Section 2D
FOM Definitions

Appendix 2D. FOM Definitions

Figure of Merit	Definition	Measures and Proxy Parameters
Safety and Mission Success		
Probability of Loss of Crew (P(LOC))	Probability of loss of crew across all mission phases.	**Measures:** P(LOC) **Proxy Parameters:** Number and type of abort/safe haven options per mission phase; crew rescue capability; time required to return crew to Earth at various key points in the mission; capability to stabilize and treat sick or injured crew member; capability to stabilize and return sick or injured crew member to Earth (e.g., entry g-level; habitable volume); level of radiation exposure/protection; system inherent reliability (e.g., Probability of Loss of Mission (P(LOM))/Probability of Loss of System).
Probability of Loss of Mission (P(LOM))	Probability of a critical failure occurring resulting in loss of one or more major mission objectives.	**Measures:** P(LOM) **Proxy Parameters:** Number and type of system risks and mission hazards; subsystem inherent reliability; system/subsystem functional redundancy (e.g., engine-out capability); number and complexity of major lunar architecture elements/systems; number of interfaces between major lunar architecture elements/systems; number of rendezvous and dockings required; number of engines and stages; number of propulsion system

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		restarts; total mission duration; launch window and return window frequency.
Effectiveness/Performance		
Cargo Delivered to the Lunar Surface	Usable cargo delivered to the lunar surface (e.g., habitats, rovers, instruments, consumables) per mission and annually.	**Measures:** Mass and volume of usable cargo (active, passive, pressurized and unpressurized cargo exclusive of all vehicle and logistics container weights) delivered to the lunar surface per mission annually. **Proxy Parameters:** Per-mission and annual cargo capacity (exclusive of all vehicle and logistics container weights) and reliability of surface delivery systems.
Cargo Returned from the Lunar Surface	Usable cargo returned from the lunar surface per mission and annually.	**Measures:** Mass and volume of usable cargo (active, passive, pressurized and unpressurized cargo exclusive of all vehicle and logistics container weights) returned to Earth from the lunar surface per mission and annually. **Proxy Parameters:** Cargo capacity and reliability of the architecture elements.
Surface Accessibility	Percent of required mission sites and percent of lunar surface accessible with a given architecture.	**Measures:** Number of required mission sites (high-priority science locations) that are accessible. Percent of lunar surface that is accessible. Depth of access below the lunar surface. **Proxy Parameters:** Amount of propellant transported to the lunar

Figure of Merit	Definition	Measures and Proxy Parameters
		surface or lunar orbit; lunar lander mission life, propellant capacity, and ease of refueling; number and type of human and robotic surface mobility systems.
Usable Surface Crew-Hours	Intra-Vehicular Activity (IVA) and Extra-Vehicular Activity (EVA) crew-hours on the lunar surface available for science and engineering (exclusive of maintenance hours).	**Measures:** Usable (i.e., non maintenance) IVA and EVA crew-hours on the lunar surface per mission and annually. **Proxy Parameters:** Estimated maintainability of surface systems; level of automation of surface systems; number of crew; volume of lunar lander and habitat, crew-days of life support and consumables provided by lunar lander and habitat.
System Availability	The probability that the system is available to execute a mission when called upon.	**Measures:** Probability of System Availability. **Proxy Parameters:** System robustness to weather at launch/processing site (e.g., Thermal Protection System (TPS) type); ability of fueled/unfueled system to stay on launch pad for extended time (e.g., fuel type); ability of system to launch as rapidly as possible in emergency (e.g., redundant launch vehicles/pads/facilities, streamlined launch processing.); ability of system to allow operators to perform mission functions as required.
System Operability	The ability of the system to provide an environment that allows	**Measures:** Probability of Mission Objectives Satisfied. **Proxy Parameters:** Level of crew

Figure of Merit	Definition	Measures and Proxy Parameters
	the operators to accomplish the mission objectives.	comfort provided; adequacy of net usable crew volume to accomplish required tasks; adequacy of tools provided to accomplish mission objectives; number and severity of crew health and safety hazards.
Extensibility/Flexibility		
Lunar Mission Flexibility	Ability of an architecture to increase capabilities to meet evolving lunar mission requirements.	**Measures:** Performance margins of crew and cargo transportation systems; marginal costs of delivering additional cargo mass and volume to lunar surface; marginal costs of delivering additional crew and usable crew-hour capacity to the lunar surface; marginal costs of visiting additional lunar surface sites through human or robotic means; marginal costs of providing additional square kilometers of human or robotic surface mobility; marginal costs of returning additional cargo from the lunar surface. **Proxy Parameters:** Level of commonality and modularity of crew and cargo transportation systems; level of preplanned product improvement in crew and cargo transportation systems.
Mars Mission Extensibility	Applicability and extensibility of technologies, systems, and operations of a lunar mission architecture to future Mars missions.	**Measures:** Level of hardware commonality and traceability between lunar and Mars mission technologies, systems, operations, infrastructure, and approaches (e.g., closed-loop life support; CEV applicability as Mars-

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	Also includes an assessment of Mars mission risks that are retired/reduced.	Earth return vehicle; use of in-situ resources; number of crew); net present value of reduction in future Mars mission life cycle costs; total improvement in reliability/safety for future Mars missions; percent of key Mars mission programmatic risks retired or reduced; number and type of improvements in Mars mission performance (e.g., usable crew surface-days per Initial Mass in Low Earth Orbit (IMLEO)). **Proxy Parameters:** Similarity of in-space and surface environments between lunar and Mars missions (e.g., temperatures, radiation, lighting, dust); total number of crew-days on surface by a single crew member; assessment of percent of key Mars mission programmatic risks retired or reduced.
Extensibility to Other Exploration Destinations	Applicability and extensibility of technologies, systems, and operations of a lunar mission architecture to other potential exploration missions/destinations.	**Measures:** Level of hardware commonality and traceability between lunar and other exploration mission technologies, systems, operations, infrastructure, and approaches; net present value of reduction in future mission life cycle costs to other exploration destinations (e.g., asteroids, Mars moons); total improvement in reliability/safety for other exploration missions; number and type of improvements in performance of other exploration missions.

Figure of Merit	Definition	Measures and Proxy Parameters
		Proxy Parameters: Similarity of in-space and surface environments between lunar and other exploration missions.
Commercial Extensibility	Applicability and extensibility of technologies, systems, and operations of a lunar mission architecture to commercial activities.	**Measures:** Level of hardware commonality and traceability between lunar mission and commercial technologies, systems, and operations infrastructure and approaches. **Proxy Parameters:** None.
National Security Extensibility	Applicability and extensibility of technologies, systems, and operations of a lunar architecture to support national security interests.	**Measures:** Level of hardware commonality and traceability between lunar and national security mission technologies, systems, operations, infrastructure, and approaches. Net present value of reduction in future mission life cycle costs to national security missions; total improvement in reliability/safety for national security missions. **Proxy Parameters:** None.
Programmatic Risk		
Technology Development Risk	Likelihood of lunar architecture technology development activities to exceed schedule and budget constraints and consequence of occurrence.	**Measures:** Risk Exposure Score using five-level qualitative assessment of likelihood and consequences of major technologies not being available at technology need dates. Total Risk Exposure = $\Sigma(\text{Likelihood}_i \times \text{Consequences}_i)$. **Proxy Parameters:** Number of technologies required; average Technology Readiness Level (TRL) of technologies; average RD^3 score of

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		technologies; number and type of large-scale integrated ground demonstrations required; number and type of flight tests required.
Cost Risk	Likelihood of lunar architecture life cycle costs (technology development; Design, Development, Text, and Evaluation (DDT&E); and operations) to exceed planned budget and consequence of occurrence.	**Measures:** P(Technology Development Costs > Planned Budget); P(DDT&E Costs > Planned Budget); P(Average Annual/Mission Operations Costs > Planned Budget) from probabilistic risk analysis. **Proxy Parameters:** Comparison of cost profiles to relevant historical development programs; number and level of complexity of lunar architecture systems; number of interfaces between major lunar architecture elements/systems; percent of new hardware and hardware that uses new technologies used in lunar architecture systems; management and acquisition approaches used in the development and operation of lunar architecture systems; level of communications and navigation infrastructure required; number of rendezvous and dockings required; level of autonomy (for ground and flight operations) of lunar architecture systems; maintainability/life of lunar architecture systems; level of reusability of lunar architecture systems.
Schedule Risk	Likelihood of lunar architecture DDT&E	**Measures:** P(Actual IOC Date < Planned Date) from probabilistic risk

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	activities to exceed planned schedule and consequence of occurrence.	analysis. **Proxy Parameters:** Comparison of schedule profiles to those of relevant historical development programs; number and level of complexity of lunar architecture systems; number of interfaces between major lunar architecture elements/systems; percent of new hardware and hardware that uses new technologies used in lunar architecture systems; management and acquisition approaches used in the development of lunar architecture systems. Level of modularity; amount of parallel/phased development.
Political Risk	Likelihood of a lunar architecture to fail to gain or to lose political support and consequence of occurrence.	**Measures:** Use of controversial new technologies (e.g., Nuclear); level of involvement of multiple NASA Centers and geographically distributed contractors; public perception of effectiveness/ performance; public perception of flexibility/extensibility to: an expanded lunar mission, other potential exploration destinations including Mars, commercial activities, and national security interests; number of international partners; ability to accommodate budget fluctuations; year of first crewed lunar mission. **Proxy Parameters:** None.
Affordability		

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Technology Development Cost	Cost to develop required technologies to TRL–6.	**Measures:** NPV (Technology Program Development Costs): peak annual funding costs. **Proxy Parameters:** Number of technologies required; average TRL of technologies; average RD^3 score of technologies; number and type of large-scale integrated ground demonstrations required; number and type of flight tests required.
DDT&E Cost	Cost to design, develop, test, and evaluate all lunar architecture systems to Initial Operational Capability (IOC).	**Measures:** NPV (DDT&E costs); peak annual funding cost. **Proxy Parameters:** Total dry mass of lunar architecture systems; number and level of complexity of lunar architecture systems; number of interfaces between major lunar architecture elements/systems; percent of new hardware and hardware that uses new technologies used in lunar architecture systems; management and acquisition approaches used in the development of lunar architecture systems.
Facilities Cost	Cost to establish new or modified facilities (e.g., manufacturing, launch, processing, propellant production) needed to conduct lunar missions.	**Measures:** NPV (Facilities costs); peak annual funding costs. **Proxy Parameters:** Total volume and mass of facilities required; level of complexity of facilities; percent of new hardware and hardware that uses new technologies used in facilities; management and acquisition approaches used in the development of new facilities.

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Operations Cost	Average annual and per mission costs after IOC (fixed and variable).	**Measures:** Average annual costs. Average per-mission costs. **Proxy Parameters:** Annual and pre-mission IMLEO; launch diameter of largest stowed lunar architecture element; level of communications and navigation infrastructure required; number and complexity of major lunar architecture elements/systems; number of interfaces between major lunar architecture elements/systems/ number of rendezvous and dockings required; level of autonomy (for ground and flight operations) of lunar architecture systems; maintainability/life of lunar architecture systems; level of reusability of lunar architecture systems.
Cost of Failure	Net present value of average cost of failure occurring during a lunar mission, including all direct and indirect return-to-flight costs.	**Measures:** NPV (Average cost of failure). Time to return to flight after failure. **Proxy Parameters:** Difference between P(LOM) and P(Loss of System); difference between P(LOM) and P(LOC); number and type of alternate launch systems; level of commonality and modularity between systems; system production costs.