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RUSSIAN/CIS SPACE CAPABILITIES: ISSUES AND OPPORTUNITIES

H. Hagar, *Project Leader*

November 1992

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The current and evolving space capabilities of the former Soviet Union are described, including the impact of political and institutional changes that have occurred since the breakup of the USSR. The implications of these changes for the U.S. space program are discussed, and issues and opportunities for cooperative relationships, both commercial and governmental, are identified. Despite the traumatic breakup, and the fecklessness of the Commonwealth of Independent States, the former Soviet space program maintains a notable degree of vitality. However, coherent political and economic policies have not jelled fully, and depending upon the evolution of such policies in Russia and the rest of the Commonwealth, this vitality could degrade substantially. Desperate for hard currency to aid economic stability, Russia and some of the other States are mounting strong international efforts to sell the convertible wealth of their space technology. Despite certain pitfalls and threats to the U.S. space industry, actions are being taken to forge long-term commercial ventures in space technology between Russia and the U.S. At the same time, short comings in national space policy tend to hamper such opportunities. To facilitate collaboration, not only with the Russians but with the world space community at large, a timely, comprehensive national space policy, as well as a more definitive NASA strategic plan would enhance the capabilities and international competitive stance of the U.S. space industry.

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PREFACE

This paper was internally funded under IDA's Central Research Projects to provide background material on the space program of the former Soviet Union. Drawing on information from only unclassified sources, it describes the basic characteristics of the space assets and infrastructure inherited by the Commonwealth of Independent States. It discusses some basic needs of the Commonwealth, and identifies challenges facing the United States in this area. In this light, the paper suggests certain opportunities that could benefit both the Commonwealth and the United States.

In carrying out this work the authors received generous help from Mr. James French, Ms. Joanne Padron, and Mr. Brad Biegon at the American Institute of Aeronautics and Astronautics; Ms. Ekaterina Varley of the Space Policy Institute, Georgetown University; and Dr. Elizabeth Teague on leave of absence from the Radio Free Europe/Radio Liberty Research Institute to the U.S. Institute of Peace. Dr. Victor Suchorebrow provided some of the material on Russian space systems. The extensive and valuable knowledge of these individuals is gratefully acknowledged. In addition, the comments and suggestions of the reviewers--Mr. James Carlson, Dr. William Greer, Mr. Antonio Marra, Dr. Maile Smith, and Dr. David Randall--are sincerely appreciated.

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GLOSSARY

APEX	Active Plasma Experiment
AUOS	Automatic Unified Orbital Station
CIS	Commonwealth of Independent States
COMSTAC	Commercial Space Transportation Advisory Committee
CPSU	Communist Party of the Soviet Union
CYSA	Cape York Space Agency
ELINT	Electronic Intelligence
ELV	Expendable Launch Vehicle
EOS	Earth Observing System
ESA	European Space Agency
FOBS	Fractional Orbit Bombardment System
FSU	Former Soviet Union
GLONASS	Navigation Satellites
GOMS	Geostationary Orbit Meteorological Satellite
GPS	Global Positioning System
GUKS	Main Directorate of Space Systems
IMF	International Monetary Fund
ITP	Integrated Technology Plan
LDS	Launch Detection System
LEO	Low Earth Orbit
LPAR	Large Phased Array Radar
MIK	Space Vehicle Assembly Building
MO	Ministry of Defense

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MOM	Ministry of General Machine Building
NASP	National Aerospace Plane
NIITP	Scientific Research Institute for Thermal Processes in Moscow
NLS	National Launch System
OSTP	Office of Science and Technology Policy
OTH	Over-the-Horizon
PRO	Ballistic Missile Defense Forces
R&T	Research and Technology
RTG	Radioisotope Thermoelectric Generators
SDIO	Strategic Defense Initiative Organization
SDRN	Satellite Data Relay Network
SEI	Space Exploration Initiative
SKKP	Outer Space Monitoring System
SPRN	Ballistic Missile Early Warning Attack System
SRF	Strategic Rocket Forces
SSTO	Single State to Orbit
STS	Space Transportation System
TOMS	Total Ozone Mapping Sensor
TsAGI	Central Aerodynamics Institute
TsSKB	Central Specialized Design Bureau
TT&C	Telemetry, Tracking, and Control
VAB	Vertical Assembly Building
VPK	Military Industrial Commission

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EXECUTIVE SUMMARY

A. PURPOSE

This study has been undertaken as an IDA-funded research project to provide background material on the space program of the former Soviet Union. The basic purpose is to understand the nature of the space program inherited by the Commonwealth of Independent States (CIS) and its relationship with the United States. Specific objectives of the effort are:

1. *To describe the current and evolving Russian and CIS space capabilities (including existing systems, technologies and manufacturing enterprises, administrative organizations, and launch and operations infrastructure).*
2. *To understand the evolving political and economic context wrought by the dramatic changes following the coup of August 1991.*
3. *To examine selected issues and needs facing the U.S. space program.*
4. *To identify various issues relevant to potential investment in the space capabilities of the CIS republics.*

B. BACKGROUND

Following the dramatic changes in Europe and the breakup of the Soviet Union, the transitioning of the former Soviet republics to market economies and more democratically oriented societies has resulted in significant challenges as well as potential opportunities for the West. The changes begun (principally) under Mikhail Gorbachev, and accelerated by the attempted coup in August 1991, have produced a disruptive momentum that has yet to be spent. While it seems that any return to a structure similar to the former Soviet regime is simply impossible, there remain crucial, contentious issues that could make the transition to peaceful and stable conditions rather traumatic. These issues are only slowly coming to light and are incompletely understood, not only by Western analysts, but perhaps by government leaders of the new republics themselves. Further, individual priorities and interests of the newly independent republics often appear to differ significantly, sometimes leaving accommodation among the republics at an impasse. The host of meetings among

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the members of the CIS illustrates the difficulties of establishing a position of international unity.

Within this context there are possible commercial arrangements among the West and some of the former Soviet republics that are being increasingly recognized and explored. However, while there is considerable enthusiasm over the possible commercial benefits of unique Soviet technologies being available on the world market, the ramifications for the West, and particularly the United States, are still being sorted out. Using certain Russian space boosters may offer significant cost advantages to the United States while providing much-needed hard cash to the CIS republics. On the other hand, purchase of such boosters would detract from the business of the U.S. space launch industry. A further detriment to the U.S. space industry would be the marketing of cheap Russian launch services to other nations developing their own space capabilities.

Finally, political and economic upheaval has raised serious questions about long-term stability in the CIS, and the associated risks of long-term investment. Without some degree of confidence in political and economic stability, Western companies would be reluctant to invest substantially in ventures entailing long times for return on their investments. On the other hand, long term investments may offer the prospect of mitigating these instabilities.

Thus, there is significant value in understanding current and evolving space capabilities inherited by the CIS, and how they might provide opportunities for the United States in ways that could prove mutually beneficial. At the same time, risks inherent in political and economic instability, and the potential positive and negative effects of such cooperation on U.S. interests must be recognized.

C. SCOPE

Because conditions in the CIS republics are turbulent, only general conclusions can be reached about cooperative opportunities and their likely outcomes. Often, since the changes can be rapid and difficult to assess, assumption rather than fact must prevail. Outcomes of the political and economic contests are uncertain; hence, the *assessments made here assume some degree of stability being achieved and maintained over the next 5 to 10 years*. However, the implications of greater political and economic instability are discussed.

The breadth of topics considered is extensive. We feel this is necessary in order to achieve a reasonably comprehensive overview of the existing and evolving context in

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which the CIS and other space-faring nations--particularly the United States--must operate. This thrust, combined with the uncertainty and rapid changes in the CIS, make extensive details both impractical and unnecessary at this juncture.

Technical material is taken solely from unclassified sources, and should not be assumed to reflect national intelligence estimates. Our intent was to provide a broad overview of general capabilities and outlook. Hence, we felt that the desire for wide and easy access to the observations made here would outweigh any benefit that might be achieved by quoting official intelligence estimates.

Finally, we emphasize that the results here can only be preliminary. Our information is current through October 1992, and we recognize that any unexpected turn of events could substantially change our assumptions and hence, our findings.

D. METHODOLOGY

Our approach toward accomplishing the objectives entailed extensive search and review of professional publications, and interviews and discussions with a number of experts. The report is organized into chapters corresponding generally to each of the objectives. Throughout each chapter, key ideas are indicated by italics to make it easier for the reader to spot items of specific interest. The final chapter represents an integration of the information in each area, and a synthesis of their key features into overall results.

E. OBSERVATIONS

In becoming a world power the Soviet Union developed a space capability rivaling, and in some cases exceeding, that of the United States. Launch services, propulsion systems, and manned space flight are particularly notable. The Vostok launch vehicle, first flown in 1959, continues to offer highly robust launch service, as exemplified by the 1988 launch of an Indian satellite in the middle of a raging snowstorm. The RD-170 LOX/kerosene engine, perhaps the most advanced rocket propulsion system in the world, offers high reliability, is reusable, and has the highest chamber pressure and thrust of any engine. Russian SPT-100 electric thrusters have a specific impulse of 1,600 seconds and an efficiency of 50 percent, exceedingly good performance by Western standards. The former Soviet manned space program has accumulated over 22 years of crew time in space, more than three times that of the United States. The Mir space station, having accommodated cosmonauts from Afghanistan, Britain, Bulgaria, Cuba, Czechoslovakia, France, Germany, Hungary, India, Mongolia, Poland, Romania, and Vietnam, is the only operational manned space station in the world, offering a variety of *in situ* space research services. Under Russian leadership, the CIS continues significant efforts in microgravity research. Other areas of excellence include materials science, thermal management technology, and applied mathematics, to name a few. Further, while the pace of former Soviet space operations has certainly subsided, it is nevertheless quite rapid. During the first 6 months of 1992 the Russian Federation launched 19 spacecraft, compared with 16 for the rest of the space faring nations together. Of the roughly 2,000 payloads in orbit at the end of 1991, nearly 60 percent were Soviet; 30 percent were U.S., with all other nations making up the balance. Thus, *with the breakup of the Soviet Union, the successor republics comprising the Commonwealth of Independent States inherited valuable and highly capable space assets (although they are no longer necessarily well-integrated).*

Recognizing that the assets of the former Soviet space program are scattered among the republics, most of the CIS members signed the Commonwealth Agreement on the Joint Use of Space to coordinate use of these assets. However, *provisions of the agreement lack strength sufficient to instill confidence in the continued viability of the program enjoyed by the former Soviet Union.* Space program costs and benefits are to be shared proportionately, but the definition of "proportionate" is not clear. The agreement provides for an Interstate Space Council, which is left to its own discretion in establishing its specific powers and responsibilities. Although Ukraine is a significant producer of launch vehicles, and Kazakhstan has important launch facilities, Russia retains the vast bulk of the former Soviet space program assets; being the major shareholder she appears to be the only candidate likely to have a broadly successful program. There appears to be no adequate mechanism for ensuring fulfillment of the agreed terms; hence, success is likely to depend more on individual agreements among the CIS members than on the execution of the agreement. (The joint agreement allowing Russia to continue using Kazakhstan's Baikonur Cosmodrome is a case in point.)

The member states of the CIS face substantial political and economic challenges. *The lack of coherent political and economic reform policies -- particularly those of Russia -- is complicating transition throughout the Commonwealth.* Russia's liberal "shock therapy" approach of freeing prices and reining in inflation is being resisted by the industrialists as well as the reactionaries who argue strongly that major industries must be maintained to avoid massive unemployment and, in the extreme, strikes and riots. This is despite the lack of demand and resulting inefficiencies of blindly maintaining such production efforts. As the political competition continues, expediency is forcing concessions that are at best uninformed. Coherent, well-managed reform is being impeded, production capacity is being lost, expertise is being siphoned off, and quality is being degraded. Further deterioration of general economic conditions is likely over the remainder of the decade, and possibly well into the next. *The competition between the liberals and industrialists may well be moot if conditions deteriorate to chaos (as some observers have projected) and the reactionaries seize control. Fortunately, liberal-industrial accommodation appears more likely than the latter.*

As the production capacity, quality, and expertise of the former Soviet space program fade, attempts to retain or salvage these capabilities are confused by the disappearance of the centralized planning and production system, and general lack of experience with the market concepts presumed to be replacing it. Although space capabilities alone will not succeed in tiding over the Commonwealth in its bid to join the market economies of the world, *Russia and her CIS companions are in desperate need of hard currency, and are mounting strong efforts to sell the convertible wealth of their space technology capabilities to virtually any takers.*

In so doing they face both willing and reluctant buyers. In instances where space products and services compete with other space faring nations marketing their own capabilities (such as the U.S. launch vehicle and services market), they are meeting stiff resistance. In other areas, particularly those offering unique and commercially viable opportunities, they are welcomed with open arms. *The best arrangements appear to be those involving close, mutual collaboration on joint, long-term commercial ventures, thereby offering economic stability and growth potential to all involved.* By capitalizing on advanced, unique space technology developed under the former Soviet regime, the United States can advance its own space efforts, maintaining and advancing its own industry. Long-term commercial arrangements offer needed hard currency for Russia and her CIS companions, and the prospect of improved economic stability. The risk of failure due to existing political and economic instabilities in the Commonwealth can be mitigated through close coordination between the participating U.S. and CIS companies.

There is a window of opportunity for taking advantage of these space technologies and capabilities. Because of the fragile political and economic conditions in the former Soviet republics, and the resulting likely degradation of their space capabilities, the possibilities for exploiting these opportunities could soon "dry up." In addition, a number of other space faring nations (e.g., France, Germany, and Japan) are already making deals on what the Russians have to offer. Many such nations operate with close collaboration

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between government and industry regarding space, resulting in advantageous competitive postures--illustrated, for example, by France's governmental subsidy of the French Ariane.

The U.S. space industry, however, is impeded by a certain vagueness in space program goals and strategies. As noted in the *Report of the Advisory Committee on the Future of the U.S. Space Program*, NASA traditionally has approached the many rich and diverse areas of space across a broad front, reflecting a desire to explore all these areas, but not clearly establishing program priorities among them (particularly necessary during lean economic times). *Vision 21: the NASA Strategic Plan*, while attempting to redress this shortcoming, does not clearly set sufficient priorities among its programs. While specific *space technology* needs and priorities are established in NASA's Integrated Technology Plan, a comprehensive, long-term space strategy that establishes priorities and is resilient to changing national needs appears lacking. Further, a 1991 survey of senior U.S. research and technology managers concluded that *the United States has been hampered by "failure to manage strategically with a long term view, and an inability to effectively integrate new technology into business strategy."* Thus, *a definitive U.S. policy needs to be firmly established to provide greatest assistance and advantage for participating U.S. companies.*

A national space policy and program strategy that defines, encourages, and facilitates U.S. industry actions could enhance the international competitive posture of U.S. companies. Under the auspices of the National Space Council, the current assessment of U.S. national space policy through comprehensive review of space launch strategy, the space industrial base, commercial space rules, and the competitive threat to the U.S. space launch industry should aid this process significantly. Thus, *a timely, comprehensive national space policy that recognizes and resolves these issues, together with a more definitive NASA strategic plan can be expected to help the U.S. space industry take best advantage of Russian/CIS space technology, thereby enhancing its international competitive stance and its space capabilities in general.*

I. CHARACTERISTICS OF THE POST-SOVIET SPACE PROGRAM

The signing of the Commonwealth Agreement on Joint Research and Use of Space (Joint Space Agreement) signaled the intentions of the CIS members to continue the successful space program begun 34 years earlier with the launch of the world's first artificial satellite. Sharing world leadership in space with the United States, the Soviet Union achieved remarkable success, the full magnitude and scope of which is only rather recently being acknowledged by the West.

Despite the stated commitment to maintain this success, and the declarations by some successor states to institute their own programs, economic and political uncertainties appear to weigh heavily against the likelihood of near-term, robust space efforts by the Commonwealth. As seen below, the challenges facing the successor states are complex and difficult; it is commonly assumed that the social and economic problems are unlikely to be rectified in less than a generation or two.

Yet space launches have continued. Though fewer in number compared to even a year ago, communications and Earth monitoring satellites have been orbited. During its existence, the world's only space station, Mir, has received visits by astronauts of many countries, among them France, Germany, Britain, Bulgaria, Afghanistan, Japan, and Austria.[1] According to an agreement signed in the fall of 1992, even a U.S. astronaut will visit Mir. The need of the CIS to continue space efforts, both collectively and individually, is motivated generally by the recognition that the space capability represents a valuable and marketable commodity to help build a more viable economy. Thus, the success of three decades of space development appears advantageously poised to help vitalize social and economic conditions that are drastically disarrayed. This chapter examines the revised organization of the space program, and reviews some of the more prominent space systems, technologies, and capabilities unique to the former Soviet Union.

1 In addition, astronauts from North Vietnam, Cuba, India, and Syria visited the earlier Salyut space stations.

A. AN HISTORICAL PERSPECTIVE

On 4 October 1957, the world was startled by the unexpected launch of the world's first artificial satellite, Sputnik I. The Soviet Union had stepped through the doorway to space.

Subsequently perceived as a technological superpower, the Soviet Union racked up a string of firsts: Yuri Gagarin, first man to orbit Earth; Valentina Tereshkova, first woman in space; the first spacewalk; first pictures of the lunar farside; first permanently manned space station; and others. Sparked to action by Sputnik, the United States countered with its own launches. Initially stumbling with Vanguard, von Braun's successful Jupiter began a competition between the two countries that centered around desires for national security and international prestige. The United States pulled ahead in the race with the memorable first manned lunar landing, 21 July 1969.

As both countries continued their expansion of space technology, different technological capabilities took them down different paths. The U.S. approach involved increasingly more reliable technologies and systems and resulted in the need for fewer satellites. The infrastructure became geared towards a more leisurely pace of launching more sophisticated and capable satellites. Soviet technology did not keep pace, and success in space became dependent on less reliable and less capable satellites that were launched much more frequently.[2] The sense of this historical evolution of the two can be seen in Figure 1, which gives the launch rates of the two countries (as well as the rest of the space community) over the past three and a half decades. Although fairly even until 1967, twenty years later the Soviet Union carried out nearly an order of magnitude more launches than the rest of the world put together. Today, despite the severe problems in the successor states of the former Soviet Union, the Russian Federation maintained the lead, launching 19 spacecraft in the first 6 months of 1992 compared with 16 for the rest of the world.[3] Of the roughly 2,000 payloads in orbit at the end of 1991, nearly 60% were Soviet; 30% were U.S., with all other nations making up the balance.[4]

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2 *Joint Military Net Assessment*, 1992, Joint Chiefs of Staff, p. II-3, 1992, UNCLASSIFIED.

3 *Defense Daily* (Special Supplement), Friday, July 24, 1992.

4 *TRW Space Log: 1957-1991*, Vol. 27, TRW Space & Technology Group, Redondo Beach, CA.

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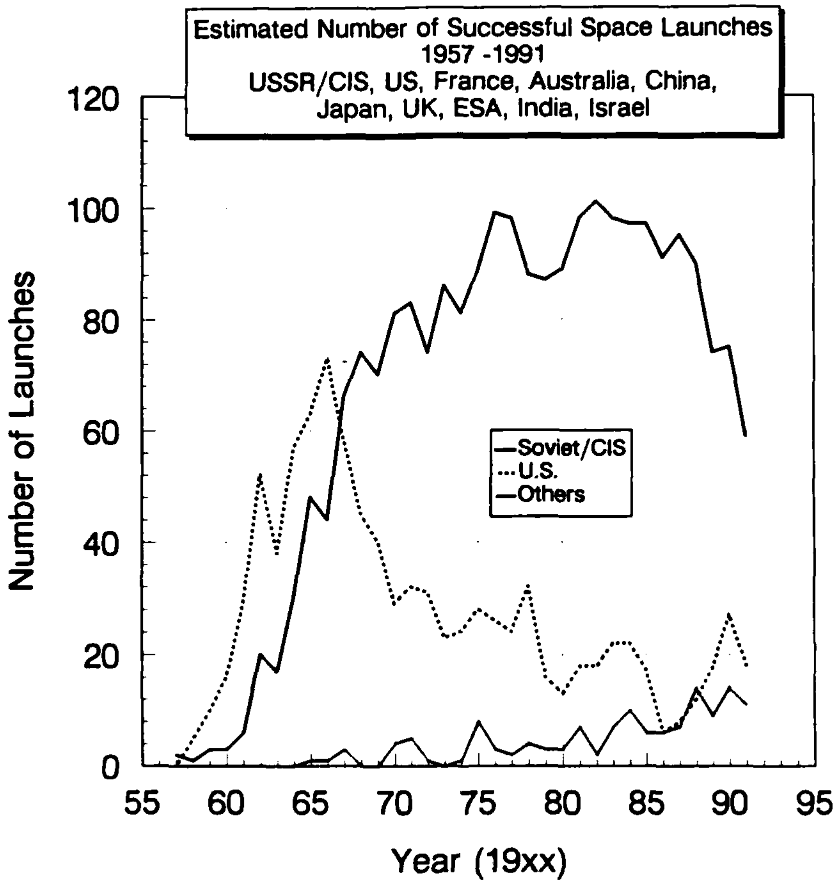

Source: M.S. Smith, *Space Activities of the United States and Other Launching Countries/Organizations: 1957-1991*, CRS Report 92-427SPR, May 11, 1992. Library of Congress

Figure 1. Estimated Successful Space Launches

B. ORGANIZATION AND INFRASTRUCTURE

1. The Joint Space Agreement

The demise of the Soviet Union, and its replacement by 15 independent states (see Figure 2), 11 of whom joined the CIS, has introduced an *organizational strain on the coherence of the former Soviet space program.* The Commonwealth Agreement on Joint Research and Use of Space[5] formalizes the recognition by the Commonwealth of Independent States that coordination is necessary for continued ability to exploit space for various military, scientific, and economic purposes (perhaps currently the most important). Signed on 30 December 1991 by 9 of the 11 former Soviet republics (except Ukraine which later signed in July 1992, and Moldova), the agreement appears roughly to follow the model of the European Space Agency (ESA). However, certain significant differences exist, and there are some critical issues that remain to be addressed.

The agreement states that implementation will be "coordinated by an interstate space council, which [will be] formed from the empowered representatives" of the participating member states. The *specific powers and responsibilities of this council are not defined, however*.

Implementation of the agreement is to be "on the basis of existing space complexes and space infrastructure facilities" (Article 4). That the majority of launch complexes, control facilities, design bureaus and manufacturing enterprises lie within its borders (essentially) confirms the expected *major role to be played by the Russian Federation*.

According to the agreement, financing of interstate programs is to be "by means of proportionate contributions" of participating member states, and "profit gained from space projects and the launch of space equipment carried out on a commercial basis" will be "distributed in accordance with the proportionate participation of the states..." How *proportionate sharing is to be calculated is not specified.*

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5 Agreements leading to formal establishment of the Commonwealth of Independent States and end of the Soviet Union culminated in the final meeting of the Supreme Soviet on 31 December 1991 at which time the Soviet Union was dissolved.

infrastructure are spread among a number of the member states, and due to the uncertainty

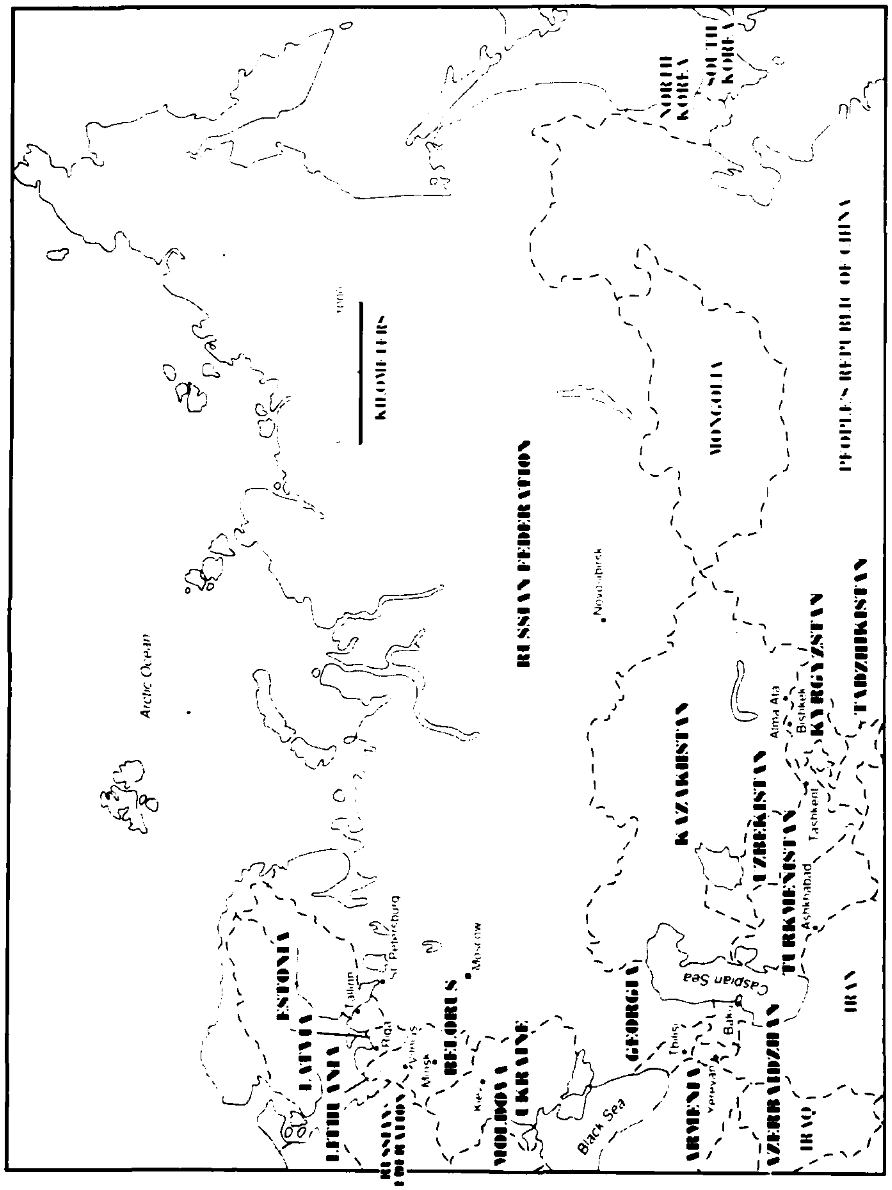

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Figure 2. Successor States to the Soviet Union

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Nothing in the agreement inhibits individual programs from being established by each state. In fact, Article 2 permits individual programs, and Article 6 explicitly calls for the participating states "to develop their activity in space research and exploitation in accordance with existing international legal norms, and to coordinate their efforts aimed at settling international legal problems..." Further, the states "pledge to provide the persons and facilities involved in the execution of ... programs with the material and technical resources, to make payments under the system of state regulation, and also to deal with the issues of social support and protection." However, given the social and economic strains facing the Commonwealth members, it is questionable how successful either their own programs, or substantive support for the interstate program will be.

Perhaps most telling is the *lack of any strong mechanism to ensure fulfillment of the agreed terms.*

An additional difference relative to ESA is that the CIS agreement includes military space activities. Fulfillment of the interstate program is "ensured by the joint strategic armed forces"; what this actually means is unclear, but apparently relates to the concept (discussed below) of a common defense structure for the member states. This could present some significant problems. The relations between some of the states--Armenia and Azerbaijan, for example--suggests there would be reluctance, if not outright refusal, to share satellite reconnaissance data of each other's regions.

Thus, in spite of the stated desire to retain a coordinated viable space program, the *viability of an interstate program is questionable.* Since "use of the aforementioned infrastructure for conducting independent programs ... is determined by separate agreements by the interested parties," success may turn out to be most easily, and perhaps more meaningfully, measured on an individual state basis. With this in mind, and given the preponderance of infrastructure contained within its boundaries, it is clear that *the Russian Federation is the only likely candidate for having a broadly successful program.*

2. Organization: The Old System

Prior to 1989, some 5,500 Soviet defense establishments came under rigid control of 8 production ministries whose actions were coordinated by the Military Industrial Commission (VPK) of the Council of Ministers. The Ministries directed the production of weapons and military systems in detail, controlling resources, prices, and wages. The VPK had the power to commandeer supplies and resources to ensure that production targets were met. The whole system was geared and prioritized toward the possibility of war. Production of civilian goods was based on the unused potential mobilization capacity.

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Thus, "civilian products were designed for compatibility with the military product mix and for rapid conversion to weapons production."[6] By 1985 this civilian production accounted for about 40 percent of the industrial output. Until around 1990, this principle dominated to varying degrees. When the idea became prevalent that producing civilian goods should be detached from excess mobilization capacity, and should occupy some priority, it met stiff resistance from conservative elements in the leadership.

Gorbachev viewed the militarized economy as a handicap, but believed it had a central role to play in fostering economic renewal. Through a process of "demilitarization" in which military production was deemphasized and portions of the command economy dismantled, attempts were made at converting from the dated fixations of an industry based on war mobilization to one in which civilian production occupied some degree of priority. Amidst growing economic difficulties, conversion became an issue between traditionalists and radicals. "By the time of the coup, several localities had developed their own conversion plans, joint schemes, and collaborative projects."[7]

Within the Soviet military industrial complex, the Soviet space and missile programs were tightly integrated. Even under glasnost and perestroika, it was difficult to distinguish between civil and military space efforts. Further, these programs occupied a privileged status, receiving high priority in terms of resources: raw materials, manpower, financing and capital equipment. The reason, of course, was that missiles and space systems, as part of a huge war-making potential, represented principal evidence of the Soviet Union's claim to superpower status. Throughout the history of the Soviet space program the leadership paid considerable attention to these efforts, and key individuals in the design and production infrastructure had easy access to that leadership.[8]

As part of the command economy system of the former Soviet Union, the launch vehicle program was exclusively the domain of the military, and somewhere from 70 to 95 percent of all the spacecraft were military in nature. Even today, as discussed below, the Space Units of the CIS Joint Armed Forces continue to hold responsibility for the operational infrastructure.

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6 *Potential Russian/Ukrainian Entry into Commercial Space Launch Markets*, 8 July 1992.

7 Ibid.

8 As reported by Berner, Lanphier and Associates, after WWII, when Leonid Breshnev became a member of the Politburo, Mikhail Yangel (who established the important design bureau that later became NPO Yushnoye in Ukraine) had direct access to the Politburo and all the resources necessary for it to become a leading missile design and production enterprise.

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a. Tasking and Funding

A diagram reflecting the centralized organization of the former Soviet space program is given in Figure 3.[9] The dashed lines surrounding various organizational groups identify certain responsibilities. For example, responsibilities for space science lay principally with the Soviet Academy of Sciences and the Space Research Institute. Procurement decision making was shared between the Ministry of General Machine Building (MOM) and the Ministry of Defense (MO).

Under the former system, the Ministry of Defense represented the primary consumer of the space systems produced under the direction of the Ministry of General Machine Building. The two main directorates under MO were:

- Directorate of the Chief of Space Systems (roughly equivalent to the U.S. Space Command), which commanded the Space Units, which managed the operational infrastructure (launch, tracking, and control).
- Main Directorate of Missile Armaments, which commanded the Strategic Rocket Forces (roughly equivalent to the U.S. Strategic Air Command minus bombers), which operated the ICBM and IRBM forces.

The key point regarding this organizational structure was the *very high degree of vertical control.* On the consumer side, the Scientific Research Institute (NII; roughly equivalent to a USAF System Program Office) of the Directorate of the Chief of Space Systems was responsible for identifying the operational and design requirements. However, it had no direct contracting authority with the design bureaus or production plants subordinate to MOM. Identified requirements would pass through the Ministry of Defense Military Industrial Commission which decided all development and production actions. Once a production quota was approved, the Commission would task MOM and arrange funding from the state budget. MOM would then distribute the responsibilities for development among its constituent design and production enterprises. While there was frequent and necessary interface between the Scientific Research Institute and the various design bureaus and production plants, there were no formal contractual relationships. Similarly, among the various design and production enterprises there were technical and

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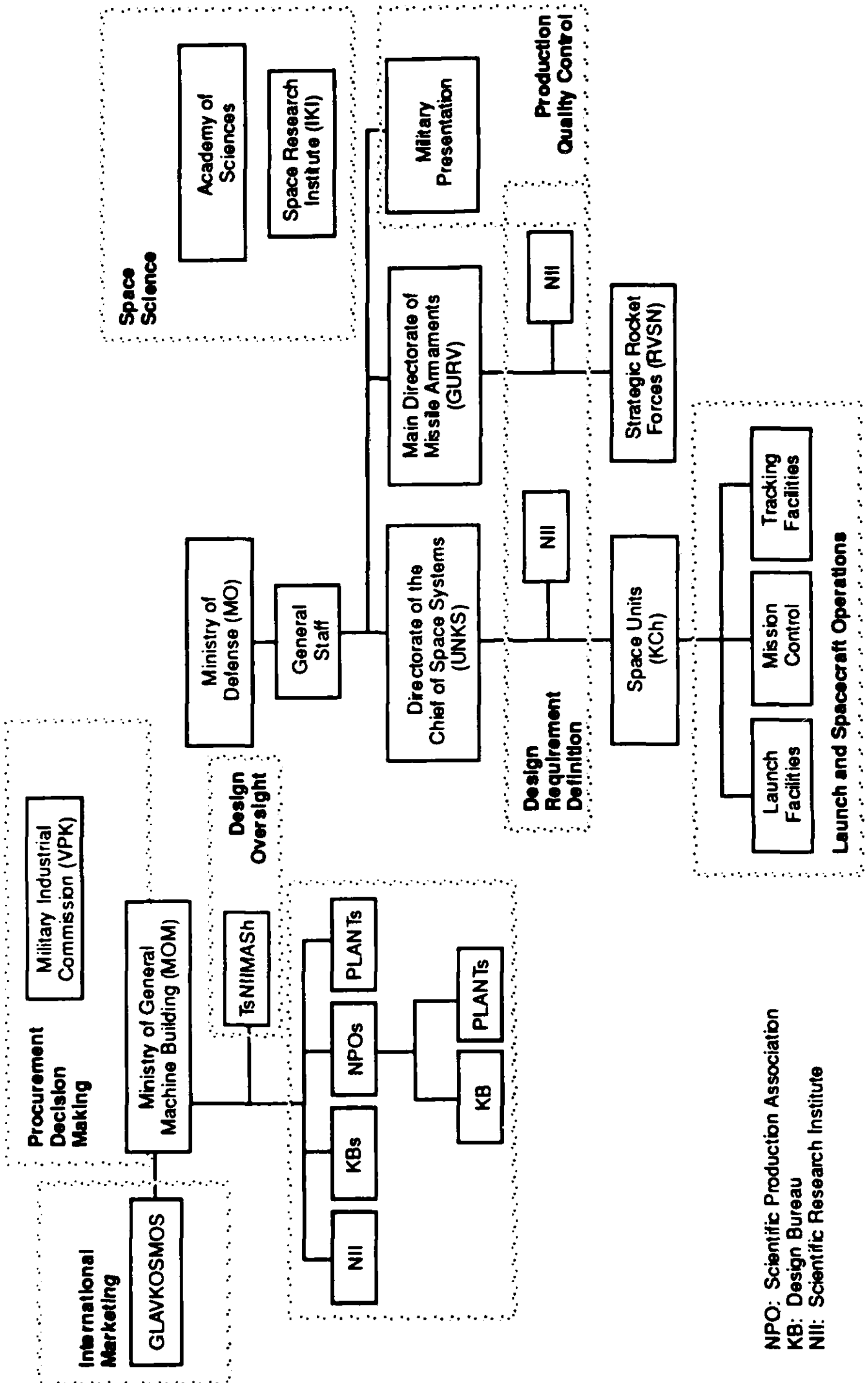
9 The diagram and the associated discussion were taken from Berner, Lanphier, and Associates, Potential Russian/Ukrainian Entry into Commercial Space Launch Markets, 8 July 1992.



NPO: Scientific Production Association
KB: Design Bureau
NII: Scientific Research Institute

Source: Berner, Lanphier and Associates, Inc.

Figure 3. Organization of the Former Soviet Space Program

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logistical ties, but again no formal contractual relationships. *The fact that all tasking and funding came directly from MOM represents the fundamental difference between the former Soviet program and the currently evolving arrangement. This difference constitutes a significant, and perhaps the principal, difficulty in the transition of former Soviet space enterprises to a market orientation.*

b. Quality Control

Under the old system, quality control was carried out through the Military Representative system. Because plants received their annual bonuses on the basis of quantitative production, left alone, quality would surely have suffered. Although the United States has some military representatives in certain key production plants, the Soviet Union had military representatives in virtually every plant. This system constituted the quality control mechanism. Every major component was accompanied by a quality control document called a "production passport" that had to be signed off by the production and quality control representatives at every stage in its manufacture and testing. Unlike the United States, the military representatives of the Soviet system had unilateral authority to shut down a production line on the spot.[10] *Under the new system, quality control is a matter for each individual enterprise (at least for non-military efforts).*

c. Commercial Interfaces

Under Gorbachev, when the Soviet Union first began to make its space products available on the international market, it set up an organization called the Glavkosmos (Main Directorate for the Development and Use of Space Technology for the Economy and Scientific Research). Established in 1985 to promote commercial space activities, it actively marketed goods and services abroad to obtain hard currency to help finance the Soviet space program. Although touted as an agency roughly similar to NASA or ESA, in fact it was very tightly linked to the Ministry of General Machine Building. Since so much of the Soviet space capability was highly classified even at that time, Glavkosmos was really nothing more than a front for the international marketing of products produced under the control of MOM.

As shown in Figure 4, under the old organization a potential customer for Soviet space technology would involve relatively simple interfaces. Technical issues would be handled through Glavkosmos, while legal and contractual matters would be handled by VO

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10 Ibid.

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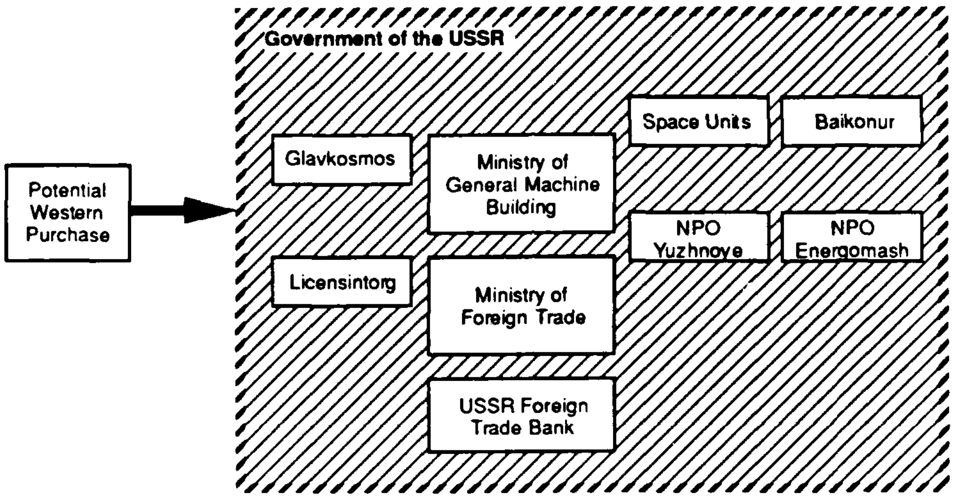
Licensintorg, a registered foreign trade organization and part of the Ministry of Foreign Trade. Financing would be handled by the Foreign Trade Bank of the USSR; insurance by Ingostrakh. If launches were to be involved they would undoubtedly have been carried out by the Space Units. Since all these organizations really were elements of the state, *a customer could be assured that all associated activities from production through launch would be backed by the Soviet government.*

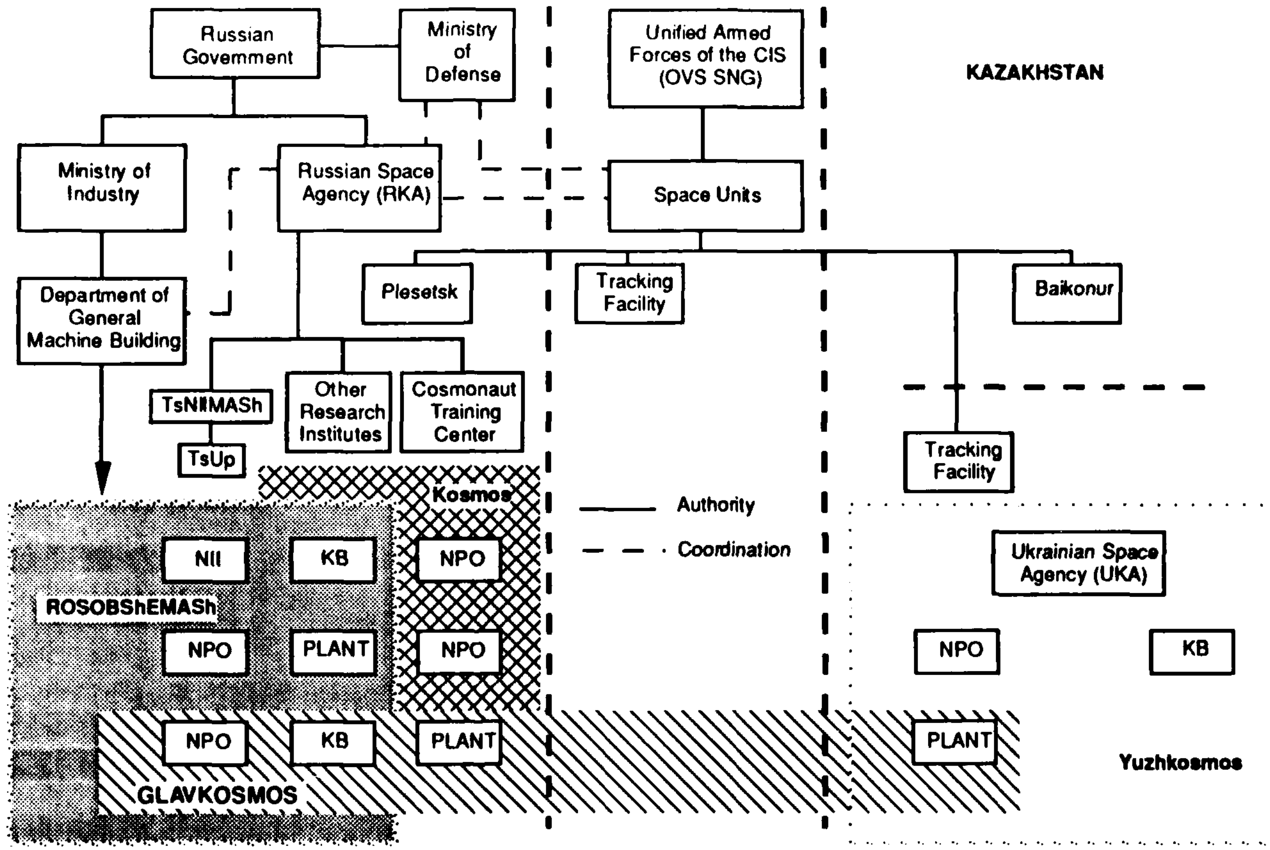


Source: Berner, Lanphier and Associates, Inc.

Figure 4. Customer Interfaces Under the Soviet Organization

3. Organization: The System in Transition

Following the dissolution of the Soviet Union, the monolithic and highly centralized way of carrying out the space program now must depend on a totally new way of operating (see Figure 5). With the dissolution, the various states have laid claim to those elements of the former system--including both operating and manufacturing facilities--that are in their territories. While some 70 percent of the production enterprises and design bureaus are located in the Russian Federation, some of the major enterprises are not. One key example is NPO Yuzhnoe, the largest missile production plant of the former Soviet Union, which is located in Ukraine. Another example is the Baikonur Cosmodrome, sole launch site of two important classes of missions, geosynchronous satellites, and manned launches. The cosmodrome now belongs to Kazakhstan. Another issue (discussed later)



Sources: Berner, Lanphier and Associates, Inc., and Central Intelligence Agency

Figure 5. Organization of the Russian Space Program

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relates to the operation of the space infrastructure. The Space Units, an element of the Unified Armed Forces of the CIS, commands the operational infrastructure of the CIS space program. One of its key tracking facilities lies in the Crimea, a region embroiled in Russian-Ukrainian controversy. Ukraine initially and steadfastly claimed control of the tracking site (although it has since agreed that control should remain with the Space Units).

a. Enterprises: Coping with the Lack of Direction

As mentioned above, under the new arrangements, individual enterprises are "on their own." Gone are the former means of tasking and payments, and with them the priorities and linkages with needed resources. The shift of ownership of existing enterprises from the state and the emergence of industrial "concerns" has, in some cases, resulted simply in repackaging the ministries into smaller units that still retain much of the power of the ministries they replaced. "In one reported case, a deputy minister (a lieutenant general) of the Radio Ministry, boasted that as president of his new concern, he could stay in his old office and control the same 50 factories he had always controlled."[11]

Similar arrangements in the form of commodity exchanges have emerged in an attempt to serve other areas of the economy. These have tended to produce self-serving barter arrangements that now resist further shifts to a market economy.

An attempt to help solve some of the dilemmas attending the disruption has been the formation of industry associations. These are informal groupings of NPOs, design bureaus, production plants, and research institutes that attempt to establish the interfaces with other organizations necessary to accomplish functions previously performed by government. A few examples are Kosmos, RosObsheMash,[12] Yuzhkosmos, and Glavkosmos, shown by the various shaded areas in Figure 5.[13] (As mentioned above,

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11 Sherr, James. "Russia's Defence Industry - Conversion or Rescue?," *Jane's Intelligence Review*, July 1992.

12 Marc J. Berkowitz reports in "Space Fallout From Soviet Disintegration," *Jane's Intelligence Review*, March 1992, that plans are being made to establish the RosObsheMash Corporation and Space Rocket Association out of facilities from the Ministry of General Machine Building. "The corporation will absorb Glavkosmos and coordinate the activities of the design bureaus and production associations remaining on the Russian Federation's soil. While it was originally announced that the Energia Scientific and Production Association, developer of the Buran space shuttle, would join RosObsheMash as a constituent company, the association has reportedly decided to remain independent." Subsequent information suggests that this arrangement may have been overtaken by the formation of the Russian Space Agency, intended to serve the same purpose as RosObsheMash.

13 The lines of authority and communication shown in the figure are highly uncertain. While the Russian Space Agency is ostensibly analogous to NASA, there appears to be a residual of vertical control by the Department of General Machine Building. At the same time the various competing and cooperating

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Glavkosmos no longer serves as the sole interface for international marketing of space products.)

Another mechanism being employed by some enterprises is the formation of "joint stock companies." The newly founded Kazakh Space Research Agency, the Space Rocket Associations of the Russian Federation and Ukraine, and commercial investment banks announced the formation of a joint stock company in November 1991 to develop the new International Spaceport at Baikonur.[14] Under the arrangement, 80 percent of the shares will be distributed among its founders with the remaining shares sold publicly. The intention is to attract private capital to establish and operate a spaceport offering a variety of launch services employing Soyuz, Proton, Zenit, and Energiya boosters. (The Space Units seem most likely to provide the resources and manpower necessary to operate the complex.)

The degree to which such associations and companies assist in furthering the space industry is far from clear, either in maintaining domestic support, or in garnering international business opportunities.

b. Interfaces: Coping with Confusion

With the changes in the system, Glavkosmos (formerly the key interface between the MOM and potential international customers for Soviet space technology) is now an "independent" entity. In spite of this independence, it continues seeking to perform many of the same functions it claimed to have performed under the old system. However, most of the production enterprises and research institutes now have their own independent authority to negotiate international trade arrangements, and do not have to go through Glavkosmos. *The independence of many enterprises from Glavkosmos has added to the difficulties in transitioning to the market orientation.* Many enterprises simply do not have the experience in dealing in a market environment, and many Westerners do not know with whom to deal. Hence, some enterprises continue to go through Glavkosmos simply through "inertia," because of inexperience, or because some systems are still highly classified. With the establishment of the Russian Space Agency in early 1992, the

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groups of design bureaus and production organizations appear to operate in any way that holds the potential for funds from any source.

14 Berkowitz, "Space Fallout From Soviet Disintegration," *Jane's Intelligence Review*, March 1992.

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continued existence of Glavkosmos, at least in attempting to perform its earlier function, is open to question.

From a potential customer's viewpoint, the process of doing business with the former Soviet space industry has become confusing at best. Whereas formerly the interfaces were simple, they now involve contacts with numerous enterprises possibly in a number of the CIS states. An example of one of the more difficult situations--purchase of a Zenit launch--is shown in Figure 6. In this case, four CIS republics would have major involvement: Ukraine (which produces the Zenit vehicle at NPO Yuzhnoe in Dniepropetrovsk along with KB Yuzhmash to design the payload interface, and NPO Elektropribor for avionics); Russia (for the RD-120 engines produced by NPO Energomash and the RD-170 engines produced at the Baranov Engine-Building Plant, Omsk); Belarus (PO Kommunar provides the inertial guidance package); and Kazakhstan (which owns the Baikonur Cosmodrome). In addition, tracking facilities are located throughout the Commonwealth (e.g., a major Ukrainian installation, Yevpratoria, is located in Crimea), and while individual arrangements would likely not be required with the owning states (since the whole operation would be conducted by the Space Units) there is no guarantee that this will hold (see the discussion under a., above).

Another cause for customer concern is the degree of reliability. Under the new system, as we have seen, the quality control process is unclear. The loss of skilled personnel has and is making an impact. "Experienced, highly skilled...workers surrendered to even higher wages in cooperatives. Irregular production of Zenit, which instantly rose in price, came to be of lesser quality than [before]..."[15] "The results were deplorable: after 12 successful launchings from the beginning use of the Zenit in 1988 there were two accidents in a row, [and] the destruction of the launch pad."[16] Another illustration deals with production of the RD-253 engine used in the Proton booster: "We're having a lot of difficulties because it is a complicated engine to produce, and we have to retain the quality while reducing the annual production output."[17]

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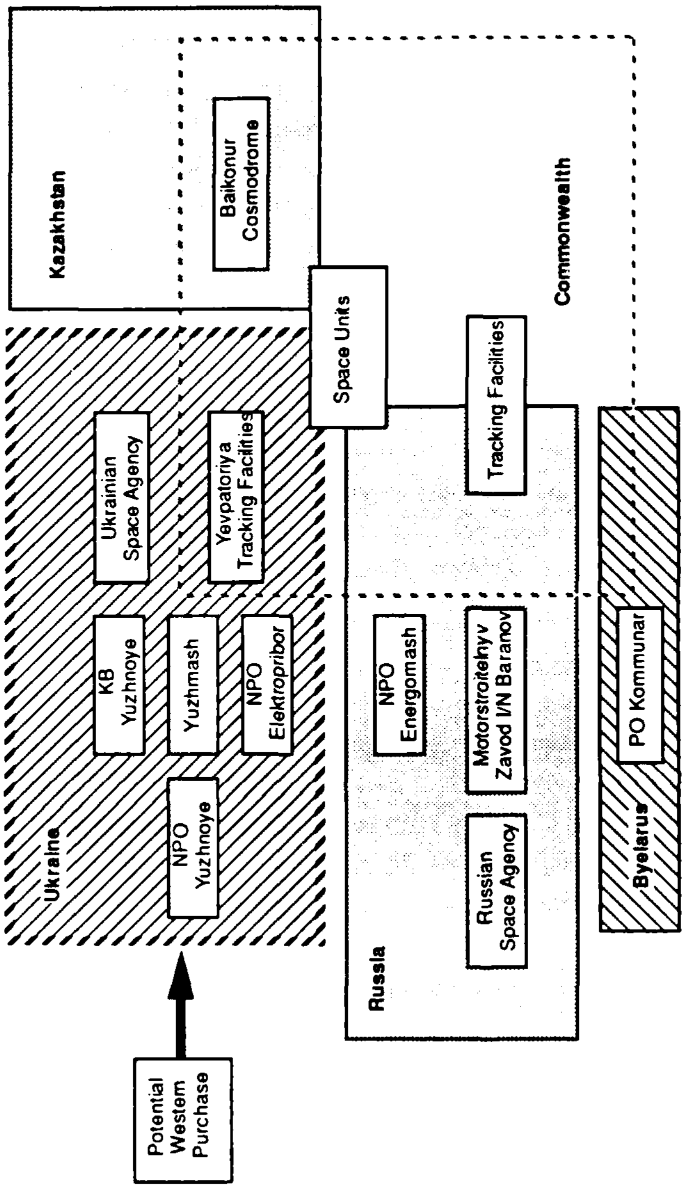
15 Lt. Col. M. Arkhipov, Space Units, Ministry of Defence, October 1991, as quoted from Berner, Lanphier, and Associates, Inc.

16 Anatoly Zak, Space Journalist, Nesavisimaya Gazeta, 21 November 1991, as quoted in Berner, Lanphier, and Associates, Inc.

17 *Aviation Week and Space Technology*, 30 March 1992; interview with engineer at PO Motorstroyeniya, Perm. The plant has been privatized, and as of that time received no orders for its primary product, aircraft engines.



Source: Berner, Lanphier and Associates, Inc.

Figure 6. Customer Interfaces Under the Russian Organization

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The clear implication is that *the complexity, and attendant difficulty and uncertainty involved in doing major space business with the CIS is not likely to inspire confidence in a potential customer.*

4. Organization: Military Space Forces

Under the Joint Space Agreement, the member states agreed that "the fulfillment of interstate programs of space research and exploitation in the area of military and dual purpose (military and civilian) space facilities [will be] ensured by the joint strategic armed forces" of the CIS. The meaning of strategic forces has been a key topic among the states. As defined in the Agreement on Strategic Forces (also signed in Minsk on 30 December 1991) they are given as: "groupings, formations, units, institutions, the military training institutes for the strategic rocket troops, air force, navy, and air defenses; the directorates of the space command and the airborne troops and strategic and operational intelligence and the nuclear technical units and the forces, equipment and other military facilities designed for the control and maintenance of the strategic forces of the former USSR." Apparently, the backbone of the Commonwealth's joint strategic forces will be the Strategic Deterrence Forces (SDF) created by Gorbachev in November 1991. The SDF will be comprised of key forces of the former Soviet Union:

- Strategic Rocket Forces (SRF)
- Ballistic Missile Early Warning Attack System (SPRN)
- Outer Space Monitoring System (SKKP)
- Ballistic Missile Defense Forces (PRO)
- Main Directorate of Space Systems (GUKS)

According to Army General Vladimir Lobov, the initial step in forming the SDF will be the formation of Space Forces. The key assets and capabilities provided to these Space Forces are expected to be drawn from the above elements of the former Soviet military. These are shown in Figure 7.[18]

Notable is the fact that the Space Units will continue to operate the launch, control, and tracking infrastructure (including the various cosmodromes). It appears that the concept is not too unlike the operation of the U.S. Space Command in that the command operates the assets, but does not "own" them. Since the various assets of the operational

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18 The figure is based on information derived from Berkowitz, Marc J., "Space Fallout From Soviet Disintegration," *Jane's Intelligence Review*, March 1992.

infrastructure are spread among a number of the member states, and due to the uncertainty in the CIS' longevity, *the success of space operations, both military and civilian, is likely to depend more on bilateral arrangements than on multilateral arrangements decided within the CIS*.

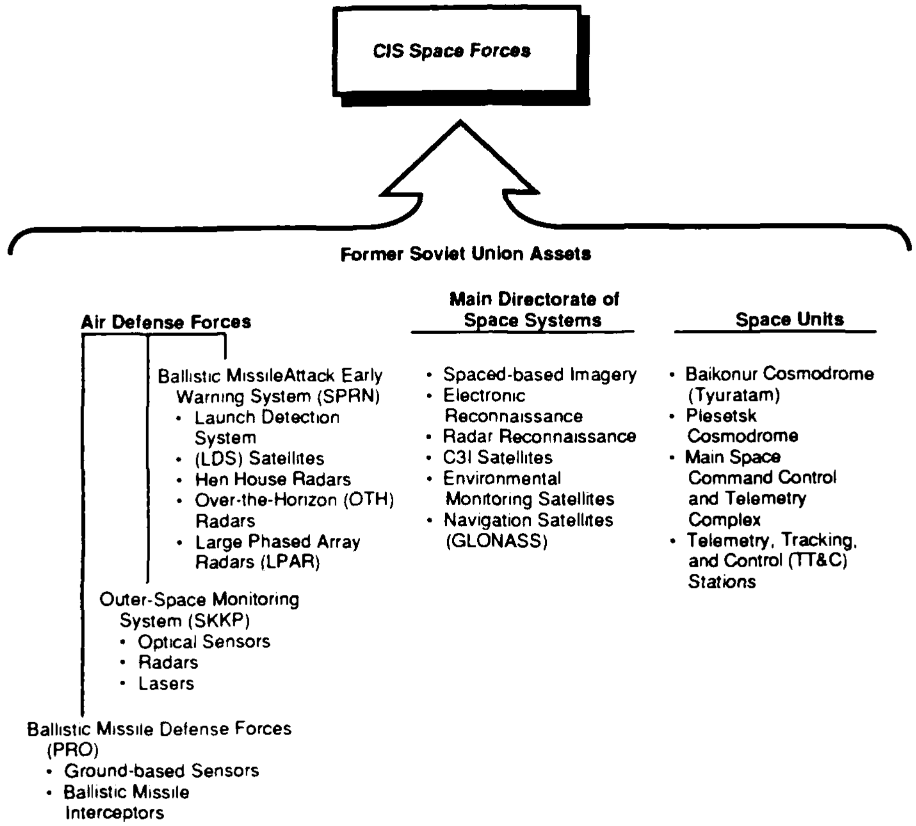

Figure 7. General Organization of CIS Space Forces

C. ASSETS AND CAPABILITIES

The competition in space between the Soviet Union and the United States produced an impressive array of launch vehicles, satellites, and space facilities. However, the United States and the Soviet Union approached the development of their programs in significantly different ways. The difference in the evolution of the two countries' space programs has resulted in some unique features of the space capabilities of the former Soviet Union.

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doctrinal need for rapid military launches, turn-around times had to be relatively short. Thus, *one of the basic features is the capability to achieve rapid launch rates, necessitated by both military need and the Soviet's lack of technological sophistication in certain areas.* This lack of sophistication in some areas has occasionally been compensated by other strengths. For instance, one limitation in the Soviet space program has been the paucity of clean room facilities. By virtue of this limitation, rocket engine components were designed to tolerate a dirtier environment. As a result, what may have been considered a limitation is now a strength, since assembly of many space hardware components does not require the kinds of clean room environments found in the United States.

In general, the early lack of technological sophistication that had been achieved by the United States in some cases resulted in "brute force" approaches. Ultimately, the brute force approach evolved into a substantial degree of sophistication with the former Soviet Union producing boosters of unprecedented lift capacity. A prominent example is the Energiya (SL-17) booster. *The space capabilities of the former Soviet Union, while unsophisticated in some areas, now place Russia and other CIS states in the lead in other areas, particularly propulsion.*

The following sections describe the general features and capabilities of the assets inherited from the former Soviet Union. Attention is given primarily to assets that are currently active, noting, where appropriate, differences in operations from the former regime. (The information on launch facilities, boosters, propulsion systems, and spacecraft is taken from the *Space Activities of the United States and Other Launching Countries:1957-1991*[19] and the *Interavia Space Directory*,[20] the *International Reference Guide to Space Launch Systems*,[21] and *Potential Russian/Ukrainian Entry into Commercial Space Launch Markets*.[22]

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19 Smith, Marcia S. *Space Activities of the United States and Other Launching Countries: 1957-1991*, Congressional Research Service, the Library of Congress.

20 *Interavia Space Directory: 1991-1992*, ed. Andrew Wilson, Jane's Information Group, 1340 Braddock Place, Suite 300, Alexandria, VA, 22314-1651.

21 Isakowitz, Steven J., *International Reference Guide to Space Launch Systems*, American Institute of Aeronautics and Astronautics, Washington, D.C., 1991.

22 *Potential Russian/Ukrainian Entry into Commercial Space Launch Markets*, Berner, Lanphier and Associates, Draft Final Annotated Report, 8 July 1992.

1. Key Research Institutes, Design Bureaus, and Manufacturing Facilities

As mentioned previously, by far *the majority of space-related organizations lies in Russia, and the bulk of that in or around Moscow, indicating the dominant role Russia plays in the space activities of the CIS.* The organizations fall into three rather general categories:

- NPO - Scientific Production Organization, or PO - Production Organization
- KB - Design Bureau, or OKB - General Design Bureau
- NII - Scientific Research Institute.

Their names indicate their prime functions, although there is overlap with other functions. The basic characteristics of the major organizations are summarized in Table 1.

2. Launch, Control, and Tracking Facilities

a. Flight Control Center

The **main Flight Control Center**, located about 10 kilometers northeast of Moscow in Kaliningrad, serves both manned and unmanned flights. The main control room carries out the control functions for the Mir space station and supporting Soyuz and Progress flights, with a smaller room for controlling Soyuz and Progress flights independent of Mir. A similar, independent room controlled the first Buran (space shuttle) mission, and an additional room accommodates communications between cosmonauts and their families.[23]

b. Cosmonaut Training Center

Cosmonauts are trained at the **Gagarin Cosmonaut Training Center (also called Star Town)** 30 kilometers northeast of Moscow. Facilities include classrooms, laboratories, centrifuges, and thermal chambers. Simulators allow training in Soyuz-TM and Mir. A IL-76 aircraft provides short weightlessness flights and also allows EVA training. Until the dissolution of the Union, cosmonauts had exceptional living conditions, including superior food, housing, and other perquisites. Since that time, conditions have deteriorated significantly, and at one point both the cosmonauts at Star Town and the flight controllers at Kaliningrad threatened to strike unless conditions improved. Neither

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23 *Interavia Space Directory: 1991-1992*, ed. Andrew Wilson, Jane's Information Group, 1340 Braddock Place, Suite 300, Alexandria, VA, 22314-1651.

Table 1. Russian/CIS Space R&D Facilities

Facility	Produces
NPO Kommunar Minsk, Belarus	Zenit inertial guidance
Central Aerodynamics Institute (TsAGI) Moscow, Russia	Aerodynamics research, possible use of thermal vac chamber for ESA's Hermes
Central Specialized Design Bureau (TsSKB) & Progress Plan Samara, Russia	Vostok, Soyuz, Molniya
Glavkosmos Moscow, Russia	Technical/management interface for commercial space systems
Institute for Space Research (IKI) Moscow, Russia	Micro-gravity research
Institute of Biomedical Problems Moscow, Russia	Premier life science research center
Intersputnik Moscow, Russia	Telephone, television, and data transmission services to subscribing customers (including AT&T, et al). Uses Russian Gorizonts and facilities
KB Khimautomatika Voronezh, Russia	RD-0120 engine
KB Machinostroyeniya Chelyabinsk, Russia	SS-N-8, SS-N-18, SS-N-23
KB Photon Samara, Russia	Resurs - F Earth obs, biocosmos, Photon & Nika-T microgravity spacecraft
KB Salyut Moscow, Russia	Proton, SS-19
NII Elektromekaniki Moscow, Russia	GOMS, Resurs - O, Meteor Earth obs satellites instruments for Almaz, Mir
NII Kosmisheski Pribor Moscow, Russia	Remote sensing and meteorological satellite pay-loads, mobile communications terminals, geodetic satellites, s/c electronics
NII Machinostroenye Yekaterinburg, Russia	Propulsion R&D institute and test facility
NPO Eksperimentalnoe Machinostroyeniya Reutov, Russia (Moscow)	Almaz radar satellite
NPO Energiya Moscow, Russia	Energiya

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Table 1. (Cont'd)

Facility	Produces
NPO Energomash Moscow, Russia	Liquid fueled engines (e.g., RD-170 engine)
NPO Kompozit Kaliningrad, Russia (Moscow)	Materials research, incl. Buran themal protection; micorgravity research equipment, s/c instrumentation
NPO Lavotchkin Moscow, Russia	Planetary & deep space craft, science satellites (Luna, Venera, Mars, Phobos, Spektrum, Astron, Granat)
NPO Molniya Moscow, Russia	Buran aerodynamic design, BOR cosmos subscale space plane, hypersonic research
NPO Prikladnoi Mekhaniki (PM) Krasnoyarsk, Russia	Ekran, Gorizont Raduga, all other comm sats
NPO Tekhnopribor Votinsk, Russia	SS-25, SS-20
NPO Zvesda Tomilino, Russia (Moscow)	Space suits
PO Polyot Omsk, Russia	Kosmos
PO Yuzhmash Dniepropetrovsk, Ukraine	Zenit tankage & integration
Splav Technical Center Moscow, Russia	Sole center dedicated to microgravity research & p/l
TsNII mashinostroenye Moscow, Russia	Applied research tasks, manages space operations/flight control center (TsUP)
VO Licentsintorg Moscow, Russia	Foreign trade organization; negotiates specific commerical space deals
Yuzhkosmos Dniepropetrovsk, Ukraine	Marketing services for NPO Yuzhnoye
NPO Elektropribor Kharkov, Ukraine	On-board computers, Zenit avoinics
NPO Yuzhnoye Dniepropetrobsk, Ukraine	TSiklon, Zenit, SS-18, SS-24

Source: *Interavia Space Directory: 1991-1992.*

alternative materialized; there was simply no way to improve the situation substantially, and controllers and cosmonauts alike realized that a strike would jeopardize lives. It is interesting and perhaps sobering to note that during the coup, Cosmonaut Sergei Krikalev, orbiting in the Mir station, was aware only that something unusual was occurring.

However, since the Flight Control Center operates under military control, there was great reluctance for controllers to explain anything until some resolution of the situation was clear.

c. Launch Complexes

There are three launch complexes in the former Soviet Union (see Figure 8). Located about 965 southeast of Moscow, on the banks of the Volga River, **Kapustin Yar** (also known as the Volgograd Station) was the first Soviet rocket development center, first used in 1947. It may be considered analogous to the NASA's Wallops Island launch site. During early years most of its launches were of sounding rockets carrying small animal experiments. Since then it has launched a number of orbital missions, most of which have been small scientific satellites. Before the coup it was launching only about one flight per year, but was determined to be the launch site of the subscale spaceplane test in 1984.

Figure 8. CIS Launch Sites

Plesetsk averages on the order of 50 percent more launches than the other sites. It is located 170 km south of Archangel, and is used principally for polar launches (which include certain communications and reconnaissance satellites). Because most of its launches have historically been associated with military missions, Plesetsk is generally considered the analog of the Western Test Range at Vandenberg AFB. It has had more launches than the rest of the world put together.

For safety reasons, retrograde orbital missions (such as meteorological satellites) are never launched from Plesetsk. Satellites launched from Plesetsk appear to be limited to orbit inclinations of from 62 to 83 degrees. Retrograde-orbit meteorological satellites are launched from Baikonur, despite the slight penalty required in launch energy due to Baikonur's lower latitude.

Using fairly extensive automation and horizontal integration of payloads and stages, the site launches the powerful SL-6 Molniya (used in launching Molniya commsats into highly elliptic orbits), as well as the SL-14 Tsiklon. It has a minimum of nine available pads. Before the coup, there were plans to construct pads and facilities to accommodate the SL-16 Zenit booster.

Two explosions at Plesetsk (1980 and 1989), both during refueling operations, may suggest occasional laxness in safety. During the launch of the U.S. TOMS instrument on the SL-14 Tsiklon booster, one technician approached within a few feet of the fueled third stage carrying a lighted cigarette; he was, however, admonished by a guard.

In another instance, during preparations for the August 1991 launch of a Tsiklon (SL-14) carrying the U.S.' TOMS instrument, there appeared to be no great concern when a transformer powering an ultraviolet inspection light began giving off sparks near the fueled third stage.[24] Despite these incidents, there is increasing awareness and concern for safety as reflected in the fairly high degree of automation inherent in Tsiklon launch operations.

Given the high launch rate of the installation, over the years a great deal of spent stages and debris has fallen on the surrounding area. The situation became so bad that in 1991 residents of the surrounding area complained about the environmental contamination. The debris is now recovered and to some extent recycled.

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24 *Aviation Week and Space Technology*, September 16, 1991.

Tyuratam, now officially the **Baikonur Cosmodrome**, is the site for all manned launches, geosynchronous, and planetary missions. It was also the site for launches of the ASAT interceptor until those missions ceased in 1982. Missions have been launched from Baikonur less than 24 hours apart, and Protons have been separated by as little as 4 days.

Located in Kazakhstan, near the rail stop village of Tyuratam, Baikonur represents that country's principal space program asset, and the largest and most versatile launch site of the CIS space program. The major residential area of Leninsk grew up around "Old Town" Tyuratam as a planned city beginning in the mid-1950s. Under bilateral agreement (in addition to the Joint Space Agreement), and amidst some turmoil dealing with equitable treatment of Kazakh personnel, Russia and Kazakhstan have arranged for the continued use of the site.

Baikonur provides a minimum of 10 available launch pads to support launches of the A-Class boosters (Vostok, Molniya, and Soyuz), and Proton, Zenit, and Energiya (including the Buran configuration) vehicles. It is the only facility capable of launching the Proton, Zenit, and Energiya. All other boosters except the Kosmos can be launched from Baikonur. Integration and launch processing involves a significant amount of automation.[25] For the A-class boosters, mating of payloads and stages is done in separate buildings. Progress and Soyuz spacecraft are integrated in the same building. Following mating, the launch vehicle is transferred via a rail transporter to the main Soyuz pad (about 5 km northeast), erected and fueled. Other A pads are further east. (See Figure 9.)

The Energiya area is located to the northwest of the Soyuz area. The SL-17 Energiva booster is flown in via aircraft, and integrated horizontally in two buildings. The core of the Energiya arrives at the nearby airstrip from its manufacturing facility in the Russian Federation. It is integrated in one facility, then mated with the Zenit strap-ons in a separate building. The assembly is then transported to a high bay facility for integration with either its payload canister or the Buran orbiter. The combination is then placed on a transporter-erector, and transferred to the pad by rail.

Further to the northwest is the Buran landing strip, some 4.5 km long that also supports various test and training aircraft flights. The strip is instrumented for fully automatic landings, with operations controlled from a nearby building.

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25 More discussion of launch processing can be found in the individual sections describing each booster.

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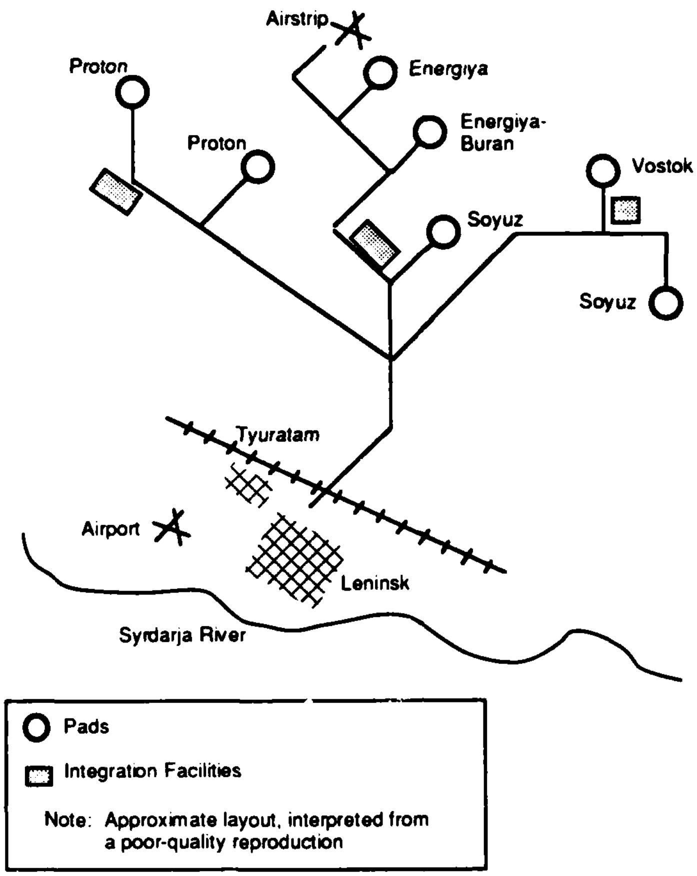

Figure 9. Approximate Layout of Baikonur Cosmodrome

To the west of the airstrip lies the Proton launch area. Integrated Proton boosters are rail transported to one of two launch pads separated by a distance of only 600 meters. Eventually these are expected to be replaced, and are planned to accommodate the new Proton KM with cryogenic fourth stage.

d. Tracking Facilities

Worldwide tracking and communications coverage is made possible by an array of ground, ship-based, and satellite systems. Control of high altitude and deep space missions is provided by the Long Range Space Communications System at Yevpratoria in the troubled Crimean region. The site has 70- and 32-meter antennas, with similar antennas at Ussirsk. A 25-meter system is located at Ulan Ude, and together with radio telescope antennas at Suffa Plateau (70 m), Medvezhi Ozera (64 m), Simiez, and

Pushchino (22 m) form an extensive, sensitive tracking capability for deep space spacecraft.

The main Flight Control Center near Moscow (discussed above) is supported by telecommunications sites located as shown in Figure 10. This network is augmented by Luch geostationary satellite data relay network satellites, and Molniya communications satellites that provide links between tracking ships and land sites to Moscow.

Because under the former Union the Soviets were intent on not having permanent facilities in other countries, tracking ships were used to achieve global coverage for satellite telemetry, tracking, and control. Flagship of the tracking fleet is the Cosmonaut Yuri Gagarin, which employs over 6 dozen antennas, including pairs of 25 m and 12 m parabolic dishes. Seven other ships can support tracking. The fleet is monitored by the West since deployment is an indication of likely space launches; little activity of these ships has been seen recently. While the fleet may become obsolete due to increasing reliance on data relay satellites, the events of 1991-1992 suggest this may be some time in the future. Further, the youngest ship was built in 1989; the keel was laid in 1988 for yet another ship.

3. Space Boosters and Propulsion Systems

One of the principal strengths of the former Soviet Union's space program is its rocket propulsion capabilities. As noted earlier, military payload needs coupled with an early lack of technological sophistication led the Soviets to the development of large boosters. The result is a stable of impressive, large payload launch capabilities. Another distinguishing feature is the *robust ability of boosters and launch systems to operate in extreme weather and climate conditions*.

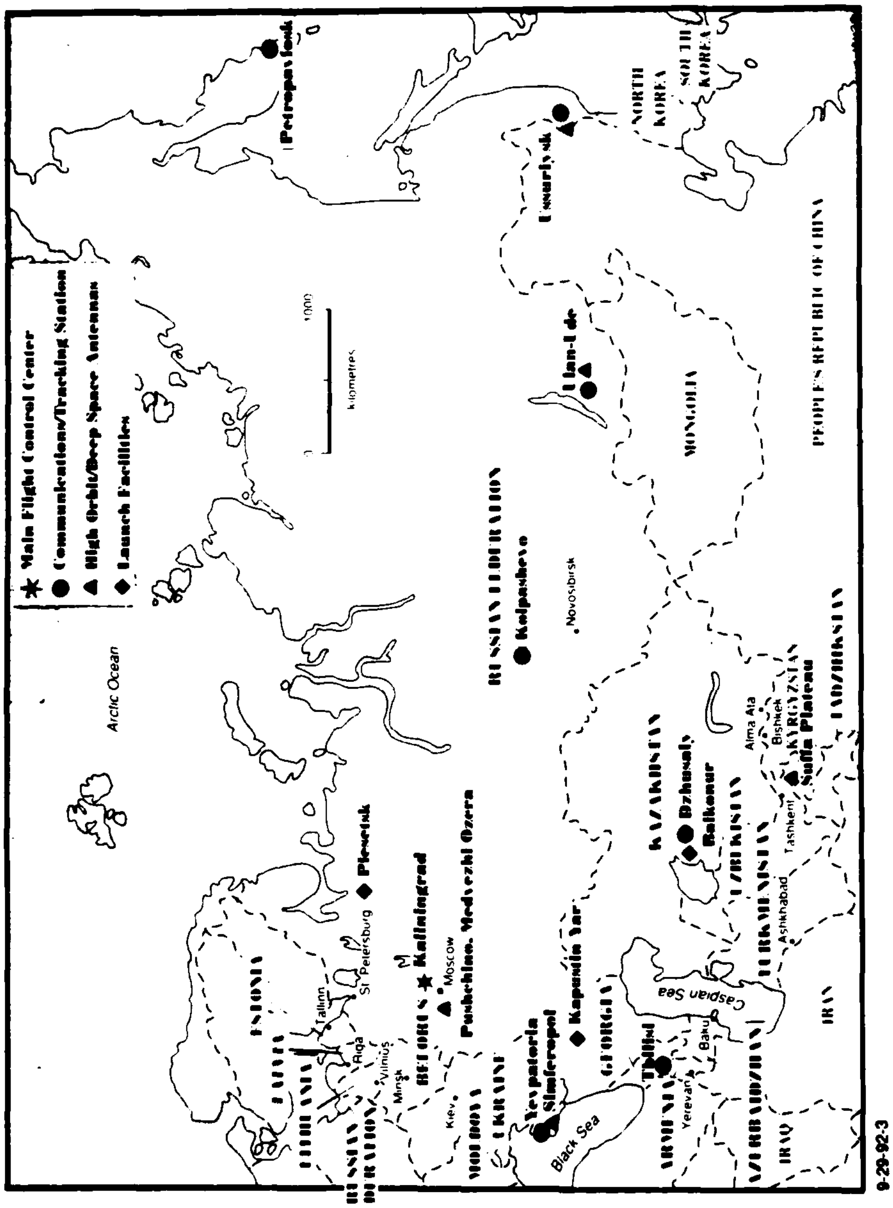

Figure 10. Launch Facilities, Flight Control and Tracking Stations

Figure 11 gives the names and major characteristics of the currently active space boosters.[26] (Only the major characteristics of these systems are discussed here; for more information about payloads, flight profiles, performance characteristics, etc., see footnotes 27 and 28.)

a. Vostok/Soyuz/Molniya

The A-class Vostok, Soyuz, and Molniya launch vehicles can be considered *the backbone of the former Soviet launch capability*, having comprised some 60% of all Soviet launches. Belonging to the same family of vehicles, they are based on the original Soviet ICBM, the SS-6. The early versions (SL-1,-2, and -5) have been replaced by the SL-3 Vostok, SL-4 Soyuz, and the SL-6 Molniya. These vehicles have been produced under the Central Specialized Design Bureau (TsSKB) and Progress Plant, located in Samara, Russia.

Vostok boosters are primarily used to launch sun-synchronous satellites. A two stage vehicle, they are launched exclusively from Tyuratam (although the capability exists to launch from Plesetsk). This vehicle was used for the first commercial Soviet launch in March 1988, when the Indian remote sensing satellite, IRS 1A, was launched. That the launch was carried out on schedule from Tyuratam, amidst a driving snowstorm, is testimony to the robust ability of former Soviet technology to operate successfully in weather and climate extremes. At $500,000, Vostok is an unparalleled bargain.

The **Soyuz**, also a two stage rocket, may be considered the workhorse of the Russian rocket stable. It has been used for all manned missions, and has continuously supported photoreconnaissance and remote sensing missions. It is the principal vehicle for

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26 The alpha-numeric labels associated with the boosters represents the designation system originated by Dr. Charles Sheldon of the U.S. Library of Congress. For example, a variant of the Proton has the designation D-1-e, where:

D is the family
1 is the variant of upper stage within the family
e indicates Earth escape capability.

Others are:

m - maneuverable
r - reentry.

27 Smith, Marcia S. *Space Activities of the United States and Other Launching Countries: 1957-1991*, Congressional Research Service, the Library of Congress.

28 *Interavia Space Directory: 1991-1992*, ed. Andrew Wilson, Jane's Information Group, 1340 Braddock Place, Suite 300, Alexandria, VA, 22314-1651.

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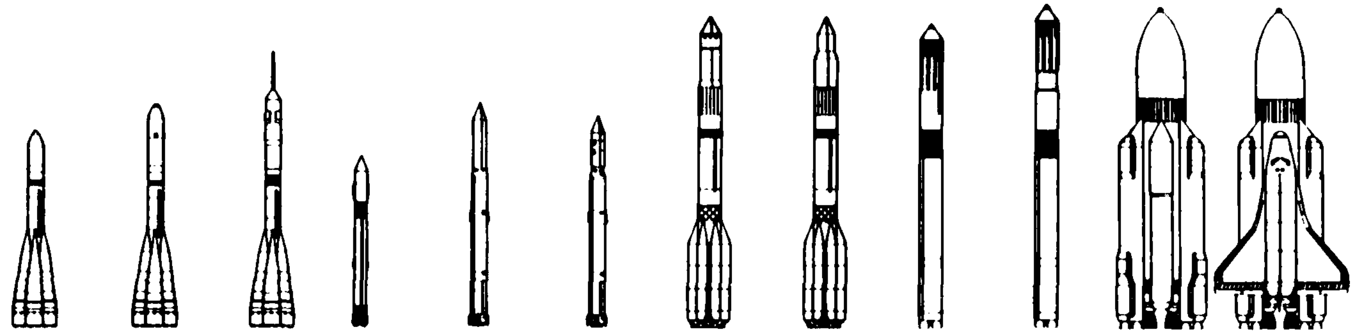

Note: Alpha-numeric lables are the Sheldon designation

LAUNCH VEHICLE		MAXIMUM	FIRST	LAUNCH HISTORY			LAUNCH
RUSSIAN NAME	US NAME	PAYLOAD (lbs)	LAUNCH	SUCCESS RATE (%)	SUCCESS/ TOTAL	AVG RATE 1985-90	FACILITY
VOSTOK MOLNIYA SOYUZ	SL-3[1] SL-6[1] SL-4[1]	LEO 10,400 MOL 3,300 LEO 15,400	1959 1960 1963	95.6	1358/1421	49.3	BK, PL BK, PL BK, PL
KOSMOS	SL-8[2]	LEO 3,000	1964	98.4	371/377	10.8	PL, KY, BK[5]
TSIKLON	SL-11[3]/14	LEO 8,800	1966/77	99	199/201	13	BK, PL
PROTON K PROTON	SL-12 SL-13	GTO 12,100 LEO 44,100	1967 1968	87.7	164/187	10.5	BK
ZENIT ZENIT-3	SL-16[4]	LEO 30,300 GTO 9,480	1985 1993	82.4 ---	14/17 ---	2.2 ---	BK,PL[6]
ENERGIYA	SL-17	LEO 194,000	1987	100	2/2	0.5	BK

LAUNCH FACILITIES: BK - BAIKONUR, PL - PLESETSK, KY - KAPUSTIN YAR

1. BASED ON THE SS-6 ICBM
2. BASED ON THE SS-5 ICBM
3. BASED ON THE SS-9 ICBM
4. FIRST STAGE SERVES AS ENERGIYA STRAP-ON
5. NOT LAUNCHED AT BAIKONUR SINCE 1984
6. CONSTRUCTION OF ZENIT PAD AT PLESETSK ON HOLD

Figure 11. Russian and Ukrainian Launch Vehicles

launching the Soyuz and Progress spacecraft (in support of the Mir space station), and was used in the launch of a Japanese journalist to the Mir station in December 1990. It is the most flown launch vehicle in the world.

The **Molniya** provides a somewhat greater lift capability than the Soyuz, mainly due to its third stage. During the 1960s it supported all the planetary and most lunar flights. Today its sole purpose appears to be for launch of Molniya communications and Kosmos launch detection satellites into their highly elliptical, semi-synchronous orbits. Initially flown from Baikonur, it is now launched exclusively from Plesetsk.

For an A-class launch, the particular vehicle is delivered to an assembly complex (the Space Vehicle Assembly Building, or MIK). The integration process starts a few weeks prior to launch, and entails assembling the four strap-on boosters together with the first, second, and, for Molniya, third stages all in a horizontal position. In the case of Vostok and Molniya, however, the payload and final stage are integrated vertically. The spacecraft (fully fueled!) is also mated to the launch vehicle from a horizontal position. Following integration and test, the entire assembly is transported to the pad by rail (usually within 48 hours of launch) where it is erected for launch.

b. Kosmos

Based on the SS-5 Skean, the SL-8 Kosmos is a two stage, storable propellant system produced by PO Polyot in Omsk, Russia. Although it has been launched from all three launch sites (it is the only vehicle with this capability), Tyuratam was only used for initial flights. Kosmos' primary launch site is Plesetsk. During the period 1982-1984 the Kosmos vehicle carried the BOR-4 subscale spaceplane on launches from Kapustin Yar to test materials performance associated with development of the Buran space shuttle program.

Although it is the *smallest vehicle in the launch stable*, it is typically used to launch multiple satellite payloads into low Earth orbit. Most of these are low altitude navigation and store/dump communications satellites. Integration of booster and payload is carried out using the typical horizontal approach, transported to the pad, then erected for launch.

c. Tsiklon

The SS-9 forms the basis for the SL-14 Tsiklon, a two or three stage vehicle depending on its application. The two stage variant, (F-1 in the Sheldon designation) was *used principally for military missions*, having been used for the fractional orbit bombardment system (FOBS, F-1-r) and for the antisatellite interceptor (F-1-m).

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Additionally, its military missions have included launches of radar and electronic ocean reconnaissance satellites. Launches of the F-1 variant are only done at Baikonur.

The F-2 variant, launched from Plesetsk, has assumed many of the earlier missions performed by the Kosmos and Vostok vehicles. *In overall capability it can be considered to lie between the Kosmos and A-class vehicles.* Its missions include launching various communications, meteorological, remote sensing, geodesy, and ELINT satellites.

The Tsiklon, produced by NPO Yuzhnoe in Dniepropetrovsk, Ukraine, is now offered as a medium class booster on a commercial basis. It was used in 1991 to launch a payload that included the U.S. Total Ozone Mapping Sensor (TOMS).

Despite the fact that this vehicle has suffered launch accidents (explosions during 1989 and 1990 refueling operations), *ground servicing prior to launch entails a fairly high degree of automation, thus minimizing the need for personnel at the pad.* The ability for rapid launch (as little as 60 to 90 minutes on the pad) was motivated in part by its use in the Soviet ASAT co-orbital interceptor program. Integration and transport to the pad is done horizontally. Launch can be accomplished within 24 hours after payload integration, in temperatures ranging from -40°C to +50°C, and in winds up to 20 m/s.

d. Proton

Developed during the early sixties by KB Salyut, Moscow, the Proton has been the *largest booster in the former Soviet inventory (until the emergence of the Energiya in 1987).* Two, three, and four stage variants were developed, although only the three stage (SL-13, D-1) and four stage (SL-12, D-1-e) versions are in use today.

A versatile vehicle by virtue of its size, its primary *missions include the full range from low Earth orbit through planetary missions.* Nearly 90 percent of the Proton launches use the D-1-e variant. It is employed extensively for geosynchronous satellites such as Ekran, Raduga, and Gorizont (see below), as well as Earth escape missions (lunar, Venus, Mars, etc.). It is being offered commercially for about $25 million, and has been selected to launch Inmarsat-3, a Western geosynchronous communications satellite. Representative payload capabilities are shown below:

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Mission	Proton Payload Mass (kg)
LEO	20,000
Lunar Transfer	5,700
GEO Transfer	5,500
Venus Transfer	5,300
Mars Transfer	4,600
Sun Synchronous	2,800
GEO	2,200

Sun synchronous missions entail retrograde orbits. The associated retrograde launches must overcome the Earth's rotational velocity, which is why the delivered payload is so much smaller than that for interplanetary missions. GEO missions require additional fuel mass in order to achieve final orbit, resulting in relatively small payload masses compared to the others.

Proton is launched only from Baikonur. Assembly and integration of the Proton's stages are carried out horizontally in the main Proton assembly building. This building can accommodate as many as six boosters at a time, and up to three Protons can be assembled over a period of 3 weeks.

If a fourth stage is employed (it usually is), integration with the spacecraft payload is accomplished in a separate satellite preparation building. It is then transported to the Proton assembly vehicle building, via truck, for horizontal integration with the booster. The entire assembly is rail-transported to one of two operational pads. Installation of the vehicle on the pad takes about 4 hours, with launch occurring 3 to 4 days later.

e. Zenit

Zenit is the second launch vehicle now owned and produced in the Ukraine (recall that the other vehicle is the Tsiklon, also produced by NPO Yuzhnoe in Dniepropetrovsk). There are two variants, Zenit-2 and Zenit-3. The Zenit-2 is a two stage booster capable of 13,740 kg to LEO, and is essentially the same vehicle used for strap-ons to the heavy lift Energiya. While its *principal support is for military ELINT missions*,[29] it is expected to provide space station support, as well as remote sensing and other scientific satellite launches.

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29 *Potential Russian/Ukrainian Entry into commercial Space Launch Markets*, Berner, Lanphier and Associates, 8 July 1992.

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The first launch of the three stage variant is planned no earlier than 1993. It is expected to provide the capability to place about 4,300 kg into geosynchronous transfer. The vehicle was originally intended to be the mainstay booster of the Cape York Space Agency (CYSA, a private concern involving the former Soviet Union, Australia, and the U.S.' United Technologies that planned to provide commercial launch services). Aside from its near-equatorial location allowing greater performance efficiencies,[30] it was intended to circumvent the U.S. restriction on launching U.S. satellites from the Soviet Union, despite Soviet assurances that no Soviet access to the satellite payloads would be allowed. With the dissolution of the Union, this advantage has faded sufficiently that the initial CYSA plans have been discontinued. However, there appears to be some renewed interest in reconsidering Cape York for commercial launch services.

Zenit is launched from Baikonur (although pads were intended for Plesetsk, these have been suspended, at least temporarily, in the face of tough economic times). Like the other launch vehicles, Zenit is assembled horizontally. Benefiting from the NPO Yuzhnoe experience with Tsiklon/ASAT, all assembly, integration, and checkout are accomplished with a high degree of automation. The system can be readied rather rapidly, with assembly requiring about 80 hours, and payload integration about 4.5 days. Following integration, the integrated system is moved to the pad and erected.

At the pad virtually all the processes of positioning, fueling, and on-pad checkout are automatic. This capability makes it possible to launch up to 15 missions per year from the dual-pad complex.

In 15 launches, Zenit has experienced a string of 3 failures, the first occurring in October 1990. (There are assertions that claim the drastic political and economic changes may have played a role.)[31] This has resulted in delay of the Zenit-3 reaching service.

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30 Located about 12 degrees south of the equator, launches from Cape York would achieve slightly greater assist from the Earth's rotation (around 440 m/s when inserting into LEO at 200 km versus 380 m/s for Cape Canaveral launches or 324 m/s for Baikonur launches). More beneficial could be the fuel savings when inserting into GEO, because the plane change required for equatorial orbit from high latitudes entails large velocity impulses. GEO launches from Cape Canaveral would require about 20% more fuel for the GEO insertion maneuver than from Cape York; launches from Baikonur would require nearly double the fuel for insertion.

31 Experienced, highly skilled workers surrendered to even higher wages in cooperatives. Irregular production of Zenit...came to be of lesser quality...," LtCol M. Arkhipov, Space Units, Ministry of Defense, October 1991.

f. Energiya

Preceded by the discontinued N-1 launch vehicle development program,[32] the SL-17 Energiya has been *developed as a modular heavy lift capability to support a variety of payload requirements, including the former Soviet space shuttle, Buran.* While claims of 100 metric tons (100,000 kg) in LEO have been made for this vehicle, the actual capacity provides only a suborbital capability for this mass. The corresponding orbital capability to LEO is about 88 metric tons (still rather impressive). Two new auxiliary stages have been planned, and once these are available, high Earth orbits and Earth escape missions will be possible for this vehicle.

The vehicle employs from two to eight Zenit-2 boosters as strap-ons for the first stage. These are recoverable and reusable (employing the impressive RD-170 LOX/kerosene engine, they are designed for up to 10 reuses). For the Buran application, four strap-ons are used.

While one motivation for the vehicle was the desire to emulate the U.S. shuttle capability, certain *significant features make the system unique.* First, it is dual purpose in that it can fly either manned (using Buran) or unmanned (using cargo carriers). In both cases, the "payload" (either Buran or a cargo carrier) is side mounted. Buran differs from the U.S. space shuttle in that Buran includes no main propulsion. Hence development of the propulsion system was able to proceed relatively independently of the Buran orbiter. The modular design including the varying number of strap-ons allows for a wide range of payloads--from 10,000 to 200,000 kg. An additional capability is an all-azimuth launch. Safe impact of spent stages is satisfied by the two stage configuration, making possible low burnout velocity of the initial stages, and hence recovery and reuse. In addition, reliability is incorporated at high levels through extensive application of redundant systems.

Originally, a scaled down version, Energiya-M, was planned for test launch in 1993. This vehicle would employ two strap-ons and a scaled down core for a payload capacity of about 40,000 kg. While the current Energiya employs 4 core engines, the Energiya-M would use only a single core engine. Modular design would allow two additional strap-ons (a total of four). An Energiya-T was also being considered that included a Buran on one side and a small spaceplane on the other.

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32 The N-1 employed 30 first stage engines for a total of a whopping 10.1 million pounds (45 million Newtons) of thrust.

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The future status of these alternative versions is uncertain--as is the complete Energiya program--owing to the significant uncertainties facing the Russian and CIS space programs in view of the difficult economic conditions. Developed under NPO Energiya in the Kaliningrad region of Moscow, the program involves the coordinated action of over 500 enterprises, which is unlikely to continue undisrupted. There has also been criticism of the Energiya and Buran programs as inappropriate, and consideration of outright cancellation of at least Buran and perhaps Energiya as well.

Launch of the Energiya, either manned or unmanned, takes place at Baikonur. There have been two launches to date--one in 1987 without the Buran and the other in 1988--which successfully placed the Buran in orbit. Although the Zenit strap-ons are transported to Baikonur via rail, the core vehicle is flown in from the manufacturing facility in Russia to the nearby 4.5 km Buran landing strip. Assembly, integration, and checkout are all done horizontally in the Space Vehicle Assembly Building, a structure resembling the Vertical Assembly Building (VAB) at Kennedy Space Center. For Buran missions, the orbiter is mated horizontally on top of the Energiya vehicle. Once integration is complete the entire system is transported to one of the two Energiya/Buran pads, or the single Energiya only pad. Transport is also horizontal, requiring four diesel locomotives to lug the huge assembly to its designated pad. Once there, a massive hydraulic system lifts the vehicle into place for launch.

Launch preparations at the pad are highly automated, employing three dual-processing systems; only two computers are necessary to accomplish the launch.

4. ICBM and SLBM Conversions

With the drastically changed situation, there have been a number of plans put forth to convert former Soviet strategic missiles into orbital and suborbital launch vehicles, primarily for small payloads such as microgravity capsules. While some may offer certain advantages, their resulting capabilities do differ markedly from the existing stable of boosters. In fact, some observers have noted that these plans may be based on an unclear understanding of the potential commercial launch market. As a result, *these conversion proposals may be intended more to keep workers employed in their traditional skills*. Consequently, the discussion here is brief, being provided principally for completeness.

a. SS-18

Manufactured by NPO Yuzhnoe in Ukraine, the liquid propellant SS-18 provided the greatest throw weight of any ICBM in the world, offering the potential for a significant

LEO capability. NPO Yuzhnoe sets its performance at 4,410 kg to a 200 km orbit. Baikonur would be the intended launch site. Although the Ukrainian government announced that SS-18s are no longer being produced, NPO Yuzhnoe is working with NPO Lavochkin on developing a microgravity capsule that could be used by the coverted vehicle. The program is at least 2 years short of operational status, and success will depend on western investment.

b. SS-19 (Rokot)

Developed by the Salyut Design Bureau, Rokot is also derived from a liquid propellant ICBM. In addition to the two stages of the ICBM, a new third stage is planned to provide the needed orbital capability. However, its payload is only about half that of the SS-18.

Most advanced in its conversion, its suggested uses include microgravity experiments, and for "ship rescue capsules." KB Salyut has indicated a possible application illustrated by a trapped Soviet icebreaker a few years ago. Difficult to reach otherwise, the (claimed) high accuracy of the SS-19 would have allowed the prompt delivery of emergency supplies to within meters of the ship.

c. SS-25 (Start-1)

The road-mobile, solid propellant SS-25 has also been identified as a potential small payload launch vehicle. Although its applications are expected to be primarily microgravity, a unique feature that could make it attractive for other applications is its mobility--presumably it could be launched from anywhere air or ground transport could place it.

Currently under development, the conversion is being carried out under NIITP (Scientific Research Institute for Thermal Processes in Moscow), and produced by the Votkinsk Machine Building Plant. Its performance to LEO is estimated at 350 kg, and advertised availability is 1993.

d. SS-24 (Space Clipper)

This system concept involves development of an air-launch capability based on the technology of the SS-24 solid propellant ICBM. Because conditions of the START Treaty prohibit new basing mode for current ICBMs, existing SS-24s will not actually be converted. Instead, NPO Yuzhnoe will apply its experience in the development of a similar launch vehicle to be launched from an AN-124 aircraft. This airbasing offers both highly

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mobile and inclement weather launch capability. Payload capacities are expected to range from below the Scout class to above Pegasus capability.

Development is being hampered by the difficult economic conditions, and success will depend heavily on foreign investment.

e. SS-N-8(Vysota)/SS-N-18(Volna)/SS-N-23 (Shital)

Conversion of SLBMs has also been in the works. These missiles were all developed by KB Machinostroyeniya in Moscow, and produced at a Siberian plant near Chelyabinsk. The capabilities of these vehicles are more limited than the ICBM conversions discussed above; their primary application would be for microgravity experiments involving payload weights of around 130 kg. The launch platform, of course, would be one of the Delta class submarines, ostensibly allowing launch from any accessible ocean region.

5. Propulsion Systems and Technologies

As previously noted, notoriety of the former Soviet space capability is owed in part to its very capable propulsion systems technology. Two particularly notable systems are discussed below. Table 2 provides key information associated with the propulsion systems of current launch vehicles.

a. RD-107/108

Because these two engines are used extensively in the A-family of launch vehicles (Vostok, Soyuz, Molniya), they can be considered the most used rocket engines in the world. Over 25,000 have flown: 16 RD-107s (4 for each strap-on) and 4 RD-108s (4 in the core stage) are used. Originally designed during 1954-1957 by OKB-GDL (now NPO Energomash), the long use of these engines attests to the durability of their design.

b. 11D58M

This engine powers the only operational upper stage for delivering CIS satellites to GTO or GEO. This upper stage, originally designated Block D, and now DM, constitutes the fourth stage of the Proton D-1-e launch vehicle. It is also planned for the Zenit-3 to provide it with GTO/GEO capability (notable is the fact that the Block DM stage delivers a satellite directly into GEO, obviating the need for an apogee kick motor, normally used by the West).

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Table 2. Current Launch Vehicle Engine Characteristics

Engine	Launch Vehicle: Stage	Fuel	Oxidizer	Max Thrust (K lbs)		Specific IMP (s)		Burn Time (s)
				SL	Vac	SL	VAC	
RD-107	SOYUZ, VOSTOK, MOLNIYA: SO	KER	LOX	184.6	224.8	257	314	140
RD-108	SOYUZ, VOSTOK, MOLNIYA: CORE	KER	LOX	167.5	211.5	248	315	320
RD-461*	SOYUZ, MOLNIYA: 2	KER	LOX	---	67	---	330	230
RD-448*	VOSTOK: 2	KER	LOX	---	12.4	---	323	430
U/I*	MOLINYA: 3	KER	LOX	---	14.8	---	340	200
RD-216	KOSMOS: 1	UDMH	NO/NA	165	194.2	248	291	170
RD-712?	TSIKLON: 1	UDMH	N_2O_4	551	617.1	309	U/I	120
RD-219M?	TSIKLON: 2	UDMH	N_2O_4	---	222.6	---	324	160
U/I	TSIKLON: 3	UDMH	N_2O_4	---	17.5	---	U/I	U/I
RD-253	PROTON: 1	UDMH	N_2O_4	331.4	367.5	285	316	130
RD-0210*	PROTON: 2, 3	UDMH	N_2O_4	---	134.9	---	343	212
11D58M*	PROTON K: 4 & ZENIT-3: 3	RP-1	LOX	---	19.1	---	351.8	680
RD-170	ZENIT1	KER	LOX	1,631	1,776.80	309.00	337	140-51
	ENERGIYA: STRAP ON							145
RD-120	ZENIT: 2	KER	LOX	---	181.5		350	200-315
RD-0120*	ENERGIYA: CORE	LH	LOX	326	441	354	452.5	480

Fuels: KER-Kerosene, UDMH - Unsymetical Dimethylhdrazine, LH - Liquid Hyrdrogen Oxidizers: LOX - Liquid Oxygen, NO/NA - Nitrous Oxide/Nitric Acid, N_2O_4 - Nitrogen Tetraoxide

* Designed by the Kosberg Design Bureau, now KB Khimavtomatiki.
Remainder were designed by Glushko's organization (OKB-GDL, OKB Glushko, NPO Energiya, now NPO Energomashi)

Source: Bemer, Lanphier and Associates

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c. RD-170

This is perhaps the most advanced rocket propulsion system in the world. Developed by NPO Energomash (Moscow), this LOX/kerosene engine has received strong interest from the West, no doubt because of the following points:

- Highest chamber pressure: 250 atmospheres vs. 204 for the U.S. Space Shuttle Main Engine (SSME)
- Highest thrust: 7256 kN (1,631,00 lbs) vs. 6,900 kN (1,552,000 lbs) for the old Saturn V F-1
- 96 percent success rate: 25 flights with only one RD-170 failure
- Reuse: Designed for up to 10 (SSME is designed for many more reuses, however)

The RD-170 employs a single turbopump to feed four combustion chambers. As noted previously, the RD-170 is employed by the Zenit launch vehicle, and hence the strap-ons for the Energiya.

d. RD-0120

This second notable propulsion system was developed by KB Khimautomatiki, and represents the first operational, fully cryogenic engine used on a Soviet launch vehicle. Four of these single chamber engines are used to power the core section of the Energiya launch vehicle. Reusability of the engine is not clear.

e. Spacecraft Propulsion Systems

In addition to the launch vehicle propulsion systems discussed above, there are a variety of former Soviet spacecraft propulsion systems. Table 3[33] summarizes performance data associated with those commonly used on lunar and interplanetary flights, principally for maneuvers, orbit insertions, and surface landings. Thrust levels range from about 2 kN to nearly 20 kN; propellants tend to be quite toxic, but produce high specific impulses (approaching 300 seconds). All of these were designed by OKB Isayev, which is now apparently part of KB Soyuz.

Attitude control propulsion systems commonly employ hydrazine thrusters, as in the West, and provide thrusts ranging from below one Newton up to a few hundred Newtons.

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33 Berner, Lanphier, and Associates, Inc., *Potential Russian/Ukrainian Entry into Commercial Space Launch Markets*, Draft Annotated Report, 8 July 1992.

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Table 3. Spacecraft Propulsion Systems Characteristics

Engine	Thrust (kN)	Isp (s) In Vacuum	Number of Firings	Operating Time (s)	Chamber Pressure (atm)	Fuel	Oxidizer	Applications
TDU-1	15.83	261	1	45	U/I	AMINES	NA	VOSTOK, VOSKHOD
KTDU-5A	45.5	278	1	43	64	AMINES	NO	LUNA 4, 9, 10, 14
KTDU-414	1.96	271	2	40	12	UDMH	NA	VENERA 2-8; MARS 1; ZOND 1-3; KOSMOS
KTDU-425A	9.86-18.89	293-315	7	560	95	AMINES	NO	MARS 4-7; VENERA 9-16 VEGA 1-2; PHOBUS 1-2
KTDU-35/53/66	4.09	281	25	500	40	UDMH	NA	SOYUZ 1-40; ZOND; SALUT 1 SPACE STATION
KTDU-417 (Primary)	735-18.92	308-314	11	650	U/I	UDMH	NO	LUNA 15, 24
(Secondary)	2.06-3.43	249-254	U/I	30	U/I			PHOBUS
KRD-61	18.8	313	1	53	95	UDMH	NO	LUNA 16, 20, 24

Engine Designators: KTDU - Corrective-Braking Rocket Motor
KDU - Corrective Rocket Motor
TDU - Braking Rocket Motor

Fuels: AMINES - Amine Based; UDMH - Unsymetical Dimethylhydrazine
Oxidizers: NA - Nitric Acid; NO - Nitrous Oxide

Source: Berner, Lanphier and Associates, Inc.

Ion thrusters, particularly the *stationary plasma thrusters, SPT-70 and SPT-100*, have received considerable attention from the West, since this technology has not been adequately achieved there (the term used in the United States is "Hall effect thrusters"). NIITP (Scientific Research Institute for Thermal Processes in Moscow) played a principal role in developing this technology. NPO Fakel (Kaliningrad region near Moscow) currently produces the SPT-70, over 50 of which have been flown, and its upgrade, the SPT-100, which has yet to fly.

A U.S. government evaluation of this technology is being sponsored by the Strategic Defense Initiative Organization (SDIO) and carried out jointly by NASA's JPL and Lewis Research Center. To date, the performance appears to live up to claims (shown in Table 4). In addition, in the U.S. Space Systems/Loral has negotiated an exclusive agreement with NPO Fakel for non-government use in the West of the SPT-100. NPO Fakel will provide the thrusters while Loral will develop the integrated power system.

Table 4. Stationary Plasma Thruster Characteristics

	SPT-70	SPT-100
Propellant	XENON	XENON
Input Power 660 W	660 W	1.35 kW
Thrust	0.040 N	0.080 N
Specific Impulse	1,600 S	1,600 S
Efficiency	-	0.50
Xenon Flow Rate	-	5.0 x 10 kg/s
Lifetime	3,500 hrs	4,000 hrs
Start/Stop Cycles	-	3,000
Mass	1.5 kg	4 kg

Source Berner, Lanphier and Associates, Inc.

Loral claims this technology will decrease satellite weight by 20 percent for the same on-orbit lifetime. For certain common applications of electric propulsion, optimum specific impulse ranges from 1,000 to 2,000 seconds. The SPT-100 has a specific impulse of 1,600 seconds and an efficiency of 50 percent, exceedingly good performance by Western standards.[34]

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34 Ibid.

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Table 5. Major Satellite Constellations

Program	Altitude (km)	Incl (deg)	Period (mi)	Normal Phasing
Communications				
Store & Forward	790-810	74	101	3 planes spaced 120° 1 satellite per plane;
Direct Communication	1350-1550 1385-1415	74 83	115 114	24 satellites in one plane; 2 planes spaced 90° 6 satellites per plane
Molniya 1	400-40,000	63	718	8 planes spaced 45°, 1 satellite per plane
Molniya 3	400-40,000	63	718	4 planes spaced 90° 1 satellite per plane
Geosynchronous				
Raduga, Gorizont, Ekran, Luch	35,785	0-2	1436	21 locations over the Equator
Earth Observation				
Meteor 2	940-960	83	104	3 planes spaced 60°, 1 satellite per plane
Meteor 3	1230-1250	83	110	Deployment in progress (3 planes spaced 60°)
Okean	635-665	83	98	Deployment in progress
Early Warning				
Launch Detection System	400-40,000	63	718	9 planes spaced 40°, 1 satellite per plane
Ocean Surveillance				
Rorsat	250-270	65	90	1 plane, 1-2 satellites
Eorsat	405-420	65	93	2-3 planes, 3-6 satellites
Worldwide ELINT	635-665	83	98	6 planes spaced 60°, 1 satellite per plane
	850-855	71	102	Deployment in progress (4 planes spaced 45°)
Navigation				
Tsikada	965-1020	83	105	6 planes spaced 30°, 1 satellite per plane
Nadezhda	965-1020	83	105	4 planes spaced 45°, 1 satellite per plane
GLONASS	19,000-19,200	65	676	Deployment in progress (3 planes spaced 120° 3 or more satellites per plane)

Source: *Interavia Space Directory: 1991-1992.*

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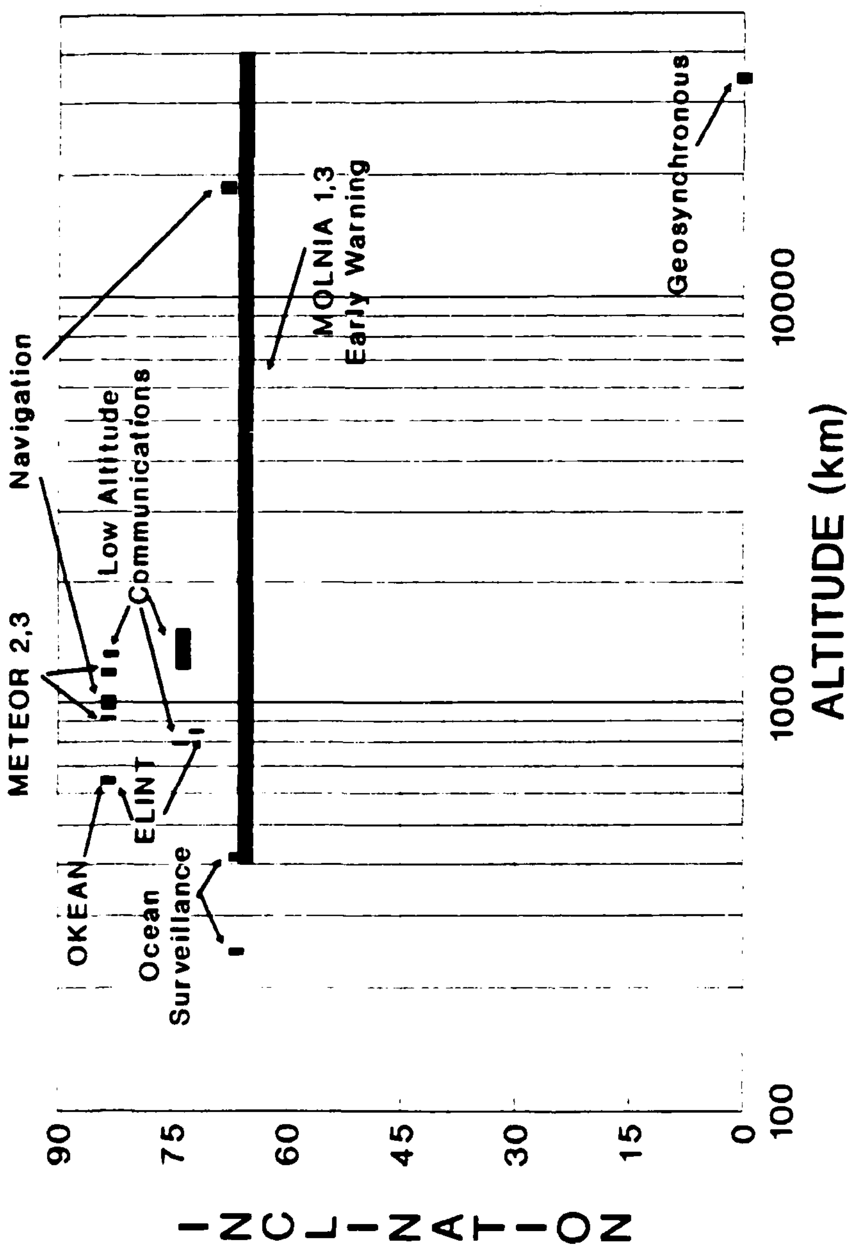

Source: *Interavia Space Directory: 1991-1992.*

Figure 12. Major Russian/CIS Satellite Constellations

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6. Satellites

The general name given by the Soviet Union for all its satellites is **Kosmos**. In general, the satellite and spacecraft systems discussed here only include the more recent ones, typically those that are still operational or were planned by the Soviets. Table 5[35] gives specific data on the major constellations of former Soviet satellites; corresponding distributions of these systems in terms of altitude and inclination are plotted in Figure 12. Table 6[36] summarizes space science missions, most of which are international, and in which the Soviet Union played the lead role. (The status of international programs is unclear given the evolving situation in the C.I.S. To the extent they are still viable, Russia most likely is playing the lead role.)

a. Communications Satellites

The higher latitudes of both the service areas and the launch sites initially led the Soviet Union to locate its high altitude communications satellites in semi-synchronous, highly eccentric, high-inclination orbits. These so-called **Molniya** orbits are inclined to the equator about 65 degrees (near the critical, stabilizing inclination required to minimize movement of perigee), have perigee altitudes from a few hundred to a few thousand kilometers, and apogee altitudes approaching 40,000 kilometers. The satellites themselves are usually referred to as Molniyas also, and historically have had lifetimes of around 1,000 days. Typically, there are eight satellites in orbital planes separated by 45°. These types of communications satellites, launched on SL-6s (Molniya launch vehicles) are used for both military and civilian applications. The civilian constellations are launched only from Plesetsk; military birds may be launched (typically 2 to 4 times a year) from either Plesetsk (usually) or Tyuratam (occasionally).

In addition to the traditional elliptic orbit communications satellites, geosynchronous systems have also been deployed. These include the **Ekran** (to be replaced by the **Gals**[37] and **Gelikon** satellites), **Gorizont** (whose successor is the **Express**), and **Raduga**. Ekran, launched in 1976, provided the world's first direct

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35 *Interavia Space Directory 1991-1992*, ed. Andrew Wilson, Jane's Information Group, 1340 Braddock Place, Suite 300, Alexandria, VA, 22314-1651.

36 Ibid.

37 Gals and Luch also refer to transponder types and services, often used on Raduga and Gorizont spacecraft.

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Table 6. Current and Planned Science Missions of the Former Soviet Union

PROJECT	LAUNCH DATE	SPACECRAFT	ORBIT	OBJECTIVE
Aktivny-IK	Sep 1989	Parent + Magion[1] subsatellite	Low Earth Orbit (500 x 2500 km @ 83°)	Study the effects of ULF waves on the magnetosphere; Intercosmos project
Granat	Dec 1989	Astron-type	Prognoz-type (1760 x 202,480 km @ 52°)	Study of gamma- & X-ray radiation in co-operation with France & Denmark
Gamma 1	Jul 1990	Progress-type	Low Earth Orbit (417 x 437 @ 52°)	Study of gamma- & X-ray radiation in co-operation with France
Bion	Aug 1992	Vostok-type	Low Earth Orbit	Study of effects of weightlessness on a variety of living organisms, including two monkeys
Apex	Oct 1991	AUOS-type & Magion[1] subsat	Low Earth Orbit (400-500 X 1500-300 km @ 83°)	Electron and plasma probing of magnetosphere; Intercosmos project (Czechoslovakia providing Magion)
Coronas-1	1992	AUOS[2]-SM	Prognoz-type & 500 km circular	Helioseismology and solar activity; Intercosmos project
Interball	Oct 1992 Dec 1992	Prognoz-M2 & Magion-types	Prognoz (500 x 200,000 km @ 65°) and Intermediate Molniya-type (500 x 20,000 @ 65°	Study of magnetosphere and plasmasphere in 14-nation co-operation; one Prognoz/magion pair in each orbit type
Relikt 2	1993	Prognoz-M2	L2 halo orbit	Study of Universe's microwave background
Regatta-Equator	1993	SSL-type	High Equator (19,100-25,500 x 64,000-76,500 km @ 0°)	Near-equatorial Sun-Earth interactions
Spektrum-Xγ	1993/4	Spektrum-type	Prognoz (2000 x 200,000 km @ 52-65°)	High-energy astronomical observations
Mars '94	Oct 1994	Phobos design	315 day transfer >180°; highly elliptic Mars orbit; entry & landing	Comprehensive Mars investigations involving twin orbiters with penetrators, landers, and aerostats.
Regatta-Cluster	1995	SSL-type	Cluster -type (25,000 x 140,000 km @ 90°)	Sun-Earth interactions, complementing ESA's Cluster
Radiostron (Spektrum-R)	1994/5	Spektrum-type	Elliptical 24-hour (7400 x 77,000 km @ 65° & 45,000 x 818,300 km @ 0°, 32.5 day period)	VLBI study of cm-radio emissions
SAS-1	1994/5	Intercosmos? + subsats	LEO Polar (400-500 km @ 92°)	Parent + 2 subsats; thermosphere and mid-atmosphere studies. Intercosmos project
Ikar	1995	Prognoz-M2	?	8, 12, & 16μm mapping. Tentative only.
Spektrum-UV	1995+	Spektrum-type	Elliptical, super-synchronous? (2000 x 200,000 km @51°)	Study of ultraviolet sources with 170 cm-dia telescope
Lomonosov	1995-6	MBH-type	Prognoz-type, super-synchronous (500 x 120,000 km @ 52°)	Astrometry with 1m dia telescope
SAS-2	1996	Intercosmos? + subsats	Low Earth Orbit	Parent + 2 subsats; as SAS-1. Intercosmos project
Spektrum-IR	1997+	Spektrum-type	Elliptical?	Study of sub-mm emissions in co-operation with France & others
Radiostron-mm	2000?	Spektrum-type	Eccentric, synchronous	Study of mm radio emissions with single 10m dia telescope for VLBI in conjunction with ground telescopes
Radiostron-KK	2010?	Spektrum-type	GEO + 27-day + L2 halo	Three 30m dia radio telescopes to study mm and cm emissions, including VLBI

[1] Czechoslovakian. [2] Ukrainian

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broadcast services, serving Siberia and the eastern and northern regions. Gorizont relays TV and also carries multi-purpose, international, and maritime services. Together, Molniya, Ekran, and Gorizont ensured that 97% of the Soviet Union's population had access to at least one TV channel. Raduga carries general domestic links in addition to certain military/government services.

The **Luch**[38] spacecraft serves as the basic platform for the geosynchronous satellite data relay network (SDRN), which began operation in October 1985; a second satellite was on-orbit at the end of 1989. The coverage provided by the network reduced the need for communications ships.

Other geosynchronous communications satellites that have been planned for deployment include:

- **Energiya** - A 10 ton GEO platform accommodating nearly 8 tons of payload providing communications services in the 11 to 18 GHz range
- **Goroscop-S** - A 1 ton class GEO satellite providing C- and Ku-band channels for service over the Urals and Siberia
- **Arcos** - Part of the Inmarsat-compatible Marathon mobile communications system (1.6GHz up, 1.5GHz down). Planned to begin 1992-93, the system is also expected to employ a Molniya-type craft, **Mayak**.

Other (LEO) communications satellites include:

- **Informator** - Possibly a derivative of a military store and forward satellite, apparently serves as a data relay platform for survey and disaster relief operations
- **Locsyst/Gonets** - Based on a military system, this constellation of six satellites at 1,400 kilometers offers a commercial capability to foreign buyers interested in establishing their own store and forward system.

Military communications satellites[39] include not only the Molniya-type systems, but lower altitude satellites as well. These provide *direct communications* between ships, aircraft, and bases. They have typically been launched into 74° to 83°, 1350 to 1550 kilometer orbits in groups of eight and six using a single launch vehicle. For the octet group, about 24 satellites (spaced 45° in a single plane) are required for global coverage. The sextet group consists nominally of two planes 90° apart, with six satellites per plane spaced 60°. Communications are in the VHF and UHF bands. Longer range

38 Ibid.

39 Information on military communications satellites taken from *Interavia Space Directory: 1991-1992*.

communications employ *store and forward* satellites in 785-810 kilometer orbits at 74° (three per orbit plane separated by 120°). Coverage for these repeats every 85 days and allows uplink from around the world. Information is stored until downlinked to an appropriate station.

b. Navigation Satellites

There are three navigation satellite networks inherited from the Soviet Union. Two are Transit-type systems, one for military applications (**Tsikada**), one for civil use (**Nadezhda** and also **Tsikada**). They involve four (civil) to six (military) satellites in orbital planes separated by 45° and 30°, respectively, and use the same Doppler techniques and similar frequencies as the U.S. Navy's old Transit system.

The third system is the **GLONASS** system similar to the U.S. Global Positioning System (GPS), and there is a distinct possibility that the two systems may operate together.[40] Flying at 19,100 kilometers altitude in 64.8° orbits, the satellites repeat their ground tracks every 8 days (17 revolutions). It is a dual frequency system operating at 1602.5625 and 1615.5 MHz, and is expected to provide accuracies of 100 meters in position, 150 meters in altitude, and 15 cm/s in velocity. The high precision mode is expected to give 10 to 20 meters if fully deployed by 1995 as originally planned. As of the end of 1990, 11 of the 21 satellites had been deployed.

c. Special Purpose Military Satellites[41]

Included in this category are early warning, ELINT, ocean surveillance, imaging, and other satellites having special military missions. Deployed in Molniya-type orbits, the nine **early warning satellites** are intended to detect missile launches. Estimated to give about 30 minutes warning, improved reliability is expected if the system is operated together with the two Over-the-Horizon radars. Prior to the dissolution of the Union, a geosynchronous system was believed to have been under development.

Only two types of **ELINT** satellites now appear to be employed. One system consists of six satellites in planes spaced at 60° intervals in 635 to 665 kilometer orbits at

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40 Honeywell tested two GLONASS receivers in 1991. Under a joint agreement, Honeywell worked with the Soviets to develop a dual GLONASS/GPS receiver; a production line was to be established to meet commercial standards. The status of the effort is unclear.

41 Information on military communications satellites taken from *Interavia Space Directory: 1991-1992*.

81° to 83°. Another system, which has had some difficulty in deploying, consists of four satellites in planes spaced 45°[42].

The two types of ocean surveillance are the familiar **RORSATs** and **EOSATs**. **R**adar **O**cean **R**econnaissance **SAT**ellites and **E**LINT **O**cean **R**econnaissance **SAT**ellites work in pairs, with their combined data building up a comprehensive picture of the ocean surface. Apparently they can relay, in real time, the position, heading and identity of naval vessels. They carry low-thrust engines to maintain orbit altitude (RORSAT at about 270 kilometers; EORSAT at about 435 kilometers) and adjust separation (which affects timing and coverage). Working together, any ship's attempt to jam a RORSAT would be detected by an EORSAT. RORSATs are paired in the same plane, inclined at 65°. EORSATs occupy 2 to 3 planes (also inclined 65°) with 3 to 6 satellites per plane. The last RORSAT was launched in March 1988, possibly in view of the risks and problems associated with its nuclear power supply.[43] However, EORSATS continued to increase: five were launched between March 1990 and January 1991, with a record six operating at one time in late 1990.

From the earliest days of the space age, *imaging reconnaissance satellites* were recognized to be of high value. In fact, the 18th Soviet launch occurring in 1962 carried a film-based imaging satellite. Since then payloads have increased to the point where the fifth generation imaging satellite weighs 6 to 7 metric tons. Such satellites maintain low altitudes to achieve best resolution, and are generally in high inclination, circular orbits. The latest in the fifth generation series was diverted from its normal global surveillance mission on 20 January 1991 to monitor events in the Persian Gulf.

d. Scientific Satellites and Planetary Probes

In recent years, the scientific space missions of the former Soviet Union shifted substantially to involve significant international cooperation. The majority are listed in Table 6. France appears to head the list of cooperating countries, which also includes the

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42 For each type of system two satellites are actually in the same geometric plane. However, because each pair moves in opposite directions the satellites are considered to be in different planes.

43 Normally, at the end of its 60 to 70 day mission, the reactor was separated and boosted to 900 kilometer orbit (500-600 year lifetime). Cosmos 954 malfunctioned and started to decay on 1 November 1977.

Controllers were unable to boost the reactor package to higher orbit, and the satellite re-entered, with the main debris falling west and south of Yellowknife, Canada, along an 800 kilometer strip in the Northwest Territories. Weeks later, at a cost of about $6 million, Operation Morning Light collected the globules of uranium that had formed when the reactor melted during re-entry. Five years later a similar incident occurred with Cosmos 1402. However, modifications to the system allowed the reactor core to re-enter and disintegrate completely over the South Atlantic.

European Space Agency, Czechoslovakia, and the United States. One, Interball, involves 14 nations.

Intercosmos is a collaborative organization previously led by the Soviet Union through the USSR Academy of Sciences (and now presumably through the Russian Academy). Until the dissolution it included the Aktivny, APEX, Interball, Relikt, and Regatta science satellite projects.

Aktivny, launched in 1989, included Czechoslovakia's Magion 2 subsatellite, forming a dual spacecraft, active monitoring of the magnetospheric propagation of VLF waves, and associated effects on the Van Allen radiation belts. Technical problems associated with antennas and subsatellite separation degraded quality of the investigation.

Granat, a follow-on to the earlier Astron astrophysical mission, was designed to obtain gamma and X-ray observations in a joint Soviet-French-Danish effort. Launched in 1989, the platform represented the last design based on the Venera interplanetary spacecraft, and has been replaced by the Spektrum design. The 52° inclined orbit is a highly elliptical one (417 x 202,480 km), referred to as a Prognoz-type of orbit.

Initiated as a Soviet program for gamma ray observations, the French joined the **Gamma** effort in 1974. The spacecraft payload includes three telescopes covering 50-50,000 MeV, 20 keV-5.4 MeV, and 2-25 keV.

The tenth **Bion** in the biosatellite series was due for launch in August of 1992 (status unknown). The 10 day mission, steadily maintained by the Institute of Biomedical Problems, aims at continuing research into the biomedical effects of the space environment on small plants and animals. NASA is providing some of the hardware, as well as participating in some of the primate experiments. Other contributors include Italy, Belgium, France, and the Netherlands.

The Active Plasma Experiment (**APEX**), one of the Intercosmos missions, employs a Czechoslovakian Magion 3 subsatellite to monitor the effects of the magnetosphere on the propagation of plasma beams produced by the parent spacecraft (Automatic Unified Orbital Station - AUOS - built by Ukraine's NPO Yuzhnoe) over ranges of 1000-2000 km. Supplemental balloon and ground-based monitoring are planned. Originally planned for launch in 1991, the status of the program is unknown.

The **Coronas** observatories are placed in both highly elliptical and near-Earth circular orbits to monitor solar events and their effects on the near-Earth environment. Utilizing the Ukrainian AUOS spacecraft, the economic difficulties make it likely that only the Coronas I spacecraft will be launched into the circular (500 x 500 km) orbit.

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Interball is a 14 nation joint effort to explore the effects of the Earth's magnetosphere and plasmasphere on solar radiation. Dual satellite-subsatellite pairs will investigate the auroral region and the magnetotail. The parent satellite uses the Prognoz-M2 platform; Czechoslovakia will provide the sub-S2-A and S2-T satellites. The orbits are of Prognoz and Molniya type: 500 x 200,000 km for the tail, and 500 x 20,000 for the auroral oval.

Relikt 2, a follow-on to Relikt 1's investigation into the microwave background which failed, is planned for launch in 1993 into a 180 halo orbit about the L2 libration point (behind the moon). Relikt 1's failure was due to interfering radiation from the Earth and Moon; the halo orbit location should eliminate this. Relikt will also employ the Prognoz-M2 platform.

The Regatta series is another sequence intended to explore the Sun-Earth interactions. **Regatta-E(quator)** is to be launched in 1993 into a near-equatorial orbit (in the range of 19,100-25,500 x 64,000-76,500 km) while Regatta-A or **Regatta-Cluster** is intended for an elliptic polar orbit (25,500 x 140,000 km) and should supplement ESA's cluster of four satellites. Observations of the interactions of the magnetosphere with the solar radiation will be collected over the regions from the bowshock through the magnetotail.

Spektrum-X is a follow-on to the Granat X-ray observatory. With a highly uncertain launch date (last estimated as 1994), this joint mission with the U.K. and Italy will provide observations of up to X-ray sources and gamma-burst events from a highly elliptic Prognoz-type orbit (2000 x 200,000 km).

A **Spektrum-R/Radioastron** program of Very Long Baseline Interferometric measurements was initiated with the 1990 launch of the Astron mission. Ultimately a series of up to six spacecraft, working in conjunction with the 70 meter antennas in Yevpatoria (Ukraine), Usserisk (Russia), and Suffa Plateau (Uzbekistan), will perform centimeter (**Radioastron-cm**) and millimeter (**Radioastron-mm**) mapping of galactic radio sources. The United States has volunteered tracking support using its Deep Space Antennas, thereby doubling coverage to 90 percent. However, funding limitations make it likely that only the first Radioastron will be launched in the near future (1994/95), into a highly eccentric, 7400 x 77,000 km, 65° synchronous orbit. (The Radioastron 2 mission would take its spacecraft on a month-long orbit twice as far as the Moon, resulting in perturbations of the orbit to give better celestial coverage.) An advanced mission, **Radioastron-KK**, originally planned beyond 2001, would include three satellites: in

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GEO, 27-day, and halo orbits. A follow-on spacecraft design appears to be required to carry the estimated 20 ton payload that includes a 30 meter dish antenna.

Spektrum-UV and **Spektrum-IR,** as the names suggest, are intended to investigate these spectral regions using the Spektrum platform to carry a 170 cm mirror telescope, and a cryogenically cooled sub-millimeter IR telescope. Uncertain launches are estimated for the late 1990's.

The SAS System of Aeronomical Satellite missions consist of two triple satellite missions, one planned for 1994/95, the other about a year later. The objective is to collect data on the upper atmosphere and thermosphere at high latitudes during a period of maximum solar activity. The two sub-satellites planned for SAS-1 are the Czech Magion-type A-2, or Macek, and the A-3.The primary satellite (IKAR-1) would enter a circular polar orbit at 500 km with the A-3 varied from it by 10 to 1,000 km to assess temporal and spatial variations. The A-2 would carry a small accelerometer, dipping into the atmosphere to measure atmospheric drag. SAS-2 would be a similar mission, and its S-2 would have a small propulsion system to compensate for atmospheric drag. Poland, Bulgaria, Romania, and Germany were slated as additional contributors; however, as with most of these missions, their status is highly uncertain.

The **Ikar** mission would carry a cryogenically-cooled, 1.5m IR telescope to map the 8,12, and 16 micron regions. The mission has been proposed for international participation; launch would not be until well into the 1990's.

Lomonosov is a proposed astrometry mission employing a 1m diameter telescope to provide position, photometric, proper motion, and parallax data on 400,000 stars. Rapid pointing and stabilization together with CCD imaging would allow up to 3,000 star position determinations per day. UV spectrophotometry would also be accomplished (2,000-35,000 Angstroms). With a highly elliptic, 1500 x 120,000 km, 52° orbit, the spacecraft would spend about 32 hours each orbit making observations above the radiation belts.

Although not an international mission, **Tsiolkovsky** was proposed as a solar mission to investigate the corona to within 5 to 7 solar radii following a Jupiter gravity assist flyby. Alternative flight profiles, including Earth swing-by maneuvers, have been considered as well. Technically demanding, it apparently would require a new spacecraft bus, powered by radioisotope thermoelectric generators (RTGs). Depending upon flight profiles and, more significantly, funding, launch would not occur until late in the 1990's.

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Other scientific satellites include geodetic and microgravity missions, all established solely by the Soviets. These include the **GEO-IK** and **Etalon** geodetic satellites for determining Earth and lunar gravitational, rotational, and related parameters. GEO-IK includes Doppler and flashing light beacons to active tracking sources, and along with Etalon also carries laser retroreflectors.

The microgravity activities of the former Soviet Union include the **Photon** materials processing satellite that first flew in 1988. Based on the Vostok craft[44], the Photon capsule, built by KB Photon, is commercially marketed for 2 week to 1 month missions. The system has been successfully employed in various materials processing experiments, including organic crystal growth for non-linear optics applications. Processing options include electric furnaces and electrophoresis units.

KB Photon's enhanced **NIKA-T** is planned to be capable of carrying more than 2.5 metric tons of microgravity payload for up to 120 days; 1,200 kg is recoverable. Availability was originally planned for Zenit launches in 1993/94, but is currently uncertain.

Lavotchkin, a 2.5m high by 2.5m base diameter capsule, represents a competitor for the Photon. It is a joint effort involving NPO Yuzhnoe, NPO Machinostroenye, and others. Availability is planned no earlier than 1993, and offers 10^{-5} g for 500 kg recoverable mass.

The Soviet Union enjoyed a remarkable record of planetary exploration that included unmanned lunar landings and rovers, first penetrators into the Venusian atmosphere, as well as a hard lander on that planet, and Mars flybys. However, the planetary space science activity atrophied significantly following the end of the Mars Phobos mission in 1989. As discussed in Chapter IV, Russia has continued with the Soviet **Mars '94** project to land an instrumented craft on that planet. It will be supplemented by a similar **Mars '96** mission 2 years later. Two orbiter spacecraft are planned, one for each mission, with each releasing three small instrument packages and two penetrators. Following entry into highly elliptical orbits, the two orbiters will perform extensive surface mapping as well as other measurements. The landing capsule will deploy a French inflatable balloon; in addition, a small surface rover might be included. Funding pressures have threatened the project, and the United States has agreed to participate through inclusion of two soil chemistry instruments on the spacecraft. In addition,

44 With almost 700 successful missions under its belt, the Vostok carried Yuri Gagarin, first man in space.

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NASA's Deep Space Network will aid in tracking. Each orbiter is planned to enter a 500 x 18,400 km, 66° to 100°, 12 hour orbit. Approximately 3 days after insertion, perigee will be lowered to between 200 and 300 km. About 3 weeks later the orbiter will be maneuvered to an entry trajectory, the capsule released, and the orbiter deflected to re-establish safe orbit. Following release, the orbiter will serve as a data relay.

The balloon (probably **Mars '96** only) will be deployed between 7.5 and 10 km above the surface, trailing an instrument package that will bring it in contact with the surface at night and travel about 150 km during the day. Its payload will include instruments for sensing and monitoring environmental conditions, and will include T.V. imaging. If the mass budget allows, a small RTG-powered electric-driven rover (**Mars '96**) will be deployed providing a range of about 200 km over a 2-year life. Instrument candidates include drills, gas chromatograph, and mass spectrometer.

The *three instrumented packages* released by each orbiter prior to arrival will drop by parachute to the surface, and will perform measurements using candidate instruments such as seismometers, magnetometers, cameras, and meteorological sensors. The two titanium *penetrators* from each orbiter will impact at 100 to 150 m/s, burrowing as deep as 10 meters. The payloads include seismometer, accelerometers, soil composition instruments, and thermometers.

e. Earth Observing Satellites

The Earth observing satellites of the former Soviet Union include meteorological (Meteor and GOMS/Elektron), imaging (Resurs and Prognoz), and radar (Almaz and Okean) satellites. The Meteorseries is a polar orbiting meteorological satellite comparable to the U.S.' NOAA polar platforms. They provide essentially routine weather coverage from usually sun-synchronous, 82.5° orbits. The spacecraft are 3-axis stabilized. Meteor 3 contains plasma thrusters designed for small orbit adjustments, and a Meteor 3 carried the U.S. TOMS instrument, launched aboard a Tsiklon booster in 1991. Four primary ground stations [Moscow, Tashkent (Kazakhstan), Novosibirsk, Khabarovsk] operate in conjunction with more than 80 smaller ground stations to receive the visible and IR imaging data.

The Geostationary Orbit Meteorological Satellite (GOMS), **Elektron**, is slated to carry a set of visible and IR instruments similar to the U.S. GOES-Next. In addition it will carry radiation detectors to monitor electron, alpha, and solar X-rays, plus magnetic field indicators. Delayed for a number of years, its first launch was scheduled on a Proton SL-12 for 1991.

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The **Resurs-F** satellite is based on the Vostok photoreconnaissance spacecraft. Orbits are typically inclined at 82.5°, and at altitudes ranging from 250 to 450 kilometers. The film camera systems are returned to Earth after missions of up to 45 days in spherical canisters that are reused up to three times. **Resurs-O** is the multi-spectral imaging equivalent to the U.S. Landsat. The spacecraft is based on the Meteor 3 platform, and carries sensors in both the visible and IR regions. Data are downlinked at a realtime rate of 7.68 Mbits/second from a sun-synchronous orbit at 98°.

Prognoz is a geostationary complement to the Resurs series. Originally launched in April 1988, it failed 5 months later; no additions had appeared by early 1991.

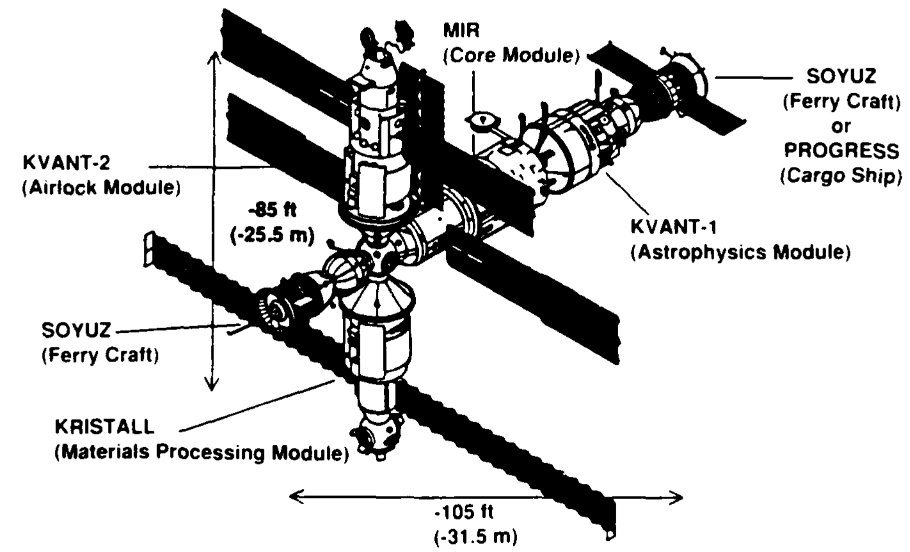
Originally designed as a military reconnaissance vehicle, **Almaz** utilizes the Salyut/Mir core vehicle to carry a 3 GHz synthetic aperture radar providing 15 meter resolution radar images, particularly for monitoring oil pollution and ice coverage. Under a joint venture agreement between Glavkosmos and NPO Machinostroenye, Space Commerce Corporation has exclusive marketing rights in the West, although the actual marketing is handled by the Almaz Corporation. Data are relayed to a processing center in Moscow via a Luch data relay satellite. The 18.5 metric ton spacecraft typically occupies a 275 kilometer orbit inclined at about 73°, and has a revisit time of 1 to 3 days (the orbit is adjusted about every 24 days).

Okean is an all-weather radar oceanographic satellite system. Employing a 1.5 meter resolution, 8.6 GHz side-looking radar, and visible and IR radiometers, data are returned to the four primary Meteor ground stations (see above). Ice monitoring forecasts are communicated to ships via the Ekran geostationary satellites. The spacecraft, built by NPO Yuzhnoe (Ukraine), is 3-axis stabilized, with gravity gradient assistance, and typically occupies a 630 to 660 kilometer orbit inclined 82.5°. An updated and improved Okean B was planned for the 1991-92 time frame; however, its status is uncertain.

f. Manned and Man-Related Spacecraft

The former Soviet Union had a successful history of manned spaceflight, including the first man in space, Yuri Gagarin, and first woman, Valentina Tereshkova. The evolution of Soviet manned space craft has led through the Salyut and early Soyuz series to today's systems: the **Mir** space station, **Soyuz-TM** (manned) and **Progress-M** (unmanned) ferry craft that support Mir; the Buran space shuttle; and finally the alleged spaceplane.

The **Mir** space station currently is the world's only functioning space station, having replaced the earlier Salyut in 1986. As with all manned missions, it is launched from Baikonur using the Proton SL-13 into a 300-400 km circular orbit at about 52°. A multi-vehicle spacecraft, it was derived from the Salyut 6/7, and consists of a core habitation module mated to a five-port docking unit. This allows up to four science modules plus a manned Soyuz ferry to be accommodated (see Figure 13). Docking always occurs along the axial direction. Subsequently each docked science module is automatically swung around to be received by the radial ports, since side docking places unacceptable loads on the spacecraft. The Soyuz ferry docks and remains in the axial orientation.



Drawing Courtesy of Daniel Gauthier

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Figure 13. Mir Space Station Complex

First of the four science modules is the **Kvant** series. Kvant 1 and Kvant 2 serve as general science laboratory modules (carrying photographic and TV cameras, spectrometers, incubator, as well as storing EVA suits).

The **Kristall**, also referred to as the technology Module T, carries materials processing furnaces and biotechnology units. Annual production of up to 500 kg of material is estimated.

The **Spektrum Module,** yet to be launched, is planned to carry module remote sensing instruments, principally for Earth atmospheric studies.

Priroda is the remaining science module intended for remote sensing and study of the Earth's land and ocean areas, as well as the atmosphere. Priroda also has yet to be launched.

Supporting the Mir are two Salyut derivative ferry vehicles, the Soyuz-TM and the Progress-M. **Soyuz-TM** (Transport Modified) carries the cosmonaut crews to and from the space station, and have the capability for independent operation of as much as 3.2 days. Attached to the Mir it can remain on orbit for 180 days before returning to Earth.[45]

Progress-M is very similar to Soyuz. Nearly 2,500 kg of cargo, including propellant supplies, can be carried by the Progress-M spacecraft. This is about 100 kg more than its predecessor. There is also the option to return a cargo capsule with up to 150 kg.

Russia is marketing the Mir and science modules for space station research services, and is slated to receive a U.S. astronaut in 1995 for a 90-day mission of scientific and operational research. Though significantly smaller than the international Space Station Freedom,[46] it offers several unique features:

- Rendezvous and docking, using the Kurs system, is done automatically.
- Mir can be remotely refueled from the Progress resupply craft.
- Because the Soyuz ferry craft remains attached to the Mir as long as the station is occupied, there is always the capability for return in an emergency. During critical operations, such as automated docking of the Progress, the crew retires to the Soyuz in the event they might have to make an emergency departure.
- A high degree of modularity and interface standardization allows for replacement of equipment in the event of failure. It also provides the capability to take advantage of technology improvements.

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45 In conjunction with NPO Energiya, which manufactures the system, Rockwell and Lockheed are studying the pros and cons of employing the Souyuz-TM as an interim assured crew return vehicle (ACRV) in the event of emergencies on the international Space Station Freedom.

46 However, the interior volume of the full Mir complex is greater than the volume projected for Space Station Freedom at time of man-tended capability.

- Each module (Soyuz, Kvant, Kristall, Spektrum, Priroda) has its own power generation capability that can also be shared with the other modules.
- The separate scientific modules allow for evolution of technology and accommodation of new mission requirements, hence flexibility to meet changing requirements is basic to the design and configuration of the station.

The station also has some drawbacks. It is difficult to keep the station clean because bacteria and mold proliferate on walls in hard-to-reach places. Its living space is cramped, and makes for a rather tortuous existence during the typical 6-month stays served by cosmonaut crews.

Buran is the Soviet-developed equivalent of the U.S. space shuttle. Similar in appearance, it differs significantly in that its main propulsion is not integral to the vehicle, but rather is provided by the Energiya booster that lifts it to orbit (see Energiya entry above). After separation from the Energiya, the Buran's elliptical orbit is circularized at apogee using LOX-kerosene thrusters integral to the shuttle vehicle. The crew module carries two pilots, two engineers, and up to six passengers. About 30 metric tons can be placed into a 250 km orbit at 52°, assuming 8 metric tons of propellant (doubling propellant reduces payload by about 10 percent, and allows nearly 450 km of orbit altitude). Earth return capacity is about 2/3 of the payload upmass.

The vehicle can be flown unmanned from a dedicated room at the Kaliningrad Flight Control Center north of Moscow (see Flight Control entry above). During descent, a TACAN-like system aids approach. Landing, which takes place on the 4.5 km airstrip at Baikonur Cosmodrome, can be assisted by a microwave landing system at both ends of the runway. From orbit, approximately 200 km of cross-range capability can be achieved to the landing site.

At the end of 1990 the Buran-Energiya had made only one flight (November 1988). Although successful, it does not appear to enjoy a high priority in the Russian space program funding principally due to its lack of definitive mission.

Although efforts to develop a small, short-mission reusable spaceplane were sporadic, the mid-80's saw evidence[47] of continuation with various launchings a one-third scale vehicle. Four test launches were believed to have been carried out culminating in water recoveries. The status of the program is at best uncertain, and most likely has been shelved.

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[47] Orion aircraft of the Australian Navy monitored recovery operations of the unmanned vehicle in the Indian Ocean.

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7. Related Technologies

Other areas that reflect significant capabilities growing out of the former Soviet space program entail a variety of unique technologies of particular interest in the West. A complete discussion of these is beyond the scope of this document; however, they include developments in the following areas:

- Human space physiology experience
- Space nuclear power
- Electric propulsion thrusters
- Certain materials processing and fabricating technologies
- Applied mathematics, particularly computer applications
- Higher pressure space suits
- Improved life support methods
- Laser systems and technology
- Optical sensors and sensor materials
- Microgravity research.

Extensive interactions are being conducted, particularly with Russian companies and organizations to determine the extent to which such capabilities offer prospects of mutual benefit between the West and the CIS. (Some key examples are discussed in Chapter III.)

8. Summary

The divergent paths in the evolution of U.S. and Soviet space programs produced unique capabilities. One of the more notable is the robust launch capabilities of the former Soviet Union. Although the fragmentation of the USSR into independent republics makes maintaining the space program difficult, the Commonwealth is aspiring to maintain some semblance of coherence, if not through the Joint Space Agreement, then through bilateral arrangements. Despite the organizational and economic difficulties being encountered (further discussed in Chapter II), the space technologies and capabilities are being actively and successfully marketed by Russia (the major shareholder of the space infrastructure) and some of the other Commonwealth nations. In addition to launch vehicles and services that are priced well below corresponding capabilities in the West, various other capabilities are also up for sale. These include an emerging satellite communications capability, as well as uniquely capable developments in electric propulsion and spacecraft thermonuclear power

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(discussed further in Chapter IV). Other areas include certain materials processing and sensor technologies, lasers, applied mathematics, life support systems and technologies, and space physiology and microgravity experience.

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II. RUSSIAN ECONOMIC DEVELOPMENTS AND PROSPECTS FOR THE SPACE PROGRAM

A. RUSSIAN ECONOMIC FORECASTS

The course of Russian economic reform is by no means certain over the next month, let alone the next several years. Economic trends at present are quite dismal: output continues to fall, inflation is spiraling, exports are off dramatically, and greater unemployment is to come. One of the on-going fundamental debates within the context of economic reform is whether to bail out state-run industries. The resolution of this debate will obviously have a significant impact on the space industry. This section of the paper addresses the future of Russia's space program after assessing the political and economic environment more generally. Hence, *despite all the uncertainties, it is possible to identify some of the emerging factions within Russian political life and speculate about how the balance between these forces might affect the future focus of economic reform*. In general terms, three leading factions can be identified that are vying for influence within the Russian political and economic system.[1]

1. Liberal Reformers

The first can be characterized as the liberal reformers. This group wishes to continue the course of radical economic reform and to cooperate closely with the West in the foreign policy arena. In short, *they strive for the Westernization of Russia*. In this effort, as Robbin Laird has argued, "the role of the state is to sponsor development and the formation of a private sector and of civil society to lead in the process of change."[2] Certainly the foremost leader in the economic realm within this group is Prime Minister Yegor Gaidar, the architect of Russia's current economic reform plan. Gaidar's program advocates austerity measures, similar to Poland's shock therapy approach, and one of its

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1 These three factions are not meant to comprehensively represent the Russian political and economic scene; rather they are designed to illustrate the general trends and possible options.

2 Robbin Laird, *The New East-West Nuclear Challenge*, IDA working paper, August 1992, p. 19, UNCLASSIFIED.

principle aims has been to enlist political and economic support from Western countries.[3] It is also designed to meet the specifications of the International Monetary Fund (IMF), whose approval is necessary for large-scale Western assistance and investment. Indeed, Gaidar views the IMF as "'the pivot of the modern world financial system.... [T]he stance of the IMF and the institutions associated with it the World Bank and the International Development Association exercise a determining influence on the decisions adopted by nearly all international economic institutions."[4]

The challenges today to the Gaidar program are severalfold. First, the difficulties that Poland is experiencing with this type of model reinforce *doubts among many that this is the proper course* for Russia to adopt. Second, there is clear evidence of a *lack of support for this economic plan among the population* at large and among many other leading political forces. The key question lies in the need to provide greater social protection to the Russian people in this time of tremendous economic upheaval. Illustrative of this lack of support are two polls conducted in March and May 1992 in 25 different regions of the Russian Federation. For example, there is increasing dissatisfaction with the current economic program, whereby in May three-quarters of those polled indicated a negative attitude toward the program and more than 50 percent did not approve of the practical steps that have been implemented in switching to a market economy. Perhaps most striking is a lack of support even among younger people, below age 35.[5] These attitudes toward the Gaidar program, coupled with growing Russian pessimism about their lives, raises the scepter of social unrest, as articulated in the following:

> *It seems that the obvious deterioration in citizens' prosperity and social sense, and their gloomy outlook on the future (three-fifths of those polled have already stopped believing in the possibility of an improvement in their own material position even in the indefinite future) are the real sources of the increase in social tension.*[6]

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3 Elements of his program are discussed in some detail in Lauren Van Metre, *Russia's Four Possible Economic Reform Directions and Their Impact on the Military-Industrial Complex*, Center for Naval Analyses Working Paper 92-1498, August 1992, pp. 3-5.

4 "Gaydar Addresses Deputies on Entry into IMF," Russian Television Network, 22 May 1992, published in Foreign Broadcast Information Service, *Daily Report: Central Eurasia* (hereafter FBIS-SOV)-92-101, 26 May 1992, p. 26, as quoted in Van Metre, *Russia's Four Possible Economic Reform Directions*, p. 4.

5 "Impassive Statistics," *Pravda*, 9 July 1992, p. 2, as translated in FBIS-SOV-92-134, p. 45. It should be kept in mind that *Pravda* is a conservative newspaper and is therefore more likely to emphasize opposition to economic reform efforts. Nevertheless, the general conclusions that can be drawn from these polls appear to be reflected in a range of press reports across a fairly broad segment of the population.

6 Ibid., p. 46.

At this point, virtually everyone is in agreement that the Gaidar "shock" program has failed. The question remains whether the program will be reshaped or entirely replaced by a new one. Probably the most optimistic outcome would be a continuation of the government pushing for reform via austerity measures and then allowing for concessions when necessitated by pressure from the parliament and society.[7] This appears to be the current approach, as evidenced in the head of Russia's central bank calling for the renegotiation of certain elements of the reform plan because the IMF obligations cannot be met without unacceptable social consequences.[8]

2. Industrialists

It is precisely the rising concerns about providing adequate social protection that appear to have given impetus to the emergence of an increasingly powerful faction on the Russian political scene: the industrialists. It is the industrialists that form the second of the groups examined here. The primary foundation for this group has been the Russian Industrialists' and Entrepreneurs' Union, led by Arkadii Volskii; this union has set up a suborganization called the All-Russia Renewal Union. In turn, at the end of June 1992, this suborganization united efforts with two of the strongest and centrist political parties in Russia: the Democratic Party of Russia, headed by Nikolai Travkin, and the People's Party of Free Russia, leaded by Vice President Aleksandr Rutskoi. These three organizations combined have formed a political bloc known as the Civic Union.[9] The Civic Union "favors less painful and more socially oriented economic reform and an isolationist approach to foreign policy" and it aims "to preserve the integrity of the Russian Federation, stabilize the economy, and eliminate social tension."[10]

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7 This outcome is articulated by Van Metre, *Russia's Four Possible Economic Reform Directions*, p. 9.

8 This appeal came on 20 August 1992, as reported in Michael Dobbs, "Russian Banker Urges Renegotiation of Economic Reform Plan," *Washington Post*, 21 August 1992. Gaidar has, himself, admitted that it might be necessary to make some concessions in economic reform in order to avoid social disorder.

9 These alliances are discussed in greater detail in Alexander Rahr, "Liberal-Centrist Coalition Takes Over in Russia," *RFE/RL Research Report*, vol. 1, no. 29, 17 July 1992, pp. 22-25 and Elizabeth Teague, "Russia's Industrial Lobby Takes the Offensive," ibid., vol. 1, no. 32, 14 August 1992, pp. 1-6.

10 Rahr, *RFE/RL Research Report*, 17 July 1992, pp. 24-25.

While the industrialists do not seek to halt reform, they do want *to proceed more cautiously and with less disruption than called for under the Gaidar plan.* Indeed, the Gaidar team has already had to make concessions to the industrial lobby, in the form of additional subsidies to state-run industries (that would otherwise go bankrupt) and three representatives from this lobby have been brought into the government: First Deputy Premier Viktor Shumeiko, Deputy Premier Georgii Khizha, and Deputy Premier Viktor Chernomyrdin.[11] Moreover, the Gaidar team itself has taken steps to moderate its program, seeking to soften the effects of shock therapy, and has offered an approach for the second phase of Russian economic reform entitled "Medium-Term Program for Deepening the Economic Reforms." This package has been rejected by the industrialists,[12] and the Civic Union has put together its own economic reform proposal, "Economic Policy Alternatives."

The Civic Union's economic plan, although not yet published, reportedly seeks to save Russia's industry by abandoning shock therapy efforts and advocating "a regulated transition to the market" under firm state control. Therefore, *while it supports a move toward a market economy, during the transition to that stage, the industrialists wish to see the preservation of a safety net.* The plan also calls for, among other things, more credits, lower taxes, price controls on energy, special subsidies for the conversion of defense industries to civilian production.[13] The liberal press brands the plan as "a recipe for hyperinflation" that will result in "a state-regulated economy founded on a strong defense industry extending throughout the former USSR."[14]

There are several questions about the industrial lobby. The first is how well they will seek to work with the Yeltsin's economic team, currently headed by Gaidar. There is, in fact, considerable speculation that Gaidar will soon be replaced, with the likely replacement coming from a more centrist position. At the same time, these two groups have certain *common interests, most importantly keeping conservatives and reactionaries at*

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11 Shumeiko was formerly the director of a defense industry enterprise in Krasnodar; Khizha was the director of an electronics defense factory in St. Petersburg; and Chernomyrdin was previously the USSR minister of the petroleum and gas industry.

12 For example, the co-chairman of the Renewal Party, Aleksandr Vladislavlev argued that the government's (i.e., Gaidar's) program would lead to the "Kuwaitization" of Russia, meaning that it would destroy Russia's industrial base and reduce the country to the status of an exporter of energy to rich Western nations." As explained and quoted in Teague, *RFE/RL Research Report*, 14 August 1992, p. 4.

13 As outlined in ibid.

14 Articles published in *Nezavisimaya gazeta*, 16 July 1992 and *Izvestiya*, 23 July 1992.

bay. Moreover, as already noted, they do not necessarily differ on the fundamental principle of Russia having a market economy system; their differences lie in the transitional stage to a market economy. Namely, how much social protection should (or must) be provided to the Russian people (who have, after all, lived under a regime that guaranteed employment, housing, and basic food, however modest)? To what extent should state industry be sustained by continuing subsidies, etc., and to what extent should they be forced to fend for themselves and survive or not? While there is no doubt about the rise in the strength of the industrial lobby, one additional consideration should be taken: just as the "Russian military" is not one huge monolith with only one set of priorities and interests, so too do Russian industrialists differ in their own views of the future of the Russian economy and what should be done. *Therefore, it should not be concluded that all industrialists will consistently act with one voice on all issues.*

3. Conservatives and Reactionaries

The third political faction to be considered are conservatives and reactionaries. This group includes *those who remain staunchly pro-communist and advocate extreme nationalism.* In addition to restoring Russia's position in the world and protecting the Russian Diaspora elsewhere in the former Soviet Union, the conservatives oppose such foreign influences as the IMF, World Bank, and NATO. One representative of this group is the National Assembly, "which wants to return Russia to the administrative-command system and revive the former USSR."[15] The most troubling phenomenon is the increased activism of such groups, and it is legitimate to fear that they will be *strengthened even more as the Russian economy continues to deteriorate.*

As Lauren Van Metre articulates the problem, if the conservatives gained the upper hand and consequently sought to re-centralize Russia, such actions

> *will not only jeopardize the reform efforts, but will launch a political struggle between the democratic and communist camps. As this is an issue of national identity and the basic political and economic character of Russia, there is no doubt that the general population will have to choose sides. The nation will likely split along political as well as geographical lines. For example, certain regions of the country will excel under a market economy, others can only be hurt.... Areas like St. Petersburg and the Far East are far better suited for the transition to a market economy than heavy industrial regions such as Udmurtia and Gorky. The more progressive regions will*

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[15] As noted in Rahr, *RFE/RL Research Report*, 17 July 1992, p. 24.

fight any attempt to recentralize, especially if it means jeopardizing already-achieved growth and development.[16]

In this context, an alliance between the reformers/liberals and the industrialists/centrists becomes all the more crucial.

B. IMPLICATIONS FOR THE RUSSIAN SPACE PROGRAM

Just as Russia's economy faces a host of uncertainties in the future, so too does its space industry. Clearly, the Russian space program has not remained unaffected by the myriad economic changes sweeping the former Soviet Union. Here we will examine several of the factors that will shape the Russian space program's future: the implications of conversion, the loss of skilled personnel, the level of governmental support, and the level of success in international and CIS cooperation. It can be said at the outset that, given the extraordinary difficulties facing Russia today, *the government to date has demonstrated a (perhaps) surprising commitment to stay involved in the space world.* The ability and willingness to maintain that level of commitment into the future hinges in part on the factors outlined above.

1. Implications of Conversion

Under the Soviet system, the space effort was dominated by military priorities, with the result that some 90 percent of all space industry orders reportedly came from the military.[17] Just as the military-industrial complex has been subjected to a conversion process (switching to more production of civilian goods), the space industry has been faced with the same pressures for conversion. *In part, the conversion has come as a result of the drop in military orders*, so it is setting up suborganizations to push commercialization and international cooperation. But in addition to seeking to perform more civilian space work, various space enterprises have also found themselves forced to produce non-space related goods (such as milk separators and auto exhaust pipes) in order to survive. The danger is that the production of capable space equipment will disappear as activities promising near-term profits begin to dominate. "For example, we have set up a shop producing disposable syringes. And although only around 300 people work there, one half the profit earned by the plant last year came from syringe production....Privatization will lead to just one thing: the replacement of space production by something that is short-term and ultraprofitable.

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[16] Van Metre, *Russia's Four Possible Economic Reform Directions*, pp. 15-16.

[17] See, for example, "Vesti" newscast, 5 January 1992, as translated in FBIS-SOV-92-003, p. 19.

The sophisticated equipment will then go out of commission and the plant will go under the hammer."[18] This is not to say, however, that the military has lost its influence in the Russian space program. For example, although the overall number of launches in 1992 has been much reduced (only 19 to date), more than half of these launches have been for military purposes.[19] In light of Russia's severe economic difficulties, one trend that is likely to emerge is a more concerted effort at *combining civilian and military tasks.*

2. Loss of Skilled Personnel

One of the consequences of the space conversion efforts has been the loss of skilled personnel, whose scientific capabilities are not being fully utilized, particularly *to private enterprise* where they can at least earn much more money, even if they do not make use of their high-technology skills. Current estimates among Russian and Western analysts are that perhaps 50 to 60 percent of the overall space industry will survive.[20] This, of course, raises serious questions about where the surplus personnel are likely to go. In addition to those who have already opted for private enterprise, it is generally feared that at least some portion of *skilled workers will be enticed to work in Third World countries* who are willing and able to compensate them adequately for their services.

An alternative--and much more desirable prospect--would be for various industrialized countries involved in space efforts to employ individual Russian scientists, engineers, and other skilled workers to work on specific small-level projects, namely in areas where Russian industry excels. Such arrangements could provide several mutual benefits: they would *not need to be costly* since the pay scale in Russia for such skilled workers is considerably lower than that in Western countries, they could *reduce the overall cost and development time* needed relative to a comparable Western effort, and they would keep these workers employed thereby contributing in a small way (but very significant to those employed) to a more stable Russian domestic science and international environment (since the workers would be less likely to emigrate to a Third World country). Care in such approaches must be taken to ensure U.S. jobs in comparable industries are not jeopardized as has been happening to some extent in the computer software development

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18 Anatoliy Petrushin, Deputy Director for Finance, Progress Plant (TsSKB), Samara, 28 March 1992, as reported by Berner, Lanpier, and Associates.

19 *Defense Daily*, Special Supplement, July 24, 1992

20 Based on off-the-record interviews conducted in August and September 1992.

software development industry.[21] The more desirable approach would be to take advantage of expertise not possessed by corresponding U.S. industry.

3. Government Support

For its part, the Russian government has indicated its determination to maintain a space program, and on 25 February 1992, President Yeltsin announced the establishment of the Russian Space Agency, to be headed by Yurii Nikolaevich Koptev and staffed by approximately 150 people. *There has also been considerable support within Parliament for maintaining a space program*, and the rise of industrialist interests within the government at least for the foreseeable future should be more favorable to the space industry than if the reformers were to completely control the agenda. This is not to say, however, that plans will not need to continue apace in diversifying (to focus more on civilian uses) and expanding international cooperation, because even full-fledged *government support cannot translate into adequate financial support to preserve the industry* as it existed in previous years.

While the Russian Space Agency largely consists of the old nomenklatura from the Soviet space effort (including Koptev himself), they are knowledgeable and appear committed to making the space program work. The key responsibilities of the Russian Space Agency include: "the development of a state program for the development of space research and the principles to finance it, and the shifting of the center of gravity from military projects to civilian ones," as well as coordinating commercial projects, and cooperating with the space programs of other CIS member states and foreign countries.[22] According to Koptev's own assessment,

> *Despite the country's grave financial situation, funds are being allocated to maintain the [space] sector's activity at roughly the same level as last year.... We do not intend to torpedo manned spaceflights, or scientific projects, or national economic satellites, or the dual-purpose systems that are essential for the security of our state. However, the [Russian Space]*

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21 "A loophole in U.S. immigration laws is allowing thousands of foreign computer programmers and analysts to enter the United States each year on temporary business visas, enabling them to take jobs from American workers...Alex Dubenko, for example, is a computer analyst recruited by a Kiev company to work in the United States...Dubenko said he was paid $20 a week, which, after conversion to rubles, he calculated as a proper wage for equivalent work in the Soviet Union." "Visa Loophole Seen Costing U.S. Workers Computer Jobs," *Washington Post*, Nov. 9, 1992.

22 See interview with members of the Moscow Space Club, Sergei Zhukov and Vladimir Postyshev on Moscow radio, translated in FBIS-SOV-92-033, p. 43 and Yeltsin presidential decree "On the Structure of Space Activity Management in the Russian Federation," *Rossiiskaya gazeta*, 28 February 1992, translated in FBIS-SOV-92-041, pp. 28-29.

> *agency intends not only to attract budget funds [from the Russian state] but also commercial structures, and it plans to exploit international cooperation more widely.... It has not been ruled out that we will attract international capital and set up a joint-stock company to jointly operate the Mir station.*[23]

Koptev has further stated that unless the Energiya launcher and Buran shuttle programs can be commercialized internationally in the next 4 years, they will be eliminated. At the same time, Koptev stresses that the Mir program is worth maintaining, at least in part because it brings in desperately needed hard currency.[24] In short, Koptev is well aware of the difficulties of trying to maintain the space program and recognizes the need for international cooperation, although he also stresses that Russia is committed to retaining a national space program.[25] The new head of NASA, Daniel Goldin, confirms this commitment following his trip to Moscow in July 1992: the Russian space program "is not as robust as it was under the Soviets but Russians remain committed to space in general and a manned program in particular."[26]

What is more difficult to determine is the exact monetary level of commitment. While Koptev states that the funding for 1992 aims to keep the space program at the same level of activity as 1991, as noted above, Western estimates indicate that *outlays for the space program were down almost 50 percent in 1991*,[27] and it is hard to believe, with the current rate of inflation and overall economic uncertainty in Russia, that even the 1991 level can be maintained in 1992. Just as one indicator, the reduced number of launches seems to bear out such a conclusion. Another indicator is an estimate of the Russian Gross Domestic Product over the next several decades. Figure 14 gives one such estimate, considered by many to be quite optimistic.[28]

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23 Interview with Yuri Koptev in *Izvestiya*, 28 February 1992, translated in FBIS-SOV-92-044, p. 57.

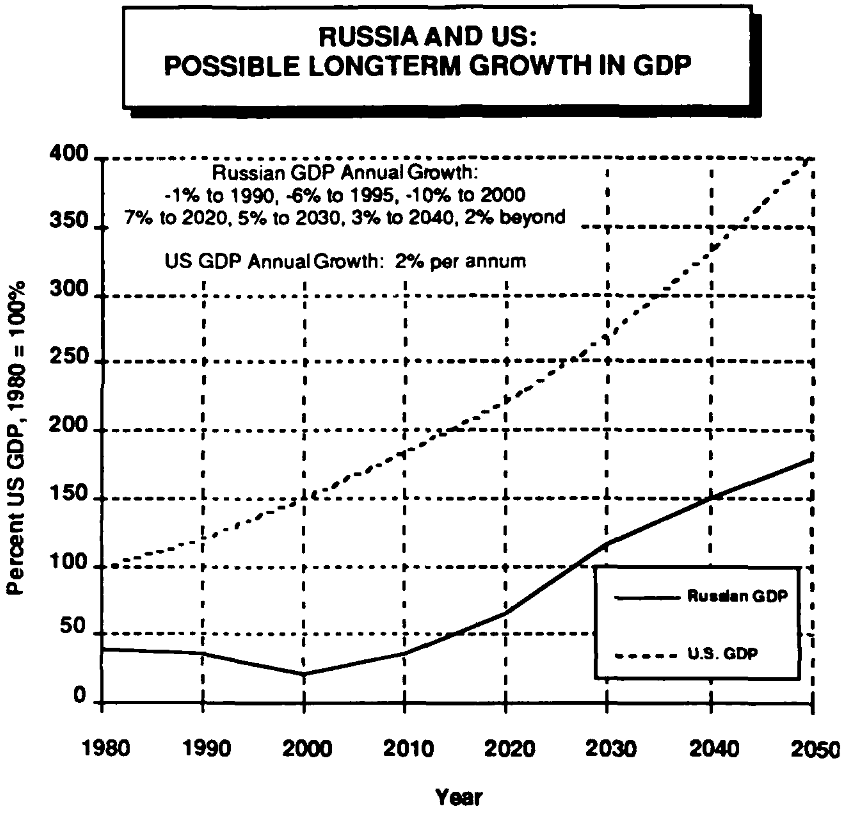
24 As outlined in Furniss, *Flight International*, 8-14 April 1992, p. 18.

25 Koptev and Goldin interview, as reported by Federal News Service Kremlin Transcripts, 16 July 1992.

26 As quoted in "NASA's Goldin Foresees Cooperation, Not Sales after Visiting Russian Space Facilities," *Aviation Week & Space Technology*, 27 July 1992.

27 See, for example, Paul Mann, "Soviet Defense Crumbling, U.S. Intelligence Says," *Aviation Week & Space Technology*, 15 June 1992, p. 35.

28 This figure is based on data provided from BDM Corporation.



Source: BDM Corp.

Figure 14. Comparison of Possible Growth in GDP: Russia and the U.S.

4. International Investment

One of the lynchpins for the space program's survival is its ability to commercialize and attract Western cooperation and investment. The level of international exchange pursued by the Soviet Union, and now by Russia, has increased during recent years, namely since the initiation of Mikhail Gorbachev's policies of expanded contacts with the Western world, including for the space program. As noted in *Jane's Intelligence Review*, under perestroika, the space program

> *was considered to be one of the programs which, at least in theory, could be self-financing because it was able to produce goods and services which might compete in the international marketplace. The Main Administration*

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for the Development and Use of Space Technology for the National Economy and Scientific Research (GLAVKOSMOS) established in 1985 to promote Soviet space commercialization activities, actively marketed goods and services abroad to obtain hard currency to finance the space program.[29]

Over the years, participants from 13 nations have flown to Soviet space stations as part of their international cooperative (rather than commercial) efforts. In addition, in December 1990, the company of a Japanese journalist paid $12 million for an 8-day flight to the Mir space station, representing the first of the USSR's commercial customers. Other commercial agreements have also been reached with Great Britain, France, and Germany.[30]

The current Russian space effort is, without a doubt, focused on *broadening international cooperation*. Some Russian officials talk about the possibility of a single space program in non-commercial areas such as human and robotic space exploration, robotic science and satellites to study the environment and weather.[31] And, indeed, contacts with European countries (both on a bilateral basis and with the European Space Agency[32]) and several Asian countries (such as Japan and China) have been expanding.[33]

There is some discussion of including Russia in the European space program, and space contacts with France and Germany are long-standing and continuing.[34] There are, in fact, possible mutual benefits to be derived from such collaboration. Two major programs being undertaken by the European Space Agency, the Hermes shuttle and the Columbus lab

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29 Marc J. Berkowitz, "Space Fallout From Soviet Disintegration," *Jane's Intelligence Review*, March 1992, p. 125.

30 Marcia S. Smith, "Soviet Space Commercialization: Selling the Mir Space Station," *CRS Report for Congress*, 30 September 1991, pp. 5-6.

31 As discussed in Kathy Sawyer, "U.S. Space Team Hunts Bargain, Allies in Russia," *Washington Post*, 29 July 1992.

32 The European Space Agency has 13 members: Austria, Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

33 For example, Russia has been discussing a possible comprehensive agreement on cooperation in space with Japan, which could include the sale of the Energiya launcher, Buran shuttle technology, launchers to carry Japanese satellites, and medical and biological space data. Reported in Tim Furniss, "Japan and ESA Fight for Energia," *Flight International*, 17-23 June 1992, p. 21. One question here will be whether Yeltsin's decision to cancel his long-awaited trip to Japan in September 1992 and the continuing tensions between the two countries over the Kurile Islands will ultimately put any such deal on ice. Information about other space deals with Japan is contained in, for example: *Kyodo* report, 5 December 1991, published in Foreign Broadcast Information Service, *Daily Report: East Asia* (hereafter FBIS-EAS)-91-235, pp. 9-10; TASS, "Japanese Partner's Bankruptcy Strains Energiya," translated in FBIS-SOV-91-087, p. 34; *Kyodo* report, 1 November 1990, published in FBIS-EAS-90-213, p. 7; and *Kyodo* News Service, 17 January 1990, published in FBIS-EAS-90-016, pp. 5-6.

34 For example, according to a report in *Izvestiya* on 15 July 1992, Germany will be investing DM30 million in Russian aerospace industry in fiscal year 1993.

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module for Space Station Freedom face a very uncertain future, in large part because the European governments are finding it difficult to meet the necessary funding levels of these increasingly expensive programs.[35] This is compounded by the recent crisis in stability of European currencies. Yet there remains (especially among the French) a commitment to Europe's having its own manned space program, as well as a general preference among Russians to join efforts with the United States. Consequently, it has been suggested that "the emergence of the CIS as a member of ESA could provide opportunities for manned flights to the Mir space station to fulfill European aims for a manned presence in space."[36] Proponents of collaboration with Russia (and perhaps other CIS members) point to the low costs and demonstrated Russian capability in this area. Germany has been one of the greatest supporters of ESA-CIS cooperation and has, in fact, proposed a joint effort to build a launch the Mir-2 station in 1996; Germany has offered to provide one-third of the money, estimated at $100 million annually. The station would be built in the CIS (thereby keeping at least some of the space industry alive there) and would accelerate ESA's plans for manned presence in space.[37] There are also reports that ESA may be considering the purchase of the Energiya launcher.[38]

There have also been increased contacts between the United States and Russia in the space arena. Indeed, there are valid arguments that *Russian and U.S. space programs have complementary strengths*, with the Russian emphasis on rockets, long-term space flight, and walking in space. Following the high-level visit led by NASA Administrator Goldin in July 1992, future joint efforts being discussed include: sending a Russian cosmonaut on the U.S. shuttle in October 1993; sending an American to the Mir space station; docking the U.S. shuttle at the Mir; using Soyuz spacecraft as an emergency rescue ship for the space station Freedom; and a specific $1 million contract with NPO Energiya to study the application of Russian space technology for the U.S. space station. Given current uncertainties about Russian economic and political development (and their implications for overall stability of the space program), much greater *caution is understandably in evidence*

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35 Overall within the ESA, France is the number one contributor (43.5 percent), followed by Germany (28 percent); both countries are facing economic difficulties as France deals with budget austerity and Germany copes with the heavy costs of unification. France has been particularly committed to the Hermes (it pays for 45 percent of the overall Hermes program), but its future is increasingly in question. Hermes will be a key focus at the next ESA Council of Ministers meeting scheduled for November 1992 in Spain.

36 Tim Furniss, "Budget Brings Hermes Back Down to Earth," *Flight International*, 22-28 April 1992, p. 18.

37 Tim Furniss, "NASA Awards Russians Contract," *Flight International*, 1-7 July 1992, p. 17.

38 Furniss, *Flight International*, 17-23 June 1992, p. 21.

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when talking about longer-term, large-scale projects such as joint exploration of the Moon and Mars.

5. CIS Cooperation

Under the rubric of international cooperation it is now possible to include not only cooperative efforts with Western countries, but also cooperation among the new states of the former Soviet Union. Although Russia (and Russia alone) has the capability to have its own independent space program,[39] as we have noted elsewhere Kazakhstan possesses a vitally important launch site (Baikonur), whence all manned flights are launched. In addition, Ukraine has an important missile production facility, which also produces the SL-16 Zenit, a booster in its own right as well as serving as the strap-on boosters for the Energiya SL-17.[40] There are other space facilities located in other CIS states as well. As noted in Chapter I, the members of the CIS reached an agreement in Minsk in December 1991 on space cooperation,[41] but *without the structures* to actually implement the agreement, it is necessary to *develop bilateral arrangements*, as Russia and Kazakhstan did in May 1992.[42] The additional challenge facing Russia--both in its relations with other CIS states and even within its own territory--is the need to establish a *new network of ties for obtaining supplies* since the old network has disintegrated with the dissolution of the Soviet system. One vehicle for space cooperation among the CIS states may be the Inter-State Space Council, founded in early 1992 as part of the Joint Space Agreement,[43] although, as pointed out in Chapter I, the specific authority and responsibilities of the Council remain to be defined. One of the persisting problems is, of course, that of *funding*. To date, none of

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39 The Russian Federation possesses some 80 to 85 percent of all the former Soviet Union's space science and industry.

40 There has been some discussion that Ukraine may be intending to produce its own Zenit missiles for civilian use and sales.

41 Ukraine did not, however, sign it until July 1992.

42 Because of the vital importance of the Baikonur facility to the overall space program, it is crucial for Russia to maintain good working relations with Kazakhstan, a fact which the latter can certainly seek to exploit in overall relations between the two states. As long as their respective presidents, Yeltsin and Nazarbaev, remain in power, the prospects for good relations are favorable.

43 The nine signatories are: Azerbaijan, Belarus, Kyrgyzstan, Tajikistan, Uzbeksitan, Armenia, Turkmenistan, Kazkhstan, and Russia. It was reported, however, that the use of space centers is subject to separate agreement (such as the one reached between Russia and Kazakhstan in May 1992). Tim Furniss, "CIS Tightens Space Management," *Flight International*, 29 January-4 February 1992, p. 17. Several of the states have also established their own space agencies, including Kazakhstan, Ukraine, and Belarus.

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the agreements have addressed exactly what each CIS participant's share and monetary responsibility are to be.

6. Summary & Prospects

All these factors point to *a great deal of uncertainty in the Russian space program's future*. Referring back to the three key factions in Russian politics and economics discussed in the previous section, if the liberals should subsequently gain the upper hand, the importance of the space industry's ability to diversify and maintain contacts (and contracts) with Western nations will be paramount. If there is an alliance of sorts between the liberals and the industrialists, diversification and Western cooperation will still be important, but some level of support from the government to ensure some of the industry's survival would be more likely. Here the argument that the space program must be maintained or else Russia will be forced to pay tremendous amounts in foreign currency reserves for meteorological surveys, communications, etc., will have strong support.[44] In the event conservatives take the reins, certainly greater emphasis would again be placed on the military components of the space program.

While this assessment has focused on the prospects for Russian civilian space efforts, it is also important to note Russia's continued interest in the military aspects of its space program--even without the advent of a "conservative" leadership. Indeed, the establishment of the Space Forces as a separate branch of the Russian Armed Forces in October 1992, along with consistent governmental support for putting greater emphasis on advanced technology weapons within the defense procurement budget, would indicate a continued commitment to the military space program, even in this time of economic crisis. Still, military space efforts will be competing for increasingly scarce resources. First, Russian military personnel costs have risen dramatically and are taking a much larger share of the entire defense budget than they have historically. Second, competition within the procurement budget will also be stiff, as overall emphasis in the Russian Armed Forces is being place on enhancing the mobility of the forces (which means spending money on new, lighter types of equipment). Thus, Russia's civilian space program is not alone: its military space program faces a host of uncertainties as well.

From the Western perspective, while it is logical to examine our options carefully with respect to Russia's civilian space program and to learn as much about the dynamics of

44 See, for example, Report by M. Ponomarev, "Vesti" newscast, 27 December 1991, translated in FBIS SOV-92-001, p. 69.

the situation as possible before making major commitments, *the risk we run is that much of the structure may disappear* before our very eyes. What we need to determine is *what kinds of cooperative efforts make the most sense and what elements we might purchase in order to keep Russian space technology alive.*[45] We address this topic in more detail in Chapter IV.

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45 Based on discussions with Andrew Aldrin, July 1992.

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III. CHALLENGES FACING THE U.S. SPACE PROGRAM

The scale of expectations for the future of the U.S. space program is set in the metric of the past. The past will be a challenge to live up to, much less exceed. The United States remains the only nation ever to have its people walk on the surface of the moon. It has sent out exploratory spacecraft to every planet in the solar system except Pluto, and returned breathtaking, close-up views. The space program precipitated the revolution in communications that changed the lifestyle of nations, and gave them the ability for near-instant contact. The U.S. space program has produced a bounty of civilian well-being and commercial opportunities.

A. OVERVIEW OF U.S. CAPABILITIES

NASA is currently engaged in or planning five major space programs. One is maintaining and expanding our space transportation system to assure continuous access to space for spacecraft and astronauts. A second is the building of the international Space Station Freedom. A third is the multi-year Mission to Planet Earth and its centerpiece program, the Earth Observation System, essential to improving understanding of how the world is changing and how man's activities will affect future generations. Fourth is a continuing commitment to scientific research in the areas of astrophysics and unmanned planetary exploration. Fifth is the Space Exploration Initiative to expand human presence beyond Earth. These five areas constitute the basic elements of the U.S.' civilian space program. (For more details than presented below, see for example, *Interavia Space Directory, Space Activities of the United States and Other Launching Countries: 1957-1991*, and *International Reference Guide to Space Launch Systems*.[1])

NASA also has an active program of aeronautical research and engineering development that is not discussed here, since it is not strictly space related.

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1 *Interavia Space Directory, 1991-1992*, ed. Andrew Wilson, Jane's Information Group, Alexandria, VA; *Space Launch Capabilities of the United States and Other Launching Countries: 1957-1991*, Marcia S. Smith, Congressional Research Service, Library of Congress; *International Guide to Space Launch Systems*, American Institute of Aeronautics and Astronautics, Washington D.C., 1991.

1. Space Launch Capabilities

The backbone of the U.S.' launch capability is the Space Shuttle (more specifically, Space Transportation System (STS) or space shuttle. The Shuttle is the first spacecraft to return to Earth on wings and land like an airplane. The current fleet of four orbiters is a unique asset, offering a capability no other nation can legitimately claim: human access to space while carrying an additional large payload. (While the Soviets essentially duplicated the U.S. achievement in its Buran, it is an unknown quantity in reliability, has only flown once, and is unlikely to be further developed by Russia, at least in the near future. The European Hermes is only in the planning stage, and continues to be delayed.)[2] The U.S. space Shuttle provides a versatile tool for space research, spacecraft deployment or return, and satellite repair. Although the question of cost-benefit has not been clearly answered, evidence for the value of human dexterity in space can be found in the success of the Intelsat VII rescue, Solar Max repair, and pending repair and maintenance of the Hubble Space Telescope.

In 1989, Congress required that the Shuttle be reserved only for those missions requiring presence of a crew. Since that time, United States commercial expendable launch vehicle (ELV) capabilities have expanded, and now offer a spectrum of launch vehicles ranging from the Titan, Delta, and Atlas variants down to the newer Pegasus, Scout II, Conestoga, and pending Taurus. The United States is now actively pursuing what is intended to be a modernized, more competitive family of launch vehicles to carry it into the next decade. This concept is captured in the National Launch System (NLS) with a family of small, medium, and possibly heavy-lift vehicles. In addition, the National Aerospace Plane (NASP) and Single Stage to Orbit (SSTO) continue to be futuristic options for new approaches in access to space, although funding continues to elude their supporters. Key characteristics of U.S. launch vehicles are summarized in Table 7.

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2 deSelding, Peter B., "ESA Pushes More Cooperation With Russia," *Space News*, Vol. 3, No. 34, September 14-20, 1992, Army Times Publishing Co., Springfield, VA.

Table 7. U.S. Launch Vehicle Characteristics

Launch Vehicle	Pounds to 28° LEO*	Pounds to Polar LEO*	Pounds to GEO	Manufacturer	Cost Per Launch $M
Scout (GTO)	560	460	120 (GTO)	LTV	10-12
Enhanced (Scout)	1000	820	240 (GTO)	LTV	15
PEGASUS	1,000	800	---	Orbital Sciences Corporation	12
ATLAS E	---	1,8000	---	General Dynamics	50
DELTA II 6925	8,780	6,490	1,600/2,000	McDonnell Douglas Space System Co.	50
DELTA II 7925	11,100	8,420	---	McDonnell Douglas Space System Co.	50
ATLAS I	12,300	10,300	1,000/2,500	General Dynamics	75
ATLAS II	14,100	11,900	1,270/3,100	General Dynamics	80
ATLAS II A	14,900	12,600	1,340/3,300	General Dynamics	90
ATLAS II AS	18,500	15,000	2,310/4,100	General Dynamics	120
TITAN II	---	4,200-8,200	---	Martin Marietta	45
TITAN III	31,200-32,700	---	5,500	Martin Marietta	150
TITAN IV	39,000-47,700	31,000-41,000	5,200-11,500	Martin Marietta	160-250
STS	46,000	---	2,800-13,000	Rockwell Intl	180
Proposed/In Development					
- NLS	50,000	---	---	---	200
TAURAS (XL, XL/S)	3,000 (3,500; 4,300)	---	860 (GTO) (1,140; 1,515)	Orbital Sciences	13 (1st Launch)

* LEO = Low Earth Orbit at 100 nm altitude, circular orbit

2. Space Station Freedom

Space Station Freedom remains a central commitment of NASA. Space Station Freedom and Shuttle have been closely interwoven in engineering, design, and operational compatibility. Freedom was originally intended to be a versatile national laboratory in space, providing modern facilities for microgravity, life sciences, astronomy, and physics.

It was also considered by some to hold the potential as a transportation node for points beyond Earth orbit, and a service station for repair and refurbishment of satellites. A still relevant mission was to obtain much-needed experience the United States has been lacking in long-duration missions, essential experience if the United States were eventually to execute the Space Exploration Initiative.

The station has undergone frequent redesign since its inception. Today, after repeated cost-cutting measures that recognized the exceptional costs entailed in achieving such a capability, the station has taken on a more modest mission as an internationally supported laboratory for microgravity and life sciences research. Part of the consequences of the altered design to achieve less ambitious goals is that it retains some of the features that are more appropriate for the greater capabilities originally intended. The result is a less-than-optimum design for achieving its current objectives. While there is hope that the station will one day "grow" to accommodate its original mission, this is questionable in the face of competition for funding from other federal programs.

3. Mission to Planet Earth

The third major program area is the Mission to Planet Earth, of which the Earth Observing System (EOS) is the centerpiece effort. It is a major program in terms of cost (originally estimated at nearly $30 billion), which attracted considerable Congressional attention, and which resulted ultimately in a flexible approach more resilient in the face of programmatic and operational contingencies. It involves major interaction with other agencies, and is intended to study the process of global change--particularly climate change--and to assess the impact of and to human activity on Earth. It will involve an unprecedented effort to collect, process, catalogue, and analyze orders of magnitude more data than have been collected by the entire space program to date (estimates are on the order of 1 terabit per day). To complement this, NASA is also planning a series of satellites and Shuttle experiments--the Earth Probe missions--intended to yield comprehensive data on the atmosphere, land surface characteristics, and the oceans. One example is the joint U.S.-French TOPEX/Poseidon mission, launched in 1992. This oceanographic satellite mission is designed to improve knowledge of Earth's oceanic processes and gravitational field, and to evaluate precision satellite navigation technology.

4. Space Science

Basic space science and research has probably been the least visible endeavor, although there have been some elements that have certainly caught the attention of the public, both domestically and internationally. The exploits of the Viking Mars Lander, the Voyager Missions, and a host of others have generated good will, national pride, and general excitement about the promise of space science. Most of the basic science research goes on outside the public mind's eye. As noted by NASA Administrator Daniel Goldin at the recent World Space Congress, typical coverage of a NASA Shuttle mission does not go much beyond the film footage of the take-off. On the other hand, while the story of space science historically has gone relatively untold, former Associate Administrator for Space Science and Applications, Lennard Fisk,[3] has noted a renaissance in the subject with the launching of the Great Observatories. The Hubble Space Telescope, Advanced X-ray Astrophysical Facility, Gamma Ray Observatory, together with the soon-to-be-launched Space Infrared Telescope Facility are aimed at making simultaneous measurements of the universe over the infrared, visible, UV, X-ray, and gamma ray wavelengths. Meanwhile, the Magellan radar mapper has penetrated cloud-covered Venus providing a clear view of more than 80 percent of the surface. Galileo, launched in 1989, will follow the Voyager missions with a Jupiter orbiter and probe mission. The Ulysses mission is a joint international effort to study the polar regions of the Sun. After a hiatus of many years, the United States is returning to the red planet with the Mars Observer, launched in September 1992. The Cassini mission to be launched in 1994 is the Galileo analogue for Saturn. Preliminary planning is underway for a 7.5 to 9 year mission to Pluto, the last of the solar system planets to be explored. Lunar and Mars surveyors and probes are planned as near term precursors for the Space Exploration Initiative.

5. Space Exploration Initiative

The Space Exploration Initiative (SEI) is another major goal. Set forth by President Bush on the occasion of the 20th anniversary of the first human landing on the moon, he called for a permanent base on the moon and human exploration of Mars by 2019. Interest in this goal, incredulous or supportive (as measured by the large number of studies of the proposals on how best to execute the initiative), is racing ahead of the program's current budget. While the program faces strong challenges to its benefit and budget, it is proceeding nonetheless, albeit at a very slow rate.

3 Fisk is now NASA Chief Scientist.

B. POST COLD WAR REALITIES

The end of the Cold War has had a major effect on military priorities which underlaid the space program. The standing down of much of the U.S. and U.S.S.R. strategic ballistic missiles has shifted attention from all-out nuclear war between nuclear superpowers to concern about Third World proliferation, regional instabilities and limited strikes. The new world order is in flux. Military budgets are being redirected or cut. The national imperative to beat the Soviets is gone. The military challenge has been replaced by a domestic economic challenge. All space faring nations are faced with the difficulties brought on by a global recession. Economic lassitude is making it very difficult to maintain a solid coalition for large, expensive space programs.

1. A Growing World Space Community

As a direct result of the importance of space technology to the modern nation, developing countries around the world are seeking to participate at different levels. *Space industries and capabilities are no longer the province of just two world powers.* Japan, Germany, France, and Italy have been making large investments and significant progress. France has dominated the world commercial market in launches through Arianespace. Third World countries now see their national defense inextricably tied to space launch capability. Many countries, such as China, Israel, India, South Africa, Brazil, and Iran are seeking independent launch capability and satellite technology for reasons of military and economic security. Developing countries with large land area are likely to be most critically interested in developing the satellite applications that provide their population with television, telephone, weather services, and agricultural analysis support. For many years the U.S. and U.S.S.R. have been unable to claim the title as the world's only space-faring nations. Table 8 is evidence of the growth of space capabilities and aspirations of many countries around the world.

Table 8. International Civil Space Programs, 1992

Country	Budget ($M)	Major Programs
Argentina	10	Astronomy satellites
Australia	13	Deep space tracking, space science
Austria	28.5	ESA, Mission to Mir
Belgium	134.8	ESA
Brazil	100	Launch vehicles, remote sensing satellites
Canada	292	ESA associate member robotics, communications satellites
China	1,200	Launchers, communications satellites, meteorological satellites
Denmark	28.9	ESA
European Space Agency	3,000	Launcher, space station, space shuttle
Finland	46	ESA associate member
France	1,380	ESA, Mir missions, remote sensing satellites
Germany	969	ESA, communications satellites, space plane research
India	182	Launchers, remote sensing satellites, communications satellites
Ireland	5.9	ESA
Italy	973.4	ESA, tethered satellites
Israel	6	Communications satellites, research satellites, launchers
Japan	1,262	Space station, remote sensing satellites, launchers space science, lunar probes
Netherlands	87.4	ESA, X-ray and infrared cameras
Norway	29.2	ESA, sounding rocket range
Pakistan	7.5	Research satellites, sounding rockets
Russia	741	Launchers, planetary probes, space shuttle, communications, remote sensing, and navigation satellites
South Africa	?	Launchers and satellites programs
South Korea	50	Communications satellite program
Spain	144.6	ESA, micro-satellite research
Sweden	81.9	ESA, science satellites, communications satellites
Switzerland	60.8	ESA
Taiwan	75	Communications satellites program
Ukraine	?	Launchers, instruments
United Kingdom	206.6	ESA, remote sensing instruments
United States	14,700	Space Shuttle, space station, space science, remote sensing, planetary probes

Source: *Space News*, Aug 31-Sept 6, 1992.

Developing countries are seeking technology transfer from Western countries and the former Soviet Union (FSU). Technology transfer from European and U.S. companies is constrained to some extent by trade agreements and national defense policies, but pressure to compete for launch market or the communications satellite market is breaking down these prohibitions. For instance, Arianespace's successful bid for Brazilsat second generation launch services during 1989 was reported to include proposals for transferring thruster, gyro, and other satellite technologies. As we have seen, the economic conditions in Russia and the other FSU countries are exerting strong pressure to trade technology for hard currency. Faced with this need, rapid dispersion of Soviet advantages in propulsion and launcher vehicles is likely to occur.

Despite Russian President Yeltsin's apparent reluctance to conduct arms trade, Russia's worsening economic plight is making such moves increasingly attractive as a means of obtaining hard currency.[4] In Kazakhstan, pressures appear so strong that opium export has been legalized.[5] Apparently, raising the ire of the West is an acceptable risk compared to the intense economic needs.

No single nation has a distinctive lead across the board in all space technologies. Whereas deals with the FSU could be advantageous in launchers, rocket engines, thrusters, gyros, automated docking and rendezvous, and others, none of the former Soviet states can claim the strength of leadership in communications satellite technology and remote sensing that has hallmarked U.S. achievement. Through both solitary and cooperative ventures, Third World countries are becoming educated consumers. India, successfully pursuing development of its own space infrastructure is in the market for a variety of space technologies and has managed to participate simultaneously in cooperative ventures with the U.S., U.S.S.R., and ESA. With France, India shares the distinction of being one of two countries with mission specialists who have flown on both the U.S. Shuttle and U.S.S.R. space station. For the developing country there is no one-stop shopping.

2. The Restraints of Recession

Although comparison of living standards of the United States and the former Soviet states is a study in contrasts, both countries are dealing with shifts in their political-economic situation. Compounded by global recession, most developed nations of the

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4 "Soviet Defense Crumbling, U.S. Intelligence Says," *Aviation Week & Space Technology*, June 15, 1992.

5 Interview with Elizabeth Teague, September 18, 1992.

world are being forced to reconsider space policy and defense strategy. Although the shifts are much more dramatic in the CIS, the Europeans and the United States as well are examining the degree to which they can afford government funded space programs, and are reconsidering existing space policies.

The recession is making it harder for Congress to justify large federal programs in research whose importance is little understood by the general public. Contractions in the defense budget raise the issue of how much cut-backs will atrophy military and space technology capabilities.

Cuts in funding for ESA have resulted in bare-bones programs. The Hermes space plane will exist only on paper for some time; the Columbus Laboratory for Space Station Freedom "may be little more than a multi-billion-dollar empty can."[6] Other projects helpful in preparing users for the space station era are also in doubt.

The Russians and Ukrainians, in more dire economic straits, have been voicing anxious arguments for continuation of their space program.

> *"Unless we save our space program and make it serve the interests of the people, scientists are warning that we may fall behind world standards irretrievably in a matter of one to two years. And then we will have to pay a hundred fold, and in dollars for meteorological surveys, communications, television, and many other things... World experience has shown that sensible funding of space programs is the best and shortest way to develop all the sectors of the national economy, and thus enhance society's prosperity."*[7]

Thus, all space-faring countries--developed and undeveloped--are facing severe pressures tending to inhibit viability and growth of their space programs, and forcing reconsideration of national policies.

3. International Competition and Cooperation

Worldwide competition and interchange of space technology is underway and, in spite of economic conditions, likely will increase in the future. Post-cold-war space may well be an arena in which contestants compete for new customers of the Third World, as well as existing clients. Threading throughout these actions will be an undercurrent of military implications. New alliances are likely to spring up, and it seems clear the United

6 deSelding, Peter B., "ESA Short on Money to Use Columbus," *Space News*, September 28 - October 4, 1992.

7 Vesti newscast, FBIS-SOV-92-001.

States must formulate a strategy for maintaining a competitive edge in the post-Cold War period.

In the post-Cold War environment various alliances of complementary national space programs have the potential to outperform the United States on numerous fronts. For instance, while the long-standing bitterness over the Kurile Islands presents serious obstacles, Japan and the FSU are in the process of exploring potential arrangements,[8] and may soon assemble a powerful alliance in the world space industry markets.[9] Japan was the fifth country (after the U.S.S.R., U.S. and France and Australia) to achieve a national satellite launch capability to LEO and the third to achieve geostationary orbit. It now ranks third in the world in space expenditures. It rivals the United States in computers and microelectronics where the FSU has been traditionally weak. On the other hand, the CIS complements Japan with an extensive stable of reliable launch vehicles.

Another possible alliance that should be of concern to the United States would be a French or German arrangement with CIS to advance the European manned program to the exclusion of the United States. The United States has now invested over $4 B in the design and development of the Space Station Freedom, and yet there are numerous reasons why ESA might consider pulling its support for SSF and attach the Columbus module to Mir instead. Among these reasons we can list the following:

- Mir is available now whereas SSF faces constant threat of funding loss.
- ESA members have often been unhappy with the results of the U.S. annual ritual of redesign - too often performed without input by the international partners.
- The Soviets accumulated 20 years experience in the reliable, safe operation of their space stations.
- Mir is less expensive to operate and less expensive to purchase cosmonaut time on board.
- Mir design is easier to upgrade with new laboratory facilities as research dictates a new interest or requirement.
- The United States has sometimes been less than diplomatic about always insisting on U.S. interests first on SSF.

8 "Russians Seek Japan Space Ties," *Space News*, June 8-14, 1992.

9 "Japanese, Russians To Sign Space Accord in September," *Space News*, August 31 - September 6, 1992.

For all of these reasons collaboration with CIS is going to look very much more attractive in the post-Cold War period. We need to address the question - "How would it affect our manned space program if Japan or Europe were to ally themselves with CIS in direct competition with the U.S.?"

One of the advantages of having so many countries now participating in space programs is world wide acceleration of activity and new progress. The disadvantage to the United States is the increasing difficulty in retaining leadership in so many areas. Collaboration and competition represent the challenges and opportunities facing the United States and other countries intent upon maintaining healthy space programs and technologies. *The United States needs to be very selective in formulating a strategy that best balances resources to meet domestic needs, while still exploiting strength in those areas in which it can maintain undisputed leadership.*

C. MAJOR CHALLENGES FACING THE U.S. SPACE PROGRAM

The special strengths of the U.S.' space capabilities lie in satellite engineering and manufacturing (particularly microelectronics and communications technology), its remote sensing technology base, the achievements of its planetary missions and its great observatories programs, and the uniqueness of the Shuttle and Manned Space programs. At the same time, NASA has experienced certain difficulties that are perhaps inherent in a democratic society, but nevertheless have exerted a retarding effect on its coherence and robustness. A survey conducted among senior U.S. research and technology managers identified a number of significant issues that must be resolved for the United States to improve its competitive posture in the international marketplace. In order of priority, these include:[10]

- General management practices
- External financial pressures
- Changing global technology environment
- Technology management practices
- Technology policies of the federal government

10 American Institute of Aeronautics and Astronautics (AIAA)/Center for Advance Technology (NCAT), Conference on Technology Policy and Global Competitiveness, Washington D.C., September 5-6, 1991.

Within the area of general management practices, the key problems were associated with the *failure to manage strategically with a long term view, and an inability to effectively integrate new technology into business strategy.*

An additional, more technically oriented issue is the growing international challenge to NASA's leadership role in many areas of space. *One of the most pressing of these issues is the competitive threat to the U.S. launch industry.*

The following paragraphs discuss major aspects of these challenges, with particular attention to those that relate to Russian space capabilities.

1. Strategies, Requirements, Plans, and Funding

NASA's history of phenomenal success needs no recounting. From the early days, the United States consistently carried out mission after mission of solar system exploration, all of unparalleled achievement. Perhaps the capstone achievement, at least in the public eye, was the Apollo Program of Manned Lunar landings. However, while it was "an enormous technological achievement, and its momentum carried the NASA manned programs forward into the 1970's...the transient motive behind the Apollo program--and the rapid mobilization of funds and personnel that made success possible--eventually impeded the gradual evolution of a stable and broad public consensus about the nation's purpose in space."[11] While most citizens support a viable space program, *there is a lack of consensus on what the goals and direction of that program should be.* This may be partially reflected in NASA's traditional breadth of attack on the many rich and diverse areas challenging the focus of the country's space endeavors. As concluded by the Augustine Committee, "NASA is currently over committed in terms of program obligations relative to resources available--in short, it is trying to do too much, and allowing too little margin for the unexpected."[12] This tendency has attracted increasing Congressional attention to the details of NASA's business, illustrated to an unusual degree by recent Congressional restriction on Space Station Freedom redesign as part of Station funding provisions in 1993. When this is considered in the broader context of Congress' obligations to other programs, and its associated unwillingness to institute multi-year funding mechanisms, the current chances for an efficient, coherent set of programs aimed at consistent, achievable goals appear slim.

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11 *Report of the Advisory Committee on the Future of the U.S. Space Program*, December 1990, Superintendent of Documents, Washington, D.C.

12 Ibid.

One of NASA's responses to the criticism of attempting too much is *Vision 21: The NASA Strategic Plan.*[13] This plan establishes (or more accurately, re-emphasizes) a balanced set of goals for the nation's civil space program, and identifies the key programs employed to attain these goals. The essence of the plan is summarized in Figure 15. However, while it sets forth a laudable set of goals, and identifies the corresponding missions and enabling capabilities to achieve those goals, it does not appear to go far enough in identifying and integrating the basic requirements of each of the missions and how they are to be attained. With few exceptions (the Integrated Technology Plan being one), it fails to identify subsequent implementing plans. For example, the Office of Space Science and Applications has developed its own strategic plan that treats in much greater detail its own requirements based on space science objectives, associated budget requirements, as well as alternatives and contingencies in recognizing budget uncertainties.[14] No mention of this fact is made in *Vision 21*. In short, the plan is more a mandate of what should be done, but says little about implementation. There is no discussion that cuts across mission areas as to the priorities, implications, and tradeoffs among programs and resources. The Augustine Committee believed that "NASA should develop a 10-year plan to provide Congress with sufficient information on objectives and implementation approaches to permit sound initial budget decisions. *Most importantly, this plan should provide cost information, based on straightforward and understandable assumptions, including the costs of development, launch and operations*[15] (emphasis added). Thus, in view of the drastically changed political and economic world in which space endeavors are being strongly affected, *not having a strategic plan that clearly charts courses of action and contingency options would appear to place NASA at a disadvantage, and could significantly impede the civil space program.*

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13 *Vision 21: The NASA Strategic Plan*, National Aeronautics and Space Administration, January 1992.

14 *Office of Space Science and Applications Strategic Plan 1991*, NASA/OSSA, April, 1991.

15 *Report of the Advisory Committee on the Future of the U.S. Space Program*, December 1990, Superintendent of Documents, Washington, D.C.

NASA's **Vision 21** envisions an aeronautics and space program that inspires and betters the lives of all Americans, young and old, through our achievements as the world leader in space exploration and aeronautics.

GOALS

- Advances scientific knowledge of the planet Earth, the sun, the solar system, the universe, and fundamental physical and biological processes;
- Expand human activity beyond Earth orbit into the solar system;
- Strengthen the competitive posture of the United States in the fields of space and aeronautics; and
- Attract young people to the wonders of mathematics, science and technology and ensure a more technically literate society equipped for the world of tomorrow.

MISSIONS

- Space Science
- Mission to Planet Earth
- Mission from Planet Earth
- Aeronautics Research

ENABLING CAPABILITIES

- Human Resources
- Physical Resources
- Space Technology Research
- Space Station Freedom
- Space Transportation and Communications Systems

Source: *Vision 21: The NASA Strategic Plan,* National Aeronautics and Space Administration, January 1992.

Figure 15. Basic Elements of the NASA Strategic Plan

In today's world the strategic plan should also recognize the role of both competition and cooperation. As we have sketched previously, the United States can no longer afford to establish its goals and objectives as unilaterally as appears to have occurred in the past. Thus, *an adequate strategic plan for civil space should recognize the context of international activities, and identify areas where cooperation and competition offer both advantages and disadvantages to the United States.*

While a comprehensive and definitive strategic plan is necessary, its development is a different--and difficult--matter. The challenges of the world changes wrought since 1991 are being recognized by the National Space Council. In mid- and late-1992 the Council established three task groups aimed at (1) finding ways to make most efficient use of U.S.

space assets, (2) reviewing U.S. space launch strategy, and (3) reviewing the U.S. space industrial base.[16] The first, the Space Policy Assessment Task Group, is charged with recommending ways in which the United States could "save money by avoiding duplication in space efforts, keep the U.S. political and technological lead in space for the next century and prevent the industrial base from disintegrating in the wake of the Cold War."[17] It will build on the findings of the other two reviews dealing with space launch strategy and the U.S. industrial base. Thus these efforts, to be completed by the end of 1992, clearly reflect awareness of the need for revised strategic thinking. *They will provide a strong foundation upon which NASA can build a comprehensive, integrated strategic plan.*

2. Issues in U.S. Satellite Systems and Launch Capabilities

The U.S. launch industry, like many space industries, has evolved a great deal in recent years. Originally the U.S. launch vehicle industry largely adapted itself to meet needs specific to the U.S. Defense Department where payloads might be one, or at least few, of a kind, expensive, and sometimes experimental. The early Shuttle program was explicitly aimed at being the sole provider of launch services for both DoD and NASA. [Recognizing the danger in this approach, the DoD insisted on retaining a basic expendable launch vehicle (ELV) capability.] Since Shuttle launch services were originally priced below real costs, the U.S. ELV industry delayed the development of commercial class launch vehicles that could compete in the international markets.

The Challenger disaster unmasked the wisdom of the DoD's position on having a diversified launch capability. But the period of relative monopoly of the Shuttle and DoD-tailored ELVs in the United States offered the opportunity for foreign launch vehicle capabilities to flourish. The European Arianespace's Ariane family of vehicles captured more than 50 percent of the world market in commercial launches for Western-built communications satellites.

Acknowledging that a dependable launch capability is built upon a diverse inventory of vehicles,[18] as well as the recognition of the growing international market in launch

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16 The Space Policy Assessment Task Group is being chaired by Laurel Wilkening; Edward C. Aldridge, a member of this task group, is chairing the space launch strategy review; Daniel J. Fink is leading the space industrial base review.

17 Lawler, A., "Panel to Chart U.S. Space Course," *Space News*, September 28-October 4, 1992.

18 See, for example, Heimerdinger, Daniel J., et al, "Systems Perspectives on Future Orbital Transportation Needs," and Deitchman, Seymor, et al, "Assured Human Access to Space," Institute for Defense Analyses, 1992.

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services, the United States has recently tried to construct an environment more conducive for home-growing a competitive launch industry. New vehicles, particularly Pegasus, Taurus, and the improved Scout II, have been developed. In addition, promulgated by the Space Council, and legislated by Congress, NASA is no longer supposed to carry payloads on Shuttle that do not specifically require manned presence (except under extenuating circumstances).

Further, the National Space Launch Strategy, released in 1991, elaborated U.S. space policy, calling for "a vigorous space launch technology program to provide cost effective improvements in launch systems, and ... development of advance space launch capabilities..."[19] While the National Launch System family is intended to respond to this direction for new launch vehicles, the concept is coming under increasing scrutiny, particularly regarding the heavy lift configuration, NLS-1. A particularly important issue for the Space Exploration Initiative is its stated need for heavy lift launch capability; NLS-1 apparently is insufficient to meet the large payload demands for SEI.

In seeking to develop a competitive launch industry, protective policies have had a restrictive effect on the U.S. commercial satellite industry. In the past, U.S. satellite builders have been prevented from flying on certain foreign launch vehicles, such as the below-market-priced Soviet and Chinese launchers. While this has been largely to limit dissemination of defense-related technology, an *unfortunate consequence of these restrictions has been to slow the sale of communications satellites, and encourage other countries to develop and market their own space technology and capabilities*.

For instance, the United States has enjoyed a clear world leadership in space communications, but Japan has become a worthy student of our success.[20] Japan is a large consumer of U.S. satellites. The Japanese appetite for communications satellites boomed in the eighties, and Japan has been a fairly lucrative market for U.S. builders of communications, weather, and broadcast satellites. Japan's three private satellite operators are consumers of Hughes Space and Communications Group, and Space Systems/Loral. European satellite builders have lagged significantly in competition with the United States for the Japanese market.

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19 *Integrated Technology Plan for the Civil Space Program*, Office of Aeronautics and Space Technology, National Aeronautics and Space Administration, 1991, Superintendent of Documents, Washington, D.C.

20 Japan plans to launch an experimental satellite in 1997 that will test the use of laser optics to transmit data between satellites, "Japan To Experiment With Laser Links in Orbit," *Space News*, August 31-September 6, 1992.

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Recently, the Japanese CS-1 and CS-2 series of satellites were built jointly by Mitsubishi Electric and Ford Aerospace. Two CS-4 satellites were approved by the Japanese government, but it required pressure from the United States to assure that the satellites would be procured on the open market. To retain U.S. domination of the market may be difficult, as Japanese firms are starting their own businesses. Further, U.S. government restrictions to prevent dissemination of U.S. defense-related technologies tended to depress the sale of communications satellites.

More recently these regulations have undergone some relaxation. Despite launch industry concerns, a limited number of U.S. satellites have been allowed to be launched on the Chinese Long March. Following U.S. permission to allow Russia to bid for launch of the U.S.-built Inmarsat-3, the London-based, 64-nation International Maritime Satellite Organization selected the Proton booster as the launch vehicle. In its bid, Russia offered to place the Inmarsat-3 satellite in orbit for $35 million compared to $60 to $65 million from General Dynamics (Atlas) or Arianespace. Thus, what is good for the U.S. communications satellite industry can pose a problem for the U.S. launch industry.

With the growing space capabilities of other countries, and the Russian and CIS intentions to sell virtually anything in their space program, most notably cheap launch services, *U.S. providers are becoming very concerned over their ability to compete. There is growing pressure and some actions within the government to make the receipt of aid from the United States and other western countries contingent on appropriate restrictions in marketing Russian launch services.*[21,22]

There are two additional areas in which launch capabilities are an issue. One is the stated need on the part of NASA's Office of Exploration for a heavy lift capability beyond that envisioned for the NLS' heavy lift configuration. SEI needs are on the order of 250,000 pounds or larger, while the largest NLS version is expected to be capable of only about 130,000 pounds.

The other area deals with Space Station assembly and resupply. Some dozen and a half Shuttle flights are planned in supporting assembly of SSF. Further, approximately five to seven flights per year are planned for logistical support to the Station over its 30

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21 H.R. 4547, A Bill to Authorize Supplemental Assistance for the Former Soviet Republics, Report No. 102-569, Parts I,II,III, and IV., March 1992.

22 *Recommended Policy Toward the C.I.S. Space Industry, Commercial Space Transportation Advisory Committee (COMSTAC)*, U.S. Department of Transportation, 8 May 1992.

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year lifetime. Analyses[23] have pointed out the importance of explicitly recognizing the need to manage the risks involved in assuming overly optimistic performance of the Shuttle, by providing for an appropriate level of contingency operations capability.

In both these instances suggestions have been made to employ the Russian Energiya heavy lift launch vehicle. With the capability to place 88 metric tons in LEO, the appeal is clear. However, launch infrastructure and other considerations open this alternative to question (see Chapter IV for further discussion). Nevertheless, *these two areas--the need for heavy lift, and contingency transportation modes for supporting SSF operations to accommodate risk--represent two troublesome areas* that might conceivably benefit from cooperative efforts with the Russians.

3. U.S. Space Science Characteristics

While the foundation of the U.S. space technology lead in computers, software, and electronics lies in the early emphasis on defense, it is also due in part to an aggressive pursuit of basic space science research. Currently the United States still leads, by a wide margin, all other nations in exploration of the solar system. The string of successes beginning with the Surveyor and Mariner missions, followed by the singular Viking Mars lander, and then the Pioneer series represent just one series of testimonials to *an exceptional degree of outstanding system engineering capability in the U.S. space science program.*

However, the successes have not been without problems. At the Saturn encounter, Voyager experienced a stuck instrument scan platform, but was able to work around the problem by pointing the whole spacecraft with minimal impact to other science instruments. A partially failed data system computer that would have limited the amount of data returned was overcome through clever data compression schemes. Following on the heels of the successful Voyager and earlier missions, the Galileo mission is the most recent in the robotic exploration of the planets. When it reaches Jupiter in July 1995, it will release a probe that will enter and profile the Jovian atmosphere. The mother ship will insert into orbit about Jupiter and carry out multiple flyby inspections of the Jovian moons. However, the failure of the Galileo high gain antenna to properly deploy places the success of the mission in jeopardy due to the very much lower data rate provided by the low gain antenna. As a result, the idea of collaborating with the CIS on using the former Soviet Union deep space tracking antennas has been raised as a possibility to strengthen the feeble low gain signal, and has been met with considerable interest. *The operational experience of*

23 Ibid.

U.S. space system engineers and their ability to innovate forms another strength of U.S. space capabilities.

While the United States has had unparalleled success in its solar system exploration programs, the difficulty in sustaining such efforts given the continuing and growing competition for federal dollars is increasingly clear. Consequently, there has been greater discussion about the possibility of combined efforts and joint missions with the Russians, and perhaps ESA. While the benefits of sharing the costs and the responsibilities may seem obvious there are significant questions to be decided, not the least of which is "who's in charge?" We address some of these questions in Chapter IV.

One of the direct benefits of the U.S. planetary exploration programs has been in helping to stimulate the development of techniques for multispectral surveillance of planets and stellar objects. In the Mission to Planet Earth, these techniques are being applied to understand the impact of humanity on the balance of life. This area of the space program--*Monitoring the Earth and its changes--is receiving wide consensus; it appears to be more closely linked to the problems facing the world.* However, as noted previously, the high cost and lack of contingency capability for EOS has resulted in restructuring, and placed it under the eye of Congressional scrutiny.

Earth monitoring is slowly becoming a vital Earth business. Potential applications are expected to be manifest in many diverse fields as soon as the data become widely available, dependable, and easy to use. Earth observation is becoming increasingly commonplace. Earth observing satellite services have diversified tremendously from initial defense applications and communications. They now include activities as diverse as natural resource management, crop monitoring, geologic mapping, disaster monitoring, transportation planning, water resource assessment, compliance with international treaties, domestic contracts, weather, oceanography, and global change research. Earth monitoring from space is becoming a virtual necessity for most countries and therefore presents commercialization potential.

While the United States pioneered the research and development of Earth observation from space, it has not actively followed this up with any significant success at commercializing its skills. The French Earth observation corporation, SPOT, has overtaken the United States' attempt at commercialization through EOSAT. Although EOSAT was basically a creation of the U.S. government intended to stimulate Earth observation and commercialize it, the effort has been less than satisfactory. More recently, following the war in the Persian Gulf in which the Landsat data were found to be

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particularly helpful to U.S. forces, the Landsat operation is being returned to government control, with Air Force procurement and NASA operation of Landsat 6 and, ultimately, Landsat 7. **Continued U.S. commercialization of remote sensing of the Earth remains to be pursued successfully.**

4. Space Systems and Technology Needs

A subject that relates strongly to the existence of a viable, meaningful strategic plan is the acknowledgment of areas of need. The Augustine Committee emphasized that the "development of advanced technology is ... crucial to the success of the exploration and exploitation of space--whether human or robotic." It is the technology base "that makes major missions possible--new materials, electronics, engines and the like. The technology base of NASA has now been starved for well over a decade and must be rebuilt if a sound underpinning is to be regained for future space missions."[24] Since NASA is a major consumer of space products, NASA bears part of the responsibility to assure the viability of the technology base upon which to build the missions of the future."[25]

NASA's *Vision 21* has recognized the recommendation of the Augustine Committee by developing its Integrated Technology Plan (ITP) for the Civil Space Program. "This plan is designed to serve both as a strategic plan for the NASA space research and technology (R&T) program and as a strategic planning framework for national space R&T participants in conducting engineering research that supports future U.S. civil space missions."[26]

In its development, this plan considered the broad context in which other competing technology requirements and funding needs operate, and responded further to National Space Policy in identifying civil space program technology needs. Detailed assessments of the technology areas needed for the civil space program are compared against the assessments of other groups, such as the Office of Science and Technology Policy (OSTP).

The ITP provides a detailed assessment of the various areas within NASA and their associated technology needs, and includes prioritization of these needs. Figure 16 summarizes these priority areas of technology need. Those receiving greatest attention in

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24 *Report of the Advisory Committee on the Future of the U.S. Space Program*, December 1990, Superintendent of Documents, Washington, D.C.

25 Ibid.

26 *Vision 21: The NASA Strategic Plan*, National Aeronautics and Space Administration, January 1992.

1992 are indicated in bold type. Note that this includes some of the second highest priority items, and omits a few of the highest priorities. Describing these technology needs is unnecessary here (details can be found in the ITP); however, an important point to note is that *a number of the technology needs identified by the ITP can be complemented by knowledge and capabilities of the former Soviet Union's space program* (indicated by the shaded areas in the figure). While identifying all the potential areas of capability possessed by the former Soviet space program, is well beyond the scope of this report, included among these are:

- Russian heavy lift launch capabilities and other propulsion technologies
- Extensive engineering and operational experience in manned space flight, including biomedical data regarding human physiology under long duration space flight
- Space nuclear power
- Regenerative life support systems
- Extra-vehicular activity systems (high pressure space suit)
- Automatic rendezvous and docking systems and experience
- Certain materials and thermal management technologies.

Finally, and equally important to emphasize is the fact that these *strengths of the former Soviet Union space program form competitive threats as well as capabilities potentially complementary to U.S. capabilities.*

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Space Science Technology	**Submillimeter Sensing**	**Direct Detectors** Sensor Electronics	Active µwave Sensing **Laser Sensing**	Sample Acq. Analysis & Preservation	Passive Microwave Sensing	...	**Optoelectronics Sensing & Processing**	**Probes and Penetrators**	...
	Cooler and Cryogenics	**Microprecision CSI**	Telescope Optical Systems	Data Archiving and Retrieval	Data Visualization	...	Precision Instrument Pointing	**Sensor Optical Systems**	...
Planetary Surface Technology	Radiation Protection	**Regenerative Life Support (Phys-Chem.)**	**Space Nuclear Power (SP-100)**	**High Capacity Power**	Planetary Rovers	Surface Habitats and Construction	**Exploration Human Factors**	...	Artificial Gravity
	...	...	**Extravehicular Activity Systems**	Surface Solar Power and Thermal Mgt	In Situ Resource Utilization	**Laser-Electric Power Beaming**	**Medical Support Systems**	...	...
Transportation Technology	**ETO Propulsion**	**Nuclear Thermal Prop.**	Aeroassist/ Aerobraking	Transfer Vehicle Avionics	ETO Vehicle Avionics	**ETO Vehicle Structures & Materials**	**Autonomous Rendezvous & Docking**	COHE	Auxiliary Propulsion
	Cryogenic Fluid Systems	Aeroassist Flight Experiment **Advanced Cryo. Engines**	Low-Cost Commercial ETO Transport	**Nuclear Electric Propulsion**	CONE	...	Autonomous Landing	**TV Structures and Cryogenic Tankage**	HEAb
Space Platforms Technology	**Platforms Structures & Dynamics**	**Platforms Power and Thermal Mgt.**	**Zero-G Life Support**	Platform Materials & Environ. Effects	Station-Keeping Propulsion	...	**Spacecraft On-Board Propulsion**	**Earth-Orbiting Platform Controls**	Advanced Refrigerator Systems
	...	...	Zero-G Advanced EMU	Platform NDE-NDI	Deep-Space Power and Thermal	...	**Spacecraft GN&C**	**Debris Mapping Experiment**	...
Operations Technology	**Space Data Systems**	High-Rate Comm	**Artificial Intelligence**	Ground Data Systems	Optical Comm Flight Expt	Flight Control and Operations	Space Assembly & Construction	Space Processing & Servicing	Photonics Data Systems
	...	CommSat Communications	**TeleRobotics**	Operator Syst/Training	Flt. Telerobotic Servicer/DTF-1 Navigation & Guidance	CommSat Communications Flight Experiments	...	Ground Test and Processing	...
	Highest Priority			2nd-Highest Priority			3rd-Highest Priority		

Possible cooperative/competitive areas of Russian space technology

Bold Type: Areas receiving 1992 program emphasis

Figure 16. 1991 ITP Strategic Plan: Focused Programs

5. Summary

Historically, NASA seems to have operated as a rather loose federation of centers, each somewhat autonomous in carrying out its individual charter. As space technology has evolved, as systems have become more complex, and as charters and missions have tended to overlap, it has not always been clear that this traditional approach has been the most efficient. What seems to be lacking, particularly in items of highly constrained resources, is a comprehensive strategy for carrying out the nation's civilian space program.

NASA has been, and most likely always will be, hampered by intense competition for resources due to other national needs as well as from the competitive efforts of other nations emerging into the space arena. The competition is likely to be exacerbated as Russia and the CIS move to a market economy. Thus, it appears that NASA can no longer afford the relative luxury of covering a broad front of space endeavors with the intent of maintaining unchallenged leadership in all areas. While a viable strategic plan seems to exist for pursuing its space technology needs, in the broader sense NASA's Vision 21 does not appear to be a robust plan for pursuing its overall goals in space. While it establishes laudable goals, it appears to lack priorities, and is therefore susceptible to funding and unexpected contingencies. Given the recent years of intense competition for resources, both from national needs as well as maturing technologies of other nations, such a plan seems most necessary--one that recognizes the increasing constraints on resources, and therefore identifies priorities and tradeoffs among its goals and programs.

At the same time, however, a consistent, comprehensive national space strategy is necessary as the basis for guidance in establishing a viable NASA strategic plan. Our space leadership has been criticized for "failure to manage strategically with a long term view." Thus a timely, comprehensive national space policy is needed that recognizes the challenges and opportunities for U.S space activities, and provides guidance for resolving conflicting needs and goals.

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should the Proton deal not work out, the Titan remains as a fall-back, albeit a more

IV. U.S.-CIS INTERACTIONS: OPPORTUNITIES AND ISSUES

Various CIS member states are anxious to market the capabilities of the former Soviet space program. Although Russia, with about 90 percent of the space assets, has indicated a preference to deal with the United States, its need for hard currency makes it difficult not to do business with virtually any buyer. Depending on the nature of an interaction, this could have adverse implications for the United States.

In this chapter we examine various types of interaction and identify possible guidelines for crafting desirable exchanges. We assess some sample transactions with the intent of characterizing the more desirable exchanges.

The first step in the assessment identifies a set of *guidelines* against which a proposed interaction or exchange might be evaluated for its relative appeal. Next, various types or *categories* of interaction are identified that characterize the full range of interactions that might be constructed. Third, a dozen *examples* are suggested that encompass all of the defined categories.[1] These represent actual proposals, in order to be as realistic as possible. These examples are evaluated with respect to the proposed guidelines. Finally, an overall *assessment* is made to identify in a general way those kinds of exchanges that appear to offer the greatest benefit to both the United States and the CIS.

A. CONSIDERATIONS AND GUIDELINES FOR EXCHANGES

There are a number of ways that CIS interactions regarding its space program might affect the United States. One is through the republics engaging in exchanges with the United States. Another is through the republics interacting with other nations in ways that might affect the United States. In either case, leverage might be applied through both trade and aid agreements in order to avoid unfavorable developments as well as to craft favorable ones. While a variety of such arrangements could conceivably be formed (foreign aid, international agreements regarding fair competition, etc.), our focus here is on commercial and government acquisition of products for direct application or consumption, acquisition

1 We did not produce or examine an exhaustive list of opportunities. Such a list would be beyond the scope of this effort, and would likely be incomplete.

of new technology, or contracting for various technical services. With this in mind, we examine the features of potential transactions that would weigh favorably for the United States.

Independent perspectives are taken, each for the United States and the CIS, in order to ensure a complete and "bipartisan" view of potential exchanges. Further, certain assumptions are made that influence the determination and application of guidelines:

- The Westernization of Russia/CIS is desirable (from the Russian perspective, this contradicts the political position of the conservatives/reactionaries, and even those occupying a more moderate position).
- Interactions and exchanges that enhance United States technological capabilities and competitiveness are desirable.
- Despite liberal Guidar policies such as freeing prices, there is a need and at least some merit for maintaining production capabilities of the space industries of the former Soviet Union. This tends to favor some of the compromises between the liberals and industrialists already in place (subsidies and credits).
- Given the analysis of Chapter II, there is a significant risk of economic and political instability in the states of the former Soviet Union. Thus, for collaborative endeavors involving long implementation times, an increasing risk of failure is assumed.

Note that these last two imply conflicting desires: Western financing that helps maintain the existing manufacturing infrastructure through long term contractual arrangements also incurs varying degrees of risk.

1. Guidelines for Exchange: United States Perspective

One source for establishing guidelines may be found in legislation (introduced into the United States House of Representatives in March 1992) "To authorize supplemental assistance for the former Soviet republics."[2] Section 103 of the bill provides "Criteria for Assistance to Governmental Entities in the Independent States." In essence, assistance from the United States depends on the CIS states'

"(1) making significant progress toward...implementation of a democratic system...;

(2) respecting internationally recognized human rights,...;

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2 H.R. 4547, A Bill to Authorize Supplemental Assistance for the Former Soviet Republics, Report No. 102-569, Parts I, II, III, and IV.

(3) making significant progress in...economic reform based on market principles, private ownership, and integration into the world economy;

(4) respecting international law and obligations...;

(5) adhering to their arms control obligations and to responsible security policies, including --

(A) ...agreements signed by the former Soviet Union;

(B) reducing military forces...

(C) not proliferating nuclear, biological, or chemical weapons, their delivery systems, or related technologies; and

(D) restraining conventional weapons transfers." (Perhaps the most prominent principle here is the need to ensure that any potential arrangement does not jeopardize U.S. national security.)

The principles set forth in this legislation are clearly applicable in crafting trade arrangements with the former Soviet republics. However, to help identify overall approaches offering general advantages to the United States these principles can be augmented by some additional tests. The goals expressed in NASA's *Vision 21* provide an additional source for determining guidelines:

* "Advance scientific knowledge of the planet Earth, the sun, the solar system, the universe, and fundamental physical and biological processes;
* Expand human activity beyond Earth orbit into the solar system;
* Strengthen the competitive posture of the United States in the fields of space and aeronautics; and
* Attract young people to the wonders of mathematics, science and technology and ensure a more technically literate society equipped for the world of tomorrow."[3]

With these considerations in mind, we suggest the following guidelines:

a. Increase U.S. Space and Aeronautics Technological Capabilities

Ideally, agreements should offer some form of technical or performance "leverage" that cannot be achieved easily in other ways. The degree of variability here reflects how unique the capability is. The more unique (in the sense that it's a capability the United

3 *Vision 21: The NASA Strategic Plan*, January 1992.

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States does not have) the more desirable. Uniqueness may also entail a technical capability already possessed by the United States, but for some reason (e.g., geographic location) cannot be applied. In addition, the more permanently such a capability can be maintained the more desirable it is.

b. Enhance Potential for U.S. Commercial Applicability

Ideally, an industry (for example, the satellite development and manufacturing industry) should be enhanced in some way. Thus, the acquisition of Russian technology by the U.S. government implies that this technology would be available to all interested and capable concerns. As a result, the industry in general would be enhanced.

At the same time, the more desirable agreements should not create competitive vulnerabilities for the relevant U.S. industry, as might happen with the purchase of Russian launch vehicles and services. Further, as noted in the earlier assumptions, long term contracts that entail substantial dependencies, while perhaps preferable from the CIS perspective, present increased risk as a result of the political and economic instabilities increasing the possibility of failure. Russian and CIS laws governing international trade must give favorable recognition and treatment to foreign investors.

c. Advance Fundamental Space Science and Technical Expertise

Some arrangements could entail capitalizing on scientific knowledge such as space physiology learned during the extensive Soviet manned space program. Other endeavors could entail the transfer of technical information regarding aeronautical or astronautical knowledge. Thus the acquisition of such information directly supports NASA's goals.

d. Expand Human Presence in Space

Where applicable, desirable arrangements should encourage and enhance the means and opportunities for implementing and sustaining manned space flight operations.

e. Contribute to Global Stability and U.S. National Security

Agreements should be structured consistent with the spirit and letter of the legislation discussed above. Hence, they should not have provisions that could retard or inhibit Westernization, or bestow military advantages to countries hostile to U.S. security interests.

2. Guidelines for Exchange: CIS Perspective

While a particular interaction or arrangement may be advantageous for the United States, this does not necessarily create a complementary advantage for CIS interests. In planning for exchanges and discussing cooperative ventures, the CIS criteria for accepting an agreement could be different.

As noted in Chapter II, perhaps the most urgent challenge facing the CIS is to establish an economic infrastructure capable of meeting the basic subsistence needs of the population. Hampered by opportunism,[4] the immediate concern has been and continues to be obtaining easily convertible wealth, principally in the form of hard currency. A second, related priority is to establish and maintain a viable industrial base that can sustain the production and meet demands for consumer and related products. The industries supporting the former Soviet military and space program represent one of the more valuable assets the CIS has (1) for obtaining hard currency, and (2) for maintaining technical expertise.

Russian industrialists have been holding out the promise that it is worth some sacrifice to keep the inter-republic space industries functional because these industries are among their best hopes for commercialization. Given this assumption, it is important that they succeed in finding an outlet for their launch expertise and manned programs in spite of the associated misalignments in supply and demand fostered by blindly maintaining existing industries.[5] In Russia, stabilization of the strength of the industrialists has both its good side and its bad. It could prevent what could become a slide back into virtual chaos,[6] or a return to power of the reactionaries nationalists. It could also cement back some of the old style bureaucratic structures, and retain positions of power for old ex-party bosses. As

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4 In some instances, the flow of Western humanitarian aid is being tapped for later resale. So-called commodity exchanges have become "vital substitutes for the now moribund command allocation system...In 1988, the CPSU [Communist Party of the Soviet Union] authorized the Komsomol (Young Communist League) to commercialize its activities. Today the Komsomol elite dominates the exchanges. It has become a skillful and increasingly well-heeled opponent of more radical change." James Sherr, "Russia's Defence Industry - Conversion of Rescue?", *Jane's Intelligence Review*, July 1992.

5 "Russia and many of the other new eastern European and former Soviet states are still bankrupting themselves by directing resources - now via cheap credits - to the oversized military-industrial complex and associated civilian heavy industries. It is mind-boggling, for example, that steel production in the Soviet Union was 80 per cent higher than in the US, even though its economy was less than one-eighth the size." Jeffrey Sachs and David Lipton, "Russia on the Brink," *Financial Times*, October 16, 1992.

6 Alternatively "...the process could soon change from orderly change to dangerous chaos if there is hyperinflation" as a result of increasing credits and subsidies. Ibid. (Interestingly, MacDonald's Corporation has been trading rubles, earned by its Russian restaurants, for steel.)

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noted in Chapter I, there are indications that the former communist leaders of yesterday could well become the wealthy cooperative owners of the future.[7] Associated with maintaining the viability of the space industrial infrastructure is the need to minimize the loss of skilled talent into other sectors or even to other countries. Sophisticated knowledge siphoned off to other ventures could well bleed the space industry to death. Thus from the CIS perspective, exchange provisions that help retain the needed technical and scientific talent appear to be crucial.

The CIS also needs to achieve military security of its republics. As we have seen, this is somewhat more difficult given that this depends on cooperation rather than coercion. In spite of the formal Agreement on Strategic Forces, there is some feuding over certain issues that could lead to political manipulations involving space assets as pawns.[8] Thus, agreements with CIS members should not tend to establish provisions advantageous to one state but detrimental to the security of another. In their urgent need for stability the Commonwealth members might be faced with the difficult choice of sacrificing their collective or individual military security for an expedient arrangement to obtain cash.

Thus from the CIS perspective, guidelines for an attractive agreement can be summarized as:

a. Produce Income

The most urgent criteria is to bring in hard currency. This is true regardless whether through capital investment from the West, or in return for direct services or products. In addition to immediate needs for easily convertible wealth, longer term arrangements would lend a degree of stability in generating income.

b. Preserve Research, Development, and Production Capacity

Extended contracts for major services, products, or joint efforts appear essential to preserve the corresponding manufacturing and operational infrastructure. In some cases, Western investment may generate new commercial efforts.

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7 See also James Sherr, "Russia's Defence Industry - Conversion or Rescue?" *Jane's Intelligence Review*, July 1992.

8 Ukraine, which was slow in signing the space agreement, has disagreed with Russia over various issues regarding the CIS' armed forces. At one point there was concern over the possibility of Ukraine's taking control of the assets of Ministry of Space Units located on its soil. Berkowitz, Marc J., "Space Fallout From Soviet Disintegration," *Jane's Intelligence Review*, March 1992.

c. Retain Technical Expertise

Agreements should aim to stem a potentially serious brain drain as CIS scientists and engineers look for opportunities in other sectors and other countries.

d. Promote National Security

Agreements should not make the CIS militarily more vulnerable, either individually or collectively.

Note that a balance must be struck between the first two guidelines. Agreements should not focus so intently on short term gain (hard currency) that they "give up" unique and valuable technologies that could provide a strong, competitive market position over the long term.

Certain facets should be recognized as presenting potential conflicts with U.S. interests. First, if the United States were to implement sanctions that are exceptionally hard on the former Soviet booster and launch service commercialization efforts, this could jeopardize stability. On the other hand, an approach that is too lax and accommodating could significantly and adversely affect the U.S.' launch industry and capabilities, particularly on the international market. Hence the United States may be faced with tolerating some losses in commercial launch business in order to keep a healthy world space program and contribute to CIS stability. While a delicate balance is needed, failure to achieve it could force the formation of international commercial alliances among Russia and Japan or Europe that could compete vigorously with U.S. interests.

Secondly, as noted earlier, long term contractual arrangements with Russia or certain other CIS members increase risk given the potential instabilities. Yet without those longer term arrangements, instabilities are also likely to increase. Hence a difficult and delicate balance seems necessary.

B. CATEGORIES OF POTENTIAL COMMON INTEREST

Part of the process of understanding the various facets and possible ramifications of potential interactions with the CIS is to identify and characterize the ways in which these interactions might be carried out. In general, there appear to be four basic categories consisting of various combinations of *products, services, data, technologies, and joint ventures*. Table 9 summarizes the principal characteristics of these categories, and gives a few examples that have been accomplished, are in process, or are being considered.

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Table 9. Characteristics of Categories of Exchange

Category	Characteristics
Products	Purchase of items with the intent to use them primarily as designed, built, and received. Examples: Russian boosters; weapons-grade uranium.
Services	Purchase of functions performed by the provider, often involving some element belonging to the purchaser. Examples: Launch services; spacecraft tracking; wind tunnel testing.
Scientific Data	Pure data or information, generally dealing with natural science, is provided to the purchaser. Examples: Remote sensing data; solar-terrestrial data; biomedical data.
Processes and Technologies	Purchase of engineering information dealing with new technologies, either for direct space application or for manufacturing. Associated hardware items are purchased primarily for evaluation. Examples: Hall thrusters; RD-170 engine.
Joint Endeavors	Joint missions, generally through governmental cooperation, or joint commercial ventures. Both parties are integral to the endeavor, and contribute essential elements. Examples: Joint Mars mission; joint development of docking adapter; development of thermionic nuclear power systems.

1. Products

Products entail specific Russian/CIS hardware products normally intended for direct application or consumption, such as launch vehicles, rocket engines, etc. Depending on the application and the perceived risk due to possible economic instability, such items might be procured in either large or small quantities. The purchase of large quantities involving development and production over extended periods could entail a longer term commitment on the part of the producer. As noted above, this implies some risk due to potential instabilities; single or near-term purchases would not generally incur such risk.

2. Services

Services are functions performed by the provider, often involving some element belonging to the purchaser. Examples here could include launch services and spacecraft tracking, the purchaser's element being the spacecraft. Another is providing space station services for foreign astronauts on the Russian Mir.

One of the principal advantages for developed countries in purchasing such services would be the potential to complement and enhance their own capabilities. As mentioned, CIS tracking services to improve signal integration from the U.S. Galileo spacecraft low gain antenna is one example.

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For developing countries, purchase of services offers advantages where little or no infrastructure exists. Thus, a country such as India, interested in launching either its own or a purchased satellite, might find it cost effective to contract for launch services with the Russians.

Another useful arrangement is technical consulting services. The Russians have demonstrated capability in the area of applied mathematics, computing algorithms, etc., motivated largely by their undeveloped computing hardware capability. This expertise is available, at least for the moment, at low prices. Thus an industrial concern might contract for analytical and computational services. An example (further discussed below) is the recent decision by Boeing Commercial Airplane Corporation to open a technical research center near Moscow. Close consideration of this approach suggests that this could offer cost effective benefits to both purchaser and provider.

3. Science Data and Information

In a sense this category is similar to services: information or data produced through Russian/CIS efforts are provided to the purchaser. Also, although a somewhat artificial distinction, it differs from technology information in that this type of data normally involves natural scientific phenomena and may be considered an end in itself (technology information is considered a means to an end). Included here might be remote sensing data and certain biomedical information gained by the former Soviet Union in its successful manned program (and which is already shared with the West to some extent).

As another example, the former Soviet Union operated a network of magnetic, optical, and ionospheric observatories along the breadth of its vast northern latitudes. These have made substantial contributions to solar-terrestrial physics. The facilities, their staffs, and valuable data will be lost unless international arrangements are made to purchase these data on some basis.[9]

4. Processes and Technologies

This category entails both primary, space-application technologies (e.g., the Topaz II space nuclear power reactor, Hall thrusters, etc.), as well as production (manufacturing) technologies. Principal interest would be in the technology on which a product is based, despite the fact that a purchase might entail a hardware item (e.g., Topaz II).

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[9] EOS Transactions, *American Geophysical Union*, Vol. 73, No 35, September 1, 1992, p. 373.

The technology category appears to represent one of the more interesting and popular avenues for the United States and other countries to do business with the Russians. Technologies purchased for space applications could provide economic benefits to the United States (jobs, etc.), needed cash to the former Soviet republics to bolster their economies, and the opportunity to develop and market new products based on unique Russian technology. The downside is the reluctance of the Russians to part with unique capabilities that would subsequently be disseminated and become available for exploitation by others, thereby depriving Russia of competitive advantages. A more reasonable arrangement might entail licensing or leasing agreements in which Russia could continue to benefit from "value added" by the United States (or other purchasing country). Joint commercial ventures (discussed below) form another viable alternative.

The argument of purchasing sole rights to technologies to limit international competition has been viewed unfavorably by the Russians, and they have stated an unwillingness to accommodate such arrangements. Nevertheless, such developments are not without possibility.

5. Joint Endeavors

Joint endeavors could involve a number of the previous categories and could take essentially two forms: commercial ventures or joint (government sponsored) missions. Commercially, the United States or some other country(ies) might team with the Russians to achieve competitive advantage in some market such as launch services. As we have noted, this appears to be important to Russia, not only for the potential to produce some hard currency, but also for the implied long term investment possibilities. Although the U.S. space industry enthusiastically endorses joint missions, such enthusiasm is not necessarily reciprocated by the cash-hungry CIS. A joint mission to go to Mars holds insufficient promise of commercial stimulation for CIS industrialists who need to show that their space industries can be one of the better revenue-generating endeavors in their economy. On the other hand, it is easy to argue that the only affordable way to accomplish major missions such as SEI is through joint missions arranged at the government level.

Thus joint commercial ventures appear to be the more desirable, at least from the Russian/CIS perspective. Government sponsored missions, such as manned Mars exploration, would likely entail Russian/CIS commitments that would tax already severely strained resources.

C. EXAMINATION OF TRANSACTIONS: EXAMPLES

As pointed out earlier, it is impractical if not impossible to identify a complete list of opportunities for space trade and cooperation with the CIS. It does seem instructive to examine a few of the popular "candidates" that have been identified in order to understand their implications in terms of the guidelines discussed above. In addition, such an analysis should aid in generalizing desirable and undesirable forms of interaction. The transactions discussed in the following paragraphs are real; some have already been consummated, while others have been proposed. However, for the purposes of analysis we treat all as though they are under consideration.

1. Russian Boosters and Launch Services

Russian propulsion technology has been found to be exceptionally good, surpassing in some cases the capabilities of the United States. A key example is the RD-170 engine used on the Zenit and Energiya launch vehicles.

As pointed out in Chapter III, the marketing of Russian/Ukrainian launch vehicles and services has been viewed in the United States as a commercial threat to the U.S. launch industry. Infrastructure issues aside, because of the exceptionally low prices (at least as claimed by the Russians), the U.S. launch industry claims it would be unable to compete effectively in the world market. Russia has attempted to market launch vehicles at extremely low rates to attract needed cash and begin establishing itself as an international competitor in this area. The Bush administration has already permitted KB Salyut to bid for an up-coming launch of a U.S.-built Inmarsat communications satellite. Russia has offered to launch the satellite for $35 million, more than 40% less than the bids placed by General Dynamics and Arianespace. General Dynamics has complained that one-time concessions set a precedent for further opportunities.

This problem has been recognized by the Commercial Space Transportation Advisory Committee (COMSTAC), which has advised against the use of CIS launch services by U.S. satellites until such time as enforceable fair rules are agreed to by the United States and CIS.[10] The committee also recommended that the United States seek common backing of this principle with other market economy countries. Thus the U.S. launch industry holds the view that use of CIS launch services or purchase of Russian or Ukrainian boosters would adversely affect the U.S. launch industry.

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[10] Recommended Policy Toward the C.I.S. Space Industry, Commercial Space Transportation Advisory Committee (COMSTAC), U.S. Department of Transportation, 8 May 1992.

On the other hand, purchase of boosters or launch services would have a positive effect on the Russian and some of the other CIS economies, thereby contributing positively to the chances for increased stability. The impact to the U.S. economy might be relatively neutral. Because of the needed changes in launch infrastructure, jobs might be created. However, the funds used would mean some other sector would likely be deprived of those funds.

Any purchase of large numbers of boosters would induce a dependence, unless backup approaches were poised to accommodate production failures on the part of the Russians -- an expensive and unlikely strategy.

a. Energiya for SEI

Because of its capabilities, particularly to lift some 80 or more metric tons to low Earth orbit, there has been much interest in the possibility of NASA purchasing Energiya launch vehicles. Energiya has been proposed as a workhorse for SEI, and possibly for Space Station Freedom. According to a Stanford University study, an SEI mission to Mars could employ six Energiya flights to low Earth orbit for assembly of the Mars vehicle at a cost of about $72 billion (a savings of about $15 billion and 10 years that would otherwise be required to develop a different heavy lift vehicle). Contributions from ESA and Japan are included in the plan, which calls for six astronauts to Mars for a 500-day stay in 2009. By including contributions from other space agencies, overall savings of 50% in hardware costs and 30% in total mission costs are estimated.[11,12]

At the same time there are significant technical[13] and political problems with this concept. Launch of the Energiya from Cape Canaveral would involve such extensive changes and additions to the existing launch infrastructure as to render it impractical, particularly if only a few vehicles were purchased. Energiya is integrated horizontally and erected at the pad -- completely different from the U.S. approach. As a result, a completely new system of integration and checkout probably would be required to handle Energiya launches in the United States. Such an eventuality would most likely not be cost effective. In addition, the logistics of moving the boosters and associated elements to the launch pad

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11 "Stanford Team Proposes International Mars Mission," *Aviation Week & Space Technology*, July 1991, and "NASA Exploration Office Reviewing Mars Architectures," *Space Exploration Technology*, October 23, 1992.

12 Not having performed an independent assessment of these putative savings and cost, we can neither support nor refute their validity.

13 J. Cartier, P. Kysar, J. Carlson, *The Effect of Heavy Lift Launch Option Choice on the Character of SEI*, IDA Document D-1252, November 1992.

from Russia could be expensive. On the other hand, it might be possible to ship payloads to Baikonur and launch SEI missions from Kazakhstan. This would make maximum use of inexpensive ground operations, offsetting some of the associated logistical burdens.

Two complete Energiya launchers are in storage and must be launched within the next 3 to 5 years. Because of the apparent lack of other applications for Energiya, unless such launches take place, this capability is likely to disappear as tools, technicians, and engineers become unavailable. Hence the opportunity for use of Energiya in support of such an SEI mission is perishable.[14]

The putative threat to the U.S. launch vehicle industry is questionable here. Buying and using Energiya, it is argued, would take away business opportunities from the industry. On the other hand, noting that Russia has failed to find any significant application[15] for Energiya on the world market suggests that (at least currently) very heavy lift vehicles have no viable commercial application. Thus, if the United States were to purchase this vehicle for SEI use, it would be attractive to Russia by providing hard currency and would not likely undermine the development of a critical commercial capability. Precisely for this reason, purchase of Energiya for this single application does not seem detrimental to the U.S. launch industry.

b. Proton for Pluto

In another specific example of the possible use of a Russian launch vehicle, NASA is considering using a Proton to launch two unmanned probes for a flyby of Pluto, the only such unexplored planet in the solar system. The mission would involve two 150-kilogram probes launched from Earth 1 year apart, arriving at Pluto after 7 1/2 to 9 years in flight. By reaching Pluto before 2010, the probes would be able to study atmospheric transitions as the planet's eccentric orbit takes it deeper into the outer solar system.

Since the number of launch vehicles involved would be only two, such a purchase might not inflict severe damage on the U.S. industry. However, as opposed to Energiya, for which there is no real market, the Proton vehicle represents a capability suitable for the full range of LEO to GEO missions, and therefore is competitive with the U.S. launch industry, in this application, the Titan IV. While a Titan IV is also being considered as the launch vehicle, cost considerations have made the Proton attractive. On the other hand,

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14 "Time May Be Running Out on Energiya Option," *Space Exploration Technology*, October 23, 1992.

15 SEI appears to be the only candidate that might benefit.

should the Proton deal not work out, the Titan remains as a fall-back, albeit a more expensive one.

2. Augmentation of Spacecraft Tracking Services

The possibility of using CIS tracking facilities to enhance the signal received from the Galileo spacecraft has been examined in detail by NASA/JPL, and appears to be a fruitful approach to acquiring data that would otherwise be lost. Overlapping viewing periods exist among the five western CIS deep space tracking sites, and might also be arrayed with the NASA 64-meter antenna at Madrid, Spain. The two sites in the far east (Ulan Ude and Ussuriysk) overlap with NASA's DSN station at Woomera, Australia. Combined, arraying could significantly boost the low gain signal transmitted from the only operable antenna on Galileo.

In this application, the United States would benefit significantly in terms of receiving the Jupiter system science data. While it would be a loss for the space program if the arrangements could not be worked, no permanent dependence would be created. The nature of the compensation arrangement with the CIS is not clear. Presumably it would be effected at some acceptable level, thereby contributing economically over the next few years. The extent to which such services are accomplished effectively would point to the advisability of arranging for such services in the future. As noted previously, dependence entails increased risk. Thus use in contingencies, as in Galileo, or in conjunction with other alternatives could effectively augment U.S. deep space missions, and hence the U.S. space program, without introducing severe risk.

3. Technical Services: Boeing Technical Research Center

Space scientists and engineers of the former Soviet Union embody a substantial and competitive pool of technical knowledge that has proven in some cases quite superior to that in the West. Areas such as applied mathematics, computational methods, nuclear power, nuclear propulsion, hypersonic aerodynamics, and thermal management processes are a few areas of expertise. It seems, therefore, that considerable advantage could be achieved by directly arranging for employment of those technical services, principally by U.S. companies (although by government agencies does not seem unreasonable). Rather than "import" this expertise through emigration, the approach envisioned would have the individuals remain in their home countries.

The advantages here could be substantial. One principal advantage is that Russian space technology and related expertise would not wither. While this might have national

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security implications if political stability were to degrade (e.g., emergence of the reactionary elements), it would help stem the flow of this expertise into non-space related areas or to other, possibly adversarial, countries.

As noted, significant economic benefits would accrue to the participating CIS members resulting from virtually any economic arrangement. In the case of products purchased from or through major enterprises such as NPO Energiya, the focus likely would be on fairly large projects involving the production of substantial items of hardware and associated development times. However, while there may be as many as 2,000 "sub contractors" for major space activities such as those conducted by NPO Energiya, the drive simply to survive the current economic crisis may tend to create suboptimal teaming arrangements. The pressure of bureaucratic or economic considerations might force the selection of the most needy or the most vociferous subcontractors over the most qualified.

Technical consulting procured via a local research institute instead of a major production enterprise might result in less overhead, and more money going to the individual scientist/technologist. One example close to this concept is the recent protocol agreement between the Boeing Commercial Airplane Corporation, and the Russian Ministry of Foreign Economic Development[16] "The center will employ Russian scientists and technicians who, together with Boeing researchers, will work to adapt Russian technology for Boeing's commercial aircraft business."[17] The technical center will not be a joint venture; Boeing will provide all financing for the center, and will initially employ 15 to 30 Russian researchers and engineers. Licensing and technology transfer arrangements have yet to be worked out.

It has been suggested that the quickest and most effective way to help stabilize the former Soviet republics is through aid and economic arrangements at the "grass roots" level.[18,19] Technical consulting services, as opposed to product manufacturing, appear to offer an effective mechanism for accomplishing this. The interface need not be complex, and advanced research expertise would be enhanced. In addition, this approach does not require the complexities of maintaining a particular enterprise and the associated orders for hardware products.

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16 "Russian Technology Draws Boeing to Open Research Center Near Moscow," *Aviation Week & Space Technology*, August 17, 1992.

17 Ibid.

18 Varley, Katerina, Interview, 15 September 1992.

19 Teague, Elizabeth, "Prospects for Reform in Russia," presented at the Institute for Defense Analyses, 18 September 1992.

One way to enhance this process is to involve many U.S. firms, each investing a relatively small amount of funds. The process could be stimulated by Congressional action through approaches such as tax advantages. From the perspective of U.S. firms, small investments would entail relatively low risk in the event of disruption that might result from a worsening political and economic environment. Little or no initial investment sums would be required by participating companies. As illustrated by the case of the Boeing research center mentioned above, the basic plan is to "start small and grow as the opportunity arises."[20]

Difficulties in the concept stem from the need to be able to identify which individuals or CIS enterprises are the most appropriate to contact. Possibilities are the newly formed Russian Space Agency, as well as the Defense Industrial Investment Company in Kaliningrad, which purports to function like a western-style investment bank, using its funds to underwrite promising ventures with Russia. However, both these organizations appear more oriented toward ventures involving production efforts. The Space Research Institute in Moscow might be a more appropriate candidate. The pending Congressional legislation referenced above contains some provisions to help stimulate discussions regarding potential economic arrangements with the CIS. For example, Section 602 of Title VI, Space Trade and Cooperation, provides for favorable and expedited treatment regarding such discussions and potential arrangements.[21] However, *identifying the appropriate contacts to achieve the maximum benefit remains a difficulty.*

A second issue might pertain to U.S. employment in the field of space technology. Given the current economic situation, particularly in the aerospace industry,[22] hiring Russian technical and analytical services might unfavorably affect U.S. technical expertise. While this is certainly a consideration, it is more likely that a prudent U.S. firm would be interested in the unique expertise that did not exist in this country. Thus, the impact on U.S. employment in such areas would likely be minimal. At the same time it would offer the opportunity to enhance U.S. technical knowledge in such areas. This in fact seems to be the case with the Boeing Technical Center.

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20 "Russian Technology Draws Boeing to Open Research Center Near Moscow," *Aviation Week & Space Technology*, August 17, 1992.

21 H.R. 4547, A Bill to Authorize Supplemental Assistance to the Former Soviet Republics, Report No. 102-569, Parts I, II, III, and IV.

22 For example, because of cutbacks in work associated with the Space Shuttle external tank, Martin Marietta laid off 500 workers in April 1992. In September, another 500 were laid off, and by 1994 the Space Systems Division will have shrunk from 3,991 in January to 2,350.

Thus the "grass roots" approach of maximum contact and dispersion of support to the broad population appears to be a particularly beneficial approach in enhancing political and economic stability in the CIS, both in the short term as well as over the longer haul.

4. Acquisition of Space Physiological/Biomedical Information

Although the United States is intent upon developing its own experience and data regarding the physiological effects of long term exposure to weightlessness and space missions in general, there is the opportunity to benefit from the experience gained by the former Soviet manned space program. To some extent information is already shared.[23]

In terms of existing data, such an approach for obtaining data is very straightforward. There are no complications with long term contracts in an uncertain political environment. The information procured does not threaten U.S. industry. While one might argue that it might obviate needs for similar U.S. efforts, the United States has clearly stated its intention of collecting its own physiological data. In the broader sense of making use of Russian data, this might actually help to plan U.S. space activities better by helping identify where science information is lacking.

For data not yet available but whose collection is expected in the future, there is the risk that political or economic changes may reverse this. To the extent that little or no investment is made initially, this risk would be low. However, again due to economic needs, it is likely that under such conditions Russia might reasonably insist on some up front cash. An example is the situation described earlier regarding the solar-terrestrial observatories in the northern regions of the former Union. Without some sort of support these data and the potential to continue collection will be lost.

5. U.S.-Russia Joint Mars Mission

The exciting idea of a joint U.S.-Russian mission aimed at manned Mars landing has been proposed more than once.[24] More recently,[25] NASA and Russia have expressed interest in joint efforts to send unmanned probes to Mars. At the University of Colorado, several instruments are being designed to fit on a Russian lander The U.S. experiments

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23 Largely through direct negotiation with the Institute of Biomedical Problems, carried on at a time when such direct negotiations were unusual, NASA Chief Medical Officer A. E. Nicogossian arranged an agreement of fruitful exchange of biomedical data.

24 For example, *An Analysis of A Joint U.S./U.S.S.R. Manned Mission to Mars*, Anser Corp., September 1989.

25 David, Leonard, "Russia May Play Large Role In Missions to Pluto, Mars," *Space News*, August 31-September 6,1992.

will involve measuring soil magnetic properties and soil reactivity/composition through chemical analysis of the volatile components of the Martian soil.[26]

A small landing platform would be purchased by NASA as part of the Russian Mars '94 mission. The Mars landing platform would provide a modest amount of hard currency to Russia. Estimates are that such funding could save the Russian Mars '94 mission.[27] While NASA has not yet provided funds, both Germany and France have. Hence, such arrangements appear desirable from the Russian perspective. In general, such a mission also has payoff in terms of prestige, and demonstrates sophisticated technical capabilities that might have commercial "advertising" benefit. In general, as noted earlier, the near-term need for hard currency likely will make joint missions unattractive if they do not generate some sort of revenue for Russia.

6. Mir-Shuttle Astronaut Exchange

An agreement signed between NASA and the Russian Space Agency provides for an exchange of U.S. and Russian astronauts in a mission reminiscent of Apollo-Soyuz. A Shuttle mission planned for 1995 will fly Russian cosmonauts as a replacement team for Mir. A U.S. astronaut, transported to the Russian space station aboard a Soyuz spacecraft some 90 days earlier, will focus on life sciences, and engineering and operational objectives. The Mir and Shuttle will exchange teams, with both the replaced team and the U.S. astronaut landing in the United States on the Shuttle.

Although Russia is anxious to maintain operation of its Mir, this mission entails no major funds for Russia, which must bear its own expenses. On the other hand, Russia gains the flight experience and operational knowledge of the U.S. space shuttle. Likewise, the U.S. astronaut receives 3 months of on-board experience in the Mir. Thus the principal benefit in both cases is operational flight experience, and perhaps some enhancement of good will.

7. Joint Rockwell-NPO Energiya Project for Docking System

In September 1992, Rockwell International and NPO Energiya agreed to work together on a docking system that would allow the U.S. Space Shuttle to dock with Mir.[28]

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26 "U.S., Russia Sign Joint Space Accords," *Aviation Week & Space Technology*, October 12, 1992.

27 David, Leonard. "Russia May Play Large Role In Missions to Pluto, Mars," *Space News*, August 31-September 6, 1992.

28 Lawler, A. "Rockwell, NPO Energiya to Build Docking Device for Shuttle, Mir," *Space News*, September 14-20, 1992.

This example of joint commercial ventures with a CIS member clearly will provide economic benefits to both parties, provide experience for future cooperative ventures, and provide substantial benefit for the U.S. space program. Although it might be argued that some dependence could occur early in the effort, it is likely that Rockwell engineers would gain enough complete knowledge of the system if NPO Energiya failed to perform at some later time.

8. Joint Development and Marketing of Stationary Plasma Thrusters

As noted in Chapter I, NPO Fakel in Russia and Space Systems/Loral in the United States have agreed on a joint venture regarding the further development and marketing of the SPT-100 propulsion unit. The SPT-100 offers both weight and performance efficiency advantages: producing a specific impulse of 1,600 seconds, the unit weighs 4 kilograms, and approaches twice the efficiency (50%) of similar units (30%) under development in the West. Under the agreement, NPO Fakel will provide the thrusters while Loral will add various elements of the associated power supply system (solar arrays, power conditioning, and distribution hardware) needed to drive the thrusters.

While this offers commercial advantages to both parties, it entails some dependence on Loral's part, at least initially, since NPO Fakel must provide the thrusters. However, as in the Rockwell-Energiya arrangement, assuming sufficient sharing of knowledge would lessen the impact of potential default on the part of NPO Fakel.

9. Acquisition of the Topaz II Thermionic Nuclear Reactor

Although the United States has had a space nuclear power program--the SP-100--in progress for some time, there are substantial differences compared with the Russian Topaz I reactor, which has prompted strong interest in the United States. The Russian system is a thermionic system (electric power generated within the reactor system) while the SP-100 is thermoelectric (power generated outside the reactor core). The former generates lower levels of power (5-7 kW), but is a working system. The SP-100 has yet to be built, but is expected to generate more power. At the end of 1991 the Strategic Defense Initiative Organization terminated its participation in the SP-100 program, indicating that its mission needs for spacecraft power did not warrant the high levels anticipated for SP-100. NASA and DoE intend to continue the effort; NASA's need is for power sufficient to support long term missions.

As a result of the strong interest, particularly on the part of SDIO, the Topaz II was purchased for study by DoD and DoE, and to understand the Russian technology for thermionic conversion. Future purchase of a large number of the reactors is not currently envisioned, so the effect on the Russian economy is not expected to have an on-going impact (although the estimated cost of $10 million will surely be of benefit). Although the use of nuclear power in space presents certain health and safety issues, better understanding will certainly benefit the U.S. space program. Economically for the United States, arguments were presented that purchase of the Topaz would sacrifice U.S. jobs. The extent to which this has happened is probably not severe.

10. Joint Development of Thermionic Nuclear Power

While the Topaz II was purchased principally to evaluate the technology, there is joint commercial effort involving U.S. and Russian companies to develop a space nuclear power system based on the thermionic technology developed by the Russians. Financing is being provided by the Strategic Defense Initiative Organization (66%), the U.S. Air Force (28%), and the Department of Energy (6%). The 3-year program is being managed by DoE's Office of Nuclear Energy in which two joint U.S.-Russian teams are working to develop spacecraft power systems based on thermionic nuclear technology. Space Power, Inc. and the Russian consortium Intertek are employing the single cell thermionic design of Topaz II, offering easier, less costly testing and better fission product management. The other team, Rockwell International/Rocketdyne and Krasnaya Zvezda, is employing a multi-cell design offering better electrical performance at the expense of more difficult, costly testing and complex fission product management. One of the approaches will be chosen at the end of the 3 years for full scale flight development. The aim is for a capability of $550/Watt ($20 million for 40 kW) and a 10-year lifetime. Principal interest by SDIO is for use on its missile defense satellites. In addition, the technology should provide for higher capacity, longer life communication satellites, and (with the addition of Brayton or Stirling generators) power generation capability to support lunar and Mars missions.

Involvement of Russian expertise should help in keeping costs low while providing compensation to the respective companies. In addition, 11 U.S. subcontractors are involved.

On the down side of the technology, there is concern over a positive reactivity coefficient that could result in reaction instability; however, there is some indication that the coefficient may go negative at slightly higher operating temperatures. In addition, the technology competes for funding with the SP-100 nuclear power system development joint NASA/DoD program that has been under way in the United States for some time.

11. Purchase of Weapons-Grade Uranium

In terms of the guidelines, there is little in this example that is technologically unique or that contributes to the U.S. space program. However, we have included this example to see how it fairs under the various guidelines.

An agreement of significant advantage to both the United States and Russia, the plan is to negotiate the purchase of at least 10 tons of enriched, weapons-grade uranium per year for 5 years, and at least 30 tons thereafter. Under a yet-to-be-negotiated contract, Russia would get needed hard currency, and the United States would acquire relatively low-cost fuel along with the knowledge that the uranium would no longer be available for weapons. A potential problem is the chance that the weapons-grade uranium could fall into the hands of terrorists or a rogue government, thus presenting a national security issue.

D. OVERALL ASSESSMENT

In order to gain a general idea of the possible relative advantages and disadvantages of the areas of investment, we developed an overall assessment of the sample transactions discussed above. Note that this assessment is qualitative; it is based on examples representative of the categories identified in Section B above. The assessment involves only a high level consideration of key advantages and disadvantages.[29]

Table 10 summarizes the advantages and disadvantages of each sample transaction based on the guidelines of Section A. We employed a simple scheme of +'s and -'s to indicate the advantages (+) and disadvantages (-).

29 A more detailed, quantitative analysis could be done involving a technique such as the analytic hierarchy process (AHP). The AHP technique would entail the assignment of weights or priorities requiring an assessment of relative importance of the various guidelines. Further, a lower level, more detailed breakdown of the guidelines with increased refinement would also be required. For our purposes of broadly characterizing traits of desirable transactions, such a detailed and intensive breakdown appears excessive.

Table 10. Advantages/Disadvantages of Sample Transactions

	Advantage	Disadvantage
1. Energiya for SEI	+ SEI is feasible with Energiya heavy lift capability (80 metric tons to LEO) + Energiya launch vehicle is less expensive than any projected U.S.-built heavy lift launch vehicle + Lack of commercially identifiable needs means little inhibiting effect on U.S. commercial launch industry + Offers positive, stimulative effect on U.S. industry developing and supporting SEI systems + Six or more launches mean moderate term income for Russia + Helps maintain Russian expertise	- Restricts U.S. development of heavy lift launch vehicle - Russian participation entails substantial internal expenses - Unfamiliarity of integration and checkout of payloads at Baikonur likely to be complicated - Expense of transporting elements to Baikonur partially offsets cheaper cost of vehicle - "Window of opportunity" requires start of program in near future (before expertise is lost) - Long term nature of program entails risk from political/ economic instabilities
2. Proton for Pluto	+ Supports U.S. solar system science investigations + Offers lower cost launch vehicle + Provides for near term income to Russian company (KB Salyut) + Helps maintain Russian expertise and space vehicle capability + Dependence on Russian company is not long term	- Risk that infrastructure may not be retained long enough to meet early 2000's launch date - Offers no long term income for Russia - Near term disadvantage to U.S. company (notably, Martin Marietta) - Potential negative impact to U.S. launch vehicle industry
3. Galileo Spacecraft Tracking Augmentation	+ Obtains Jupiter system science data otherwise lost + Provides income for CIS space infrastructure + Aids in gaining experience and maintaining infra-structure for possible future application + Involves little investment risk to U.S.	- Moderate dependencies on CIS space infrastructure

Table 10. (Cont'd)

	Advantage	Disadvantage
4. Boeing Technical Research Center	+ Aids in maintaining Russian advanced aeronautical research expertise + Provides income for Russian aeronautical sciences experts + Increases fundamental aeronautical technology of both U.S. and Russia + Enhances commercial aircraft competitiveness for Boeing + Offers long term contractual benefit for Russia	- Entails modest investment risk to U.S.
5. Space Physiological/ Biomedical Data	+ Obtains physiological data on manned space flight experience of former Soviet Union and Russia + Past experience forms basis for future transactions + Aids in sustaining efforts of Russian space physiology research	- No long term contractual arrangements (case-by-case basis) - Financial compensation to Russians is minor
6. Joint U.S.-Russian Mars Mission	+ Provides new opportunity for U.S. study of Martian geochemistry + Potential for near term income for Russia + Contributes to success of planned Russian Mars '94 mission	- Extent of U.S. funding contributions unclear - Entails some risk to U.S. since little control over mission development and operations - Provides no long term contractual arrangement (single mission)
7. Mir-Shuttle Astronaut Exchange	+ Enhances Russian knowledge and experience in U.S. Shuttle systems and operations + Enhances U.S. knowledge and experience in Russian Mir systems and operations + Enhances U.S. manned spaceflight capabilities and creates potential for future collaboration	- Success depends on joint U.S.-Russian development of docking adapter (see 8., below) - Russia/CIS receives little or no monetary monetary compensation - Mission is a one-time operations (no long term activity)

Table 10. (Cont'd)

	Advantage	Disadvantage
8. Joint Development of Docking Mechanism	+ Enhances U.S. space capabilities (rendezvous and docking + Increases Russian knowledge of U.S. space shuttle systems and capabilities + Provides income for Russian company (NPO Energiya) + Gives temporary help in maintaining Russian expertise	- Involves near term dependence on timely Russian contributions - No major, long term commercial payoff (one-time activity)
9. Joint Development of SPTs	+ U.S. acquires advanced ion propulsion technology + Provides basis for long term commercial space effort for U.S. company (Loral) + Provides income for Russian company (NPO Fakel) + Offers long term commercial space opportunity for Russian company + Helps maintain Russian propulsion expertise	- Involves significant dependence on Russian company and availability of expertise - Entails significant investment of effort by U.S. company
10. Purchase of Topaz II Thermionic Nuclear Reactor	+ U.S. acquires Russian technology in space nuclear thermionic power for U.S. industry + Provides potential for U.S. commercial applications + Provides near-term income for Russia	- Entails no long term contractual arrangement

Table 10. (Cont'd)

	Advantage	Disadvantage
11. Joint Development of Thermionic Nuclear		
	+ Provides advanced development of spacecraft nuclear power technology	- Entails significant investment of effort by U.S. company
	+ Offers long term commercial opportunity for U.S. companies (Space Poser, Inc.; Rocketdyne; subcontractors)	- Entails long term dependence on Russian companies
	+ Provides income for Russian enterprises (Intertek; Kransnaya Zvezda)	- Competes with U.S. SP-100 nuclear power development effort
	+ Offers long term commercial opportunity for Russian company	- Involves potentially risky technology (positive reactivity coefficient)
	+ Maintains and enhances Russian expertise in spacecraft power technology	
	+ Offers substantial applications to missile defense satellites, and increased lifetime and capacity of communications satellites	
	+ Offers possible applications for manned space explorations (lunar and mars base power systems)	
12. Purchase of Weapons-Grade Uranium		
	+ Entails low cost	- Dilution of highly enriched CIS uranium provides supply source in direct competition with U.S. industry
	+ Reduces weapons-grade uranium in Russia/CIS	- Presents potential for diversion of uranium to hostile governments or terrorist organizations
	+ Provides income for Russia/CIS (on the order of $45 million for first 10 tons)	- Purchase of highly enriched uranium maintains Russian nuclear materials capability
	+ Involves long term contractual arrangement	- Blending down of highly enriched uranium not cost effective in terms of potential later use for defense needs

Consideration of the guidelines together with the advantages and disadvantages summarized in the table suggest that exchanges offering extended joint commercial opportunities are among the most desirable. Support for this preference has been voiced by NASA Administrator Daniel Goldin.[30] Goldin has also expressed the view that cooperation is most likely to evolve slowly with a goal of melding technological capabilities.[31] NASA's Associate Administrator for International Relations, Margaret Finarelli, also states that cooperation in space should be limited to acquisition of Russian technology and hardware.[32] Evidence upholding these views may be more clearly observed in Figures 17 and 18. Figure 17 plots each example transaction simply in terms of the number of advantages versus disadvantages (taken from Table 10) to give a sense of relative risk and benefit. Figure 18 makes a simpler, and perhaps clearer, comparison by showing the net benefit (the number of advantages minus disadvantages) of each example. Both seem to confirm the conclusion that *longer term, closely coordinated commercial arrangements that offer unique capabilities are of most benefit to both the United States and the participating CIS members.*

The figures together with Table 10 also suggest that those *interactions are attractive that (in addition to offering unique capabilities) entail minimal capital investment (thereby minimizing exposure to loss) while still retaining cooperative efforts.* The Boeing Technical Research Center is such an example, along with (to a lesser extent) tracking augmentation for the Galileo spacecraft.

Arrangements that entail purchase of products or services produced solely by the CIS provider present greater risk because of the absence of close U.S. involvement. For the United States this risk is mitigated somewhat when such purchases are on a one-time or case-by-case basis. However, while reducing U.S. risk, this also detracts from the CIS need for long term income-producing arrangements.

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30 *Aerospace Daily*, Wednesday June 17, 1992.

31 "I don't think it's appropriate, given the state of aerospace, just to ship money to Russia and to get back product. The intent was to have American companies work with Russian companies to build American products," *Aviation Week and Space Technology*, July 27, 1992.

32 "In order to do traditional cooperation, the other side has to fund its responsibility." Moscow lacks the money to engage in a traditional type of partnership, "...so what we're looking at is acquisition activities." *Space Exploration Technology*, August 14, 1992.

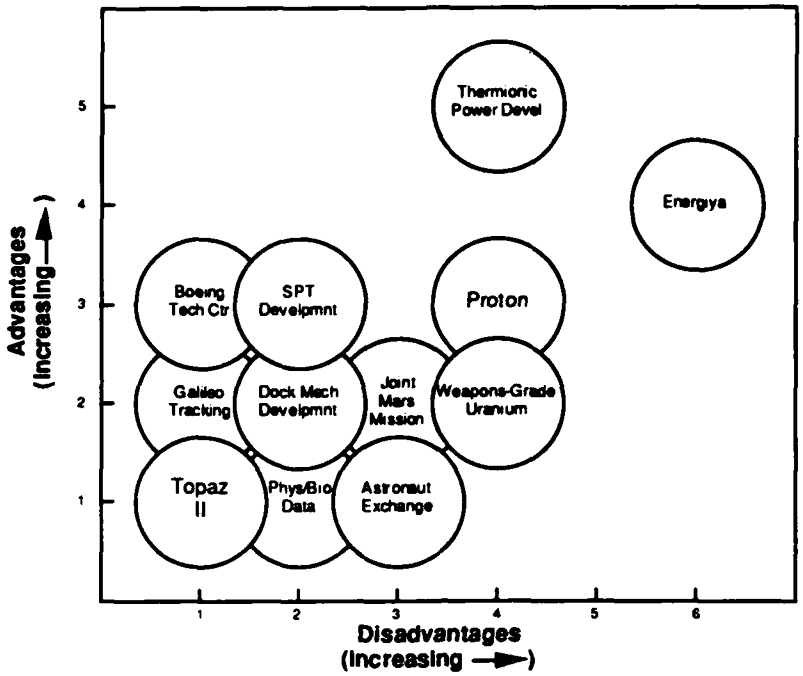

Figure 17. Relative Comparison of Sample Transactions

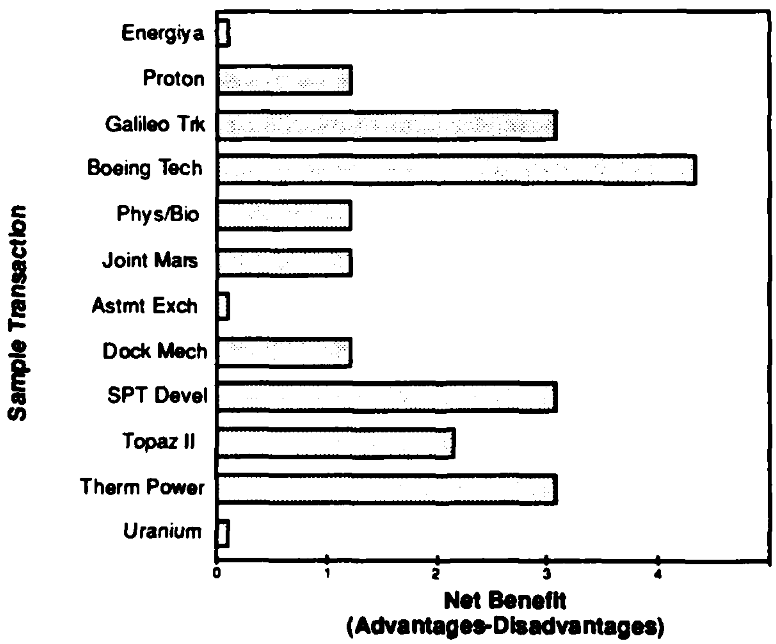

Figure 18. Sample Transactions Estimated Net Benefit

Interactions that compete with U.S. commercial interests, or offer weak or non-unique capabilities, generally are not attractive (e.g., Russian/Ukrainian launch vehicles and services). Joint missions such as the astronaut exchange also are not strongly attractive because generally they do not support the CIS need for hard currency, often requiring significant CIS expenditures with little income in return. (On the positive side, goodwill and demonstrated cooperation may be significant).

In all potential transactions between Russia and the West, one of the key risks is due to the changing Russian laws and regulations governing international trade. Hence, the above conclusions must be weighted significantly by the degree to which the Russian Parliament, and similar governing bodies of the other CIS members, enact laws protecting foreign investments.

E. TIMELINESS

We have said little in this chapter about the issue of timeliness. In Chapters I and II we cited various evidence that, in addition to supporting other issues, conveyed the sense of urgency facing the Russians and other CIS states in achieving economic and political stability. As noted, the drive to obtain hard currency is important for this goal. To the extent that the West wishes to support the stabilization of Russia and the CIS, it must share this sense of urgency and *establish competitive agreements and collaborative arrangements before the opportunities disappear*. To the extent that such arrangements can be expedited through policy guidance and strategic planning, the National Space Council, NASA, and the Department of Commerce can play significant facilitating roles.

F. SUMMARY

In this chapter we have examined some of the potential arrangements, principally on a commercial basis, that might be struck between the United States and republics of the CIS. Building on principles promulgated in pending U.S. legislation, as well as goals established in NASA's *Vision 21*, we have identified a set of guidelines for use in assessing the relative merits of candidate arrangements. Categories of interactions were identified that define the range of characteristics of potential interactions. Finally, through the use of examples in one or more of these categories, we have applied these guidelines in a broad assessment that suggests a preferable ranking of exchange arrangements:

(1) Long term, joint commercial ventures that promise unique capabilities, and involve continuous, close interaction between U.S. and CIS companies

(2) Near-term arrangements for case-by-case purchases of products or services produced solely or predominantly by the CIS

(3) Purchase of CIS products or services that compete with U.S. interests, or that offer weak or non-unique scientific or commercial value.

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