



Interoperability Management on the Lunar Surface

"... for the precious things put forth by the Moon"

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Lunar Surface Interoperability Management

Moon2Mars Interoperability Working Group (IoWG)

Manages interface standards among NASA Moon2Mars program assets and for commercial elements interfacing with those assets

- Current Standards posted at <https://www.internationaldeepspacestandards.com/>, baselined for Moon2Mars Gateway **use cases**, and approved under Gateway Multi-lateral Control Board (for International Partner concurrence) and ESDMD Directorate Program Management Council (DPMC)
- Selected standards are being expanded to include **use cases** on the Lunar surface and across the Moon2Mars architecture. Study team sponsored by ESDMD Moon2Mars SE&I office developing governance process for baselining upcoming revisions.
 - Standards flowed down as required into interface definition documents and specifications specific to Moon2Mars assets (e.g., EHP assets such as xEVA suit, LTV, PR).
- More standards will be baselined as use cases evolve.

M2M Gateway Use Cases
Baselined at Gateway MCB and DPMC

➔

Lunar Surface & cis-Lunar Use Cases
Future baselining process under development

International Communication System Interoperability Standards (ICSIS)	International Thermal System Interoperability Standards (ITSIS)	International Avionics System Interoperability Standards (IASIS)
International Space Power System Interoperability Standards (ISPSIS)	International Rendezvous System Interoperability Standards (IRSIS)	International Software System Interoperability Standards (ISwSIS)
International External Robotic Interface Interoperability Standard	International Environmental Control and Life Support System Interoperability Standards (ECLSSIS)	
International Docking System Standard Interface Definition Document (IDSS IDD)		

LOGIC

Lunar Operating Guidelines for Infrastructure Consortium

Purely commercial use cases

- IoWG standards considered as examples

Advisement ➔

← New use cases

Space Technology Mission Directorate
2024 GCD Program Review
August 29, 2024 | 2

To state the obvious, it is in the interest of NASA, industry, and the Artemis Accord partners that systems on the Lunar surface be interoperable...for interfaces and the efficient sharing of resources.

Interoperability is brought about through the development of standards and their application for use casesI'll keep repeating that term.

For the Lunar surface, interoperability standards are being managed in two forums...differing in the use cases they consider:

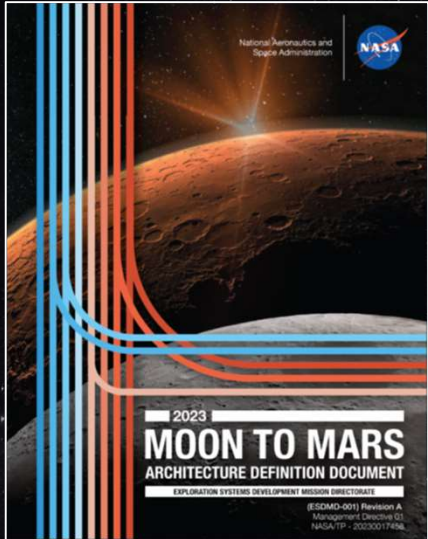
- M2M IoWG maintains standards for use cases requiring interoperability among and with USGOV/IP M2M program assets (e.g., gateway, HLS, LTV, xEVA, etc.)
- LOGIC consortium will develop standards for purely commercial use cases.

Moon2Mars program initially baselined standards for earliest accepted use cases: interoperability between Orion, Gateway, and HLS. IoWG now considering revisions to those standards to accommodate use cases on the Lunar Surface and throughout the M2M architecture. Standards are flowed down to detailed IDD and specs for specific use cases. IoWG has a team developing a standards governance plan to efficiently baseline these revisions.

As new use cases with new elements are defined, modification of standards can become a “tax” on the development of the earlier program assets This must be balanced with the value of

interoperability in a given new use case.

Lunar Surface Interoperability Management



ESDZMO-001 Rev-A MD-01

3.1.5 Element Mapping

The following tables map elements to the functions they fulfill.

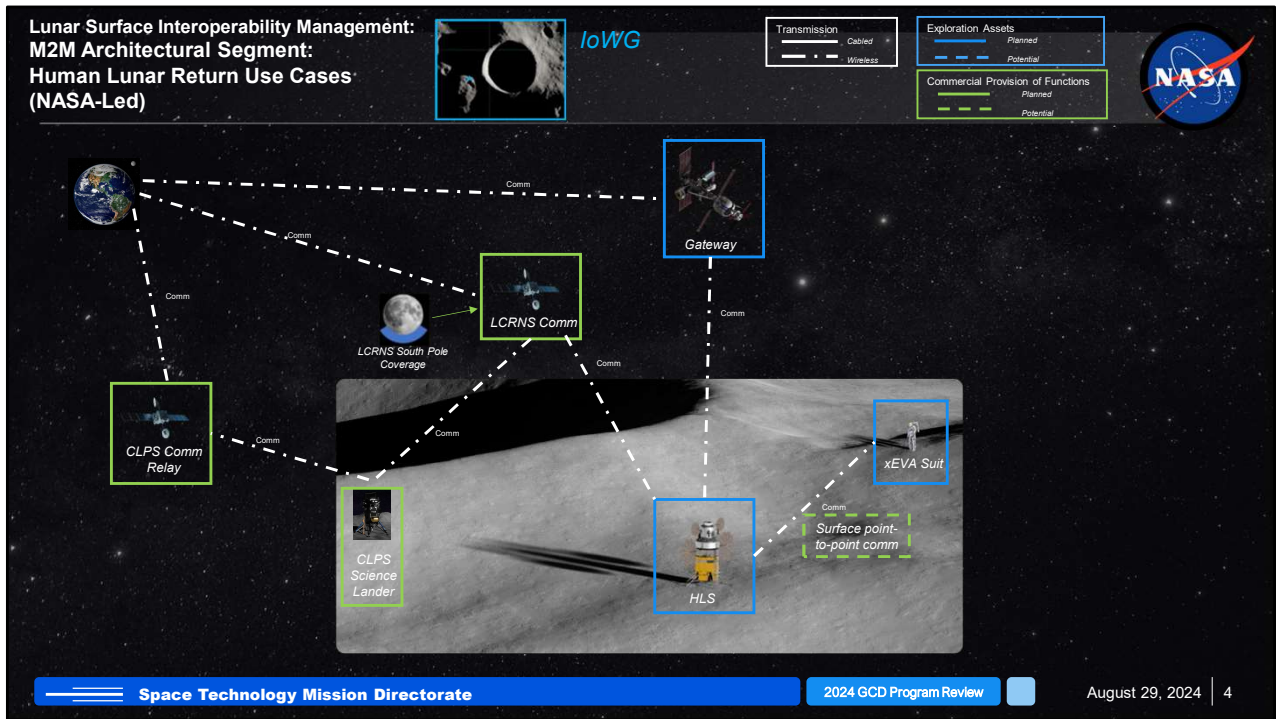
Table 3.2. Functions Fulfilled by LCRNS During the HLR Segment

Function	Description	Use Case
FN-024-L	Provide high availability position, navigation, and timing capability in lunar space	UC-011-L
		UC-024-L
		UC-025-L
FN-024-L	Provide high availability position, navigation, and timing capability in lunar space	UC-011-L
		UC-024-L
		UC-025-L
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		UC-027-L
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Example →

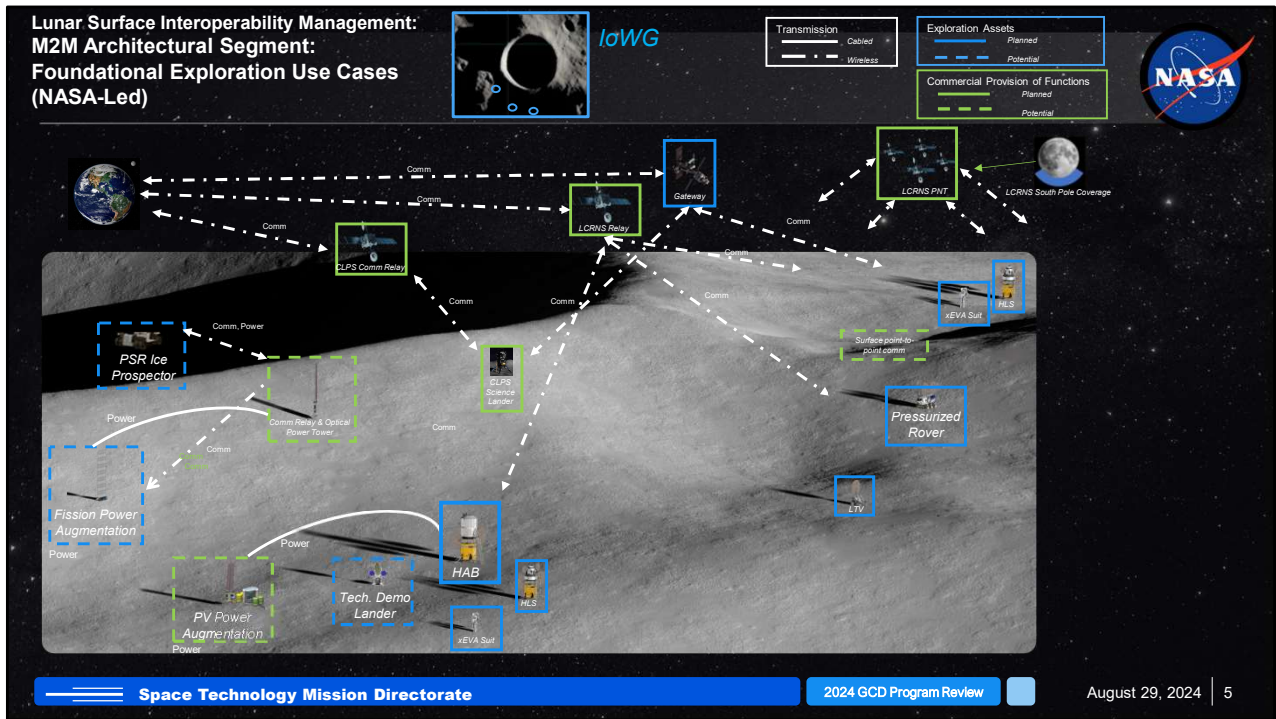
These use cases are defined in the Moon to Mars Architecture Definition Document and associated with functions. Accepting a use case into the ADD drives its consideration in the interoperability standards. Such activities are prioritized for the near term uses cases as others remain speculative.

In this briefing, we will show at a top level how these use cases are prioritized in the Moon2Mars Architectural segments and then give a status on each of the standards being managed.

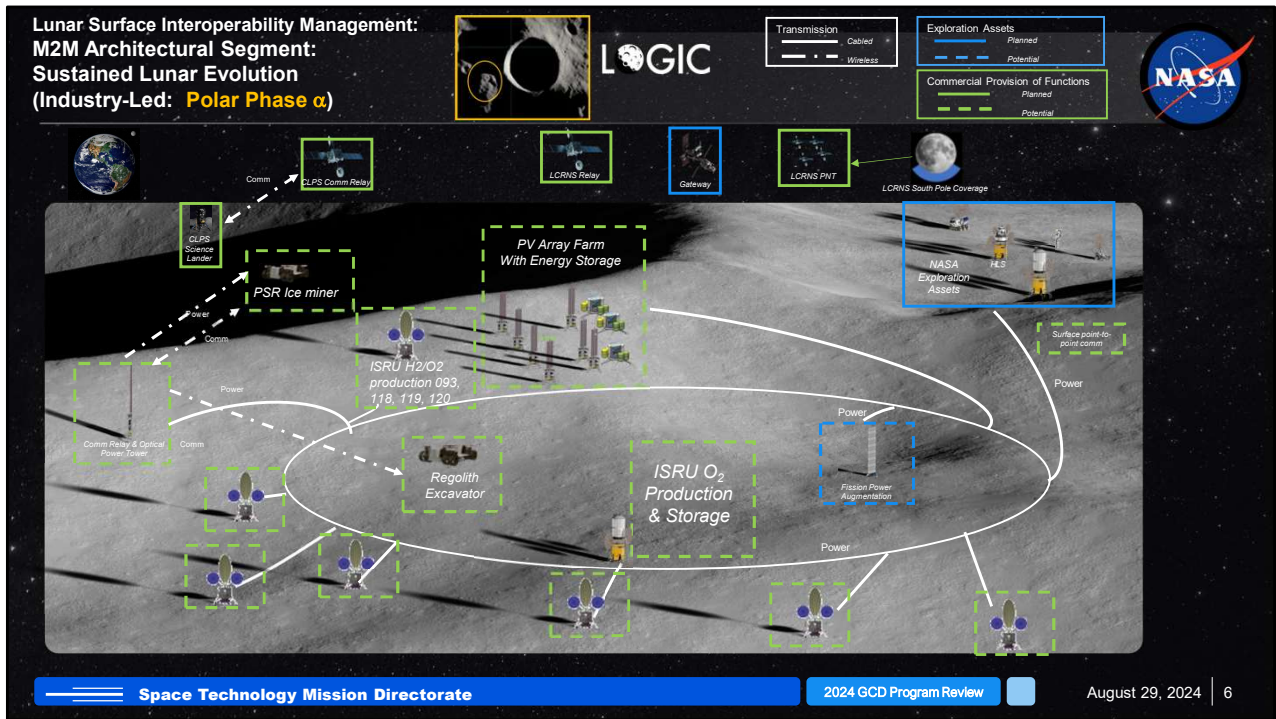


The first priority Lunar surface use cases driving revisions of the standards ioWG manages are those dealing with comm starting with Artemis III: Human Lunar return.

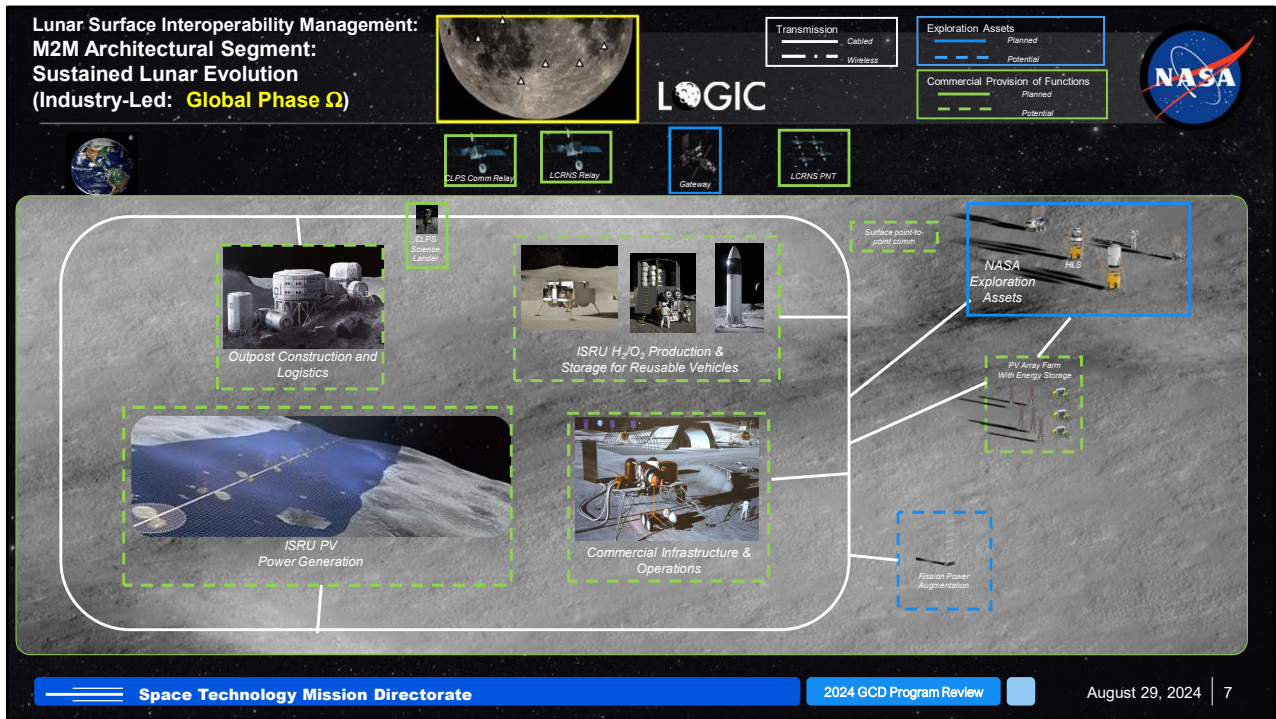
Explain the Legend



The next priority use cases driving revisions to the standards managed by IoWG are those involving comm and power for the Foundational Exploration segment.



Use cases for the industry-led segment of the M2M architecture are being considered by LOGIC, which may develop standards for interoperability among commercial assets.



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Lunar Surface Interoperability Management



Communications & Navigation

Consultative Committee for Space Data Systems (CCSDS)

Catalog of Protocols

Managed Under IoWG

International Communication System Interoperability Standards (ICSIS), Rev B

Baselined by NASA Gateway MCB and ESDMD DPMC. Use cases for connection among NASA Moon2Mars Assets and with orbital relay networks:

Summary contents:

- X-Band for Direct-to-Earth (Comm. & Tracking)
- Ku-Band for Direct-to-Earth (High Rate)
- S-Band and Ka-Band for Lunar surface-to-cis-Lunar uplink/downlink
- Receiver for Lunar Augmented Navigation System (LANS)
- On-surface comm options for UHF, Wi-Fi, 3GPP, Bluetooth, etc.

Future revisions: Align w/ LunaNet V5, more definitive, on-surface comm.

EHP Communications Specification (in Draft, CUI content)

Baselined by Extravehicular and Human Mobility (EHP) Program Office. Use cases for comm among EHP assets and orbital relay

- Requirements lowered from ICSIS
- Unified on-surface comm in work (potential incorporation in ICSIS).

Selected Protocols

LunaNet Specification, Version 4

Baselined by SCA/N CCB (w/input from ESA and JAXA)

Requirements for Lunar Communications, Relay, and Navigation System (LCRNS), ESA-Moonlight, Gateway. Use cases for connectivity among relay provider networks and with Lunar surface

Summary content:

- Currently aligned with ICSIS
- Navigation ranging per CCSDS 414.1-B-2
- No spec for EVA-to-Asset link
- WiFi (CCSDS 883.0) for on-surface comm

Commercial Lunar Payload Services (CLPS)

CLPS providers implement their own communications relays
LunaNet Specification followed for use case as relay provider

Legend

Requirements flowdown

Management coordination

Among the standards being managed by IoWG, we'll treat comm first. It is the most complex in terms of uniting efforts. and highest priority.

Comm relay users within M2M should start with ICSIS

Comm relay providers should start with LunaNet

Lunar Surface Interoperability Management



Power

Managed Under IoWG

International Space Power System Interoperability Standards (ISPSIS), Rev A

Baselined by NASA Gateway MCB and ESDMD DPMC. Use cases for source-to-load connection among NASA Moon2Mars Assets (cis-Lunar and Lunar Surface).

Summary content

- Standards at 28 VDC and 120 VDC
- Voltage ripple & transients
- Impedance Separation
- Fault protection and grounding

Revision under consideration for possible use case of kVAC, long distance transmission

Gateway Subsystem Specification for Power,

Baselined by Gateway Program Office. Use cases specific to Gateway

Content summary:

- Requirements flowed down from ISPSIS
- Variable voltage requirements and connectors defined.

Artemis Payload IDD M2M Utilization IRD

Baselined by M2M Exploration Operations Office. Use cases for EVA/IVA payloads & other utilization on Artemis Campaign vehicles

Content summary:

- Requirements flowed down from ISPSIS
- Variable voltage requirements and connectors defined.

EHP Power Specification (in Draft, CUI)

Baselined by Extravehicular and Human Mobility (EHP) Program Office. Use cases for bidirectional power transfer to/from Moon2Mars Surface Assets (unidirectional for EVA suits)

Content summary:

- Flowed down from ISPSIS
- Connector power levels, dust protection, pinouts

Legend

Requirements flowdown

Management coordination



Robotic Interface Standards

Managed Under IoWG

International External Robotic Interface Interoperability Standard
*Baselined by NASA Gateway MGB and ESDMD DPMC, with heavy involvement from CSA.
Use cases for micro-gravity extravehicular robotics activities.*

Summary Content:

- Interface planes and classes
- Coordinate Systems (Mounting, Mating, Operations)
- Common Requirements
- Clearance Envelopes
- Mechanical and Structural Interfaces (Bolt Patterns, Fastener Configurations, Interface Loads, and Interface Stiffness)

Special requirements in Gateway IRDD

Revision under consideration for end effectors and attach points in Lunar surface gravity and for intravehicular robotics activities.

Consideration is also being given to the continued relevance of this standard, given the other standards in place (e.g., Docking, Rendezvous, etc.



Software Standards

Consultative Committee for Space Data Systems (CCSDS)
Catalog of Protocols

Selected Protocols

Managed Under IoWG

International Software System Interoperability Standards (ISwSIS)

Baselined by NASA Gateway MCB and ESDMD DPMC. Use cases for interaction between spacecraft and among spacecraft modules. Standards flowed down to individual vehicle-to-vehicle rendezvous specifications.

Summary Content:

- Syntactic Interoperability: CCSDS Space Packet Protocol and Network Byte Order
- Semantic Interoperability: CCSDS Electronic Data Sheets (SEDS) and eXtensible Markup Language (XML) Telemetric and Command, Exchange (XTCE)
- Software Framework Standard: Core Flight System (cFS)

Tailoring done to create Gateway Software Specification as M2M-wide Packet Protocol Standard. Gateway XTCE and SEDS conversion to M2M standards is in work.



Avionics Standards

Managed Under IoWG

International Avionics System Interoperability Standards (IASIS)

Baselined by NASA Gateway MCB and ESDMD DPMC. Use cases for interfaces between spacecraft and among spacecraft modules.

Summary Content:

- "Best Effort" Ethernet Services: per 802.3-2008 1000BaseT standard (Gigabit)
- Deterministic-Rate Constrained Data Services: per tailorable ARINC 664-p7
- Time-Critical Data Services: per tailorable SAE AS6802 standard (Time-triggered Ethernet)
- Umbilical Pin-out Compliance: per International Docking System Standard

Tailoring in work per EHP element interfaces through Artemis V.



In-Space Rendezvous Standards

Managed Under IoWG

International Rendezvous System Interoperability Standards (IRSIS)

Baselined by NASA Gateway MCB and ESDMD DPMC. Use cases for cis-lunar, micro-gravity rendezvous

Summary Content:

- Safety guidelines:
 - Approach and Keep out sphere
 - Approach, Departure, Relocation & Abort corridors
- Secondary state determination
- Inter-vehicle telemetry (exchange of vehicle state data), monitoring and commanding

Changes under consideration for addition of requirements for smallsats and free-flyers and for specification of navigation alignment aids



Docking Standards

Managed Under Multi-Agency Panel

International Docking System Standard Interface Definition Document (IDSS IDD) – In Space

Originated to define basic common design parameters to allow system developers to independently design compatible docking systems

First baseline 2010 via panel including NASA, CSA, JAXA, ROSCOSMOS, and ESA.

Baselined for NASA Moon2Mars via Gateway MCB and ESDMD DPMC. Use cases for ISS Visitation in LEO, Exploration missions beyond LEO (incl. cis-Lunar), crew rescue, and international cooperation

Summary Content:

- Mating interface definitions (transfer passageway, soft capture system, hard capture system, electrical bonding, environments, materials and surface finishes)
- Docking Performance (Vehicle Mass Properties, Initial Contact Conditions, Loads)
- Resource Umbilical Definitions
- Rendezvous and Alignment Aids
- Berthing Interfaces

Revision (IDSS-Surface) in development for Lunar surface use cases

- Contents to include docking interface definition, load limits, peripheral systems.

Lunar Surface Interoperability Management



Thermal Standards

Managed Under Multi-Agency Panel

International Thermal System Interoperability Standards (ITSIS)
Baselined for NASA Moon2Mars via Gateway MCB and ESDMD DPMC. Use cases for commonality of EVA cold-plate interfaces among Moon2Mars assets and for common fluid connectors.

Future revisions may be needed to accommodate Lunar dust environmental impacts..

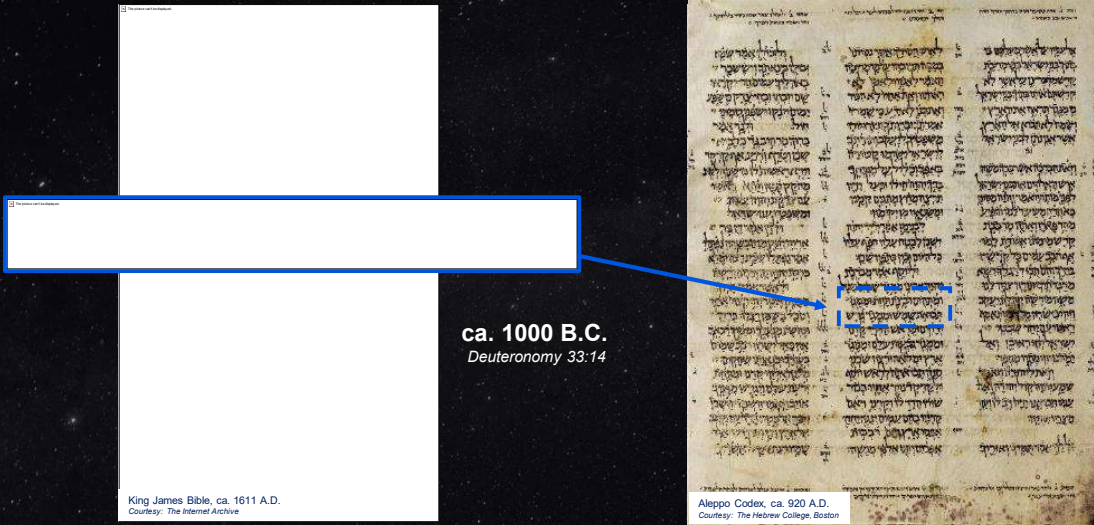
ECLSS Standards

Managed Under Multi-Agency Panel

International Environmental Control and Life Support System Interoperability Standards (IECLSSIS)

Baselined for NASA Moon2Mars via Gateway MCB and ESDMD DPMC. Use cases for commonality atmospheres among Moon2Mars assets and for common fluid connectors.

Interoperability on the Lunar surface will bring the benefits of the Moon to all Humanity.



Looking at the moon has always been a connection across humanity. Oldest surviving human writings refer to the Moon as a light or sign but also as a source of riches.

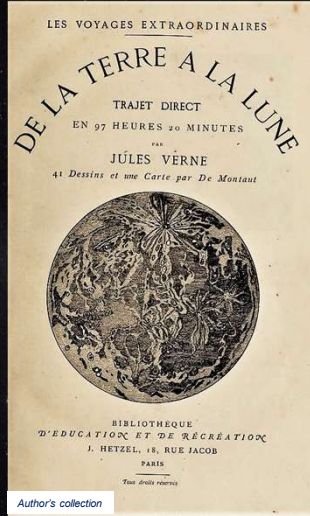
By 1865, When Jules Verne sat down in Paris to write the book that kicked off the space age, the Moon was understood to be a place, but reasonable people still believed there might be life on the Moon.

Maybe by the bicentennial of Verne's book, life will have settled there, to gather up those precious things.

Interoperability on the Lunar surface will bring the benefits of the Moon to all Humanity.



ca. 1000 B.C.



Author's collection

1865

Interoperability on the Lunar surface will bring the benefits of the Moon to all Humanity.



1st millennium B.C.



1865



Public Domain

2065 ?