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Monterey, California: Naval Postgraduate School

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**NAVAL  
POSTGRADUATE  
SCHOOL**

**MONTEREY, CALIFORNIA**

**THESIS**

**THE FUTURE OF HUMAN SPACE EXPLORATION:  
TOWARD COOPERATION OR COMPETITION?**

by

Priscilla M. Adams

September 2013

Thesis Advisor:  
Second Reader:

James Clay Moltz  
Daniel W. Bursch

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**THE FUTURE OF HUMAN SPACE EXPLORATION: TOWARD  
COOPERATION OR COMPETITION?**

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Captain, United States Air Force  
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Submitted in partial fulfillment of the  
requirements for the degree of

**MASTER OF SCIENCE IN SPACE SYSTEMS OPERATIONS**

from the

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## **ABSTRACT**

Over the past 52 years, the world has progressed from the first man in space, to landing on the moon, to permanent human presence on manned space stations. Mankind is now poised to explore even farther. The purpose of this thesis is to analyze whether international cooperation or competition is more in the U.S. interest from the perspective of political, technological, and cost-effectiveness criteria for returning humans to the moon, Mars or an asteroid and establishing a permanent presence. The 1960s space race between the U.S. and USSR and current cooperation on the International Space Station will provide a historical basis for comparison. Countries with major space programs will be reviewed for possible partnerships in future space endeavors. This thesis concludes that the future and next steps for human spaceflight with international partners will need to begin as a coordinated and interdependent effort at the onset with the goal of habitation on the moon.



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# TABLE OF CONTENTS

<b>I.</b>	<b>INTRODUCTION.....</b>	<b>1</b>
	<b>A. BACKGROUND .....</b>	<b>1</b>
	<b>B. PURPOSE.....</b>	<b>1</b>
	<b>C. RESEARCH QUESTIONS .....</b>	<b>1</b>
	<b>D. BENEFITS OF STUDY.....</b>	<b>2</b>
	<b>E. LITERATURE REVIEW .....</b>	<b>2</b>
	<b>F. SCOPE AND METHODOLOGY .....</b>	<b>5</b>
	<b>G. SUMMARY OF CHAPTERS.....</b>	<b>5</b>
<b>II.</b>	<b>THE 1960S SPACE RACE: COMPETITION BETWEEN U.S. AND RUSSIA.....</b>	<b>7</b>
	<b>A. INTRODUCTION.....</b>	<b>7</b>
	<b>B. HISTORICAL BACKGROUND.....</b>	<b>7</b>
	<b>1. Russian Space Exploration.....</b>	<b>7</b>
	<b>2. United States Space Exploration .....</b>	<b>10</b>
	<b>C. ADVANTAGES.....</b>	<b>13</b>
	<b>D. DISADVANTAGES.....</b>	<b>15</b>
	<b>E. LESSONS LEARNED .....</b>	<b>17</b>
	<b>F. CONCLUSION .....</b>	<b>17</b>
<b>III.</b>	<b>INTERNATIONAL SPACE STATION: A COOPERATIVE EFFORT .....</b>	<b>21</b>
	<b>A. INTRODUCTION.....</b>	<b>21</b>
	<b>B. HISTORICAL BACKGROUND.....</b>	<b>22</b>
	<b>C. ADVANTAGES.....</b>	<b>34</b>
	<b>D. DISADVANTAGES.....</b>	<b>37</b>
	<b>E. LESSONS LEARNED .....</b>	<b>38</b>
	<b>F. CONCLUSION .....</b>	<b>39</b>
<b>IV.</b>	<b>INTERNATIONAL HUMAN SPACEFLIGHT PROGRAMS.....</b>	<b>41</b>
	<b>A. INTRODUCTION.....</b>	<b>41</b>
	<b>B. CAPABILITIES OF OTHER COUNTRIES .....</b>	<b>42</b>
	<b>1. Russia .....</b>	<b>42</b>
	<i>a. Human Spaceflight Experience.....</i>	<i>42</i>
	<i>b. Facilities, Launch Sites, and Vehicles .....</i>	<i>45</i>
	<i>c. Future Plans.....</i>	<i>47</i>
	<b>2. China .....</b>	<b>50</b>
	<i>a. Human Spaceflight Experience.....</i>	<i>51</i>
	<i>b. Facilities, Launch Sites, and Vehicles .....</i>	<i>56</i>
	<i>c. Future Plans.....</i>	<i>59</i>
	<b>3. ESA Countries.....</b>	<b>61</b>
	<i>a. Human Spaceflight Experience.....</i>	<i>62</i>
	<i>b. Facilities, Launch Sites, and Vehicles .....</i>	<i>66</i>
	<i>c. Future Plans.....</i>	<i>70</i>
	<b>4. Japan .....</b>	<b>71</b>

a.	<i>Human Spaceflight Experience</i> .....	72
b.	<i>Facilities, Launch Sites, and Vehicles</i> .....	76
c.	<i>Future Plans</i> .....	78
5.	<b>India</b> .....	79
a.	<i>Human Spaceflight Experience</i> .....	80
b.	<i>Facilities, Launch Sites, and Vehicles</i> .....	82
c.	<i>Future Plans</i> .....	84
C.	<b>CONCLUSION</b> .....	86
V.	<b>CONCLUSION</b> .....	89
A.	<b>KEY POINTS AND RECOMMENDATIONS</b> .....	89
1.	<b>Competition or Cooperation?</b> .....	95
B.	<b>AREAS TO CONDUCT FURTHER RESEARCH</b> .....	100
	<b>LIST OF REFERENCES</b> .....	103
	<b>INITIAL DISTRIBUTION LIST</b> .....	111

## LIST OF FIGURES

Figure 1.	Overview of space exploration capabilities .....	86
Figure 2.	Crewed space vehicles .....	87
Figure 3.	Potential lunar capabilities .....	100

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## LIST OF TABLES

Table 1.	Timetable of Space Events: 1960s.....	18
Table 2.	Timetable of ISS Assembly Events .....	28
Table 3.	A Summary of the Integrated Options Evaluated by the Augustine Committee.....	33
Table 4.	Space Station Total Costs as of 2010.....	36

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## LIST OF ACRONYMS AND ABBREVIATIONS

ACTS	Advanced Crew Transportation System
ACV	Advanced Crew Vehicle
AECA	Arms Export Control Act
APM	Attached Pressurized Module
ARV	Advanced Reentry Vehicle
ASAT	Anti-Satellite System
ATV	Automated Transfer Vehicle
ATV-CC	Automated Transfer Vehicle Control Centre
CAS	Chinese Academy of Sciences
CASC	China Aerospace Science and Technology Corporation
CNES	Centre National d'Etudes Spatiales
CNSA	China National Space Administration
COMSAT	Communications Satellite Corporation
DOS	Durable Orbital Station
ELDO	European Launch Development Organization
ERA	European Robotic Arm
ESA	European Space Agency
ESOC	European Space Operations Centre
ESRO	European Space Research Organization
EVA	Extravehicular Activity
FAI	Fédération Aéronautique Internationale
FY	Fiscal Year
GCTC	Yuri Gagarin Cosmonaut Training Center
GES	Global Exploration Strategy
GSLV	Geosynchronous Satellite Launch Vehicle
HTV	H-II (or Hope) Transfer Vehicle
IGA	Intergovernmental Agreement
INTELSAT	International Telecommunications Satellite Organization
ISAS	Institute of Space and Aeronautical Science
ISECG	International Space Exploration Coordination Group



ISRO	Indian Space Research Organization
ISS	International Space Station
ITAR	International Trafficking in Arms Regulations
JAXA	Japan Aerospace Exploration Agency
JEM	Japanese Experiment Module
MLM	Multipurpose Laboratory Module
MOU	Memoranda of Understanding
MSS	Mobile Servicing System
MTFF	Man-Tended Free Flyer
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency
OPS	Orbital Piloted Station
SLV	Polar Satellite Launch Vehicle
SRE	Space Recovery Experiment
TBS	Tokyo Broadcasting System
UDMH	Unsymmetrical Dimethylhydrazine
USSR	Union of Soviet Socialist Republics
VSE	Vision for Space Exploration

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Finally, none of this would be possible without the grace and mercy of my Lord and Savior. Unto Him be the glory.

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# I. INTRODUCTION

## A. BACKGROUND

Dr. Joan Johnson-Freese stated in testimony before the Senate Committee on Commerce, Science, and Transportation, Space, Aeronautics, and Related Sciences Subcommittee May 7, 2008 “America needs to be seen as a leader into the future, and no venture, no journey, no undertaking represents the future more than human spaceflight.”<sup>1</sup> Over the past 52 years, the world has progressed from the first man in space, to landing on the moon, to permanent human presence on manned space stations. Mankind is now poised to explore even further, but the question remains, should this be done in competition or cooperation?

## B. PURPOSE

The purpose of this thesis is to analyze whether international cooperation or competition is more in the U.S. interest from the perspective of political, technological, and cost-effectiveness criteria for returning humans to the moon, Mars or an asteroid and establishing a permanent presence. The 1960s space race between the U.S. and USSR and current cooperation on the International Space Station (ISS) will provide a historical basis for comparison. Countries with major space programs will be reviewed for possible partnerships in future space endeavors.

## C. RESEARCH QUESTIONS

This research will be used to review current international space dynamics with a view toward determining if it is in the best interests of the U.S. to be a competitor or a cooperative partner. The overarching research question of this thesis is whether international cooperation or competition is the best means for future human space exploration.

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<sup>1</sup>*Reauthorizing the Vision for Space Exploration: Hearing Before the Senate Committee on Commerce, Science, and Transportation, Space, Aeronautics, and Related Sciences Subcommittee*, 110th Cong. 14 (2007) (statement of Joan Johnson-Freese, Chair, National Security Decision Making Department).

Breaking the above question down further, some smaller inter-related questions can be asked. What lessons can be learned from the 1960s competitive space race between the U.S. and USSR as well as from the international cooperation on the ISS? Both case studies will be looked at in regards to political, technological, and cost dynamics. Lastly, this thesis asks what the major space programs of other countries can contribute to enhance human space exploration.

#### **D. BENEFITS OF STUDY**

This thesis will provide a full historical, global review of the major events and players in human spaceflight. From this analysis a clear picture of available human space exploration options and the best course of action for the U.S. will be presented.

#### **E. LITERATURE REVIEW**

Considerations of the future of human spaceflight can be broken down into three schools of thought: single nation, collaborative process, or commercial means. The latter will not be discussed in this thesis. In order to rationalize the best method, historical experiences and countries' current capabilities will be investigated. Various articles from *Aviation Week & Space Technology*, *Jane's Space Systems and Industry*, *Space News*, and *Space Policy* will be utilized. Numerous internet sources to include the National Aeronautics and Space Administration (NASA) website, European Space Agency (ESA) website, and Japan Aerospace Exploration Agency (JAXA) website will be employed. Public records such as the Review of U.S. Human Space Flight Plans Committee and Congressional Research Service's Report on the *Space Activities of the United States, Soviet Union, and Other Launching Countries-organizations, 1957-1993* will be drawn on. The works of Daphne Burleson, Susan Eisenhower, Joan Johnson-Freese, Roger Handberg and Zehn Li, Brian Harvey, John Logsdon, James Clay Moltz, and Asif Siddiqi will be referenced.

John Logsdon is an experienced space policy expert. He has written many books and articles on the 1960s space race and the ISS. His works include *John F. Kennedy and the Race to the Moon*, *The Decision to Go to the Moon: Project Apollo and the National Interest*, "Together in Orbit: The Origins of International Participation in the

Space Station,” “Ten Presidents and NASA,” and “International cooperation in the space station programme.” As quoted in his most recent book, *John F. Kennedy and the Race to the Moon*:

I am now inclined to accept an alternative explanation that I rejected forty years ago; that the lunar landing decision and the efforts that turned it into reality were unique occurrences, a once-in-a-generation, or much longer, phenomenon in which a heterogeneous mixture of factors almost coincidentally converged to create a national commitment. If this is indeed the case, then there is little to learn from the decision to go to the Moon relevant to twenty-first century choices.<sup>2</sup>

This is quite different from how he ended his 1970 book, *The Decision to Go to the Moon*, in which he stated that the capabilities of Apollo would have a lasting effect on humanity. In *The Decision to Go to the Moon*, Logsdon ends with Kennedy’s announcement to land a man on the moon and return safely; whereas in *John F. Kennedy and the Race to the Moon*, Logsdon continues to the end of Kennedy’s presidency. This thesis will take the two contradicting views from Logsdon as well as various other works to include speeches and articles from the time period to see what can be learned from the space race and the ISS.

For more in-depth study on the Soviet space program, Asif Siddiqi’s two volumes, *The Soviet Space Race with Apollo* and *Sputnik and The Soviet Space Challenge* with over 1,000 pages were consulted. This research provides one of the first authoritative sources on the Soviet space program as he had access to material from the Soviet archives to include “official institutional histories, biographies, oral histories, memoirs and historical articles.”<sup>3</sup> However, Siddiqi’s research stopped after Russia’s first thirty years. Therefore, for a view of more current Russian history, Susan Eisenhower’s *Partners in Space: US-Russian Cooperation After the Cold War* describes the partnership leading to the ISS. A main theme of her book is the nonproliferation concerns, which led the U.S. to include the Russians in the space station project. This

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<sup>2</sup> John M. Logsdon, *John F. Kennedy and the Race to the Moon* (New York: Palgrave Macmillan, 2010), 237.

<sup>3</sup> John Berryman, Review of *Challenge to Apollo: the Soviet Union and the space race, 1974–1975*, by Asif A. Siddiqi, *Space Policy* 18, no. 1 (February 2002), 75.

thesis plans to tie in historical and current events of human spaceflight in order to decide the road ahead.

Joan Johnson-Freese has published multiple books and articles on space security with particular emphasis on China. Her works include: *Space as a Strategic Asset*, *Changing Patterns of International Cooperation in Space*, *The Chinese Space Program: A Mystery Within a Maze*, and “Will China overtake America in space?” In her book, *Space as a Strategic Asset*, she has a chapter on human spaceflight and describes the government’s lack of enthusiasm for a strong human spaceflight program. This is evident, as mentioned above, in her testimony to the Senate. She concludes this chapter in her book: “Manned space activity yields benefits in the form of jobs, education, technology development, and prestige... What manned spaceflight offers is a soft-power strategic alternative to counterbalance some, though not all, of the international fears generated by U.S. military ambitions in space.”<sup>4</sup>

James Clay Moltz has also published multiple books and articles on space security with an emphasis on Asia. His works include: *The Politics of Space Security: Strategic Restraint and the Pursuit of National Interests*, *Asia's Space Race: National Motivations, Regional Rivalries, and International Risks*, and “Toward Cooperation or Conflict on the Moon?” Moltz’s *The Politics of Space Security* reviews the history of the first 50 years of space security and presents an argument about the evolving role of great power learning regarding the space environment in causing states to exercise restraint, in part in order to preserve low-Earth orbit for human spaceflight. His more recent book, *Asia’s Space Race*, discusses the emerging competition among such rising space powers as China, India, Japan, and the two Koreas. He makes the case that space cooperation has been very limited among Asian countries and that human spaceflight has played an important role in stimulating both nationalism and regional space competition.

For more information on the specific countries’ human spaceflight experiences, this thesis draws on a variety of sources, including: Handberg and Li’s *Chinese Space Policy: A Study in Domestic and International Politics*, Burleson’s *Space Programs*

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<sup>4</sup> Joan Johnson-Freese, *Space as a Strategic Asset* (New York: Columbia University Press, 2007), 80.

*Outside the United States* and Harvey's *The Chinese Space Programme: From Conception to Future Capabilities*, *Europe's Space Programme: to Ariane and Beyond*, *Russia in Space: The Failed Frontier?* and *Emerging Space Powers: The New Space Programs of Asia, the Middle East and South America* (with Henk H.F. Smid, and Theo Pirard). Some of these authors concentrate on a specific country or region, while others have provided a broad overview of space programs in general. This thesis will delve into these experts' research, concentrating only on their human spaceflight programs or what capabilities they currently have that could be used for such missions.

## **F. SCOPE AND METHODOLOGY**

The thesis will focus on the various national space programs and how they might interact and cooperate in the future. This thesis will be limited to these programs' human exploration potential and not their whole space programs. This thesis will only use information available in the unclassified realm.

This thesis intends to answer the research questions by conducting a literature review of the 1960s space race, the ISS, and various international space programs with emphasis on their human space exploration ambitions. Recommendations from this historical review will be developed based on the most cost-efficient, technically expedient, and politically manageable way toward future human exploration of space.

## **G. SUMMARY OF CHAPTERS**

Chapter II examines a case study of the 1960s space race as an example of competition between the U.S. and Russia. As a case study for a cooperative effort, Chapter III discusses the ISS. For both chapters, a brief historical background will be provided as well as the advantages, disadvantages and lessons learned. Chapter IV suggests what the next steps in the human space exploration could be drawing on the capabilities of other space-faring countries. Finally, Chapter V concludes this thesis by providing a final analysis and a set of recommendations.



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## **II. THE 1960S SPACE RACE: COMPETITION BETWEEN U.S. AND RUSSIA**

### **A. INTRODUCTION**

The 1960s space race is a case of competition leading to a human stepping foot on the moon. During this timeframe, there were attempts at cooperation but these were rejected due to the framework of the U.S. and Soviet political/military systems. Both sides of the competition took alternate routes to try and be the first to put a man on the moon. Advantages and disadvantages of this competition were seen by both sides and from them lessons for the future can be gleaned.

### **B. HISTORICAL BACKGROUND**

#### **1. Russian Space Exploration**

Russia's route into space started off quickly with what seemed to be little regard to safety. Unlike their rival, the Soviet's space program was simplistic. Materials like stainless steel were used instead of aluminum or titanium as well as simple rocket engines that ran on kerosene and liquid oxygen.<sup>5</sup> They took the first leap into space and shocked the American populace with their launch of *Sputnik* on October 4, 1957.

Nikita Khrushchev, the Soviet premier during this part of the Cold War, had a strategy for initial and spectacular space firsts with little regard to safety or scientific importance.<sup>6</sup> In Khrushchev's mind, "cooperation in outer space would be impossible as long as there was no disarmament."<sup>7</sup> Because of this mindset, the U.S. attempts for space cooperation both publicly from speeches by President Kennedy to more informal meetings at the Vienna Summit meeting in June 1961 were not heeded. In his memoirs, it was discovered that the main reason for Khrushchev's unwillingness to cooperate was

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<sup>5</sup> Daphne Burleson, *Space Programs Outside the United States* (Jefferson, NC: McFarland & Company), 224.

<sup>6</sup> James Clay Moltz, *The Politics of Space Security: Strategic Restraint and the Pursuit of National Interests* (Stanford, CA: Stanford University Press, 2008), 146.

<sup>7</sup> Quoted in Logsdon, *John F. Kennedy*, 167.

the fear that it would reveal Soviet weakness in intercontinental ballistic missiles at the time.<sup>8</sup>

The Russian human launch vehicles started with the *Vostok* capsules, followed shortly thereafter by the *Voskhod* program. Sergei Korolev and Konstantin Feoktistov conceptualized the *Vostok* spacecraft as early as June 1956. Construction started in January 1958.<sup>9</sup> Korolev wrote a document on September 7, 1960 titled “Basic Status of the Development and Preparation of the Object 3KA (The Piloted Space Ship ‘Vostok-3A’)”<sup>10</sup> which spurred state-level interest into the program. Only three days later, according to Siddiqi:

[T]he ten most powerful leaders in the Soviet defense industry...along with the six original core members of the Council of Chief Designers, signed and sent a document on the Vostok program to the Central Committee of the Communist Party....Unlike all earlier Soviet space projects, the fact that this document was signed by ministerial heads rather than the standard deputy ministers clearly underlines the importance with which the Soviet leadership viewed the program.<sup>11</sup>

Another spectacular space first occurred on April 12, 1961, with the world’s first piloted space mission of a single orbit totaling 108 minutes around the Earth by Yuri Gagarin. It was later discovered that the *Vostok* spacecraft piloted by Gagarin actually had a malfunction, which could have resulted in his death.<sup>12</sup>

*Vostok* had no maneuvering capability and the cosmonauts had to parachute to safety at the end of flight, a fact that the Soviets concealed for a long time because manned landing was required to be eligible for world space records by the Fédération Aéronautique Internationale (FAI).<sup>13</sup> Over the next few years, Russia chalked up additional space firsts, putting the Americans always a few steps behind. In 1962, the

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<sup>8</sup> Logsdon, *John F. Kennedy*, 160–168.

<sup>9</sup> Burleson, *Space Programs*, 236.

<sup>10</sup> Asif A. Siddiqi, *Sputnik and the Soviet Space Challenge* (FL: University Press of Florida, 2003), 254.

<sup>11</sup> *Ibid.*, 254–255.

<sup>12</sup> Andrew Chaikin, “Greatest Space Events of the 20th Century: The 60s,” *Space.com*, December 27, 1999, [http://www.space.com/news/spacehistory/greatest\\_space\\_events\\_1960s.html](http://www.space.com/news/spacehistory/greatest_space_events_1960s.html).

<sup>13</sup> Burleson, *Space Programs*, 235.

first day-long flight was achieved by Cosmonaut Gherman Titov. The first dual spaceflight was accomplished in 1963 with Andriyan Nikolayev in *Vostok 3* and Pavel Popovich in *Vostok 4*. Valentina Tereskhkova became the first woman in space in 1963.<sup>14</sup>

After only six missions, *Vostok* was cancelled in 1964 for a modified *Vostok* design designated *Voskhod*.<sup>15</sup> *Voskhod* was also short lived, as it was developed in nine months and only had two missions.<sup>16</sup> Once again, safety was overlooked as the 1964 maiden flight of the *Voskhod* launched three cosmonauts into space. The *Voskhod* was actually a *Vostok* without ejection seats, escape tower, or spacesuits to make additional room.<sup>17</sup> Luckily, there were no problems with this flight.

However, Pavel Belyayev and Alexei Leonov in *Voskhod 2* had difficulties on the first spacewalk. Leonov's suit inflated, causing him to be unable to climb back into the cabin. In a desperate attempt, he reduced the air pressure in his suit, allowing him to squeeze back in.<sup>18</sup> As Leonov described the situation:

Near the end of my walk I realized that my feet had pulled out of my shoes and my hands had pulled away from my gloves. My entire suit stretched so much that my hands and feet appeared to shrink. I was unable to control them. It was as if I had never tried the suit on even once...I couldn't get back in straightaway. My space suit had ballooned out and the pressure was quite considerable. I was tired and couldn't go in feet first as I had been taught to do. But using a valve...I decreased the pressure to just under 0.27 atmospheres. Then I felt freer and I could move about more easily. Then I pushed myself into the airlock head first, with my arms holding the rails. I had to turn myself upside down in the air lock in order to enter the ship feet first and this was very difficult.<sup>19</sup>

This marked the last first the Soviets would have in the race to the moon. The *Voskhod* program was cancelled after Sergei Korolev's death and plans were shifted to

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<sup>14</sup> Chaikin, *Greatest Space*.

<sup>15</sup> Burlison, *Space Programs*, 236.

<sup>16</sup> *Ibid.*, 237.

<sup>17</sup> *Ibid.*, 236.

<sup>18</sup> *Ibid.*, 237.

<sup>19</sup> Quoted in Siddiqi, *Sputnik and the Soviet*, 456.

*Soyuz*. A few years later, the Soviets' luck ran out. In April 1967, the parachute on the *Soyuz 1* failed to deploy killing Vladimir Komarov.<sup>20</sup> This would set the Soviets' lunar program back 18 months.<sup>21</sup>

Two significant changes in the Soviet space program would alter its direction and slow the pace, giving the moon to the Americans. In October 1964, Khrushchev was removed from office by a coup led by Leonid Brezhnev. This cost the lunar space program a strong government ally.<sup>22</sup> Brezhnev had different ideas when it came to space, mainly shifts toward new military programs. In particular, possible nuclear missile strikes aimed at the U.S., launching at its unprotected southern border as well as an anti-satellite (ASAT) system. The other change that slowed down the Soviet moon effort was the sudden death of Sergei Korolev, one of the Soviets' lead rocket designers. His death left a leadership gap that his successor was unable to fulfill with increasing press from the U.S.<sup>23</sup> As Siddiqi describes it: "As a manager, designer, politician, lobbyist, engineer, and flight director, he had carved out a position for himself that defied any singular title. Each one of the responsibilities that he had carried on his shoulders was vacant. His successors would try to fill the vacuum, but in truth, things would never be the same again."<sup>24</sup>

## **2. United States Space Exploration**

Unlike the Russians, who took a running start to the space race, the U.S. had a slightly different initial view on this space competition. The Eisenhower administration actually didn't view it as a race of space programs at all. President Eisenhower believed that the accomplishment of *Sputnik I* was not one of space achievement, but as an achievement in their rockets. Therefore, Eisenhower focused funding toward accelerating U.S. ballistic missile programs especially in the area of hardening against

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<sup>20</sup> Chaikin, *Greatest Space*.

<sup>21</sup> Burleson, *Space Programs*, 237–238.

<sup>22</sup> *Ibid.*, 225.

<sup>23</sup> Moltz, *The Politics of Space*, 155–157.

<sup>24</sup> Siddiqi, *Sputnik and the Soviet*, 516.

attack. With this budgetary concentration on missile programs, funding for other programs was kept as low as possible, including space programs.<sup>25</sup>

Just a few months before Gagarin's historic voyage, an advisory committee was formed to justify putting a human into space. The President's Science Advisory Committee stated on December 1960,

We have been plunged into a race for the conquest of outer space. As a reason for this undertaking some look to the new and exciting scientific discoveries which are certain to be made. Others feel the challenge to transport man beyond frontiers he scarcely dared dream about until now. But at present the most impelling reason for our effort has been the international political situation which demands that we demonstrate our technological capabilities if we are to maintain our position of leadership. For all of these reasons we have embarked on a complex and costly adventure.<sup>26</sup>

This committee concluded that "It seems, therefore, to us at the present time that man-in-space cannot be justified on purely scientific grounds, although more thought may show that there are situations for which this is not true. On the other hand, it may be argued that much of the motivation and drive for the scientific exploration of space is derived from the dream of man's getting into space himself."<sup>27</sup> Without additional justification in December 1960, it didn't seem likely that the U.S. was going to try to put a man into space at all, let alone to the moon.

Gagarin's flight in April 1961 made way for a "full-scale inquiry which would be necessary before a final and precise decision could be made."<sup>28</sup> However, this historical flight also "demonstrated to the President the importance of going ahead with an all-out space effort."<sup>29</sup> The sentiment under the Kennedy administration had changed. May 5, 1961, exemplified this new attitude with America's first space flight piloted by astronaut Alan B. Shepard, Jr., lasting 14.8 minutes. The American people were now invested in

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<sup>25</sup> John M. Logsdon, *The Decision to Go to the Moon: Project Apollo and the National Interest* (Cambridge, MA: MIT Press, 1970), 13, 16.

<sup>26</sup> The President's Science Advisory Committee, "Report of the Ad Hoc Panel on Man-in-Space," *NASA Historical Reference Collection*, December 16, 1960.

<sup>27</sup> *Ibid.*

<sup>28</sup> Logsdon, *The Decision to Go*, 107.

<sup>29</sup> *Ibid.*

this race. A new deadline was set just days after Shepard became the first American in space by President John F. Kennedy's famous speech. "...I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the earth."<sup>30</sup>

On multiple occasions in his early speeches as president, Kennedy urged the Soviet Union for cooperation in space. The motivation for cooperation with the Soviets was of personal and diplomatic interest to President Kennedy in the hope that it would alleviate much of the tensions between the two countries and therefore the global tensions as well.<sup>31</sup> "Together let us explore the stars..." Kennedy stated in his Inaugural Address.<sup>32</sup> On the day of Gagarin's flight, Kennedy sent a congratulatory telegram to Khrushchev again asking for cooperation "it is my sincere desire that in the continuing quest for knowledge of outer space our nations can work together..."<sup>33</sup> However, these efforts were mostly ignored by the Soviets at the time. But ten other nations did express their desire to take part in this endeavor, allowing the U.S. to "reinforce our old alliances and build new ones."<sup>34</sup>

Unlike the change in leadership for the Soviets, President Kennedy's assassination and Johnson's presidency helped accelerate the U.S. space program. President Johnson had already made a name for himself as a proponent of the space competition and with that, his space policy as president gave a strong commitment and drive to the U.S. manned space program as the international leader.<sup>35</sup> President Johnson was not going to modify Kennedy's goal of the lunar landing and turned it into a memorial for him.<sup>36</sup> Cooperation was going to take a back seat to this reinvigorated U.S. drive.

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<sup>30</sup> John F. Kennedy, "Special Message to the Congress on Urgent National Needs," (speech, Washington, DC, May 25, 1961), *John F. Kennedy Library Presidential Library and Museum*, <http://www.jfklibrary.org/Historical+Resources/Archives/Reference+Desk/Speeches/JFK/Urgent+National+Needs+Page+4.htm>.

<sup>31</sup> Logsdon, *John F. Kennedy*, 160.

<sup>32</sup> Logsdon, *The Decision to Go*, 93.

<sup>33</sup> *Ibid.*, 104.

<sup>34</sup> *Ibid.*, 98.

<sup>35</sup> Moltz, *The Politics of Space*, 142.

<sup>36</sup> Logsdon, *John F. Kennedy*, 223.

The U.S. caught up fast with its first spacewalk aboard *Gemini's* second mission, occurring only a couple months after the Russians. However, tragedy also struck the Americans in 1967, when three astronauts were killed aboard *Apollo 1* during a routine test. After almost two full years of testing and enhanced safety measures, the first *Apollo* mission took flight with astronauts Walter M. Schirra, Jr., Donn F. Eisele, and Walter Cunningham, whose mission it was to test this new hardware in Earth orbit.<sup>37</sup>

Christmas Eve 1968 was an emotional and historic day as the astronauts aboard *Apollo 8* circled the moon for the first time reading from the first book of the Bible and sending back video of the Earth from lunar orbit. This proved to the world that the U.S. had not only caught up to the Soviets, but had far surpassed them. Finally, on July 16, 1969, Neil A. Armstrong and Edwin E. Aldrin stepped foot on the surface of the moon.<sup>38</sup> “One small step for man; one giant leap for mankind.” Neil Armstrong’s quote, as he became the first person to set foot on the moon, ended the 1960s space race between the U.S. and the Soviets.

### C. ADVANTAGES

The main advantage of a space race was the fact that this was a competition. Today, the deadline of putting a man on the moon in nine years almost seems unachievable. This was exactly the point, to do an unthinkable feat before the Soviets. This would have the symbolic value of demonstrating technological leadership, as well as military power. The Soviets and the U.S. were not only fighting to be the first to put a man on the moon, but to prove to the world that their form of government was superior and therefore better choice for alliance.<sup>39</sup> As President John F. Kennedy stated “We choose to go to the Moon in this decade... not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to

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<sup>37</sup> National Aeronautics and Space Administration, “Chronology of Selected Highlights in the First 100 American Spaceflights, 1961–1995,” *NASA History Program Office*, January 27, 2005. <http://history.nasa.gov/Timeline/100flt.html>.

<sup>38</sup> Ibid.

<sup>39</sup> Moltz, *The Politics of Space*, 69, 121.



postpone, and one which we intend to win, and the others, too.”<sup>40</sup> With the politics involved and the backing of the American populace, this deadline became achievable. Many journalists of the day agreed, it was setting the mind to the task and concentration in effort and control that assured the success.<sup>41</sup> As Johnson-Freese wrote “Only commitment from the office of the president—first Kennedy, and then Johnson—maintained because of the program’s strategic goal of beating the Soviets, ensured that Congress maintained support for long enough to guarantee success.”<sup>42</sup>

The concentration of effort was exactly what NASA was hoping for in 1961 when it told President Kennedy that it was feasible to get a man to the moon within the decade. The stipulation was policy approval and adequate funding because scientists already believed the technology would be there. The Low Committee, a task force established to define NASA’s manned lunar landing program, concluded that “no invention or breakthrough is believed to be required to insure the over-all feasibility of safe lunar flight.”<sup>43</sup> With this increase in technology and funding, came thousands of new jobs. NASA’s budget was astronomically large, but on the other hand so was the number of jobs needed. As L. C. McHugh wrote, “in fact the entire space industry, which formally came into being less than five years ago, has already given rise to five thousand companies or research organizations. Moreover, if NASA officials guess correctly on the lunar venture, this ambitious feat will require the mobilization of an army of four hundred thirty-five thousand people, and its hardware requirements will ultimately involve ten thousand firms.”<sup>44</sup> President Johnson received almost everything he asked from Congress for NASA because of the jobs this program produced as well as “nobody wanted to draw attention to funding going for a program without widespread public support.”<sup>45</sup>

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<sup>40</sup> John F. Kennedy, “Address at Rice University on the Nation's Space Effort,” (speech, Houston, TX, September 12, 1962), *John F. Kennedy Library Presidential Library and Museum*, <http://www.jfklibrary.org/Historical+Resources/Archives/Reference+Desk/Speeches/JFK/003POF03SpaceEffort09121962.htm>.

<sup>41</sup> Logsdon, *The Decision to Go*, 3.

<sup>42</sup> Johnson-Freese, *Space as a Strategic*, 61.

<sup>43</sup> Logsdon, *The Decision to Go*, 40, 61–62.

<sup>44</sup> Laurence C. McHugh, “The Why of Space Programs,” *America: National Catholic Weekly Review*, May 19, 1962, 155.

<sup>45</sup> Johnson-Freese, *Space as a Strategic*, 79.

A surprising advantage was the bettering of the education system. When *Sputnik* was launched, it not only jumpstarted a space race but an education race as well. As Logsdon wrote, “Soviet space successes had prompted a reevaluation of American education and technology; they brought to the surface many unsolved problems and unsatisfied demands in virtually all sectors of American society.”<sup>46</sup> As a result, sciences such as physics became emphasized at a younger age. Language studies in Russian and Chinese were also made more available and to younger students. This revamp of the U.S. education system began in 1958, in which the human space race helped in speeding it up.<sup>47</sup>

#### **D. DISADVANTAGES**

With time being the driver of the space race, safety was not. Because of the imperative to win, corners were cut. This was evident in both space programs with numerous malfunctions and unfortunate deaths. The Russians had malfunctions ranging from suit failures to a failed parachute. They also took shortcuts such as sending three men into space without ejection seats or spacesuits. According to Moltz, “Part of the pressure for haste had led to a disastrous explosion on October 24, 1960, at Baikonur, which killed the new head of the Strategic Rocket Forces, Field Marshal Mitrovan I. Nedelin, and 126 scientists, engineers, and soldiers working at the site.”<sup>48</sup> The Americans also had their share of close calls. John Glenn manually flew the last two of his three orbits due to a failure of his autopilot. *Apollo 13*’s mission changed from landing on the surface of the moon to getting the crew home alive after an oxygen tank rupture. With the loss of human life by both parties, the true cost of the competition was felt.

“Reinventing the wheel” sums up the duplicative efforts of the two nations to put a man on the moon. Two of everything was needed. Two rockets, two space programs, two budgets. Therefore it can be estimated that twice the cost and manpower was used.

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<sup>46</sup> Logsdon, *The Decision to Go*, 64.

<sup>47</sup> Newsweek, “The Schools: How to Teach—What to Teach,” October 8, 1962.

<sup>48</sup> Moltz, *The Politics of Space*, 117.

With everything kept a deep secret to ensure the success of their own program, the United States and Russia were not learning from each others' successes and failures. The U.S. actually had its own duplication on its space efforts between the Army, Air Force and NASA. The Office of the Secretary of the Air Force sent out a memorandum in 1961 stating that "for the sake of operational effectiveness and to avoid wasteful duplication" there needs to be an "interdependent team effort."<sup>49</sup>

Taking place due in part to the Cold War, tensions were so high between these two competitors that everything became a race. Not only was there the space race, but education became a competition. A nuclear arms race was also brewing with "an increasing danger that space may become man's newest battlefield," according to U.S. Secretary of State Dean Rusk in 1962.<sup>50</sup>

This idea of space as a battleground caused fear should the U.S. lose this race. The moon itself could become the ultimate "high ground" and lead to the "ultimate domination of the solar system."<sup>51</sup> Senior military officers actually called for a lunar missile base in 1958; a base that would be able to deploy nuclear weapons.<sup>52</sup> Some U.S. military men saw this as a national-defense measure.<sup>53</sup> The reasoning became that the U.S. must get to the moon first, or the Soviets would be the ones building a base. According to McHugh, "For all we know, it may indeed be true that the imponderable value of scientific prestige, coupled with the unknown military potential of outer space, will lead directly to dominion over the earth."<sup>54</sup>

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<sup>49</sup> Logsdon, *The Decision to Go*, 76.

<sup>50</sup> James Clay Moltz, "Protecting safe access to space: Lessons from the first 50 years of space security," *Space Policy* 23, no. 4 (November 4, 2007), 200.

<sup>51</sup> Harland Manchester, "The Senseless Race to Put Man in Space," *Reader's Digest* (May 1961), 103.

<sup>52</sup> James Clay Moltz, "Toward Cooperation or Conflict on the Moon?" *Strategic Studies Quarterly* 3, no. 3 (Fall 2009), 90.

<sup>53</sup> Manchester, "The Senseless Race," 105.

<sup>54</sup> McHugh, "The Why of Space," 153.

## **E. LESSONS LEARNED**

The nuclear arms race in space and the negative effects of orbital nuclear tests from 1958 to 1962 actually created the most noteworthy lesson learned. Realizing the harmful effects on satellites of electro-magnetic pulse radiation of the two countries took an “unprecedented step of beginning to narrow considerably the permitted avenues of military space competition through a series of bilateral and multilateral agreements.”<sup>55</sup> These agreements included the 1963 Limited Test Ban Treaty.

In President John F. Kennedy’s Address before the 18th General Assembly of the United Nations on September 20, 1963, he stated:

Today we may have reached a pause in the Cold War—but that is not a lasting peace. A test ban treaty is a milestone—but it is not the millennium. ... But if we can stretch this pause into a period of cooperation—if both sides can now gain new confidence and experience in concrete collaborations for peace—if we can now be as bold and farsighted in the control of deadly weapons as we have been in their creation—then surely this first small step can be the start of a long and fruitful journey.<sup>56</sup>

This was only the first step. Three months later a UN resolution was issued creating a basis for the Outer Space Treaty, which created the basis for international space law in 1967.<sup>57</sup>

## **F. CONCLUSION**

The mentality of the 1960s space race was mainly one of competition, national pride and relative gain. The political tensions between the U.S. and Russia propelled them each to try to be the first country to put a man on the moon, which they believed would assist their ultimate victory in the broader Cold War struggle.

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<sup>55</sup> Moltz, “Protecting safe access,” 200.

<sup>56</sup> John F. Kennedy, “Address Before the 18th General Assembly of the United Nations,” (speech, New York, NY, September 20, 1963), *John F. Kennedy Library Presidential Library and Museum*, [http://www.jfklibrary.org/Historical+Resources/Archives/Reference+Desk/Speeches/JFK/003POF03\\_18thGeneralAssembly09201963.htm](http://www.jfklibrary.org/Historical+Resources/Archives/Reference+Desk/Speeches/JFK/003POF03_18thGeneralAssembly09201963.htm).

<sup>57</sup> Moltz, “Protecting safe access,” 200.

This complex and costly adventure started with *Sputnik* and many firsts on the Soviets' part. But by 1969, the U.S. had caught up and surpassed the Soviets with the greatest achievement of placing a man on the moon. Below is a table highlighting the firsts in this space race.

Table 1. Timetable of Space Events: 1960s<sup>58</sup>

<b>Achievement</b>	<b>Country</b>	<b>Crew</b>	<b>Spacecraft</b>	<b>Launch Date</b>
First human in space	Soviet Union	Gagarin	Vostok 1	April 12, 1961
First American in space	United States	Shepard	Freedom 7	May 5, 1961
First daylong spaceflight	Soviet Union	Titov	Vostok 2	August 6, 1961
First woman in space	Soviet Union	Tereshkova	Vostok 6	June 16, 1963
First multi-person spaceflight	Soviet Union	Komarov, Yegorov, Feoktistov	Voskhod 1	October 12, 1964
First spacewalk	Soviet Union	Belyayev, Leonov	Voskhod 2	March 18, 1965
First lunar-orbit flight	United States	Borman, Lovell, Anders	Apollo 8	December 21, 1968
First lunar landing	United States	Armstrong, Collins, Aldrin	Apollo 11	July 16, 1969

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<sup>58</sup> Chaikin, *Greatest Space Events*.

With the first lunar landing, came the perception that the U.S. had won this space race. The Soviets did not continue to strive for the moon because they did not want to take the risks or the expense “since the Americans had already taken the big prize.”<sup>59</sup> Thoughts of further lunar exploration were put aside. Similar thoughts were true in the U.S. NASA’s budget was cut drastically as was the Apollo program. According to Logsdon “The program had enough forward momentum to carry it through six more missions, but Apollo was conceived as a closed-end effort to beat the USSR to the Moon, not as the first step in a long-term, sustainable program of space exploration.”<sup>60</sup>

From these first steps during the 1960s space race, advantages and disadvantages led to important lessons learned. As a 1969 NASA report summarized:

The landing on the Moon has captured the imagination of the world. It is now abundantly clear to the man in the street, as well as to the political leaders of the world, that mankind now has at his service a new technological capability, an important characteristic of which is that its applicability transcends national boundaries. If we retain the identification of the world with our space program, we have an opportunity for significant political effects on nations and peoples and on their relationships to each other, which in the long run may be quite profound.<sup>61</sup>

The outcome of the 1960s space race was actually to stop the competitive mind-set and to initiate the seeds of cooperation.

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<sup>59</sup> Moltz, “Toward Cooperation?” 92.

<sup>60</sup> John M. Logsdon, “Why space exploration should be a global project,” *Space Policy* 24, no. 1 (February 2008), 3.

<sup>61</sup> Space Task Group, “The Post-Apollo Space Program: Directions for the Future,” *NASA Historical Reference Collection*, September 1969, <http://www.hq.nasa.gov/office/pao/History/taskgrp.html>.

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### III. INTERNATIONAL SPACE STATION: A COOPERATIVE EFFORT

#### A. INTRODUCTION

The idea of international cooperation regarding space exploration was not a new concept that came out of the 1970s détente era. NASA was created with this in mind. The National Aeronautics and Space Act of 1958, which formed NASA had a clause that mandated this new space agency to engage in “cooperation...with other nations and groups of nations.”<sup>62-63</sup>

Early attempts at cooperation include U.S.-European collaboration with Spacelab, while Canada was commissioned to construct the Remote Manipulator System, or Canadarm, on the shuttle. Known as the “handshake in space,” the Apollo-Soyuz Test was the first international manned spaceflight.<sup>64</sup> This mission occurred in July 1975 and its success enhanced space relations between the U.S. and the USSR, which would eventually lead to future cooperation on the ISS.<sup>65</sup> Following this mission, President Ford predicted “the day is not far off when space missions made possible by this first joint effort will be more or less commonplace.”<sup>66</sup>

Therefore, when discussion of building a space station began in the late 1970s, there was motivation to build it cooperatively due in part to the Space Act and previous cooperation attempts as well as cost concerns. In President Reagan’s State of the Union Address on January 25, 1984, he made it abundantly clear that building a space station was the next great step in space and that it could not be done without international support.

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<sup>62</sup> Roger D. Launius, “United States Space Cooperation and Competition: Historical Reflections,” *Astropolitics* 7, no. 2 (May 2009), 90–91.

<sup>63</sup> John M. Logsdon, *Together in Orbit: The Origins of International Participation in the Space Station* (NASA Contractor Report 4237), (Washington, DC: NASA History Division, Office of Policy and Plans, November 1998), 3.

<sup>64</sup> *Ibid.*, 1–2.

<sup>65</sup> Burleson, *Space Programs*, 242.

<sup>66</sup> John M. Logsdon, “Ten Presidents and NASA,” in *NASA: 50 Years of Exploration and Discovery* (Washington, DC: NASA, 2008), 232.



A space station will permit quantum leaps in our research in science, communications, in metals, and in lifesaving medicines which could be manufactured only in space. We want our friends to help us meet these challenges and share in their benefits. NASA will invite other countries to participate so we can strengthen peace, build prosperity, and expand freedom for all who share our goals.<sup>67</sup>

This invitation was not given or taken lightly, and the groundwork was already in place thanks to initial meetings. Accordingly, during the late spring to early summer of 1985, Canada, Japan and Europe (under ESA) formally agreed to partner with the U.S. in what is now the most extensive international technical project ever undertaken.<sup>68</sup>

## **B. HISTORICAL BACKGROUND**

Well before President Reagan's invitation and decree to build a space station, NASA had been setting the framework. In the post-Apollo era, it became evident that the major human spaceflight efforts were all now being considered as international partnerships,<sup>69</sup> and the U.S. did alter its approach to cooperation to one that involved real participation instead of just data exchange and launch services. There were concerns on how sophisticated other spacefaring nations were and therefore whether or not to provide them access to sensitive or proprietary technology which then might be used to compete with the U.S.<sup>70</sup> Even with these concerns, NASA asked Europe, Canada, Japan, (and much later the Russians) to participate in this new space era.

A permanent human presence in space with a station was perceived as the next logical step. In a change from earlier policy, NASA involved potential partners at a very early stage in the program. This early involvement allowed these potential partners' inputs to help influence NASA as well as aid it in understanding from the beginning what their roles would be. As early as 1982, representatives from Europe, Canada, and Japan

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<sup>67</sup> Ronald Reagan, "Address Before a Joint Session of the Congress on the State of the Union" (speech, Washington, DC, January 25, 1984), *The American Presidency Project*, <http://www.presidency.ucsb.edu/ws/index.php?pid=40205#ixzz1LnngUymQ>.

<sup>68</sup> Logsdon, *Together in Orbit*, 1.

<sup>69</sup> Launius, "United States Space," 91.

<sup>70</sup> Logsdon, *Together in Orbit*, 1-3.

were called together for a status update and a discussion of potential participation.<sup>71</sup> There would be negotiations about long-term use as well as hardware development. Nowhere was it mentioned about who would manage the station.<sup>72</sup>

The reason there was no mention of who would manage the space station was that NASA had already taken on this role by decreeing that the U.S. would develop a space station capable of functioning on its own. This meant that operationally, right from the start, Europe, Japan and Canada had to accept a junior role and become dependent on the U.S. However, the original principles declared that all station elements would be open to all participants with no jurisdiction issues.<sup>73</sup> The decision to proceed by the international community was taken on the belief that because of the presidentially initiated invitation to cooperate, this program would have to have the political and financial support required for mutual success.<sup>74</sup>

In late spring and early summer of 1985, the original potential partners (Europe, Canada and Japan) for this space station entered into three Memoranda of Understanding (MOU). The MOUs were to be the framework for cooperation as far as detailing the technical aspects as well as the managerial arrangements of the partnership. However, the MOUs were not as binding of a commitment as the potential international partners wanted from the U.S. Yet, on that basis on September 29, 1988, the parties reached a 30-year Intergovernmental Agreement (IGA) for the space station.<sup>75</sup> Europe, Canada, and Japan treated the IGA as a treaty. On the other hand, the U.S. Congress did not formally commit to any of the provisions in the IGA. Due to this, there was no means to force the U.S. to honor its commitments in the MOUs or IGA if funding was not provided by Congress.<sup>76</sup>

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<sup>71</sup> Logsdon, *Together in Orbit*, 8.

<sup>72</sup> Johnson-Freese, *Space as a Strategic*, 177.

<sup>73</sup> *Ibid.*

<sup>74</sup> John M. Logsdon, "International cooperation in the space station programme: Assessing the experience to date," *Space Policy* 7, no. 1 (February 1991), 43.

<sup>75</sup> Johnson-Freese, *Space as a Strategic*, 181.

<sup>76</sup> Logsdon, "International cooperation," 38.

The Europeans were split on their decision to press forward with the U.S. They wanted to be a partner in this endeavor in order to have more of a voice in the management of the station and a guarantee that the U.S. would not back out. But there were also those in Europe that wanted a longer-term policy of developing their own autonomous capabilities. This hesitation can be traced back to the Europeans' previous displeasure with the outcome of its *Symphonie* satellite. The International Telecommunications Satellite Organization (INTELSAT) is an organization "whose main objective is to provide a commercial basis, the 'space segment' for international public telecommunications services."<sup>77</sup> Originally, the U.S. Communications Satellite Corporation (COMSAT) had 61% of the system with Europe only having 30.5%.<sup>78</sup> The Franco-German designed *Symphonie* was seen as a threat to INTELSAT and as Europe did not have a launcher of its own, it had to agree that *Symphonie* would only be used for experimental and not commercial purposes in order for the Americans to launch it.<sup>79</sup> This led to the ESA's decision to develop the Ariane launcher family in July 1973, so as to no longer have to rely on another country for launch capabilities.<sup>80</sup>

Ultimately, Europe entered into the space station negotiations with less than full faith in the partnership's set of conditions for cooperation. ESA would contribute three elements to the space station, together known as the Columbus program. These elements were a permanently attached pressurized module (APM), a polar platform, and a man-tended free flyer (MTFF), capable of autonomous operation for periods of six months or longer.<sup>81</sup>

Like ESA, Japan planned to contribute multiple elements. The purpose of its elements involved scientific research in the fields of microgravity and materials processing. The Japanese Experiment Module (JEM), nicknamed Kibo, would consist of

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<sup>77</sup> Joan Johnson-Freese, *Changing Patterns of International Cooperation in Space* (Malabar, FL: Orbit Book, 1990), 17.

<sup>78</sup> *Ibid.*, 18.

<sup>79</sup> Brian Harvey, *Europe's Space Programme: To Ariane and Beyond* (Chichester, United Kingdom: Springer, 2003), 160.

<sup>80</sup> Burleson, *Space Programs*, 98.

<sup>81</sup> Johnson-Freese, *Space as a Strategic*, 178.

a logistics module, a pressurized research module, and an exposed section.<sup>82</sup> Based on its partnership, Japan intended to have a permanent Japanese presence in space, hoping to always have a Japanese astronaut as one of the six member permanent crew originally planned.<sup>83</sup>

Canada was called on again for its advanced robotics. Unlike the other partners, Canada would not be contributing a module. Its contribution was the system that would assemble all the modules together to form the station, called the Mobile Servicing System (MSS). The MSS consists of a long robotic arm used for the construction (known as the Canadarm2), a two-armed robotic handyman used for maintenance (known as Dextre), and the Mobile Base used as a work platform (which moves on rails and can be used for storage).<sup>84</sup>

But the early 1990s were laden with problems, funding being the main contributor. The partners were falling behind schedule and over budget, repeatedly forcing design downsizing. The design was too complicated. It was too heavy. It provided too little power. The political commitment in the U.S. was weak. Due to all of this, the timeline and the design for the ISS constantly had to be rewritten.<sup>85</sup> With all the rewrites, it became apparent that the budget allocated for the construction of the station was inadequate.

When President Bill Clinton took office in January 1993, he was advised to cancel the space station program because it was over budget and behind schedule.<sup>86</sup> As Dan Goldin, NASA Administrator, recalled “Panetta [President Clinton’s budget director] told me that the President campaigned on the economy, we have to cut the budget, and the

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<sup>82</sup> Japanese Aerospace Exploration Agency, “About Kibo-Kibo Japanese Experimental Module - JAXA,” September 25, 2008, <http://kibo.jaxa.jp/en/about/>.

<sup>83</sup> Brian Harvey, Henk H. F. Smid, and Theo Pirard, *Emerging Space Powers: The New Space Programs of Asia, the Middle East and South America* (Chichester, United Kingdom: Praxis, 2010), 112–113.

<sup>84</sup> Canadian Space Agency, “International Space Station- Canadian Space Agency,” August 18, 2011, <http://www.asc-csa.gc.ca/eng/iss/default.asp>.

<sup>85</sup> Johnson-Freese, *Space as a Strategic*, 181–182.

<sup>86</sup> Logsdon, “Ten Presidents,” 234.

space station solves the problem.”<sup>87</sup> Goldin sought alternatives to cancellation, with one solution being an invitation to the Russians to join the program. The Soviet Union had dissolved in December 1991 and the new government was no longer communist. But the Russians were in a similar situation with its Mir-2 space station.<sup>88</sup> With the Russians’ experience, having them join the space station program would save time and money. In an interview in May 1993, the chief manager of the Mir-2 project, Leonid Gorshkov commented “When space budgets are being reduced around the world, even the richest country would have trouble financing its space program. Coordinated implementation of Freedom and Mir 2 could help to reduce the financial burden on all of their participants and increase the efficiency of future stations.”<sup>89</sup>

However, there were caveats before the Russians became official partners. President Clinton did not cancel the space station program because Dan Goldin linked the space station with Clinton’s foreign policy of preventing Russian scientists from proliferating weapons to U.S. enemies.<sup>90</sup> President Clinton was more interested in the non-proliferation impacts of a Russian-U.S. space project.<sup>91</sup> On July 16, 1993, a Russian delegation in Washington signed two agreements. The first was that Russia agreed not to transfer cryogenic technology to India. The second agreement was to adhere to the Missile Technology Control Regime. In exchange, Russia would be permitted to conduct eight commercial launches of American-made satellites as well as be paid \$400 million for specific space cooperation activities.<sup>92</sup> This would symbolize a new post-Cold War and post-Soviet relationship with Russia.<sup>93</sup> As Susan Eisenhower describes it: “Nonproliferation has been an important but ‘silent’ success of space cooperation...The

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<sup>87</sup> Susan Eisenhower, *Partners in Space: US-Russian Cooperation After the Cold War* (Washington, DC: The Eisenhower Institute, 2004), 37.

<sup>88</sup> Harvey, Smid, and Pirard, *Emerging Space*, 112–113.

<sup>89</sup> Eisenhower, *Partners in Space*, 39.

<sup>90</sup> W. Henry Lambright, “Exploring Space: NASA at 50 and Beyond,” *Public Administration Review* 70, no. 1 (January/February 2010), 155.

<sup>91</sup> Logsdon, “Ten Presidents,” 234.

<sup>92</sup> Eisenhower, *Partners in Space*, 42–45.

<sup>93</sup> Scott Pace, “American Space Strategy: Choose to Steer, Not Drift,” *The Diplomat*, (March 28, 2013).

decision to engage the Russians assured the employment of countless rocket engineers in this cooperation eliminating the temptation to sell their services or their expertise to regimes hostile to the United States....”<sup>94</sup>

Therefore in the winter of 1993, in order to save both programs, the United States invited Russia to join the original partners.<sup>95</sup> A single space station became the developmental plan with the Russian inclusion and the modules from Europe and Japan, thus changing the name from Freedom to the ISS. In his State of the Union address on January 25, 1994, President Clinton highlighted international space cooperation by saying “This is a promising moment. Instead of building weapons in space, Russian scientists will help us build the International Space Station.”<sup>96</sup>

But Russia becoming a full partner in the space station program was a decision made without consultation to the original partners. In March 1993, the international partners were represented on the Station Redesign Team authorized by the Clinton administration. Their report was that “new opportunities for Russian participants should be considered” as well as “consideration may be given to greater use of...the Russian Mir space station.”<sup>97</sup> After that, it was not until October 1993 that they were formally informed about the intention to invite Russia to join.<sup>98</sup> Europeans took this as the U.S. attempting to undermine their capabilities. Japan, wanting to ease U.S. criticism of its trade surplus, supported the decision.<sup>99</sup> The partners were reassured that 75 percent of the hardware designed for Freedom would still be used. However, it became very evident that the U.S. and Russia were now the senior partners, much to the chagrin of the other original partners.<sup>100</sup>

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<sup>94</sup> Eisenhower, *Partners in Space*, 147.

<sup>95</sup> Logsdon, *Together in Orbit*, 42.

<sup>96</sup> Logsdon, “Ten Presidents,” 234.

<sup>97</sup> Eisenhower, *Partners in Space*, 39.

<sup>98</sup> *Ibid.*, 52.

<sup>99</sup> *Ibid.*, 50–51.

<sup>100</sup> *Ibid.*, 52.

Five years later, in November 1998, Russia launched the first module for the station program into space aboard a Proton rocket. The Russian-built Zarya control module became the first segment of the ISS to orbit, 14 years after the space station program was first announced in 1984.<sup>101</sup> At the turn of the century, the first occupying crew arrived. Below is a table highlighting the major achievements on the ISS assembly.

Table 2. Timetable of ISS Assembly Events<sup>102</sup>

<b>Achievement</b>	<b>ISS Assembly Mission</b>	<b>Spacecraft</b>	<b>Launch Date</b>
<b><u>Zarya Control Module</u></b> - battery power and fuel storage	1 A/R	Russian Proton rocket	November 20, 1988
<b><u>Unity Node</u></b> - two pressurized mating adapters	2A	Space Shuttle Endeavour	December 4, 1998
<b><u>Zvezda Service Module</u></b>	1R	Russian Proton rocket	July 12, 2000
The <b><u>first crew</u></b> to live and work aboard the International Space Station.	2R	Soyuz spacecraft	October 30, 2000
<b><u>P-6 Truss</u></b> - supports the first U.S. solar arrays	4A	Space Shuttle Endeavour	November 30, 2000
<b><u>Destiny Laboratory Module</u></b>	5A	Space Shuttle Atlantis	February 7, 2001
Italian-built <b><u>Leonardo Multi-Purpose Logistics Module</u></b> - resupply cargo	5A.1	Space Shuttle Discovery	March 8, 2001
<b><u>Canadarm 2</u></b> - the Station's robotic arm	6A	Space Shuttle Endeavour	April 19, 2001
<b><u>Joint Airlock</u></b> - Russian and American spacewalks may take place.	7A	Space Shuttle Atlantis	July 12, 2001
Cargo crane and the <b><u>Russian Pirs Docking Compartment</u></b> - Soyuz docking port and Russian-based spacewalks.	4R	Russian Soyuz rocket	September 14, 2001

<sup>101</sup> Burleson, *Space Programs*, 267.

<sup>102</sup> National Aeronautics and Space Administration (NASA), "International Space Station Assembly - Past Flights," accessed November 11, 2012, [http://www.nasa.gov/mission\\_pages/station/structure/iss\\_assembly.html](http://www.nasa.gov/mission_pages/station/structure/iss_assembly.html).

<b>Achievement</b>	<b>ISS Assembly Mission</b>	<b>Spacecraft</b>	<b>Launch Date</b>
<b><u>S0-Truss</u></b> and the <b><u>Mobile Transporter</u></b> - gives extra mobility to the Canadarm2.	8A	Space Shuttle Atlantis	April 8, 2002
<b><u>Mobile Base System</u></b> - completing the <b><u>Mobile Servicing System</u></b> .	UF-2	Space Shuttle Endeavour	June 5, 2002
<b><u>Harmony Node 2</u></b>	10A	Space Shuttle Discovery	October 23, 2007
European Space Agency's <b><u>Columbus laboratory</u></b>	1E	Space Shuttle Atlantis	February 7, 2008
<b><u>Experiment Logistics Module</u></b> - first pressurized component of the Japanese Kibo laboratory. <b><u>Dextre</u></b> - a Canadian robotic device	1J/A	Space Shuttle Endeavour	March 11, 2008
<b><u>Pressurized Module</u></b> and robotic arm of the Japanese Kibo laboratory	1J	Space Shuttle Discovery	May 31, 2008
<b><u>Starboard 6 (S6)</u></b> - final major U.S. truss segment and its final pair of power-generating solar array wings	15A	Space Shuttle Discovery	March 15, 2009
<b><u>Kibo Japanese Experiment Module Exposed Facility and Experiment Logistics Module Exposed Section</u></b> - "front porch" for experiments in the exposed environment and a robotic arm attached to the Kibo Pressurized Module.	2J/A	Space Shuttle Endeavour	July 15, 2009
<b><u>Lightweight Multi-Purpose Experiment Support Structure Carrier</u></b>	17A	Space Shuttle Discovery	August 28, 2009
<b><u>Mini-Research Module-2 (MRM2)</u></b> - serves as an additional docking port for Russian vehicles, as an airlock for Russian-based spacewalks and as a platform for external science experiments.	5R	Soyuz booster rocket	November 10, 2009



<b>Achievement</b>	<b>ISS Assembly Mission</b>	<b>Spacecraft</b>	<b>Launch Date</b>
<b><u>Node 3, named Tranquility</u></b> - pressurized module that provides room for many of the life support systems	20A	Space Shuttle Endeavour	February 8, 2010
<b><u>Integrated Cargo Carrier and the Russian-built Mini-Research Module-1 (MRM1)</u></b> - provides cargo storage and an additional docking port to the station.	ULF4	Space Shuttle Atlantis	May 14, 2010
<b><u>Permanent Multipurpose Module Leonardo and the EXPRESS Logistics Carrier 4</u></b> as well as <b><u>Robonaut 2</u></b> , a human upper torso-like robot that could be a precursor of devices to help during spacewalks.	ULF5	Space Shuttle Discovery	February 24, 2011

But with each new U.S. president, there was anticipation and anxiety over what the new administration's space policy concerning the ISS would be, specifically for the international partners. On January 14, 2004, President George Bush introduced his Vision for Space Exploration (VSE). With this vision, there would have to be a new cooperative approach to human space exploration in order to pursue "the Moon, Mars, and beyond."<sup>103</sup> Once again, funding became a concern, for the station already had a tight budget and now would have to compete with President Bush's vision.<sup>104</sup> There was fear that the ISS would become victim to the new priority of the human spaceflight vision. According to Johnson-Freese, the money would "come through retiring the shuttle in 2010 and limiting ISS use to only tasks related to returning to the moon, freeing up money previously planned for those programs."<sup>105</sup> On the other hand, this vision was

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<sup>103</sup> Alain Dupas and John M. Logsdon, "Creating a productive international partnership in the Vision for Space Exploration," *Space Policy* 23, no. 1 (February 2007), 24.

<sup>104</sup> Johnson-Freese, *Space as a Strategic*, 183.

<sup>105</sup> *Ibid.*, 73.

also met with some jealousy from other space agencies that once again human spaceflight had jumped to the forefront of the U.S. president's agenda.<sup>106</sup>

At the end of 2005, the international players in the ISS no longer had to fear when the budget decision was finally made to complete assembly on the ISS before retiring the space shuttle in 2010, therefore maintaining the U.S. commitment to the project.<sup>107</sup> But, in 2006, the ISS assembly plan was significantly reduced to 16 flights and revised to stop the conduct of research on the ISS after 2016. The international partners, specifically Russia and Japan, made it clear that they wished to operate the ISS facilities well after 2016. In January 2009, there was the worry again that a new president and administration might once again amend the ISS assembly and usage plan significantly.<sup>108</sup>

As a presidential candidate, Barack Obama's ideas about space policy appeared to change drastically, perhaps reflecting his own steep learning curve on the subject. Originally, in November 2007, Obama's plan was to cut NASA's budget over the next five years in order to fund his early education initiative.<sup>109</sup> This led to questions about the future of NASA's Constellation program or the continued use of the ISS if Obama were to win the election. In 2008, Obama published a white paper to clarify his space policy entitled "Advancing the Frontiers of Space Exploration."<sup>110</sup> In this paper, he announced his "goal of sending human missions to the Moon by 2020, as a precursor in an orderly progression to missions to more distant destinations, including Mars."<sup>111</sup> In addition, the paper also included accelerating the shuttle's successor and completing the ISS with the potential of use beyond 2016.<sup>112</sup> Now the only question became, if Obama was elected president, would he implement this policy?

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<sup>106</sup> Dupas and Logsdon, "Creating a productive," 24.

<sup>107</sup> National Aeronautics and Space Administration, *The Vision for Space Exploration* (Washington, DC: NASA Headquarters, February 2004), [http://www.nasa.gov/pdf/55583main\\_vision\\_space\\_exploration2.pdf](http://www.nasa.gov/pdf/55583main_vision_space_exploration2.pdf).

<sup>108</sup> Dupas and Logsdon, "Creating a productive," 25.

<sup>109</sup> Jeff Foust, "Space and the New Administration," *Ad Astra* 21, no. 1 (Spring 2009), 36.

<sup>110</sup> Obama for America, "Advancing the Frontiers of Space Exploration," August 15, 2008.

<sup>111</sup> *Ibid.*

<sup>112</sup> *Ibid.*

President Obama commissioned Norman Augustine, former Lockheed Martin CEO and Chairman, to lead a committee of space experts in the spring of 2009 to research viable options for the path ahead in the human spaceflight program. The commission was entitled “Review of U.S. Human Spaceflight Plans Committee,” but was commonly known as the Augustine Commission.<sup>113</sup> While waiting for the Augustine Report, the debate still continued on whether the Constellation Program—with Ares 1 and 5 along with Orion—or an expendable shuttle-derived rocket would be the shuttle’s replacement.<sup>114</sup> Either way, it was speculated that the technology was here but the political will or “economic vitality” was debatable.<sup>115</sup> Augustine said “I think money probably is going to be the deciding factor of what one can afford to do—more so than technology.”<sup>116</sup>

In October 2009, the Augustine Report was published, giving five options for the way ahead. These options are summarized in Table 3.

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<sup>113</sup> Norman R. Augustine, Wanda M. Austin, Christopher Chyba, Charles F. Kennel, Bohdan I. Bejmuk, Edward F. Crawley, Lester L. Lyles, Leroy Chiao, Jeff Greason, and Sally K. Ride, “Seeking A Human Spaceflight Program Worthy of A Great Nation,” *Review of U.S. Human Spaceflight Plans Committee* (Washington, DC: White House Office of Science and Technology Policy, October 2009).

<sup>114</sup> Joseph C. Anselmo, “Plan B,” *Aviation Week & Space Technology* 171, no. 3 (July 20, 2009), 31.

<sup>115</sup> John F. Kross, “Charting the Path Ahead,” *Ad Astra* 21, no. 3 (Fall 2009), 24.

<sup>116</sup> Anselmo, “Plan B,” 31.

Table 3. A Summary of the Integrated Options Evaluated by the Augustine Committee<sup>117</sup>

	Budget	Shuttle Life	ISS Life	Heavy Launch	Crew to LEO
<b>Constrained Options</b>					
<b>Option 1: Program of Record (constrained)</b>	FY10 Budget	2011	2015	Ares V	Ares I + Orion
<b>Option 2: ISS + Lunar (constrained)</b>	FY10 Budget	2011	2020	Ares V Lite	Commercial
<b>Moon First Options</b>					
<b>Option 3: Baseline - Program of Record</b>	Less constrained	2011	2015	Ares V	Ares I + Orion
<b>Option 4A: Moon First - Ares Lite</b>	Less constrained	2011	2020	Ares V Lite	Commercial
<b>Option 4B: Moon First - Extend Shuttle</b>	Less constrained	2015	2020	Directly Shuttle Derived + refueling	Commercial
<b>Flexible Path Options</b>					
<b>Option 5A: Flexible Path - Ares Lite</b>	Less constrained	2011	2020	Ares V Lite	Commercial
<b>Option 5B: Flexible Path - EELV Heritage</b>	Less constrained	2011	2020	75mt EELV + refueling	Commercial
<b>Option 5C: Flexible Path - Shuttle Derived</b>	Less constrained	2011	2020	Directly Shuttle Derived + refueling	Commercial

The first two options presented were within the constraints that President Obama had given the committee in the Fiscal Year (FY) 2010 Budget. Sally Ride, a member of the committee, said: “This budget is just simply not friendly to exploration (...). It’s very difficult to find an exploration scenario that actually fits within this very restrictive budget guidance.”<sup>118</sup> Therefore, the committee came up with the remaining three options with fewer constraints. It appeared the committee was leaning toward Option 5, the Flexible Plan. This plan would include NASA working more with other nations and U.S. commercial assets.<sup>119</sup> Augustine stated “We very much like the deep space option (...). It’s...doable and viable.”<sup>120</sup> The conclusion of the report indicated that if the human space program had more stringent budgetary constraints, then the U.S. would have to set lower, less grand goals with the potential of losing its lead in space. The report also

<sup>117</sup> Augustine et al., “Seeking A Human,” 14.

<sup>118</sup> Kross, “Charting the Path,” 26.

<sup>119</sup> Augustine et al., “Seeking A Human,” 14.

<sup>120</sup> Kross, “Charting the Path,” 27.

indicated that NASA needed to be able to manage itself and get back to the reason it was created: technological developments and research in new concepts instead of being “its own supplier.”<sup>121</sup>

A few months after the Augustine Report, President Obama’s FY 2011 budget cancelled the Constellation Program.<sup>122</sup> The Russians publicly backed Obama’s cancellation of the Constellation, as he committed the United States to operate the ISS through 2020, paying for it partly through savings from the Constellation program.<sup>123</sup> Constellation was officially terminated on June 10, 2011.<sup>124</sup>

Instead of the moon, President Obama has set his sights on sending human space exploration farther into the inner solar system and to asteroids.<sup>125</sup> His “bold” new space policy indicated the need for international cooperation “more than ever” and focuses on “tapping” commercial industry.<sup>126</sup> The extended U.S. commitment to the ISS, the Constellation program’s cut, and the space shuttle’s last flight on July 8, 2011 have made international cooperation even more crucial, with the sole means of getting to the ISS now being Russian rockets.

### C. ADVANTAGES

The motives behind international collaboration on the ISS highlight the advantages of cooperation. This was a political decision and a positive sign of U.S. interest in further human space exploration becoming a *global* undertaking.<sup>127</sup> Each

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<sup>121</sup> Augustine et al., “Seeking A Human,” 113–115.

<sup>122</sup> Joel Achenbach, “Obama’s new NASA strategy criticized; Aerospace community worried about future of manned space program,” *The Washington Post*, March 10, 2010.

<sup>123</sup> Interfax, “Russian official backs Obama’s axing of Moon flight project,” *Military News Agency*, February 2, 2010, 1.

<sup>124</sup> Frank Moring Jr., “Spaceflight, Interrupted” *Aviation Week & Space Technology* 173, no. 26 (July 18, 2011), 68.

<sup>125</sup> Robert Block and Mark K. Matthews, “Obama aims to ax moon mission,” *Orlando Sentinel*, January 27, 2010.

<sup>126</sup> Amy Butler, “Space for Change,” *Aviation Week & Space Technology* 172, no. 25 (July 5, 2010), 20.

<sup>127</sup> Dupas and Logsdon, “Creating a productive,” 26.

country deemed this field of science as worthy of pursuing as well as saw the potential for important technological development in industry.<sup>128</sup>

Cooperation on the ISS can be seen as a means of closing gaps between nations. This project serves U.S. foreign policy and enhances relations by working together on an enormous challenge. Specifically, the Clinton administration linked its foreign policy goals of nonproliferation to having Russia join the project. The political decision to cooperate can be broken down into two advantages. First, by cooperating, the U.S. created a positive image in the international arena. Along similar lines, secondly, it strengthened the perception of U.S. openness to outside nations.<sup>129</sup>

By pooling efforts, there would be savings on both human resources and financial means needed to tackle such a project.<sup>130</sup> In seeking international cooperation, the U.S. expanded the investment for the ISS beyond that committed by one country alone. The international investment also improved the balance of trade.<sup>131</sup> Financial contributions from international partners not only enhanced the scope of the station but also increased support with the U.S. administration and Congress.<sup>132</sup> As far as overall monetary costs, cooperation typically increases the total cost. According to Johnson-Freese:

A rule of thumb is that overall cost increases by about one-third due to management and interface expenses. Communication channels must be established; technical and legal teams assembled and exchanged, often for prolonged periods (all of the ISS partners have long had offices at Johnson Space Center); and hardware built to specifications compatible with other hardware, and transported. However, cooperative programs should also have greater capabilities, because more partners are contributing and the cost to individual countries to access those capabilities will be proportionally less.<sup>133</sup>

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<sup>128</sup> Launius, "United States Space," 91.

<sup>129</sup> *Ibid.*, 93–94.

<sup>130</sup> *Ibid.*, 91.

<sup>131</sup> *Ibid.*, 94.

<sup>132</sup> Logsdon, *Together in Orbit*, 10.

<sup>133</sup> Johnson-Freese, *Space as a Strategic*, 64.

The estimated financial contributions of each country to the ISS as of 2010 are listed in Table 4.

Table 4. Space Station Total Costs as of 2010<sup>134</sup>

Country	Cost (in billions of \$US)	Percent
U.S.	72	84
Russia	12	8
Europe	5	3.3
Japan	5	3.3
Canada	2	1.3

This puts the total cost for the ISS at \$100 billion in 2010. The above amounts do not include the shuttle or other launch costs. It is estimated that each shuttle launch costs roughly \$1.5 billion each.<sup>135</sup> According to the NASA website, as of June 2013, there have been 89 Russian launches, 37 Space Shuttle launches, 3 Japanese HTVs, and 3 European ATVs supplying the ISS.<sup>136</sup> However, when analyzing the cost-benefit analysis of the ISS, non-market valuation needs to be considered. According to Seth D. Baum, “Non-market valuation is thus, in a sense, a means of quantifying seemingly qualitative values.”<sup>137</sup> As Eligar Sadeh summarizes, “The symbolic dimension, which

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<sup>134</sup> Claude Lafleur, “Piloted Program Costs,” *Spacecraft Encyclopedia*, 2010, <http://claudelafleur.qc.ca/Programcosts.html>.

<sup>135</sup> *Ibid.*

<sup>136</sup> National Aeronautics and Space Administration, “International Space Station - Facts and Figures,” accessed November 11, 2012, [http://www.nasa.gov/mission\\_pages/station/main/onthestation/facts\\_and\\_figures.html#UigFpj\\_W3fc](http://www.nasa.gov/mission_pages/station/main/onthestation/facts_and_figures.html#UigFpj_W3fc).

<sup>137</sup> Seth D. Baum, “Cost–benefit analysis of space exploration: Some ethical considerations,” *Space Policy* 25, no. 2 (May 2009), 76.

includes prestige, legitimacy, influence and international accountability, frames the nature of the cooperation realized for the ISS program.”<sup>138</sup>

Repetition in technological research, once a disadvantage for competing countries, is now an advantage in cooperation. There is an intellectual effort applied in scientific and technological objectives across the spectrum of the partners, increasing the chance of reaching an answer in less time. Instead of duplicating experiments in space, international scientists can develop different but complementary ones. These complementary experiments and objectives ensure that the international partners are contributing to a single goal.<sup>139</sup> Also, allowing each country to provide technology in areas of its greatest experience and expertise led to a more rational division of station components and requirements. For example, the Canadians in robotics and the Russians in long-duration spaceflight.

#### **D. DISADVANTAGES**

The main overarching problem with the cooperation on the ISS was that it was not an even playing field for all involved. The U.S. had a dominant role in the program and therefore the other partners had to be dependent on the U.S. This is evident in the decision to include Russia as a partner in the space station with little to no consult from Europe, Canada and Japan. With Russia and the U.S. in the senior role, the other countries had to settle for a junior position. Now there is the sole dependence on the Russians as far as getting to and from the ISS since the retirement on the U.S. space shuttle. Sole dependence on one country or another is not a goal that countries enter into lightly and requires trust on all sides.<sup>140</sup>

From the start, there was the fundamental question related to space station cooperation of the nature of the partnership.<sup>141</sup> The U.S. basic design had itself as the

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<sup>138</sup> Eligar Sadeh, “Technical, organizational and political dynamics of the International Space Station program,” *Space Policy* 20, no. 3 (August 2004), 171.

<sup>139</sup> Launius, “United States Space,” 94.

<sup>140</sup> Johnson-Freese, *Space as a Strategic*, 184.

<sup>141</sup> Logsdon, “International cooperation,” 39.



dominant financial and technical contributor.<sup>142</sup> The wording of the IGA supported this authority: “the United States, acting through NASA, shall also be responsible for overall program coordination and direction of the Space Station...[and] shall be responsible for overall system engineering and integration...[and] shall also be responsible for overall planning for and direction of the day-to-day operation of the manned base....”<sup>143</sup> With this basic design, there was concern from both NASA and its international partners about maintaining the support that was needed to make this a successful venture, both politically and financially.<sup>144</sup>

## **E. LESSONS LEARNED**

The ISS became an international program from the onset because of the scientific, technological, and financial challenges of building such a space station could only be assured success by pooling resources of other spacefaring nations.<sup>145</sup> With such a monumental venture, the international cooperation on this program could set the stage for all future cooperation in space. If it were to fail, the consequences would be disastrous and more than likely the partners would not be willing to cooperate with the U.S. in major scientific projects for a while.<sup>146</sup> Due to this, the actors trod the ground lightly and many lessons were learned along the way.

Despite its sometimes uncompromising attitude, the U.S. invitation to work with others on the ISS alleviated fears from other countries about the U.S. possibly monopolizing space.<sup>147</sup> However, the other participants were not as keen with the U.S. being a dominant partner. There was concern of the stability of the program relying on one dominant partner being able to deliver what they promised at the risk of failure of the whole program. If the program had troubles, just having international commitment

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<sup>142</sup> Logsdon, *Together in Orbit*, 2.

<sup>143</sup> Logsdon, “International cooperation,” 39.

<sup>144</sup> *Ibid.*, 44.

<sup>145</sup> Logsdon, *Together in Orbit*, i.

<sup>146</sup> Logsdon, “International cooperation,” 44.

<sup>147</sup> Johnson-Freese, *Space as a Strategic*, 249.

would not be able to sustain it.<sup>148</sup> This initial problem could be fixed in the future by bringing in equal partners early, with the key word here being equal.<sup>149</sup> With the ISS, other countries were invited at a much earlier stage of the program than in the past and influenced NASA's choices and understanding of the options related to their participation, but they were still treated as junior partners.<sup>150</sup>

Another lesson learned comes from the desire of potential partners for a more specific and certain path for the future. A realistic analysis to sustain the partnership is required more than wishful thinking.<sup>151</sup> This requires implementing structural mechanisms that are acceptable to all, specifically in the areas of a realistic timeline and not having to compete with other programs later on.<sup>152-153</sup> As far as timelines, the U.S. focus needs to change and be more practical with shorter-term elements, based on a more concrete long-term plan.<sup>154</sup> This venture was started in 1984 and, today, small adjustments are still being made.

## **F. CONCLUSION**

International cooperation in the field of human space exploration was not a new concept with the ISS. The 1958 Space Act had the U.S. civilian space program, NASA, include international cooperation as its inception.<sup>155</sup> However, with the ISS as the largest technical cooperation program yet, this was going to be more like a marathon than a sprint.<sup>156</sup>

As with all major undertakings, whether cooperative in nature or not, there are advantages, disadvantages, and lessons learned. This major space undertaking was being

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<sup>148</sup> Logsdon, "International cooperation," 45.

<sup>149</sup> Johnson-Freese, *Space as a Strategic*, 252.

<sup>150</sup> Logsdon, *Together in Orbit*, 8.

<sup>151</sup> Logsdon, "International cooperation," 44.

<sup>152</sup> Dupas and Logsdon, "Creating a productive," 27.

<sup>153</sup> Johnson-Freese, *Space as a Strategic*, 249.

<sup>154</sup> Dupas and Logsdon, "Creating a productive," 27.

<sup>155</sup> Logsdon, *Together in Orbit*, 1-3.

<sup>156</sup> Dupas and Logsdon, "Creating a productive," 24.

used as a tool of U.S. policy and was not an easy task at that with the objective of a stable, congruent space station partnership.<sup>157</sup> The ability shown to modify the ISS partnership in order to put it on a stable and sustainable path to success was a critical test to pass in order to proceed ahead.<sup>158</sup> However, the addition of the Russians to the ISS partnership was a decision made by the U.S. unilaterally.

Roger D. Launius of the National Air and Space Museum writes about U.S. cooperation in space activities: “if one were to characterize it accurately throughout the last fifty-plus years, the undeniable conclusion is that all parties have enjoyed an uneasy relationship in which they have recognized that they were better off cooperating rather than competing and in which they constantly jockeyed, even while cooperating, for a superior position.”<sup>159</sup> So what are the next steps in the human space exploration and what are the capabilities of other spacefaring countries?

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<sup>157</sup> Logsdon, *Together in Orbit*, 2.

<sup>158</sup> Logsdon, “International cooperation,” 45.

<sup>159</sup> Launius, “United States Space,” 89.

## IV. INTERNATIONAL HUMAN SPACEFLIGHT PROGRAMS

### A. INTRODUCTION

The reasons why countries embark on a human space program fall mainly into three categories: political, technological, and economic benefits. According to David Mindell, Scott Uebelhart, Asif Siddiqi, and Slava Gerovitch, “Human spaceflight translates into a symbol of technological advantage, which brings real economic dividends, and those, in turn, translate into greater political influence.”<sup>160</sup> However, Handberg and Li state that “up to this point in history, human spaceflight has not been militarily or economically relevant...The true political value of space does not come from the successful launch of humans but from the political and other implications drawn from that act.”<sup>161</sup> Handberg and Li continue that “political considerations must significantly outweigh the economic and scientific benefits.”<sup>162</sup> There is also the prestige that is associated with the feat.

Russia, China, Europe (as part of ESA), Japan and India have embarked on various feats of human spaceflight, in part for the above reasons. In order to rationalize whether competition or cooperation is the best way forward for human exploration of space, an analysis of these countries’ human spaceflight experience, capabilities, and future plans is provided in this chapter. Their programs are summarized below with respect to human spaceflight as well as areas that could potentially be used for such activities in the future.

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<sup>160</sup> David A. Mindell, Scott A. Uebelhart, Asif A. Siddiqi, and Slava Gerovitch, *The Future of Human Spaceflight: Objectives and Policy Implications in a Global Context* (Cambridge, MA: American Academy of Arts and Sciences, 2009), 28.

<sup>161</sup> Rodger Handberg and Zhen Li, *Chinese Space Policy: A Study in Domestic and International Politics* (New York: Routledge, 2012), 5.

<sup>162</sup> *Ibid.*, 47.

## B. CAPABILITIES OF OTHER COUNTRIES

### 1. Russia

With many firsts in human spaceflight—including the first man in space, the first woman in space, the first extravehicular activity (EVA), and the first space station—the Russians are a definitive force in this field.<sup>163</sup><sup>164</sup> Due to this long legacy, the Russians have a vast amount of human spaceflight experience.

#### a. *Human Spaceflight Experience*

Early Soviet human spaceflight during the 1960s and their experience with the ISS are not described here as they were previously described in chapters 2 and 3, respectively.

With the U.S. success in their Apollo program, the Soviets started looking into options for an appropriate response. A piloted mission to Mars, an extended mission on the moon and an Earth orbiting space station were the three options the Soviets came up with in 1969. According to Asif Siddiqi, “the space station program seems to have offered the quickest return.”<sup>165</sup> April 19, 1971, marked the beginning of the Soviet/Russia’s space station era. Seven different space stations, falling into three different generations, marked the next 30 years of their human spaceflight experience.

The first generation of working space stations was called *Salyut*. The first five *Salyuts* are categorized into two types. The Long-Duration Orbital Station (DOS) was equipped with systems and electronics from *Soyuz*. DOS was considered the “civilian” version, as it was operated by a civilian crew at a higher altitude. *Salyut 1* and *4* fell into this category. *Salyut 1* became the first occupied space station in June 1971 for 24 days by the crew of *Soyuz 11*.<sup>166</sup> Unfortunately, the crew died upon reentry due to depressurization of their capsule. At the time, the three-person crew was not wearing

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<sup>163</sup> Marcia S. Smith, *Space Activities of the United States, Soviet Union, and Other Launching Countries/Organizations, 1957-1993*, CRS Report 94-347 (Washington, DC: Library of Congress, Congressional Research Service, March 29, 1994), 131.

<sup>164</sup> Burleson, *Space Programs*, 224.

<sup>165</sup> Asif Siddiqi, *The Soviet Space Race with Apollo* (FL: University Press of Florida, 2003), 713–714.

<sup>166</sup> Smith, *Space Activities*, 23–24.

spacesuits. As a result of this accident, only two cosmonauts wearing spacesuits would be launched in this model of *Soyuz*.<sup>167</sup> *Salyut 4* was launched Dec 26, 1974. Two different crews would occupy this station for a total of 93 days.<sup>168</sup> According to Asif Siddiqi, “officials decided that the goal of each mission would be to dock with the station and ‘revive’ its systems, any decision on duration would be made during a particular flight.”<sup>169</sup>

*Salyut 2*, *3* and *5* fall into the “military” version of this first-generation space station. They had a lower orbit and an all-military crew. This version was called the Orbital Piloted Station (OPS) *Almaz*.<sup>170</sup> The *Almaz* was actually the Russians’ first attempt at a space station, but it fell behind schedule. The DOS version was a combination of the *Almaz* hull and the equipment from *Soyuz*. This combination allowed the DOS version, *Salyut 1*, to achieve operation three years before an *Almaz* version.<sup>171</sup> *Salyut 2* broke apart and was therefore never occupied. *Salyut 3* reached orbit in June 1974 with only one successful crew docking.<sup>172</sup> *Salyut 5* had two successful crews occupy it for 64 days.

The DOS version of *Salyut* became the example for all future Soviet space station designs. *Salyut 6* and *7* used an improved version of DOS and are considered second-generation space stations. The improvements could sustain life for six months instead of the previous one month.<sup>173</sup> Other improvements included two docking ports instead of one. *Salyut 6* was launched on September 29, 1977. The first in flight fuel transfer occurred with *Salyut 6* from an automated expendable cargo spacecraft called Progress in 1978.<sup>174</sup> *Salyut 6* was in orbit for 4.5 years with 16 different crews, which included guest cosmonauts from Poland, East Germany, Hungary, Vietnam, Cuba,

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<sup>167</sup> Burleson, *Space Programs*, 238.

<sup>168</sup> Smith, *Space Activities*, 24.

<sup>169</sup> Siddiqi, *The Soviet Space*, 776.

<sup>170</sup> *Ibid.*, 24–25.

<sup>171</sup> Burleson, *Space Programs*, 239.

<sup>172</sup> Smith, *Space Activities*, 24.

<sup>173</sup> Burleson, *Space Programs*, 239.

<sup>174</sup> Smith, *Space Activities*, 25.

Mongolia, and Romania.<sup>175</sup> It was occupied about half of the time it was in orbit, with the longest duration being 185 days. *Salyut 6* became a modular space station in June 1981. *Cosmos 1267*, a module with life support equipment, docked with *Salyut 6* until they were both deorbited on July 29, 1982.<sup>176</sup>

*Salyut 7* was launched April 19, 1982, and hosted 10 crews until 1986. The crews had cosmonauts from France, India, and the second Soviet female cosmonaut.<sup>177</sup> The longest duration was 237 days. *Salyut 7* had an improved navigation system and two docked modules, *Cosmos 1443* and *1686*.<sup>178</sup> According to Asif Siddiqi,

Engineers perfected the very first refueling operations in space, mastered the logistics of having two ships dock to the same station, directed complex repair spacewalks outside the station, managed real-time solutions to contingencies in space, and accumulated a wealth of ground-breaking information on the effects of microgravity on the human organism.<sup>179</sup>

All the knowledge garnered from *Salyut* was applied to the third-generation Soviet space station. It was launched on February 20, 1986, and was called *Mir* (peace or world in Russian). *Mir* became the first permanent residence in space being continuously occupied from 1986 to August 1999. This new system had six docking ports and a *Salyut 5B* digital flight control computer. Although, when it was originally launched, the digital computer was not ready, so the old analogue system was used. Additionally, it was overweight when launched and had to be put in a 51.6 degree inclination instead of the desired 65 degrees, which would have allowed for more coverage over Russia.<sup>180</sup>

The final *Mir* configuration contained the original core plus five modules in a “T” shape. The modules were for scientific equipment and private sleeping quarters,

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<sup>175</sup> Burleson, *Space Programs*, 239.

<sup>176</sup> Smith, *Space Activities*, 25–26.

<sup>177</sup> Burleson, *Space Programs*, 240.

<sup>178</sup> Smith, *Space Activities*, 26.

<sup>179</sup> Siddiqi, *The Soviet Space*, 839.

<sup>180</sup> Burleson, *Space Programs*, 265–266.

something the cosmonauts requested after time on *Salyut*. *Kvant-1* was the first module added and was an astronomical observatory. In the winter of 1989, *Kvant-2* was added as the air lock module. *Kristall* was added in June 1990 as a materials processing research module and docking port for the U.S. shuttle.<sup>181</sup> *Spektr* and *Priroda* were the other two modules, sent up in 1995 and 1996.<sup>182</sup> In early 1990, a self-contained backpack started to be used during EVAs. This allowed the cosmonauts to no longer have to be attached by an umbilical.<sup>183</sup> During its 15 years in orbit, *Mir* was visited by over 100 cosmonauts and astronauts until it re-entered the atmosphere on March 23, 2001.<sup>184</sup> Asif Siddiqi described the de-orbit of *Mir* as: “That singular event will probably mean the end of an independent Russian piloted space program - the end of the journey that Yuriy Alekseyevich Gagarin began in 1961. It will be the beginning of a new and perhaps more exciting voyage.”<sup>185</sup>

**b. Facilities, Launch Sites, and Vehicles**

Beginning in 1960, the now-named Yuri Gagarin Cosmonaut Training Center (GCTC) at Star City has trained not only Russian cosmonauts,<sup>186</sup> but also over 90 international crew members, from over 30 different countries.<sup>187</sup> The center has *Soyuz* and *Mir* simulators, buoyancy lab for EVAs to simulate micro-gravity, centrifuges for G-loads and survival training.<sup>188</sup> Russian-language study is also offered, as well as New England-style houses for the NASA astronauts.<sup>189</sup>

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<sup>181</sup> Smith, *Space Activities*, 28–31.

<sup>182</sup> Burleson, *Space Programs*, 265.

<sup>183</sup> Smith, *Space Activities*, 31.

<sup>184</sup> Burleson, *Space Programs*, 267.

<sup>185</sup> Siddiqi, *The Soviet Space*, 840.

<sup>186</sup> *Ibid.*, 254.

<sup>187</sup> Yu.A. Gagarin Research & Test Cosmonaut Training Center, “Cosmonauts’ training at the Center,” accessed June 21, 2013, <http://www.gctc.su/main.php?id=117>.

<sup>188</sup> Burleson, *Space Programs*, 254.

<sup>189</sup> Brian Harvey, *Russia in Space: The Failed Frontier?* (Chichester, United Kingdom: Praxis, 2001), 205.



Once training is complete, cosmonauts and astronauts are launched into space at Baikonur Cosmodromes. Baikonur Cosmodrome was built in the 1950s and is located at Tyuratam junction, 186 miles away from Baikonur in a remote, sparsely populated region.<sup>190</sup> Because of its location, it is also referred to as Tyuratam Cosmodrome.<sup>191</sup> Since Gagarin's first flight from Pad 1, Baikonur has been the major site for piloted launches.<sup>192-193</sup> It supports a variety of launch vehicles to include: *Proton-K*, *Rokot*, *Soyuz-U*, *Molniya-M*, *Tsyklon-2* and *Zenit*. Tyuratam is located in Kazakhstan, which became an independent state in 1991. Therefore, the Russians are renting this cosmodrome at \$115 million a year. There have been some problems in the past with this relationship. For example, Kazakhstan banned launches for a few months in 1999 due to two Proton rocket launch accidents.<sup>194</sup> More recently, there have been five major Proton failures since December 2010, with the most recent occurring on July 1, 2013. Kazakhstan has concerns about the effects of the toxic fuels on the local environment and population. The most recent rocket crash carried 600 tons of highly toxic heptyl, amyl and kerosene fuel. Supposedly, the poisonous smoke given off from the burning fuel was partially contained by rain at the site. However, people in the town of Baikonur were told to stay inside with the windows closed.<sup>195</sup> Because of this, the Russians have announced plans for a launch facility in the Russian Far East, which will be discussed in the next section.

The *Soyuz* has been the bedrock of the Russian launch fleet from the early 1960s until present. With the *Soyuz 1* disaster of a failed main parachute deployment resulting in the death of cosmonaut Vladimir Komarov, another manned flight was not tried until 18 months later in October 1968. *Soyuz 4* and *5* demonstrated rendezvous and docking of two manned flights launched a day after each other. There have been a

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<sup>190</sup> Harvey, *Russia in Space*, 244.

<sup>191</sup> Smith, *Space Activities*, 109.

<sup>192</sup> Burleson, *Space Programs*, 244.

<sup>193</sup> Smith, *Space Activities*, 107.

<sup>194</sup> Burleson, *Space Programs*, 243–245.

<sup>195</sup> Clara Moskowitz, "Russian Rocket Crash Details Revealed," *Space.com*, July 2, 2013. <http://www.space.com/21811-russian-rocket-crash-details-revealed.html>.

variety of models and upgrades made to *Soyuz*. The *Soyuz T* model was introduced in 1980, while the *Soyuz TM* model was in 1986. The *Soyuz TMA* model removed the height limitation to act as a lifeboat for the ISS. More than 100 cosmonauts have flown on Soyuz rockets.<sup>196</sup>

**c. Future Plans**

Russia's near future plans include the continued use of the Soyuz. Right now, the Soyuz is the only launch vehicle able to transport crews to and from the ISS. The U.S. agreed to pay \$424 million for six seats to ferry NASA astronauts to and from the ISS through 2016 with return and rescue services until June 2017.<sup>197</sup>

The ambitious future plans for Russia in human spaceflight are documented in the "Federal Space Program of Russia for the period from 2006 to 2015," the "Concept of Russian Human Space Flight Development till 2020" and "Guidelines for the Policy of the Russian Federation in the field of Space-Related Activities until 2020 and beyond."<sup>198-199</sup> These documents outline two main objectives: to explore and utilize the near Earth space as well as to study and explore the moon, Mars, and deep space. The purpose of these two objectives are to "resolve global problems on the Earth and in space and to generate new knowledge for the benefit of the humankind."<sup>200</sup>

To meet these objectives, the Russian Federal Space Agency, or Roscosmos, has laid out steps to accomplish them. The first step is to complete the Russian Segment of the ISS by 2015 and then use this full configuration until termination by 2020.<sup>201</sup> The plan is to complete the addition of six modules resulting in a configuration that can act autonomously from the rest of the ISS. The six modules

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<sup>196</sup> Burlison, *Space Programs*, 238.

<sup>197</sup> Mike Wall, "NASA to Pay \$70 Million a Seat to Fly Astronauts on Russian Spacecraft," *Space.com*, April 30, 2013, <http://www.space.com/20897-nasa-russia-astronaut-launches-2017.html>.

<sup>198</sup> Mindell et al., *The Future of Human*, 20.

<sup>199</sup> Russian Federal Space Agency, "ISS Program - International Cooperation," June 17, 2009, [http://www.nasa.gov/pdf/361832main\\_05%20-%20%20Presentation\\_Engl.pdf](http://www.nasa.gov/pdf/361832main_05%20-%20%20Presentation_Engl.pdf).

<sup>200</sup> *Ibid.*

<sup>201</sup> *Ibid.*

include: the Mini Research Module 1 and 2, the Multipurpose Laboratory Module (MLM), the Node Module, and the Research-and-Power Module 1 and 2.<sup>202</sup> The ISS is starting to be prepared for the arrival of the MLM expected the end of this year on a Proton launch. EVAs in June and July 2013 have installed external clamps and extended cables for power and Ethernet to the designated berthing port.<sup>203</sup>

The second step involves the creation of a new crew transportation system.<sup>204</sup> Roscosmos is working with the ESA on this new spacecraft they have called the Advanced Crew Transportation System (ACTS). The draft agreement has Russia building the capsule while ESA constructs the service module and spacecraft engines. The purpose of this new vehicle is for Earth orbit in addition to lunar landings. As of 2009, the cooperation on ACTS has stopped. ESA and Russia are now pursuing their own variants based on ACTs. However, these two agencies are working on biomedical studies for missions to Mars. The first study was conducted in July 2009 when two Europeans and four Russians completed the simulation of a 105-day mission at the Institute for Biomedical Problems in Moscow.<sup>205</sup>

The next step will be to start constructing the orbital assembly experimental piloted space complex before the termination of the use of the ISS,<sup>206</sup> between the years of 2021–2026.<sup>207</sup> The last step of the plan will be the development of all the necessary tools, equipment and biomedical support to actually accomplish the missions to the moon and Mars.<sup>208</sup> They have projected to have a human landing on the moon by 2025. However, their official policy statements say within the next 20 years.<sup>209</sup>

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<sup>202</sup> Mindell et al., *The Future of Human*, 23.

<sup>203</sup> Mark Carreau, "Spacewalk Prepares ISS for Russian Module, Possible Cooling and Power Issues," *Aviation Week & Space Technology*, July 9, 2013, [http://www.aviationweek.com/Article.aspx?id=/article-xml/awx\\_07\\_09\\_2013\\_p0-595354.xml&p=1](http://www.aviationweek.com/Article.aspx?id=/article-xml/awx_07_09_2013_p0-595354.xml&p=1).

<sup>204</sup> Russian Federal Space Agency, "ISS Program."

<sup>205</sup> Mindell et al., *The Future of Human*, 24.

<sup>206</sup> Russian Federal Space Agency, "ISS Program."

<sup>207</sup> Mindell et al., *The Future of Human*, 22.

<sup>208</sup> Russian Federal Space Agency, "ISS Program."

<sup>209</sup> Mindell et al., *The Future of Human*, 4, 22.

One of the stated intentions, once they have set foot on the moon, is to mine for Helium-3.<sup>210</sup>

After landing on the moon, lunar base construction is projected to begin around 2027 to 2032.<sup>211</sup> Since the late 1980s, Russia has made references to a lunar base.<sup>212</sup> The new space vision of Russia focuses heavily on the moon with mention of potentially building a space station around it.<sup>213</sup> This puts human spaceflights to Mars as a goal for approximately 2036 to 2040.<sup>214</sup> Russia made mention of sending humans to Mars as early as 1978. Insight into the areas of logistical support, closed cycle life support systems, space nuclear power and propulsion is expected to be gained from all their space station experience.<sup>215</sup>

Projects currently underway include the construction of a new cosmodrome on Russian soil, Vostochny (or Svobodniy) and a new six-person vehicle launched atop a new rocket called Angara. A decree was signed in November 2007 to build a new launch center. In July 2008, the system design was approved for Vostochny.<sup>216</sup> Construction began in 2011 on this \$20 billion project with a schedule to have it operational by 2018.<sup>217-218</sup> There are also discussions of establishing a Proton launch site in Papua, New Guinea. The Angara rocket is projected to be ready by 2020 with an Advanced Crew Vehicle (ACV).<sup>219</sup>

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<sup>210</sup> Adrian Lee, "Truth Behind the new space race," *Daily Express*, March 24, 2010, <http://www.express.co.uk/posts/view/164815/The-truth-behind-the-new-space-race>.

<sup>211</sup> Mindell et al., *The Future of Human*, 22.

<sup>212</sup> Smith, *Space Activities*, 123.

<sup>213</sup> Space.com, "Russia Aims for Manned Moon Landing by 2030," April 20, 2013, <http://www.space.com/14915-russia-moon-landing-2030.html>.

<sup>214</sup> Mindell et al., *The Future of Human*, 22.

<sup>215</sup> Smith, *Space Activities*, 123, 127.

<sup>216</sup> Yuri Makarov and Dmitry Payson, "Russian space programmes and industry: Defining the new institutions for new conditions," *Space Policy* 25, no. 2 (May 2009), 90.

<sup>217</sup> Space.com, "Russia Aims."

<sup>218</sup> Elizabeth Howell, "Russia Promises Manned Launches from Its Own Soil in 2018," *Space.com*, June 13, 2013, <http://www.space.com/21555-russian-rocket-launch-site-kazakhstan.html>.

<sup>219</sup> Rob Coppinger, "Russia Converts Unmanned Rocket to Carry New Crewed Spaceship," *Space.com*, July 19, 2012, <http://www.space.com/16658-russia-crew-spacecraft-angara-rocket.html>.

The federal government pays for less than two-thirds of the Russian Federal Space Program. This has led to delays in the past.<sup>220</sup> Whether or not this will lead to delays in their current plan may depend on space tourism and further international collaboration.

## 2. China

On October 15, 2003, China became the third country to put a man into space. Similarly motivated as the previous two countries, the core reasons for this feat were international prestige and security by demonstration of military strength.<sup>221</sup> As Joan Johnson-Freese stated, “Manned spaceflight is clearly the ultimate prize in the prestige race for which space has long been a tool.”<sup>222</sup> Initially, political considerations dominated this military declaration of an even more robust technological capability. A more negative image of “look what we can do, don’t mess with us” at the onset has changed into a more positive, implicit show of force such as “look at our rising power and influence.”<sup>223</sup>

Other benefits include the continuous upgrading of technological capabilities needed to accomplish human spaceflight. According to Johnson-Freese, the “US Apollo program provided a prototype for China in pursuing economic and technical growth.”<sup>224</sup> In China’s 2006 White Paper, “China considers the development of its space industry as a strategic way to enhance its economic, scientific, technological and national defense strength.”<sup>225</sup> Using their space program to upgrade their technical sectors allows China to compete on the world market.

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<sup>220</sup> Mindell et al., *The Future of Human*, 21–26.

<sup>221</sup> Handberg and Li, *Chinese Space Policy*, 127.

<sup>222</sup> Joan Johnson-Freese, *The Chinese Space Program: A Mystery Within a Maze* (Malabar, FL: Krieger Publishing, 1998), 98.

<sup>223</sup> Handberg and Li, *Chinese Space Policy*, 134.

<sup>224</sup> *Ibid.*, 133.

<sup>225</sup> 2006 Chinese White Paper, as quoted in James Clay Moltz, *Asia's Space Race: National Motivations, Regional Rivalries, and International Risks* (New York: Columbia University Press, 2012), 99.

China strived to accomplish manned spaceflight independently. In the 1980s, both the U.S. and Russia offered to fly a Chinese person into space. The U.S. had to cancel its invitation due to the *Challenger* accident and nothing came of the Russian invitation.<sup>226</sup> According to Brian Harvey, China wanted the “longer, tougher and more demanding task of becoming the third country to put up its own cosmonauts through its own efforts.”<sup>227</sup>

Like the early USSR space program, secrecy surrounds the Chinese program. Johnson-Freese entitled one of her books *The Chinese Space Program: A Mystery Within a Maze* and notes that “the status of the entire manned program is currently one of the more ambiguous areas of Chinese intent.”<sup>228</sup> Below is a snapshot of what is known of this ambiguous area.

**a. *Human Spaceflight Experience***

Unlike the programs involved in the 1960s space race, the Chinese space program moved cautiously and deliberately with human spaceflight. They perceived that any failure would be public and damaging to their position in the world, especially failure early on which would have “deleterious effects upon the prestige sought by such activities.”<sup>229</sup> As Harvey describes, “They have set about the project in their typical manner: thorough long-term background preparation, the acquisition of experience from other countries, the training of trainers, and the eventual designation of a project code. When they are ready, they will fly.”<sup>230</sup> Johnson-Freese makes a “tortoise and hare” comparison between the Chinese and U.S. paths to putting a man in space: “What China has that the United States lacks—and what may give the Chinese an advantage over the long run—is patience.”<sup>231</sup>

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<sup>226</sup> Handberg and Li, *Chinese Space Policy*, 128.

<sup>227</sup> Brian Harvey, *The Chinese Space Programme: From Conception to Future Capabilities*, (Chichester, United Kingdom: Praxis Publishing, 1998), 147.

<sup>228</sup> Johnson-Freese, *The Chinese Space Program*, 98.

<sup>229</sup> Handberg and Li, *Chinese Space Policy*, 102.

<sup>230</sup> Harvey, *The Chinese Space Programme*, 151.

<sup>231</sup> Joan Johnson-Freese, “Will China overtake America in space?” *CNN*, June 20, 2012, <http://www.cnn.com/2012/06/20/opinion/freese-china-space/index.html?iref=allsearch>.

The Chinese space program can be broken down into ten-year periods with attempts at two distinct human spaceflight programs, one which failed in the Cultural Revolution and the other is ongoing.<sup>232</sup>

In the first ten years, 1956 to 1966, the program was first established. Unfortunately, it was plagued by two events: the Great Leap forward and the withdrawal of Soviet support.<sup>233</sup> Mao Zedong, in January 1956, declared development of science and technology as a national priority. During the 1960s, China broadcast intentions of human spaceflight but missile development and nuclear technology were much higher priorities. However, in 1965, the Chinese Academy of Sciences (CAS) was tasked to develop a long-term space program. The Ten-Year Plan, produced in March 1966, involved three steps to orbit a satellite, recover a satellite, and conduct a manned spacecraft.<sup>234</sup>

The years 1966 to 1976 also represent the period marked by the Cultural Revolution.<sup>235</sup> During this time frame, the first attempt at a human spaceflight program was started under Project 714. On April 1, 1968, the Space Medicine Project Research Institute was stood up to be responsible for training taikonauts, Chinese astronauts, and doing research on manned spaceflight. Project 714 was established July 14, 1970, just a couple months after their first orbiting satellite.<sup>236</sup> By March 1971,<sup>237</sup> the first round of 88 fighter pilots had been whittled down to 19 taikonaut candidates, although they were not informed what they were selected for. They would be trained by the Air Force's Astronauts Training Committee formed on May 15, 1971. It was predicted that training would start in November 1971 for the first crewed launch aboard the *Shuguang-1*, meaning dawn, atop a *Dong Feng 5* missile scheduled in 1973.<sup>238</sup>

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<sup>232</sup> Handberg and Li, *Chinese Space Policy*, 127.

<sup>233</sup> Smith, *Space Activities*, 139.

<sup>234</sup> Handberg and Li, *Chinese Space Policy*, 135.

<sup>235</sup> Smith, *Space Activities*, 139.

<sup>236</sup> Handberg and Li, *Chinese Space Policy*, 135.

<sup>237</sup> Moltz, *Asia's Space*, 80.

<sup>238</sup> Handberg and Li, *Chinese Space Policy*, 135–136.

But the plan was changed abruptly on September 13, 1971, when Lin Biao died mysteriously in a plane crash. His death came after a conflict with Mao about what he saw as his rightful place as the head of state. Due to close ties with Lin, the Astronauts Training Committee was dissolved in mid-November and Project 714 was completely shut down on May 13, 1972. However, the Space Medicine Project Research Institute continued after the original manned program was cancelled.<sup>239</sup>

During the third period, from 1976 to 1986, manned spaceflight was put on the back burner as the country was recovering from the Cultural Revolution and beginning to turn its focus to national economic development.<sup>240</sup> In 1978, Deng Xiaoping said “as far as space technology is concerned, we are not taking part in the space race. There is no need for us to go to the moon and we should concentrate our resources on urgently needed and functional practical satellites.”<sup>241</sup>

From 1986 to present, the Chinese have entered their “heyday” with space as a “cornerstone of the national science and technology development effort.”<sup>242</sup> In 1987, a space committee meeting suggested specific plans for human spaceflight for the early 21st century.<sup>243</sup> President Jiang Zemin was searching for national prestige, similar to the U.S. in the 1960s.

The second and current human spaceflight program was originally created as part of Project 863, the nation’s major technological development program. Project 863-2 was for aerospace technology with 863-204 representing development of a launch vehicle and manned spacecraft.<sup>244</sup> By 1991, the Chinese had decided to go with a three-module manned spacecraft arrangement similar to *Soyuz* with an orbital module capable of operating independently for 180 days.<sup>245</sup>

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<sup>239</sup> Handberg and Li, *Chinese Space Policy*, 73–74, 136.

<sup>240</sup> Smith, *Space Activities*, 139.

<sup>241</sup> Handberg and Li, *Chinese Space Policy*, 92.

<sup>242</sup> Smith, *Space Activities*, 139.

<sup>243</sup> Moltz, *Asia's Space*, 87.

<sup>244</sup> Handberg and Li, *Chinese Space Policy*, 137.

<sup>245</sup> *Ibid.*



On September 21, 1992, Project 921 became the road map for China's human spaceflight program.<sup>246</sup> The initial timeline consisted of the first unmanned spacecraft test launch in 1998, at the earliest. Three successful test flights were called for before the first crewed launch. The first manned launch would be by 2002 with an orbiting space lab by 2007. The final step would be a permanent space station after 2010.<sup>247</sup> The China National Space Administration (CNSA) was created in 1993 to put a civilian facade on the space program; however, most functions still remained in the defense industry.<sup>248</sup>

With a rekindled alliance, on March 25, 1994 a treaty was made with Russia. For a price, the Russians provided an engine, rendezvous system, docking module, *Soyuz* capsule minus equipment, space suit, and personnel training. Two taikonauts stayed at Star City for spaceflight training in order that they could come back and instruct the other taikonauts.<sup>249</sup> According to Tai Ming Cheung, this exchange resulted in "shortening the development cycle of the program and allowing the Chinese to make a generational skip."<sup>250</sup> While this equipment and training were helpful and accelerated the process, the Chinese believe that it probably would not have stopped their progression if it was not obtained.<sup>251</sup>

Project 921 was publicly announced in 1996. The Chinese still maintained control over all information that was reported to ensure that only a positive light was shed on the program.<sup>252</sup> Twelve new taikonauts were selected from the Air Force fighter pilot core.<sup>253</sup> Unlike the U.S. Mercury astronauts, the taikonauts' identities were not initially announced.<sup>254</sup>

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<sup>246</sup> Handberg and Li, *Chinese Space Policy*, 138.

<sup>247</sup> Ibid.

<sup>248</sup> Moltz, *Asia's Space*, 88.

<sup>249</sup> Handberg and Li, *Chinese Space Policy*, 139.

<sup>250</sup> Moltz, *Asia's Space*, 88.

<sup>251</sup> Handberg and Li, *Chinese Space Policy*, 140.

<sup>252</sup> Ibid., 141.

<sup>253</sup> Burleson, *Space Programs*, 59.

<sup>254</sup> Handberg and Li, *Chinese Space Policy*, 141.

Yang Liwei was identified as a taikonaut only on October 15, 2003, when he became the first to be launched into space aboard *Shenzhou 5*. He completed 14 orbits in 21 hours where he just sat in his spacecraft to minimize the chance of something going wrong. China was now the third nation to put a man into space and return him safely to Earth.<sup>255</sup>

Unlike the other two countries that had raced earlier and quickly sought to get additional astronauts/cosmonauts into orbit, China's second manned launch was not for another two years. On October 12, 2005, taikonauts Fei Junlong and Nie Haisheng were launched into orbit aboard *Shenzhou 6*. They moved about the capsule and conducted experiments on their five-day mission. The next crewed mission, *Shenzhou 7*, was projected to coincide with the 2008 Beijing Olympics.<sup>256</sup> But it was launched after the Olympics in October 2008 with three taikonauts aboard.<sup>257</sup> China entered the second phase on Project 921 during *Shenzhou 7*'s flight when a 14-minute EVA was conducted and included the waving of the Chinese flag.<sup>258</sup> The second phase called for advanced orbital operations to include EVA, rendezvous and docking, and a habitable space module.<sup>259</sup>

The habitable space module, *Tiangong 1*, was launched September 29, 2011, aboard a Long March 2F from Jiuquan.<sup>260</sup> A few weeks later, *Shenzhou 8* was launched, unmanned. Its mission consisted of two automatic docking maneuvers.<sup>261</sup> *Shenzhou 9*, launched June 16, 2012, had a crew of two men and China's first female taikonaut. Like her male counterparts, she was also a military pilot, but on transport

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<sup>255</sup> Handberg and Li, *Chinese Space Policy*, 144.

<sup>256</sup> *Ibid.*, 145–146.

<sup>257</sup> Moltz, *Asia's Space*, 93–94.

<sup>258</sup> Mindell et al., *The Future of Human*, 29.

<sup>259</sup> Jane's Space Systems and Industry, "Tiangong series," February 7, 2012.

<sup>260</sup> Bradley Perrett, "On Target," *Aviation Week & Space Technology* 173, no. 39 (November 7, 2011), 32.

<sup>261</sup> Bradley Perrett, "Manual Backup," *Aviation Week & Space Technology* 174, no. 22 (June 25, 2012), 34.

planes.<sup>262</sup> The crew of *Shenzhou 9* achieved the first Chinese manned space docking.<sup>263</sup> Unlike previous missions where the spacecraft was controlled from the ground, the crew of *Shenzhou 9* was given responsibility for controlling their spacecraft. They spent 10 days of their 13-day mission in *Tiangong 1*.<sup>264</sup>

The most recent feat for the Chinese human space program came on June 10, 2013. *Shenzhou 10* launched with a three-person crew to include a second female taikonaut, Wang Yaping. Again, the launch was atop a Long March 2F launched from Jiuquan. During their time in orbit, Wang Yaping gave a lecture to Chinese school children from *Tiangong-1*.<sup>265</sup> After 15 days in orbit, 12 of which they spent on *Tiangong-1*, they returned safely on June 26.

**b. Facilities, Launch Sites, and Vehicles**

As with the rest of the Chinese space program, little is publicly known about their facilities. Unconfirmed reports in 1988 described a manned space training facility in the western suburbs of Beijing with the largest centrifuge in the world. In the summer of 1992, there were rumors of a manned spaceflight center near Jiuquan.<sup>266</sup> What is known is that the Beijing Aerospace Command and Control Center with testing facilities was built in 1993.<sup>267</sup> Also, four Yuan Wang 4 tracking ships are used as tracking stations.<sup>268</sup> Because of these tracking ships, typical launches are during the northern hemisphere autumn and winter due to calmer seas.<sup>269</sup>

There are four launch sites for China: Jiuquan, Taiyuan, Xichang, and Haikou. Jiuquan is the busiest of the four and the only one thus far where manned

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<sup>262</sup> Frank Moring Jr., "Playing Catch-up," *Aviation Week & Space Technology* 171, no. 14 (October 12, 2009), 45.

<sup>263</sup> Johnson-Freese, "Will China overtake?"

<sup>264</sup> Perrett, "Manual Backup," 34.

<sup>265</sup> Wall Street Journal, "Shenzhou 10 Returns to Earth," June 26, 2013, <http://search.proquest.com/docview/1371089011?>

<sup>266</sup> Harvey, *The Chinese Space Programme*, 147.

<sup>267</sup> Handberg and Li, *Chinese Space Policy*, 140.

<sup>268</sup> Ibid.

<sup>269</sup> Burleson, *Space Programs*, 58.

launches have occurred. At the Jiuquan Satellite Launch Center, there is a vehicle assembly building, transporter, and tower for servicing on the pad.<sup>270</sup> Construction began in April 1958 in the Gobi desert of Northern China. The vehicles launched from here include the Long March 1, 2 and Feng-Bao.<sup>271</sup>

The newest site, Haikou, was originally used as a minor launch site for sounding rockets. The original construction began in 1986.<sup>272</sup> Located on Hainan Island off the southern coast of China, the site can be used for low-latitude, low altitude launches over water.<sup>273</sup> Also, due to its location, larger payloads can be launched because of delivery by ship. By 2014, a launch is planned for the larger Long March 5, which will ultimately be used to put the Chinese space station into orbit.<sup>274</sup>

On the first attempt at a manned program in the late 1960s, *Shuguang-1* was the planned capsule. It was designed with two modules, a reentry capsule capable of carrying two people and an equipment module. The landing would have been a hard ballistic landing where the taikonauts would experience up to 10G's during reentry.<sup>275</sup> Although parachutes were planned for the capsule, it was believed that the taikonauts would use their ejection seats in order to bail out before landing. Another speculated option for the landing was using a splashdown similar to the U.S. Gemini program, which *Shuguang-1* was based on.<sup>276</sup> The rocket projected to be used was the Long March 2, but with significant booster upgrades.<sup>277</sup>

The second and current design capsule is a descendant of *Soyuz* called *Shenzhou*. It is made up of three components: an orbital module, reentry capsule, and

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<sup>270</sup> Handberg and Li, *Chinese Space Policy*, 140.

<sup>271</sup> Harvey, *The Chinese Space Programme*, 116.

<sup>272</sup> *Ibid.*, 121.

<sup>273</sup> Burleson, *Space Programs*, 57.

<sup>274</sup> Moltz, *Asia's Space*, 101.

<sup>275</sup> Handberg and Li, *Chinese Space Policy*, 135–136.

<sup>276</sup> Encyclopedia Astronautica, "Shuguang 1," accessed June 29, 2013, <http://www.astronautix.com/craft/shuugang1.htm>.

<sup>277</sup> Handberg and Li, *Chinese Space Policy*, 135–136.

service module.<sup>278</sup> The orbital module will remain in orbit for up to 200 days and has a hatch where the taikonauts can conduct EVAs.<sup>279</sup> An estimated \$2.1 billion, from 1992 to 2003, was spent on this design with half of the money being spent on facilities.<sup>280</sup> *Shenzhou* is built by China Aerospace Science and Technology Corporation (CASC) and is currently launched from Jiuquan.<sup>281</sup>

On November 20, 1999, the *Shenzhou 1* prototype was launched on the Long March 2F. It made 14 orbits with an acceptable landing on November 21. Since the Chinese were not under external “space race” pressure, they sought to get it right, thus avoiding failure and embarrassment, rather than accomplish the feat quickly. Therefore, *Shenzhou 2* didn’t fly until January 19, 2001. Also an unmanned test, *Shenzhou 2* was considered the first of three needed test flights before a manned mission. It made 108 orbits in seven days<sup>282</sup> with a monkey, dog, rabbit, and snails on board. It also maneuvered in orbit three times.<sup>283</sup> Although unmanned, the launch was not wasted, as it also carried 64 experiments. There were assumed problems with the reentry module because China did not release photos.<sup>284</sup> However, the Chinese said that the various animals, plants and seeds that were carried on board were recovered intact.<sup>285</sup> The orbital module stayed up until August 21, 2001.<sup>286</sup>

*Shenzhou 3* was launched March 25, 2002, and was considered the first crew-rated spacecraft although still unmanned. Forty-four experiments along with a dummy crew member aboard *Shenzhou 3* made 107 orbits in seven days.<sup>287</sup> The final

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<sup>278</sup> Handberg and Li, *Chinese Space Policy*, 139.

<sup>279</sup> Burleson, *Space Programs*, 58.

<sup>280</sup> Handberg and Li, *Chinese Space Policy*, 141.

<sup>281</sup> Burleson, *Space Programs*, 58.

<sup>282</sup> Handberg and Li, *Chinese Space Policy*, 142.

<sup>283</sup> Burleson, *Space Programs*, 58–59.

<sup>284</sup> Handberg and Li, *Chinese Space Policy*, 142–143.

<sup>285</sup> Jane’s Space Systems and Industry, “Shenzhou series,” July 23, 2013.

<sup>286</sup> Handberg and Li, *Chinese Space Policy*, 142–143.

<sup>287</sup> Burleson, *Space Programs*, 59.

dress rehearsal was with *Shenzhou 4*, launched December 30, 2002.<sup>288</sup> The 12 taikonaut candidates were there to witness the launch. After seven days and 108 orbits, the reentry capsule returned on January 5.<sup>289</sup> The next launch, *Shenzhou 5*, would have a man on board.

*Tiangong* is China's space laboratory. It consists of a larger experiment/habitat module and a smaller support module. The habitat module consists of work and living quarters with exercise equipment and entertainment system, but no food or toilet facilities. Their *Shenzhou* capsule is used for that. The support module consists of maneuvering thrusters, attitude control, gas and water supplies, and solar arrays. The design life for *Tiangong* is two years.<sup>290</sup>

For China, their series of launch vehicles started as the Dong Feng ballistic missile developed in the 1960s. The Long March, known as the Chang Zheng or CZ series in Chinese, are designed and developed by CASC and its subsidiaries. The Long March 2F is used solely for launches of the *Shenzhou* craft and the *Tiangong* space laboratory. Its first flight was November 20, 1999, with *Shenzhou 1*, and it has had 11 successful flights to date. It is a two-stage rocket with four strap-on boosters. The fuel and oxidizer used are unsymmetrical dimethylhydrazine (UDMH) and nitrogen tetroxide.<sup>291</sup>

### *c. Future Plans*

China currently has the next generations of the Long March under development. The development of the Long March 5 began in 2001 with its first flight now planned for 2014. It will be a heavy-lift rocket launched from Haikou with payloads including space station modules. The Long March 9 is just in the design phase, but is planned to be a super-heavy lift rocket capable of launching taikonauts to the surface of the moon in 2020–2025.<sup>292</sup>

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<sup>288</sup> Handberg and Li, *Chinese Space Policy*, 143.

<sup>289</sup> Burlison, *Space Programs*, 59.

<sup>290</sup> Jane's Space Systems and Industry, "Tiangong series."

<sup>291</sup> Jane's Space Systems and Industry, "Long March (Chang Zheng)," December 27, 2012.

<sup>292</sup> *Ibid.*

In the near future, China desires to be included on the *ISS*. They have repeatedly expressed strong interest in cooperation on the station. The docking mechanism of *Shenzhou* is based on that of *Soyuz* making it possible to dock with the *ISS*. In preparation, taikonauts are learning English and Russian.<sup>293</sup> The success China has had in their human spaceflight program matches their heightened view of deserved international status and thus inclusion into the *ISS*.<sup>294</sup>

The current Chinese human spaceflight program is based on a three-step process. Having achieved the first two steps (manned spacecraft followed by a manned space station similar to *Salyut*), China is working on perfecting the process before moving onto the next step of a space station similar to the *ISS*.<sup>295</sup> *Tiangong* is meant to be a series of three space laboratories.<sup>296</sup> *Tiangong-2* is initially scheduled for launch later on this year and is expected to be larger with more advanced testing. *Tiangong-3* will be larger still with two docking ports and a possible launch by 2015.<sup>297</sup> Four more crews are planned to visit these laboratories.<sup>298</sup>

Part three of the current program includes plans for a 30-ton station by 2022.<sup>299</sup> As previously mentioned, the Long March 5 must be completed and tested before a station of this size is possible.<sup>300</sup> A new round of taikonaut candidates will be needed in the next five years to man this new station. The candidates will include scientists from the civilian sector according to Liu Shujun, the selection-committee member.<sup>301</sup>

After completion of the three-step program, the Chinese aim for the moon but not until completion of *Chang'e*, their robotic lunar exploration program.<sup>302</sup>

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<sup>293</sup> Mindell et al., *The Future of Human*, 33.

<sup>294</sup> Handberg and Li, *Chinese Space Policy*, 6.

<sup>295</sup> *Ibid.*, 117.

<sup>296</sup> Moltz, *Asia's Space*, 105.

<sup>297</sup> Jane's Space Systems and Industry, "Tiangong series."

<sup>298</sup> Mindell et al., *The Future of Human*, 29.

<sup>299</sup> Moltz, *Asia's Space*, 105.

<sup>300</sup> Mindell et al., *The Future of Human*, 30.

<sup>301</sup> Morring Jr., "Playing Catch-up," 47.

<sup>302</sup> Mindell et al., *The Future of Human*, 30.

According to China's 2006 White Paper, "Having made a historic breakthrough in manned spaceflight, China has embarked on a comprehensive lunar exploration project."<sup>303</sup> Although it is known that China plans to put a man on the moon, the projected dates range from possibly by 2024<sup>304</sup> to 2030 or beyond.<sup>305</sup>

Whether China's space future involves more cooperative missions with the U.S. is unknown. According to Handberg and Li, "China by necessity and increasingly by choice chooses to be a solo operator... Cooperation for China, however, will now come as an equal partner or not at all."<sup>306</sup> In November 2009, President Obama and President Hu Jintao made a joint statement of "expanding discussions on space science cooperation and starting a dialogue on human space flight and space exploration." NASA Administrator Charles Bolden visited China in October 2010 to discuss possible cooperation in human spaceflight. A Chinese space scientist, Yi Zhou, stated although "the future is promising... There is no obvious way to jump-start actual cooperation in a short period of time."<sup>307</sup>

### **3. ESA Countries**

Unlike Russia, China, and the U.S., the European Space Agency does not have an independent human spaceflight program. However, like Japan, ESA does have extensive human spaceflight experience obtained by using the U.S. and Russia to access space.<sup>308</sup> Nineteen countries now make up ESA, with France and Germany being the two major contributors.

With the first satellite launches from the Soviets and Americans, Europe was the most publicly concerned about their space "technology gap." ESA has pursued

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<sup>303</sup> Quoted in Moltz, *Asia's Space*, 94.

<sup>304</sup> Moltz, *Asia's Space*, 105.

<sup>305</sup> Handberg and Li, *Chinese Space Policy*, 149.

<sup>306</sup> *Ibid.*, 149.

<sup>307</sup> Quoted in Moltz, *Asia's Space*, 95, 105.

<sup>308</sup> Mindell et al., *The Future of Human*, 41.



independent spaceflight options in the past, but have been hindered by budget uncertainties.<sup>309</sup> ESA invests roughly 25% of its overall budget to human spaceflight.<sup>310</sup>

*a. Human Spaceflight Experience*

The origins of ESA start with the creation of two European organizations: the European Launch Development Organization (ELDO) and the European Space Research Organization (ESRO). Both of these organizations were created in 1964<sup>311</sup> and both seemed to lack direction. The British Trade Minister, Michael Heseltine, became the political leader to force the combination of ELDO and ESRO. He proposed the merger in the summer of 1972.<sup>312</sup>

In January 1973, an initial agreement was made about merging into a single agency. However, the July 12, 1973 conference to formalize the merger ended with disagreement. The conference was rescheduled for July 31, giving the council time to figure out how to get the three major players, France, Germany and Britain, to agree. The solution was three founding projects, one each for the major players: a new launcher led by France, cooperation with the U.S. on *Spacelab* led by Germany, and a Maritime Orbital Test Satellite led by Britain.<sup>313</sup>

Besides the founding projects, ground rules were set for ESA so as not to run into the same problems that hindered ELDO and ESRO. The budget would be set each year by the Minister of Science from each member state. There were two mandatory programs that all participants had to support: general administration and the science budget. A major selling factor was that the states had the ability to opt out of all other programs. They could follow national preferences and decide which programs they would participate in. However, the contracts for each program were awarded based on a country's financial inputs. Although individual countries would be awarded a contract,

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<sup>309</sup> Handberg and Li, *Chinese Space Policy*, 134.

<sup>310</sup> Mindell et al., *The Future of Human*, 41.

<sup>311</sup> Smith, *Space Activities*, 147.

<sup>312</sup> Harvey, *Europe's Space Programme*, 157.

<sup>313</sup> *Ibid.*, 161–162.

each project would be managed by ESA directly or a delegated agency. This created a single management point, a fix to a problem with ELDO.<sup>314</sup> Also, conducting military space programs was prohibited. Initially, only civilian activities were authorized.<sup>315</sup> However, this is no longer a tenet.

ESA was not officially named until early 1975 with the first Director Roy Gibson assuming command on April 16, 1975.<sup>316</sup> ESA membership currently includes: Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Romania, Spain, Sweden, Switzerland and the United Kingdom. Canada, although not a member, has special status.<sup>317-318</sup>

The founding program given to Germany was cooperation with the U.S. on *Spacelab*. In building the space shuttle, NASA exhausted a lot of their budget. Now there was a shuttle with no mission, so the U.S. sought Europe's financial help. Europe originally wanted to build a space tug to boost payloads from the shuttle into a higher orbit. Eventually, the negotiations had Europe building a Research and Applications Module that they called *Spacelab*. The overall outcome fell short of initial expectations.<sup>319</sup>

On August 14, 1973, the agreement was made between NASA and ESA on the *Spacelab* program. Europe would build the *Spacelab* and NASA would launch it. They would share the research space for the first mission as well as have at least one European astronaut on board. Afterwards, NASA would buy a completed *Spacelab* and Europe would have to pay for launch services.<sup>320</sup>

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<sup>314</sup> Harvey, *Europe's Space Programme*, 158, 163.

<sup>315</sup> Smith, *Space Activities*, 147.

<sup>316</sup> Harvey, *Europe's Space Programme*, 164.

<sup>317</sup> Burleson, *Space Programs*, 75.

<sup>318</sup> European Space Agency (ESA), "About Us," accessed July 22, 2013, [http://www.esa.int/About\\_Us/](http://www.esa.int/About_Us/).

<sup>319</sup> Harvey, *Europe's Space Programme*, 269–271.

<sup>320</sup> *Ibid.*, 271–272.

To prepare for *Spacelab*'s first mission, ESA started recruiting their first astronauts in 1974. The ESA astronauts would become payload specialists with generic astronaut training, but the majority of their training time would be spent on familiarization of the experiments to be flown. Each ESA country did its own initial selection process given common guidelines for candidates. By the summer of 1977, 12 countries sent up a total of 53 candidates to ESA for consideration. After extensive medical, psychological, and English proficiency tests, ESA decided on its first four astronauts on December 22, 1978. They were from Italy, Germany, the Netherlands and Switzerland. However, for most of the 1980s, Europe mainly relied on nationally selected astronauts for missions instead of the initial four selected by ESA.<sup>321</sup>

The first European manned flight occurred from November 28 to December 8, 1983 aboard STS-9 *Columbia* with *Spacelab 1*. Ulf Merbold, from Germany, was the chosen astronaut.<sup>322</sup> He also was the first non-American to fly on the shuttle.<sup>323</sup> During the ten-day mission, 72 experiments were conducted. In 1985, *Spacelab 2* and *3* would fly, although *Spacelab 3* ended up flying before *Spacelab 2*. Both missions had European experiments, but no European astronauts.<sup>324</sup>

Three more European astronauts flew from October 30 to November 6, 1985 as a part of the *Spacelab D* mission. This was a dedicated German mission, which flew 75 experiments with two German astronauts and Wubbo Ockels from the Netherlands. Ockels was one of ESA's original four. This shuttle mission was actually controlled from the Operation Control Centre in Oberpfaffenhofen, Germany. After the *Challenger* accident, *Spacelab* was suspended for five years and reduced to 18 more missions. In those remaining 18 missions, Merbold would fly for a second time and five other European astronauts would also get a chance.<sup>325</sup>

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<sup>321</sup> Harvey, *Europe's Space Programme*, 273–274, 287.

<sup>322</sup> *Ibid.*, 249, 274–275.

<sup>323</sup> Smith, *Space Activities*, 151.

<sup>324</sup> Harvey, *Europe's Space Programme*, 275, 277–278, 285–286.

<sup>325</sup> *Ibid.*, 274, 278–279, 281, 284.

ESA came out with a long-range plan for space in 1987. This plan included a new launcher, contributions to the U.S. led space station program, and a reusable space plane. Ariane 5, *Columbus*, and the *Hermes* space plane could have potentially given Europe complete autonomy in space and its own human spaceflight program. Due to financial constraints, particularly from German reunification, by 1993 *Hermes* was cut and *Columbus* was greatly downsized. However, Ariane 5 remained intact.<sup>326</sup>

In the summer 1993, an agreement was reached with Russia for two ESA missions to *Mir*, called *Euromir* missions. Four ESA astronauts were assigned to these missions. They started their training in Star City in August 1993. This training included Russian language studies, spacecraft familiarization, and mission-specific training. With experience from the *Spacelab* missions, Merbold was launched on October 4, 1994, along with two Russian cosmonauts. Merbold conducted 20-minute broadcasts daily to the ESA facilities in Apris, Cologne and the Netherlands.<sup>327</sup>

The second *Euromir* mission was launched on September 3, 1995 with Thomas Reiter as the ESA astronaut. On October 20, he conducted the first ESA's EVA, spending five hours out of the spacecraft. An ESA council meeting was occurring at the same time as the EVA, so Reiter made a broadcast to the meeting. Due to Russian delays, Reiter ended up spending 44 extra days in space, which enabled him to conduct a second spacewalk. He returned to Earth on February 29, 1996, after 179 days in space.<sup>328</sup>

ESA decided to combine their astronauts with the national astronauts on March 26, 1998. This would enable all European astronauts to have the same training and be based out of the European Astronaut Training Centre in Cologne. The plan was to get 16 astronauts by 2000 and then hold selections for new astronauts every two years to replace those who left the program.<sup>329</sup>

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<sup>326</sup> Smith, *Space Activities*, 148.

<sup>327</sup> Harvey, *Europe's Space Programme*, 264–266.

<sup>328</sup> *Ibid.*, 266–268.

<sup>329</sup> *Ibid.*, 288.

As for experience on the ISS, Reiter became the first European to do a complete six month visit to the ISS in 2006.<sup>330</sup> Frank De Winne of Belgium became the first European to command the ISS as part of Expedition 21<sup>331</sup> during his stay on the ISS from May 27 to December 1, 2009.<sup>332</sup>

**b. Facilities, Launch Sites, and Vehicles**

The EAC was created in 1990 in Cologne, Germany.<sup>333</sup> EAC is currently the home to ESA's 14 astronauts. It is organized into four sections: the Astronaut Department, the Astronaut Training Division, the Medical Crew Support Office, and the Management and Support Office.<sup>334</sup> As a part of the facilities, there are a number of spacecraft mock-ups and simulators to include the *Spacelab* simulation facility.<sup>335</sup> Also on the grounds is the largest water tank in Europe for training in EVAs. In addition, to aid in simulating weightlessness, the French Airbus 300 aircraft is used.<sup>336</sup> The "basic training" at the EAC consists of 16 months broken into four training blocks: introduction, fundamentals, space systems and operations, special skills to include learning Russian and spacewalk training in the Neutral Buoyancy Facility, water tank.<sup>337</sup>

Germany also has four major control centers. The European Space Operations Centre (ESOC) in Darmstadt<sup>338</sup>, Germany, was created in 1967 and has been mission control for over 60 satellites.<sup>339</sup> The Operation Control Centre in Oberpfaffenhofen, Germany controlled *Spacelab D*.<sup>340</sup> It is now called the German

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<sup>330</sup> Mindell et al., *The Future of Human*, 43.

<sup>331</sup> *Ibid.*, 43.

<sup>332</sup> European Space Agency (ESA), "Human Spaceflight," accessed July 22, 2013, [http://www.esa.int/Our\\_Activities/Human\\_Spaceflight/](http://www.esa.int/Our_Activities/Human_Spaceflight/).

<sup>333</sup> Harvey, *Europe's Space Programme*, 290.

<sup>334</sup> ESA, "Human Spaceflight."

<sup>335</sup> Burleson, *Space Programs*, 128–129.

<sup>336</sup> Harvey, *Europe's Space Programme*, 288.

<sup>337</sup> ESA, "Human Spaceflight."

<sup>338</sup> Harvey, *Europe's Space Programme*, 290.

<sup>339</sup> ESA, "About Us."

<sup>340</sup> Harvey, *Europe's Space Programme*, 274, 278–279.

Space Operations Centre and controls the Interconnection Ground Subnetwork used by the Automated Transfer Vehicle (ATV) Control Centre (ATV-CC).<sup>341</sup> The ATV-CC is based out of the Toulouse space center and is “responsible for carrying out the programmed mission plans and, if needed, to implement any changes. Additionally the Centre is in charge of the orbitography, the localization of ATV and monitoring its approach to the International Space Station.”<sup>342</sup> The Columbus Control Center is also based in Oberpfaffenhofen, Germany. As defined on the ESA website, “The Control Centre is the direct link to Columbus in orbit. The centre’s main functions are to command and control the Columbus laboratory systems, to coordinate operations of the European payloads on board the ISS and to operate the European ground communications network.”<sup>343</sup>

While Germany has a majority of the facilities, France provides the launch site. Centre National d’Etudes Spatiales (CNES) is the French space agency. CNES chose Kourou, French Guiana, as their spaceport in 1964. It is located on the northern coast of South America and averages 15 launches per year. In 1975, France offered to share its launch center with ESA.<sup>344</sup> Since then, ESA has funded two-thirds of the spaceport’s annual budget.<sup>345</sup> The site is ideal for geostationary launches as it is just 300 miles north of the equator.<sup>346</sup> Also due to its geographical position, it offers a launch angle of 102 degrees, which gives it a wide range of potential missions.<sup>347</sup>

As France is a “strong driving force behind initiatives and proposals of programs led by the ESA,” it is also responsible for the European launcher.<sup>348</sup> The Ariane rocket series is considered quite reliable despite several failures.<sup>349</sup> In July 1973,

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<sup>341</sup> ESA, “Human Spaceflight.”

<sup>342</sup> Ibid.

<sup>343</sup> Ibid.

<sup>344</sup> Burleson, *Space Programs*, 99.

<sup>345</sup> European Space Agency (ESA), “Launchers,” accessed July 22, 2013, [http://www.esa.int/Our\\_Activities/Launchers/](http://www.esa.int/Our_Activities/Launchers/).

<sup>346</sup> Burleson, *Space Programs*, 99.

<sup>347</sup> ESA, “Launchers.”

<sup>348</sup> Burleson, *Space Programs*, 113.

<sup>349</sup> Smith, *Space Activities*, 147.

ESA made the decision to begin development. An Ariane rocket was first launched on December 24, 1979. By 1984, the more powerful Ariane 2 and then Ariane 3 were produced.<sup>350</sup> Since then, Ariane 1, 2 and 3 have been phased out.<sup>351</sup> June 15, 1988, marked the first launch of the Ariane 4, which would become the “workhorse” for ESA. The Ariane 4 can place 1,700–4,800 kilogram payload into geostationary orbit. There are six different versions of the Ariane 4. The Ariane 5 had its first successful launch on October 30, 1997. Future upgrades plan to improve the performance of the Ariane 5 and make it more versatile.<sup>352</sup>

The contract for *Spacelab* was given to FW-Fokker Erno, a Germany company since Germany footed a majority of the bill. However, program management was given to the European Space Technology Centre in the Netherlands. *Spacelab* had three separate configurations. In one configuration, a full laboratory took up all the available space. Another configuration was filled with pallets only. The final configuration was a combination of the other two with a smaller lab and some pallets.<sup>353</sup>

*Hermes* was ESA’s attempt at a space plane program. CNES originally announced the idea of a space plane in October 1978, but was not officially committed until 1981. Original plans for *Hermes* had it launched atop the Ariane 5 and capable of carrying five crew members. The idea for a space plane was a potential outcome from the frustrations felt due to the minimal use of *Spacelab* by European astronauts. France pushed for it to become an European project. Nonetheless, in January 1985, ESA chose to stick with Ariane 5 and *Columbus*, their contribution to the ISS, instead. ESA wanted to take small steps toward manned flight and the American shuttle would do for now. France still pressed forward hoping other countries would join on and that they would be successful because it was a “small” space plane compared to the shuttle or Soviet *Buran*.<sup>354</sup>

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<sup>350</sup> Burleson, *Space Programs*, 99.

<sup>351</sup> Smith, *Space Activities*, 147.

<sup>352</sup> Burleson, *Space Programs*, 99–100.

<sup>353</sup> Harvey, *Europe’s Space Programme*, 272.

<sup>354</sup> *Ibid.*, 294–296, 308.

Finally in October 1985, ESA adopted the *Hermes* project.<sup>355</sup> Unfortunately, there were multiple design changes. *Hermes* kept getting larger and the bigger it got, the more upgrades were needed to the Ariane 5 to provide the thrust. In 1990, *Hermes* was redesigned to be smaller, with only a three-person crew and parts of it not being reusable. The non-reusable parts included the rear part of the spacecraft containing the propulsion, docking, and resource modules that would be dropped before re-entry. *Hermes* started to lose support. The program started to be stretched out by delaying its first launch. By now, it was 40.5% over budget. Although, never actually terminated, it started to wither away after a ministerial summit in Granada, Spain.<sup>356</sup>

At the same meeting that ultimately ended *Hermes*, the *ATV* was provisionally approved. It was decided if Europe could not have independent manned access to the ISS, at least it should be able to have an unmanned supply vehicle. The *ATV* program was officially approved in 1995 at an ESA council meeting in Toulouse.<sup>357</sup> The purpose of the *ATV* is to ferry cargo to the ISS, correct the station's orbit, and then finish as an incinerator.<sup>358</sup> The original plans foresaw the *ATV* being launched from Kourou every 12 months, hauling 7.5 tons of cargo. It would then dock with the ISS for up to 6 months, and then dispose 6.5 tons of waste by burning up in the earth's atmosphere. Thus, the *ATV* can carry supplies three times that of *Progress*.<sup>359</sup> The estimated cost was about \$400 million per vehicle.<sup>360</sup> Four *ATVs* have successfully docked with the ISS since April 3, 2008. Each *ATV* carried food, clothes, equipment, and oxygen as well as propellant to reboost the ISS' orbit.<sup>361</sup> *Albert Einstein, ATV-4*, docked with the ISS on June 15, 2013 and is currently still docked.<sup>362</sup>

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<sup>355</sup>Harvey, *Europe's Space Programme*, 297.

<sup>356</sup> *Ibid.*, 299–304.

<sup>357</sup> *Ibid.*, 320.

<sup>358</sup> Burleson, *Space Programs*, 80.

<sup>359</sup> Harvey, *Europe's Space Programme*, 320.

<sup>360</sup> Mindell et al., *The Future of Human*, 45.

<sup>361</sup> ESA, "Human Spaceflight."

<sup>362</sup> *Ibid.*



*c. Future Plans*

ESA's future plans contain more work and practice with long-duration human spaceflight. Since 2005, it has had a permanently crewed base in the Antarctic called Concordia. ESA uses Concordia to study human interaction for a long-duration spaceflight. Also according to ESA, "The base is so unlike anything found elsewhere in the world that ESA participates in the Italian-French base to research future missions to other planets, using the base as a model for extraterrestrial planets."<sup>363</sup>

The European Robotic Arm (ERA) is Europe's next contribution to the ISS. ERA is a joint ESA-Russian Federal Space Agency project with the purpose of supporting assembly and servicing tasks to include the installation and exchange of external equipment. Dutch Space is leading the ESA portion of the project, which was approved in 1994. ERA is a direct descendant of the *Hermes* Robotic Arm. The original launch date was supposed to be in November 2007.<sup>364</sup> However, it is now projected to launch this year from Baikonur aboard a Proton rocket. It will be attached to different locations on the Russian Multipurpose Laboratory Module.<sup>365</sup>

ESA is also cooperating with NASA on the *Orion* space capsule. ESA is working on the development of *Orion's* propulsion system. The first manned flight is predicted for 2021. ESA plans to use the rocket engines and other technology from its *ATV*. Since ESA needs to meet NASA's human spaceflight standards, it will use NASA's testing facilities.<sup>366</sup> The first unmanned test flight of *Orion* is expected in 2017. Dan Dumbacher, deputy associate administrator for exploration systems development at NASA headquarters in Washington, D.C., stated: "It is a testament to the engineering progress made to date that we are ready to begin integrating designs of an ESA-built service module with *Orion*."<sup>367</sup>

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<sup>363</sup> ESA, "Human Spaceflight."

<sup>364</sup> Jane's Space Systems and Industry, "European Space Agency (ESA)," November 13, 2012.

<sup>365</sup> ESA, "Human Spaceflight."

<sup>366</sup> Rob Coppinger, "NASA's Orion Space Capsule to Get European Boost," *Space.com*, November 29, 2012, <http://www.space.com/18680-nasa-orion-capsule-european-module.html>.

<sup>367</sup> Quoted in ESA, "Human Spaceflight."

The *Advanced Reentry Vehicle (ARV)* is ESA's newest project for an independent human spaceflight vehicle. It will be integrated with the *ATV* service module. Its first robotic mission is planned for 2015, with the first manned mission scheduled for 2020. ESA is using experience from their successful Atmospheric Reentry Demonstrator in 1998<sup>368</sup> and their initial work on the Crew Return Vehicle from 1998 to 2002. The *ATV's* Integrated Cargo Carrier is replaced with a cargo re-entry capsule for the *ARV*. It will be launched using the Ariane 5 ES and will land in the Atlantic Ocean off the coast of Europe.<sup>369</sup>

The Aurora Exploration Program is ESA's current roadmap to explore the solar system. It was started in 2001 with the goal "to create, and then implement, a European long-term plan for the robotic and human exploration of the solar system, with Mars, the Moon and the asteroids as the most likely targets." The capstone of the Aurora Exploration Program is "a voyage by European astronauts to Mars by 2030, with a return to the Moon in the meantime."<sup>370</sup>

#### **4. Japan**

Although Japan does not currently have its own independent human launch program, it is considered an accomplished space power with considerable experience in human spaceflight. Close ties with the U.S. and, more recently, commercial arrangements with Russia have enabled Japan to use American space services and technology to transport Japanese astronauts and hardware into space and the ISS. Japan opted for an unmanned transfer vehicle for the ISS instead of the higher cost and work needed for a human rated spacecraft.<sup>371</sup> While Japan has the technology to compete in space, it currently lacks the organizational and financial backing needed for an independent human spaceflight program.<sup>372-373</sup> According to James Clay Moltz, "Japan

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<sup>368</sup> Mindell et al., *The Future of Human*, 43–44.

<sup>369</sup> ESA, "Human Spaceflight."

<sup>370</sup> Mindell et al., *The Future of Human*, 44.

<sup>371</sup> Moltz, *Asia's Space*, 43.

<sup>372</sup> *Ibid.*, 44.

<sup>373</sup> Handberg and Li, *Chinese Space Policy*, 48.

is likely to struggle with the costs necessary to operate a much larger space program - one replete with independent human spaceflight capacity....”<sup>374</sup>

Hiroataka Watanabe stated that “autonomy and international cooperation have been central pillars of Japan’s space policy.”<sup>375</sup> Contradictory in nature, these two pillars are what Tokyo decision makers are now faced with: whether to continue with cooperation and relying on other countries to put their astronauts in space or to have a more active and independent human spaceflight program with the associated costs and risks.<sup>376</sup>

*a. Human Spaceflight Experience*

Early Japanese space experience starts with the creation of the National Space Activities Council in 1960. In 1964, the Institute of Space and Aeronautical Science (ISAS) at the University of Tokyo was created. Hideo Itokawa, who is considered the leader of Japan’s rocket program, was put in charge of ISAS. However, the years from 1966 to 1969 were plagued by failures of four Lambda launches and delays with the Mu rocket, which ultimately forced Itokawa to resign from ISAS.<sup>377</sup>

The National Space Activities Council was renamed and elevated to the Space Activities Commission in 1968. In 1969, the National Space Development Agency (NASDA) was formed and became responsible for “civil space activities, including satellite development, major launcher development, and the operation of launch facilities and tracking and control stations.”<sup>378</sup> As Harvey puts it: “Japan in effect developed two different, parallel space programmes, a unique situation.”<sup>379</sup>

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<sup>374</sup> Moltz, *Asia's Space*, 44.

<sup>375</sup> Quoted in Moltz, *Asia's Space*, 45.

<sup>376</sup> Moltz, *Asia's Space*, 45.

<sup>377</sup> *Ibid.*, 46, 48–49.

<sup>378</sup> *Ibid.*, 49.

<sup>379</sup> Quoted in Moltz, *Asia's Space*, 49.

The Diet, in 1969, made a resolution that the space program be exclusively for nonmilitary purposes and means. An agreement was also made with the U.S. not to transfer launch technology to third parties.<sup>380</sup>

In February 1970, Japan's first satellite to orbit the earth, *Ohsumi*, was launched atop the Lambda 4S-5. Subsequently, the Space Activities Commission developed a 15-year plan in 1978 entitled the "Outline of Japan's Space Development Policy," which included an independent human spaceflight program concentrating on materials processing. However, in 1984, the plan was revised to link their manned activities with what is now the ISS.<sup>381</sup>

April 1984 saw the first selection process for Japanese astronauts. The 533 applicants were whittled down to three in 1985. The launch of a NASDA selected astronaut was delayed after the *Challenger* disaster. Russia offered to fly them and their experiment to *Mir* but NASDA chose to stick with U.S.<sup>382</sup> Incidentally, Japan's first astronaut was actually a journalist, Toyohiro Akiyama. The Tokyo Broadcasting System (TBS) paid the Russians \$12 million for a flight aboard *Mir* in December 1990<sup>383-384</sup> While NASDA was waiting for NASA, Russia moved up their timeline with TBS so the first Japanese astronaut would fly on a Soviet rocket.<sup>385</sup> As part of his first broadcast in orbit, Akiyama echoed the words of Yuri Gagarin "This is Akiyama! The Earth is blue!"<sup>386</sup>

NASDA's wait was over in September 1992, when Japan's second astronaut was sent into space. Mamouri Mohri was launched aboard the U.S. space shuttle STS-47 *Endeavor*.<sup>387</sup> His *Spacelab J* mission focused on the use of Japanese

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<sup>380</sup> Moltz, *Asia's Space*, 49.

<sup>381</sup> *Ibid.*, 49, 51.

<sup>382</sup> Harvey, Smid, and Pirard, *Emerging Space*, 102–103.

<sup>383</sup> Smith, *Space Activities*, 167.

<sup>384</sup> Moltz, *Asia's Space*, 52.

<sup>385</sup> Harvey, Smid, and Pirard, *Emerging Space*, 105.

<sup>386</sup> Quoted in Harvey, Smid, and Pirard, *Emerging Space*, 105.

<sup>387</sup> Moltz, *Asia's Space*, 53.

equipment<sup>388</sup> for materials processing research.<sup>389</sup> While in orbit, Mohri gave a microgravity lesson to Japanese school children. He flew for a total of seven days, returning on September 20.<sup>390</sup>

Chiaki Mukai became the third Japanese astronaut aboard STS-65 *Columbia* from July 8 to 23, 1994. She was the first Japanese female to fly and would also be the first to fly twice with over 566 hours in space. From January 11 to 20, 1996, Koichi Wakata flew aboard STS-72 *Endeavor*.<sup>391</sup> As part of his mission, he retrieved Japan's free flier, aptly named the *Space Flier Unit*.<sup>392</sup> Following the mission, the whole crew of STS-72 toured Japanese schools, factories and civic associations. As Harvey writes: "American astronaut Dan Berry recalled many years later how he was taken aback by the level of enthusiasm with which they were greeted, with Wakata treated like a rock star by teenage girls screaming his name and rushing forward with flowers."<sup>393</sup>

In May 1996, Soichi Noguchi was selected in the third round of astronaut applications. He would be the first Japanese astronaut to train at both NASA Johnson Space Center and the GCTC in Star City.<sup>394</sup> The first Japanese EVA was conducted by Takao Doi aboard STS-87 *Columbia* on his flight in November 1997. He ended up conducting two EVAs on this mission.<sup>395</sup> Mukai's second flight came on October 29 to November 7, 1998. She flew on STS-95 *Discovery* alongside John Glenn.<sup>396</sup>

In October 2003, Prime Minister Junichiro Koizumi merged ISAS and NASDA into the Japan Aerospace Exploration Agency in an attempt to reduce organizational problems, following the failed launch of two Japanese rockets.<sup>397</sup> Two

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<sup>388</sup> Harvey, Smid, and Pirard, *Emerging Space*, 106.

<sup>389</sup> Smith, *Space Activities*, 164.

<sup>390</sup> Harvey, Smid, and Pirard, *Emerging Space*, 107.

<sup>391</sup> Burleson, *Space Programs*, 190–191.

<sup>392</sup> Harvey, Smid, and Pirard, *Emerging Space*, 111.

<sup>393</sup> *Ibid.*

<sup>394</sup> *Ibid.*, 107.

<sup>395</sup> Burleson, *Space Programs*, 191.

<sup>396</sup> Harvey, Smid, and Pirard, *Emerging Space*, 108.

<sup>397</sup> Moltz, *Asia's Space*, 56.

more changes to the Japanese space program came in 2008. First off, Takeo Kawamura stated that, “I came to realize that there was no organization in control and exercising leadership in space development in Japan.”<sup>398</sup> This led to the Kawamura initiative, which put emphasis on applications, streamlined administration, and military use of space.<sup>399</sup> Secondly, a Diet vote removed restrictions on military use of space due to security concerns over North Korea’s nuclear and missile programs.<sup>400</sup> According to Setsuko Aoki, the 2008 Basic Space Law moved Japan’s space policy toward “user-oriented space applications.”<sup>401</sup>

Takao Doi made his second flight on March 11, 2008 as part of STS-123 *Endeavour*. This mission took the first of the Japanese components to the ISS, the Experiment Logistics Module of the Japanese *Kibo* laboratory.<sup>402</sup> *Kibo* is Japan's first manned experiment facility. The Pressurized Module and robotic arm of *Kibo* was brought to the ISS aboard STS-124 *Discovery* on May 31, 2008.<sup>403</sup> Akihiko Hoshide accompanied the component. In March 2009, Koichi Wakata was brought to the ISS for a four-month mission aboard *Discovery*.<sup>404</sup> Thus, he became the first resident ISS crew member from Japan.<sup>405</sup>

The second Japanese resident on the ISS was Noguchi. He was launched aboard a *Soyuz* in December 2009. He spent 161 days aboard the ISS. In March 2010, Naoko Yamazaki flew aboard STS-131 *Discovery*. She operated the Remote Manipulator System both on the Shuttle and the ISS. Her arrival to the ISS marked the first time that two Japanese astronauts worked together in space. In February 2011, Wakata was assigned as a Flight Engineer of ISS Expedition 38 and the Commander of

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<sup>398</sup> Quoted in Moltz, *Asia's Space*, 57.

<sup>399</sup> Moltz, *Asia's Space*, 57.

<sup>400</sup> *Ibid.*, 43–44.

<sup>401</sup> Quoted in Moltz, *Asia's Space*, 61.

<sup>402</sup> NASA, “International Space Station Assembly.”

<sup>403</sup> *Ibid.*

<sup>404</sup> Harvey, Smid, and Pirard, *Emerging Space*, 120–122.

<sup>405</sup> Japan Aerospace Exploration Agency (JAXA), “JAXA Astronauts,” accessed July 17, 2013, <http://iss.jaxa.jp/en/astro/>.

Expedition 39, making him the first Japanese astronaut that will command the ISS. Currently, Japan has 8 active astronauts.<sup>406</sup>

***b. Facilities, Launch Sites, and Vehicles***

NASDA opened the Tsukuba Space Center in June 1972. It has become the Japanese equivalent to Mission Control Houston staffed by 60 personnel working eight-hour shifts.<sup>407</sup> In 1996, a Space Station Operations Facility was built at the center for astronaut training. It consists of a 10 meter-deep swimming tank for EVA practice, an isolation chamber and a high-altitude chamber.<sup>408</sup> There is also a full-scale model of *Kibo* for the astronauts to train on.<sup>409</sup>

The two Japanese launch sites are Uchinoura and Tanegashima. Uchinoura is near<sup>410</sup> Kagoshima on the island of Kyushu in the south of Japan. It was established by ISAS in 1962. Launches from here are eastward over water.<sup>411</sup> Uchinoura was the first Japanese launch facility, but is now just used for sounding rockets with the last satellite launch in September 2006.<sup>412</sup> The Mu series rockets were launched here.<sup>413</sup>

Tanegashima is further south than Kagoshima Island and started as NASDA's launch site. It has launched the N-1, N-2, H-I and H-II.<sup>414</sup> It has become the main launch site, currently launching the H-IIA.<sup>415</sup> Both launch sites have government agreements with local fisherman. Originally, they could not launch more than twice a

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<sup>406</sup> JAXA, "JAXA Astronauts."

<sup>407</sup> Harvey, Smid, and Pirard, *Emerging Space*, 135–136.

<sup>408</sup> *Ibid.*, 113.

<sup>409</sup> Burleson, *Space Programs*, 187.

<sup>410</sup> Smith, *Space Activities*, 163.

<sup>411</sup> Moltz, *Asia's Space*, 48–49.

<sup>412</sup> Harvey, Smid, and Pirard, *Emerging Space*, 133–134.

<sup>413</sup> Smith, *Space Activities*, 163.

<sup>414</sup> *Ibid.*, 164.

<sup>415</sup> Harvey, Smid, and Pirard, *Emerging Space*, 132.

year and only in the summer and winter.<sup>416</sup> A new agreement was struck to extend the launch window to 180 days, while still preserving the prime fishing period of March to mid-June at Tanegashima.<sup>417</sup>

The Japanese got their start with the Kappa, Lambda, and Mu-series launchers<sup>418</sup> developed by ISAS. All of these rockets were solid propellant. The NASDA rockets started with the N-1,<sup>419</sup> Japan's first major liquid-fuel rocket based on the U.S. Delta. There were a total of seven launches of the N-1 from September 1975 to 1982.<sup>420-421</sup> The N-II was a heavier booster with its first flight in 1981.<sup>422</sup> It launched eight times from 1981 to 1987.<sup>423</sup>

The H-I, another U.S.-derived vehicle, had nine successful flights from 1986 until 1992. The H-II represented Japan's first independently designed rocket. After two major explosions, the first successful launch of the H-II was in 1994. This launch was followed by another flight failure but then four successful flights through 1997. Launch failures struck again in February 1998 and November 1999 causing NASDA to cancel the series.<sup>424</sup>

In 1994, NASDA and Mitsubishi announced plans for a reusable space plane, *Hope*<sup>425</sup> (or H-II Orbiting Plane).<sup>426</sup> The late 1990s saw a series of revisions to reduce cost. Ultimately, it was decided to have a smaller and unmanned vehicle.<sup>427</sup> According to Harvey, Smid, and Pirard, "Space development is littered with failed

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<sup>416</sup> Smith, *Space Activities*, 164.

<sup>417</sup> Harvey, Smid, and Pirard, *Emerging Space*, 133.

<sup>418</sup> Moltz, *Asia's Space*, 48.

<sup>419</sup> Smith, *Space Activities*, 163.

<sup>420</sup> Moltz, *Asia's Space*, 50–51.

<sup>421</sup> Burleson, *Space Programs*, 187.

<sup>422</sup> Moltz, *Asia's Space*, 51.

<sup>423</sup> Burleson, *Space Programs*, 187.

<sup>424</sup> Moltz, *Asia's Space*, 51–52, 54–55.

<sup>425</sup> *Ibid.*, 53.

<sup>426</sup> Harvey, Smid, and Pirard, *Emerging Space*, 124.

<sup>427</sup> Moltz, *Asia's Space*, 57.



spaceplane projects among all the main space powers and the Japanese were no more successful than the others in breaking out of this unforgiving field of research.”<sup>428</sup>

The H-IIA made its first successful flight in August 2001.<sup>429</sup> Its relatively light weight adds to its high rate of performance. It weighs only 285 tons compared to Ariane 4 at 460 tons and Proton at 1,000 tons.<sup>430</sup> The first mission of the alternative design to Hope occurred in September 2009. Named the *H-II (or Hope) Transfer Vehicle (HTV)*, it can ferry six tons of cargo to the ISS and burn up trash in the atmosphere upon reentry.<sup>431</sup> Unlike the Russian *Progress* and Europe’s *ATV*, the *HTV* supports pressurized and unpressurized cargo.<sup>432</sup> The current plan for the *HTV* is for one flight per year until 2016.<sup>433</sup>

**c. Future Plans**

While there is solid public support for an independent Japanese human spaceflight program with a purpose of stimulating younger people’s interest, there are still concerns with costs and risks: the death of an astronaut could create negative implications. However, the Japanese have shown their commitment to space.<sup>434</sup> Their close ties with the U.S. continue with the commitment to lunar and/or Mars exploration. The U.S. is currently without a human-rated launch vehicle, which may have motivated recent discussion regarding human-rating the *HTV*.<sup>435</sup>

In March 2005, JAXA issued the “JAXA 2025 Vision.” This vision states the goal to “Promote ‘top science’ in the field of space science while preparing for

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<sup>428</sup> Harvey, Smid, and Pirard, *Emerging Space*, 129.

<sup>429</sup> Moltz, *Asia's Space*, 55.

<sup>430</sup> Burleson, *Space Programs*, 190.

<sup>431</sup> Moltz, *Asia's Space*, 57.

<sup>432</sup> Mindell et al., *The Future of Human*, 46.

<sup>433</sup> Harvey, Smid, and Pirard, *Emerging Space*, 117.

<sup>434</sup> Moltz, *Asia's Space*, 62, 68.

<sup>435</sup> *Ibid.*, 69.

Japan's own human space activities and the utilization of the Moon."<sup>436</sup> The vision is broken down into two 10-year periods, with their independent human spaceflight program coming in the second 10 years. Before entering the second half of the vision, it will be reanalyzed and the government will decide whether to continue or reevaluate. The current vision has the Japanese human-rated spacecraft being based on the *HTV*. The vision concludes that:

As a goal to be achieved in the coming years (next ten years or so), while Japan would not yet initiate its own human space program, it should promote the fundamental research and development with a view to making it possible to initiate its own human space activities. Japan continues human space activities through the ISS program. And it is necessary to start a study of Japan's goal and vision for future.

As for future perspectives for the long-term development (in twenty to thirty years), based on the accomplishments of the on-going and planned activities, Japan should make necessary preparations for enabling its own human space activities that would contribute to various space utilization.<sup>437</sup>

## **5. India**

India expresses similar intentions to China in regard to human spaceflight, which are more long-term in nature. India's political interests are driven by their regional rivalry with China.<sup>438</sup> Unlike the three countries that have put a man in space, India's space launch vehicles started out as civilian rockets, not converted missiles. Currently there is major debate regarding a human spaceflight program.<sup>439</sup> According to Moltz,

The difficulty, as has been the case historically, has been maintaining the firm commitment and funding required to see programs through to their fruition. But India's dynamic information technology sector, its slowly internationalizing educational system, its rising middle class, and its increased recognition of its military needs for first-class support

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<sup>436</sup> Japanese Aerospace Exploration Agency (JAXA), "JAXA Vision Summary," March 2005, [http://www.jaxa.jp/about/2025/pdf/summary\\_e.pdf](http://www.jaxa.jp/about/2025/pdf/summary_e.pdf).

<sup>437</sup> Japanese Aerospace Exploration Agency (JAXA), "JAXA Vision -JAXA 2025-," March 31, 2005, [http://www.jaxa.jp/about/2025/pdf/jaxa\\_vision\\_e.pdf](http://www.jaxa.jp/about/2025/pdf/jaxa_vision_e.pdf), 51.

<sup>438</sup> Handberg and Li, *Chinese Space Policy*, 127.

<sup>439</sup> Moltz, *Asia's Space*, 110-111.

technology from space suggest that the past may not be a mirror of the future.<sup>440</sup>

*a. Human Spaceflight Experience*

While India does not have an independent human spaceflight program, its space experience is extensive. Following the launch of *Sputnik*, the Indian Astronautical Society was formed in 1957. In 1962, the Indian National Committee for Space Research was established.<sup>441</sup> Vikram Sarabhai, the father of India's space program realized India could not compete in a space race. Therefore, he decided India "must be second to none in the application of advanced technologies for the real problems of man and society."<sup>442</sup> Thus, the program focused on communications, meteorology, and remote sensing.<sup>443</sup> In fact, G.B. Pant criticized the U.S. lunar program in 1967, "Is this a valid enterprise? Could not this effort be applied for the teaming, starved, illiterate, ill housed, ill clad, ill cared [for] population of the world?"<sup>444</sup>

In 1969, the Indian Space Research Organization (ISRO) was established with Sarabhai as chairman. In 1972, the Space Commission was created to act in a supervisory role, while the Department of Space was for administrative purposes.<sup>445</sup> According to Sundara Vadlamudi, "During India's formative phase, its space program benefited greatly from foreign assistance, chiefly provided by the United States, the USSR, Japan, West Germany, and other countries."<sup>446</sup>

The Indians took an offer from Russia to train and fly the only Indian astronaut on *Salyut 7*. In 1981, they started taking applicants. From the initial 150 applicants, six were sent to train at Star City. In the fall of 1983, the original six were

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<sup>440</sup> Moltz, *Asia's Space*, 111.

<sup>441</sup> *Ibid.*, 113–114.

<sup>442</sup> Quoted in Moltz, *Asia's Space*, 114.

<sup>443</sup> Moltz, *Asia's Space*, 115.

<sup>444</sup> Quoted in Moltz, *Asia's Space*, 114.

<sup>445</sup> Moltz, *Asia's Space*, 115.

<sup>446</sup> Quoted in Moltz, *Asia's Space*, 116.

narrowed down to two air force pilots.<sup>447</sup> Rakesh Sharma was picked for this honor, even though he had less flying experience than the other candidate, because he spoke Russian better.<sup>448</sup>

On April 3, 1984, Rakesh Sharma was launched into space. He spent a week in space on *Salyut 7*<sup>449</sup> along with 43 Indian experiments.<sup>450</sup> The U.S. offered India a flight aboard *Challenger* for their satellite and a crew member. But, even before the *Challenger* accident, India decided to launch its own satellite and eventually withdrew from the agreement.<sup>451</sup>

After China's first launch of a taikonaut, India reexamined its space program. According to Bharath Gopalalswamy, "India no longer views space as only enhancing the living conditions of its citizens but also as a measure of global prestige."<sup>452</sup> In the winter of 2003, Indian space experts and officials held a conference to discuss manned flight, which started several study groups. Eighty Indian space engineers were brought together on November 7, 2006, to listen to the results of the 2003 study groups. They decided that the way forward was to develop a two-person spacecraft launched from their Geosynchronous Satellite Launch Vehicle (GSLV) mark III. Using the experiences of other countries, India decided that three unmanned launches had to occur first, as had been the Chinese plan. Also for the initial spacecraft design, they looked to Russia.<sup>453</sup>

For India, the way forward is going to be costly, but the alternative is "relegating itself to falling further behind China in a field of technology that is critical to national defense and to its economic competitiveness."<sup>454</sup> In the fall of 2012, an

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<sup>447</sup> Moltz, *Asia's Space*, 118.

<sup>448</sup> Harvey, Smid, and Pirard, *Emerging Space*, 233.

<sup>449</sup> Smith, *Space Activities*, 159.

<sup>450</sup> Harvey, Smid, and Pirard, *Emerging Space*, 233.

<sup>451</sup> Moltz, *Asia's Space*, 118.

<sup>452</sup> Quoted in Moltz, *Asia's Space*, 126.

<sup>453</sup> Harvey, Smid, and Pirard, *Emerging Space*, 238.

<sup>454</sup> Moltz, *Asia's Space*, 134–135.

announcement has further postponed the human spaceflight effort to at least 2021. According to K. Radhakrishnan, chairman of ISRO: “As of now, we do not have a program to launch a human spaceflight over the next five years. We are also yet to get approval from the government for the manned mission.”<sup>455</sup> Potential reasons for the lack of final government approval include the huge cost and two recent failures of GSLV launches. The government had cut the budget allocation for the human spaceflight work in their financial year, which just ended in April 2013 by more than a third. Radhakrishnan explained “Though we had successfully conducted a 12-day space capsule recovery experiment using a lower-orbit rocket in January 2007, we have to work on a full-fledged project on mission mode for the human spaceflight at a revised cost.”<sup>456</sup>

***b. Facilities, Launch Sites, and Vehicles***

In 2008, ISRO bought a site near the Bangalore airport for the construction of an astronaut training center.<sup>457</sup> The original completion date was in 2012, but it seems not much progress has actually been made. Early this year, the founder of India’s first private space company, Susmita Mohanty indicated in an interview that ISRO “is planning to build a residential astronaut training facility.”<sup>458</sup>

India’s main launch site is the Satish Dhawan Space Center,<sup>459</sup> named after the second head of ISRO on September 5, 2002.<sup>460</sup> It is located on the barrier island Sriharikota, located east of Bangalore,<sup>461</sup> in the Bay of Bengal. Bangalore is where ISRO is based.<sup>462</sup> The GSLV is launched from the Satish Dhawan Space Center.<sup>463</sup>

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<sup>455</sup> Quoted in Jay Menon, “Mission Incomplete,” *Aviation Week & Space Technology* 174, no. 35 (October, 1, 2012), 43.

<sup>456</sup> *Ibid.*

<sup>457</sup> Harvey, Smid, and Pirard, *Emerging Space*, 239.

<sup>458</sup> Vijaysree Venkatraman, “One minute with...Susmita Mohanty,” *New Scientist* 217, no. 2905 (February 23, 2013), 27.

<sup>459</sup> Burleson, *Space Programs*, 137.

<sup>460</sup> Harvey, Smid, and Pirard, *Emerging Space*, 246.

<sup>461</sup> Moltz, *Asia's Space*, 117.

<sup>462</sup> Smith, *Space Activities*, 157.

<sup>463</sup> Burleson, *Space Programs*, 142.

The Polar Satellite Launch Vehicle (PSLV) was the first to have a liquid-fuel second stage. Up to this point, all the Indian rockets were solid fuel.<sup>464</sup> The first successful test flight was on September 20,<sup>465</sup> 1993.<sup>466</sup> Developed at the Vikram Sarabhai Space Center,<sup>467</sup> the PSLV is currently the main launch vehicle.<sup>468</sup> The liquid propellant stages for the PSLV were developed at the Liquid Propulsion Systems Center.<sup>469</sup>

Using existing technology and experience from PSLV,<sup>470</sup> the GSLV was designed. A deal was initial struck with the Soviet Union for cryogenic liquid-fuel engines and production technology for the upper stage of the GSLV. The U.S. worried this deal could be used for long-range ballistic missiles, which led to pressure on both Russia and India, sanctions, and ultimately financial aid to Russia to prevent the sale. Instead, the Indians were given completed boosters but no production information.<sup>471</sup> Ironically, hearing that India was in the market for cryogenic engines, American General Dynamics Corporation had approached India before the Soviet Union about the engines and transfer technology, but India had deemed the U.S. offer too costly.<sup>472</sup>

The first flight of the GSLV was on April 18,<sup>473</sup> 2001, with the Soviet boosters. But the Indians wanted to build their own cryogenic engines.<sup>474</sup> The next generation GSLV, GSLV mark II, had the Indian upper stage called the Cryogenic Upper

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<sup>464</sup> Burleson, *Space Programs*, 142.

<sup>465</sup> *Ibid.*, 141.

<sup>466</sup> Moltz, *Asia's Space*, 121.

<sup>467</sup> Burleson, *Space Programs*, 137.

<sup>468</sup> Moltz, *Asia's Space*, 125.

<sup>469</sup> Burleson, *Space Programs*, 137.

<sup>470</sup> Harvey, Smid, and Pirard, *Emerging Space*, 220.

<sup>471</sup> Moltz, *Asia's Space*, 121–122.

<sup>472</sup> Harvey, Smid, and Pirard, *Emerging Space*, 223.

<sup>473</sup> Burleson, *Space Programs*, 137.

<sup>474</sup> Moltz, *Asia's Space*, 122.

Stage.<sup>475</sup> However, they are still perfecting their engine technology<sup>476</sup> at the Liquid Propulsion Systems Center.<sup>477</sup>

On August 17, 2002, the new version of GSLV, the mark III, was approved. The GSLV mark III was supposed to carry a manned flight in 2016. The capsule is supposed to be the *Space Recovery Experiment (SRE-2)*. The *SRE-1* atop the PSLV was launched on January 10, 2007. The *SRE-1* had a successful re-entry and parachute deployment. In December 2008, a deal was made with Russia to base the Indian manned spacecraft on the *Soyuz* design and to have Russia aid with training of Indian astronauts.<sup>478</sup> But, as noted above, the first mission now has been postponed to after 2020.<sup>479</sup>

### *c. Future Plans*

India has shown a major commitment to human spaceflight, seeming to stem from its strong desire not to be out done by China.<sup>480</sup> In announcing India's human spaceflight program in 2006, ISRO chairman G. Madhavan Nair stated that the main reason for this change in policy was that a "human presence in space may become essential for planetary exploration."<sup>481</sup> Other reasons included: independence from the other major space actors, use of the moon for energy materials, benefits for industry, useful spin-offs, and that India was in need of a new goal.<sup>482</sup> But, according to Asif Siddiqi, "From a purely practical perspective, the manned program seems unnecessary to ISRO's original mandate; it is clear that the manned program is not about the pursuit of scientific or technical knowledge or about alleviating poverty—it is first and foremost about prestige."<sup>483</sup>

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<sup>475</sup> Harvey, Smid, and Pirard, *Emerging Space*, 229.

<sup>476</sup> Moltz, *Asia's Space*, 125.

<sup>477</sup> Burlison, *Space Programs*, 137.

<sup>478</sup> Harvey, Smid, and Pirard, *Emerging Space*, 231–232, 239.

<sup>479</sup> Menon, "Mission Incomplete," 43.

<sup>480</sup> Moltz, *Asia's Space*, 133.

<sup>481</sup> Quoted in Mindell et al., *The Future of Human*, 35.

<sup>482</sup> Mindell et al., *The Future of Human*, 35.

<sup>483</sup> Quoted in Moltz, *Asia's Space*, 133.

In the eleventh “Five-Year Plan” for ISRO covering the years from 2007 to 2012, it was stated that “Space has emerged as the next frontier of human endeavor and manned missions are the logical next step to space research.”<sup>484</sup> An estimated \$2 billion to \$2.45 billion will be needed for the manned program.<sup>485·486</sup> In the 2008–09 budget, however, only \$25 million was given for the developmental phase.<sup>487</sup> India will need to commit to a major increase in funding for human spaceflight if it is going to meet its goal. According to a space department official, “Once the project gets the final approval, it will take at least six to seven years for the launch.”<sup>488</sup> As Radhakrishnan stated, “Though we have identified critical technologies for such an ambitious project, we have to build the capabilities for undertaking such a challenging mission.”<sup>489</sup> This pushes the original timeframe to 2020–21 before India’s first human spaceflight, if the project is approved this year.

An ISRO official stated “We are currently aiming to have a manned spaceflight program. A manned lunar mission will come much later.”<sup>490</sup> A manned moon mission was originally discussed for 2020, but that now seems to be a distant dream.<sup>491</sup> Although, according to a minister in the Indian prime minister’s office, “There is no immediate plan for a manned mission to the Moon. The work on the Indo-Russian joint project, *Chandrayann II*, is in progress, but *Chandrayann II* does not envisage [a] manned lunar expedition.”<sup>492</sup> Former ISRO chairman, G. Madhavan Nair, has suggested that priority should be given to the manned mission initiative rather than to the *Chandrayann II* Mars mission. Either way, as Jay Menon of *Aviation Week & Space*

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<sup>484</sup> Mindell et al., *The Future of Human*, 36.

<sup>485</sup> *Ibid.*, 38.

<sup>486</sup> Moltz, *Asia's Space*, 133.

<sup>487</sup> Mindell et al., *The Future of Human*, 37.

<sup>488</sup> *Ibid.*

<sup>489</sup> Quoted in Menon, “Mission Incomplete,” 43.

<sup>490</sup> *Ibid.*

<sup>491</sup> Moltz, *Asia's Space*, 133.

<sup>492</sup> Menon, “Mission Incomplete,” 43.



Technology put it “With dwindling funding and no clear road map, India is said to be weighing its options for collaborating on human spaceflight...”<sup>493</sup>

### C. CONCLUSION

Besides the United States, Russia and, more recently, China have independent human spaceflight capabilities. Up to this point, Europe and Japan have relied on the U.S. and Russia for their spaceflight experience. While Japan and Europe actively pursued human spaceflight from the 1980s through the mid-1990s, the cost-to-benefit ratio was inadequate to show the program through.<sup>494</sup> Europe and Japan are technologically closer to an independent human space program than India, but lack the political impetus India has.<sup>495</sup> Below is a table summarizing the capabilities of these major space powers. Also below is a figure comparing the past, current, and future human space vehicles.

	United States	Russia	Europe	Japan	Canada	China	India
Launch system	D	D	D	D	NE	D	D
Human spaceflight capabilities	D	D	NE	NE	NE	D	UD
Astronaut corps	D	D	D	D	D	D	UD
Satellite manufacturing capabilities	D	D	D	D	D	D	D
Deep space network	D	D	D	D	NE	UD	UD
Moon missions	D	D	D	D	NE	D	D
Mars missions	D	D	D	D	D	UD	UD
Other planetary and NEO missions	D	D	D	D	D	NE	NE
ISS participation	D	D	D	D	D	NE	NE
GES participation	D	D	D	D	D	D	D

D: developed; UD: under development; NE: not existent.

Figure 1. Overview of space exploration capabilities<sup>496</sup>

<sup>493</sup> Menon, “Mission Incomplete,” 43.

<sup>494</sup> Handberg and Li, *Chinese Space Policy*, 128.

<sup>495</sup> *Ibid.*, 132.

<sup>496</sup> P. Ehrenfreund, N. Peter, K.U. Schrogl, and J.M. Logsdon, “Cross-cultural management supporting global space exploration,” *Acta Astronautica* 66 (June-July 2010), 249.

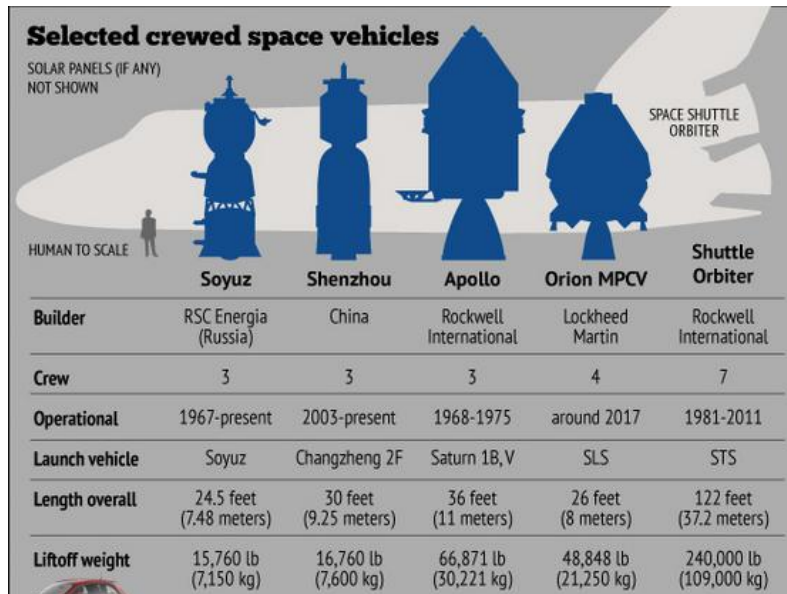


Figure 2. Crewed space vehicles<sup>497</sup>

According to Handberg and Li, “human spaceflight remains the crowning feat for all states regardless of its immediate economic and technological usefulness.”<sup>498</sup> This has become the high point of space activity due to its extreme technical difficulty, great cost, and uniqueness. Thus far, only three countries have achieved independent human spaceflight.<sup>499</sup> Handberg and Li conclude that “the international prestige along with the technological cachet associated with human spaceflight justifies the added expense...though instrumented flight has prestige value, the attention and interest of the world are captured much more by manned flight.”<sup>500</sup>

<sup>497</sup> Karl Tate, “Russia’s Manned Soyuz Space Capsule Explained (Infographic),” *Space.com*, February 2, 2012, <http://www.space.com/14456-russia-soyuz-space-capsule-infographic.html>.

<sup>498</sup> Handberg and Li, *Chinese Space Policy*, 49.

<sup>499</sup> *Ibid.*, 129–130.

<sup>500</sup> *Ibid.*, 5.

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## V. CONCLUSION

### A. KEY POINTS AND RECOMMENDATIONS

This thesis sought to answer the question on what the future should hold for the U.S. human spaceflight program. As the Augustine Commission wrote, “The human exploration of space is historically intertwined with the recent evolution of America’s international relationships.”<sup>501</sup> Because of this global dimension, the competition of the 1960s space race and the cooperation on the ISS were analyzed for lessons for the future. According to Launius, “Mirror image twins international cooperation and competition between nation states has driven many of the key decisions in the major programs undertaken by the United States, especially in the evolution of its human spaceflight initiatives.”<sup>502</sup> In addition, the capabilities of potential partners were researched to see how they could enhance a human spaceflight program.

The biggest lesson learned from the 1960s space race was that it is actually not an example to use for future planning. As Logsdon wrote, after many years of research,

Apollo should not serve as a model for the many programs for lunar and planetary explorations currently making headway: it was a unilateral effort whose generous budget would be inconceivable today. Apollo was a cold war political project, driven by President Kennedy’s judgment that the United States had to enter—and win—a space race. Apollo was conceived as a closed-end effort to beat the USSR to the Moon, not as a first step in a long-term, sustainable program of space exploration.<sup>503</sup>

He goes on to list three reasons why: “They were not preparing the way for others to live and work on the lunar surface...Science was rather clearly a secondary motivation...Another way in which Apollo cannot serve as a model for future exploration is in terms of its budget profile.”<sup>504</sup> The International Space Exploration Coordination Group (ISECG) agrees that “The brief sorties by the Apollo astronauts required the

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<sup>501</sup> Augustine et al., “Seeking A Human,” 105.

<sup>502</sup> Launius, “United States Space,” 89.

<sup>503</sup> Logsdon, “Why space exploration,” 3.

<sup>504</sup> Ibid.

ability to sustain humans for only a few days on the lunar surface; there was no attempt to establish a long-term presence or exploit local resources.”<sup>505</sup>

In a 1962 article, Laurence C. McHugh accurately describes the lessons that can be taken from the 1960s space race:

How quickly the strange environment of outer space will contribute to general human welfare depends in great measure on how free we can keep space from outright military use and national territorial claims. These two freedoms, in turn, hinge upon the growth of international cooperation in space and the immediate formulation of the rudiments of space law.<sup>506</sup>

The 1963 Limited Test Ban Treaty and the 1967 Outer Space Treaty were two of the three greatest lessons learned from the 1960s space race. McHugh also wrote about the third lesson learned, “But the difficulty of entering space, and its costliness, make it likely that the third great space power will not be, for instance, Great Britain...but a coalition of nations working with pooled resources.”<sup>507</sup>

Therefore, the next case study was the ISS. The two advantages of this cooperative project for the U.S. were creating a positive image and strengthening the perception of openness to outside nations. The lessons learned in this venture include the need to bring in equal partners at the onset and have a more specific and certain path for the future. To ensure the success of this project, which could be the basis for all future cooperation, in President Bush’s speech in January 2004 he stated “Our first goal is to complete the International Space Station by 2010. We will finish what we have started, we will meet our obligations to our 15 international partners on this project.”<sup>508</sup> Without meeting these obligations the ISS partners would not consider cooperating in the VSE or future plans.<sup>509</sup> However, to pay for the VSE, the U.S. indicated it would withdraw completely from the ISS by 2015. The Obama administration, per the recommendation

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<sup>505</sup> International Space Exploration Coordination Group (ISEG), *The Global Exploration Strategy: The Framework for Coordination*, (May 2007), 9.

<sup>506</sup> McHugh, “The Why of Space,” 157.

<sup>507</sup> *Ibid.*, 158.

<sup>508</sup> Johnson-Freese, *Space as a Strategic*, 68.

<sup>509</sup> Dupas and Logsdon, “Creating a productive,” 25.

of the Augustine Commission, has proposed staying with the ISS until at least 2020. “A decision not to extend its operation would significantly impair the U.S. ability to develop and lead future international spaceflight partnerships.”<sup>510</sup> Instead of abandoning the ISS for a new exploration plan, the two should be integrated.<sup>511·512</sup> By finding a role for the ISS in the exploration plans, the capabilities and intentions of the ISS will increase and evolve giving the program more power for bargaining than it has had previously.<sup>513</sup>

However, cooperation is not without negative aspects and risks mainly stemming from delays, cost increase and technology transfers. As Ehrenfreund and Peter state, “Political changes, lack of vision and investment, natural disasters, and unstable economic conditions in spacefaring countries are factors that can all lead to the cancellation or delay of space exploration activities.”<sup>514</sup> Other reasons for delays are due to “legal issues and intellectual property rights regulations.”<sup>515</sup> The ISS is a prime example. The delays in the initial Russian modules raised doubts of the actual feasibility of the ISS. These delays also caused unexpected costs to the other partners.<sup>516</sup> Additionally, following the *Columbia* accident and delayed return of the space shuttle, the launch of Europe’s contributions were delayed over three and a half years.<sup>517·518</sup>

Delays lead to possible increases in cost. As Rendleman and Faulconer describe, “There is no easy way to back out of cooperative relationships once they have been initiated. The end result of this is that one may choose to endure the high price and

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<sup>510</sup> Augustine et al., “Seeking A Human,” 10.

<sup>511</sup> Johnson-Freese, *Space as a Strategic*, 249.

<sup>512</sup> Dupas and Logsdon, “Creating a productive,” 25.

<sup>513</sup> *Ibid.*, 26.

<sup>514</sup> P. Ehrenfreund and N. Peter, “Toward a paradigm shift in managing future global space exploration endeavors,” *Space Policy* 25, no. 4 (November 2009), 247.

<sup>515</sup> *Ibid.*, 249.

<sup>516</sup> Randall R. Correll and Nicolas Peter, “Odyssey: Principles for enduring space exploration,” *Space Policy* 21, no. 4 (November 2005), 256.

<sup>517</sup> *Ibid.*, 257.

<sup>518</sup> NASA, “International Space Station Assembly.”

continue even failed cooperative efforts.”<sup>519</sup> Ehrenfreund and Peter observe that “The management of international programs adds layers of complexity to their specification and management and introduce additional elements of dependency and risk that can undermine successful performance and increase total costs.”<sup>520</sup> Once again, the ISS is an example of cooperation leading to increased cost. According to Rendleman and Faulconer, “Billions of dollars have been squandered in order to construct, supply and operate it...The need to support the ISS has gobbled up moneys needed by other programs...”<sup>521</sup>

Lastly, there is the concern with the U.S. Congress about technology transfer. This is especially true in regards to China. As Rendleman and Faulconer described the relationship between the U.S. and China, “space cooperation between the two countries has thus far been only marginal given the strict security controls that needed to be imposed.”<sup>522</sup> The Arms Export Control Act (AECA) and International Trafficking in Arms Regulations (ITAR) govern technology transfer. The AECA seeks “to slow the proliferation of missile and other technologies used to deliver weapons of mass destruction,”<sup>523</sup> while ITAR “defines many commercial, dual-use space technologies as munitions.”<sup>524</sup> Johnson-Freese equated this process to be like Alice trying to talk to the Cheshire Cat in *Alice in Wonderland*. She writes,

The events leading up to the convening of the Cox Committee by the US Congress in 1998, and those following the declassification of its report in 1999, have had a significant worldwide impact on the US export licensing process. US laws that were once business-friendly have become more stringent to accommodate national security concerns, but with no differentiation between potential adversaries and allies.<sup>525</sup>

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<sup>519</sup> James D. Rendleman and J. Walter Faulconer, “Improving international space cooperation: Considerations for the USA,” *Space Policy* 26, no. 3 (August 2010), 148.

<sup>520</sup> Ehrenfreund and Peter, “Toward a paradigm,” 244.

<sup>521</sup> Rendleman and Faulconer, “Improving international,” 147.

<sup>522</sup> *Ibid.*, 146.

<sup>523</sup> *Ibid.*, 148.

<sup>524</sup> Correll and Peter, “Odyssey: Principles,” 257.

<sup>525</sup> Joan Johnson-Freese, “Alice in Licenseland: US satellite export controls since 1990,” *Space Policy* 16, no. 3 (July 16, 2000), 195.

To address these problems, the Obama Administration has implemented an Export Control Reform Initiative. As described on the Export.gov website, “The Administration is implementing the reform in three phases. Phases I and II reconcile various definitions, regulations, and policies for export controls, all the while building toward Phase III, which will create a single control list, single licensing agency, unified information technology system, and enforcement coordination center.”<sup>526</sup> In a White House Press Release on March 8, 2013, “President Obama signed an Executive Order today to update delegated presidential authorities over the administration of certain export and import controls under the Arms Export Control Act of 1976, and yesterday the Administration notified Congress of the first in a series of changes to the U.S. Munitions List.”<sup>527</sup>

There is still more progress to be made if international cooperation is going to be an essential feature on future projects, but the structure of the ISS relationship was on a much more even footing than before for the international partners.<sup>528,529</sup> Entering into partnerships with other countries that have similar space objectives is the best, if not the only, way to achieve an ambitious future space agenda for the world. According to the Augustine Commission, “The strong and tested working relationship among international partners is perhaps the most important outcome of the ISS program.”<sup>530</sup>

As Jean-Jacques Dordain, Director General of ESA, stated “We know now that it is always easier not to cooperate, but that it is always more difficult to succeed alone.”<sup>531</sup> Therefore, five countries, or a group of countries in Europe’s case, were researched to see if a working relationship for human spaceflight would be advantageous. The countries included Russia, China, Europe, Japan and India. Along with the U.S., Russia and China have both obtained the capability to launch humans safely into space. Europe and Japan

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<sup>526</sup> Export.gov, “About Export Control Reform,” October 22, 2012, [http://export.gov/ecr/eg\\_main\\_047329.asp](http://export.gov/ecr/eg_main_047329.asp).

<sup>527</sup> The White House, Office of the Press Secretary, “Fact Sheet: Implementation of Export Control Reform,” March 8, 2013, <http://www.whitehouse.gov/the-press-office/2013/03/08/fact-sheet-implementation-export-control-reform>.

<sup>528</sup> Launius, “United States Space,” 95.

<sup>529</sup> Logsdon, “International cooperation,” 36.

<sup>530</sup> Augustine et al., “Seeking A Human,” 11.

<sup>531</sup> Rendleman and Faulconer, “Improving international,” 144.



have extensive human spaceflight experience, but that comes from hitching a ride from the U.S. and Russia. India has launch capability, but thus far only has plans for a human space capability. The Augustine Commission summarized the capabilities of these countries:

Russia has a complete suite of space capabilities, from a robust launch vehicle stable to a broad spectrum of spacecraft design, production and operation capabilities...The highly evolved Soyuz spacecraft is currently programmed to become the linchpin of the ISS in the immediate future. Russia has also demonstrated capabilities in: large space structures; pressurized modules; life support; power generation and storage; communications; thermal control; propulsion and attitude control; guidance and navigation; remote sensing; computation equipment; subsystems; and operations techniques...

The PRC [People's Republic of China] has demonstrated capabilities in life support, power generation and storage, pressurized module construction, in-space propulsion and attitude control, guidance and navigation, communications and computation...

ESA is a partner in human spaceflight for the ISS and has demonstrated large pressurized habitable modules for use as part of the ISS, as well as launch, rendezvous, and other critical capabilities. Through Arianespace (a French company owned by the French government), the Europeans possess the most active commercial space launch program in the world...The Automated Transfer Vehicle has provided significant logistics support to the ISS and has the potential to be upgraded to a cargo return vehicle, and eventually a human-carrying spacecraft...

JAXA...is a partner in the ISS. Its workhorse launch vehicle, the H-II, has been upgraded to the H-II Transfer Vehicle for use as a logistics carrier to the ISS...it has extensive capabilities...which includes teleoperated robotics. Japan has extensive experience in Earth- and space-science missions and telecommunications satellites, as well as in-ground-based facilities for astronaut training, mission operations, communications and tracking...

ISRO possesses two very capable launch vehicles...To date, the Indian space program has concentrated on telecommunications, Earth observation, and other low-Earth orbit satellite programs.<sup>532</sup>

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<sup>532</sup> Augustine et al., "Seeking A Human," 107.

These countries' attention seems to be toward the moon, in part due to the VSE. China, ESA, Japan and India have recently sent independent unmanned spacecraft to the lunar surface.<sup>533</sup>

### **1. Competition or Cooperation?**

Why should the United States send people into space now and how should the U.S. go about proceeding in the future? The first step should be to have a specific goal that the U.S. human spaceflight program will accomplish. As the Augustine Commission discovered, "Too often in the past, planning the human spaceflight program has begun with the 'where' rather than 'why.'"<sup>534</sup> Unfortunately, while this may be the best technical means to proceed, it is not always the best political strategy. Szajnfarber, Coles, Sondecker, Wicht, and Weigel argue, "...for a clear destination, not because this is the most sustainable technical approach, but because it may be the only politically feasible approach for accomplishing a large-scale exploration endeavor that requires international cooperation for success."<sup>535</sup> This forces the question to become not just how the U.S. should proceed, but where.

The answer is that cooperation should be the way forward in human spaceflight exploration and the moon should be the next destination. As noted above from McHugh during the competition of the 1960s space race and now with the ISS, international cooperation is the best way to proceed. As identified by the ISECG, "Sustainable space exploration is a challenge that no one nation can undertake on its own."<sup>536</sup> The initial steps for forging a cooperative program can be found in the ISS program, having "forged strong ties, including cultural and political understanding."<sup>537</sup> As Handberg and Li stated, "space activities became in practice yet another device by which to politically bind

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<sup>533</sup> Rendleman and Faulconer, "Improving international," 148.

<sup>534</sup> Augustine et al., "Seeking A Human," 111.

<sup>535</sup> Zoe Szajnfarber, Thomas M.K. Coles, George R. Sondecker, Anthony C. Wicht, and Annalisa L. Weigel, "Moon first versus flexible path exploration strategies: Considering international contributions," *Space Policy* 27, no. 3 (August 2011), 142.

<sup>536</sup> ISEG, *The Global Exploration*, 2.

<sup>537</sup> *Ibid.*, 12.

their allies more closely in this important field.”<sup>538</sup> The major benefits of cooperation are summarized below by Ehrenfreund, Peter, Schrogl, and Logsdon:

The benefits of international cooperation are numerous and well documented. Among others, they include improving capability, sharing costs, building common interests and increasing the total level of available resources, eliminating the duplication of efforts, and improving international relationships. Cooperation potentially makes the implementation of a space project more affordable to each individual partner involved, while enriching the pool of scientific and technological expertise. In addition, international cooperation offers robustness and redundancy through added mission options and access to alternative transportation systems. It also enhances domestic legitimacy of space projects and gives them international credibility and consequently makes them less vulnerable to cancellation due to domestic political or financial problems.<sup>539</sup>

The benefits for cooperation are politically, economically and technologically based. As the ISECG states, “Nations have varying scientific, technological and societal objectives for their space activities, and—inevitably—some can afford to do more than others.”<sup>540</sup> However, together nations can afford to do even more than individually.

How nations should cooperate is seen in Ryan Zelnio’s four types of cooperation: coordination, augmentation, interdependence, and integration. Coordination is defined as “Each country operates a separate program independent of others but coordinates on technical and scientific matters.”<sup>541</sup> This appears to be the easiest of the four for countries to agree too. The ISECG has started along this path. The ISECG set-up a “Global Exploration Strategy (GES): The Framework for Coordination.” As a part of this framework, 14 space agencies set out to produce “a common set of space exploration themes.”<sup>542</sup> The GES “makes the case for a voluntary, non-binding forum (the Coordination Mechanism) where nations can share plans for space exploration and

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<sup>538</sup> Handberg and Li, *Chinese Space Policy*, 131.

<sup>539</sup> Ehrenfreund et al., “Cross-cultural management,” 249.

<sup>540</sup> ISEG, *The Global Exploration*, 5.

<sup>541</sup> Ryan Zelnio, “A model for the international development of the Moon,” *The Space Review*, December 5, 2005.

<sup>542</sup> ISEG, *The Global Exploration*, 5.

collaborate to strengthen both individual projects and the collective effort.”<sup>543</sup> As stated in the GES, “The historic decision to start the human journey to Mars is still several years away. However, two important first steps are being taken: first, the engagement of more nations in space exploration; and second, the start of global coordination, as foreseen in this Framework document.”<sup>544</sup> While this is an important starting point and an immediate way forward for cooperation, it lends itself to duplication of effort as already demonstrated on the multiple countries’ missions to the moon.<sup>545</sup>

Zelnio’s second type of cooperation is through augmentation. He defines augmentation as “other countries provide for and enhance the project of the prime country but are not on the critical path.”<sup>546</sup> While in the past, this has been the preferred method for the U.S., potential partners such as ESA are no longer willing to jump on board and accept a back seat to the plans of the U.S. Scott Pace writes “human space exploration beyond Earth orbit will not be done by individual nations...so it makes sense to ask potential international partners what they are capable of and interested in doing... [The U.S.] can and should avoid unrealistic and dangerous hopes that other nations will naturally align their interests with ours in space.”<sup>547</sup> In Audrey Schaffer’s analysis of what other nations want from space collaboration, from the perspective of 10 of the 14 GES nations, “The mechanism must allow all space agencies to make a visible contribution to exploration...[the mechanism] cannot be synonymous with a single US-centric project for which other space agencies provide only augmented capabilities.”<sup>548</sup>

Interdependence, the third type of cooperation, is defined as “cooperation on the critical path of the project as well as on functional systems with each participant still

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<sup>543</sup> ISEG, *The Global Exploration*, 5.

<sup>544</sup> *Ibid.*, 20.

<sup>545</sup> Rendleman and Faulconer, “Improving international,” 150.

<sup>546</sup> Zelnio, “A model for the international.”

<sup>547</sup> Pace, “American Space Strategy.”

<sup>548</sup> Audrey M. Schaffer, “What do nations want from international collaboration for space exploration?” *Space Policy* 24, no. 2 (May 2008), 100.

controlling their part of the project.”<sup>549</sup> To make this type of international cooperation work, Launius offers some guidelines to follow:

- Cooperation is undertaken on a project-by-project basis, not on an on-going basis for a specific discipline, general effort, etc.
- Each cooperative project must be both mutually beneficial and scientifically valid.
- Scientific and technical agreement must precede any political commitment.
- Funds transfers will not take place between partners, but each will be responsible for its own contribution to the project.
- All partners will carry out their part of the project without technical or managerial expertise provided by the other.
- Scientific data will be made available to researchers of all nations involved in the project for early analysis.<sup>550</sup>

As he summarizes, “it is imperative that a coordinated approach to project definition, planning, funding, and conduct of future missions be undertaken.”<sup>551</sup> This is the model that the ISS is based on. As Correll and Peter write, it is based on “pooling resources and maintaining clean divisions in systems, tasks and responsibilities...”<sup>552</sup> Currently, this is the most logical way forward with countries such as Russia, China and India to overcome the technical transfer issue.

The fourth type of cooperation is integration. Integration is “full cooperation with shared and joint research and development with a pooling of resources. This framework spreads out the financial costs, and utilizes the industries of multiple nations while still maintaining a single entity that controls the critical path.”<sup>553</sup> This is the model that ESA uses. While this is the ultimate goal for cooperation, it is not likely in the near future. This is due in part to the high levels of technology transfer<sup>554</sup> and the U.S. desire to

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<sup>549</sup> Zelnio, “A model for the international.”

<sup>550</sup> Launius, “United States Space,” 94–95.

<sup>551</sup> *Ibid.*, 98.

<sup>552</sup> Correll and Peter, “Odyssey: Principles,” 256.

<sup>553</sup> Zelnio, “A model for the international.”

<sup>554</sup> Rendleman and Faulconer, “Improving international,” 150.

maintain program and budget decisions independently.<sup>555</sup> As a truly cooperative method, integration is the ultimate goal and may someday be achievable, for the near future it is not viable. Therefore, the future and next steps for human spaceflight with international partners will need to begin as a coordinated and interdependent effort at the onset, similar to the ISS.

Although there should be flexibility in what projects a country can be a part of, the projects themselves need to be more rigid. A main disadvantage to cooperation is the perception of many international partners that the U.S. has a tendency to change plans with each new administration.<sup>556</sup> A solution was provided by the Augustine Commission:

Programs need to be planned, budgeted and executed so that development and operations can proceed in a phased, somewhat overlapping manner...Changes to ongoing programs should be made only for compelling reasons... human spaceflight program are in need of stability, having been redirected several times in the last decade.<sup>557</sup>

Although disruptive to the original program agreed upon by the U.S., Europe, Canada, and Japan, the inclusion of Russia in what became the ISS, saved the space station. This was a change for a compelling reason.

A planned and budgeted program takes into account the political and economic aspect of international cooperation. As Joan Johnson-Freese writes, “Americans are not known for patience. The real danger for the United States is in ceding space exploration and leadership to China because it lacks the political will to proceed at a steady, supportable pace.”<sup>558</sup> But a steady pace, is often perceived as a slow pace. Therefore, in order to have political backing, the public needs to be involved worldwide.<sup>559</sup> Currently, the world appears to be looking toward the moon as the next destination. Below is a table comparing the potential lunar capabilities of NASA, ESA and JAXA.

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<sup>555</sup> Schaffer, “What do nations?” 97.

<sup>556</sup> Augustine et al., “Seeking A Human,” 16.

<sup>557</sup> Ibid., 112.

<sup>558</sup> Johnson-Freese, “Will China overtake?”

<sup>559</sup> Ehrenfreund et al., “Cross-cultural management,” 255.

Program Elements	NASA	ESA	JAXA	CSA
Robotic Precursor Missions (includes satellite reconnaissance and rovers)	C	C	C	C*
Crew Capsule	C	F*	F	N
Crew Launch Vehicle	C	F	F	N
Earth departure Stage	C	F	F	N
Heavy Lift vehicle	C	N	D*	N
Lunar Surface Access Module (human rated + cargo)	C	D*	D*	N
Surface Robotics (includes buggies, rovers and assistive robotics)	C	F*	D*	D*
Surface Habitation Modules	C	C	C	N
In-orbit assembly or refueling	D*	D*	D*	C*

Figure 3. Potential lunar capabilities<sup>560</sup>

“C” indicates the agency is capable. “D” denotes it is in development. “N” means the agency is not capable and has not indicated plans to pursue the element. “F” signifies a capability the country has identified as being involved with in the future. The asterisk means that only a part of the element was considered.<sup>561</sup> Russia, China, and India were not included in the chart mainly due to the limits of information surrounding their programs. Russia and China have proven their capabilities in robotic precursor missions to the moon, a crew capsule, crew launch vehicle, and pressurized modules. While India has completed robotic missions and a launch vehicle, they are further behind the other countries’ technology for lunar exploration. Working together in a coordinated, integrated cooperation all of these spacefaring countries will one day be able to have habitats on the moon.

## B. AREAS TO CONDUCT FURTHER RESEARCH

This thesis concentrated on human spaceflight and national programs. Therefore, an area for further research includes other aspects of a countries’ space program, such as robotics. While the Augustine Commission also concentrated on human spaceflight, they suggested that

both the human spaceflight program and the science program are key parts of a great nation’s space portfolio... It is in the interest of both science and human spaceflight that a credible and well rationalized strategy of coordination between the two types of pursuit be developed—without

<sup>560</sup> Szajnfarber et al., “Moon first,” 139.

<sup>561</sup> Ibid.

forcing unwarranted intermingling in areas where each would better proceed on its own.<sup>562</sup>

Since this thesis concentrated on national programs, commercial options were not investigated. However, research in this area is warranted as commercial companies are supplying the ISS and making plans for developing human rated launch vehicles. This seems to be an up-and-coming option to pay attention to. U.S. companies such as Space Exploration Technologies Corporation, Orbital Sciences Corporation, Boeing, and Sierra Nevada Corporation have already received money from NASA under the Commercial Orbital Transportation System effort and two rounds of Commercial Crew Development to support research for future human spaceflight.<sup>563</sup>

Lastly, while this thesis concentrated on politics, economics, and technology, it did not take into consideration cultural differences. As Ehrenfreund, Peter, Schrogl, and Logsdon state,

International cooperation adds layers of complexity to the specification and management of the programs and introduces additional elements of dependence and risk that can undermine successful performance within budget and the planned schedule. One of those layers of complexity is the issue of cross-cultural management.

A cooperative framework has therefore not only to take into account the differences in political systems, budgets, and goals but also the cultural values of the involved actors. The increased participation of new actors and stakeholders in space exploration activities requires a multi-dimensional understanding of culture and business practices. The new era of space exploration will be international, human centric, trans-disciplinary and participatory. An effective integration of the stakeholders requires bridging the cultural differences in market and financial aspects, technology, regulations and outreach to provide common strategies.”<sup>564</sup>

More detail in these areas will need to be researched to make a more complete, informed decision in the future of human space exploration.

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<sup>562</sup> Augustine et al., “Seeking A Human,” 114.

<sup>563</sup> Morring Jr., “Spaceflight, Interrupted,” 68.

<sup>564</sup> Ehrenfreund et al., “Cross-cultural management,” 249.



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