Abstract

The NASA Office of Exploration case studies for FY 89 are reviewed with regard to study groundrules and constraints. Three study scenarios are presented: lunar evolution, Mars evolution, and Mars expedition with emphasis on the key mission objectives.
Specific Exploration Studies Goals and Objectives for FY 1989

Primary Goal

- Develop knowledge base for FY 91 "decision Year" Budget

Objectives

- Update and refine exploration cases
- Obtain a detailed understanding of prerequisite requirements
- Continue building exploration team capability
- Develop effective external interactions
- Conduct first relative cost estimate
Objective: Update and Refine Exploration Cases

Strategy for Case Study Additions and Modifications

- Do an in-depth penetration of technologies, systems, and operations capabilities required to conduct a "bare bones" trip to Mars

- Investigate the potential for Mars evolution capability using scaled down vehicles and systems (relative to FY 88 studies) and constant annual investment (i.e., mass-to-LEO)

- Using the same constant annual investment strategy as in the Mars evolution case study, investigate the potential for a lunar evolution capability characterized by robust objectives for scientific achievement, technical research and development, operations support, and human acclimation

Objective: Update and Refine Exploration Cases

Strategy for Case Study Analysis

- Conduct systematic evaluations to ensure determination of cause and effect. Emphasize parametric analyses of capabilities and configurations, and conduct broad trade studies

- Identify enabling technology areas and special exploration opportunities along with their associated systems alternatives

- Conduct trade studies in technology and operations areas having potential for high yield relative to reduced mass-to-LEO, reduced dependency to a LEO node, improved systems performance and operation, and reduced cost

- Evaluate the impact of using an artificial-g transfer vehicle and a conjunction trajectory on a mission to Mars/Phobos

- Augment understanding of the effect of constant annual investment (using mass-to-LEO as the investment constraint) on lunar and Mars evolution strategy
Objective: Update and Refine Exploration Cases

Strategy for Program Planning

- Formulate an advanced development plan and identify candidate case study technologies
- Conduct technical studies of international participation implications

Objective: Obtain a Detailed Understanding of Prerequisite Requirements

Areas

- Earth-to orbit transportation
- Life sciences
- Scientific precursors
- Space Station Freedom
- Technology

Strategy

- Seek to understand truly enabling vs. enhancing prerequisites
- Iterate plans with appropriate program offices
- Initiate (with Code E) science studies and user requirement and opportunity development
- Develop artificial gravity research facility feasibility and concepts
- Emphasize exploiting the systems and infrastructures that will be in place in the late 1990s for initiating exploration
Generic Groundrules and Constraints for Studies

- All case studies shall be evaluated to answer the question "why send humans?"
- All case studies shall be evaluated for the potential of maximizing science return
- All case studies shall be unconstrained by budget
- Relative, not absolute, cost estimates will be made for the FY 1989 case studies
- Evolutionary case studies shall be evaluated for the potential suitability of extraterrestrial resources
- All case studies shall be evaluated for the potential of international cooperation

FY89 Focused Case Studies

Lunar Evolution

Mars Evolution

Mars Expedition

Earth

Earth

Earth
Study Parameters Spread

<table>
<thead>
<tr>
<th>Destination</th>
<th>Moon Case Study</th>
<th>Mars Case Study</th>
<th>Mars Expedition Case Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration Approach</td>
<td>Permanent Base</td>
<td>Permanent Base</td>
<td>Expeditionary</td>
</tr>
<tr>
<td>Vehicle Gravity Environment</td>
<td>Zero-G</td>
<td>Artificial-G</td>
<td>Zero-G</td>
</tr>
<tr>
<td>Trajectory Type</td>
<td>Minimum Energy</td>
<td>Minimum Energy</td>
<td>Sprint</td>
</tr>
<tr>
<td>On-orbit Assembly</td>
<td>In LEO</td>
<td>In LEO</td>
<td>None</td>
</tr>
<tr>
<td>Reusability vs. Expendability **</td>
<td>All Reusable</td>
<td>Reusable/Expendable</td>
<td>All Expendable</td>
</tr>
<tr>
<td>Aerobrake L/D</td>
<td>None Specified</td>
<td>None Specified</td>
<td>0.9-1.2</td>
</tr>
</tbody>
</table>

*To Be Studied*

**Mars Expedition**

- Split Mission Concept

- Outbound cargo consists of crew sortie vehicle for descent and ascent at Mars and supporting infrastructure

- Outbound piloted vehicle carries trans-Earth injection stage
MARS EXPEDITION CASE STUDY -- flight profile.

MARS EXPEDITION CASE STUDY -- flight profile.
Mars Evolution Case Study

Exploration Objectives

- the emplacement of a permanent, self-sufficient base on Mars, and the establishment of early leadership in manned exploration of the Mars system

Key Features

- Annual limit on mass to low Earth orbit
- Advanced technology
- Establishment of an initial manned habitat on Mars
- Early emphasis on a martian moon gateway to produce water and cryogenic propellants
- Utilization of in situ resources
- Varied classes of missions using varied trajectories
- Block I reference
  - Initial flight uses opposition-class trajectory
  - all other flights use conjunction-class or opposition-class
  - advanced chemical propulsion
  - aerobraking at Mars and Earth
  - reusable vehicles
  - propellant production from indigenous resources
- Block II update
Mars Evolution

• BASE SITE LOCATION

• Simund Valley (Chryse Basin) in Hydraotes Complex
• 0 deg latitude, 33.5 deg west longitude
MARS EVOLUTION CASE STUDY

Initial Science Outpost

Flight 1
- 1 Crew Members
- All-Up, Opposing Class
- Artificial Life
- 2 Crew to Phobos, Then Down
- Mars Tele-Robotic Exploration
- Mars Tele-Robotic Exploration
- 360 Degree View of Mars
- AC in Space Station

Flight 2
- All-Up, Multi-Stage Return Class
- Artificial Life
- 2 Crew to Mars Surface, in Pressurized Rovers
- Open-Spaced Station in 100 Days
- AC in Space Station

Flight 3
- Mars Surface Equipment Land
- Mars Surface Equipment Land
- Mars Robotic Controlled
- Mars Robotic Controlled
- Operation of HPP Plant

Gateway Operational

Human-Tended Phase

Flight 4
- All-Up, Conjunction Class
- Artificial Life
- 2 Crew
- HPP
- HPP
- Propellant for HPP
- HPP
- AC in Space Station

Operational Phase

Flight 5
- HPP Freighter

Long Range Objective: Permanent, Self-Sufficient Base

Key Constraint: Constant, Annual Investment Strategy

Flight 4.1
Profile for Human Flight to Martian Moons

TMI May, 2026

Aerocapture At Mars

April, 2026

Earth

Mars

12
Lunar Evolution Case Study

Exploration Objectives

- Long range objective
  - establishment of a permanent facility on the lunar surface with a significant capability for self support

- Evolutionary objectives
  - provision of test bed and learning center for long duration planetary missions
  - cut the tie to Earth by development of the lunar resource potential including propellant production and exploitation of resources
  - development of a significant science research capability for astronomy, planetary science, life sciences, and other fields
  - development of a gateway both inward for lunar base expansion and outward to support expansion of human presence into the solar system
Lunar Evolution Case Study

Key Features

- Lunar base evolves through three phases: human-tended, experimental, and operational
- Annual limit on mass to low Earth orbit
- Use of advanced technology
- Emphasis on early development of a human-tended outpost
- Utilization of in situ resources
- Lunar facility has a variety of scientific, technological, and operational objectives
- Block I reference
  - advanced chemical propulsion
  - aerobraking
  - reusable vehicles
  - propellant production from indigenous resources
- Block II update
  - additional mass-to-LEO allocation, and/or
  - new technology

Lunar Evolution

- BASE SITE LOCATION
  - North of crater Moltke in southern region of Mare Tranquillitatis
  - 0 deg latitude, 24 deg east longitude

- FAR-SIDE ASTRONOMY SITE
  - 0 deg latitude, 141 deg longitude
LUNAR SITE DIAGRAM

LUNAR EVOLUTION CASE STUDY

2004  2005  2006  2007  2008

HUMAN-EXPEDITION

BASECAMP FOR EARLY SCIENCE OUTPOST
- CREWS OF 4 ROTATED WITH VARYING STAY TIMES
- OXYGEN PRODUCTION FACILITY DELIVERED
- SCIENCE EXPERIMENTS EMPLACED
- PHASE CONCLUDES WHEN CAPABILITY TO SUPPORT CREW OF 4 FOR 6 MONTH TOUR OF DUTY HAS BEEN ACHIEVED

EXPERIMENTAL

PERMANENT HABITATION
- ESTABLISH AND TEST SYSTEMS TO EXTEND BOTH CREW SIZE AND TOUR OF DUTY
- EXPAND TO 6 CREW
- 6 MONTH TO 1 YEAR TOUR OF DUTY
- LUNAR SURF/LUNAR ORBIT ROUND-TRIPS USING LUNAR PROPS
- LUNAR OBSERVATORY SET-UP UNDERTAKEN
- PHASE CONCLUDES WHEN CAPABILITY TO SUPPORT CREW OF 6 FOR 2 YEAR TOUR OF DUTY HAS BEEN ACHIEVED

LONG-RANGE OBJECTIVE: PERMANENT, SELF-SUFFICIENT BASE

Evolutionary Goals:
- Learning center for long-duration planetary missions
- Lunar resource utilization
- Significant science research capability

KEY CONSTRAINT: CONSTANT, ANNUAL INVESTMENT STRATEGY

OPERATIONAL

SELF-SUFFICIENCY WITH MINIMAL EARTH RE-SUPPLY
- UP TO 30 CREW
- UP TO 2 YEAR TOUR OF DUTY
- LUNAR HYDROGEN PRODUCTION FOR PROPPELLANT USAGE INITIATED
- INITIATE MARS EVOLUTION PROGRAM
LUNAR EVOLUTION CASE STUDY -- science outpost/human-tended phases.
LUNAR EVOLUTION CASE STUDY -- experimental phase.

LUNAR EVOLUTION CASE STUDY -- operational phase.