MOBIUS

Supersynchronous Earth Orbits for Lunar Missions
(An Evolutionary Strategy for Lunar Tourism)

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Master of Science in Astronautical Engineering (MS ASTE)
 ASTE 527 Space Concepts Studio

- Since 1993
- 3-unit elective modeled after Architecture Design Studio
- Focus on Concept Creation
- Rapid Complex Ideation
- Architecture + Engineering tools
- No time for engineering optimization rigor
- Concepts help planners make choices—may or may not work, expands breadth of investigation
Borrow from other professions that deal with complex “wicked” problems
Solve using “out of bounds” approach
Associative Logic
Connections
Case Studies
Lectures from creative professionals
Iterative process – till you get it right!
Sandbox for creativity – Writer’s Workshop
ASTE 527 Graduate Space Concept Synthesis Studio Web Site

- https://sites.google.com/a/usc.edu/aste527/home
Baseline Scenario

If NASA continues its business as usual without a major increase in its budget and without using nonterrestrial resources as it expands into space, this is the development that might be expected in the next 25 to 50 years. The plan shows an orderly progression in manned missions from the initial space station in low Earth orbit (LEO) expected in the 1990s, through an outpost and an eventual space station in geosynchronous Earth orbit (GEO) (from 2004 to 2012), to a small lunar base in 2016, and eventually to a Mars landing in 2024. Unmanned precursor missions would include an experiment platform in GEO, lunar mapping and exploration by robot, a Mars sample return, and an automated site survey on Mars. This plan can be used as a baseline scenario against which other, more ambitious plans can be compared.
ISS Future

- End of mission 2024
- NASA Plan – Deorbit
- ISS Consortium
- Send to Moon
- Some Alternatives
  - Bring more partners into program
  - Turn over to private sector
  - Historical Artifact - Park in high orbit
  - Disassemble and bring back to Earth
Evolution of ISS as Spacecraft Integration Platform

- Original purpose
- Repurpose - Gerstenmaier
- Commercial Use
- Large Spacecraft assembly - MALEO – ISU 1988
- USC Space Concept studies – Evolution of ISS 1&2
- International Space Transit Vehicle
- Cosmic Mariner

https://sites.google.com/a/usc.edu/aste527/home
Space Exploration Initiative [SEI]
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
8 Mars excursion vehicle separates and arrives 1 day before Mars transfer vehicle
MALEO : MODULE ASSEMBLY IN LOW EARTH ORBIT

A strategy to build and commission a lunar surface habitat complex by integrating several modules in LEO using the ISS and her crew, and ship it to the lunar surface using custom propulsion systems, thereby avoiding the infrastructure otherwise needed to construct one piece by piece, and eliminating the clingy dust nuisance that hampers lunar surface activity.

- First proposed at the inaugural summer session of the International Space University at MIT in 1988
- First presented and published at the 1988 IAC in Bangalore, India
MALEO - SALIENT FEATURES

- Payload Summary [MT]
- Habitat Module = 15
- Lab Module = 15
- Power/Logistics = 15
- ECLSS Node = 5
- Sanitation/Hygiene = 5
- Airlock/EVA = 10
- Truss/Landing gear = 10
- 100kWSolar Arrays/Comm = 5
- Unpress.Electric Rover X2 = 10
- Attitude Control Pallet X3 = 6
- Touchdown Mass ~100MT
- + lander propulsion stack
MALEO Assembly with ISS Crew – Note SpaceX Dragon
MALEO Lunar Deorbit & Landing
Earth Station: Global ISS Marketing Future of Human Spaceflight

A Lunar Cruise

Michael Barrucco

ASTE 527 Space Exploration Architectures Concept Synthesis Studio Team Project. Fall 2010. Astronautical Engineering Department. Viterbi School of Engineering. University of Southern California
1. Launch from Wallops (US), Baikonur launch (Russia), Jiuquan Satellite Launch Center (China)

2. Dock with ISS during sunrise

3. Coast for 2-3 days until next TLI opportunity

4. TLI-3107 m/s

5. Trajectory correction ~80 m/s

6. Coast for ~7 days

View Starfields, and Heritage Sites

LOI~700 m/s

To the Sun
• TEI Day 11
• Moon re-aligned with ISS Orbital Plane

• Moon at EOI

ISS Nodal Regression 5° per day

7 day cruise in orbit

• LOI Day 4
• Moon aligned with ISS orbit plane

• TLI from ISS

2nd Cycle

Cis-Lunar Cruise
International Space Transit Vehicle – Roukos/Thangavelu 2010
Evolution of the Space Cruise Ship "Cosmic Mariner"

Edmundson, P. & Thangavelu, M.
Main Elements

- Laboratory/Medical Module
- Bioregenerative Life Support System Module
- Power and Control Module
- Node
- Nuclear Electric Propulsion Module
- Robotic Arms
- Habitation Module
- Solar Arrays
- Radiators
Future Evolution

Expansion to accommodate 50 passengers for travel in cis-lunar space by 2030
Future Evolution

Expansion to accommodate 100 passengers for interplanetary travel by 2050
Follow-on Missions

Support of Space-Based Solar Power Satellite Construction
Follow-on Missions

Exploration of Near-Earth Asteroids
Cislunar Orbits

- Free Return
- Halo
- Lagrange
- Weak Stability Boundary
- Backflip
- Frozen Orbits
- Resonant Orbits
- Cycler
Apollo Free Return Trajectory
Apollo 13 Free Return Timeline

- Lift-off 19:13:00.65 G.M.T April 11, 1970
- S-IVB/command and service module separation 03:06:39
- Docking 03:19:09
- S-IVB engine cutoff 00:12:30
- S-IVB engine ignition 00:09:54
- S-II engine ignition 00:02:45
- Translunar injection maneuver 02:35:46
- Command module/service module separation 138:01:48
- Fourth midcourse correction 137:01:48
- Undocking 141:30:00
- Third midcourse correction 105:18:28
- Trans-earth injection 79:27:39
- Second midcourse correction 61:29:43
- Cryogenic oxygen tank incident 55:54:53
- Return to Earth
- To the Moon
- Moon's Orbit
LUNAR SALVAGE MISSION
ORBITAL TRAJECTORIES

Post lunar fly-by
Earth perigee
May 16, 11 pm EDT
42,000 km

Trans-lunar injection
May 7, 9pm EDT

Final geosynchronous orbit
Late May
36,000 km altitude

April 28, 1 am EDT
214,000 km

5 3/4 days
to moon

May 4, 1 am EDT
321,000 km

3 1/4 days
return to
Earth

Perilune
May 13, 4 pm EDT
8000 km
HGS-1 2nd LUNAR FLYBY ORBITAL TRAJECTORIES
Supersynchronous Earth Orbit

- Beyond GSO
- High Eccentricity
- Resonant Period Design
- Cycler
MOBIUS
An Evolutionary Strategy for Lunar Tourism

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University of Southern California

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Mission Elements
Quartet of Resonant Supersynchronous Orbits

Starting point

MOBIUS mission scenario
MOBIUS Rationale

- Space Activity as opposed to Space Exploration
- Self-Sustainable Space Architecture
- Revenues from Missions used to fulfill Objective
- Use ISS beyond Retirement 2024
- Incremental Approach
  - Phase 1 - lunar approach
  - Phase 2 - lunar orbit
  - Phase 3 - lunar landing
Mission Elements

Cislunar Transit Orbit (CTO)

Edge-on illustration of MOBIUS Cislunar Transit Orbit (CTO)

Rp = 15,000 km
Ra = 300,000 km
Δi = 28.120 deg.
Δv = 2.98 km/s required for plane change

not to scale
Mission Elements - Earth-Moon Supersynchronous Orbit

- Cislunar Transit Orbit (CTO)

Moon's inclination = 22.7162°

Sun's true latitude = 282.8707°

Moon's true latitude = 109.3542°

C32 origin line

Vernal equinox

Rp = 15120 km

Ra = 299360 km

Moon & S/C's positions in January 1, 2016 (UTC=00:00:00)
Concept

Deployment of un-crewed COV to final orbit

- Moon
- L1
- apogee
- final orbit
- COV (lunar bus)
- inner Van Allen radiation belt
- outer Van Allen radiation belt
- perigee
- inbound
- outbound
- transfer orbits
- landing trajectory
- ascent trajectory
Concept
Perigee Rendezvous
The main elements of the proposed mission design architecture are as follows:

- International Space Station (ISS)
- Cislunar Orbital Vehicle (COV)
- Tourist Docking Capsule (TDC)
- Cislunar Propulsion System (CPS)
- Lunar Transit Lounge (LTL)
- Lander
- Lunar surface facilities
MOBIUS Mission Elements

Orion /Dragon/New Glenn

Lunar Transit Lounge

Commercial ISS

Upper Stage

Lunar Lander
Earth-Moon Transfer Orbit Habitat

Cislunar Orbital Vehicle (COV)
Mission Elements

COV interior cutaway

2D schematic of COV interior design

- Command & control room
- Public area
- Storm shelter
- Dining room
- Kitchen galley & storage
- Private compartment
- Window
- Bridge or EVA
Capsule departs from the ISS
Concept

Capsule departs from the ISS
Concept

Capsule departs from the ISS
Concept

Capsule is about to dock with COV
Capsule is docked with COV Concept
Concept

Ready for Cislunar Injection (CLI)
On its way …
Concept
Apogee Rendezvous

Transferring passengers to LTL
Concept
Apogee Rendezvous

Lunar Transit Lounge (LTL)
Merits & Limitations

- Optimal
- Affordable
- Feasible with current technologies
- Viable
- Free Return Trajectory- If there is an injection anomaly, the vehicle stack will return to Earth orbit without help for abort.
Merits & Limitations

- Evolutionary, phased approach-maximize revenue operating budget.
- Requires a little station-keeping due to RAAN precession over time.
- Plane change at perigee can be costly unless ISS’ inclination is changed after retirement to be aligned with that of the Moon.
- Earth’s Van Allen Belt could be challenging so proper shielding is essential.
Questions, Comments?

Welcome to the future of lunar tourism!

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Evolution - From Here to There Before
Acknowledgement

- This concept was developed by Mehdi Lali, graduate student in the ASTE527 Graduate Space Architecting Studio (aka Space Concepts Creation Studio) in Department of Astronautical Engineering within the Viterbi School of Engineering at USC. Studio slides may be accessed at: https://sites.google.com/a/usc.edu/aste527/home
- Look under team project “LunaRevolution”
References

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OST Inc., http://www.ostinc.com/#!rocketost/c1vw1


