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Resources of free space vs. flags and footprints on Mars

An examination of the competing paradigms for human space exploration and development

Gregg E. Maryniak & Richard Boudreault

Human space exploration since Apollo appears to lack an overall context. There has been an overall context for the world's space efforts. But it is an unofficial one and it is outmoded, because it was based on a false assumption. This is the space exploration plan articulated by Von Braun in the 1950s and restated as the Integrated Space Program – 1970–90, whose principal aim is to send humans to explore Mars. The critical underlying assumption of this plan was that Mars is a planet much like Earth, with an active biosphere. This Program has persisted nearly two decades after this underlying assumption has been shown to be false. There is a competing context re-emerging for human space exploration and development which is better fitted to the needs of human society in the post-Cold War era than the Mars program embraced by NASA and, to a large extent, the USSR during the period of US–Russian competition. The original space program uses the resources of free space and provides an economic rationale for human space activity.

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It is clear that the overarching rationale for the inception of manned space programs and in particular the Mercury, Gemini and Apollo programs which shaped much of the conception of what manned space programs are about had very little to do with space and everything to do with superpower competition. It is often said that the end of this competition has had a chilling effect on space exploration activities. However, the pace of human space exploration slowed markedly after the early successes of the initial lunar landings, almost two decades before the end of the Cold War.

Successful programs generally require an overall context. Mercury, Gemini and Apollo were all parts of an overall plan to land humans on the surface of the Moon. Once this goal had been achieved, human space exploration efforts slowed and faltered. Although there are a variety of economic and political reasons for this relative downturn in activity, we submit that the lack of a viable overall context for human space exploration was and remains an essential part of the cause of this malaise.

To be sure, the visionaries, scientists and engineers who brought the lunar landing goal into reach shared a greater vision of human space exploration. In short summary, the goal of this greater vision was the human exploration of a presumed-earthlike planet Mars. The roots of this vision can be traced to the dreams of the original rocketry pioneers such as Goddard, Oberth and Von Braun. Von Braun in particular, was an energetic and articulate spokesman for Mars exploration. Along with the great artists and writers of the 1950s such as Chesley Bonestell, Fred

Freeman, Willy Ley, and the film maker Walt Disney, Von Braun succeeded in presenting a compelling vision of the future of human space exploration. Von Braun's clearest early articulation of this vision can be found in his work *The Mars Project*, published in 1952.[1]

But this vision was based on a false premise. Mars is not an earthlike planet. By the 1950s it was generally known that Mars had a very thin atmosphere. Ley and Bonestell's classic book *The Conquest of Space*, published in 1951,[2] discusses the issue and suggests that life on Mars might resemble that found in cold desert regions of the Earth. The reality was far more hostile. Mariner and Viking flybys and landings discovered a barren, lifeless Mars. However, by the time that actual conditions on Mars were well understood, the vision of Mars exploration had been crystallized into a space exploration plan which continues to influence NASA and other space agencies. A close examination of the Integrated Program shows it to be a Rosetta Stone for understanding human space exploration activities since Apollo.

The Integrated Space Program

The ideas put forth by Von Braun in the 1950s were updated during the 1960s and are succinctly articulated in a memorandum prepared at the George C. Marshall Space Flight Center entitled The Integrated Space Program 1970–1990.[3] The overall goal of the program is to conduct interplanetary exploration leading to a series of Mars missions and bases. From a technical standpoint, the program is based on the development of a series of common tools and systems. Saturn V's are used for heavy lift and a fully-reusable, two-stage space shuttle provides personnel and logistics transport. In addition to the space shuttle, other new tools and systems included:

- a basic space habitation module (called a space station module in this report)
- a manned space tug
- a nuclear space transfer vehicle

These essential elements were used to conduct a series of planned activities leading to large-scale Mars activities. The purpose of the interim steps is to 'provide valuable and necessary data to extend manned space flight with the eventual goal of manned planetary exploration'. The program unfolds as follows:

Phase One

A series of two *Dry Workshops* are deployed in earth orbit. Skylab, built from an empty or dry upper stage segment of Saturn V was one half of this portion of the plan. While this activity is being conducted, Apollo-style operations to the lunar surface are maintained in parallel. These include longer surface stays and use of surface rovers such as were actually used in later Apollo landings.

A *Space Station* is constructed in LEO using one or more of the basic space habitation modules. This station, initially supports 12 persons and is used in conjunction with missions to geosynchronous orbit, the moon and eventually missions to Mars.

A *Lunar Orbit Station* is placed in a 60 nautical mile altitude circular polar lunar orbit. This station, built from the standard habitation module supports lunar orbit and surface activities.

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[1]Von Braun, Wernher, *The Mars Project.* University of Illinois, Urbana, 1953.
[2]Ley, Willy and Bonestell, Chesley, *The Conquest of Space.* The Viking Press, New York, 1951.
[3]Internal Note, Integrated Space Program – 1970–1990 (IN-PD-SA-69-4). Marshall Space Flight Center, Huntsville, December 10, 1969.

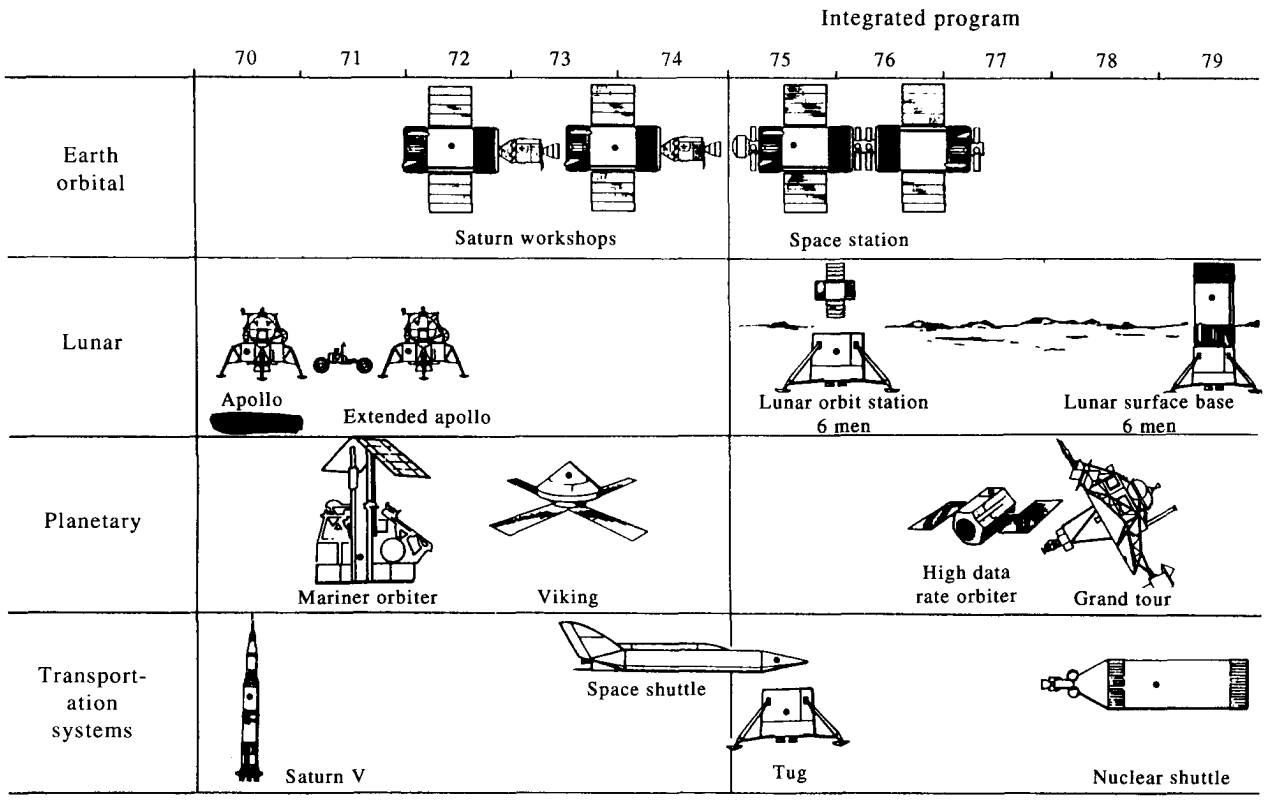

Figure 1. Integrated Program Phase One.

A multipurpose *Space Tug* is designed which can be used for interorbital travel. A variant of this vehicle with landing gear attached can also be used as a lunar lander. The propulsion system can be used for launching (unmanned) interplanetary probes or as an upper stage for the Saturn vehicle for moving heavy systems (like the Lunar Orbit Station).

With the normal crew cabin replaced with a larger habitat module, the basic Space Tug configuration becomes a *Lunar Surface Base*, trading the larger habitat for the mass of lift-off propellants.

A fully reusable *Space Shuttle* designed for rapid turn-around and long subsystem life is used for personnel and resupply for the space station.

A *Nuclear Space Transfer Vehicle* is delivered to LEO by the Saturn V and thereafter used to lower the cost of orbital transfer. Eventually it is a key element of Mars expeditions.

Once the nuclear transfer vehicle is in place a *Permanent Lunar Base* is established to 'provide invaluable data on manned planetary operations . . .' Figure 1 depicts the major program elements during Phase One.

Phase Two

A 100 person earth-orbiting *Space Base* is developed from the earlier space station.

A *Mars Initial Landing* is made using a vehicle made up of basic habitation modules and the nuclear space transfer vehicle plus additional tanks.

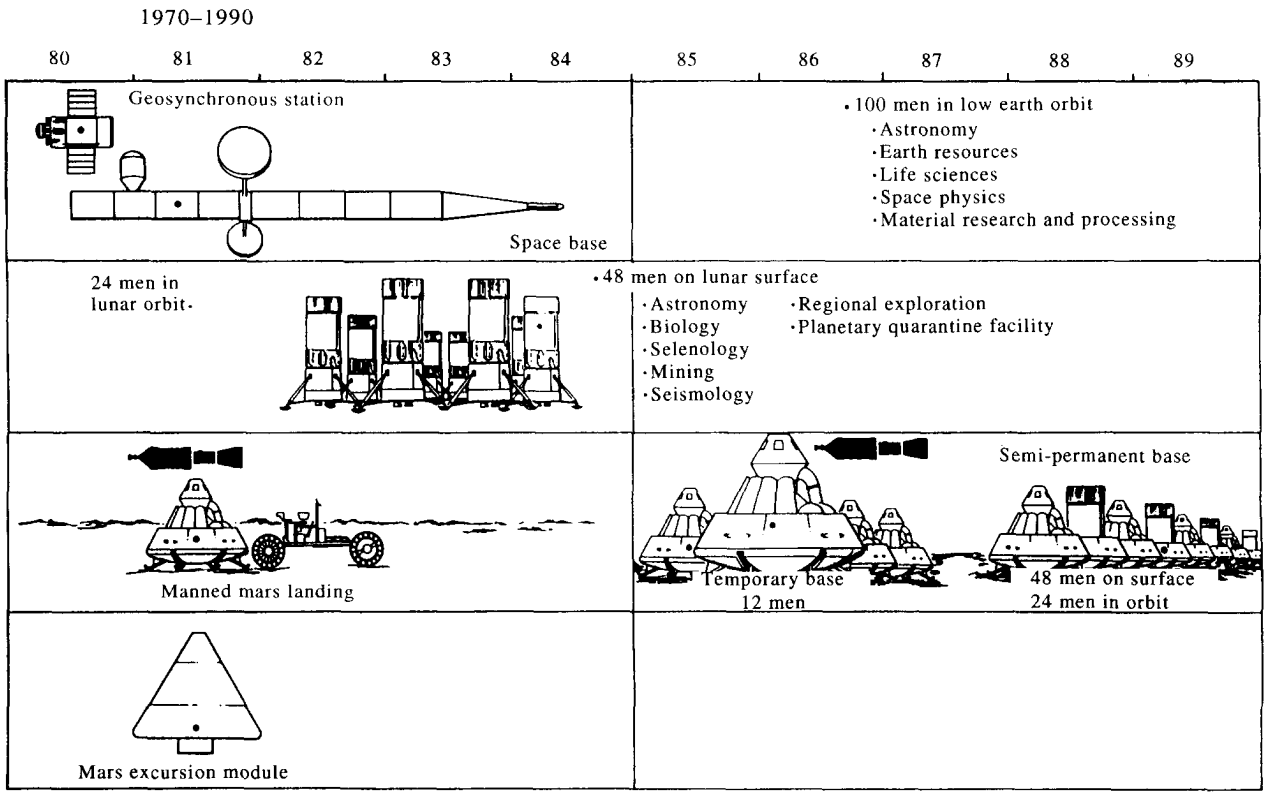

Figure 2. Integrated Program Phase Two.

The lunar surface operations are expanded into a *Lunar Colony* to provide practice for Mars habitation.

A *Temporary Mars Base* is established for a 300 day stay on the martian surface.

A more permanent *Mars Base* is constructed using space habitation modules.

A *Mars Semi-Permanent Base* is established with 48 persons on the surface of the planet and 24 additional persons in a space station in Mars orbit. Figure 2 depicts the major program elements during Phase Two.

The Integrated Program was presented by NASA to the President's Space Task Group which had been created by President Richard M. Nixon on 13 February 1969. Vice President Spiro T. Agnew chaired this group, which was composed of NASA (which had proposed the basic elements of the plan), Air Force senior representatives and others. Agnew was enthusiastic about the plan and publicly talked about a manned Mars landing in the 80s. The Space Task Group presented three variations for executing the integrated program to President Nixon in September of 1969:

- A full-up version of the plan with Mars exploration with first landing in 1985 preceded by the 50 person space station serviced by the fully reusable space shuttle and a lunar orbiting manned space station. Cost of these activities was approximately US$10 billion per year.
- Mars exploration with first landing deferred to 1986, space station and space shuttle but with the elimination of the lunar projects.

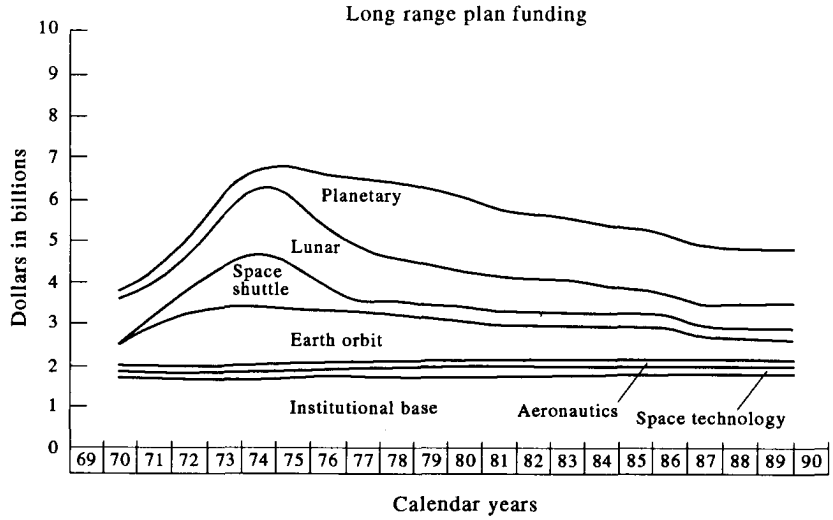

Figure 3. Cost projections for Integrated Plan.

Cost of this version was approximately US$8 billion per year.

- A program encompassing only the space station and space shuttle, estimated at US$5 billion per year. In this version the manned Mars exploration is discussed as a goal to be realized before the turn of the century.

Figure 3 shows the proposed funding for the full-up plan in 1969 dollars.

Jerry Grey in *Enterprise*, a chronicle of the beginnings of the space shuttle program, characterized the national reaction to the Space Task Group proposals as 'violent'. Liberals opposed to space program funding, space scientists and even those advocates of competition with the Russians in space efforts 'all jumped on the bandwagon to urge cuts in the space budget, and almost unanimously (and quite properly) blasted the expenditure of vast sums "just to go to Mars".'[4]

President Nixon ultimately rejected each of the above variants of the Integrated Program. In March, 1970 he issued a comprehensive space-policy message which did not include commitments to any of the elements of the plan although it did allow for studies of both Space Shuttle and Space Station.

Nonetheless, Grey observes that NASA continued to underestimate opposition to the plan and entered Congressional hearings with Shuttle and Station and with the Mars Landing fully visible as a potential prospect. Grey recounts how Joseph Karth, the chairman of the pro-space Subcommittee on Space Science and Applications (of the House Committee on Science and Astronautics) was angered in 1970 by NASA's insistence in furthering the plan: 'Karth was not opposed to the relatively modest research effort on shuttle-related technology . . . but he saw the US$80 million shuttle project money as the first step in a precommitment to a US$50 to US$100 billion manned Mars landing. This, he claimed was NASA's real goal and he was unalterably opposed to it.'[5]

Later, in 1971, NASA was more circumspect and had an easier time of it in Congress: 'Budget authorization in the House of Representatives that year was relatively smooth sailing: this time NASA had done its homework well. Deputy Administrator George Low had flatly and publicly stated that "no Mars landing plans exist".'[6] Yet despite the dramatic lack of political acceptance of the plan, it became the accepted

[4]Grey, Jerry, *Enterprise.* William Morrow and Company, New York, 1979, p. 55.
[5]*Op cit*, Ref. 4, p. 65.
[6]*Op cit*, Ref. 4, p. 73.

paradigm at NASA and has remained so at least up until the tenure of the present Administrator. Rather than being accepted on an official basis, the plan's general philosophy and goals shaped the agency's actions and formed the core of a sort of unofficial NASA manned space exploration wish list.

Some of the goals of the plan have been achieved. NASA was successful in flying one of the two Dry Workshops as Skylab during the 1970s. The second Skylab flight article was constructed but never flown and now is one of the world's most expensive museum exhibits at the National Air and Space Museum in Washington, DC.

Some of the goals of extended lunar exploration were met by the final Apollo lunar missions. However the Saturn V's displayed at the Kennedy and Johnson Space Centers and in the rocket park of the US Space and Rocket Center in Huntsville are the result of the cancellation of the Apollo missions to the lunar surface and the termination of Saturn boosters.

NASA tried to get political support for a Space Shuttle which would reduce the cost of space transportation and operations dramatically. Here a partial success was achieved. However the resulting compromise design was much more of an experimental vehicle than the low-cost workhorse referred to in the Integrated Program.[7] The struggle to develop a vehicle which is designed from the beginning to drastically reduce the human workforce requirements for maintenance and operations continues in the DC-X and related programs to this day.

Space Station has at various times during its programmatic lifetime incorporated aspects of planetary exploration scenarios into itself. Station in some of its earlier configurations included space transportation node functions including provisions for assembly and tending of lunar and martian vehicles.

Although the present configuration is not designed to directly support human missions beyond LEO, the use of Station to gain experience in long-term human habitation in space is an oft-mentioned function of Space Station. The Soviet/Russian Space Station work has a more direct linkage. The long duration orbital stays conducted by cosmonauts on Mir are attributed to Mars ambitions on the part of the Soviet and now Russian programs. Within moments of the 1995 docking of Mir and Space Shuttle the comment was made among the astronauts and cosmonauts that the docking could be a precursor of 'Mars together.' During visits to NPO Energia in 1988 we were shown scenarios for human Mars landing missions using extensions of Mir technology and a nuclear-electric propulsion system.[8]

Indeed, the one area where the long-term dream remained most steadfast (and perhaps most unattainable) was the penultimate goal of Mars. The general shape of the integrated plan calling for practice in LEO and perhaps on the Moon and then onward to Mars remained remarkably intact.

This notion became so generally accepted (in both the US and Soviet space communities) that two decades after the premise of an earthlike Mars was shattered, it remains imprinted in the minds of much of the science and engineering establishment today. This plan was never accepted by any President or Legislative body yet it continues to influence space exploration planning and policy. A second attempt to gain official approval for the plan proved even more disastrous than the Space Task Force recommendation debacle of 1969. The most recent

[7]A comprehensive illustrated history of the development of space shuttle concepts can be found in Dennis R. Jenkins work, *Space Shuttle – The History of Developing the National Space Transportation System*. Walsworth Publishing, Marceline, MO, 1993.

[8]This took place during a visit by Maryniak to Moscow and Kaliningrad in December, 1988.

Table 1. Timelines for a space exploration initiative.

Milestone	Dates Reference approach A	Reference approach B	Reference approach C	Reference approach D	Reference approach E
Lunar emplacement	1999–2004	1999–2004	1999–2004	2002–2007	2002–2007
Lunar consolidation	2004–2009	2004–2007	2004–2008	2007–2012	2008–2013
Lunar operation	2010→	2005→	2005→	2013→	2014→
Humans on the Moon	2001	2001	2001	2004	2004
Permanent habitation	2002	2002	2002	2005	–
Constructible habitat	2005	2006	2007	2008	2011
Eight crew	2006	2007	2007	2009	–
Lunar oxygen use	2010	2005	2005	2013	–
Lunar farside sortie	2012	2008	2008	2015	2022
Lunar steady state mode	2012	2008	2012	2015	–
Mars emplacement	2015–2019	2010–2015	2015–2019	2017–2022	2024→
Mars consolidation	2020–2022	2015–2018	2020–2022	2022→	–
Mars operation	2022→	2018→	2022→	–	–
Humans on Mars	2016	2011	2016	2018	2016
Extended Mars stay	2018	2014	2018	2023	2027

attempt took place in 1989 following President George Bush's Space Exploration Initiative speech on the 20th anniversary of the Apollo 11 landing. Bush suggested that the USA should lead the world in the human exploration and settlement of the solar system. The President tasked NASA with delivering a set of space exploration plans. The result was a set of variants of plans for the human exploration of Mars with the option of some learning stages on the lunar surface. Strong space exploration champion Congressman George Brown of California would later comment that NASA was under the impression that the only place in the solar system was Mars.

Several varieties of NASA's Space Exploration Initiative plan were prepared. As in the case of the Space Task Group in 1969, the major variables were timing for the Mars mission and the option of discarding some of the lunar activities. Table 1 shows timelines for the variants. Although the technologies and tools were different, the results of the 90 day study were clearly a case of dusting off the old Mars vision and attempting to resurrect it in a new form.

Once again, Congress proved resoundingly hostile to this plan in the form of the Space Exploration Initiative. In fact, the former head of the NASA's office of Space Exploration, Dr. Michael Griffin, was repeatedly rebuffed in his efforts to initiate small, high value unmanned space exploration efforts such as low cost lunar orbiters and landers based on the poor congressional climate after word of the cost of the 'Mars expedition' plan was communicated to Congress. Just as in the case of the 1970 budget hearings, Congress was deeply concerned that NASA was attempting to get them to 'buy-in' to the first steps of a costly Mars expedition plan. Griffin described attempts to gain support for a low cost ($100 million) lunar orbiter mission to map the chemical resources of the moon. He was strongly rebuffed and told that the modest amount was 'the camel's nose, poking under the tent . . . with the rest of the camel (the Mars expedition fraction) attached and lurking outside.'[9]

Despite these political failures, US and Russian planners continue to act in accordance with the Integrated Plan. A segment of the space community has strong romantic attachment to the notion of martian exploration. Some have suggested that human enchantment with the exploration of Mars may be the eventual salvation of the space

[9]Michael Griffin, personal communication, 1990.

exploration community.[10] Proponents of Mars missions believe that they are the 'next logical step' in space exploration. Opponents suggest that they are mere 'flags and footprints' spectaculars which after hundreds of billions of dollars in expenditure will lead nowhere.

But if the Mars vision is outmoded in light of present knowledge, what alternative vision or visions can provide the context for a compelling human exploration program worthy of political support?

An alternative context

An alternative vision for human space exploration and development predates the Mars exploration dream of Von Braun and his colleagues. This context has its roots in the work of Tsiolkovsky in the nineteenth century and has been restated more recently by Dandridge M. Cole, Gerard K. O'Neill and others in this century. This context calls for the use of free space, that is the space environment other than the surface of planetary bodies for energy and material resources. Lunar and asteroidal materials and the recently discovered spent comet cores which are near earth objects are examples of the materials sources considered under this space exploration and development context.

Tsiolkovsky

Konstantine Eduardovich Tsiolkovsky (1857–1935) the Russian schoolteacher who is regarded worldwide as the father of spaceflight is generally known for his theoretical work in such areas as the rocket equation. However, a close review of his work reveals considerable thought about the issue of why humans should explore and settle space and a path which is considerably different than the program suggested by Von Braun almost 70 years later.

One of the clearest expositions of Tsiolkovsky's philosophy is his book *Beyond the Earth* published in 1920 (though parts of it were actually written in 1896.)[11] In this fictional work, an international group of scientists establish a base in the Himalayas from which they set out to explore space using a rocket invented by the Russian member of the team. The book is astonishing in its detailed accounts of living and working in weightlessness. The scientists capture solar energy in space and establish a closed cycle life support system with a greenhouse for food production. They ultilize small asteroids for material replenishment. The team sends a small two person ship to the surface of the moon for exploration.

Using telescopes they consider other destinations for space activity. They decide not to go to the trouble of landing on Mars noting that it will always be there in the future. They do however conclude that the asteroids would provide a useful source of materials. They make their discoveries known to their fellow human beings who use the information to begin a wave of colonization of near Earth space in high Earth orbit settlements.

In his works on the use of rocket devices for solar system exploration Tsiolkovsky pointed out the availability of vast resources of energy in near Earth space, billions or trillions of times more energy than that provided by the natural amount of sunlight falling on the surface of the Earth.

The essence of Tsiolkovsky's philosophy can be best summarized by

[10]Alain Dupas has suggested this in his concept of the Third Wave of space activity. See for example *Space: Scenarios for the Future* or In Search of the Third Wave in Space. CNES, Mission de Prospective et d'Évaluation, 29 Sept. 1994, CNES, Paris.

[11]Tsiolkovsky, Konstantine Eduardovich, *Beyond the Earth.*

the term he coined in the title of a monograph written in 1883 called *Free Space*. He believed that free space itself (as opposed to the surfaces of planets) was a useful and beneficial place for human exploration and settlement.

In 1926 Tsiolkovsky developed his own Plan of Space Exploration for the human race.[12] The first half of these points generally deal with advances in astronautics and the remainder with his vision of human space colonization. Tsiolkovsky's 16 points are:

(1) Creation of rocket airplanes with wings.
(2) Progressively increasing the speed and altitude of these airplanes.
(3) Production of a real rocket without wings.
(4) Ability to land on the surface of the sea.
(5) Reaching escape velocity and the first flight into earth orbit.
(6) Lengthening rocket flight times in space.
(7) Experimental use of plants to make an artificial atmosphere in spaceships.
(8) Using pressurized space suits for activity outside of spaceships.
(9) Making orbiting greenhouses for plants.
(10) Constructing large orbital habitats around Earth.
(11) Using solar radiation to grow food, to heat space quarters, and for transport throughout the Solar System.
(12) Colonization of the asteroid belt.
(13) Colonization of the entire Solar System and beyond.
(14) Achievement of individual and social perfection.
(15) Overcrowding of the Solar System and the colonization of the Galaxy.
(16) The Sun begins to die and the people remaining in the Solar System's population go to other suns.

Tsiolkovsky's discussions in this regard were generally unknown and this philosophy remained so during the beginnings of the rocketry efforts in Europe and America in the 1930s and 1940s. Goddard and the Oberth–Von Braun groups, were more interested in getting to other planets which were believed to be Earth-like (such as Mars and Venus) than in utilizing free space. Thus Tsiolkovsky's ideas found no kindred spirits until long after his death.

Dandridge M. Cole

During the 1960s an engineer at General Electric's Valley Forge facility near Philadelphia named Dandridge McFarlane Cole wrote a series of amazing articles and books suggesting that applying Apollo program technology to explore and use the asteroids could open space for mankind. In 1964, Cole (and co-author Donald W. Cox) wrote a book entitled *Islands in Space*. Cole describes moving asteroids using electromagnetic accelerators similar to the mass-drivers suggested for the same purpose years later by O'Neill and others. He suggests that asteroids might be rotated to create habitats providing artificial gravity and radiation shielding for inhabitants who could hollow out such an object. The ability to use space habitats to preserve the human species from nuclear holocaust, natural disasters such as a cometary or asteroid impact or from ecological disasters is suggested. Unfortunately, Cole's untimely death prevented most of his ideas from receiving widespread attention.

[12]The translation of Tsiolkovsky's 16 points was provided by Dr Vladimir Lytkin of the Tsiolkovsky Museum in Kaluga.

Gerard K. O'Neill

A new champion for the use of free space emerged in the late 1960s. Dr. Gerard K. O'Neill, a nuclear physcist whose work on the development of colliding beam systems for particle accelerators was known worldwide, was tasked with teaching the physics course for gifted students at Princeton University. He decided to ask his students the following question: Are the surfaces of planets the best locations for expanding technical civilizations? O'Neill and his students decided that the answer was a resounding No.

From 1969 until his death in 1992, O'Neill wrote several books, dozens of technical papers and hundreds of articles and lectures on the use of space resources. In 1977 his prize-winning book *The High Frontier* was published in the USA and its has subsequently been published in over 10 languages.[13] O'Neill's central premise was that resources outside of the deep gravity wells of the planets could be used for the construction of solar power satellites[14] and large human habitats or space colonies. O'Neill founded the Space Studies Institute at Princeton University in 1977 to conduct research into the tools and techniques necessary to use space resources to accelerate what he called the human breakout into space.

O'Neill suggested that initially materials from the lunar surface could be placed on the 'plateau of free space' without rockets through the use of an electromagnetic accelerator called a mass driver. A thumbnail sketch of O'Neill's vision might read something like this:

A teleoperated human tended lunar surface facility is established to electrically launch a steady stream of baseball sized pellets of lunar material to a collection point in Earth-Moon L2. These materials are processed in high orbit into the feedstocks for the construction of additional lunar launching and processing system. Ninety percent of the mass of each succeeding set of hardware is derived from lunar materials with control electronics and other low-mass, difficult to manufacture items coming from the Earth. The system doubles every 90 days under direct control of human operators on Earth and with occasional visits for maintenance to permit the use of present levels of automation. When the infrastructure has grown to the desired size, all output is used to provide over 99% of the mass of solar power satellites and most of the mass of human space habitats. The technologies used for initial small space habitats enable long duration solar system exploration missions. Beamed power transmission technology permits rapid solar system travel.

Eventually all of the mass of space construction is provided by lunar and asteroidal materials. Humans plus seeds and other forms of information become the principal traffic between Earth and Space. Space power eventually replaces fossil fuels and permits acceleration of the standard of living of developing countries without destruction of the biosphere. Increased affluence and per capita energy availability stabilizes the population growth rate. Eventually remediation of environmental damage done to the Earth during the Industrial Age is accomplished. Persons seeking additional opportunities and freedoms are able to establish new settlements in free space.

Although O'Neill's scenarios may seem futuristic, he was not content to think simply about the future of human space activities. O'Neill and Dr. Henry Kolm of MIT built and demonstrated a 33 gravity mass driver prototype at MIT in 1976. Subsequent mass drivers built at Princeton

[13]O'Neill, Gerard K., *The High Frontier*. Wm. Morrow & Company, New York, 1977.

[14]O'Neill and Dr Peter E. Glaser, the inventor of the solar power satellite maintained a close collaboration from the mid 1970s until O'Neill's death in 1992.

University under sponsorship from NASA and the Space Studies Institute increased mass-driver performance to accelerations of over 1800 gravities. In addition the Institute funded development of Solar Power Satellite Designs, explored techniques for mining asteroids and the lunar surface, experimented with teleoperation using lunar signal delays and otherwise conducted and supported practical development of the tools and techniques required to use space resources. O'Neill and his colleagues argued that the most effective use of space program funds would be for search efforts to locate critical lunar and asteroid resources. O'Neill and his associates were early supporters of the Spacewatch Camera project led by Dr. Thomas Gehrels which uses modern light-sensing electronics coupled with telescopes to detect asteroids. The Institute initiated the design of a small spacecraft called Lunar Prospector to chemically map the moon and determine whether or not there were ice deposits in permanent cold traps at the lunar poles. These efforts ultimately led to NASA's selection of Lunar Prospector for flight in its Discovery series of low-cost probes.

After decades of exposure to the planetary exploration paradigm, it is natural that the battle of ideas between the two competing philosophies should be an interesting one. Proponents of the Tsiolkovsky/Cole/O'Neill paradigm argue that it makes no sense to climb out of our own planet's deep gravity well just to drop down into another one. However the Mars model was imprinted on most of today's space professionals and its continues to exert great influence even 20 years after Mars was found to be a cold dead world, greatly different than what had been assumed as late as the 1969 Integrated Space Program plan. Isaac Asimov, the great science and science fiction writer called the belief that the surface of planets are the only fit places for exploration or settlement 'planetary chauvinism.'

The competition between the philosophies has begun. Although the free space paradigm is the underdog of this battle, there is evidence that this context is becoming recognized internationally as a valid alternative to conventional exploration thinking.

The first example of the inclusion of the Tsiolkovsky/Cole/O'Neill thinking into the mainstream of space policy debate took place during the mid 1980s with the creation by President Ronald Regan in 1985 of the President's National Commission on Space, chaired by Dr. Thomas Paine, former NASA Administrator. Included on the commission were Dr. Gerard O'Neill and Dr. David Webb, both strong advocates of the Tsiolkovsky approach.

Although the report appears on the face to be a relatively unified document, a closer inspection shows it to contain both of the competing philosophies of our discussion. Dr. Paine was a strong advocate of traditional Mars thinking. However, he was also a broad thinker and a good chairman and therefore did not impede the inclusion of a very significant body of discussion in the report on a series of proposals and concepts which were directly from the Tsiolkovsky school of thought. (Drs Paine and O'Neill became friends and Paine would later serve on the board of O'Neill's Institute.)

The National Commission on Space Report marked a milestone in that, for the first time since the dawn of the space age, the Tsiolkovsky paradigm was seriously considered. Amongst all of the traditional discussions of Missions to Mars, we find serious discussion of self-replicating systems, space solar power for earth, large-scale space

habitats in free space and the use of Phobos and Deimos (which Dandridge Cole had romantically referred to as the 'offshore islands of Mars' and which played no role in the Integrated Space Program plan). The report said that it was a 'first priority' to search the lunar polar regions for possible water ice and other useful volatiles.

Unfortunately, the release of the Commission's report was overshadowed by the loss of the Space Shuttle Challenger in early 1986. Subsequent studies such as the Ride and Augustine Commissions and to some extent the Stafford Commission report, would mainly reflect the Mars paradigm. However, the new ground covered by the National Commission on Space reflected a fundamentally new approach in several key areas which is beginning to be reflected in both US and foreign space programs and policies.

In the USA, for example, the Ballistic Missile Defense Organization, took advantage of a program designed to test innovative new space hardware and sensors to explore the lunar surface from orbit. The Clementine spacecraft, launched in early 1994 successfully mapped the entire lunar surface from polar orbit and provided a dramatic demonstration of the utility of smaller, faster cheaper spacecraft programs. Colonel S. Peter Worden and Dr. Stewart Nozette acknowledged the influence of the Tsiolkovsky paradigm on their planning when they dedicated the Clementine mission to the memory of O'Neill in a Pentagon ceremony and press conference shortly after the spacecraft was successfully placed into lunar orbit.

An even more exciting boost to the Tsiolkovsky/Cole/O'Neill paradigm was the discovery by Clementine of a large, deep permanently shadowed region near the South Pole of the Moon. By using the spacecraft's bistatic radar, the area was probed and provides indications that the region may contain water ice and other frozen volatiles. The selection of Lunar Prospector, originally designed under contract to O'Neill's Institute, for flight in 1997 as part of the NASA Discovery program further demonstrates growing interest in this area.

Another sign of the growing influence of the Tsiolkovsky/Cole/O'Neill paradigm can be found in the creation and composition of the International Space University. ISU was founded by three Senior Associates of the Space Studies Institute and the Institute and ISU have a long history of cooperation. The Department of Space Resources and Manufacturing reflects the University's strong interest in the Tsiolkovsky/Cole/O'Neill paradigm. A more recently added Department of Space Humanities has provided international insight into the work of Tsiolkovsky with faculty from the Tsiolkovsky Museum in Kaluga now in regular attendance at ISU.[15]

A new report on Japan's *Future in Space* shows a recognition of the Tsiolkovsky/Cole/O'Neill philosophy. This report was produced by the Special Committee on Long-Term Vision of the Space Activities Commission and is expected to provide the underlying policy foundation for all of Japan's activities in space until well into the twenty-first century. The report was commissioned on October 20, 1993 by the Space Activities Commission of Japan. This report recognizes the fundamental differences in the global space environment as a consequence of the end of the Cold War. It notes the shift toward commercial and other civil uses of space as well as the use of space to help solve pressing environmental issues.

The most important themes for the world in the 21st century will be to

[15]In a ceremony at the 1995 ISU session in Stockholm, the three founders of ISU were presented with the Tsiolkovsky Medal as a tribute to their work in space education.

establish a more peaceful, stable international order and to open the gateway to continued development of human society by such measures as ensuring ample food and energy supplies for a growing world population and protecting the global environment.

The philosophy of space development, therefore, should be that it enables access to the unknown vastness of space and use [*sic*] the infinite potential of space as the common property of all mankind, thereby making a full and effective contribution to the enduring prosperity of all the inhabitants on earth (p 1).

With specific regard to human spaceflight the report continues: 'Expansion of the sphere of human activities and prolonging the existence of mankind as a fundamental goal.' In addition to conventional space applications such as remote sensing, navigation and communications the report suggests that:

> If resources and energy, which are limited on earth, could be effectively employed and used in space in the long term, human activities in space could be expanded. Furthermore, if it could become possible to use them on earth, the sphere of human activities would be expanded tremendously, greatly contributing to the continued prosperity of mankind.

The report also discusses commercial motivations including energy

> Efficient use of solar power is very important for establishing an energy cycle in space to avoid having to carry energy from the earth to space. In the long term, if economical and environmental problems should be solved, it could be possible to transmit solar energy back to the Earth.

Japan has been one of the world leaders in work on Space Solar Power for Earth. Pioneering experiments in Wireless Power Transmission have included a series of space experiments including the first transmission of power from one spacecraft to another in the international METS experiment in 1993. A microwave powered aircraft (MILAX) was flown in 1992. The second largest utility company in Japan, Kansai Electric Company debuted a ground to ground Wireless Power Transmission demonstration system in 1994 and Kobe University hosted the Wireless Power Transmission '95 conference in October, 1995. At this conference Japanese feasibility studies of Solar Power Satellites and Power Relay Satellites were discussed at length.[16]

Another area where interest in the Tsiolkovsky/Cole/O'Neill philosophy is growing results from recent information about asteroids. Largely ignored (or even reviled by astronomers as the 'vermin of space') these planetesimals figured prominently in the work of the three pioneers. Now advances in astronomical techniques and the relentless efforts of asteroid researchers such as Eleanor Helin, Thomas Gehrels and the Shoemakers are detecting record numbers of asteroids in an array of orbits and compositions.

Although early discussions of asteroid detection and deflection were reviled by elements of the press as an excuse for the defense and aerospace communities to find some new work, the spectacular interaction between Comet (or asteroid) Shoemaker-Levy and the planet Jupiter in 1994 has generated new awareness of these small bodies. The realization that the very history of the earth was profoundly shaped by interaction with these objects has begun to alter out thinking about the

[16]Conference Proceedings on the WPT 95 Conference will be published by the *Journal of Space Energy and Transportation*. For information contact editor Aleta Jackson at 2800 Shirlington Road, Arlington, VA 22206. Tel: +1 703 671 4116.

solar system. For example, much of the Earth's water may be the result of cometary materials deposited on the Earth. Every school child now learns of the Alvarez theory of the extinction of the dinosaurs at the KT boundary.

Although NASA has been generally slow to accept any changes to the Integrated Plan[17] there are some encouraging signs in this regard. Most recently, Administrator Dan Goldin suggested that there were three general human exploration projects on the horizon. These are, he suggested, lunar bases, Mars exploration and an asteroid research base. His inclusion of asteroids, in any form, is a radical departure from the norm since the beginning of human space flight over 30 years ago.

The present Congressman majority in the US includes Congressional Dana Rohrabacher of California who intervened with NASA Administrator Richard Truly to obtain NASA support for the (then private) Lunar Prospector mission initiative. Speaker of the House Newt Gingrich is also knowledgeable and supportive of many of the Tsiolkovsky/Cole/O'Neill concepts and was personally acquainted with O'Neill.

There is a growing vocal minority which is clamoring for a change in NASA's approach to human space exploration. Internationally there is an increasing sense that the alternative approach provided by the original Tsiolkovsky paradigm is timely now.

A project conducted by ESA entitled Project Space Vision recently examined motivations for human space flight. Using the Internet and other modern communications tools, the project leaders surveyed primarily young space professionals and enthusiasts. The report of the project which was presented to support ESA policy making activities included the following admonition:

> As you formulate a policy for future space activities, consider that there are at least two distinctly different ways of thinking about space:
>
> - One is the spectacular 'Let's conquer space!' mentality inspired by Von Braun which took humanity to the Moon and still permeates much of our planning in US and Europe.
> - The other is the alternative vision of thinkers like Tsiolkovsky that emphasizes that 'Space is part of humanity's natural home.'
>
> In spite of its initial success, it seems difficult to see how the first approach can take us much further than where we are now.
>
> The second way of thinking, on the other hand, may offer a route towards a sustainable, growing space effort which can answer the needs and desires of humanity. You may find that this vision can be applied more successfully when considering the future for our generation.[18]

Trends and conclusions

The present malaise in human space exploration, which began decades before the end of superpower competition, is likely to continue if space agencies continue to follow the outmoded Mars exploration plans of the 1950s and 1960s and find rationales which connect space exploration to the challenges facing our world and our societies at present.

History since Apollo has shown that the world is largely indifferent to human Mars exploration plans and that in particular, the US Congress, now the largest customer for human space exploration funding, is positively hostile towards this notion.

[17]Though in fairness, it must be acknowledged that NASA did provide funding for O'Neill's work in such areas as the mass-driver, and studies on the space colonization, the use of space resources, solar power satellites and self-replicating systems at various times over the past 20 years.

[18]*Project Space Vision*. European Space Agency, Paris, 1995.

There is evidence that the original Tsiolkovsky paradigm is gaining momentum and is a better fit to the needs of society than the Integrated Space Program proposed in 1969. The possibility of economic return (arguably after a period of government pioneering efforts) enables the private sector to eventually become the principal force in space activity.

Facts learned since 1969 strongly favor pursuit of the Tsiolkovsky/Cole/O'Neill model of space exploration. Advances in astronomical technology such as the use of charge-coupled devices which have a higher quantum efficency than photographic emulsions are showing that the solar system is full of interesting asteroid types and locations which provide a rich range of destinations for future human and robotic visits. For example, Earth approaching asteroid 1979 VA is now known to be the spent comet core of Comet Wilson-Harrington.

If the Clementine space probe did indeed find water at the South Pole of the moon, our nearest neighbor suddenly assumes a much higher priority for human space exploration.

Further there is a growing environmental awareness which was not a factor in the original wave of human space exploration. This awareness could provide the basis for support of human space development as a means of protecting and eventually repairing the Earth's biosphere. Evidence of the casual relationship between human energy and industrial activities and global climate continues to mount. Should the world become serious about curbing carbon dioxide emissions, space power for earth could provide energy at the densities required for cities and industrial activity and provide 24 hour energy for the production of hydrogen and synthethic fuels which may replace natural petroleum as the mainstay of modern civilization.

Harry Shipman in his book *Humans in Space* argues that space activities can go in either of two directions depending on whether or not the sort of activities encompassed by the Tsiolkovsky/Cole/O'Neill vision of space become feasible.[19] He asked two fundamental questions.

(1) Will space industrialization work?
(2) Can extraterrestrial resources be used to support humans?

If the answer to both questions is yes, he sees full space settlement coming to pass. If space industrialization is feasible but the use of space resources to support humans is not, then he predicts robotic mines, factories and laboratories.

If extraterrestrial resources can be used to support humans, but space industrialization proves infeasible, than Shipman predicts space tourism and space research activities to be successful.

If however, both space industrialization and the use of space resources to sustain human communities are not practical, then Shipman sees space relegated to a very limited role where the only activity performed is space science.

We believe that it is the duty of the space community to fully explore all of the possible rationales for human space exploration and development in order to address the proper and difficult question of why invest precious resources in the face of compelling present problems. If we fail to do so or if we continue to proffer outdated rationales we will see a continued decline in both human and unmanned space exploration. On the other hand, if we are successful in addressing such urgent issues as energy and the environment through space development, we will assure the human breakout into the cosmos.

[19]Shipman, Harry, *Humans in Space*.