to allay any fears (Logsdon, 1998).

Many of the international partners, however, had goals that differed significantly from the obvious intent of many Reagan appointees to control and limit the flow of sensitive technological knowledge and information. A major objective for each country involved in the ISS was to garner

[4]This is the observation of an anonymous reviewer of this paper.

direct economic benefits from research aboard the station, as well as from spin-offs emerging from the effort to build and develop the station itself. Building the space station entailed pushing the technological frontier in various fields, such as robotics, automation, and information technology. Being part of such a project had other rewards, such as pride, prestige, and scientific recognition. Primary issues for the partners lay in their conflicting desires to use their participation in the station to help develop autonomous space technology programs that were less reliant on the United States. The solution most nations hoped for was to spend more on space generally so they could pursue advances even while remaining tied to the United States. Benefits of being part of *Freedom* overrode any reservations that any of the nations may have had. The major implication of the agreements was that the station would be built in such a way that technology transfer would not become an issue, and each nation would benefit economically from its own contribution (Logsdon, 1998).

EARLY IMPLEMENTATION, 1988–1992

While NASA and the counterpart space agencies of Europe, Japan, and Canada negotiated these issues, NASA sought to cope with various technical and managerial matters. For example, an internal NASA problem revolved around the desires of each field center to acquire a piece of the ISS, even as congressmen worked to steer contracts and projects to particular congressional districts (Bizony, 1996). The total budget began rising, even though little hardware seemed to emerge. By the time George H. W. Bush became president, the space station was becoming a domestic political embarrassment. NASA had spent approximately $10 billion over the years on plans and designs, built little hardware, and launched nothing into space (Madison & McCurdy, 1999). As the Reagan budget and timetable had been abandoned, most observers viewed NASA as a bloated and mismanaged bureaucracy. In 1992, Bush removed NASA administrator Richard Truly, an admiral and ex-astronaut, in favor of a hard-driving, reform-minded technical executive from industry, Dan Goldin (Lambright, 2001b).

Meanwhile, in 1991, the Cold War ended unquestionably when the Soviet Union collapsed. Bush decided it was imperative that the resulting states, especially Russia, be pulled in the direction of the West, rather than have them transfer their weapons knowledge to potential U.S. enemies. The president directed Goldin to initiate conversations with his counterpart, Yuri Koptev, head of the Russian Space Agency (RSA), to see if any cooperative space ventures were possible. There was considerable wariness in the Bush administration about U.S.–Russian information exchanges, and turmoil within Russia. Some progress in planning joint activity came out of the Goldin–Koptev discussions by the time Bush left office, but little was implemented (Lawler, 1993).

PRESIDENTIAL RE-ADOPTION AND RUSSIAN ENTRY, 1993

When President Clinton took office, he at first considered killing the space station project. Then he reconsidered and ordered Goldin, whom he had retained, to drastically downsize the station and lower its costs. The international partners were alarmed at the abrupt shift in policy, but were assured by Goldin that they would be involved in the redesign (Lambright, 2001b).

As the redesign process got underway, Clinton was soon confronted with a security policy and technology transfer issue that was to influence NASA space policy. Russia was negotiating with India to sell certain rockets for cash. Although the rocket technology was said to be for civil purposes, U.S. arms control specialists pointed out that it was possible to divert the technology to military missile applications. Clinton, like Bush, was extremely worried about the weapons proliferation threat from Russia—another form of technology transfer. Clinton asked his national security advisers if they could offer a positive incentive to Russian President Boris Yeltsin to cancel the Indian rocket deal. The incentive had to be positive because Clinton saw Yeltsin in a struggle with hard liners and he wanted to bolster Yeltsin and develop good relations with the Russian president. More broadly, Clinton wanted Russian scientists and engineers to work on U.S.-related projects instead of selling their skills to potential American enemies. This issue arose in the context of the Clinton administration planning for the initial summit with Yeltsin in April 1993. The White House, anxious to come up with initiatives for a “strategic alliance for reform,” placed efforts to restrict the movement of sensitive weapons technology at the heart of its policy toward Russia. The Indian rocket deal could have complicated, even derailed, this broad policy initiative (Logsdon & Millar, 2001a).

In March 1993, Koptev visited with Goldin and proposed merging the Russian and American space station programs. Koptev was seeking to ensure the survival of Russia’s space program. The *Mir* space station was aging. A *Mir-2* was planned as a replacement. However, Russia’s internal chaos was putting *Mir-2* in jeopardy. Goldin, on the other side, regarded the Russian connection as very helpful. “I was worried we had no experience dealing with [a] station whatsoever—none. We had no experience in logistics. We knew nothing about the hazards. For *Apollo*, we had *Mercury* and *Gemini* [to learn from]. For a space station, which is more complicated, we had nothing" (Burrough, 1998, pp. 265–66). The Russians, on the other hand, had been building space stations for years. The concerns about technology transfer seemed to be reversed from those prevailing in the 1980s. Now it seemed the technology flow could favor the United States and foster the space station's progress.

Word of the Russian offer reached White House national security officials including Anthony Lake, Clinton's National Security Adviser, and Leon Fuerth, Vice President's Al Gore's National Security Adviser, both of whom had played lead roles in preparing for the summit. They sensed an opportunity to achieve a number of positive outcomes at once: broad national security policy ("the strategic alliance for reform"), a better space policy (and station), and removal of the Indian rocket transfer problem. At the summit meeting in Vancouver, Canada, Clinton and Yeltsin discussed the space station as a bargaining chip to persuade the Russians not to transfer missile technology (Burrough, 1998; Logsdon & Millar, 2001b). They agreed to create an ongoing mechanism led by Vice President Gore and his Russian counterpart, Russian Prime Minister Viktor Chernomyrdin. Goldin and Koptev served as advisors to what became known as the Gore–Chernomyrdin Commission. Finalizing the terms of the American–Russian relationship required months of negotiation, but Goldin immediately brought the Russians into an advisory role in the U.S.-led redesigning and cost-cutting process.

In July, Russia agreed to abide by the Missile Technology Control Regime (MTCR). Russian officials could provide India with the rocket engine hardware, but not the know-how behind it. In return, the United States agreed not to impose sanctions and instead brought Russia into the space station project (Logsdon & Millar, 2001b).

In September, following the presentation by Goldin and Koptev of a plan of action, Gore and Chernomyrdin proclaimed the end of the Cold War in space, and signed a formal accord. The accord called for the space station project to be accomplished in three phases. First, American astronauts would fly to Russia's *Mir* to perform experiments and enhance their understanding of how to work in a space station environment. (This agreement built on an earlier understanding achieved in 1992. Now more flights were added.) Second, both the United States and Russia would launch new modules into orbit, linking them and assembling, in effect, a U.S.–Russian space station. The two nations agreed to develop the initial elements the United States was expecting to build for the ISS. Third, to this bilateral space station nucleus would be added equipment, modules, and astronauts from Europe, Japan, and Canada, making the station a multilateral assembly (Lambright, 2001a).

Goldin, with Clinton's help, worked to win the approval of the international partners. The inclusion of the Russians angered many of the international partners, who saw themselves being subordinated in the overall project. International officials did not always care for the new arrangement, but there was also little they could do about it, and they agreed to the new schedule and to inviting Russia into the partnership. Congress also had to be wooed. Like the international partners, U.S. lawmakers had been on the sidelines while negotiations with Russia were underway. The House had come within one vote of killing the project during the summer, and Congress underlined its message by restricting NASA's use of space station money until it agreed to the new plan of action. At the end of November, Clinton held a domestic political summit with key executive officials and legislative leaders invited to the White House. The nature of the U.S.–Russia space station arrangement was discussed: (1) the Russians would become full partners and the United States would provide $400 million over a 4-year period for use of *Mir* and other technical assistance; (2) Russia would abide by MTCR; (3) Clinton and Goldin would stabilize Station expenditures at $2.1 billion a year for at least the next 5 years; (4) Congress would appropriate that sum every year; and (5) Congress would release the money it was holding back from NASA (Broad, 1993; Sawyer, 1993).

In December, President Clinton signed a decision memo committing to the new three-phase program in the Gore–Chernomyrdin accord. The United States and international partners sent a written invitation to the Russians to join the project and Gore led a U.S. delegation to Moscow where Chernomyrdin officially accepted the invitation (Berke, 1993).

Congress and the media generally applauded the new space station, now called the *International Space Station* (ISS). Goldin said that bringing Russia aboard would save the United States money and speed up the program. He estimated the cost of ISS would total $17.4 billion from 1993 to 2001. A target date of 2001 was set for assembly of all elements—U.S., Russian, and the original international partners (Lambright, 2003).

This decision process (which took place over the course of one year) dramatically changed the program technically, organizationally, and politically. Although a minority of observers warned that decisions shaped by security policy might not necessarily produce efficient space policy, the fact was that in 1993 the linkage between security and space policy probably saved the space station program politically. With the Cold War over, the geopolitical rationale that had persuaded Reagan no longer held. Clinton was not initially interested in the space station but was determined to find a way to create what he called a "strategic alliance" with Russia.[5] Many observers saw the decision as historic—the major space rivals becoming partners.

NASA had enlarged the political coalition underlying the space station. The coalition included the U.S. President, Congress, Russian political officials and agencies, and international partners, as well as the aerospace industry. The Russian connection also brought the State Department and National Security Council into space decision making as allies of NASA. The space station gained renewed priority and visibility in Washington. Although traditional worries about security and economic-related transfer and diffusion remained, these seemed far less important than the need to prevent Russian know-how from going in the wrong direction by linking it to a collaborative U.S. venture. Skeptics were overwhelmed by those who saw positive advantage for the United States in the arrangement. A number of technology transfer arguments voiced in 1984 were turned upside down in 1993.

U.S.–RUSSIAN SPACE STATION IMPLEMENTATION, 1994–2000

The policy adoption decision to bring Russia aboard the space station was made. Now, the policy process shifted to implementation. There were three phases.

Phase One: "Shuttle–Mir"

Phase One, *Shuttle–Mir*, had four stated goals for the United States and Russia: (1) to learn to work with one another, both in space and in ground support activities; (2) to reduce the risks to ISS development and operations by testing hardware, refining joint procedures, and integrating the operational practices; (3) to gain experience in long-duration stays on a space station and develop biomedical countermeasures to the damaging effects of extended periods of weightlessness; and (4) to conduct scientific and technological research in a long-duration environment, gaining both valuable data and developing effective research procedures and equipment for use in the ISS (Culbertson, 1997).

Concern remained, as always, about giving away sensitive information during the *Shuttle–Mir* phase. The United States had no space station and Russia had no space shuttle. Therefore, the two countries inevitably would learn about each others' technical systems. But the positive aspects of shar-

[5]For a general study of U.S. Russian policy under Clinton, see Talbott (2002).

ing information overshadowed concerns about the potential dangers of technology transfer. Also, as one NASA official said, the real technological know-how concerned living and working in space, and the psychological and physical condition of astronauts living in space for long periods of time. This was, in terms of technology transfer, she said, “pretty soft” (L. Cline, Deputy Assistant Administrator for External Relations, NASA Headquarters, personal communication, October 8, 2002).

The United States had little knowledge about long-duration spaceflight. Space shuttles remained in orbit for a relatively brief time. If human space exploration was ever to go beyond earth orbit, the United States had to learn about the physical and psychological aspects of being in space for months. For instance, a flight to Mars and back would be measured in years. Assuming future spaceflight involved multinational crews, it was critical also to learn how language and cultural differences affected relationships in close quarters for long periods of time.

A major issue in Phase One was safety. The United States and Russia had different ideas about acceptable risk, how to assess it, and what to do about it. The United States wanted exhaustive data, analysis, and science in assessing risk, whereas Russia relied more on experience and practical knowledge. The different attitudes also emerged in hardware. The United States believed more shielding against space debris was necessary on *Mir* and on spaceships in general than did Russia. The United States worried about risks of loss of cabin pressure in an accident, and was bothered by the incessant noise pollution of the machinery on *Mir* (Li, 2000).

The safety debate soon turned into a political discussion that threatened the alliance in 1997. Beginning in February, crews experienced a flash fire and breakdowns in an oxygen generator, carbon dioxide remover, cooling system, and main computer. The most serious event took place in June, when a Russian cargo supply ship slammed into *Mir*. The resulting loss of air pressure could have resulted in deaths, but the bilateral crew responded quickly and skillfully to alleviate the emergency.

Critics of the *Shuttle–Mir* program, and the U.S.–Russian space arrangement in general, used the accident to sound the alarm on safety. James Sensenbrenner (R-Wisconsin), chair of the House Science Committee overseeing NASA, blasted the agency and called for a halt in the *Shuttle–Mir* phase. He was also joined by NASA's Inspector General in attacking the safety precautions on board *Mir*. The Russians defended their program and *Mir*. The controversy escalated, and the media made it into a major national and international question (see Burrough [1998] for an in-depth discussion of the collision and the following controversy).

In response, Goldin appointed two independent study teams to address the safety issue. Both panels concluded that the collision was an anomaly and that the Russian safety hardware and procedures were acceptable risks. Goldin decided the program should move forward, and with President Clinton's approval, NASA scheduled the launch of the next American to *Mir*. All went well; Phase One concluded in 1998 and NASA hailed the project as a success in learning about space station hardware, procedures, and cross-cultural human cooperation. Even the near-disaster was called a useful learning experience. As a whole, Phase One was a critical example of technology transfer through experience and interaction.

Phase Two: building the U.S.–Russian complex

As Phase One, *Shuttle-Mir*, evolved into Phase Two, the legal aspects of the 1988 international agreement governing the ISS needed to be updated to include Russia. The most important issue of control was settled using the formula adopted earlier: decision making was by consensus. Where partners disagreed, the U.S. view would prevail; but there was an exception where Russia was concerned. If Russia continued to disagree, the decision would not apply to its part of ISS (Yakovenko, 1999).

Meanwhile, hardware development and assembly issues came to the fore, elevating technology transfer questions. Three modules occupied center stage in this part of the project. The first, the Functional Cargo Block or *Zarya*, was financed by the United States and built by a Russian contractor using funds not included in the original $400 million paid for Russian technical assistance. The second, *Unity*, was a U.S. docking node. The third module was Russia's primary contribution; called *Zvesda*, it was based on the *Mir-2* design. This section was designed to supply long-term propulsion to keep the entire space station in proper orbit as well as to provide living accommodations for a crew. Called a service module, *Zvesda* was to be financed by the RSA and constructed by Russian contractors. The three modules would be joined in space and provide the core of the manned station in space. After *Zvesda* was up, the United States would add a laboratory and other equipment and complete the core, allowing the project to move to Phase Three, attachment of international partner modules.

By the time Phase One ended, however, it was clear that Phase Two was in trouble. The problem was *Zvesda*, which had fallen behind schedule. The Russian economy was in free fall and RSA was not getting the money from its political masters that it needed to keep *Zvesda* on track. If *Zvesda* did not go up on schedule in 1998, the United States could not launch the follow-on modules and Phase Three would have to wait. Russia's contribution was part of "the critical path" as Sensenbrenner complained, meaning that NASA had made itself and its international partners technologically dependent on Russia. In the original conception, NASA explicitly had avoided this possibility with the other partners. Partner nations provided only enhancements to what was a de facto U.S. space station. The Russian relationship, however, made Russia's participation necessary to completing the core of the space station. In other words, without *Zvesda*, there could be no space station. Delays in Russia turned into a budget crisis in America, as the $2.1 billion annual level budget cap for the ISS was breached. The budget woes at NASA stemmed from more than the Russian delay, but the primary cost problems for the Station emanated from the Russian relationship. NASA had to spend additional money on contingent technologies, and trust between the two partners eroded. In late 1998, the first two elements of ISS were launched and linked successfully in space. This was a positive moment in the history of U.S.–Russia relations and ISS. However, they could not stay in orbit indefinitely without *Zvesda*.

Delays continued during 1999, even as events external to ISS worsened relations among the partners. Reports circulated that Russia was violating MTCR by transferring technology to Iran that potentially could be used to manufacture missiles. Russia denied that its purposes were anything but peaceful. Anger surfaced in Congress over the perceived violation of understandings reached about proliferation when the U.S.–Russian arrangement began in 1993. In addition to missile transfer, Russia was perceived as aiding Iran's efforts to acquire nuclear technology. In 2000, Congress passed legislation intended to force the Clinton administration to address the Russian proliferation problem. The bill directed NASA not to pay Russia for any ISS equipment unless the president certified Russia was complying with MTCR. Congress also put a cap of $25 billion on U.S. expenditures for ISS beyond those accrued before 1993. At this time, Goldin had reported that the final cost for ISS would be $17.4 billion. Yet by 2000, the costs were moving toward the $25 billion mark and climbing fast (NASA, 1998; 2001).

Goldin had constantly defended Russia over the years, and it remained the policy of the Clinton administration to stick with the space strategic alliance as the centerpiece of its overall security arrangement with Russia. However, the possibility that Russia was once again transferring weapons-potential technology tested the limits of congressional support for the inclusion of Russia in the space station partnership. As technology transfer useful to the United States earlier had brought the U.S.–Russian relation in space closer, now concerns about Russian technology transfer activities that were unwelcome from a U.S. perspective threatened to tear the alliance in space apart. Security policy and technology transfer became part of the political environment within which Goldin and Koptev struggled to maintain a joint space policy built around the space station. However, whereas the United States and Russia had resolved their differences over missile-related technology for India in 1993, the two nations could not agree in the case of Iran. The United States possessed less leverage on Russia; the space station was so far along and Russia had a place in the critical path.

Goldin also was exasperated by Russia's decision to keep *Mir* aloft after Koptev had agreed to bring *Mir* down and devote total attention (and resources) to ISS. Goldin gave a virtual ultimatum to Russia—either launch *Zvesda* or NASA would soon put substitute technologies into space. He hinted that if NASA developed a substitute for *Zvesda*, Russia would risk being excluded from the space station coalition. Russia came through in 2000, launching *Zvesda* two years late. Far from saving the U.S. money, the Russian connection had proved very expensive. No official cost figures were published, but critics measured the overall total given delays, U.S. purchase of know-how and equipment, and U.S. development of contingent substitute technology, in the billions. Moreover, Russian actions in 2001 further exasperated NASA's leaders by initiating uses for the space station for civilian tourists, starting with Dennis Tito, who paid $20 million to visit *Mir* (Morring, 2001b).

TOWARD "CORE COMPLETE," 2001–PRESENT

In January 2001, George W. Bush followed Clinton and his father into the White House. He soon learned that it would cost the U.S. $4.8 billion more to complete ISS than projected just a few months before. His administration immediately curtailed a number of space station developments to cut costs and avoid breaking Congress's $25 billion limit (Morring, 2001a). Projects to develop contingencies in case *Zvesda* could not be launched were killed. A major development that was terminated was the Crew Return Vehicle (CRV). This vehicle was to provide a way for the crew to escape the space station in a disaster and return to Earth safely. Without a CRV, Russia assumed even more importance in the ISS project because of an existing agreement between the United States and Russia that until the CRV came on line, Russia would park an unmanned *Soyuz* vehicle at ISS to evacuate personnel. Thus, the Bush administration made the United States more dependent on Russia, even though it wanted to take a hard line on the continuing Iran weapons proliferation issue, which remained unresolved.

In late 2001, Bush appointed Sean O'Keefe, Deputy Director of the Office of Management and Budget, to succeed Goldin as NASA administrator.

The choice of O'Keefe underlined the president's determination to deal with the ISS budget crisis. In 2002, O'Keefe set 2004 as the date for achieving what he called *core complete*, the point when the U.S. contribution to the station would be finished, and a decision regarding the international partners' modules could be made. This was a new stage made necessary in part by the problems in making the U.S.–Russia station the complete core. It was sometimes called *U.S.-Core Complete* to emphasize the U.S. role.

O'Keefe also asked independent science panels to define the scientific user requirements for ISS. These panels reported that little science could be accomplished unless a crew of six or seven persons was aboard. The existing crew was limited to three by the size of the *Soyuz* life boat. Scientific advisers found it took inordinate amounts of time on the part of three crewmembers just to maintain equipment and their own physical well-being, much less conduct path-breaking science. That finding meant that a replacement for the CRV, permitting a larger number of personnel aboard, had to be found. The answer to this problem might be provided by the Orbital Space Plane (OSP), a space vehicle O'Keefe proposed that could serve various purposes including crew rescue (Berger, 2002).

Unfortunately, NASA's relatively static budget and other priorities meant it might be 2010 before an OSP could be operational. NASA and the ISS partners were forced to continue to rely on *Soyuz* and Russia for the foreseeable future. Critics argued against such dependency and proposed simply purchasing two *Soyuz* spacecraft from the Russians, a technology transfer solution that would allow at least six crewmembers to work the station. That option was precluded, however, by legislation Congress had passed in 2000 requiring the president to certify that Russia was adhering to U.S. proliferation policy before paying for Russian equipment for the space station. In the wake of the September 11 terrorist attacks and other security policies of the Bush administration, nonproliferation concerns gained an even higher priority for Bush than they had for Clinton. Moreover, Congress was hardly willing to pay more money to Russia for the space station. Space, security, and politics intertwined to limit NASA's options.

Then came the *Columbia* disaster in February 2003. That event forced NASA to place space station construction on hold, pending decisions about the shuttle in response to the accident investigation. This latest crisis in the space station's history provided a major test of the cooperative abilities of the nations involved. In late 2003, the only certainty was that the ISS would take longer and cost more to finish, and that the technology transfer issue would continue to affect relationships.

CONCLUSION

As the largest civilian, multinational R&D project in history, the ISS illuminates a host of significant policy issues and processes. Highlighted in this essay is technology transfer, which has been a part of the larger political context of ISS. Some writing in the field of political science speaks of policymaking in the contemporary world as increasingly involving two-level games, in which policymakers must appease both international and domestic constituencies (Putnam, 1988). The history of ISS conforms to this pattern, revealing the two-level games that technological managers at NASA (and its counterparts) have played to keep this complex project moving forward. In 1984, NASA brought Ronald Reagan aboard the ISS coalition, because of his interest in competition with the Soviets. NASA also added international partners soon after, partners who saw gains, including economic spin-offs, from participation. Technology transfer, a potential barrier for NASA, was effectively neutralized by compartmentalizing the work on a modular structure.

In 1993, the project needed a new political rationale and broader constituency. Bringing erstwhile adversary Russia aboard served both purposes. The station became a symbol of post–Cold War U.S.–Russian cooperation and helped President Clinton to head off unwanted missile proliferation. The new alliance attracted arms control–oriented lawmakers to the project.

The Russian connection turned out to be extremely controversial from the point of view of technology transfer and diffusion. Space technology transfer and knowledge did flow toward the United States as a result, and unwanted technology transfer to India from Russia was stopped. But Russian technology later moved toward Iran, U.S. complaints notwithstanding. In the wake of *Columbia*, Russian technology was critical to the space station, limiting the ability of the United States to adopt stiff sanctions against Russian transfer activities.

NASA officials had once hoped to build a technically efficient space station. Instead, the space agency now pursues a space station that reflects a host of political compromises reflective of the scope of this huge project that extends over decades, involves multiple actors, and must adapt to events ranging from elections to disasters. Technology transfer questions have been central to many of the debates about the ISS, and factors in many of the compromises adopted along the way. If technical efficiency in space policy requires organizational relations without boundaries, then this space station fails to meet that condition. The price tag for the ISS has forced NASA to accommodate the realities of conflicting national and subnational interests that shift over the years.

The project thus illustrates the political complexity of multinational projects. Most importantly, the history of ISS illuminates not just interdependencies among nations, but also the significant role that technology flows have played. These have been internal and external to the project. They have been both positive and negative from the U.S. perspective, and have helped and hindered the advance of this project at different stages of its history. Technology transfer issues have played a pivotal role in U.S. decision making related to whether and how to include international partners, and how to structure the entire project. Although concerns regarding technology transfer initially hindered the prospect of international cooperation on the space station, those same concerns later fostered U.S. efforts to reach out to Russia to prevent Russian weapons technology from flowing to other countries. The space station serves as the prime example today of how technology transfer concerns can hinder international cooperation on technological projects, but it also illuminates how such projects can be used as incentives to prevent unwanted technology transfer. In an era of globalization and shifting notions of national security, international R&D projects will inevitably be fraught with technology transfer politics, and the ongoing history of the ISS provides many lessons on how such projects can influence and be influenced by the movement of technology among nations.

IMPLICATIONS FOR FUTURE RESEARCH

The sometimes surprising place of technology transfer concerns within the case of the space station suggests that the general significance of technology transfer issues within large-scale R&D projects is a subject in need of additional research. The topic is not the only aspect of the political context of such large projects, but it seems quite significant. The space station is thus a harbinger of the future. Science and technology projects are reaching a financial scale where nations have little choice but to cooperate to bring about major facilities and scientific programs.

Future social science research on such large-scale projects might investigate questions such as the following:

1. How do technology transfer issues push nations together and pull them apart in the pursuit of large-scale R&D projects?
2. How do nations (and agencies within them) use technology transfer to advance specific project goals? What goals?

3. How, in particular, does the interaction of technology transfer and security play out in influencing the course of large-scale R&D projects? What is the nature of technological cooperation and competition in a security-conscious world?

These and other questions require cases written with theory building in mind. Issues seen in the ISS case exist in other science and technology areas and need to be researched and better understood. However, the technology transfer literature is sorely lacking in theoretical perspectives; case studies present an opportunity to move the theoretical literature related to technology transfer significantly forward. Such case studies have practical implications as well, because detailed case projects allow a chance to build theory that can, in turn, be useful in guiding policy.

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Notes from the Field

ROGER D. LAUNIUS

The International Space Station (ISS) has been at the center of a debate over technology transfer since even before its inception. The movement of knowledge from one entity to another about space hardware and the techniques necessary for creating it has long been of concern to government policymakers and commercial leaders. There are two sides of this debate, each in tension with the other. First, at a fundamental level technology transfer represents a positive partnership between government, industry, and research institutions as knowledge is made available to all potential locations on an equal basis. Because of this, the National Aeronautics and Space Administration (NASA) has sought to undertake cooperative ventures from its earliest years, sometimes with notable success. This story is well known (Frutkin, 1965; Johnson-Freese, 1990; Logsdon, 1984; Whalen, Wiliamson, & Acker, 1995).

Second, and what I wish to focus on in this short essay, is the effort by NASA and many other organizations to stem the flow of technical knowledge to rivals, be they corporations, other nations, or research teams. Knowledge represents power, and concerns over its spread have led political leaders in the United States to create a strict control regime governing international technology transfer. Accordingly, the prevention of technology transfer to competitor nations with the ISS serves as an especially important sticking point in all aspects of the program. (There is considerable literature on this subject in the spaceflight arena; see, for example, Allen, 1984; Bonnet & Manno, 1994; Garud & Nayyar, 1994; Krige, 1997; Logsdon, 1991; Pedersen, 1992; Pinelli, Barclay, Kennedy, & Bishop, 1997; Shaffer & Shaffer, 1980.)

NASA sought to cooperate with European allies during the development of the space shuttle in the early 1970s, but some technologists in NASA, and even more in the U.S. Department of State, expressed fears that bringing other nations into any significant space project really meant giving them technical knowledge that only the United States held. Only a few nations were space-faring at all, and only a subset of those had significant capabilities; many American leaders voiced reservations about the advisability of ending technological monopolies. Initially promised complete involvement, in the end other nations—even close allies—only tangentially participated in the shuttle development effort. The French were so upset over the issue that they persuaded most of the other nations of Europe to create the European Space Agency (ESA) and to develop the *Ariane* launch vehicle as a competitor to the Space Shuttle (Launius, 1995; Sebesta, 1994).

The concerns found repetition in the space station program, but with a different result. As early as 1980, NASA began establishing technology transfer offices and setting aside funds to oversee technology transfer in response to the Stevenson-Wydler Technology Innovation Act. This aimed toward fostering technology transfer and opened greater possibilities for international cooperation; NASA negotiated several agreements with other nations to construct parts of the space station (Logsdon, 1998). At the same time, NASA officials worried that the United States might lose technological superiority through these agreements. In a 1984 letter to the European leaders to whom he had pitched the space station program during a trip, NASA administrator James M. Beggs commented that "technology transfer has been an increasing concern on all our parts in the past few years, and we will need to work together to make sure we are protecting our mutual technology bases in this partnership" (NASA Historical Reference Collection, 1984).

Accordingly, in April 1984 NASA developed standards to prevent "adverse technology transfer" while still encouraging international cooperation in the space station program. This found concrete expression in policies established at NASA in the fall of that year to limit the flow of technical data by compartmentalizing it and withholding all but what was necessary for any individual task. NASA also developed a review program to ensure that critical data did not end up in "the wrong hands." These checks on the system have become more sophisticated over time, so much so that many NASA engineers have complained that their restrictiveness has both inhibited and made much more costly the completion of the International Space Station (Office of Space Station Files, 1984; Space Station Task Force Files, 1984).

In spite of these concerns, in the 1980s NASA leaders pressed forward with international agreements among 13 nations to take part in the Space Station *Freedom* program. Japan, Canada, and the nations pooling their resources in the ESA agreed in the spring of 1985 to participate. Canada, for instance, decided to build a remote servicing system. Building on its *Spacelab* experience, ESA agreed to build an attached pressurized science module and an astronaut-tended free flyer. Japan's contribution was the development and commercial use of an experiment module for materials processing, life sciences, and technological development. These separate components, with their plug-in capacity, eased somewhat the overall management (and congressional) concerns about unwanted technology transfer. To make this work, NASA developed and maintained continuing relations with the nation's export control officials (Logsdon, 1991; Messerschmid, 1995; NASA Historical Reference Collection, 1982; National Academy of Sciences, 1987).

Accordingly, the space station program offered NASA the opportunity to advance a collaborative space policy, and generally its officials have found ways around the technology transfer issue, successfully ensuring the flow of necessary information to international collaborators. They were successful, at least with the European participants in the ISS, for two core reasons:

- U.S. preeminence in space technology had come to an end as ESA developed and made operational its superb *Ariane* launcher, and its ancillary space capabilities made it increasingly possible for Europe to go it alone. Accordingly, the United States both had less to lose when it came to dealing with the Europeans and it needed them every bit as much as they needed American capabilities (Sebesta, 1994).
- U.S. commitment to sustained preeminence in space activities waned and significantly less public monies went into NASA missions. Only international collaboration made it possible to undertake a program as aggressive as the space station (Clinton, 1996).

Although similar perspectives made possible cooperative efforts with the Russians in the 1990s, caution reigned in this arena with fear that Russian collaborators might be a conduit for technological knowledge going to enemies of the United States. For example, Russia signed a bilateral space cooperation agreement with China in 1994, and began training Chinese astronauts in 1996. Moreover, Russia provided technical assistance to China in the development of the *Shenzhou* spacecraft. Some Western analysts note similarities but also differences in certain features of the capsule. For example, the *Shenzhou* orbital module has its own propulsion system, whereas the *Soyuz* capsule does not. An open question remains as to whether or not knowledge of critical space technology is being made available by Russia to China (Chen, 1991; Clark, 2003; "First Chinese astronaut," 2003; Smith 2003b).

With the ISS, NASA increasingly acceded to the demands of collaborators to develop critical systems and technologies. This overturned the policy of not allowing others into the critical path, something that had been flirted with but not accepted in the shuttle development project. This was in large measure a pragmatic decision on the part of American officials. Because of the increasing size and complexity of the space station, according to Kenneth Pedersen, it produced "numerous critical paths whose upkeep costs alone will defeat U.S. efforts to control and supply them." He added, "It seems unrealistic today to believe that other nations possessing advanced technical capabilities and harboring their own economic competitiveness objectives will be amenable to funding and developing only ancillary systems" (1992, p. 217).

Recent events with the possible transfer of technology to the People's Republic of China have again raised the specter of American space capabilities moving to rival nations—perhaps to enemies. After the Tiananmen Square uprising in June 1989, the United States suspended export licenses for three satellites purchased legally by China, but the United States eventually reversed the suspension and China launched the satellites. This highlights the difficulty of the space technology transfer issue. In the 1990s, repeated instances of granting, suspending, and reinstating the purchase of space technology took place. The most serious of these occurred in 1997 when allegations arose over whether or not China obtained critical space information from Loral and Hughes. The State Department has not granted any export licenses for space technology to go to China since then (Smith, 2003a).

At present, a concern exists that in the United States, where technology transfer fears, economic competitiveness, and national prestige in space presently constitute such a powerful motivation for going it alone that with every passing year there will be less tolerance for large-scale collaborative projects in space.[1] Since the 1990s, the rise of competitive economic activities in space, and the resultant technology transfer concerns, have served to mitigate the prospects for any future cooperative activities. Historian John Krige astutely commented, "collaboration has worked most smoothly when the science or technology concerned is not of direct strategic (used here to mean commercial or military) importance." As soon as a government feels that its national interests are directly involved in a field of R&D, it would prefer to go it alone. He also noted that the success of cooperative projects may take as their central characteristic that they have "no practical application in at least the short to medium term" (Krige, 1997, p. 6).

A question remains about whether or not the United States will undertake significant collaborative space programs—in part because of technology transfer concerns—after the completion of the International Space Station. The disagreeable aspects of ISS might sour both national and NASA officials on similar future endeavors. It is certain, for example, that it will be a very long time before anyone in authority in the United States will sign on to an international project with similar complexity. This ensures that the chances are rare that a human research station on the Moon or a human mission to Mars—which because of size, cost, and complexity will have to be undertaken as a cooperative venture—will be undertaken anytime soon.

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[1] A superb example of this is the effort beginning in 1997 to shift American launch operations to the private sector by contracting out the majority of activities at Kennedy Space Center to the USA Corporation. For an excellent account of the process whereby commercial activities were initiated, see Kay (1998).

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