Space Exploration Logistics Analysis

Taurus-Littrow Valley Scenario

Introduction

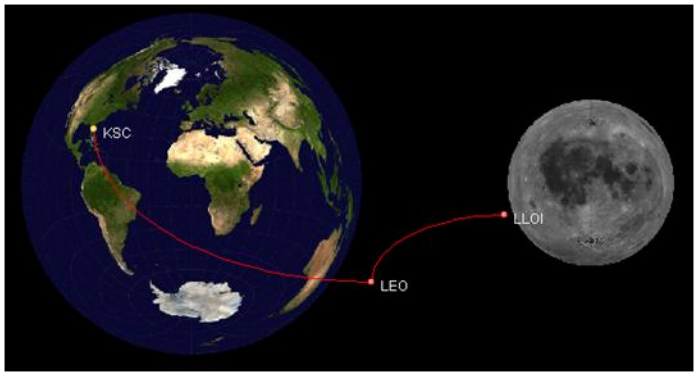
This scenario analyzes aspects of a proposed mission to explore Taurus-Littrow Valley in two parts:

- Part I will create a model to analyze a checkout (test) mission to lunar orbit.
- Part II will modify an existing model of a human exploration mission to maximize effectiveness.

Part I – Lunar Checkout Mission

Part I of this scenario models a single uncrewed mission from the Earth and the Moon. Your goal is to verify there is sufficient fuel to complete the mission and deliver the in-space vehicles to lunar orbit.

Reference Information



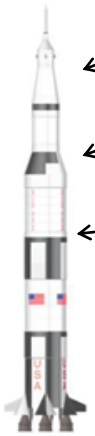
Nodes (Locations)

KSC	Kennedy Space Center
LEO	Low Earth Orbit
LLOI	Low Lunar Orbit - Inclined

Edges (Transports)

KSC-LEO	Earth Launch (9500 m/s)
LEO-LLOI	Earth Departure (3150 m/s) Moon Arrival (1100 m/s)

Saturn V Launch Vehicle



Lunar Module Adapter — Supports the Service Module and protects the Lunar Module
Empty mass: 1,800 kg

Third Stage — 3rd stage of the launch vehicle (specific impulse: 420 s)
Empty mass: 12,000 kg Fuel capacity: 105,000 kg

Second Stage — 2nd stage of the launch vehicle (specific impulse: 420 s)
Empty mass: 38,500 kg Fuel capacity: 450,000 kg

First Stage — 1st stage of the launch vehicle (specific impulse: 300 s)
Empty mass: 135,000 kg Fuel capacity: 2,135,000 kg

Command and Service Module

Command Module — In-space vehicle to carry crew (empty)
Empty mass: 4,800 kg

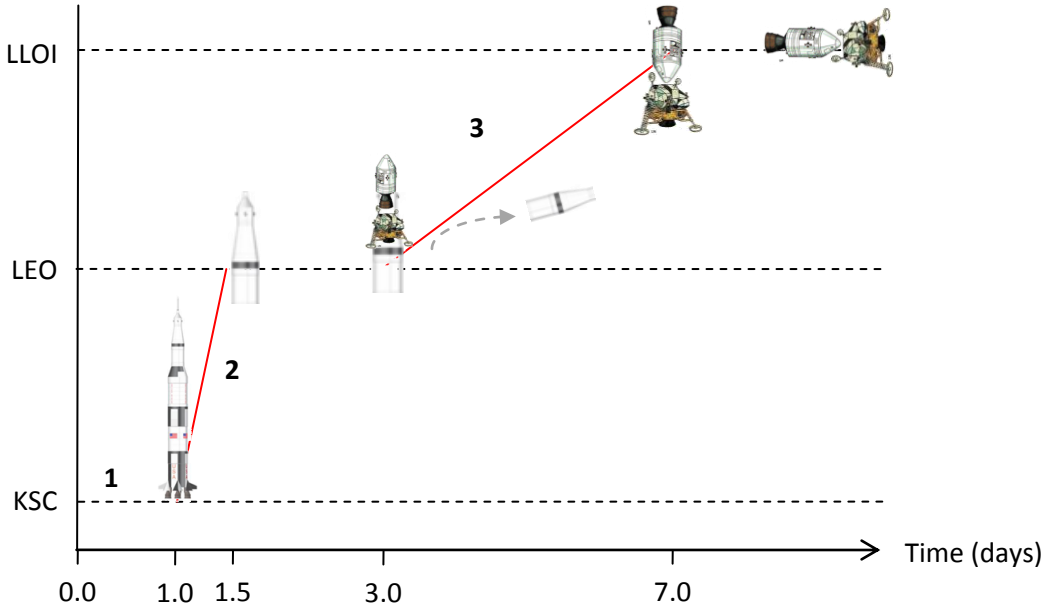
Service Module — In-space vehicle with propulsion (specific impulse: 315 s)
Empty mass: 6,000 kg Fuel capacity: 15,000 kg

Other Elements

Dummy Lunar Module — Mock-up of the lunar module used to add payload mass
Empty mass: 12,000 kg

Mission Outline

The mission takes place over the span of 7 days, completing the transfer of cargo from the launch site (Kennedy Space Center, KSC) through Low Earth Orbit (LEO) and to a Low Lunar Orbit – Inclined (LLOI).



This mission is based on Apollo 6.

Mission Events

1. (T+0.0) Create complete launch stack at Kennedy Space Center (KSC)
    - Launch Vehicle: First Stage, Second Stage, Third Stage, Lunar Module Adapter
    - Command Module, Service Module
    - Dummy Lunar Module
2. (T+1.0) Launch stack to low Earth orbit (LEO)
    - *Burn and stage (discard) the First Stage.*
    - *Burn and stage (discard) the Second Stage.*
    - *Burn the Third Stage to complete the launch burn.*
3. (T+3.0) Transfer in-space vehicle to low lunar orbit - inclined (LLOI)
    - *Burn and stage (discard) the Third Stage for the Earth departure burn.*
    - *Stage (discard) the Lunar Module Adapter.*
    - *Burn the Service Module for the Moon arrival burn.*

Analysis Objectives

Your analysis should confirm of the following results:

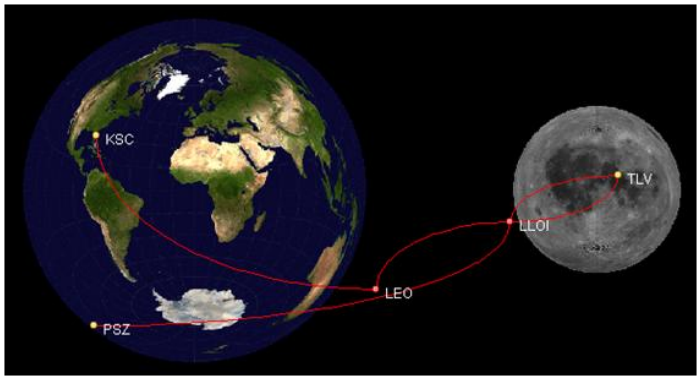
- Proposed mission is feasible (sufficient fuel for all burns)
    - **Third Stage residual fuel** (after Earth departure burn): **10,018 kg**
    - **Service Module residual fuel** (after Moon arrival burn): **3,679 kg**

Part II – Taurus-Littrow Valley Mission

Part II of this scenario models a 3-day human exploration mission at Taurus-Littrow, a lunar valley on the near side of the Moon. Your goal is to modify the baseline mission to provide the maximum *relative exploration capability* while satisfying all demands for resources and fuel.

Astronauts require 7.5 kilograms per person per day for provisions. This covers water, food, oxygen, and other required items (hygiene, etc.). The lunar rover and any Exploration/Research resources in containers at Taurus-Littrow directly contribute to Exploration Capability. Provisions and containers contribute only by enabling exploration.

Reference Information



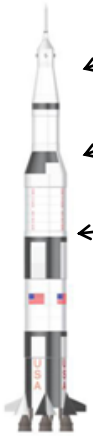
Nodes (Locations)

KSC	Kennedy Space Center
LEO	Low Earth Orbit
LLOI	Low Lunar Orbit - Inclined
TLV	Taurus-Littrow Valley
PSZ	Pacific Splashdown Zone

Edges (Transports)

KSC-LEO	Earth Launch (9500 m/s)
LEO-LLOI	Earth Departure (3150 m/s)
	Moon Arrival (1100 m/s)
LLOI-LSP	Moon Landing (1910 m/s)
LSP-LLOI	Moon Launch (1850 m/s)
LLOI-PSZ	Moon Departure (850 m/s)

Saturn V Launch Vehicle



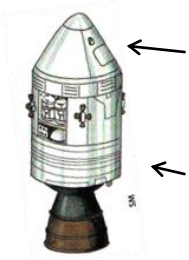
Lunar Module Adapter — Supports the Service Module and protects the Lunar Module
Empty mass: 1,800 kg

Third Stage — 3rd stage of the launch vehicle (specific impulse: 420 s)
Empty mass: 12,000 kg Fuel capacity: 105,000 kg

Second Stage — 2nd stage of the launch vehicle (specific impulse: 420 s)
Empty mass: 38,500 kg Fuel capacity: 450,000 kg

First Stage — 1st stage of the launch vehicle (specific impulse: 300 s)
Empty mass: 135,000 kg Fuel capacity: 2,135,000 kg

Command and Service Module



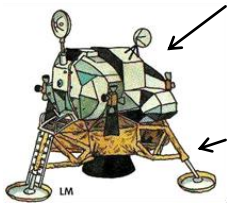
Command Module — In-space vehicle to carry crew

Empty mass: 4,800 kg
Cargo capacity: 550 kg Crew capacity: 3

Service Module — In-space vehicle with propulsion (specific impulse: 315 s)

Empty mass: 6,000 kg Fuel capacity: 18,400 kg

Lunar Module



Ascent Stage — Ascent stage to carry crew and cargo (specific impulse: 310 s)

Empty mass: 1,750 kg Fuel capacity: 2,350 kg
Cargo capacity: 250 kg Crew capacity: 2

Descent Stage — Landing-capable vehicle with propulsion (specific impulse: 310 s)

Empty mass: 3,000 kg Fuel capacity: 8,800 kg
Cargo capacity: 500 kg

Other Elements

Astronaut — Astronaut crew member

Mass: 100 kg Demands: 7.5 kg/day Crew Provisions

Command Module Container — Generic resource container for the Command Module

Empty mass: 50 kg Resource capacity: 500 kg

Ascent Stage Container — Generic resource container for the Ascent Stage

Empty mass: 50 kg Resource capacity: 200 kg

Descent Stage Container — Generic resource container for the Descent Stage

Empty mass: 100 kg Resource capacity: 400 kg

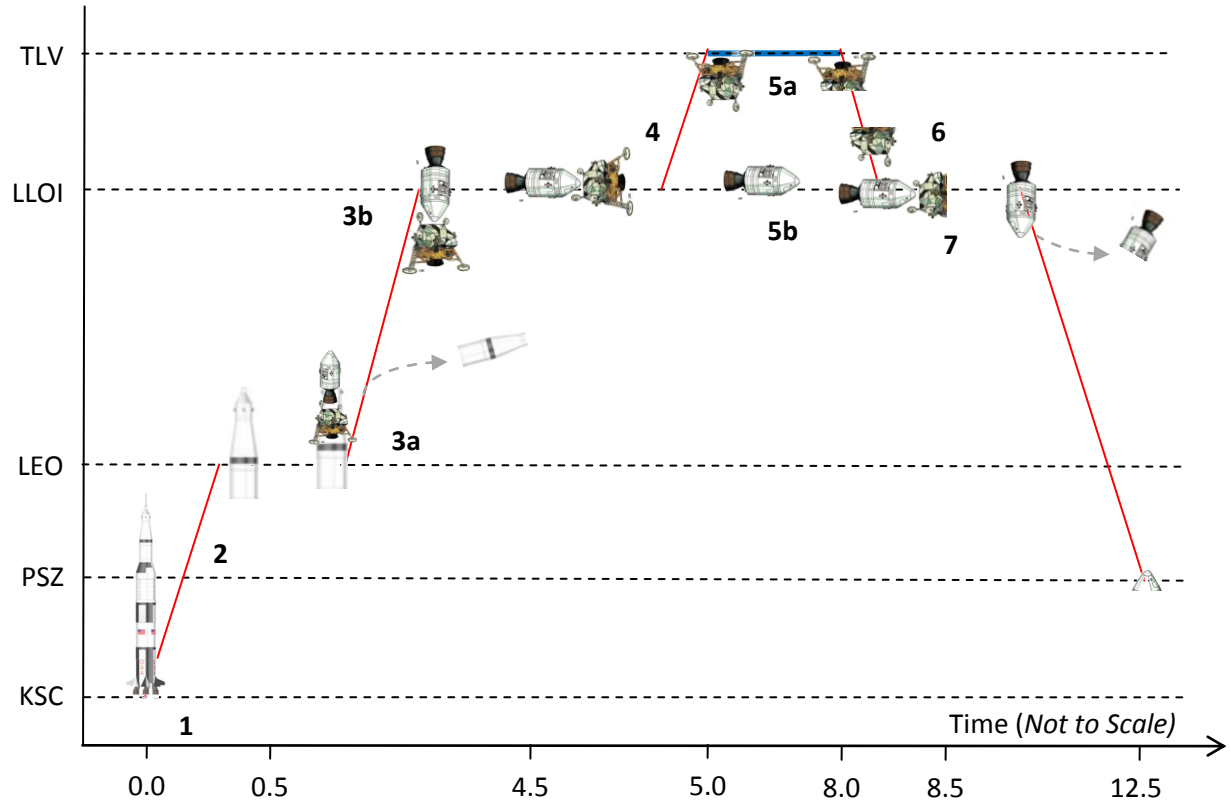
Lunar Rover — Piloted rover for exploring the surface

Mass: 210 kg

Surface Samples — Samples collected on the lunar surface

Mass: 110 kg

Mission Outline



This mission is based on Apollo 17.

Baseline Mission Overview

1. Create Saturn V Launch Stack at KSC
   - First Stage
   - Second Stage
   - Third Stage
   - Lunar Module Adapter
   - Lunar Module Ascent Stage
     - Ascent Module Container + Resources
   - Lunar Module Descent Stage
     - Descent Module Container + Resources
     - Lunar Rover
   - Service Module
   - Command Module
     - 3 Astronauts
     - Command Module Container + Resources
2. Launch Saturn V Stack to Low Earth Orbit
   - Burn/Stage First Stage
   - Burn/Stage Second Stage
   - Burn Third Stage
3. Transport from Low Earth Orbit to Low Lunar Orbit - Inclined
   a) Earth Departure: Burn/Stage Upper Stage, Stage (Discard) Lunar Module Adapter
   b) Moon Arrival: Burn Service Module
4. Move 2 astronauts to Ascent Module and Land at Taurus-Littrow Valley
   - Burn Descent Module
5. Exploration Period
   a) 3-day Exploration at the Taurus-Littrow
      - Offload Rover from Descent Module
      - At end of exploration, add surface samples to Ascent Module
   b) 4-day wait in Low Lunar Orbit - Inclined
6. Launch from the Moon to Low Lunar Orbit Inclined
   - Burn Ascent Module
7. Move astronauts to the Command Module and Depart the Moon
   - Burn/Stage Service Module
   - Direct Re-entry to the Pacific Ocean

Analysis Objectives

Modify the baseline mission to maximize the relative exploration capability while satisfying all astronaut demands. The baseline relative exploration capability is **0.49**.

Note that relative exploration capability can be increased through three strategies:

1. Increase Crew Time (longer surface explorations)
2. Increase Science/Exploration Mass (deliver more science/exploration resources)
3. Reduce Launch Mass (launch fewer provisions or fuel)

In this scenario, you **may** do any of the following:

- Decrease initial fuel levels for propulsive vehicles (including launch vehicles) to reduce the initial launch mass from Earth.
- Add or remove cargo (Crew Provisions or Science/Exploration resources) to sustain crew or provide more science/exploration mass during exploration.
- Transfer Science/Exploration or Crew Provisions resources between co-located containers, for example, to reduce launch mass for the Ascent Vehicle.
- Modify the exploration duration to change the amount of time spent on the Moon's surface.

You **may not**:

- Remove the pre-defined lunar rover or change the time of surface sample addition.
- Define new types of elements for use.
- Change element attributes (empty mass, fuel capacity, specific impulse, or cargo capacity).
- Add or remove astronauts or change the demands astronauts require.