NASA ISRU 2026

NASAM Biological and Physical Sciences in Space Fall 2026 Meeting

Panel: Expanding BPS Science Horizons

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What is In-Situ Resource Utilization (ISRU)?

Living Off the Land:

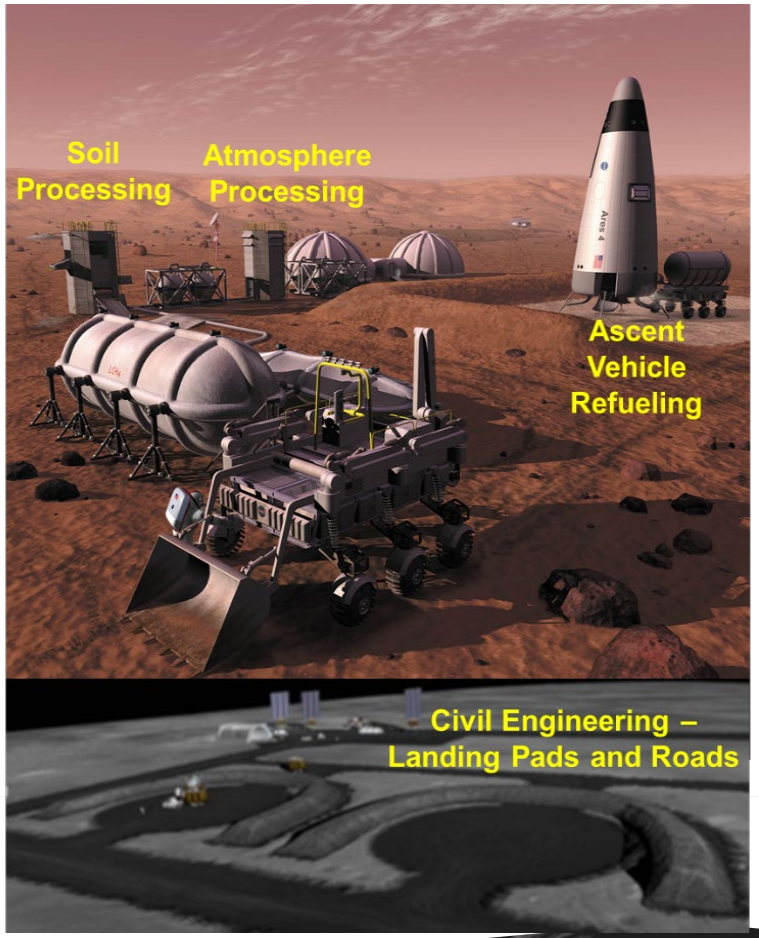
ISRU involves any hardware or operation that harnesses and utilizes 'in-situ' (local) resources to create products and services for robotic and human exploration

Resource Examples

- Water
- Oxygen
- Hydrogen
- Carbon
- Metals
- Silicon
- Nitrogen
- Regolith/Rock
- Discarded materials

Product Examples

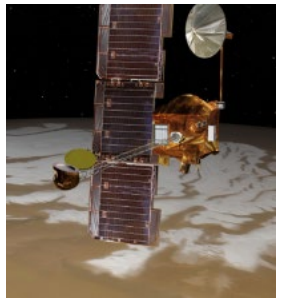
- Propellant
- Life Support Consumables
- Feed stock for:
  - Additive manufacturing
  - Construction
- Agriculture substrate and/or fertilizer



- **'ISRU' is a capability involving multiple elements to achieve final products** (mobility, product storage and delivery, power, crew and/or robotic maintenance, etc.)
- **'ISRU' does not exist on its own.** By definition, it must connect and tie to users/customers of ISRU products and services

In-Situ Resource Utilization (ISRU) encompasses:

Resource Assessment (Prospecting)




Assessment and mapping of physical, mineral, chemical, and water resources, terrain, geology, and environment

Resource Acquisition




Drilling, excavation, transfer, and preparation/ beneficiation before processing

Resource Processing/ Consumable Production




- Propellants, life support gases, fuel cell reactants, etc.

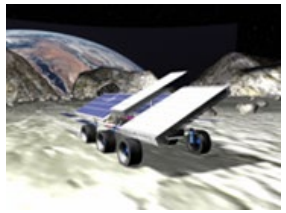
Processing resources into products with immediate use or as feedstock for construction & manufacturing

Feedstock for In Situ Manufacturing for *Manufactured* products



Production of feedstock potentially derived from one or more processed resources for use in manufacturing of replacement parts, complex products, machines, and integrated systems.

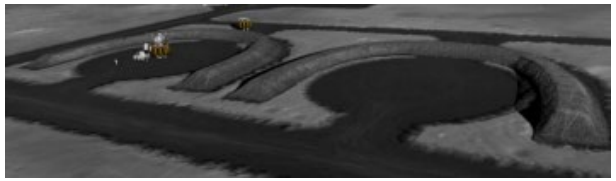
In Situ Energy

Generation and storage of electrical, thermal, and chemical energy with in situ derived materials

- Solar arrays, thermal storage and energy, chemical batteries, etc.

In Situ Construction



Civil engineering, infrastructure emplacement and structure construction using materials produced from in situ resources

- Radiation shields, landing pads, roads, berms, habitats, etc.

ISRU Traceability to NASA Lunar strategy

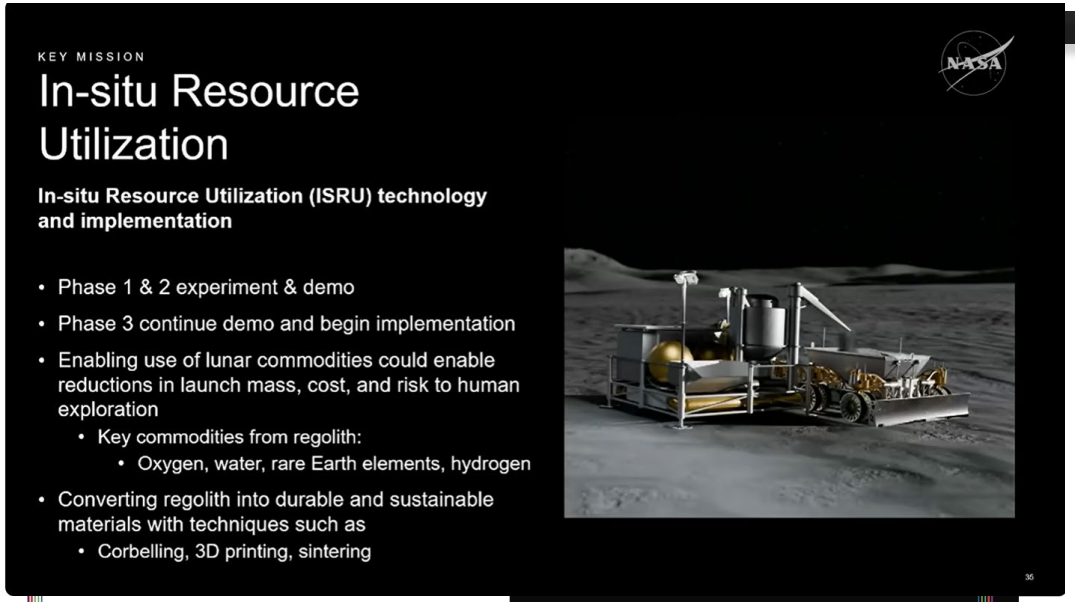
The items mapped primarily to ISRU are listed, other items can include ISRU use cases and needs (such as gaps for construction with locally produced feedstocks, CFM, propulsion, etc)

STMD 2026 Shortfalls	STMD 2024 Shortfalls (legacy)	STMD Technology Gaps*	NASA M2M objectives	ESDMD Technology Gaps (ADD App D)	ESDMD Use Case & Functions (ADD App B)	ESDMD Data Gaps (ADD App E + Moonbase)
5.1, 5.3, 5.4, 5.5, 5.6, 5.8 *Related (5.2, 5.7, 5.9, 5.10)*	1577, 1578, 1579, 1580, 1581, 1582, 1583, 1584, 1585, 581	See full list in link- ISRU Capability *These technology gaps are currently only tracked at the capability level	LI-7 MI-4 AS-3 *Related (Li-8, OP-22, TH-3, OP-3, LPS-3, TH-7, SE-3)*	601 603 604 606	UC-I-101L UC-I-202L UC-I-102L UC-I-203L UC-I-103L UC-I-204L UC-I-106L FN-I-201L FN-I-204L FN-I-202L FN-I-404L	DN-006L DN-007L DN-008L DN-010L DN-010L *Related (DN-001L thru DN005L, DN-009, DN-014L, DN-019L)*

ADD= Architecture Definition Document (Artemis)

Moon Base & ISRU

- ISRU is targeted for phase 3 of Moon base
  - This is inline with prior Artemis objectives where ISRU implementation was in the Sustained Lunar Exploration (SLE) phase
- Demonstration for ISRU technology and closure of knowledge gaps is mentioned in earlier phases of Moon Base
- Moon Base language mentions several target commodities

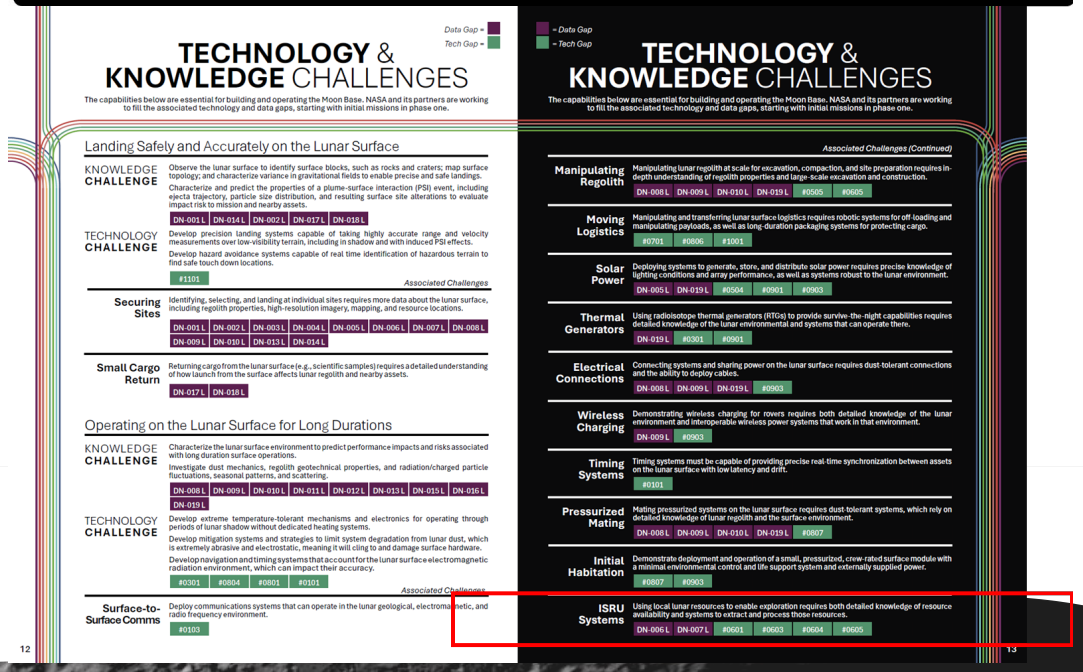


KEY MISSION

In-situ Resource Utilization

In-situ Resource Utilization (ISRU) technology and implementation

- Phase 1 & 2 experiment & demo
- Phase 3 continue demo and begin implementation
- Enabling use of lunar commodities could enable reductions in launch mass, cost, and risk to human exploration
  - Key commodities from regolith:
    - Oxygen, water, rare Earth elements, hydrogen
- Converting regolith into durable and sustainable materials with techniques such as
  - Corbelling, 3D printing, sintering



TECHNOLOGY & KNOWLEDGE CHALLENGES

The capabilities below are essential for building and operating the Moon Base. NASA and its partners are working to fill the associated technology and data gaps, starting with initial missions in phase one.

Data Gap =
Tech Gap =

Landing Safely and Accurately on the Lunar Surface

KNOWLEDGE CHALLENGE
Observe the lunar surface to identify surface blocks, such as rocks and craters; map surface topology; and characterize variance in gravitational fields to enable precise and safe landings.
Characterize and predict the properties of a plume-surface interaction (PSI) event, including ejecta trajectory, particle size distribution, and resulting surface site alterations to evaluate impact risk to mission and nearby assets.
DN-001 L | DN-014 L | DN-002 L | DN-017 L | DN-018 L

TECHNOLOGY CHALLENGE
Develop precision landing systems capable of taking highly accurate range and velocity measurements over low-visibility terrain, including in shadow and with induced PSI effects.
Develop hazard avoidance systems capable of real time identification of hazardous terrain to find safe touch down locations.
#1101

Associated Challenges

Securing Sites
Identifying, selecting, and landing at individual sites requires more data about the lunar surface, including regolith properties, high-resolution imagery, mapping, and resource locations.
DN-001 L | DN-002 L | DN-003 L | DN-004 L | DN-005 L | DN-006 L | DN-007 L | DN-008 L | DN-009 L | DN-010 L | DN-013 L | DN-014 L

Small Cargo Return
Returning cargo from the lunar surface (e.g., scientific samples) requires a detailed understanding of how launch from the surface affects lunar regolith and nearby assets.
DN-017 L | DN-018 L

Operating on the Lunar Surface for Long Durations

KNOWLEDGE CHALLENGE
Characterize the lunar surface environment to predict performance impacts and risks associated with long duration surface operations.
Investigate dust mechanics, regolith geotechnical properties, and radiation/charged particle fluctuations, seasonal patterns, and scattering.
DN-008 L | DN-009 L | DN-010 L | DN-011 L | DN-012 L | DN-013 L | DN-015 L | DN-016 L | DN-019 L

TECHNOLOGY CHALLENGE
Develop extreme temperature-tolerant mechanisms and electronics for operating through periods of lunar shadow without dedicated heating systems.
Develop mitigation systems and strategies to limit system degradation from lunar dust, which is extremely abrasive and electrostatic, meaning it will cling to and damage surface hardware.
Develop navigation and timing systems that account for the lunar surface electromagnetic radiation environment, which can impact their accuracy.
#0301 | #0804 | #0801 | #0101

Associated Challenges

Surface-to-Surface Comms
Deploy communications systems that can operate in the lunar geological, electromagnetic, and radio frequency environment.
#0103

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= Data Gap
= Tech Gap

TECHNOLOGY & KNOWLEDGE CHALLENGES

The capabilities below are essential for building and operating the Moon Base. NASA and its partners are working to fill the associated technology and data gaps, starting with initial missions in phase one.

Associated Challenges (Continued)

Manipulating Regolith
Manipulating lunar regolith at scale for excavation, compaction, and site preparation requires in-depth understanding of regolith properties and large-scale excavation and construction.
DN-008 L | DN-009 L | DN-010 L | DN-019 L | #0505 | #0605

Moving Logistics
Manipulating and transferring lunar surface logistics requires robotic systems for off-loading and manipulating payloads, as well as long-duration packaging systems for protecting cargo.
#0701 | #0806 | #1001

Solar Power
Deploying systems to generate, store, and distribute solar power requires precise knowledge of lighting conditions and array performance, as well as systems robust to the lunar environment.
DN-005 L | DN-019 L | #0504 | #0901 | #0903

Thermal Generators
Using radioisotope thermal generators (RTGs) to provide survive-the-night capabilities requires detailed knowledge of the lunar environmental and systems that can operate there.
DN-019 L | #0301 | #0901

Electrical Connections
Connecting systems and sharing power on the lunar surface requires dust-tolerant connections and the ability to deploy cables.
DN-008 L | DN-009 L | DN-019 L | #0903

Wireless Charging
Demonstrating wireless charging for rovers requires both detailed knowledge of the lunar environment and interoperable wireless power systems that work in that environment.
DN-009 L | #0903

Timing Systems
Timing systems must be capable of providing precise real-time synchronization between assets on the lunar surface with low latency and drift.
#0101

Pressurized Mating
Mating pressurized systems on the lunar surface requires dust-tolerant systems, which rely on detailed knowledge of lunar regolith and the surface environment.
DN-008 L | DN-009 L | DN-010 L | DN-019 L | #0807

Initial Habitation
Demonstrate deployment and operation of a small, pressurized, crew-rated surface module with a minimal environmental control and life support system and externally supplied power.
#0807 | #0903

ISRU Systems
Using local lunar resources to enable exploration requires both detailed knowledge of resource availability and systems to extract and process those resources.
DN-006 L | DN-007 L | #0601 | #0603 | #0604 | #0605

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NASA STMD Shortfalls: Top 40 Need Statements FY26

- The top 40 need statements were identified as primary focus areas for mission directorate investments

- This top 40 list included considerations for:
  - NASA Ignition event announcements
  - Interest of other agency organizations
  - Preserving critical skills at NASA centers
  - Establishing and maintaining relevance with Industry and Academia

Need statement	Description
05.04	Produce oxygen from lunar regolith at a scale relevant for a demonstration mission. Reference ESDMD #0601 for specific details.
(Related) 05.02	Excavate and transport lunar regolith at a scale relevant for a demonstration mission. Reference ESDMD #0605 (excavation and transportation) for specific details.
(Related) 04.01	Perform site preparation and bulk regolith manipulation for infrastructure construction, including landing pads, berms, regolith overburden for radiation protection. Reference ESDMD #0605 (manipulation) for specific details.

Example of STMD Shortfall w/ Need statements

Shortfall	Need Statements	
5.0 Produce propellant, consumables, and other usable materials from lunar resources to support human exploration and commercial activities.	5.01	Locate, characterize, and map the useful resources on the lunar surface.
	5.02	Excavate and transport lunar regolith at a scale relevant for a demonstration mission. Reference ESDMD #0605 (excavation and transportation) for specific details.
	5.03	Extract metal and manufacturing feedstock from lunar regolith at a scale relevant for a demonstration mission. Reference ESDMD #0604 for specific details.
	5.04	Produce oxygen from lunar regolith at a scale relevant for a demonstration mission. Reference ESDMD #0601 for specific details.
	5.05	Produce water from icy lunar regolith at a scale relevant for a demonstration mission. Reference ESDMD #0603 for specific details.
	5.06	Produce power components derived from in-situ resources.
	5.07	Excavate and transport lunar regolith at a scale relevant for sustained lunar exploration.
	5.08	Produce metals, oxygen, and water at a scale relevant for sustained lunar exploration.
	5.09	Manage, store, and distribute in-situ-produced materials and products at a scale relevant to sustained lunar exploration.
	5.10	Manage conversion, storage, and handling of oxygen into breathing air sufficient to support sustained lunar exploration mission needs.

ISRU Consumable Production: Phases of Evolution and Use

Demonstrate, Build Confidence, Increase Production and Usage

NPS = Near Permanent Sunlight
PSR = Permanently Shadowed Region

10 to 50 mT Range for Initial Full-Scale Production

	Demo Scale	Pilot Plant	Crewed Ascent Vehicle[1]	Full Descent Stage[1]	Lockheed Martin[6]		Dynetics[6] Single Stage/ Drop Tanks	Single Stage to NRHO[2]	Human Landing System - Starship[7]	Human Mars Transportation[3]	Commercial Cis-Lunar Transportation[4]
			3 Stage Arch to NRHO		2 Stage	Single Stage					
Timeframe	days to months	6 mo - 1 year	1 mission/yr	1 mission/yr	per mission	per mission	per mission	per mission	per mission	per year	per year
Demo/System Mass[5]	10's kg to low 100's kg	1 mt O_2 Pilot 1.3 – 2.5 mt Ice Mining	1400 to 2200 kg	2400 to 3700 kg				Not Defined		Not Defined	29,000 to 41,000 kg
Amount O_2	10's kg	1000 kg	4,000 to 6,000 kg	8,000 to 10,000 kg	10,000 kg	33,000 kg	32,000 kg	30,000 to 50,000 kg	120,000 (NRHO) 440,000 (Earth)	185,000 to 267,000 kg	400,000 to 2,175,000 kg
Amount H_2	10's gms to kilograms	125 kg		1,400 to 1,900 kg	2,000 kg	7,000 kg	Methane Fuel	5,500 to 9,100 kg	Methane Fuel	23,000 to 33,000 kg	50,000 to 275,000 kg
Power for O_2 in NPS	100's W	5 to 6 KW	20 to 32 KW	40 to 55 KW				N/A		N/A	N/A
Power for H_2O in PSR	100's W	~2 KW		~25 KW				14 to 23 KW			150 to 800 KW
Power for H_2O to O_2/H_2 in NPS		~6 KW		~48 KWe				55 to 100 KWe			370 to 2,000 KWe

[1]Estimates from rocket equation and mission assumptions
[2]Estimates from J. Elliott, "ISRU in Support of an Architecture for a Self-Sustained Lunar Base "
[3]Estimate from C. Jones, "Cis-Lunar Reusable In-Space Transportation Architecture for the Evolvable Mars Campaign"
[4]Estimate from "Commercial Lunar Propellant Architecture" study

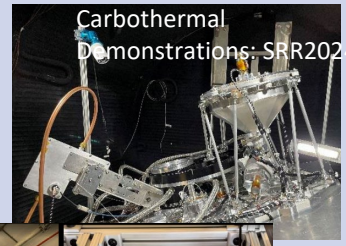
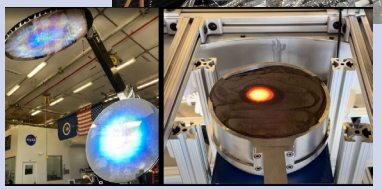
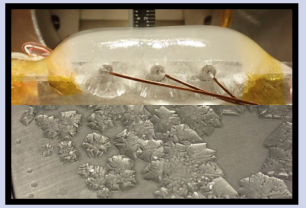
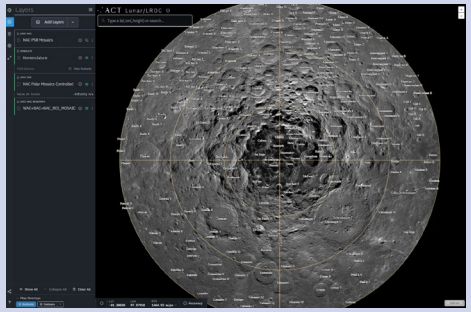
[5]Electrical power generation and product storage mass not included
[6] APL Lunar Surface Innovation Consortium Suppy-Demand Workshop, 9/17/2020
[7] Calculations/Assumptions from Publicly Available Data

- Table uses best available studies and commercial considerations to guide development requirements/FOMs
- Table provides rough guide to developers and other surface elements/Strategic Technology Plans for interfacing with ISRU

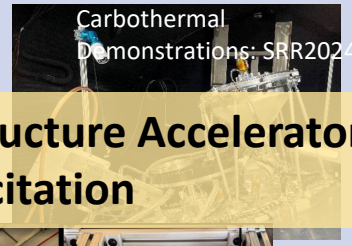
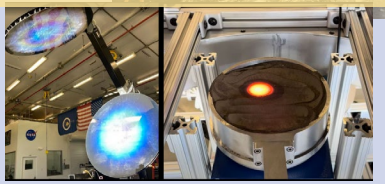
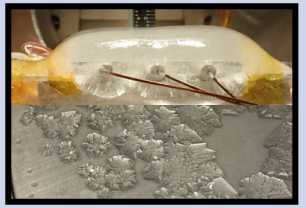
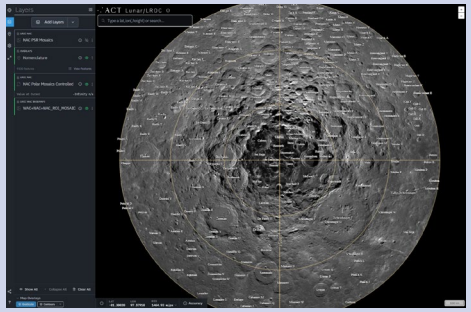
ISRU Technology Focus Areas

	Oxygen from Regolith	Lunar Water ISRU
	Extraction of oxygen from regolith minerals, ubiquitous surface material	Extraction of regolith bound water ice in Permanently shadowed regions (PSRs)
Extraction & Conversation systems	Technology options available TRL 5-6. Entering system integration efforts	Technology options at TRL 4-5. Lower development while awaiting prospecting
Excavation and Regolith Handling	Excavation option for surface material is TRL6. Material conveyance & size sorting system will depend on extraction system but options in work ~TRL4+	Bulk extraction technologies are lower TRL: excavation forces and retention of water
Prospecting	Prospecting not needed to begin efforts, but lunar demonstration of reaction processes will be needed to validate.	Needed prior to ISRU implementation. Fundamental information regarding form of ice and contaminants, as well as locating a water reserve (distribution, concentration, etc).
Modeling and simulations	The complexity and trade space of ISRU systems require modeling to explore technology compatibility and scaling. ISRU cost benefit increases at larger scales, long term planning will require these tools.	

Near term ISRU technology: Examples

	Oxygen from Regolith	Lunar Water ISRU
Extraction & Conversation systems	 MRE in TVAC: LPSC 2025  Carbothermal Demonstrations: SRR2024 	 Lunar Auger Drier: AIAA2023 
Excavation and Regolith Handling	 IPEx website  Vertical Lunar Regolith conveyor: NASA TM  Ultrasonic bucket LSIC 2024	
Prospecting		 VIPER Rover: website

Near term ISRU technology: Examples

	Oxygen from Regolith	Lunar Water ISRU
Extraction & Conversation systems	 MRE in TVAC: LPSC 2025  Carbothermal Demonstrations: SRR2024 **Lunar Enabling Infrastructure Accelerator Active Solicitation** 	 Lunar Auger Drier: AIAA2023 
Excavation and Regolith Handling	 **MoonBase** IPEx website  Vertical Lunar Regolith conveyor: NASA TM  Ultrasonic bucket LSIC 2024	 NASA's BREAK THE ICE LUNAR CHALLENGE
Prospecting		 VIPER Rover: website **MoonBase**

Summary

- From a NASA priority standpoint:
  - Significant advancements in component level hardware for the past decades. High TRL at component level for regolith based ISRU
  - ISRU was indicated in the Ignition event as a Moon Base objective
  - Recent release of STMD shortfalls shows ISRU in the top 40 priority areas
  - Solicitation released for a ISRU oxygen production system

- Opportunities for ISRU within Moon Base:
  - Excavator (IPEx) and Prospecting (VIPER) are moving ahead
  - Possible opportunities for technology demonstrations and prospecting data on CLPS missions
    - Moon Base Users guide acknowledges ISRU gap closure as near-term objectives to meet phase 3 needs.
  - ISRU moon base infusion listed as phase 3 objective, with technology development in earlier phases





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