ROCINANTE
FIELDWORKS

Field Brief 001:

How to Launch a Nuclear Reactor into Outer Space

A guide to establishing a permanent government and commercial capability for space nuclear power systems for the Moon and Mars.



Alex Gilbert, PhD

Why This Brief

General information only. This field brief does not provide legal advice.

THE MISSION

Power for the Moon. A pathway to Mars.

Fission can support sustained activity through lunar darkness, expand where missions can operate, and enable dependable surface power and nuclear electric propulsion for Mars.

SNAP-10A, launched in 1965, remains the only U.S. fission reactor to fly in space.

Later programs advanced the technology without reaching flight. Success depends on linking fuel, testing, transport, facilities, safety, and approvals into a workable deployment pathway.

Two federal targets shape planning

NASA targets a 2028 launch for SR-1 and a launch-ready lunar surface reactor by 2030.

HOW TO USE THIS FIELD BRIEF

For mission owners, reactor and spacecraft developers, spaceports, and teams planning a U.S. space nuclear mission.

1 **Compare two missions**

Compare NASA's SR-1 with CLR-1, a hypothetical commercial lunar plant. Identify which approvals and responsibilities change with the mission.

2 **Follow the lifecycle**

Start with roles and hazards, then move through design, supply, the spaceport, launch, operations, and end of life.

3 **Plan the whole campaign**

Use each phase to identify the safety work, technical dependencies, responsible organizations, and unresolved approvals.

4 **Use the evidence**

Agency badges identify principal authorities. Linked citations lead to the policies, rules, standards, and research behind the analysis.

Mission and policy status reviewed 10 November 2026. Confirm requirements with the responsible authorities. Rocinante concept illustrations appear on pp. 1, 12, 15, 17 and 22. Mars imagery: NASA/JPL/USGS.

Contents

Understand the mission, follow the six phases, and return to the issues that span the campaign.

01 / ESTABLISH THE MISSION

Read these together before selecting an approval route.



Reference missions 04

Shared reactor functions; federal and commercial cases.

Mission roles 05

Who owns, designs, supplies, launches, and operates.



Lifecycle mission safety 06

How the hazards and responsible agencies change.

Reactor hazards 07

Four physical concerns; two safety strategies.



Space nuclear authorities 08

The organizations and their different roles.

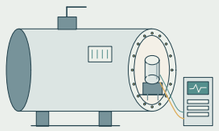
Table of authorities 09

A linked map of policy, law, procedures, and standards.

02 / FOLLOW THE DEPLOYMENT

The lifecycle framework becomes a sequence of program decisions.

1



Design

Merge nuclear and aerospace requirements.

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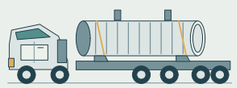
2



Supply chain

Procure, qualify, fabricate, and transport.

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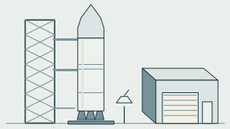
3



Spaceport

Prepare facilities and the ground campaign.

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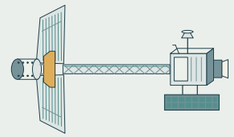
Launch

Build the SAR and secure launch approval.

PAGE 13

5



Operations

Separate in-space and lunar operating needs.

SR-1 14 CLR-1 15

6



End of life

Plan stable disposition and stewardship.

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03 / RESOLVE THE CROSS-CUTTING ISSUES

Advanced lunar architectures 17

Options that change mass, economics, and operations.

LII 18

Identify third-party risks and coverage gaps.

Export controls 19

Manage four regimes across the program.

Major challenges 20

Compare the two cases and their shared needs.

Rocinante Fieldworks 21

People and services to support deployment.

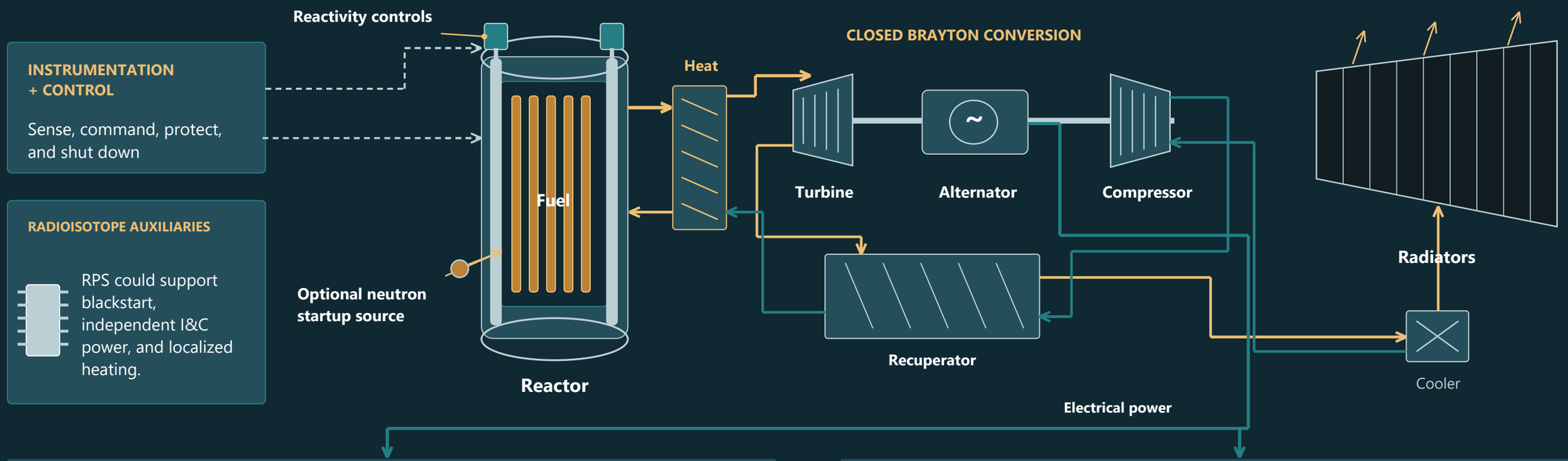
Click a section or page number to jump directly to it. The mission and reading guide are on page 02.

Reference Missions

To explore how to launch a reactor, we use two reference missions: a government reactor in space and a private lunar power plant. Together, they show the common requirements and different deployment pathways needed to build the sector.

SHARED REACTOR SYSTEM

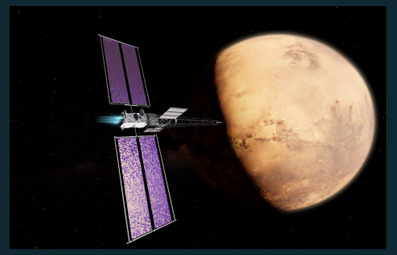
Common functions, illustrated with a closed Brayton power-conversion system.



SR-1 Freedom

FEDERAL / IN-SPACE REACTOR

NASA and DOE plan a high-assay low-enriched uranium (HALEU) reactor for SR-1. A closed Brayton system would deliver 20 kW of electricity for the demonstration of nuclear electric propulsion en route to Mars.

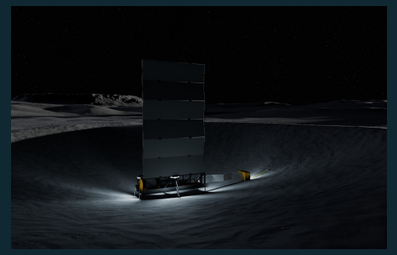


NASA SR-1 concept

CLR-1

PRIVATE / LUNAR SURFACE REACTOR

CLR-1 is a hypothetical U.S. commercial lunar power service. NASA leads the separate LR-1 mission and could pursue a similar service model. The case explores ground licensing, lunar installation, operating authority, and liability.

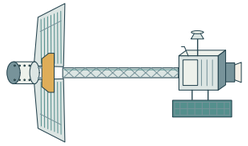


NASA lunar FSP concept

Shared functions, not a selected hardware design. RPS support is an architecture option requiring sizing and qualification. CLR-1 is a constructed reference case, not NASA LR-1.

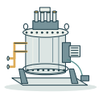
Mission Roles

Space reactor missions involve coordination across multiple entities. Nuclear ownership, operation, and possession may be split. Their interfaces determine who supplies hardware, develops the safety case, seeks approvals, and operates the mission.



SPACECRAFT / BALANCE-OF-SYSTEM DESIGNER AND DEVELOPER

Develop the bus, conversion, heat rejection, controls, and system interfaces.



REACTOR DESIGNER AND DEVELOPER

Design and fabricate the reactor; provide fuel and specialized components, testing, and safety evidence.

MISSION OWNER / RESPONSIBLE ENTITY

SYSTEM PRIME

Own the mission, integrate the system and safety case, assign approval applicants, control interfaces, and fund lifecycle obligations.



LUNAR LANDER PROVIDER / OPERATOR

Deliver CLR-1; develop landing, unloading, and installation interfaces.



NUCLEAR SYSTEM OWNER / OPERATOR

Accept the plant and operating limits; hold material custody and execute nuclear safety duties.



LAUNCH VEHICLE PROVIDER

Provide launch services, integration, vehicle data, and flight safety interfaces.

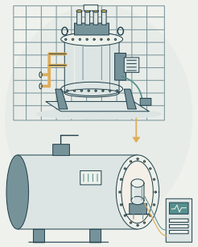
One organization may hold several roles. The mission owner remains responsible for the integrated campaign.

Illustrative contracting structure. Nuclear ownership and operation may be split or transfer by phase; define the duties and the handover explicitly.

Lifecycle Mission Safety

Criticality control, source-term management, and radiation emissions are the three primary safety concerns carried through the mission.

1. Design



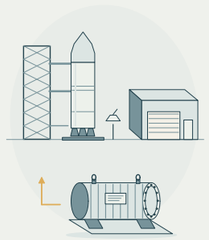
Set safety criteria

2. Supply chain



Build and transport

3. Spaceport



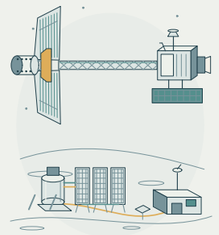
Handle and integrate

4. Launch



Survive ascent

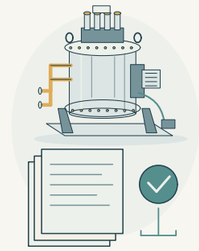
5. Operations



Deploy, then start

STARTUP

6. End of life



Shut down and steward

PRIMARY SAFETY CONCERNS

CRITICALITY CONTROL

Keep subcritical before authorized startup.

Control reactivity, power, and shutdown; prevent unintended restart.

SOURCE-TERM MANAGEMENT

Contain fresh fuel; limit accident releases.

Irradiation builds fission products; control potential releases as the radioactive inventory grows.

RADIATION EMISSIONS

Manage exposure from fuel and auxiliaries.

Manage the substantial operating radiation field and residual radiation after shutdown.

ASSUMED COLD LAUNCH

The reference pathway generally assumes no reactor operation or zero-power critical test before launch. Alternative test or assembly campaigns can change the hazards during these phases.

PRINCIPAL AGENCIES AND MISSION RESPONSIBILITY

Early engagement; mission requirements

Materials, facilities, and ground transport

Nuclear work: DOE or NRC
Range: USSF or NASA, as applicable

Vehicle route; nuclear launch tier

SR-1: federal mission
CLR-1: authorization open

Sponsor / operator; long-term stewardship

Framework adapted from Gilbert (2023). Emphasis changes at startup; all three safety concerns continue. Agency roles depend on the activity, mission, and contractual arrangement.

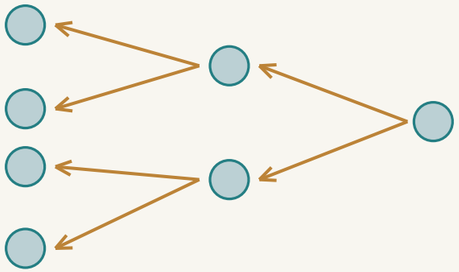
SOURCES Gilbert (2023) NSPM-20 NPR 8715.26A SPD-6

Reactor Hazards

The reactor state and accident conditions determine how these hazards arise and how they must be controlled.

01 CRITICALITY / REACTIVITY

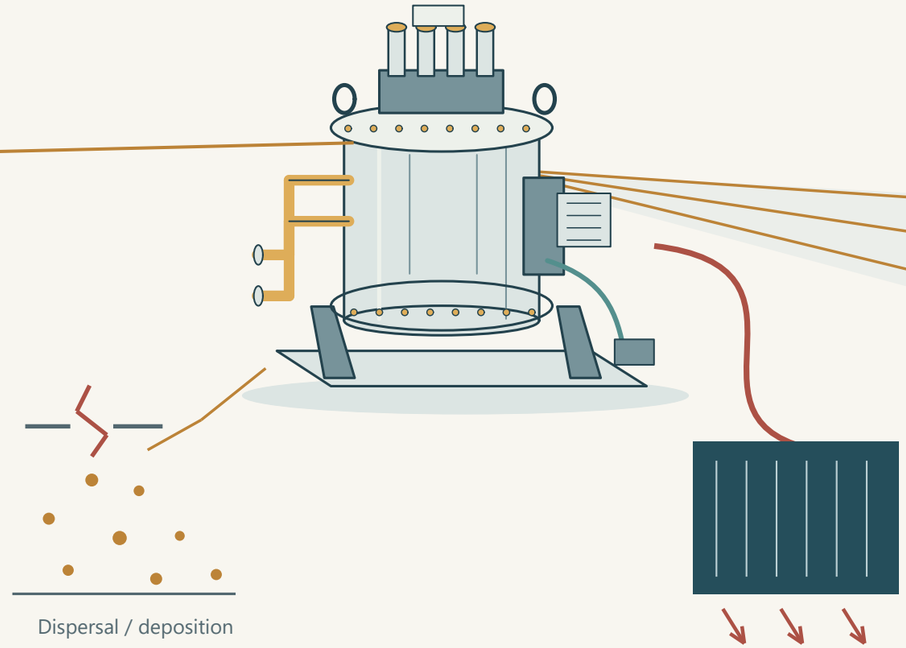
Prevent prompt criticality in accidents. Maintain subcriticality until authorized startup. Control reactivity and power during operation. Shut down safely and prevent unintended restart.



Neutron multiplication

03 RADIOACTIVE MATERIAL RELEASE

Damaged fuel or barriers can disperse radioactive material, contaminating surfaces or exposing people through intake.



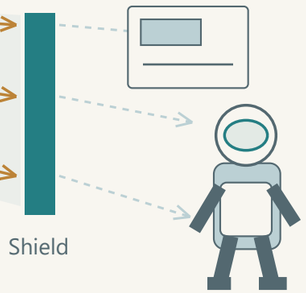
Dispersal / deposition

TECHNOLOGY OPPORTUNITY

Radiation-hardened I&C and spacecraft electronics can reduce shielding mass and relax equipment placement. Qualification against mission radiation remains essential.

02 DIRECT RADIATION

Neutrons and gamma rays expose people and equipment, even without a release of radioactive material.



Shield

04 HEAT REMOVAL

Inadequate cooling can overheat fuel and barriers. Reject heat during operation and after shutdown.

SAFETY STRATEGIES

Safety basis development

Define credible events, safety functions, and limits. Demonstrate controls with analysis and testing; maintain the basis as the design and mission change.

Defense-in-depth

Layer prevention, detection, control, and mitigation; account for common failures and limited intervention.

For example, see Granger (2026): Applying defense-in-depth to the design and operation of fission power systems on the lunar surface

SOURCES Gilbert (2023) Granger (2026) NASA NPAS (2015) NASA radiation design

Space Nuclear Authorities

The same mission crosses nuclear, transport, launch, and space authorities. No single approval covers the whole lifecycle.

01 Terrestrial licensing

DOE
Federal nuclear work and contractor facilities

NRC
Commercial facilities, material, and packages

DOT / PHMSA
Ground transport and hazardous materials

02 Launch authorization

NASA
Civil federal missions

Defense (DoD)
Defense federal missions

FAA AST / DOT
Commercial vehicle launch licensing

03 Interagency partners

State
Foreign policy and international obligations

EPA
Radiological protection and environmental expertise

Consultation extends beyond the INSRB review.

04 Other approvals

FCC / NTIA
Radio spectrum

Commerce / NOAA
Covered remote sensing

Export agencies
State, Commerce, DOE, and NRC

Also: environment, range and site access, and applicable state/local permissions.

INSRB

Technical review

NASA · DoD · DOE · DOT · State · EPA · NRC → findings / SER → OSTP

The INSRB Charter names these seven permanent members. Participation in a mission review can be tailored. The Board advises OSTP and the launch authorizer.

? **COMMERCIAL LUNAR MISSION AUTHORIZATION**

Who authorizes and continually supervises a private lunar reactor? Commerce's exploratory certification pilot leaves that question open.

Table of Authorities

A map of U.S. space nuclear policy, law, procedures, and standards. Click a document to open its source.

INFORMING GUIDANCE

UN Nuclear Power Source Principles

COPUOS / IAEA Safety Framework

SPD-6
National strategy
Lifecycle responsibilities.

NSPM-20
Launch safety guidelines, tiers, authorizers, and nuclear safety analysis.

NSTM-3
National implementation initiative
Implements EO 14369: deployment goals

Defense / DoD

STATUTE **10 USC 113** **10 USC 9013**

PROCESS **DAFMAN 91-110 (index)**
Nuclear safety review and tiered launch approval.

SUPPORT **DoDD 3100.10: space policy**

NASA

BASIS **51 USC 20113** **NPD 8700.1F**

PROCESS **NPR 8715.26A**
Flight-safety planning, SAR, independent review, and launch decision.

SUPPORT **HDBK-8715.26**
DOE systems: STD-1271 / Att. 3 MSAR

FAA / AST

STATUTE **51 USC ch. 509: commercial launch**

PROCESS **14 CFR Part 450: vehicle licensing**
450.43: payload **450.45(e)(6): safety**

SUPPORT **AC 450.45-1**
Case-by-case SNS review; accepted guidance.

INTERAGENCY NUCLEAR SAFETY REVIEW BOARD
Advisory only **Charter** **Playbook (Rev. 2)**

Independent technical review of the mission safety analysis
Review product: mission Safety Evaluation Report (SER)
INSRB technical review briefing

OTHER AUTHORITIES AND REQUIREMENTS

Ground licensing + transport

Atomic Energy Act
DOE: 10 CFR 830 **STD-1271**
NRC: 50 **52** **53** **70** **57 (proposed)**
Transport: 10 CFR 71, 49 CFR
91-710 V3 **V6** **NASA range safety**

Environment + mission

NEPA **NASA 1216** **FAA 1050.1G**
RCP: NPR 8715.26A / 3.8
Artemis Accords **NPR 8715.6E**
Exploratory Commerce certification pilot

Export controls

10 CFR 110	Nuclear material + equipment
10 CFR 810	Nuclear technology + assistance
ITAR / USML XV	Space systems + technical data
EAR	Other controlled items + technology

See page 19 · Export controls

Liability + indemnification

42 USC 2210 **DEAR 952.250-70**
PL 85-804 **FAR Part 50**
NASA: 20138 **20148**
FAA: 50914 **50915** **Part 440**
Third-party coverage; scope depends on the mission and contracts.
See page 18 · LII

EMERGENT STANDARDS

Work items are proposed. Issued standards apply through their scope and adoption.

WK86387
Operations | work item

WK99770
Spaceport | work item

ASTM SAR guide
Proposed concept | F47 committee

ANS-31.1
Space reactor testing | proposed

NASA-STD-8719.30
Nuclear flight safety | issued

ASME/ANS JCNRM
Space reactor PRA | in development

NSPM-20 coordinates launch authorization; statutes confer agency powers. International guidance informs practice. Commercial lunar mission authorization remains unresolved.

SOURCES ISO 9001 AS9100 GSFC-STD-7000B LR1-NLAM-001 (draft)

Phase 1. Design

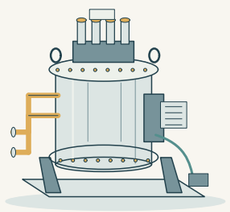
The most consequential phase: the mission owner, reactor developer, and spacecraft developer determine whether the system can fly.

EARLY ENGAGEMENT

SR-1 DOE + NASA

CLR-1 NRC + FAA

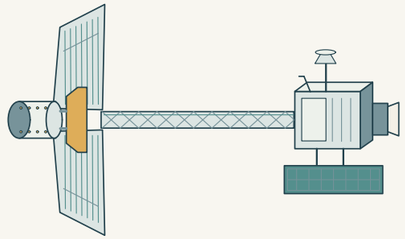
NUCLEAR ENGINEERING



Fuel, neutronics, criticality control, heat removal, shielding, nuclear QA, and radioactive inventory.

AEROSPACE ENGINEERING

Mass, power, trajectory, launch loads, deployment, communications, and fault tolerance.



COMBINE AND RECONCILE REQUIREMENTS

The mission owner integrates both disciplines into one flyable system and safety case.

Qualification evidence

- **FLIGHT**

  Vibration, shock, thermal vacuum, radiation effects, and deployment.
- **NUCLEAR**

  Benchmarked criticality and accident models; fuel and barrier tests.
- **INTEGRATED**

  Heated-system tests, controls, and fault-response demonstrations.

Separate test articles can supply evidence when the flight reactor is not tested at power.

Apply QA by subsystem

NQA-1 Nuclear safety QA.

ISO 9001 General quality management.

AS9100 Aerospace quality management.

NQA-1 can support a nuclear quality assurance (QA) program. Identify the governing requirements, the edition the project has committed to, and the duties that flow to suppliers.

Different QA requirements apply across the system; aerospace certification alone does not establish nuclear QA.

Plan the regulatory campaign

- Set safety criteria and the regulatory engagement plan (REP).
- Map safety evidence, NEPA, indemnification, and review milestones.
- Plan transport and launch vehicle databook inputs.
- Begin pre-application engagement; assign data and approval responsibilities.

LR1-NLAM-001 (draft): Plan and Deliverables for Regulatory Engagement and NSPM-20 Compliance.

Track emerging standards, including ASTM WK86387.

Conceptual design generally precedes nuclear approval; engagement and export-control planning begin while requirements can still change.

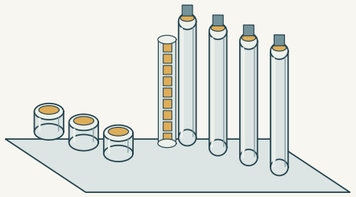
Phase 2. Supply Chain

Long-lead procurements and immature suppliers create substantial schedule and coordination risk.

PRIMARY REGULATORS

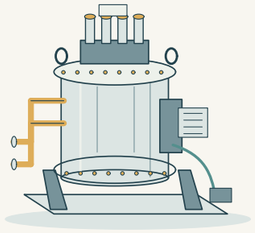
SR-1 DOE; DOT transport

CLR-1 NRC; DOT transport



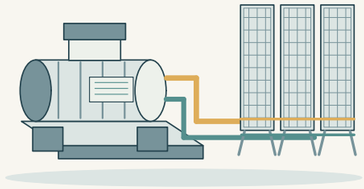
Fuel

Secure HALEU and conversion capacity. Qualify the fuel for its operating conditions and verify fabricated fuel against specifications.



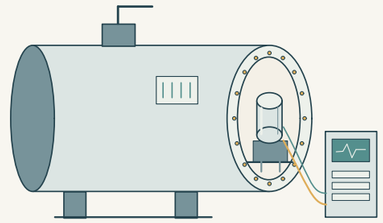
Reactor

First-unit hardware, specialist materials, controls, and shielding.



Power system

Conversion, heat transport, radiators, and electrical interfaces.



Test capacity

Specialized radiation facilities or validated surrogates.

COORDINATE, FABRICATE, INTEGRATE, AND ACCEPT

Align fuel, fabrication, conversion, QA, interfaces, and scarce test slots. Procurement sequencing must follow the transport and integration plan.

GROUND TRANSPORT

A self-contained lunar reactor can travel by road already fueled, or its fuel can travel separately for integration before flight. Plan early for transport approvals, package mass, criticality safety, and accident requirements.

For each shipment, identify the shipper, package approval, loading limits, and who takes custody at the receiving facility.

TECH / INFRASTRUCTURE OPPORTUNITY

Upstream nuclear testing needs accessible irradiation, hot-cell examination, and nuclear-rated integration and thermal-vacuum capabilities. Facilities may be constrained by queues, capability, or commercial access.

STARTUP + SURVIVAL SUPPORT

A neutron source can provide a measurable startup signal. Optional RPS can supply blackstart and independent I&C power; heater units can provide localized warmth. Plan distinct source packages, handling, and delivery.

Phase 3. Spaceport

In 2025, Lal and Myers identified a U.S. gap in facilities for handling flight reactors. Confirm current capability with the host.

Multi-user, multi-facility complexes bring the widest set of stakeholders in the campaign, requiring coordinated safety, security, and access controls.

PRIMARY NUCLEAR REGULATOR

SR-1 DOE authorization

CLR-1 NRC licensing

RECEIVE + STORE

Preserve subcriticality during handling and accidents. Set custody, material protection, security, and restricted access.

PROCESS + INTEGRATE

Assembly and fueling, if required. Coordinate the custodian, facility operator, reactor supplier, and launch provider.

TRANSFER + LAUNCH

Coordinate range, transport, and emergency services. Rehearse scrubs, storage, return, and recovery.



SR-1 / DOE-AUTHORIZED GROUND CAMPAIGN

Authorize the reactor and ground activities through DOE. Establish the facility safety basis, including a DOE-approved Documented Safety Analysis (DSA) and technical safety requirements where 10 CFR 830 applies.

CLR-1 / NRC LICENSED GROUND ACTIVITIES

Confirm the NRC route for the proposed activity before committing to a site. Fuel possession or handling may require Part 70 authorization. Assess reactor licensing separately under Parts 50, 52 or 53, as applicable. Part 57 remains proposed.

RANGE SAFETY + SITE PERMISSIONS

For either mission, engage the host and the U.S. Space Force (DoD) and NASA range safety offices as applicable. Confirm who accepts payload hazards, approves hazardous operations, and coordinates site access and emergency response.

Early ASTM effort: WK99770, New Guide for Launch-Site Handling, Storage, Processing, and Integration of Space Nuclear Systems.

Phase 4. Launch

Federal sponsorship and vehicle licensing are separate decisions. Confirm both routes and engage the applicable U.S. Space Force or NASA range safety office during design.

LAUNCH AUTHORITY

SR-1 NASA / federal route

CLR-1 FAA-licensed route

NSPM-20

Safety guidelines / launch authorizers / mission Safety Analysis Report (SAR)

SR-1 | NASA NPR 8715.26A

Authorization plan → SAR → INSRB review / SER

NASA Administrator for Tier II; President / designee for Tier III. Coordinate nuclear launch authorization, range safety, and payload safety.

CLR-1 | FAA Part 450

Pre-application → safety + payload review → vehicle license

FAA licenses the vehicle operator and coordinates nuclear-payload review by tier. Section 450.45(e)(6) calls for case-by-case protection measures.

§450.43 payload review; AC 450.45-1 provides guidance.

A reviewable SAR

System + mission
Fuel, configuration, and flight profile.

Accident environments
Sequences, probabilities, and vehicle data.

Nuclear response
Prevent prompt criticality; assess release.

Consequences
Dose, exposure pathways, and uncertainty.

Confidence
Tests, validated models, and peer review.



NEPA

Analyze alternatives and environmental impacts; complete the responsible agency's decision.

RCP

Radiological contingency planning: coordinate and rehearse notification, protective action, response, and recovery.

LAUNCH VEHICLE

Enabling technology

Match lift capacity and accident data to the selected vehicle. The safety analysis needs vehicle-specific failure probabilities and accident environments, including propellant explosion effects. Photo: SLS launching Artemis I (NASA/Joel Kowsky).

Phase 5. SR-1 Operations

SR-1's flight plan must account for reactor startup, power for propulsion, and possible Earth encounters after a failure.

MISSION AUTHORITY

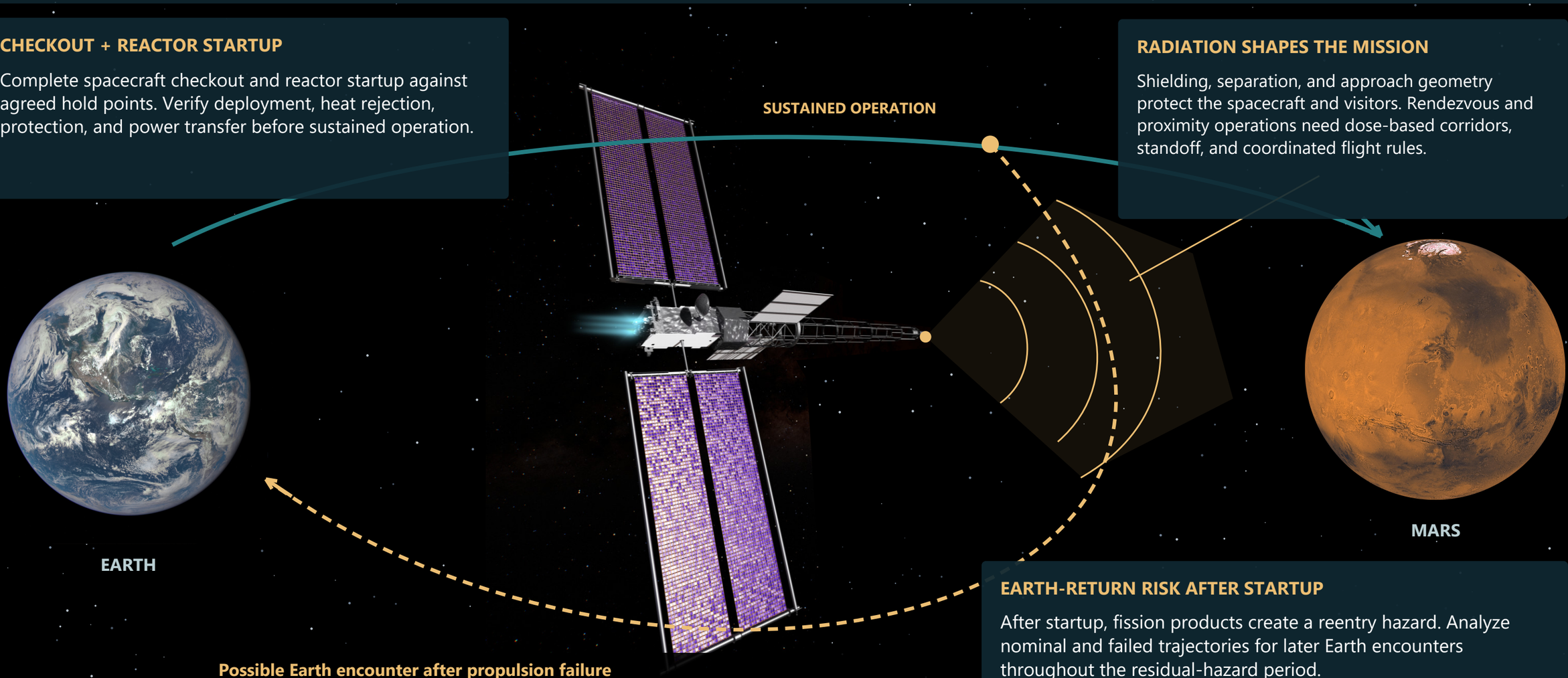
SR-1 NASA + DOE roles

CHECKOUT + REACTOR STARTUP

Complete spacecraft checkout and reactor startup against agreed hold points. Verify deployment, heat rejection, protection, and power transfer before sustained operation.

RADIATION SHAPES THE MISSION

Shielding, separation, and approach geometry protect the spacecraft and visitors. Rendezvous and proximity operations need dose-based corridors, standoff, and coordinated flight rules.



EARTH-RETURN RISK AFTER STARTUP

After startup, fission products create a reentry hazard. Analyze nominal and failed trajectories for later Earth encounters throughout the residual-hazard period.

After a ground irradiation test, the fuel can be examined in a hot cell (p. 11). A planned return of flown material would require a separate safety case.

AUTONOMY / PNT / COMMUNICATIONS

Reactor and spacecraft must handle faults autonomously. Provide positioning, navigation, and timing (PNT), plus communications support, throughout the mission.

ENABLING TECHNOLOGY / ISAM

In-space servicing, assembly, and manufacturing (ISAM) can enable boom deployment and large-system integration.

Emerging guidance: ASTM WK86387, New Guide for Safe Operations of Fission Reactors in Outer Space.

Phase 5. CLR-1 Operations

CLR-1 models a commercial lunar power service. NASA leads LR-1 and could choose a similar model.

MISSION AUTHORIZATION

CLR-1 U.S. route unresolved

01 / LAND

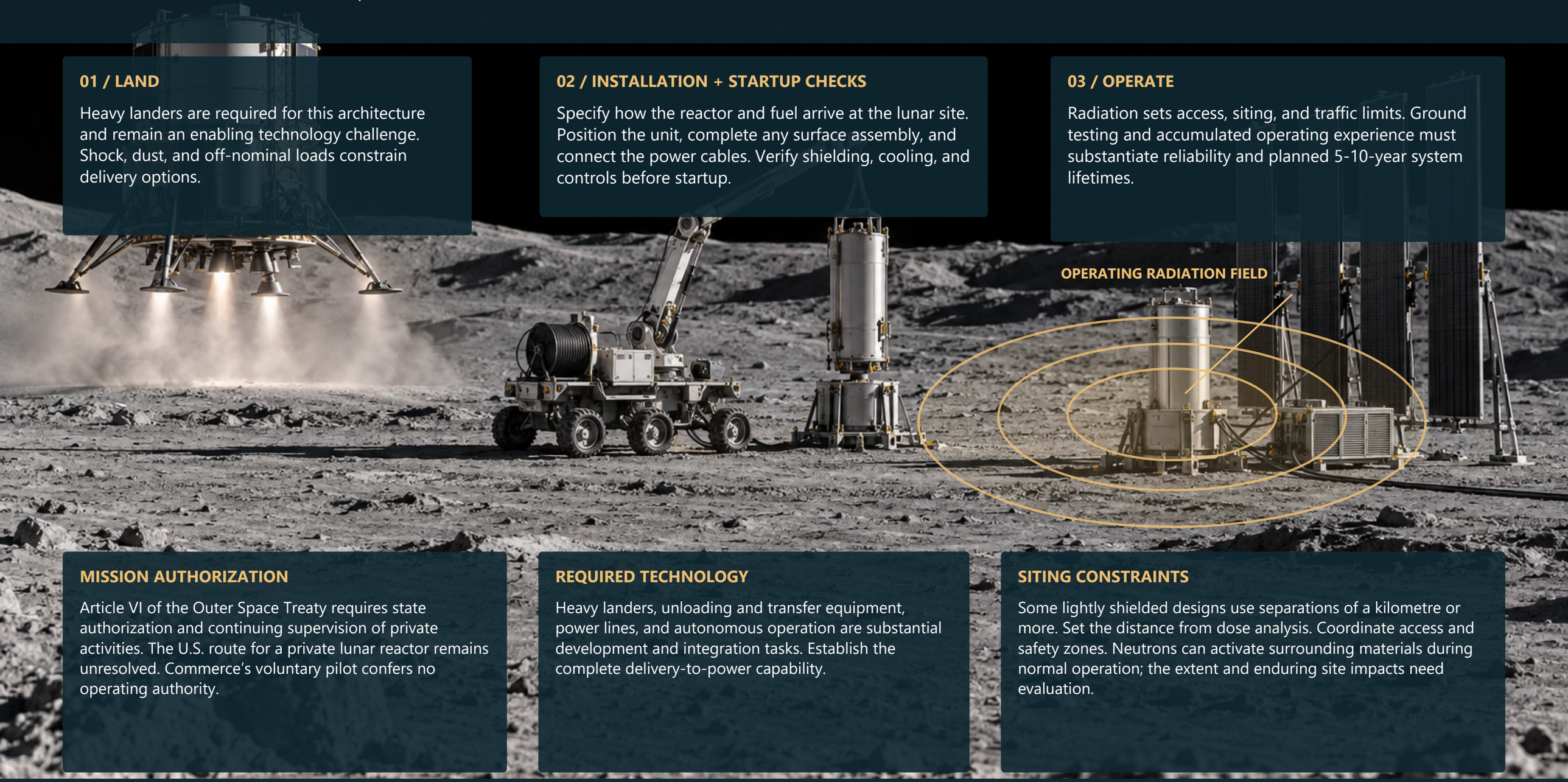
Heavy landers are required for this architecture and remain an enabling technology challenge. Shock, dust, and off-nominal loads constrain delivery options.

02 / INSTALLATION + STARTUP CHECKS

Specify how the reactor and fuel arrive at the lunar site. Position the unit, complete any surface assembly, and connect the power cables. Verify shielding, cooling, and controls before startup.

03 / OPERATE

Radiation sets access, siting, and traffic limits. Ground testing and accumulated operating experience must substantiate reliability and planned 5-10-year system lifetimes.



MISSION AUTHORIZATION

Article VI of the Outer Space Treaty requires state authorization and continuing supervision of private activities. The U.S. route for a private lunar reactor remains unresolved. Commerce's voluntary pilot confers no operating authority.

REQUIRED TECHNOLOGY

Heavy landers, unloading and transfer equipment, power lines, and autonomous operation are substantial development and integration tasks. Establish the complete delivery-to-power capability.

SITING CONSTRAINTS

Some lightly shielded designs use separations of a kilometre or more. Set the distance from dose analysis. Coordinate access and safety zones. Neutrons can activate surrounding materials during normal operation; the extent and enduring site impacts need evaluation.

SOURCES Gilbert, NLB NASA FSP design trades NASA deployment study NASA FSP lifetime Lunar activation Outer Space Treaty Artemis Accords ASTM WK86387 Commerce pilot

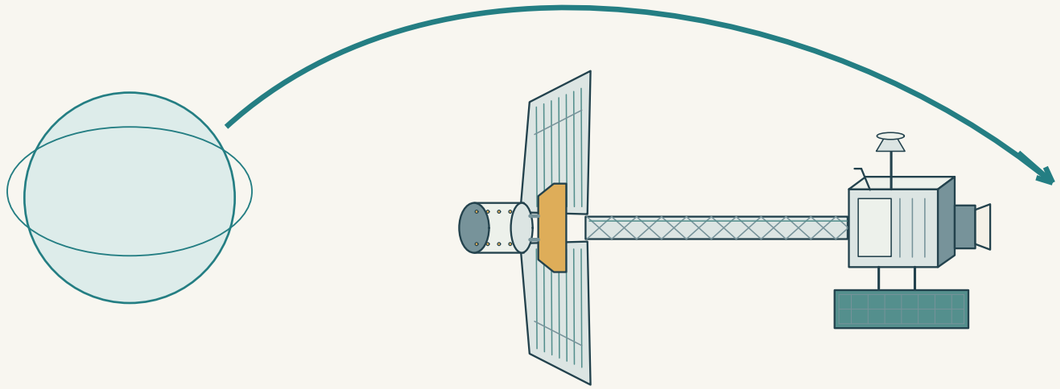
Phase 6. End of Life

Radioactive inventory creates a long-term hazard and stewardship responsibility. Establish the final state, responsible organization, and funding before startup.

RESPONSIBLE AUTHORITY

SR-1	NASA + DOE scope
CLR-1	Operator; route unresolved

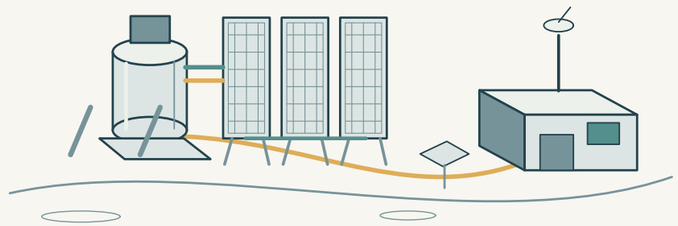
SR-1 / STABLE DISPOSITION



Demonstrate safe disposition over the residual-hazard period.

For SR-1, evaluate the interplanetary trajectory while the residual nuclear hazard persists. Model loss of propulsion and later Earth encounters to show that the mission meets its disposition criteria.

CLR-1 / LUNAR STEWARDSHIP



Shutdown and long-term stewardship

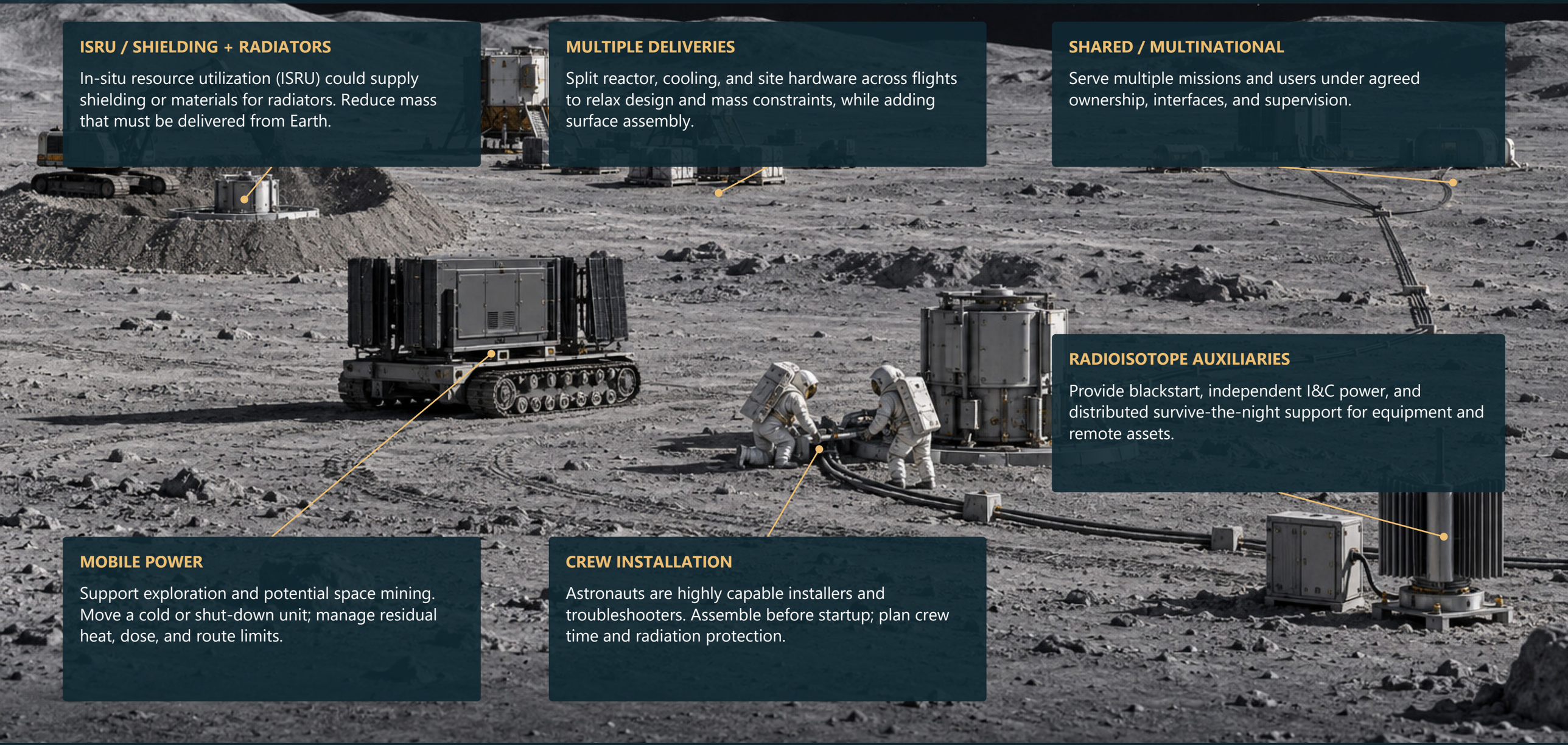
Manage residual heat and radiation; prevent unintended restart. Evaluate stabilization, shielding, or relocation with a named steward, funded access controls, and durable records for future missions.

AGREE BEFORE STARTUP Set disposition criteria, responsibilities, and funding. Apply orbital debris mitigation guidelines where relevant, alongside nuclear-hazard controls.

For Earth orbits, SPD-6 links orbital lifetime to fission-product decay and collision risk. SR-1's interplanetary mission requires a suitable disposal trajectory; it does not necessarily require an Earth disposal orbit.

Advanced Lunar Architectures

More complex deployment can reduce delivered mass, improve economics, and relieve operating constraints.



ISRU / SHIELDING + RADIATORS

In-situ resource utilization (ISRU) could supply shielding or materials for radiators. Reduce mass that must be delivered from Earth.

MULTIPLE DELIVERIES

Split reactor, cooling, and site hardware across flights to relax design and mass constraints, while adding surface assembly.

SHARED / MULTINATIONAL

Serve multiple missions and users under agreed ownership, interfaces, and supervision.

RADIOISOTOPE AUXILIARIES

Provide blackstart, independent I&C power, and distributed survive-the-night support for equipment and remote assets.

MOBILE POWER

Support exploration and potential space mining. Move a cold or shut-down unit; manage residual heat, dose, and route limits.

CREW INSTALLATION

Astronauts are highly capable installers and troubleshooters. Assemble before startup; plan crew time and radiation protection.

Benefits depend on mission economics, site conditions, and a workable safety and authorization case.

LII Liability, Indemnification, and Insurance

Safe does not mean insurable

THE PROBLEM

Space and nuclear third-party liability regimes were not designed for space nuclear missions. They do not establish a dedicated, policy-mandated insurance market for commercial lunar nuclear operations. Protection must span ground work through lunar retirement.

SR-1 / DOE PRICE-ANDERSON

Established indemnification for covered DOE nuclear work. Define the activities, parties, and duration in the mission arrangements.

Direct Pu-238 precedent

NASA / DOE arrangements have applied Price-Anderson to radioisotope missions, including Mars 2020.

Resolve the international gap

DOE indemnity for a covered nuclear incident outside the U.S. is capped at $2 billion. Assess treaty exposure separately.

AVAILABLE TOOLS

Public Law 85-804 / FAR Part 50

Can cover contract-defined nuclear hazards beyond available insurance. Government-contracted missions, including services, can make the case; the sponsoring agency must approve and make the required national-defense findings.

Additional NASA authorities

51 USC 20138: eligible space-vehicle user agreements. 51 USC 20148: eligible NASA launch / reentry contracts, excluding FAA-licensed activities.

FAA backstop / 14 CFR Part 440

Limited here to licensed launch, not lunar operations. Eligible third-party claims under 51 USC 50915 remain subject to statutory and funding conditions.

CLR-1 / COMMERCIAL LUNAR OPERATIONS

A PROPOSED CLR-1 SOLUTION

1. **Reconcile the liability regimes**

   Align space and nuclear rules; define covered entities, nuclear hazards, liability, and financial-protection requirements.

2. **Secure private nuclear coverage**

   Provide consequence bounds, qualified safety controls, QA, and operating data for underwriting. Agree policy scope, limits, and nuclear terms.

3. **Close the uninsurable gap**

   Seek a qualifying federal indemnity for residual risk; establish durable market rules through legislation.

Gilbert & Desai: A Principles-Based Liability, Insurance, and Indemnification Architecture for Commercial Space Nuclear Missions (NETS 2026).

Export Controls

Federal sponsorship leaves contractors and subcontractors responsible for classifying their work and obtaining any required export authorizations.

General information only. Consult qualified counsel for a specific transaction.

10 CFR Part 110

NRC / MATERIAL + EQUIPMENT

Fuel and nuclear equipment

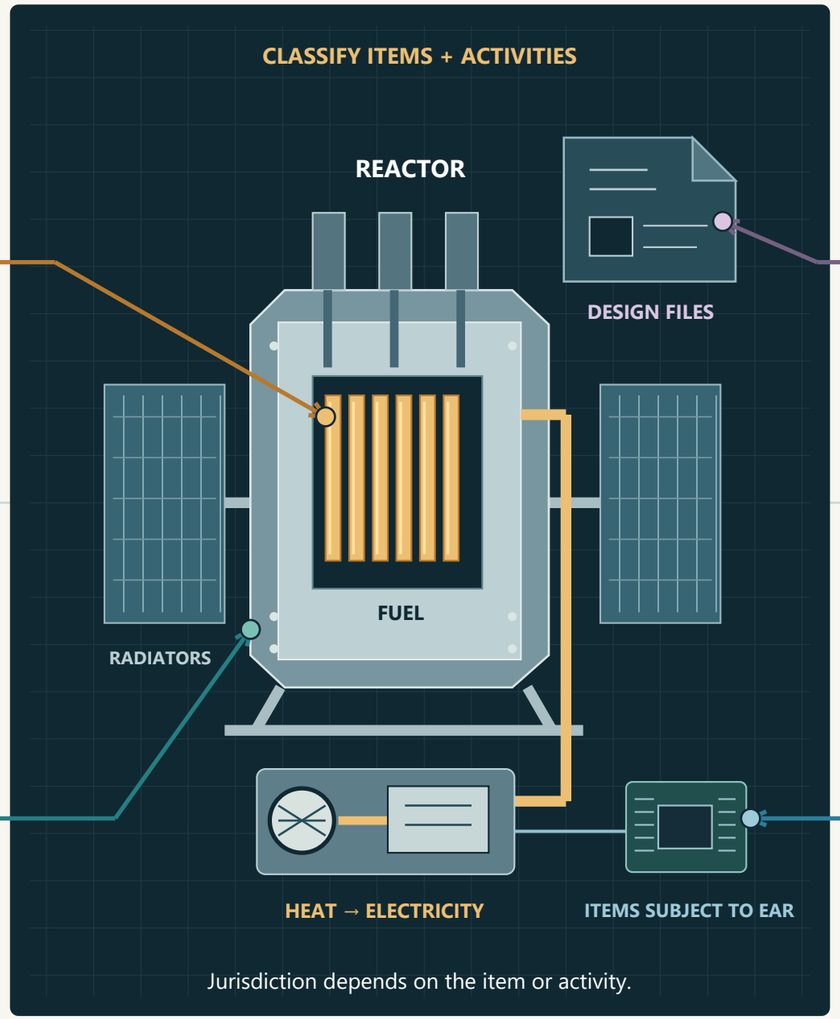
Review nuclear material and specified equipment under NRC jurisdiction. Determine the export or import authorization for each covered item.

ITAR

STATE / DDTC / SPACE SYSTEM

Reactor and power conversion

USML XV covers space-based reactors, associated conversion systems, and specially designed parts and components; related technical data and defense services also matter.



10 CFR Part 810

DOE / NNSA / TECHNOLOGY

Technology and assistance

Review nuclear design exchanges, technical support, and foreign-person access connected to foreign atomic-energy activities.

EAR

COMMERCE / BIS / OTHER ITEMS

Other items, software and technology subject to the EAR

Determine jurisdiction and classification item by item. Evaluate destination, end user and end use. Domestic access to controlled technology can also trigger requirements.

EXPORT CONTROL PROGRAM

Assign ownership; classify hardware and information; secure authorizations; screen partners; manage data and foreign-person access; and train staff and retain records. Reassess design and partner changes.

Summary of Major Challenges

The reference missions share a deployment foundation, but face different challenges from procurement to disposal.

SR-1 / GOVERNMENT

Supply chain under time pressure

The accelerated flight schedule compresses fuel, hardware, qualification, and ground-campaign lead times.

A moving nuclear electric spacecraft

The SAR and operating case must cover changing trajectories, power states, credible failures, and Earth-return risk.

End-of-life disposal

Substantiate stable disposition for the residual nuclear hazard, including loss of propulsion and later encounters.

CLR-1 / PRIVATE SECTOR

Mission authorization

No designated commercial lunar nuclear regulator or settled statutory route for continuing supervision.

Liability, indemnification, and insurance

Secure lunar coverage and an insurable allocation of public and private risk across the full mission.

Lunar surface activities

Deliver, unload, install, cable, and operate a lightly shielded plant; resolve siting, radiation fields, and safety zones.

SHARED CHALLENGES

SAR tools for reactors

Validated accident, criticality, and radiological analysis methods.

Qualified people

Nuclear and aerospace safety specialists; trained operators.

Spaceport infrastructure

Authorized facilities, ground transport, integration, and response.

FIRST PLANNING MEETING

Name the campaign owner. Identify the approval and site interfaces. Assign an owner and a due date to each missing piece of safety evidence or facility capability.

About Rocinante Fieldworks

Safety, regulatory, and operational support for a permanent space nuclear sector.



Alex Gilbert, PhD

Principal & Field Director

Space nuclear safety and regulatory strategist. Former VP of Regulation and Corporate Radiation Safety Officer at Zeno Power. PhD in Space Resources, Colorado School of Mines; adjunct faculty, Johns Hopkins University.

SELECTED PUBLICATIONS

Lifecycle mission safety for space nuclear systems

Journal of Space Safety Engineering · 2023

Governance of nuclear energy in outer space

Nuclear Law Bulletin No. 113 · 2025

A Principles-Based Liability, Insurance, and Indemnification Architecture for Commercial Space Nuclear Missions

Gilbert and Desai · NETS 2026

Safeworks

Safety and authorization

Build the safety case and approval pathway for space nuclear deployment.

01 Deployment roadmaps

Mission roles, safety criteria, approval routes, and regulatory engagement plans.

02 Safety basis and evidence

Safety-basis planning, SAR strategy, risk analysis, defense-in-depth, and review readiness.

03 Authorization support

Agency engagement, application planning, NEPA and response-plan coordination, and mission authorization strategy.

04 Operational readiness

Procedures, qualification, training, and operating requirements for in-space deployment.

Launchworks

Nuclear spaceport capability

Prepare the facilities, permissions, and operating teams for nuclear launch campaigns.

01 Ground campaign planning

Radiological planning, demand forecasting, campaign flow, and transport interfaces.

02 Facility feasibility

Site options, infrastructure gaps, readiness assessments, and pre-development planning.

03 Licensing and approvals

DOE and NRC pathways, range and spaceport permissions, and safety and security interfaces.

04 Radiological operations

Receipt, processing, integration, procedures, training, and launch-campaign readiness.

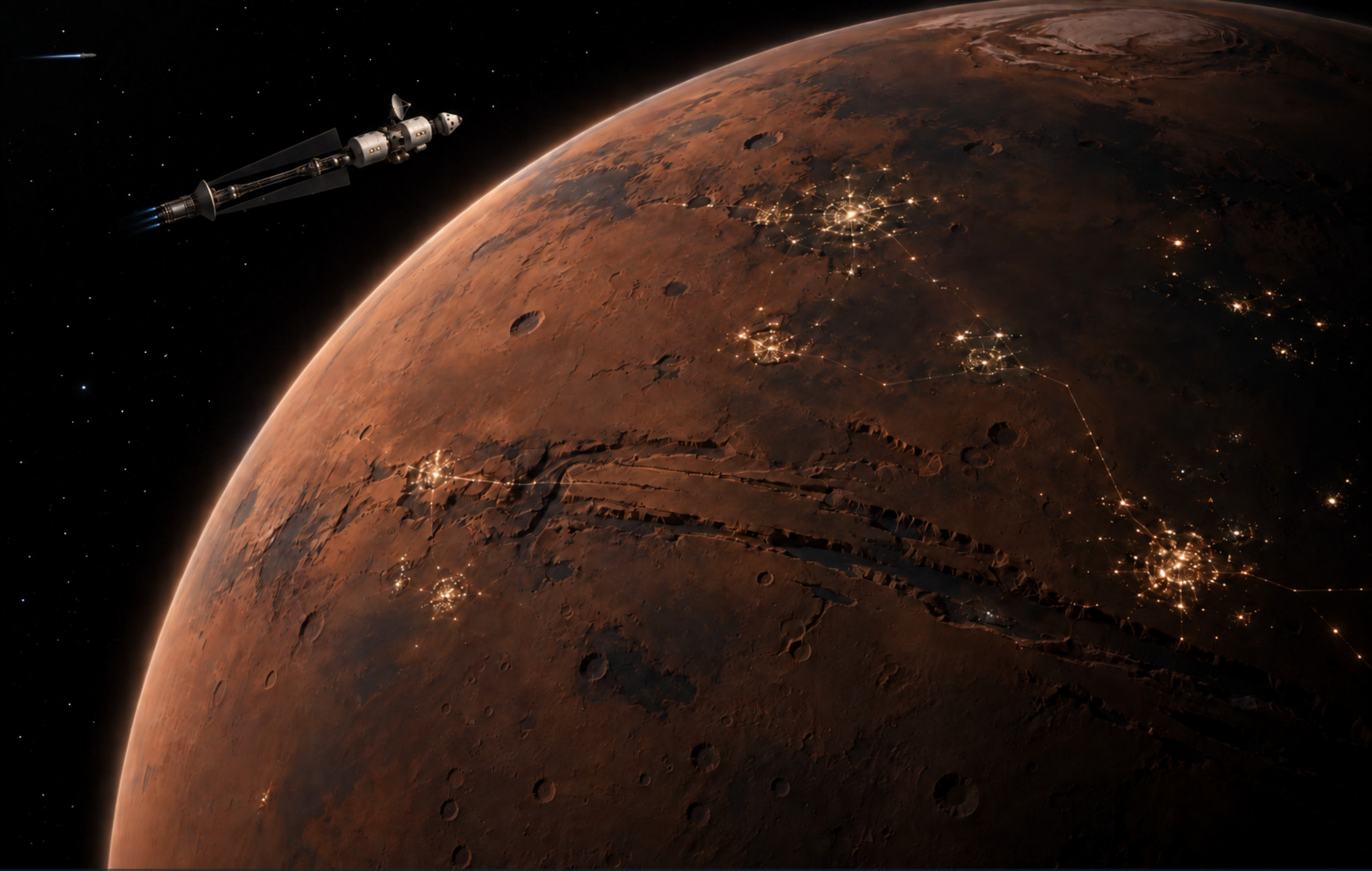
START WITH A DEPLOYMENT ASSESSMENT

Bring your mission concept and proposed site. Identify the first approval, evidence gap, and responsible team.

Read Rocinante Field Notes

alex@rocinantefieldworks.com

Serving reactor and spacecraft developers, mission owners, spaceports, government agencies, and deployment partners.



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