Columbia: A Permanent Lunar Base

FINAL REPORT to NASA Office of Space Flight

December 17, 2003

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"Our journey into space will go on. The work of the crew of the Columbia and the heroic explorers who traveled before them will continue."

> President George W. Bush August 29, 2003



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"Now it is time to take longer strides – time for this nation to take a clearly leading role in space achievement, which in many ways may hold the key to our future on Earth."

> John F. Kennedy May 25, 1961 before a joint session of Congress

"America's Space program will go on. This cause of exploration and discovery is not an option we choose. It is a desire written in the human heart. We are that part of creation which seeks to understand all creation. We find the best among us, send them forth into unmapped darkness, and pray they will return."

George W. Bush

February 7, 2003 at NASA's Lyndon B. Johnson Space Center, Houston, Texas at the Memorial Service of the STS-107 Crew of the Space Shuttle Columbia

This report assesses the current technology base and recommends a comprehensive program to reaffirm and reorient the U.S. Human Space Flight Program and reach a succinct goal:

Columbia, The First Lunar Base Within A Decade.

Achieving this worthy goal would give the American taxpayer, every night, an easily seen visual symbol of civilian U.S. effort and accomplishment, with continuous recognition and admiration by all peoples on our planet.

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Foreword

"The U.S. space effort has moved forward for more than 30 years [since Apollo] without a guiding vision, and none seems evident. In the past, this absence of a strategic vision in itself has reflected a policy decision, since there have been many opportunities for national leaders to agree on ambitious goals for space, and none have done so. . . . We believe that the White House, Congress, and NASA should honor the memory of Columbia's crew by reflecting on the nation's future in space and the role of new space transportation capabilities in enhancing whatever space goals the nation chooses to pursue."

> COLUMBIA ACCIDENT INVESTIGATION BOARD Report Volume 1, August 2003

The recent *Columbia* Accident Investigation Board, chaired by Retired Admiral Harold W. Gehman, focused on the physical and organizational causes of the *Columbia* accident and recommended actions for future safe Shuttle operations. Most profound is the Board's realization, stated on page 209, of two key missing causal realities that undermine the nation's ability to sustain a viable, vibrant manned space program:

- "The lack, over the past three decades, of any national mandate providing NASA a compelling mission requiring human presence in space;" and, following the lack of such a clearly defined long-term space mission,
- "The lack of sustained government commitment over the past decade to improving U.S. access to space by developing a second generation space transportation system."

For over three decades technical experts have differed little about what should be the space exploration steps after the American flag was placed on the Moon in response to President Kennedy's historic 1961 charge to send Americans to the Moon and return them safely "before this decade is out." What has been missing is the same kind of political commitment and will to empower NASA to take the next logical step beyond program Apollo.

Under growing adverse political and fiscal pressures associated with the Vietnam War, President Nixon rejected NASA's 1969 proposed strategic vision and detailed technical plan for a post-Apollo effort that involved full development of low-Earth orbit, permanent outposts on the Moon, and initial journeys to Mars. Since then, these objectives have reappeared in numerous proposals for the long-term vision of the U.S. space program, for example:

• The 1986 National Commission on Space, following the *Challenger* accident, proposed "to lead the exploration and development of the space frontier, advancing science, technology and enterprise, and building institutions and systems that make accessible vast new resources and support human settlements beyond Earth orbit, from the Highlands of the Moon to the plains of Mars."

 Following President George H.W. Bush's 1989 call for a Space Exploration Initiative on the 20th anniversary of the first Lunar landing, the National Space Council's 1990 Advisory Committee on the Future of the U.S. Space Program observed that the primary justification for the space station is to conduct research to plan missions to Mars and other distant destinations. In 1991, former astronaut Retired Air Force Lt. General Thomas Stafford led The Synthesis Group in examining four architectures for President Bush's proposed Space Exploration Initiative: 1) Mars Exploration; 2) Science Emphasis for the Moon and Mars; 3) The Moon to Stay and Mars Exploration; and 4) Space Resource Utilization.

Regrettably, no particular architecture was pursued – leading to another decade without a strategic vision to guide NASA in making policy or day-to-day program decisions. And, as the adage goes, "When you don't know where you are going, any road will take you there."

This report takes the perspective that 'Going to the Moon to Stay' is preferred and, after explaining the reasons for this choice, assesses the current technology and recommends a specific program for NASA to pursue such an enterprise. Based upon the wealth of available background material from studies, technology programs, and associated recommendations dating to the Apollo program and earlier – particularly to the 1969 Space Task Group, this report assesses the current technology base and recommends costs and schedules for a comprehensive program to reaffirm and reorient the U.S. Human Space Flight Program and reach a succinct goal:

Columbia, The First Lunar Base Within A Decade.

This report builds upon the original High Frontier Report of 1981, which comprised major goals and technology opportunities for both civilian and military space activities. It helped to build the base for President Reagan's Strategic Defense Initiative, but had little follow-through or programmatic impact regarding major civilian activities and goals then outlined. Hopefully, this report will help rectify three decades of a lack of a national vision for Human Space Flight Program.

Ambassador Henry F. Cooper Chairman, High Frontier December 17, 2003

Executive Summary

A Historic New Goal for NASA

This report gives a cogent rationale for Human Space Exploration, assesses the technology base, and recommends a specific program to pursue a specific objective – to establish a permanent Lunar base within a decade. In honor of the lost crew of Columbia, we propose to name this permanent Lunar Base, Columbia.

The proposal to return to the Moon and establish a permanent Lunar base is based on the consistent findings of many studies and reports dating back to the 1940s and 50s; the comprehensive post-Apollo program recommended initially by the 1969 Space Task Group¹; the Space Shuttle and later Space Station decisions of the 1970s and 80s; the various Space Commission efforts of the 1980s and early 1990s; and the recent Gehman Board report – and the associated conclusions and recommendations².

This wealth of materials and past assessments strongly suggest that establishing a permanent Lunar base within a decade is a succinct, clear, achievable goal for Human Space Flight for the next decade. For three decades, the extant technology base has provided the basis for this major reaffirmation and reorientation of the U.S. Human Space Flight Program, at acceptable costs and a set schedule. As Columbus opened the sea-lanes to a new world over half a millennium ago, so will Moon base Columbia open 'Space lanes' for human exploration and enterprise.

Assessment Criteria

The detailed assessment and recommendations elaborated in the following pages were molded by the following constraints on the program for Human Space Exploration:

- 1. <u>Accomplish within a decade</u> anything longer is beyond the attention span of U.S. political decision-making in trading off budget requirements.
- 2. <u>Require no substantial increase in NASA budget</u> a major challenge will lead to major reorientation, but should not more than double the NASA budget.
- Capitalize on past technology achievements and knowledge base including for the Apollo, Shuttle, and Space Station components, space operations know-how, and related experience of U.S. industry.
- 4. <u>Significantly increase civilian and national security uses of space</u> by opening and exploiting Cis- and Circumlunar Space for U.S. space activities.

¹ The 1969 Space Task Group was composed of the Vice President (Chairman), the President's Science Advisor, the Air Force Secretary, and the NASA Administrator – and included as observers, the Director of the Bureau of the Budget, the AEC Chairman and the Undersecretary of State for Political Affairs. See T.A. Heppenheimer, *The Space Shuttle Decision*, NASA SP-4221, p. 125.

² For example, see *Pioneering the Space Frontier: Report of the National Commission on Space*, Bantam Books, 1986; *America at the Threshold: America's Space Exploration Initiative*, The Synthesis Group, U.S. Government Printing Office, 1991; and *Columbia Accident Investigation Board Report*, U.S. Government Printing Office, 2003.

- 5. <u>Assure manageable risk</u> by reducing long duration space travel uncertainties: effects of micro gravity, cosmic heavy particle radiation, and prolonged isolation.
- 6. <u>Make a historic contribution to the expansion of human enterprise</u> in particular, to develop an Earth-independent technology base for human habitation outside and ultimately independent of Earth.
- Encourage a new regime for human and economic activities in space to allow for free enterprise in pursuit of Space activities.
- Conform to the "iron laws" of economics: transportation and time (interest) costs – to accommodate the inescapable "delta-V" and investment interest requirements which increase geometrically with distance from the Earth.
- 9. <u>Stimulate the Nation's youth and their enthusiasm for exploration, science</u> <u>and technology</u> – requiring complementary programs to involve students and academia along with industry, beyond usual Federal grants and contracts.
- 10. <u>Be a U.S.-led program</u> with welcome participation of other nations.

The GOAL: Columbia, A Permanent Lunar Base

When numerous past studies are considered, their recommendations can be grouped to compose three possible goals for NASA's near-term Human Space Exploration program: 1) Abandon Human Space Flight, 2) Go to Mars, and 3) Establish a human presence on the Moon. The first is unimaginative and unresponsive to the human thirst for exploration; the second fails several of the above assessment criteria – particularly that the goal be accomplished within a decade – but could be a logical extension of the third, which is, in any case, a precondition for further human exploration of space.

This study concludes – consistent with the 1969 Space Task Group – that establishing a Lunar base on the Moon within a decade is the logical next step in space exploration. We propose to name that Lunar base "Columbia," in honor of the crew of Columbia and all those who have given their lives in seeking to explore the last frontier of space – and for Columbus, who over 500 years ago opened the sea lanes to the New World.

The MEANS: Technology Building Blocks

- Upgrade current Space Infrastructure Investments, starting with an upgrade of the Space Shuttle system to "2000" technology, including replacement of SRBs with pressure-fed liquid (LOX/LH2) boosters – resulting in major reductions in flight costs, schedules and risks, increased payload capabilities, and a full range of STS technology modules for cargo and Human Space Flight.
- <u>Develop reusable upper stage</u> (Space Tug) for Cis- and Circumlunar operations. A modular approach should allow for the accommodation of all foreseeable manned and unmanned requirements as well as rescue and abort capabilities to/from/beyond Shuttle and Space Station orbits.
- 3. <u>Develop in-orbit fuel storage and transfer capabilities</u>, allowing Space Station uses as a "Space Port" or refueling/logistics station.
- 4. <u>Develop a Lunar Closed Ecological Life Support System (CELSS) Lunar</u> <u>Habitat</u> as NASA's primary space goal for the next decade.



Figure 1 – Closed Ecological Life Support Systems (CELSS)

Costs, Risks and Schedules

Based on several independent best judgments, a "first order" assessment of the costs of providing this "infrastructure" for human exploration of Space – on the Moon within a decade – involves a realignment of and an increase in the NASA budget well within the criteria set forth above. The benefits from this investment will exceed many times the "up-front" cost, even when considering only the "narrow" effects on the communications, information and energy sectors of the global economy.

This is thought to be a high-confidence assessment, since most required technology is well within the state-of-the-art – no fundamental advances in Space technology are needed. All anticipated needed advances are incremental – in fact, extensions beyond NASA's capabilities that have existed since the early 1970s. No overriding technology risks are involved and this initiative will substantially reduce immediate human Space flight risks: A substantial part of the required investments will fulfill the requirements proposed in the Gehman Commission report, as discussed in Chapter 3.

And yes, human Space flight will remain fraught with risk and loss of life, just as all exploration over ages past was and will remain so.

Critical to establishing a permanent Lunar base within a decade within these costs will be a single minded implementation of technology options outlined in this report, building on the existing Space Shuttle, Space Station and Life Sciences technology base.

Equally important will be that NASA be held to the requirement to accomplish this historic mission within the decade – by 2014; any 'slack' in this ironclad requirement would lead to an inexcusable squandering of taxpayers' resources.

Last and not least, in the pursuit of these opportunities while containing the costs to the public sector and taxpayers, will be the forging of a constructive partnership between NASA and the vast resources of the private sector. Critical will be defining the 'rules of the road' for opening Space for Human enterprise, with a reaffirmation of strong private property rights – similar to the original 1775 Declaration of Rights of Virginia.

PROSPECTIVES Following From This Near-Term Space Goal

Generations to come will remember this first Earth-independent Human settlement, which will far outshine the historically important settlement of Jamestown by English settlers in 1607. Indeed, Columbia will become the Jamestown of Space civilization. This overarching goal for the U.S. Space program for the next ten years will move mankind out of the 'single point failure mode' of planet Earth and revive the prospect of unknown new frontiers, the moving force in human exploration.



As illustrated in Figure 2 above, 'Columbia' will also add to our perspectives of Earth – just as the first "Full Earth" images from Apollo 8 fundamentally changed mankind's awareness of Earth and its 'vulnerability,' giving rise to an ecological movement worldwide. So will the first permanent settlement on the Moon change our awareness of Cis-Lunar Space – and add to the myriad uses of satellites already in operation, affecting our daily lives, well-being and security interests. New uses of Space and the resources of Space for and on Earth will undoubtedly follow.

Examples of areas of exploration with major improvements for planet Earth include:

- Communications and observation platforms for information activities worldwide.
- Large Geosyncronous and High Earth Orbit (HEO) structures, including at various libration points.
- Security provided by Columbia's "High Ground" – in Cis- and Circumlunar Space – may develop similarly to the "Rock of Gibraltar," which contributes to observing and controlling access to and from the Mediterranean.



Figure 3 – Large HEO Structures

• **RDT&E of inexhaustible new Space energy resources** for use on the Moon, in Space and possibly on Earth. For example, more Solar energy 'hits' the

surface of the Moon in but 10-days than the energy from all known global fossil fuel resources accumulated over eons past on Earth. A 10 Giga-Watt solar power plant can be built on the Moon with 'proven' technology. Such a concept is shown in Figure 4 [Solar Arrays (1), Microwave Transmitters (2), Reflectors (3) – all made from lunar soils by various production equipment (4, 5 and 6)].



Figure 4 – Solar Energy Production on the Moon for Cis-Lunar Space

• CELSS feedback to husbanding resources on Earth – possibly similar in its economic and environmental effects in the 21st century to the effects of electronic miniaturization and computation in the 20th century. The ability to sustain life and a community of astronauts independent of Earth by recycling waste materials and the use of "local" Lunar resources will have deep implications as to technologies and systems available on Earth, leading to a parsimonious 'husbanding' of resources.

Looking toward Earth and Cis-Lunar Space will produce the most immediate practical applications and 'paybacks' for the investment to establish a permanent Lunar base. Looking outward – toward continuing the journey into Space – will address man's thirst for information on the worlds beyond our direct experience. Specific initiatives could include:

- Large astronomical observatories on the 'back side' of the Moon a decades old dream of astronomers, allowing ultra-large, distributed aperture observatories looking into the innermost processes of the universe, its origin and ultimate destination;
- **"Earth Independence"** the Moon is the 'natural' testbed for Human exploration missions beyond the Moon in subsequent decades, such as Mars, the Asteroids and eventually the outer planets. In the long run, certainly such 'independence' of human existence must be regarded as an 'ultimate' technological achievement of mankind – wherever the journey may take us.



Figure 5 – The Moon: Platform for Solar System Exploration and Beyond

"[With future rocket developments], it will be possible to go to other planets, first of all to the Moon. The scientific importance of such trips is obvious."

> Wernher von Braun – Memorandum to the U.S. Army – Spring 1945 (See Appendix D)

Profound Education, Science and Technology Implications

Science and technology do not happen in the 'abstract,' as percentages of GNP or from incantations of the need for more Ph.D.s, engineers, technical workers and educators, more science, statistics and mathematics, high school students and college graduates.

Incantations or lamentations about America's deteriorating technology base will go unanswered without agreed goals that challenge our imagination and make us take the hard road of sweat and tears and work and risk. The "Columbia" Lunar base challenge will bring entirely new opportunities, with applications in the next decade requiring untold numbers of enterprising new employment prospects. Recent downward trends can be reversed, and not only will many Americans seek a future of opportunity but also an influx of untold thousands worldwide will join us in Space enterprise. Furthermore, the innovative spirit of free enterprise, encouraged by policies that reward risk-taking by venture capitalists and entrepreneurs, can complement and supplement NASA efforts to multiply the technological gains from seeking to establish a Lunar base within a decade.

We know of no goal or enterprise – including the Manhattan Project – that have had or will have more profound impacts and open more opportunities for generations to come than this single initiative: to return to the Moon within a decade – and this time to stay.

But beyond all these considerations, there is the spirit of the human mind and human enterprise, the historical imperative to expand into the 'void' of Space:

Let the first child born outside Earth, on the Moon, be from America, of a mother who risked her life in pursuit of flight. Let that child be named for all those who died in the quest for exploration, from Kitty Hawk to Columbia, and those yet destined to die – for all explorers of ages past, and of ages yet to come. Let that child be a messenger of freedom, a witness to the spirit of exploration and enterprise, for all generations that will follow that child on our journey into Space and, ultimately, to the stars.



"We choose to go to the Moon. We choose to go to the Moon in this decade and do the other things, 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 postpone, and one which we intend to win, and the others, too."

> President John F. Kennedy Rice University, Texas – September 12, 1962

"Here's one Small Step for a Man – One Giant Leap for Mankind"

Neil Armstrong – On the Moon July 20, 1969



Why the Moon?

"Earth's closest neighbor in space, the Moon, is surprisingly complex. It is an object for detailed exploration, a platform from which to observe and study the universe, a place to live and work in the environment of space, and a natural source of materials and energy for an emerging space-based economy.

"The Moon offers a record of four billion years of planetary history. Its violent birth and history of bombardment from space is closely related to events on the early Earth. The Moon provides a natural laboratory for detailed study of geology and planetary formation, the output of our Sun over its lifetime, and the elements of our universe. The Moon's 14 Earth-day night, crystal clear, airless sky and stable ground provide a superb platform for astronomy.

"The Moon is the nearest object in space where people can live under conditions similar to those we face on other planets. Thus, the Moon is a natural test bed to prepare for missions to Mars through simulation, system testing, operations and studying human capabilities.

"The Moon is a rich source of materials and energy for use in space. Abundant metals, ceramics and recoverable amounts of hydrogen, carbon, and oxygen can provide propellants and human life support from the lunar surface. The 14 Earth-days of a lunar daytime provide abundant solar energy. Our Moon provides a rich scientific and economic way station for human expansion into the Solar System."

America at the Threshold Report of the Synthesis Group on America's Space Exploration Initiative Chaired by Retired Air Force LGen. Thomas P. Stafford May 1991