National Aeronautics and Space Administration

Space Logistics

Technology Catalog

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Introduction

NASA Technology Catalog

A NASA Technology Catalog is a systematically arranged and curated list of technologies within a defined capability area that serves as a reference tool for stakeholders and customers.

Each catalog includes both “push” and “pull” technology developments that are funded by NASA; however, it does not represent an exhaustive list of all possible technology solutions within that capability area.

Purpose

The purpose of the catalog is to provide accessible information about NASA-funded technologies to improve technology adoption and enhance collaboration.

Learn More

Technology catalogs are intended to offer a snapshot of relevant technologies within a particular capability area. For additional information, click the hyperlink in each technology title to access its TechPort page or, when a TechPort page is not available, an alternative source.

If you would like additional information about a specific technology, its licensing potential, or how to connect with the developers, please contact hq-techport@mail.nasa.gov.

What Is Considered Logistics Technology?

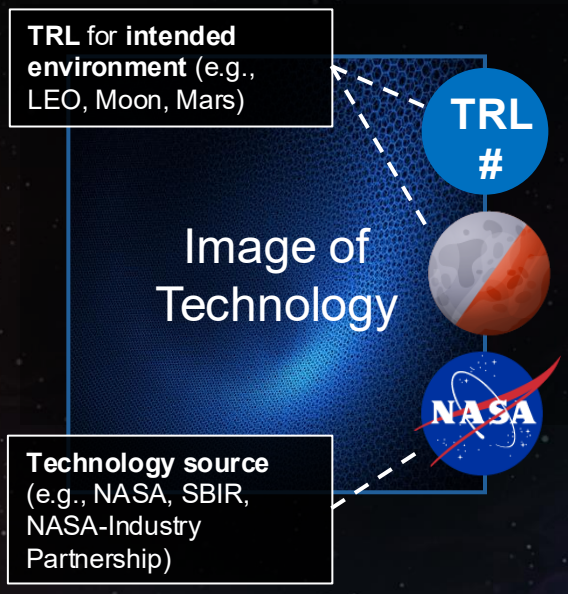
Logistics technologies support any phase of space logistics including transportation, cargo sustainment, cargo offloading and manipulation, surface mobility, cargo loading and transfer, surface mating, and disposal.

Logistics-specific technologies are those that provide a core function of the logistics workflow, such as cargo offloading, manipulation, or tracking.

Logistics-affiliated technologies* are those within tangential technology areas that support logistics elements or assets, such as power systems for logistics carriers or dust-tolerant connectors.

**Transportation, mobility, and communications technologies serve important functions within logistics; however, these domains are classified as distinct capability areas and will have their own technology catalogs. Cross-cutting technologies included in this catalog, such as autonomous systems and robotics, will also have a separate catalog describing technologies that are not affiliated directly with logistics.*

Example Technology Entry



Technology Name (linked to TechPort)

Description: high-level overview of the technology

Potential Use Cases: plausible logistics functions the technology could serve in future exploration missions

Included technologies are typically at or above Technology Readiness Level (TRL) 4. Some lower TRL technologies are included due to relevancy.

TRL definitions are shown in NASA NPR 7123.1D App. E.

Technology Readiness Level (TRL)

9 Actual system flight proven through successful mission operations.

8 Actual system completed and "flight qualified" through test and demonstration.

7 System prototype demonstration in an operational environment.

6 System/sub-system model or prototype demonstration in an operational environment.

5 Component and/or breadboard validation in relevant environment.

4 Component and/or breadboard validation in laboratory environment.

3 Analytical and experimental critical function and/or characteristic proof of concept.

2 Technology concept and/or application formulated.

1 Basic principles observed and reported.

Intended Environment


Low Earth Orbit (LEO)


Moon


Mars


LEO/Moon


Moon/Mars


LEO/Moon/Mars

Technology Source

Technology source may impact factors related to intellectual property, collaboration, and/or technology adoption.

NASA


NASA-Industry Partnership


Small Business Innovation Research (SBIR)

Table of Contents

LOGISTICS-SPECIFIC TECHNOLOGY AREA

LOGISTICS-AFFILIATED TECHNOLOGY AREA

Cargo Manipulation

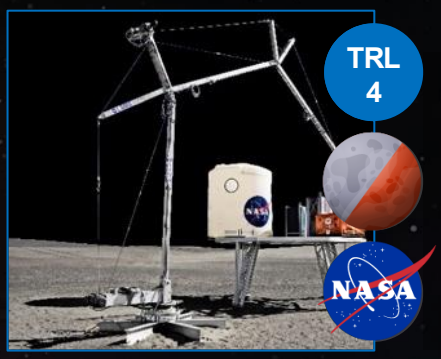
Cargo Manipulation

Cargo manipulation technologies include surface functions to offload, upload, and position cargo payloads. Cargo manipulation technologies can offload cargo from (1) the lander to the surface, (2) the lander to a mobile agent for relocation, or (3) a mobile agent to the surface. Technologies may be mounted to the lander, a mobile agent, or the surface. NASA investments in cargo manipulation technologies include systems that are commanded by tele-operation, scripted commands, or autonomous operations. Some systems can support crew operations while others offer passive offloading solutions.

CIVIL SPACE SHORTFALLS	SF16
ESDMD ARCHITECTURE-DRIVEN TECHNOLOGY GAPS	#0806
PRIMARY TECHNOLOGY TAXONOMY	TX04.3

Cargo Manipulation

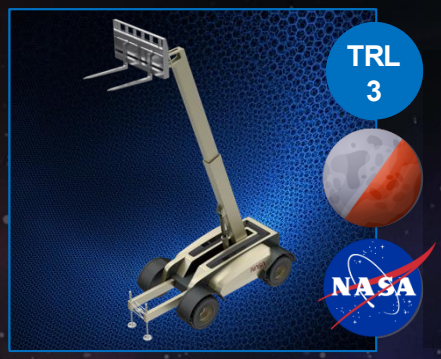
100s kg to 1000s kg



LIGHTWEIGHT SURFACE MANIPULATION SYSTEM (LSMS)

Description: Scalable autonomous robotic 4 DOF cargo manipulation (with wrist attachment)

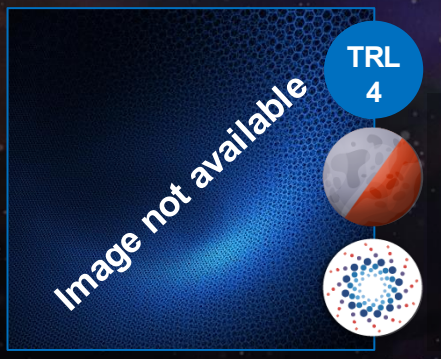
Potential Use Cases: Offloading (35 kg to 1000+ kg, reach 2.25 m to 8+ m), uploading (35 kg to 1000+ kg, reach 2.25 m to 8+ m)



TELEHANDLER

Description: Mobile, semi-autonomous cargo offloading with 4 DOF manipulation

Potential Use Cases: Offloading (2500 kg, reach 3.5 m), uploading (2500 kg, reach 3.5 m), cargo transport

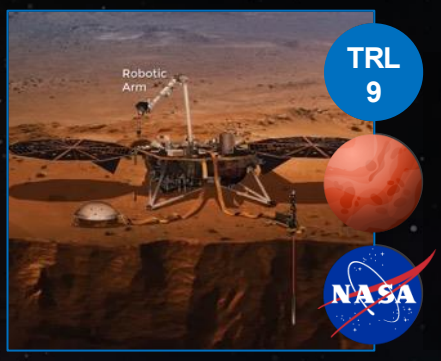


ROBOTIC EFFICIENT ARM FOR CARGO HANDLING (APPTRONIK INC.)

Description: Autonomous and crew assisted cargo offloading, 5 DOF manipulation

Potential Use Cases: Offloading (115 kg, reach 2 m), uploading (115 kg, reach 2 m), assisting crew operations

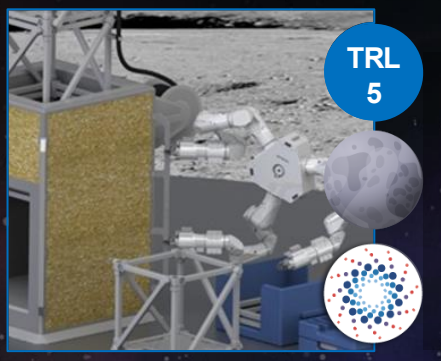
Cargo Manipulation
10 kg



MARS INSIGHT INSTRUMENT DEPLOYMENT ARM

Description: Small-scale cargo manipulation and scientific sample collection, 4 DOF manipulation

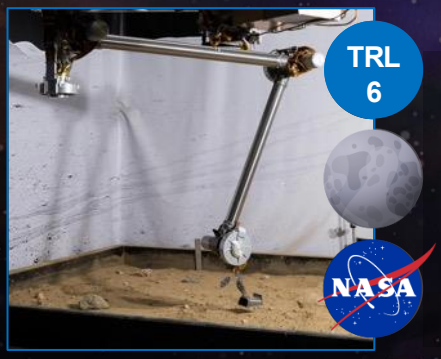
Potential Use Cases: Scientific sample collection, small payload offloading (9.5 kg, reach 1.8 m), uploading (9.5 kg, reach 1.8 m)



xWALKER (MOTIV SPACE SYSTEMS)

Description: Enhanced inspection and manipulation for lunar assembly, Small-scale 7 DOF manipulation

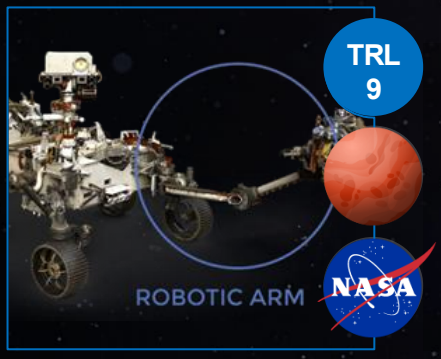
Potential Use Cases: Small payload offloading, uploading, manipulation



COLD OPERABLE LUNAR DEPLOYABLE ARM (COLDARM)

Description: Small-scale offloading and scientific tasks with bulk metallic gears and cold operable motor controllers are transferable to other robotic agents, 4 DOF manipulation

Potential Use Cases: Small scale offloading (4 kg, reach 2 m), uploading (4 kg, reach 2 m), scientific sample collection

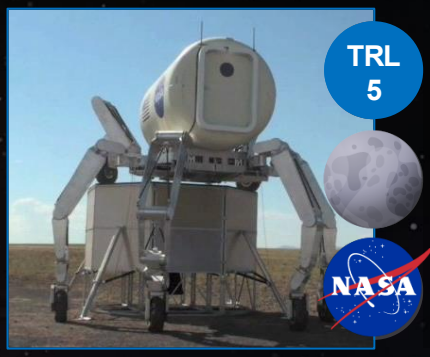


MARS PERSEVERANCE ROBOTIC ARM

Description: Small-scale cargo manipulation and scientific sample collection, 5 DOF manipulation

Potential Use Cases: Scientific sample collection, small payload offloading (45 kg, reach 2 m), uploading (45 kg, reach 2 m)

Cargo Manipulation



ATHLETE ROVER

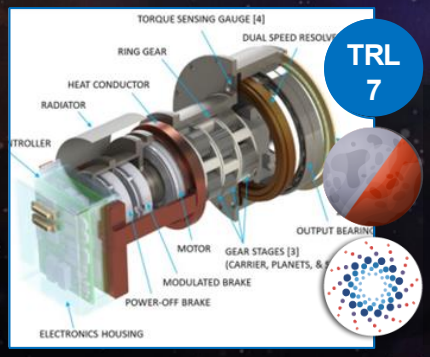
Description: Heavy-lift utility vehicle with 6 DOF limbs, each with a 1 DOF wheel attached

Potential Use Cases: Payload offloading (100s-1000s kg), uploading (100s-1000s kg), cargo mobility

REGOLITH IMMUNE LINEAR ACTUATOR FAMILY (APECH LABS)

Description: A suite of linear actuators designed to achieve full immunity to the lunar environment, including dust

Potential Use Cases: Cargo conveyance and other surface logistics operations

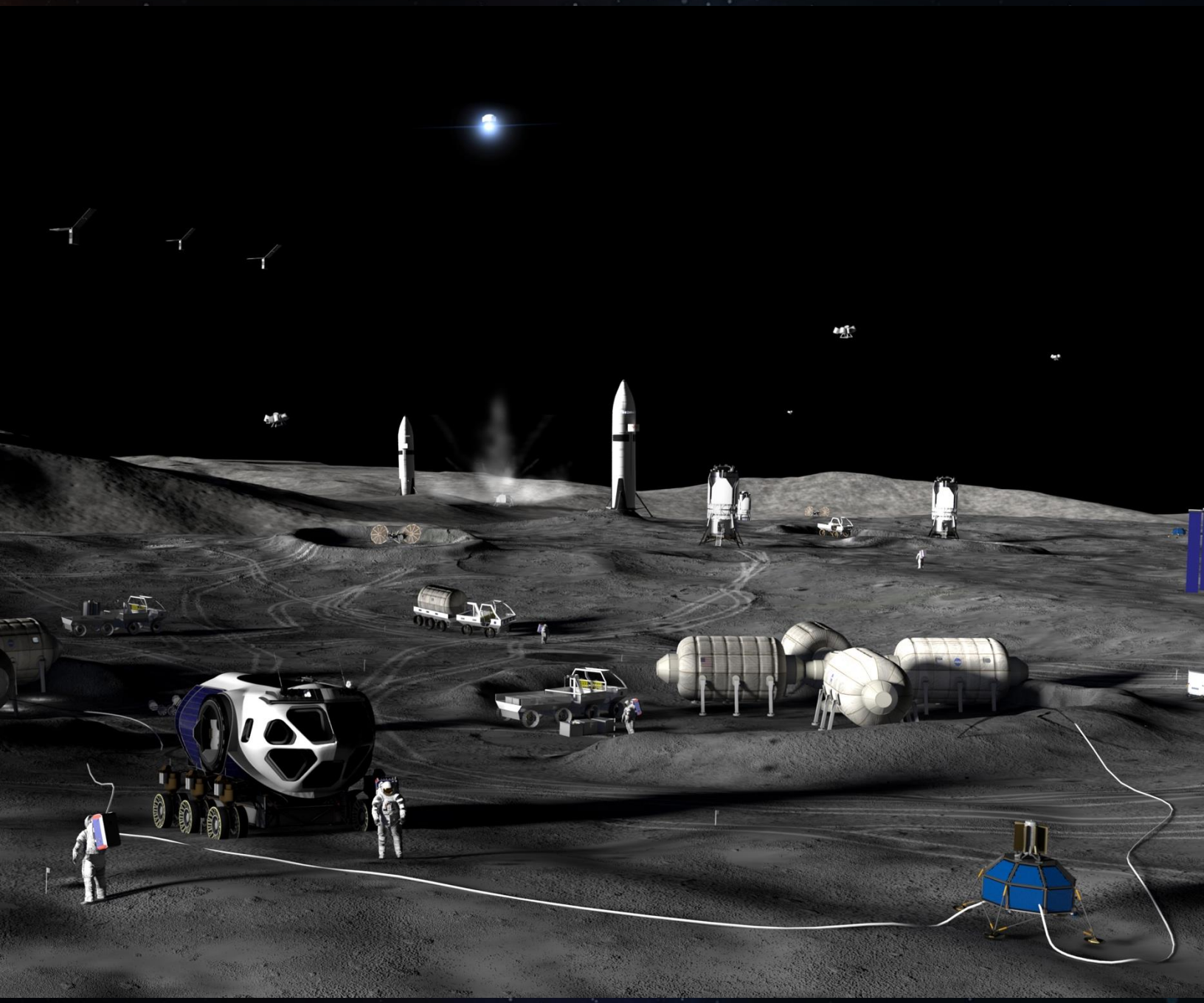


DISTRIBUTED EXTREME ENVIRONMENTS DRIVE SYSTEM (DEEDS) (MOTIV SPACE SYSTEMS)

Description: Actuation system for use across a broad spectrum of use cases including ISRU systems, robotics, cargo offloading, and mobile vehicles on the lunar and Martian surfaces

Potential Use Cases: Logistics element/asset actuation

Surface Mating

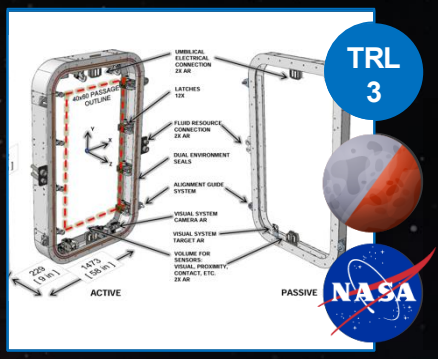


Surface Mating

Surface mating technology enables the movement of crew and cargo between mobile and stationary surface elements without the need for extravehicular activity. It is currently at the conceptual stage, as pressurized transfer remains an emerging area of research and development.

CIVIL SPACE SHORTFALLS	SF15
ESDMD ARCHITECTURE-DRIVEN TECHNOLOGY GAPS	#0807
PRIMARY TECHNOLOGY TAXONOMY	TX04.5, TX12.3.1

Surface Mating

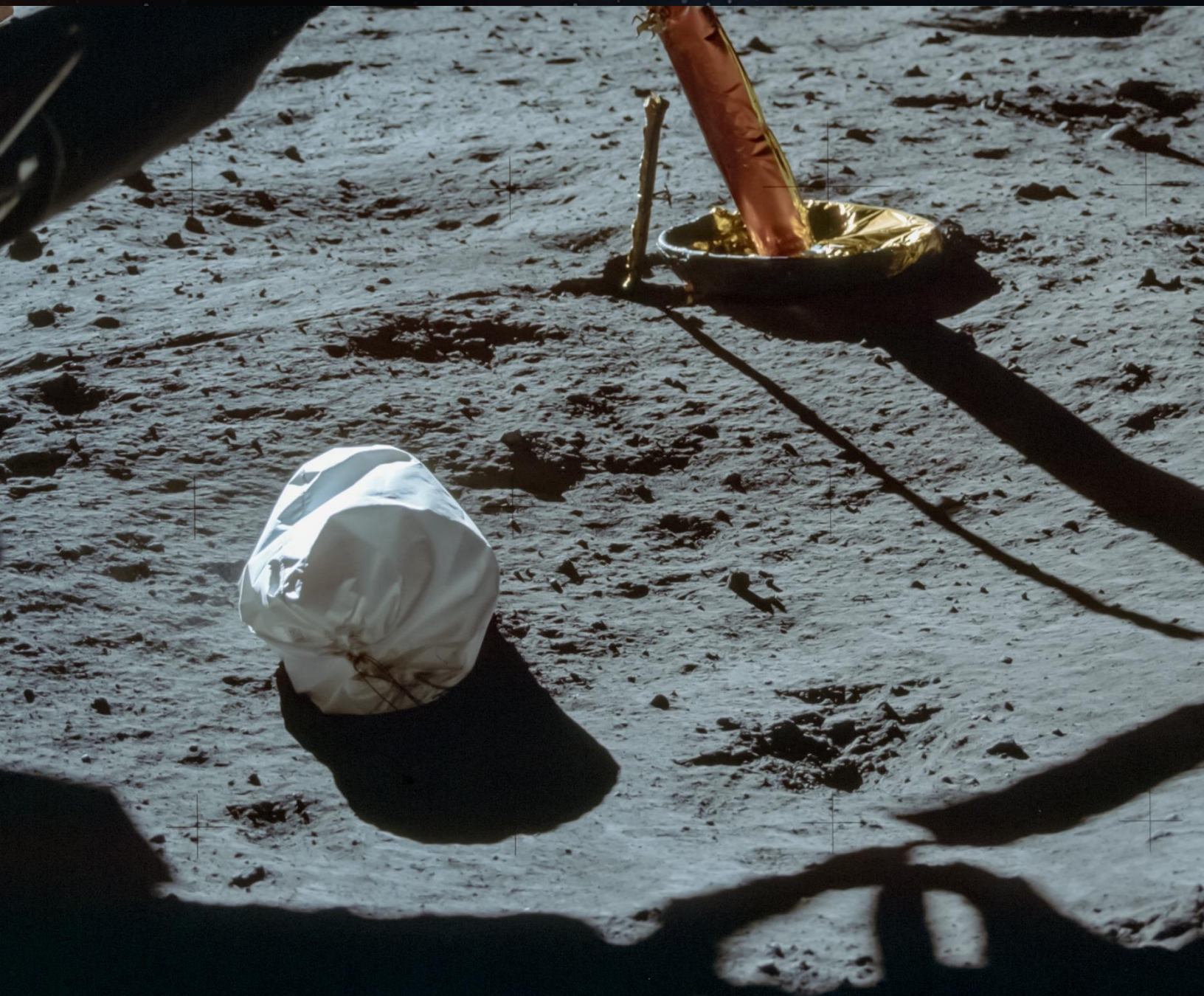


INTERNATIONAL DOCKING SYSTEM STANDARD – SURFACE (IDSS-S)

Description: Surface Standard Docking interface enables interoperability between pressurized elements providing pressurized transfer capability for crew and cargo. The IDSS-S' concept flight design, first article production, and standard interface definition are currently in work with TRL 9 estimated by 2031.

Potential Use Cases: Surface mating (76.2cm x 152.4 cm passage, active and passive-side docking interfaces)

Trash/Waste Management



Trash/Waste Management

Trash/Waste management technologies provide solutions for trash disposal, management, recycling, and processing. NASA has developed various technologies and capabilities for in-space and on-surface trash/waste management. This includes trash compaction, trash thermochemical conversion/deconstruction, bioregenerative life support systems for wastewater management, metabolic waste management, waste stabilization, and in-space manufacturing of recycled materials.

CIVIL SPACE SHORTFALLS	SF18
ESDMD ARCHITECTURE-DRIVEN TECHNOLOGY GAPS	#0702, #1202
PRIMARY TECHNOLOGY TAXONOMY	TX06.1.3, TX13.5.6

Trash/Waste Management

TRASH COMPACTION AND PROCESSING SYSTEM (SIERRA SPACE)

Description: Physical compaction and heat to reduce volume of trash, recover water, and stabilize the material from biological risk

Potential Use Cases: Trash volume reduction (375 kg/m^3 tile density); water recovery (98%); biological reduction

TRASH-TO-GAS

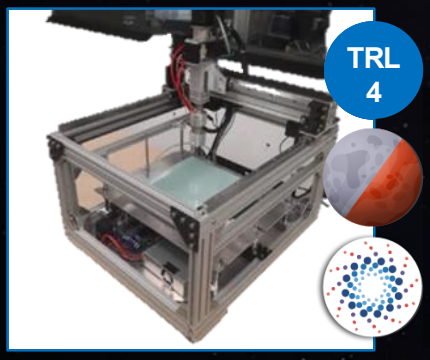
Description: Thermochemical reactions to convert trash into more useful products. Orbital Syngas/Commodity Augmentation Reactor (OSCAR) demonstrated combustion feasibility of a mixed waste stream in microgravity.

Potential Use Cases: Trash mass and volume reduction (~90% solid-to-gas conversion), water recovery, biological reduction, propellant production, ECLSS commodity production, solid carbon production

MPACTOR

Description: A simple, lightweight, pneumatically driven trash compaction system

Potential Use Cases: Trash volume reduction (283 kg/m^3 tile density)



ON-ORBIT ADDITIVE MANUFACTURING USING RECYCLED WASTE (RE:3D INC.)

Description: A 3D printing system compatible with recycled thermoplastics to produce useful parts and equipment. re:3D's Gigabot X extrusion-based printer can print directly from ground plastic flakes.

Potential Use Cases: Trash mass and volume reduction (via new part generation), tool/spares/equipment production

Trash/Waste Management

UNIVERSAL WASTE MANAGEMENT SYSTEM (COLLINS AEROSPACE)

Description: A compact toilet system that can be used across multiple crewed vehicles and habitats; flown on Artemis II

Potential Use Cases: Metabolic waste management (100% fecal collection/compaction), urine water recovery and/or vent

COLLAPSIBLE CONTINGENCY URINAL (IRPI LLC)

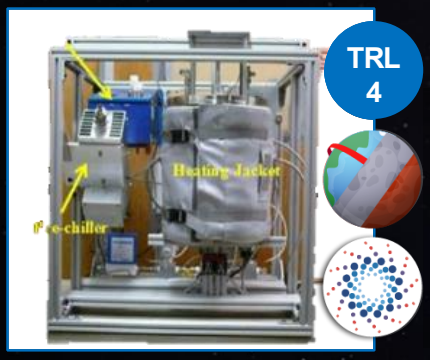
Description: Contingency wastewater collection and processing device via passive capillarity; flown on Artemis II

Potential Use Cases: Urine collection, urine venting, other fluid capture/containment in micro- and reduced-gravity environments

ULTRASONIC FECAL DRYER (ULTRASONIC TECHNOLOGY SOLUTIONS)

Description: Efficient and fast direct-contact ultrasonic drying to stabilize and recover water from feces

Potential Use Cases: Waste stabilization, fecal water recovery (80-100%)



TORREFACTION FOR HUMAN SOLID WASTE MANAGEMENT (ADVANCED FUEL RESEARCH)

Description: Torrefaction processing that sterilizes feces and produces a stable, odor-free solid product, while recovering moisture

Potential Use Cases: Waste sterilization, fecal water recovery (100+%)

Trash/Waste Management

ADVANCED ORGANIC WASTE GASIFIER (PIONEER ASTRONAUTICS)

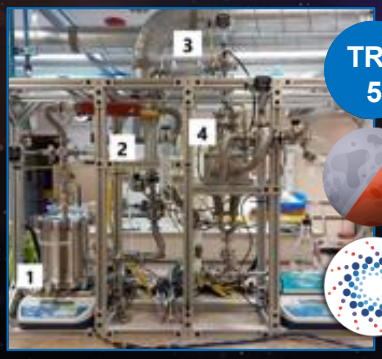
Description: Steam reformation, methanation, and electrolysis to convert organic waste into water, dry vent gas, and a small amount of inorganic residue, thereby reducing transit propellant and tankage mass

Potential Use Cases: Trash mass and volume reduction, water recovery, syngas production

CATALYTIC CONVERSION OF WASTE PLASTIC TO HYDROGEN AND PERFORMANCE CARBON (CECILIA ENERGY)

Description: Microwave-assisted thermocatalytic decomposition of mixed waste plastic

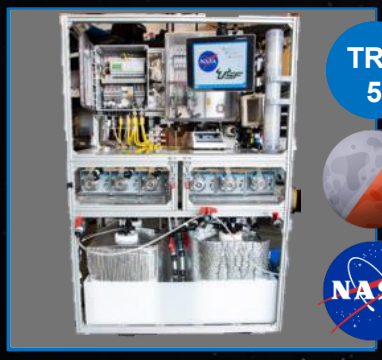
Potential Use Cases: Recover hydrogen gas for fuel, solid carbon production



SEPARATION TECHNOLOGY OF ON-ORBIT LIQUID AND EXCREMENT (PARAGON)

Description: Full-scale fecal drying system to recover water from fecal material in space

Potential Use Cases: Fecal water recovery



BLiSS BIOREACTORS

Description: A series of bioreactors that consume wastewater streams as feedstock to generate products such as methane, fertilizer, and sugars

Potential Use Cases: Waste mass and volume reduction, water recovery, fertilizer production, propellant production, ECLSS commodity production, biomanufacturing feedstock

Logistics Reduction

Logistics Reduction

Logistics reduction technologies reduce the number of materials required from Earth through means of repurposing, reusing, or extending useful lifetimes. This section captures relevant technologies that can reduce logistics up-mass beyond what is captured in the Trash/Waste Management section.

CIVIL SPACE SHORTFALLS	SF18
ESDMD ARCHITECTURE-DRIVEN TECHNOLOGY GAPS	#0702
PRIMARY TECHNOLOGY TAXONOMY	TX06.1.3, TX13.5.6

Logistics Reduction

LOGISTICS-TO-LIVING

Description: Repurposing of cargo transfer bags for on-orbit outfitting

Potential Use Cases: Repurposing end-of-life cargo bags for acoustics and habitation functionality

ALTERNATE FECAL CANISTER

Description: Light-weight, collapsible fecal canister that can provide mass and volume reduction benefits compared to hard-sided fecal canisters for the Universal Waste Management System

Potential Use Cases: Logistics mass/volume reduction

LOGISTICS MATERIALS FOR REUSE

Description: An investigation of common use materials designed to be reused or recycled that could replace pre-existing logistics and packaging materials for spaceflight

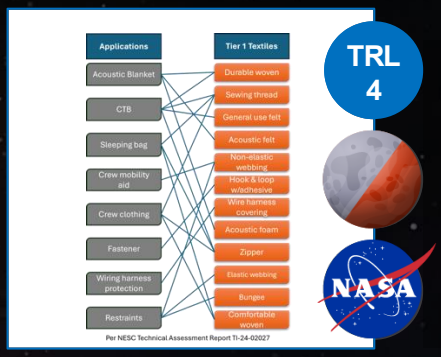
Potential Use Cases: Logistics materials mass/volume reduction; packing efficiency; recycle, reuse, repurposing potential

HYDROGEN PEROXIDE GENERATION

Description: Electrochemical production of in situ hydrogen peroxide using water, air, and electricity

Potential Use Cases: Logistics reduction of disinfectant materials and wipes

Logistics Reduction



TRL 4

SPACECRAFT MATERIALS TEXTILES

Description: Non-flammable IVA textile development and optimization for use in the Exploration Atmosphere (up to 37% O_2/8.2 psia)

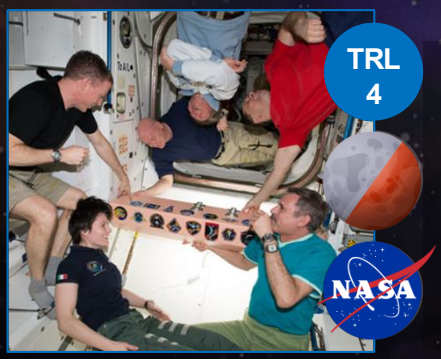
Potential Use Cases: Increased use of textiles to reduce mass and volume

TRL 7

ULTRASONIC CLOTHING WASHER/DRYER (ULTRASONIC TECHNOLOGY SOLUTIONS)

Description: Use of ultrasonic washing and direct-contact ultrasonic drying to clean crew clothing

Potential Use Cases: Laundry services (85% salt removal in 7.5 min cycle)



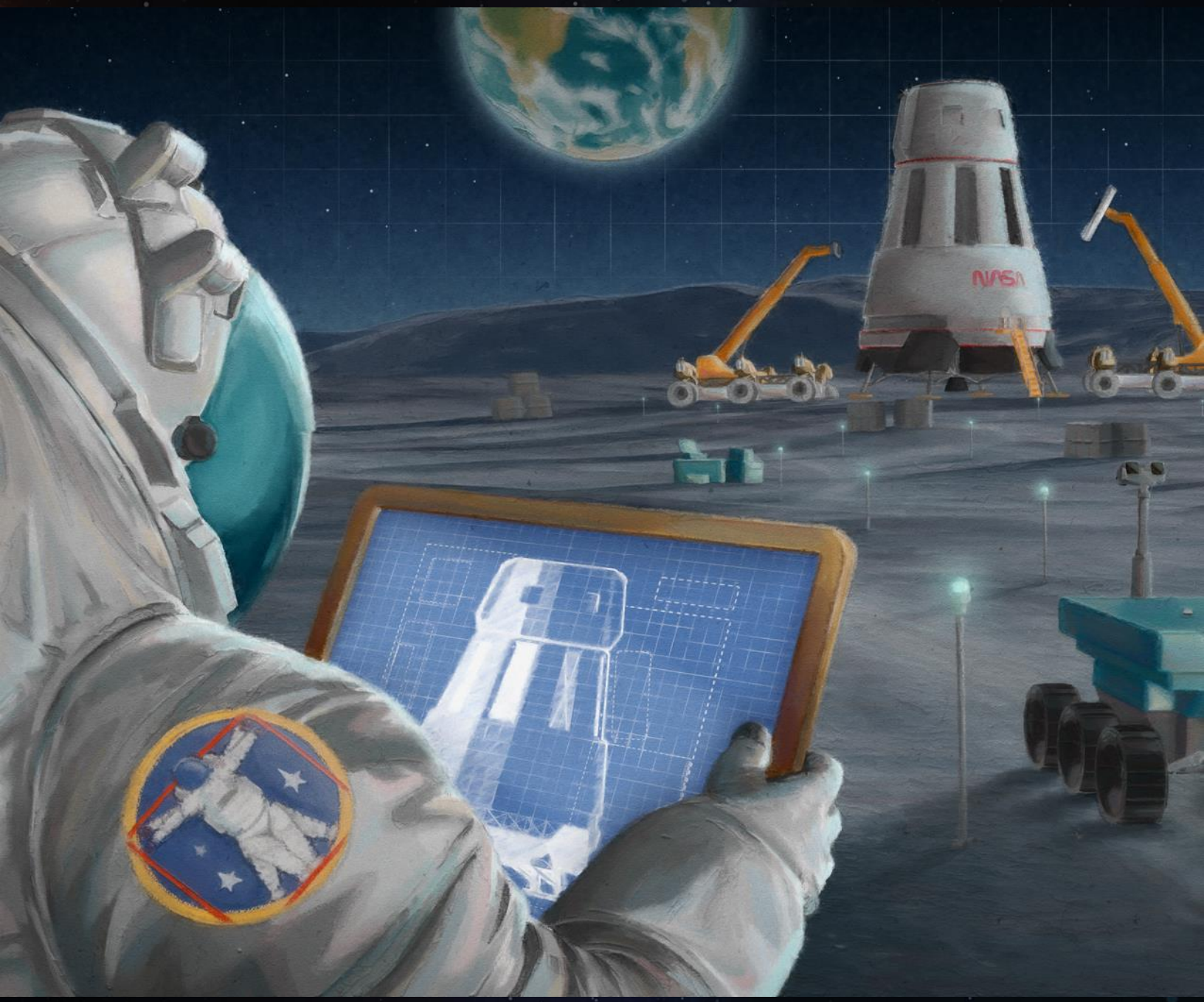
TRL 4

CREW CLOTHING TEXTILES

Description: Development, testing, and production of non-flammable knit textiles for Intravehicular Activity (IVA) crew clothing in the Exploration Atmosphere (up to 37% O_2/8.2 psia)

Potential Use Cases: Increased use of textiles to reduce mass and volume

Logistics Tracking



Logistics Tracking

Logistics tracking technologies identify, locate, and manage spaceflight hardware both in orbit and on surface. Experiences with logistics management on the International Space Station have identified a critical need for automation in logistics tracking technologies. This section outlines tracking technologies for logistics-specific items.

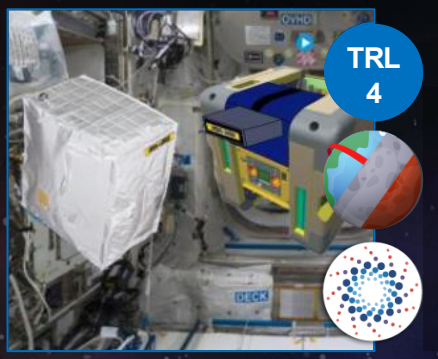
CIVIL SPACE SHORTFALLS	SF20
ESDMD ARCHITECTURE-DRIVEN TECHNOLOGY GAPS	#0701
PRIMARY TECHNOLOGY TAXONOMY	TX13.5.6

Logistics Tracking

RADIO-FREQUENCY IDENTIFICATION ENABLED AUTONOMOUS LOGISTICS MANAGEMENT (REALM)

Description: Automated localization and inventory of physical assets for, or within, a vehicle utilizing RFID technologies

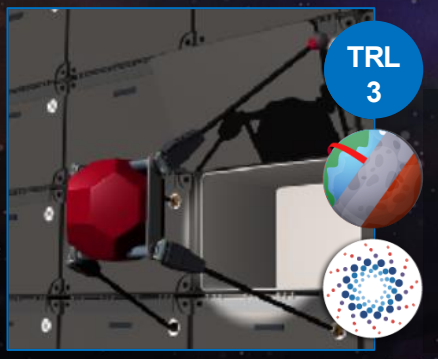
Potential Use Cases: Inventory, self-reliance, autonomous operations



SMALL FORM FACTOR RFID APPLICATOR (METIS TECHNOLOGY SOLUTIONS, INC.)

Description: Development of a small form factor, Astrobee-dedicated RFID label applicator to assist in logistics and asset tracking

Potential Use Cases: Autonomous logistics, asset tracking

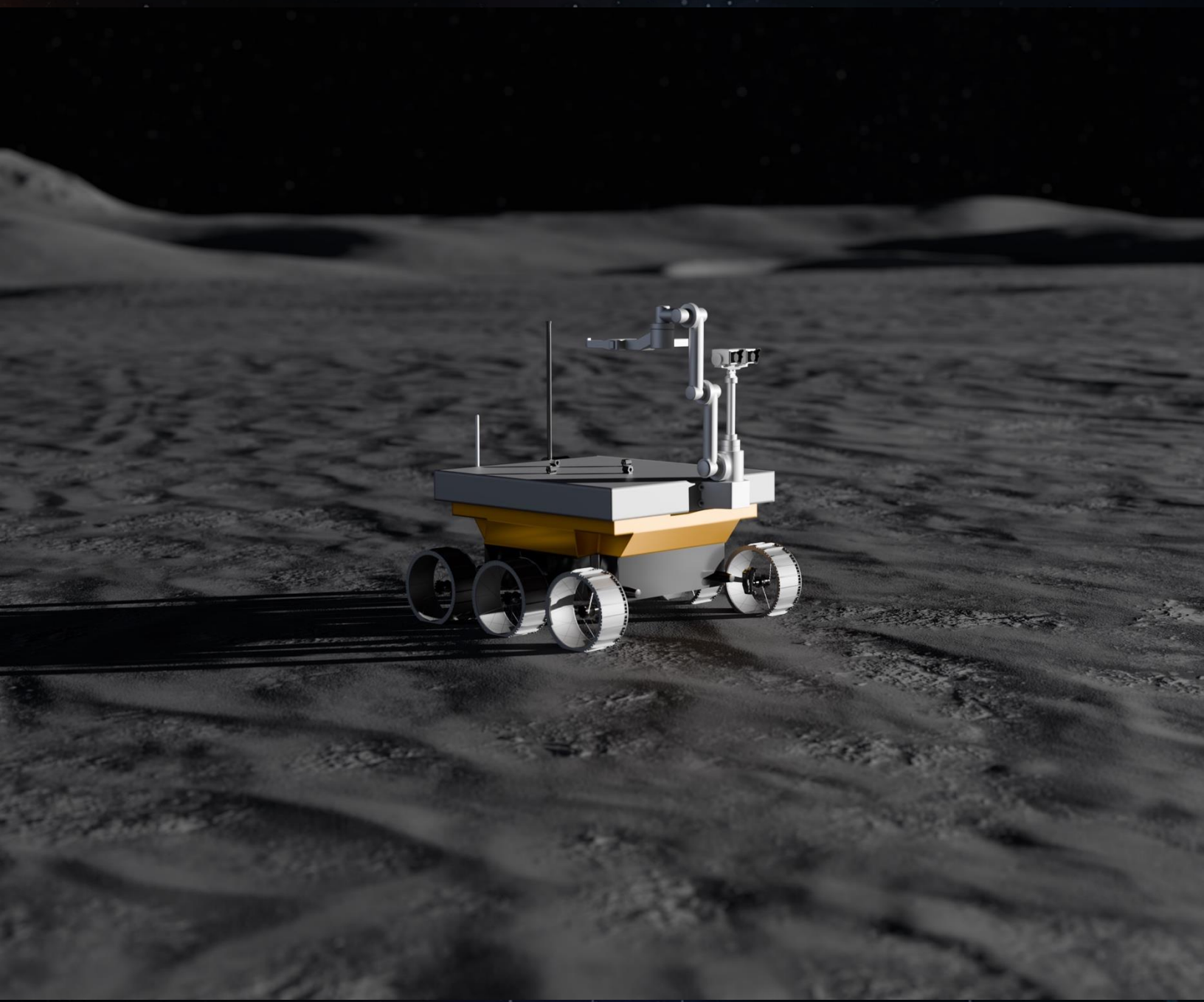


ROBOTIC INTERFACE DOGTAGS FOR AUTONOMOUS HABITAT OUTFITTING AND LOGISTICS (ALTIUS)

Description: Development of a lightweight, low-cost, passive "DogTag" robotic interface that can be attached to various habitat structures and objects

Potential Use Cases: Robotic outfitting, object identification

Autonomous Systems & Robotics

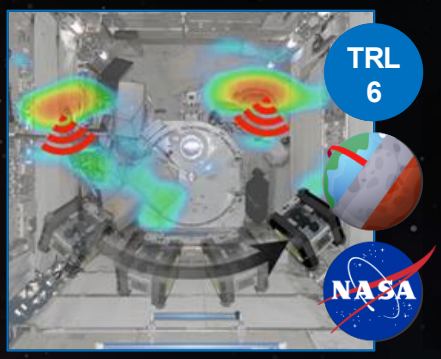


Autonomous Systems & Robotics

Autonomous systems and robotics technologies consist of software and hardware devices that enable functions that cannot be performed by the crew, enhance crew activities, or operate during uncrewed periods. As this capability is cross-cutting, some autonomous systems or robotic technologies may be included in other relevant sections of the catalog. Overall, the technologies listed are those that may be of utility to logistics.

CIVIL SPACE SHORTFALLS	SF02, SF15, SF16
ESDMD ARCHITECTURE-DRIVEN TECHNOLOGY GAPS	#0804, #0805, #0806, #0808, #1001, #1005
PRIMARY TECHNOLOGY TAXONOMY	TX04.3, TX10

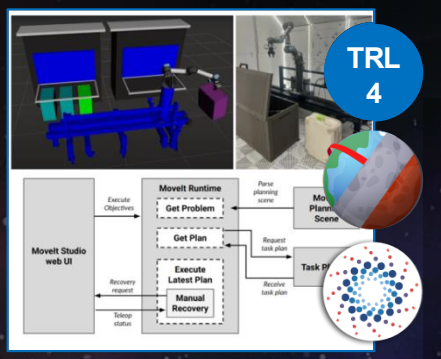
Autonomous Systems & Robotics



INTEGRATED SYSTEM FOR AUTONOMOUS AND ADAPTIVE CARETAKING (ISAAC)

Description: Remote and autonomous caretaking of Gateway when crew are not onboard using multi-sensor survey technology

Potential Use Cases: Maintenance, logistics management, utilization tasks, fault detection, isolation, and recovery



TASK AND MOTION PLANNING FOR SPACE OPERATIONS WITH HUMAN ASSISTED RECOVERY (PICKNIK)

Description: Autonomous space robotics with human-assisted task recovery planning

Potential Use Cases: Logistics, manufacturing, sustained operations (habitats, laboratories, construction sites)

HIGH PERFORMANCE SPACEFLIGHT COMPUTING

Description: Next-gen spaceflight computing: radiation hardened by design, power optimized, fault-tolerant, secure with high-performance device ecosystem (neural co-processors, networking, and more)

Potential Use Cases: Autonomous operations (100X the computational capacity of current flight processors for the same amount of power), surface exploration, crew assist systems, science payload processing

Autonomous Systems & Robotics

DUST TOLERANT ELECTROPERMANENT MAGNETIC TOOL INTERFACE (ALTIUS SPACE MACHINES)

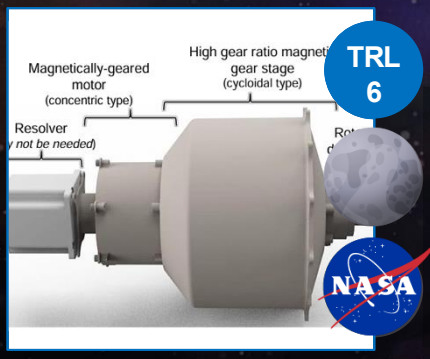
Description: Electropermanent magnet (EPM) gripping technology that can be integrated into a modular, dust-tolerant end-effector or tool-changer assembly

Potential Use Cases: Low mass/power manipulator tool for AS&R/Logistics/Mobility element

BULK METALLIC GLASS GEAR

Description: Bulk metallic glass (BMG) alloys for gearboxes and actuators to operate without wet lubricants and thus without power consuming heaters

Potential Use Cases: Logistics element/asset actuation



MOTORS FOR DUSTY & EXTREMLY COLD ENVIRONMENTS (MDECE)

Description: Unheated magnetically-geared motor and an unheated piezoelectric motor that can operate continuously for a long duration at an ambient temperature of -240 ºC (33 K)

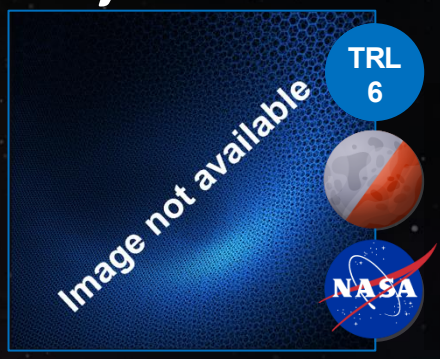
Potential Use Cases: Logistics element/asset motors/actuators

UNIVERSAL DOCKING INTERFACE FOR FREE-FLYING ROBOTS (HONEYBEE ROBOTICS)

Description: Universal Docking Interface (UDI) that provides a common electromechanical connection architecture for free-flying robots

Potential Use Cases: Robotic tool/payload/cargo manipulation on lunar surface

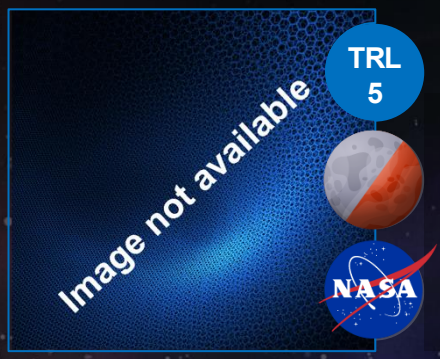
Autonomous Systems & Robotics



MOTION AND POSE ESTIMATION FOR AUTONOMY OF DYNAMIC/CONTACT TASKS

Description: Advance motion and pose estimation in support of dexterous robotics operations

Potential Use Cases: Improved machine vision capability for dynamic cargo manipulation and mating tasks

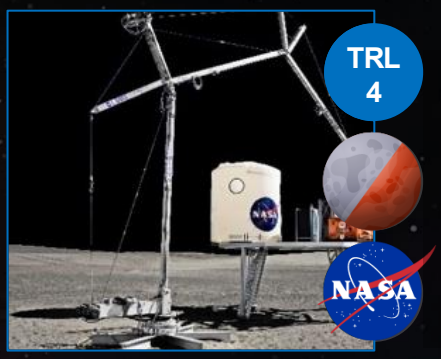


MACHINE VISION AUTOMATION FOR GROUND CONTROL TELE-ROBOTICS

Description: Advance ground based tele-robotic capabilities with the development of natural feature target tracking technology with the use of machine vision

Potential Use Cases: Machine vision generated solutions for robotic cargo manipulation and mating tasks

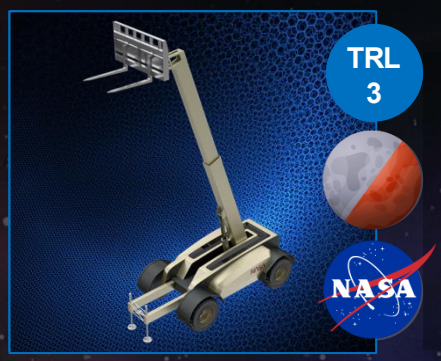
Autonomous Systems & Robotics



LIGHTWEIGHT SURFACE MANIPULATION SYSTEM (LSMS)

Description: Scalable autonomous robotic 4 DOF cargo manipulation (with wrist attachment)

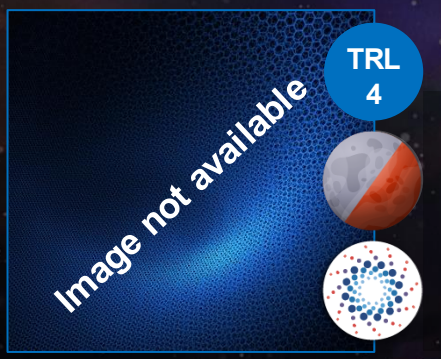
Potential Use Cases: Offloading (35 kg to 1000+ kg, reach 2.25 m to 8+ m), uploading (35 kg to 1000+ kg, reach 2.25 m to 8+ m)



TELEHANDLER

Description: Mobile, autonomous cargo offloading with 4 DOF manipulation

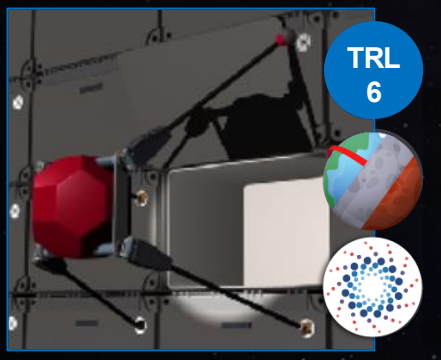
Potential Use Cases: Offloading (2500 kg, reach 3.5 m), uploading (2500 kg, reach 3.5 m), cargo transport



ROBOTIC EFFICIENT ARM FOR CARGO HANDLING (APPTRONIK, INC)

Description: Autonomous and crew assisted cargo offloading, 5 DOF manipulation

Potential Use Cases: Offloading (115 kg, reach 2 m), uploading (115 kg, reach 2 m), assisting crew operations

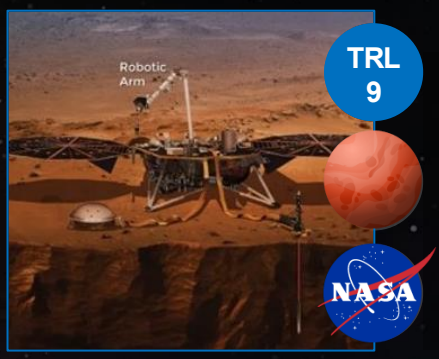


ROBOTIC INTERFACE DOGTAGS FOR AUTONOMOUS HABITAT OUTFITTING AND LOGISTICS (ALTIUS)

Description: Development of a lightweight, low-cost, passive "DogTag" robotic interface that can be attached to various habitat structures and objects

Potential Use Cases: Robotic outfitting, object identification

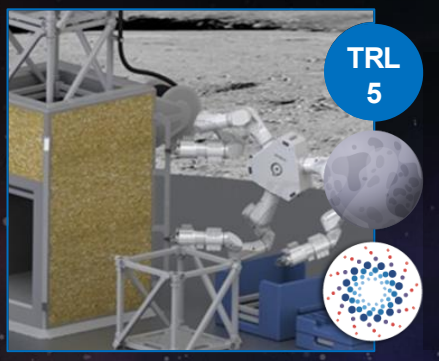
Autonomous Systems & Robotics



MARS INSIGHT INSTRUMENT DEPLOYMENT ARM

Description: Small-scale cargo manipulation and scientific sample collection, 4 DOF manipulation

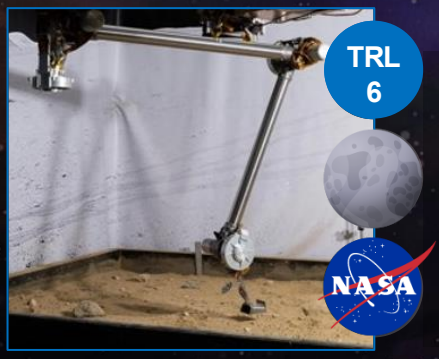
Potential Use Cases: Scientific sample collection, small payload offloading (9.5 kg, reach 1.8 m), uploading (9.5 kg, reach 1.8 m)



xWALKER (MOTIV SPACE SYSTEMS)

Description: Enhanced inspection and manipulation for lunar assembly, Small-scale 7 DOF manipulation

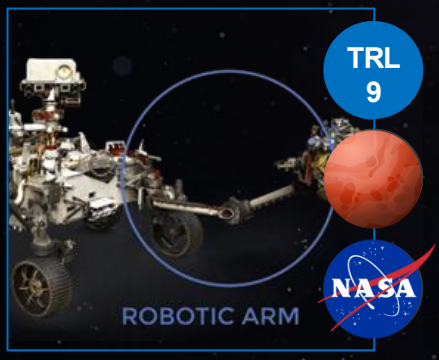
Potential Use Cases: Small payload offloading, uploading, manipulation



COLD OPERABLE LUNAR DEPLOYABLE ARM (COLDARM)

Description: Small-scale offloading and scientific tasks with bulk metallic gears and cold operable motor controllers are transferable to other robotic agents, 4 DOF manipulation

Potential Use Cases: Small scale offloading (4 kg, reach 2 m), uploading (4 kg, reach 2 m), scientific sample collection

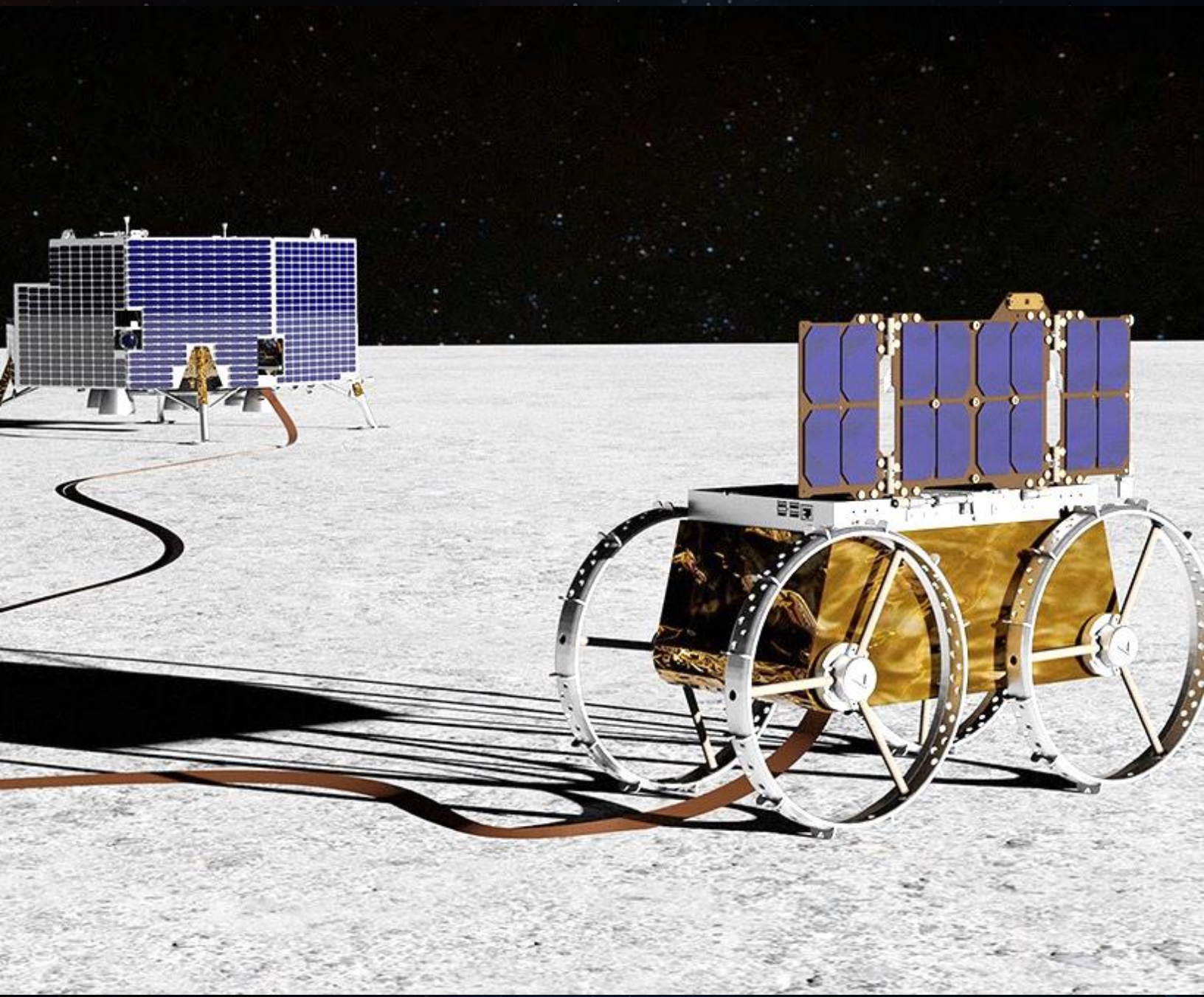


MARS PERSEVERANCE ROBOTIC ARM

Description: Small-scale cargo manipulation and scientific sample collection. 5 DOF manipulation.

Potential Use Cases: Scientific sample collection, small payload offloading (45 kg, reach 2 m), uploading (45 kg, reach 2 m).

Power

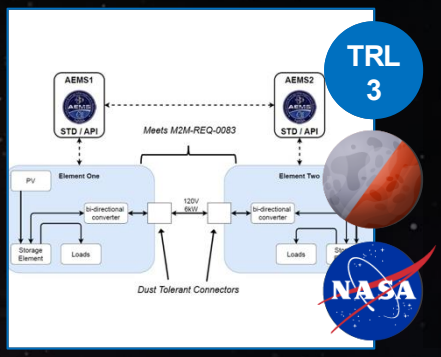


Power

Power technologies enable elements and assets to sustain nominal operations in extreme environments. This includes power generation, energy storage, power management, and distribution. Power connections enable the transfer of power from asset to asset via physical contact or wireless connection. The technologies listed below are those that may be particularly useful for logistics.

CIVIL SPACE SHORTFALLS	SF02
ESDMD ARCHITECTURE-DRIVEN TECHNOLOGY GAPS	#0301, #0901, #0903
PRIMARY TECHNOLOGY TAXONOMY	TX03

Power Standard Development

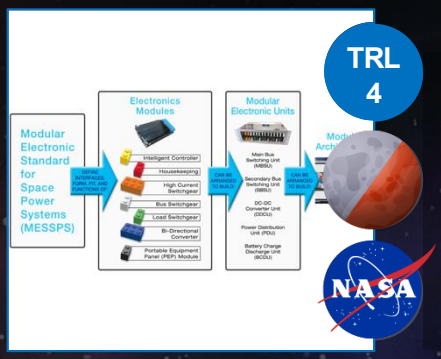


TRL 3

ADVANCED ENERGY MANAGEMENT SYSTEM

Description: Autonomous energy management capability for future lunar and Martian surface power networks, including bi-directional power transfer coordination

Potential Use Cases: Logistics element/asset power sharing and transfer with power assets

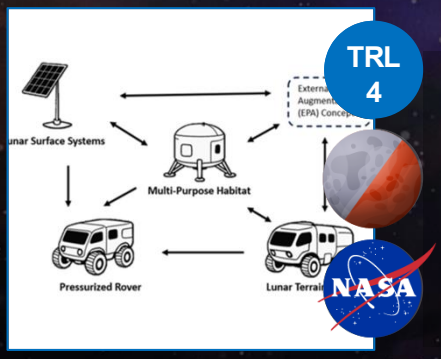


TRL 4

ADVANCED MODULAR POWER SYSTEMS

Description: Development of electronic modules which, when combined with standardized interfaces and chassis, provides commonality across a variety of exploration vehicles for future NASA missions

Potential Use Cases: Standardized power components for logistics elements/assets



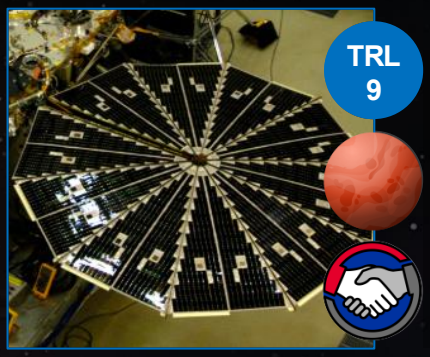
TRL 4

SURFACE POWER EXCHANGE VEHICLE INTERFACE

Description: Establishing a unified, bidirectional 6 kW (120 V, 50 A) power interface for all lunar and future Martian surface elements

Potential Use Cases: Standardized power interfaces for logistics elements/assets

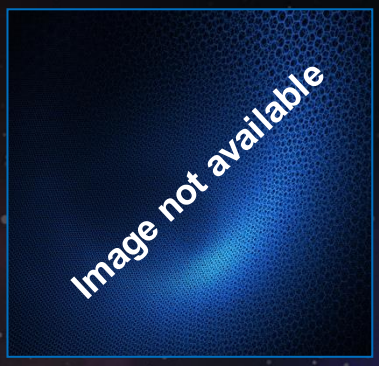
Power Generation



ULTRAFLEX SOLAR ARRAY

Description: Large, deployable, scalable, low-mass solar array (2-m-diameter Phoenix Mars lander)

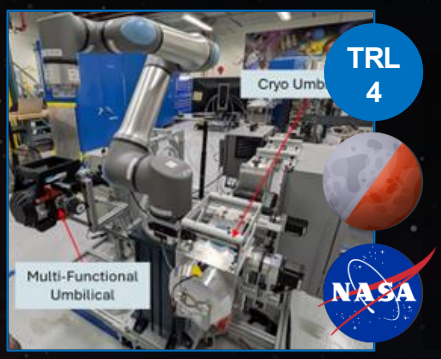
Potential Use Cases: On-orbit or surface solar power generation, post landing sustainment



RADIOISOTOPE POWER SYSTEMS

Description: For questions regarding the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG), Lightweight Radioisotope Heater Units (LWRHUs), or Radioisotope Power Systems (RPS) in development, please contact NASA's Radioisotope Power Systems Program.

Power Connectors

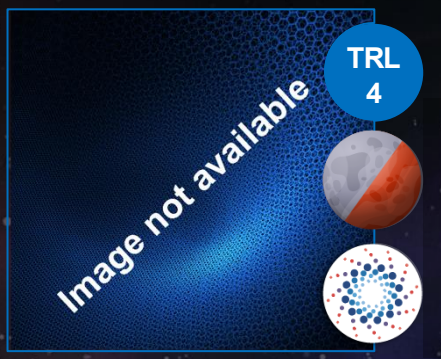


TRL 4

DUST-TOLERANT AUTOMATED UMBILICAL (DTAU)

Description: Dust tolerant, multi-functional automated umbilical for fluid and power transfer in surface environments

Potential Use Cases: Automated fluid transfer (including cryogens), automated power transfer

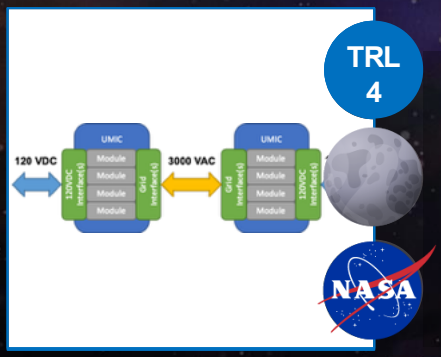


TRL 4

RESONANT TRANSFORMER CONNECTORS FOR HIGH VOLTAGE TRANSMISSION LINES (YANK TECHNOLOGIES)

Description: Dust-proof, high-voltage connectors for Moon and Mars power systems. Interface with high-voltage, three-phase 2 kV AC transmission lines to provide 1 kW power

Potential Use Cases: Power grids in dusty environment, long duration power operations



TRL 4

UNIVERSAL MODULAR INTERFACE CONVERTER (UMIC)

Description: 10 kW bi-directional power converter that allows low-mass, long-distance power transmission

Potential Use Cases: Post-landing sustainment

TRL 5

DUST TOLERANT CONNECTOR (HONEYBEE ROBOTICS)

Description: Reusable electrical connector tested in relevant lunar vacuum, thermal, and regolith conditions

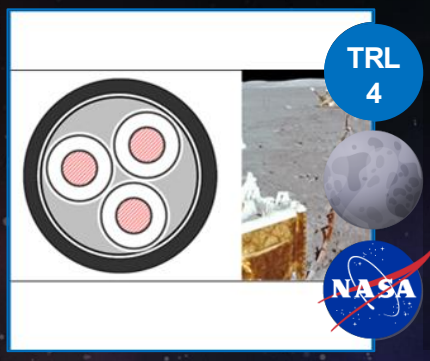
Potential Use Cases: Dust tolerant power connections between logistics assets/elements

Power Transmission

LOW MASS, HIGH VOLTAGE CABLES FOR LONG DISTANCE LUNAR POWER DISTRIBUTION (ASTROBOTIC)

Description: Cable and reel system designed with dust tolerant components capable of interfacing with a wide range of surface technologies (10 kV DC and 10 kW cabling up to 4 km)

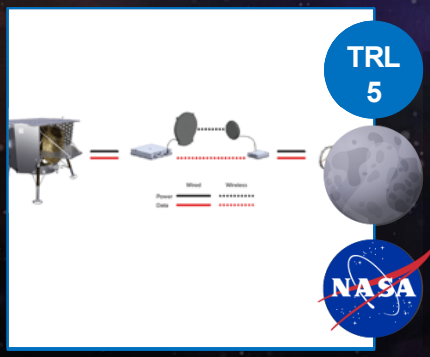
Potential Use Cases: High voltage power distribution, connecting power nodes, long distance cabling



MODULAR INTERFACE CONVERTER FOR PLANETARY SURFACES (MIPS) POWER CABLE

Description: Cable assembly enabling power transmission between UMICs over 1 km to 3 km distance, >10 kW transmission at 3 kV

Potential Use Cases: Post-landing sustainment

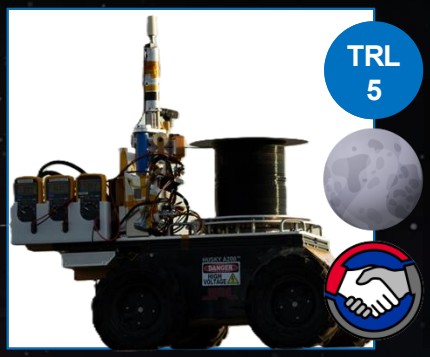


ULTRA FAST PROXIMITY CHARGING (CLPS ROVERS)

Description: Lightweight, ultra-fast in-space proximity (wireless) charging technology capable of withstanding harsh environments

Potential Use Cases: Survive the night, reliable charging

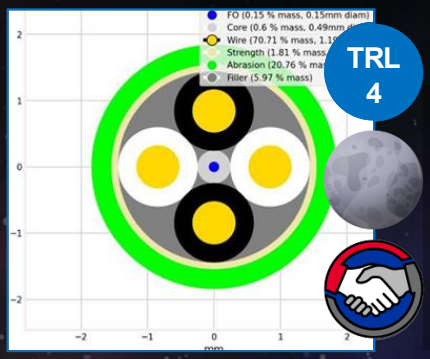
Power Transmission



TETHERED ULTRALIGHT INTELLIGENT POWER SYSTEM (TULIPS)

Description: TULIPS is a complete tethered power and communications system, using medium voltage DC to efficiently transfer power on ultralight cables. It provides power conversion (up to 10 kW), communications (1 Gb/s), cables, and cable deployers to connect surface power generation to loads kilometers away.

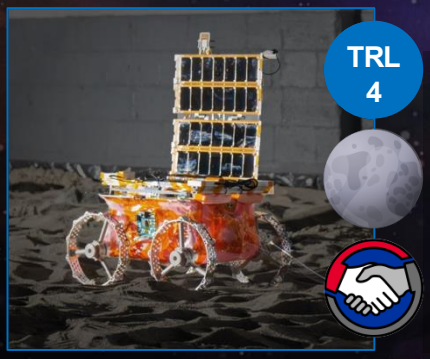
Potential Use Cases: Lunar surface power transmission and distribution, bi-directional vehicle charging, permanently shadowed regions access, CLPS power as a service



TETHERED POWER SYSTEMS FOR LUNAR MOBILITY AND POWER TRANSMISSION (TYMPO)

Description: Tether-based power transmission system to provide power (100 W – 10 kW) over several meters to several kilometers to serve remote loads

Potential Use Cases: High voltage power distribution, connecting power nodes, long distance cabling. Power density >2 W/cm^3, Specific Power >1 kW/kg

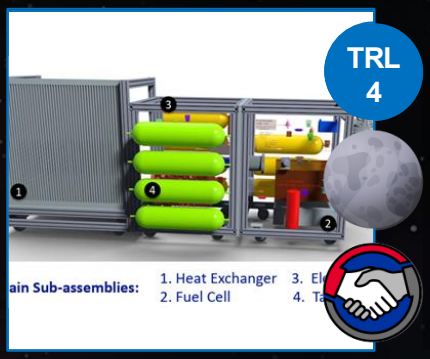


LUNAGRID-LITE (ASTROBOTIC)

Description: Lunar demo of long-distance (100 m – 500 m), high power (1 kW) transmission system leveraging vertical solar arrays, rovers, and landers

Potential Use Cases: Survive the night, wireless charging, power delivery, high power transfer

Energy Storage



REGENERATIVE FUEL CELL(RFC)

Description: Energy storage system technology that can provide sustained and reliable electrical power for surface and near surface missions where photovoltaics/battery or nuclear options may not be feasible

Potential Use Cases: Logistics element/asset energy storage, high specific energy capability (>320 W•hr/kg)

Fluid Transfer

Fluid Transfer

Fluid Transfer technologies for logistics operations include the transfer of fluids into habitation elements and for refueling assets. Fluid connectors must be leak-proof, reusable, and resist environmental effects due to dust, radiation, and thermal extremes.

CIVIL SPACE SHORTFALLS	SF02, SF06, SF12, SF16
ESDMD ARCHITECTURE-DRIVEN TECHNOLOGY GAPS	#0503, #1107
PRIMARY TECHNOLOGY TAXONOMY	TX13.5.5, TX13.5.7

Fluid Transfer

LOXSAT 1 (ETA SPACE)

Description: Complete cryogenic oxygen fluid management system including transferring liquid oxygen in LEO environment

Potential Use Cases: Refueling

LEAK MITIGATING WATER LOOP CONNECTOR (MAINSTREAM)

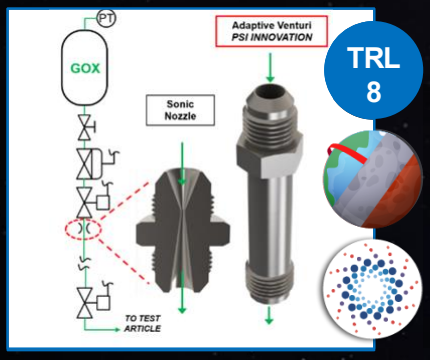
Description: Connector that eliminates the cold flow-derived liquid leakage in xEMU liquid cooled garments that develops over long durations expected on future Moon and Mars missions

Potential Use Cases: Leak prevention strategy

MULTIUSE QUICK DISCONNECT FOR LUNAR SURFACE FLUID TRANSFER OPERATIONS (CREARE, LLC)

Description: Sealing technology to transfer cryogenic fluids on the lunar surface

Potential Use Cases: Cryogenic fluid transfer

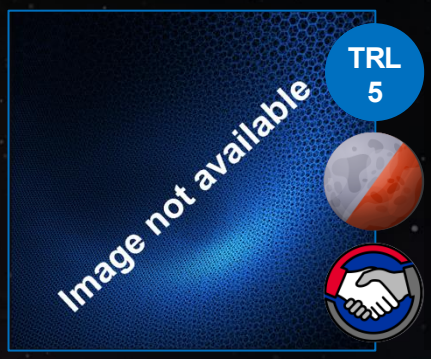


ADAPTIVE VENTURI FOR SURGE PRESSURE MITIGATION (PHYSICAL SCIENCES, INC)

Description: Venturi with passively controlled throat for rapid and automatic flow rate adjustment to prevent pressure surges

Potential Use Cases: Propellant loading, priming operations

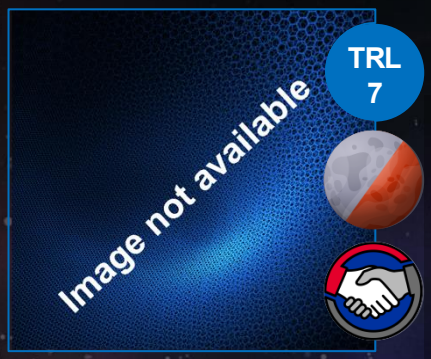
Fluid Transfer



COUPLER FOR PROPELLANT TRANSFER (SPACEX)

Description: A NASA standard common in-space cryogenic fluid transfer system capable of facilitating interfaces between different vehicles and facilities from different providers

Potential Use Cases: Refueling, methane/LOX transfer, liquid hydrogen transfer

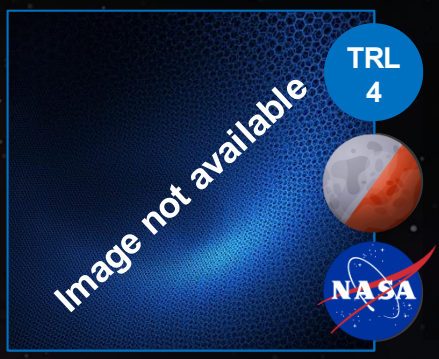


ON-ORBIT LARGE-SCALE CRYOGENIC PROPELLANT MANAGEMENT AND TRANSFER DEMONSTRATION (SPACEX)

Description: Large-scale (>10 metric tons) on-orbit cryogenic fluid transfer

Potential Use Cases: refueling, fluid transfer, fluid storage

Fluid Transfer



DUST TOLERANT MAGNETIC COUPLER

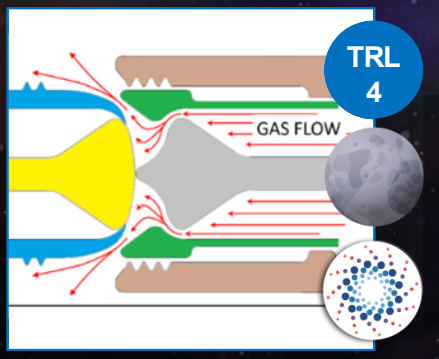
Description: Dust-tolerant cryogenic magnetic coupler enabling fluid transfer in the dusty environments on the moon and Mars

Potential Use Cases: Cryogenic fluid transfer

REMOVABLE xEMU SCC PROTECTIVE COVER (OFF PLANET RESEARCH, LLC)

Description: Dust-resistant connector port cover for xEMU service and cooling connector

Potential Use Cases: protecting connectors on rovers, in habitats, ISRU plant interfaces and control panels

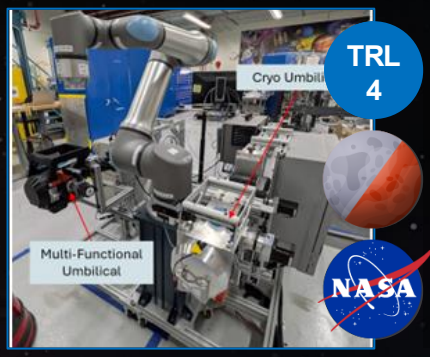


SELF-CLEARNING DUST PROOF FLUID AND GAS CONNECTOR (OFF PLANET RESEARCH, LLC)

Description: Self-cleaning dust and regolith tolerant fitting enabling gas or fluid transfer on Moon, Mars; well suited for ultra-cold regions

Potential Use Cases: Refueling ascent vehicles, automated or human operation, operations in shadowed regions, cryogenic fluid transfer, spill prevention

Fluid Transfer



DUST-TOLERANT AUTOMATED UMBILICAL (DTAU)

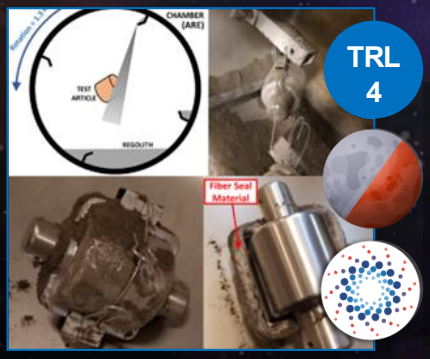
Description: Dust tolerant, multi-functional automated umbilical for fluid and power transfer in surface environments

Potential Use Cases: Automated fluid transfer (including cryogens), automated power transfer

xEMU LUNAR DUST PROTECTION DEVICES (INNOVATIVE AERSOPACE)

Description: Passive device to protect connections and seals from harmful lunar dust designed for the xEMU

Potential Use Cases: protect valves, protect quick disconnects



FLEXIBLE DUST-EXCLUDING FIBER SEALS (OFF PLANET RESEARCH, LLC)

Description: Flexible fiber dust-excluding, lubricant free seal to block planetary dust in dynamic mechanisms. 10s to 100s of months with little to no maintenance

Potential Use Cases: Operations in dusty environments, reusable seals, hatches, joints, covers, rotary joints

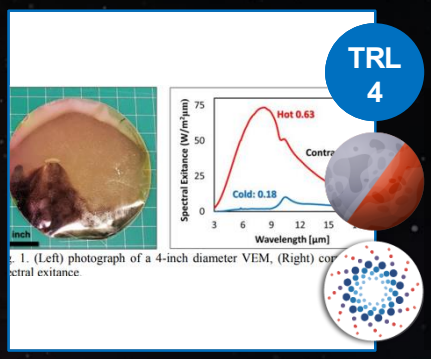
Thermal Management

Thermal Management

Thermal management technologies are critical for astronaut survival and protecting elements, assets, and equipment from the extreme temperatures encountered during spaceflight. The technologies outlined in this catalog are those particularly suited for logistics operations.

CIVIL SPACE SHORTFALLS	SF02
ESDMD ARCHITECTURE-DRIVEN TECHNOLOGY GAPS	#0301
PRIMARY TECHNOLOGY TAXONOMY	TX14

Thermal Management

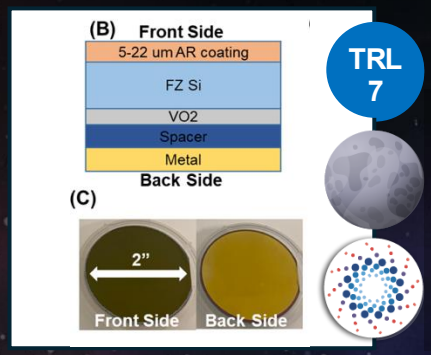


TRL 4

FLEXIBLE VARIABLE EMISSION MATERIAL (PLASMONICS INC.)

Description: Mission-tailorable, and autoregulating, thermal radiator coatings by leveraging its extensive experience in growing vanadium dioxide (VO_2) on flexible substrates

Potential Use Cases: Logistics system(s) thermal control



TRL 7

LOW-ALPHA VARIABLE EMISSIVITY RADIATOR (PHYSICAL SCIENCES INC.)

Description: Variable emissivity, low absorptivity radiator tiles to be applied to radiator panels for passive thermal regulation of spacecraft

Potential Use Cases: Logistics system(s) thermal control

TRL 4

NOVEL MULTILAYERED METAL INSULATION USING CUSTOM STANDOFFS (GINER INC.)

Description: Custom, low thermal conductivity standoffs which will reduce multi-layer metal insulation parasitic heat losses, increasing power supply efficiency

Potential Use Cases: Logistics system(s) thermal insulation

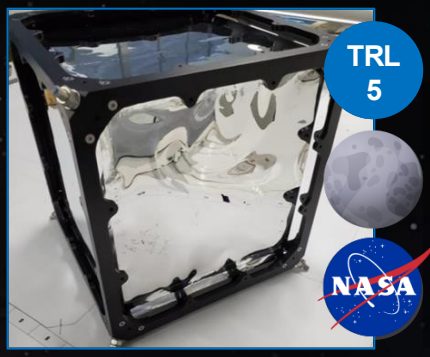
TRL 4

COMPACT HEAT EXCHANGERS FOR SPACE POWER SYSTEMS (ULTRAMET)

Description: Compact heat exchangers based on open-cell graphite foams with extremely low pressure drops

Potential Use Cases: Heat exchange/management for logistics system(s) (heat transfer coefficients that are 3.4 times greater than those of wavy aluminum fins)

Thermal Management



PLANETARY AND LUNAR ENVIRONMENT THERMAL TOOLBOX (PALETTE)

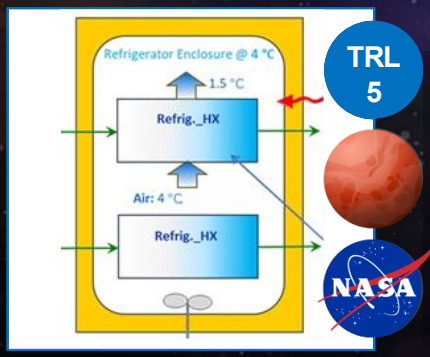
Description: Passive thermal management tools including thermally-switched enclosures, parabolic reflector radiators, spacer-less MLI, and thermal isolators

Potential Use Cases: Logistics system(s) and payload passive thermal control

HYBRID AEROGEL-MLI INSULATION SYSTEM (ASPEN AEROGELS INC.)

Description: Hybrid aerogel/MLI system, with demonstrated advantages at cryogenic temperatures and a range of vacuum conditions

Potential Use Cases: Logistics system(s) thermal insulation



MARS FOOD REFRIGERATION

Description: Efficient and low mass refrigerators and freezers

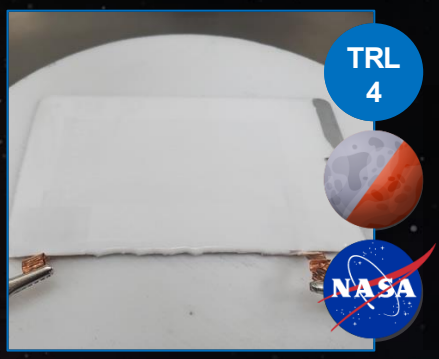
Potential Use Cases: Long-term storage and transportation of food and science samples

LUNAR EXTREME WATER CONTAINER (MOONPRINT SOLUTIONS INC.)

Description: Collapsible water container that can operate in harsh environments such as lunar dust and extreme cold. The container uses an inflatable soft goods design.

Potential Use Cases: Transport of water from production or storage locations to inside pressurized habitable volumes

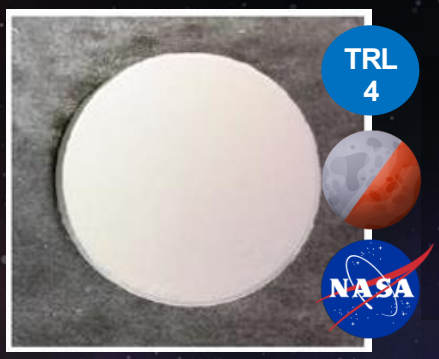
Thermal Management



THERMAL RADIATOR WITH ELECTRODYNAMIC DUST SHIELD (TREDS)

Description: Integration of electrodynamic dust shield technology (EDS) with thermal radiators to prevent dust buildup while improving radiator performance and lifetime

Potential Use Cases: Logistics element/asset radiator dust mitigation



SOLAR WHITE

Description: Solar reflector coating composed of Yttrium Oxide and Barium for cryogenic fluid storage

Potential Use Cases: Passive thermal management of fluids/cryogens

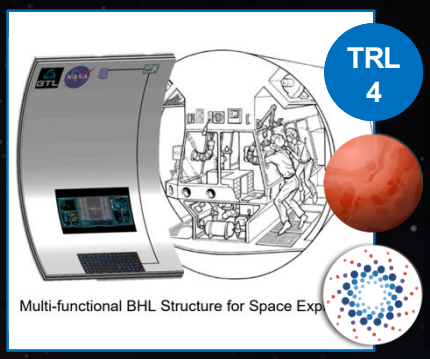
Radiation Protection

Radiation Protection

Radiation protection technologies protect the crew, elements, assets, and equipment from the harmful effects of radiation exposure, including ultraviolet radiation, solar particle events, and galactic cosmic radiation. The technologies outlined in this catalog are those particularly useful for logistics operations.

CIVIL SPACE SHORTFALLS	SF21
ESDMD ARCHITECTURE-DRIVEN TECHNOLOGY GAPS	#0307, #0308
PRIMARY TECHNOLOGY TAXONOMY	TX06.5

Radiation Protection

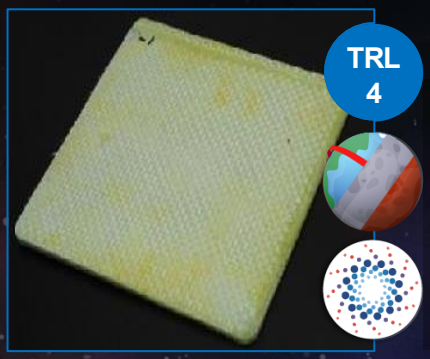


TRL 4

MULTIFUNCTIONAL BHL RADIATION SHIELD (GLOYER-TAYLOR LABORATORIES)

Description: Lightweight and multifunctional composite material that can be used as primary, secondary and interior spacecraft structure and protect from radiation

Potential Use Cases: Radiation shielding for logistics elements electronics/cargo



TRL 4

POLYBENZOXAZINE MATERIALS FOR RADIATION SHIELDING (MATERIAL ANSWERS)

Description: Lightweight shielding materials that can also serve as structural members and provide protection from micrometeoroid impact using polybenzoxazine

Potential Use Cases: Radiation shielding for logistics elements electronics/cargo; MMOD protection

TRL 5

HYDROGENOUS POLYMER-REGOLITH COMPOSITES FOR RADIATION-SHIELDING MATERIALS (INTERNATIONAL SCIENTIFIC TECHNOLOGIES)

Description: Hydrogenous structural radiation shielding materials using simulated Mars regolith combined with a minimal processing polymer

Potential Use Cases: Radiation shielding for logistics elements electronics/cargo using in situ resources

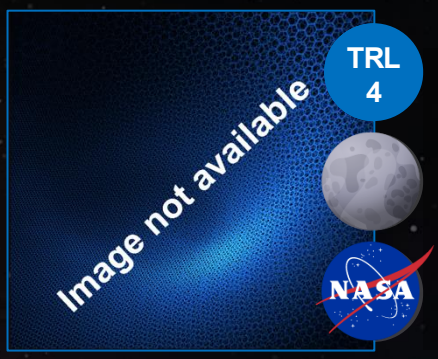
TRL 5

ADVANCED MULTIFUNCTIONAL MMOD SHIELDING

Description: Micrometeoroid and orbital debris (MMOD) shields which incorporate thermal protection, radiation protection, damage detection & location sensors and self-healing properties

Potential Use Cases: Dual radiation protection (20-25% reduction in spacecraft shield mass) and impact protection

Radiation Protection



COMPACT ELECTRON-PROTON SPECTROMETER (CEPS)

Description: Low power (<3 W), miniature Space Weather instrument (< 1 cu ft, < 4 lbs) for extended (up to 10 year) lunar operations Autonomously measure proton and electron spectra on the lunar surface.

Potential Use Cases: Radiation sensing

REGOLITH OVERBURDEN STRUCTURES ON THE MOON (AI SPACEFACTORY)

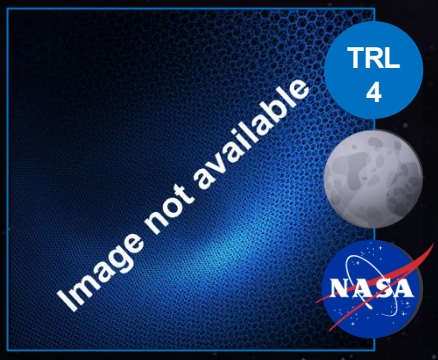
Description: Autonomous lunar construction using compacted, fortified regolith structures

Potential Use Cases: Protective structures for environmental protection (impact, radiation, thermal), storage

RELEVANT ENVIRONMENT ADDITIVE CONSTRUCTION TECHNOLOGY (REACT)

Description: ISRU based construction technologies for infrastructure such as shelters, blast protection, landing pads, roads and habitats

Potential Use Cases: Dual radiation protection and impact protection, landing pad construction, roads/berms, storage



LUNAR OUTPOST NEUTRON SPECTROMETER (LOONS)

Description: Fast neutron spectrometer for characterizing the albedo neutron environment on the lunar surface

Potential Use Cases: Radiation sensing

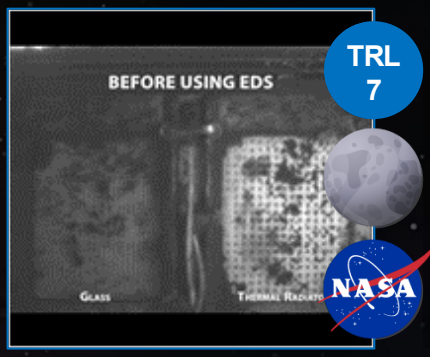
Dust Mitigation

Dust Mitigation

Dust mitigation technologies protect the crew, elements, assets, and equipment from the harmful effects of dust exposure and/or contamination. The technologies outlined in this catalog are those particularly suited for logistics operations.

CIVIL SPACE SHORTFALLS	SF02, SF06
ESDMD ARCHITECTURE-DRIVEN TECHNOLOGY GAPS	#0801, #0802
PRIMARY TECHNOLOGY TAXONOMY	TX07.2.5, TX13.4.5

Dust Mitigation

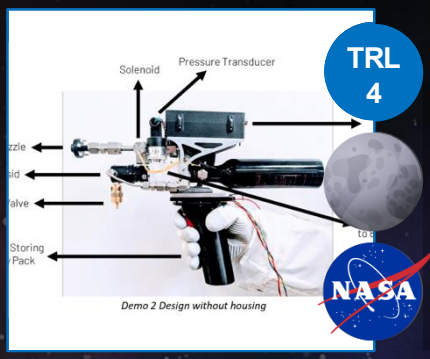


TRL 7

ELECTRODYNAMIC DUST SHIELD

Description: Clears dust off surfaces and prevents accumulation by using a pattern of electrodes to generate a non-uniform electric field over the surface being protected. Applicable to both Moon and Mars

Potential Use Cases: Active dust mitigation.



TRL 4

LUNAR ELECTROSTATICS AND DUST MITIGATION (LEDM) TOOL

Description: A handheld static ionizer tool for astronauts to remove dust and neutralize electrostatic charge from materials in a lunar environment

Potential Use Cases: Mobile active dust mitigation

TRL 5

BENDABLE ELECTRODYNAMIC DUST SHIELD (HEDGEFOG RESEARCH, INC.)

Description: Thin-film, Bendable Electrodynamic Dust Shields that allow for continuous dynamic bending over compound curvatures

Potential Use Cases: Active dust mitigation over curved surfaces

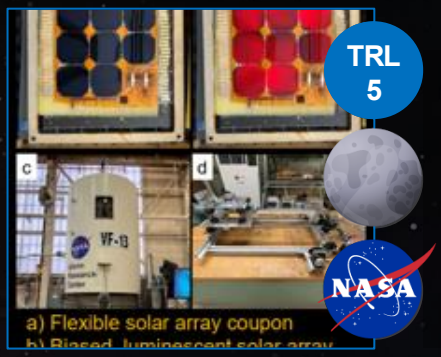
TRL 4

DUST TOLERANT JOINTS (TRITON SYSTEMS INC.)

Description: Innovative bearings solutions for contaminant-rich environments to design and fabricate dust tolerant joints

Potential Use Cases: Dust tolerant joints for logistics, mobility, robotic systems

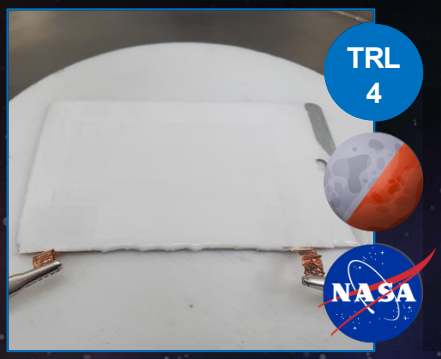
Dust Mitigation



DUST MITIGATION FOR FLEXIBLE SOLAR ARRAYS

Description: Vibromechanical dust mitigation technology for flexible solar arrays

Potential Use Cases: Logistics, robotics, mobility element solar array dust mitigation



THERMAL RADIATOR WITH ELECTRODYNAMIC DUST SHIELD (TREDS)

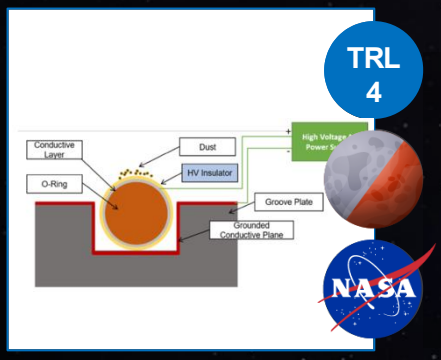
Description: Integration of electrodynamic dust shield technology (EDS) with thermal radiators to prevent dust buildup while improving radiator performance and lifetime

Potential Use Cases: Logistics element/asset radiator dust mitigation

LUNAR DUST FILTER FOR SPACECRAFT ATMOSPHERES (BLAZETECH)

Description: Self-cleaning staged dust filter for spacecraft air purification in cabin and airlock chambers

Potential Use Cases: Logistics carrier vent ports



ELECTRODYNAMIC DUST SHIELD – SEALS

Description: Seals (e.g., O-rings) with active self-cleaning capabilities via electrodynamic dust shielding

Potential Use Cases: Logistics element/asset seal dust mitigation, surface mating seal dust mitigation

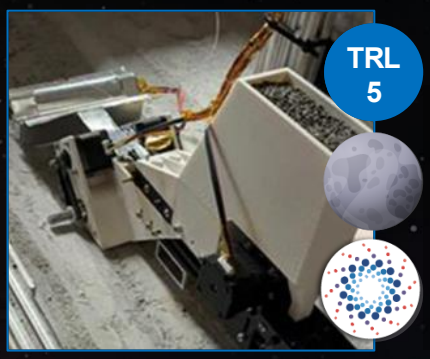
Impact Protection

Impact Protection

Impact protection technologies protect the crew, elements, assets, and equipment from harmful effects due to system bombardment from particulates, micrometeorites, or orbital debris. The technologies outlined in this catalog are those particularly suited for logistics operations.

CIVIL SPACE SHORTFALLS	SF04, SF30
ESDMD ARCHITECTURE-DRIVEN TECHNOLOGY GAPS	not identified
PRIMARY TECHNOLOGY TAXONOMY	TX12.1.1, TX13.1.7

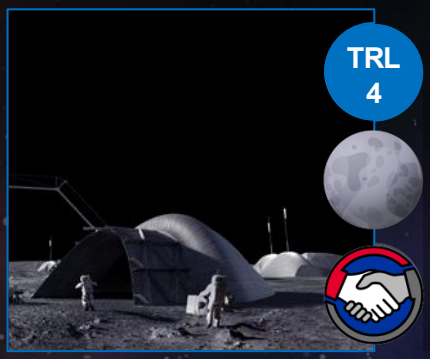
Impact Protection



REGOLITH OVERBURDEN STRUCTURES ON THE MOON (AI SPACEFACTORY)

Description: Autonomous lunar construction using compacted, fortified regolith structures

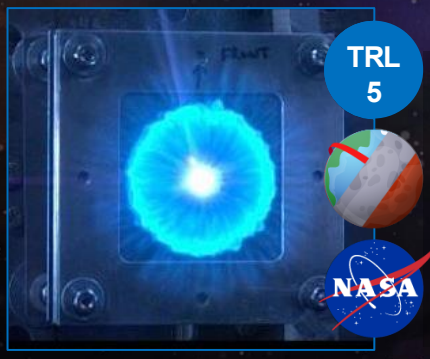
Potential Use Cases: Protective structures for environmental protection (impact, radiation, thermal), storage



RELEVANT ENVIRONMENT ADDITIVE CONSTRUCTION TECHNOLOGY (REACT)

Description: ISRU based construction technologies for infrastructure such as shelters, blast protection, landing pads, roads and habitats

Potential Use Cases: Dual radiation protection and impact protection, landing pad construction, roads/berms, storage

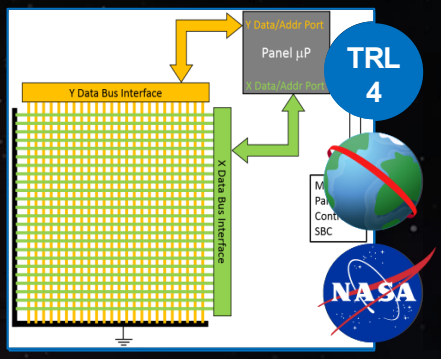


ADVANCED MULTIFUNCTIONAL MMOD SHIELDING

Description: Micrometeoroid and orbital debris (MMOD) shields which incorporate thermal protection, radiation protection, damage detection & location sensors and self-healing properties

Potential Use Cases: Dual radiation protection (20-25% reduction in spacecraft shield mass) and impact protection

Damage Detection Systems

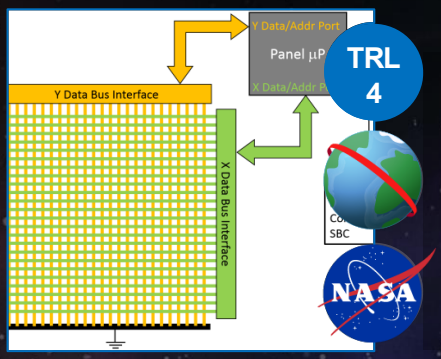


TRL 4

DAMAGE DETECTION AND VERIFICATION SYSTEM

Description: Sensory panel damage detection capability, including an autonomous inspection capability utilizing cameras and dynamic computer vision algorithms to verify system health

Potential Use Cases: Element/asset damage detection (flat surface)

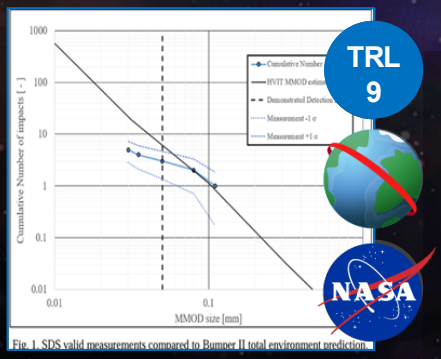


TRL 4

FLEXIBLE DAMAGE DETECTION AND VERIFICATION SYSTEM

Description: Extension of Damage Detection and Verification System for flexible surfaces

Potential Use Cases: Element/asset damage detection (flexible surface)



TRL 9

SPACE DEBRIS SENSOR

Description: ISS demonstration of a large area impact sensor for in situ measurements of micrometeoroids and orbital debris (MMOD) in the millimeter or smaller size regime

Potential Use Cases: Element/asset sensing of micrometeorite or debris impact

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