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William D. Goldsby

Chief, Program Integration & Special Projects Office Kennedy Space Center, Florida

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by William D. Goldsby
Chief, Program Integration & Special Projects Office
Kennedy Space Center, Florida

ABSTRACT

Reliable access to space through the use of a mixed fleet of launch vehicles, including the Space Transportation System (STS) and other existing and new systems, will be needed to provide the capability to accommodate the major new initiative for the Human Exploration (HEI) Program. The operational Space Station Freedom (SSF) will be established as a transportation node for Lunar and planetary missions and will required the Shuttle-C for assembly and implementation. The proposed Lunar mission schedule beginning in 1999 will also require a heavy lift launch vehicle (HLLV) capability in the class of the Shuttle-C. The large payloads and associated quantities of propellant needed for the establishment and maintenance of Lunar and Mars outposts will require a heavy-lift launch capability not now available to the United States with existing Earth-to-orbit transportation systems. This augmented mixed fleet of launch vehicles will require extensive expansion and modification in the vehicle and payload launch processing operations, to meet current commitments and to accomplish this bold new initiative.

This paper will provide an update of the planning for the Human Exploration Initiative announced by President Bush on July 20, 1989. It will review the activity that has transpired during the period following this announcement and will discuss the various options in mission design, proposed launch vehicles and program phasing under consideration, with special emphasis on the planning for the ground processing capabilities required at the Kennedy Space Center.

INTRODUCTION

On July 20, 1989, President Bush charted a new course for the human exploration of space:

"...a long-range continuing commitment. First, for the coming decade, for the 1990's, Space Station Freedom, our critical next step in all our space endeavors. And next, for the next century, back to the Moon, back to the future, and this time, back to stay. And then a journey into tomorrow, a journey to another planet, a manned mission to Mars. Each mission should and will lay the groundwork for the next."

In his speech on July 20, 1989, President Bush asked Vice President Quayle to lead the National Space Council in determining what is needed to chart a new and continuing course to the Moon and Mars and beyond: the necessary money, manpower, and materials, the feasibility of international cooperation, and realistic timetables with milestones along the way.

STUDY TASKS

Now that the President has defined where we are going, the next step is to decide how and when. To support the Vice President and the National Space Council in this task, NASA initiated a study to develop the reference base from which strategic options could be derived. The purpose of the study was to examine the elements of a human exploration program, assess current capabilities, determine ways in which new developments would be required, and provide this information in a cohesive package to support the decision making process.

The five reference approaches studied reflect the President's strategy: First, Space Station Freedom, and next back to the Moon, and then a journey to Mars. The destination is, therefore, determined, and with that determination the general mission objectives and key program and supporting elements are defined.

NASA's Office of Exploration was established in June 1987 in response to the task force's recommendation that NASA establish a focal point to fund, lead, and coordinate studies examining potential approaches to human exploration of the solar system, based on the Outpost on the Moon and Humans to Mars Initiatives. For the past 2 years, NASA has examined in detail a number of potential strategies: Apollo-type expeditions to Mars and its moons, evolutionary plans for permanent human presence on the Moon and Mars, and scientific observatories on the Moon. The goal of this effort has been to develop a substantial base of knowledge on technical and programmatic requirements in order to enable the President to define a pathway for the human exploration of the Moon and Mars.

LUNAR/MARS INITIATIVE OBJECTIVE

Our first stop as we move outward from Space Station Freedom into the solar system is the Moon, where we can find clues about the early days of Earth. Current scientific theory holds that the Moon formed when a Mars-sized body collided with Earth. By exploring lunar origins, we may understand not only the formation of Earth, but also other mysteries of our solar system, such as the tilt of Uranus and the rotational spin of Venus. The lunar surface also contains records of cratering processes, obliterated on Earth by erosion, which may contain clues about the extinction on Earth of entire species. Such breakthroughs may lead to profound discoveries about how life, including human life, evolves. Studies of the Moon will also yield important information about its natural resources, which is a vital first step in becoming a multi-planet species.

We will not stop at the Moon, but will venture to Mars, the planet most like the Earth. Mars offers many unique scientific opportunities, but perhaps the most intriguing question is whether life exists or has ever existed on Mars. Ancient river beds and channels indicate that water once flowed on Mars and that life could have formed there. Life may exist on Mars today in underground habitats where volcanic heating melts ground ice, producing a warm, wet environment protected from harsh surface conditions. Only scientists working on Mars can discover the answer to this age-old question.

EXPLORATION STRATEGY

The overarching goal of the Human Exploration Initiative is to expand human presence in the solar system, developing nearly self-sufficient communities on new worlds and promoting significant advances in science and technology. The Initiative, outlined in Figure 1, will follow an evolutionary pathway over a 30-year horizon beginning with Space Station Freedom in the 1990's, followed by a permanent outpost on the Moon at the beginning of the next century, and culminating with Mars expeditions that lead to a permanent martian outpost.

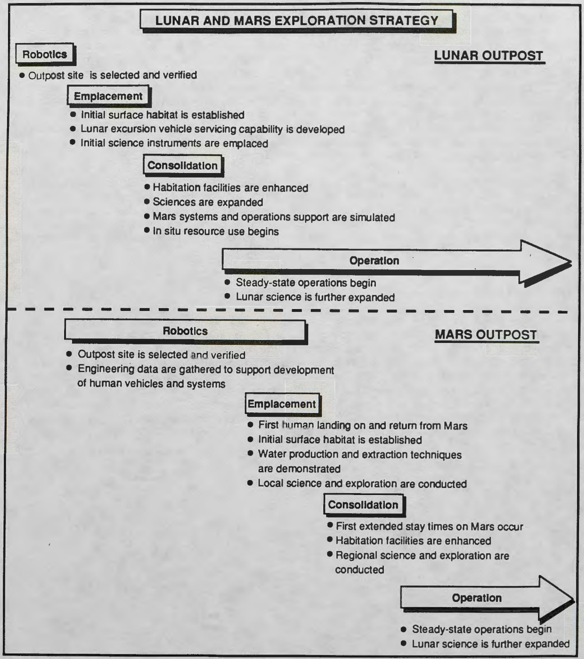


Figure 1

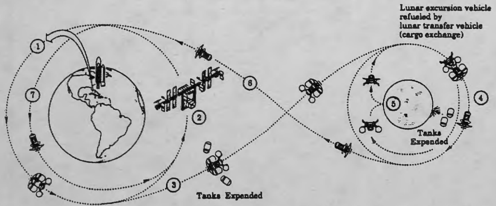
Freedom will serve as a controlled testbed for developing and validating systems and elements, such as habitation and laboratory modules and life support systems, to be used later on the Moon and Mars. In addition, Freedom will support technology experiments and advanced development in mission-critical areas, such as spacecraft assembly, servicing, and system development. When the exploration missions begin, Freedom will become a transportation node where both lunar and Mars vehicles will be assembled, tested, launched, and refurbished to fly again.

The next step in this evolutionary process will be to build a permanent outpost on the Moon to establish human presence for science and exploration. Rovers and crew will explore the geology and geophysics of the Moon itself, and rock and soil samples will be analyzed in a lunar laboratory. The unique characteristics of the lunar environment make it an excellent platform from which to conduct astronomy, physics, and life sciences research. The Moon also provides an ideal location, just a 3-day trip from Earth, at which human beings can learn to live and work productively in an extraterrestrial environment with increasing self-sufficiency, using local lunar resources to support the outpost. In this way, the lunar outpost will both advance science and serve as a testbed for validating critical mission systems, hardware, technologies, human capability and self sufficiency, and operational techniques that can be applied to further exploration.

Initial missions to Mars will prove the systems and techniques required for continuing human missions and will conduct further reconnaissance of selected landing sites. Later missions will establish a Mars outpost with the objective of conducting science and exploration on the solar system's most Earth-like planet, expanding mankind's sphere of influence in the solar system, and living and working in an extraterrestrial environment with a high degree of self-sufficiency.

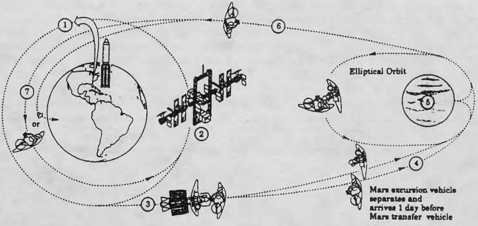
MISSION PROFILES

Missions to the Moon fall into two categories: piloted and cargo. Figure 2 illustrates the typical mission profile for delivering crew and cargo to the lunar surface. A piloted mission delivers a crew of four and some cargo to the lunar surface and returns a crew of four and limited cargo to Freedom; a cargo mission delivers only cargo, and the vehicle is either expended or returned empty. The missions use common transfer and excursion vehicles. A typical mission profile is shown in Figure 3 for flights to Mars. Piloted flights to Mars employ two different trajectory classes, distinguished by round-trip mission time: 500-day round-trip missions with short stays (up to 100 days) on the surface; and 1000-day round-trip missions with much longer surface stays of approximately 600 days.



(1) Payload delivered to Space Station Freedom	(5) Excursion vehicle returns to Moon with payload
(2) Lunar transfer vehicle mated with payload at Freedom	(6) Trans-Earth phase with transfer vehicle
(3) Trans-lunar phase with lunar transfer vehicle	(7) Transfer vehicle aerobrake maneuver and return to Freedom
(4) Lunar transfer vehicle rendezvous with lunar excursion vehicle from Moon	

Figure 2



(1) Payload delivered to Space Station Freedom
(2) Mars transfer vehicle mated with payload at Freedom
(3) Trans-Mars phase with Mars transfer vehicle
(4) Mars transfer vehicle remains in Mars orbit; Mars excursion vehicle descends to surface
(5) Excursion vehicle to/from Mars surface
(6) Trans-Earth phase with transfer vehicle
(7) Transfer vehicle aerobrake maneuver and return

Figure 3

ETO VEHICLES AND SPACECRAFT

The large masses required to undertake Lunar/Mars missions necessitate the development of a larger class of heavy-lift launch vehicle, with a capability approximately double that required for lunar missions. The Mars heavy-lift launch vehicle will also require larger payload compartments to accommodate the volume of the Mars exploration systems.

Many types of launch activities are included in currently planned missions: assembly, logistics, and crew rotation for Space Station Freedom and space platforms; servicing of satellites and Spacelab; and delivery of communications, science, planetary, and observatory satellites. The current Space Shuttle and a family of expendable launch vehicles, some of which already exist, and other of which will be operational soon, can support these activities. Augmentation with heavy-lift launch systems will provide the Earth-to-orbit launch capability necessary to support human missions to the Moon and Mars. For lunar and Mars outpost missions, the Space Shuttle will transport crews and limited cargo to low Earth orbit. It will also support related on-orbit servicing missions in conjunction with Freedom and a space-based orbital maneuvering vehicle.

By the middle to late 1990's, a heavy-lift Earth-to-orbit launch capability will be required to support the Lunar/Mars Initiative. The only heavy-lift concept being considered for use before 1999 is Shuttle-C, an unmanned Shuttle-derived cargo vehicle in which the Shuttle orbiter is replaced by a cargo carrier. Such a vehicle could support assembly of Freedom and its growth to a lunar transportation node. New, larger heavy-lift vehicles will be needed to launch the payloads, space vehicles, and propellants for the Mars missions, because the mass to be put into Earth orbit is much greater than that of any previous mission. This capability can be provided by a large Shuttle-derived launch vehicle or a future version of the Advanced Launch System vehicle.

In the area of Earth-to-orbit transportation, the Nation's current mixed fleet of Space Shuttles and expendable launch vehicles clearly requires enhancement. The Space Shuttle will be used to carry the crew to Space Station Freedom, but the massive cargo flights necessary to support extraterrestrial human exploration mandate launch vehicles with much greater lift capacity: approximately 60 metric tons for the lunar outpost, and about 140 metric tons for the Mars outpost. The current Shuttle has a capacity of 22 metric tons. Figure 4 depicts the relative sizes of the Lunar/Mars vehicles to the orbiter and its capacity. Various concepts for vehicles to accommodate these requirements range from Shuttle-derived vehicles to versions of the planned Advanced Launch System.

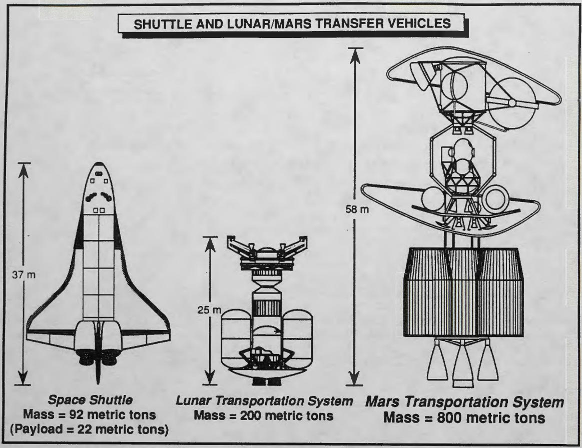


Figure 4

MANIFESTS

The Human Exploration Initiative provides a framework within which various elements of and approaches to human exploration of the Moon and Mars can be examined. In order to provide the data necessary to make these types of assessments, several reference approaches have been selected to determine which parameters drive such things as cost, schedule, complexity, and program risk. Five reference approaches were analyzed, each of which is characterized by a particular emphasis: (1) Balance and speed; (2) The earliest possible landing on Mars; (3) Reduced logistics from Earth; (4) Schedule adapted to Space Station Freedom; and (5) Reduced scale. Reduced scale approach is depicted in Figure 5. The data generated by this process are intended to capture the range of possibilities based on our technical understanding today and, consequently, can be used to develop implementation approaches for any number of options.

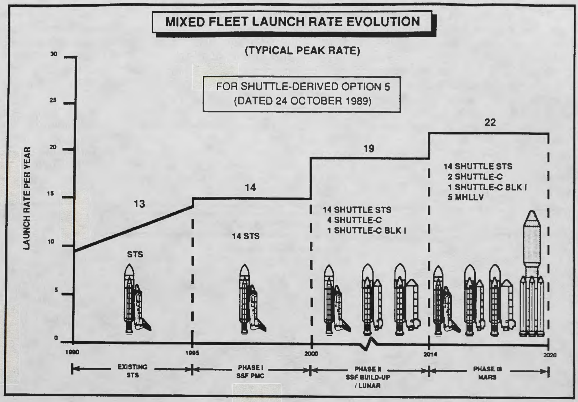


Figure 5

KSC GROUND OPERATIONS

The KSC Lunar/Mars Exploration Initiative study process consists of nine primary and interrelated tasks. The study method begins with the definition of a baseline NSTS processing flow (projected to the mid-1990's) as a reference point for development of preliminary Lunar/Mars cargo and candidate ETO launch vehicles ground processing scenarios. For each identified ETO launch vehicle, spacecraft and cargo option, requirements have been analyzed and the current baseline ground processing scenarios have evolved. A preliminary engineering and operations impact analysis of existing launch site capabilities and requirements evaluation of the baseline ground processing scenarios have progressed to the definition of preliminary facility requirements. Initial analysis of Ground Support Equipment (GSE) requirements as well as development of launch site plans, including ground operations plans and transition plans, will continue.

LUNAR PHASE

The Lunar exploration phase requires a significant activation program with the scope including design, construction and validation of an number of new facilities concurrent with modification to existing station sets. The new Mobile Launch Platform (MLP), Cargo Element Processing Facilities (CEPF), and ASRM Build-up and Stacking Facility (ABSF) are required due to increased flight rates which exceed existing station set processing capabilities or to avoid flight rate impact during reconfiguration of an existing station set. The new Shuttle-C Block 1 Mobile Service Structure (MSS) and the Lunar Payload Processing and Integration Facility (LPPIF) are primarily configuration-driven requirements.

Major facility modifications will include relocation of STS External Tank (ET) processing from the Vehicle Assembly Building (VAB) High Bay 2 to High Bay 4, allowing for the High Bay 2 upgrade to an integration cell for Shuttle-C Block 1. Modifications to launch pads 39A and 39B include increasing the cryogenic propellent storage, handling and transfer capability as well as accommodations for the new MSS. Significant alterations to the Launch Processing System software and hardware will also be required. Figure 6 illustrates the launch site flow concept for the Lunar phase.

The implementation timeline projected for the activation of the Lunar station set requirements reflects a nominal six year timeframe. This is normally preceded by a three year C of F budget cycle. The critical path is the design, construction, and validation of the new ASRM Build-up and Stacking Facility. Design should begin in FY 1993 to support an Operational Readiness Date (ORD) in September 1998, and ASRM flight hardware processing in FY 1999.

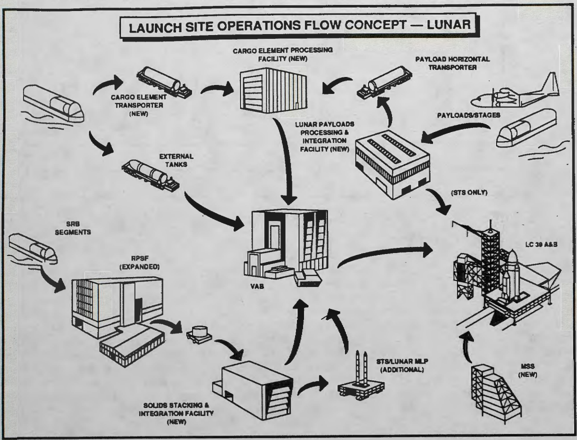


Figure 6

With the addition of the aforementioned new facilities and upgrade to existing facilities, the KSC infrastructure will require expansion of the power, sewer, water, communication, and road systems. A number of new support buildings will also be required to house the projected increase in operational personnel.

MARS PHASE

The Mars exploration phase introduces the MHLLV into the STS and SDVs mixed fleet. The MHLLV's configuration (inline vs. sidemount) and physical dimensions limit most of the shared facility options with the existing STS or the conceptual lunar exploration phase station sets. This results in another significant launch site activation program.

The new Horizontal ET Processing Facility (HETPF) will be required to relocate processing out of the VAB to allow for the upgrade of High Bay 4 to a MHLLV integration cell. The new ASRM facilities and the modification to existing facilities are required to accommodate the increased flight rate as well as the doubling of ASRMs per MHLLV flight set. With the exception of the infrastructure impacts, all the other new facilities and facility modification are MHLLV configuration-driven requirements (reference Figure 7).

The conceptual implementation plan for the activation of the Mars Station Set requirements reflects an approximate eight year timeframe. The critical path is the design, construction, and validation of the MHLLV launch pad. The design duration is 42 months including time for a study contract Preliminary Engineering Report (PER) and parallel preparation and submittal of the environmental impact statement. Design must initiate in FY 2007 to support a September 2013 ORD and first Mars ETO launch in 2014.

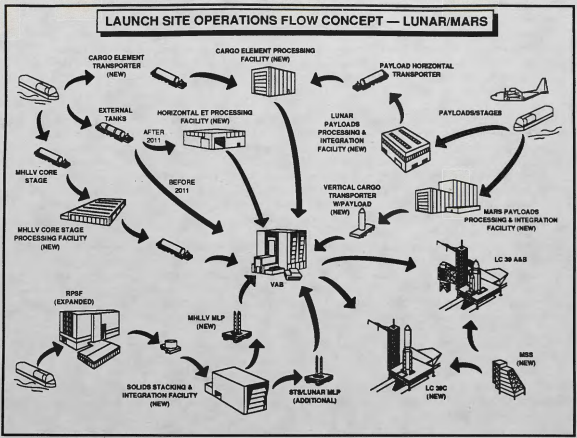


Figure 7

COMMENTS

Much of the information contained in this paper was extracted from the *Report of the 90-Day Study on Human Exploration of the Moon and Mars,* November 1989. Also, I would like to thank Steve Burns, Chuck King, and Mark Foshee of Lockheed Space Operations Company for their efforts in the preparation of this paper.