Earth-Moon L1 / L2 Infrastructure – What Role Does It Play?

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Some Context

Cis-Lunar Destination
• Near-Earth Deep Space under gravitational influence of Earth-Moon system
• Volume between GEO & moon’s orbit
  o Includes orbital locations: LEO, GEO, MEO, HEO, LLO
  o Libration / Lagrange Points: E-M L1, L2, L3, L4, L5

Cis-Lunar Destination Team Activities
• Notional crew + robot missions in cis-lunar space
• Requirements for mission support payload
• Robotic support capabilities
• Required technologies to enable cis-lunar missions
• Identify activities associated with a facility at the E-M L1 or L2 libration points to serve as a “Stepping Stone” to BEO missions
  • Focus = Human Space Exploration (HSE) crewed and uncrewed operations (2 weeks – long durations)
  • Extend HSE activities performed on ISS
  • Activities that benefit from E-M L1 / L2 Deep Space environment
WHY Earth-Moon L1 or L2?

CHARACTERISTICS of OPERATIONAL INTEREST

• Deep space location beyond Van Allen Belts
  o Demonstration & test site for long-duration HSE missions within easy return to Earth
  o For example, exploration vehicle systems, EVA systems and operations, autonomous mission operations, human + robot interactions, long-duration systems, radiation mitigation methods

• In “free space”
  o Avoids deep, expensive gravity wells of Earth and Moon
  o Avoids surface environmental issues (e.g., dust)
  o No hazard from artificial or natural space debris
  o Relatively low station-keeping propellant requirements
  o Travel between E-M L1 & L2 relatively easy
  o Travel among E-M and S-E libration points relatively easy

• Supports near earth asteroid exploration
  o Early deployment of Deep Space Habitat to validate readiness for asteroid missions

• Supports lunar exploration
  o Easily reachable and accessible from Earth and Moon with minimum launch window constraints & low Delta-Vs

• Supports deep space science operations
  o Full view of Earth and Moon hemispheres
  o At E-M L2, tight halo orbit allows spacecraft to be within “radio quiet zone”
1) Develop & certify **HSE deep space operational capabilities** at location that offers ready Earth return

2) Serve as **assembly point** for large space structures

3) Conduct **lunar support operations**

4) Serve as **off-Earth sample return quarantine & aggregation facility**

5) Serve as **initial node in HSE communications & navigation infrastructure**

6) Serve as deep space node for **international education & public outreach and media**

7) Serve as a **platform for science** from unique L1 / L2 location
1) Develop & certify HSE deep space operational capabilities at location that offers ready Earth return

- L1 / L2 facility serves as first “stepping stone beyond LEO” to develop capabilities for missions beyond Earth-Moon system
  - Deep Space “high-fidelity” test & verification environment
  - Extends HSE research & technology development conducted on ISS
  - Verify countermeasures & technologies in operational environment prior to commissioning for 1st beyond-Earth HSE mission
    - Return from libration points to Earth is relatively easy (although not “anytime”)
- Deep Space radiation biological effects & shielding materials / approaches
- Avionics / radiation shielding interaction & performance
- ECLSS reliability and performance
- Extend & certify crew autonomous mission operations
- Extend & certify crew + robotics operations
- Verify IVA robotics without crew present
- Verify & mature long duration crew medical care operations
- Test artificial gravity methods?
- Evaluate crew psychological health & performance far from Earth prior to 1st beyond-Earth HSE mission
2) **Serve as assembly point for large space structures**

- Some of these operations would require in situ crew, others do not
- Operations could be conducted autonomously (via robotics) with crew oversight
- Potential large space structures
  - Observatory, multi-element habitat, free-flying instrument platforms, microgravity co-orbiter, deep space mission stack

3) **Conduct lunar support operations**

- “Equal energy access” to entire lunar surface = no complex maneuvers (e.g., plane changes)
  - Dynamically, entire lunar surface is accessible from libration points – not the case from LLO
  - Velocities are such that it requires ~ 1 ½ days travel time from a libration point to lunar surface
- Perform Lunar exploration
  - Operate assets on lunar surface, including lunar farside from L2
  - Could teleoperate multiple rovers with very low latency
  - Nearly entire lunar hemisphere visible from E-M libration point
- Serve as:
  - Supply depot for human lunar surface operations
  - “Way station” to aggregate assets on the way to lunar surface
  - Lunar safe haven during abort from lunar surface
- Deploy spacecraft or instrument packages or rovers to Low Lunar Orbit
4) **Off-Earth sample return quarantine & aggregation facility**
   - “Off-Earth” facility for lunar, Mars, NEO, cometary dust, samples
     - Safe place for Mars samples for Planetary Protection
   - Sample canister autonomous rendezvous & dock with L1 / L2 facility
   - Aggregation & phased sample return to Earth

5) **Node in HSE communications & navigation infrastructure**
   - Facility serves as communications / navigation relay
   - Comm/nav asset @L2 would provide lunar farside access

6) **Deep space node for int’l education / public outreach & media**
   - IV & EV cameras provide live streaming on web 365/24/7
   - Supports Global educational programs and media 24/7
     - E.g., Students on Earth could control lunar rovers through the L1 / L2 Relay Station
   - Shares Human Space Exploration globally to people on Earth
     - Includes International / Global Stakeholder community
     - Serves as Earth’s “foothold” in Deep Space – Humanity’s first steps “off-Earth” into deep space
7) Platform for science from unique L1 or L2 location

- Libration point facility operating as a site for autonomous “tag along” experiments
- Earth & Atmospheric Science: Climate, magnetic mapping, “Whole Earth” view
- Heliophysics
  - Fast Plasma and coronal heating @ L1
  - Solar wind & magnetotail
  - Solar coronal characterization @L2
- Astronomy & Astrophysics
  - Deep Space Observations
  - All-Sky X-Ray Survey
  - Radio Astronomy (within L2 quiet zone)
- Exoplanets
  - Small attached survey telescope to detect occultations as targets for subsequent in-depth study
- Fundamental Physics
  - Combustion, complex fluids, microphysics
- Materials science
  - LDEF-type measures
  - Radiation shielding
- Human health & performance
  - Radiation biological effects using Tissue Equivalent Materials
  - Crew physiological monitoring during crewed periods
  - Combined effects of microgravity & radiation
  - Psychological and Behavioral Health: isolation, distance from Earth, blocked Earth view

NOTE: International Telecommunications Union (ITU) regulation prohibits harmful interference to radio astronomy. Strategies to meet this requirement while stationing a facility at E-M L2 are under consideration.
SUMMARY: Earth-Moon L1 / L2 Infrastructure – What Role Does It Play?

- Identified crewed & uncrewed activities that could be conducted at a facility based @ E-M L1 or L2
  - Focus on HSE activities – extend HSE activities performed on ISS
  - Begin with 2-week crew mission, build to longer durations

- Identified E-M L1 & L2 characteristics of interest
  - Deep space location beyond Van Allen Belts
  - In “free space”
  - Supports lunar exploration
  - Supports deep space science operations

- Identified seven primary activities to be conducted at an E-M L1 / L2 facility
  - Develop & certify HSE deep space operational capabilities
  - Assemble large space structures
  - Conduct lunar support operations
  - Serve as:
    - Off-Earth sample return quarantine & aggregation facility
    - Node in HSE communications & navigation infrastructure
    - Node for international education & public outreach and media
    - Platform for science
Selected works on “future in-space operations” concepts: [http://www.futureinspaceoperations.com](http://www.futureinspaceoperations.com)

Past presentations: “In-Space Operations” colloquia: [http://spirit.as.utexas.edu/~fiso/telecon.htm](http://spirit.as.utexas.edu/~fiso/telecon.htm)

Archived documents from the Decade Planning Team (DPT): [http://history.nasa.gov/DPT/DPT.htm](http://history.nasa.gov/DPT/DPT.htm)

- Notably: *Decade Planning Team JSC 2001 “Gateway” architecture* (EX15-001-01)

Selected reports on human habitation and operations at libration points (chronological order):

- *Using NASA’s Constellation Architecture to Achieve Major Science Goals in Free Space. IAC-08-A5.3.6* (2008)
- *First Stop for Flexible Path? Space Review* (November 30, 2009)