Human-Robot Collaboration as an Enabler of Scalable Human Presence in Space

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SICSA
Sasakawa International Center for Space Architecture

3rd AIAA LA-LV International Space Architecture Gathering

HIGHLIGHTS

Vittorio Netti,
Ph.d. candidate

> Registered System Engineer *(INCOSE)*

> Project Manager at Vector Robotics S.r.l.

> Consultant for Olympus Project *(SEArch+)*

> Ph.D. Candidate in Aerospace Engineering (*PoliBa)*

> M.Sc Space Architecture *(SICSA, UH)*

Team Lead Lunar Surface Element *(Boeing)*

Team Lead Modular Utility Vehicle *(RASC-AL)*

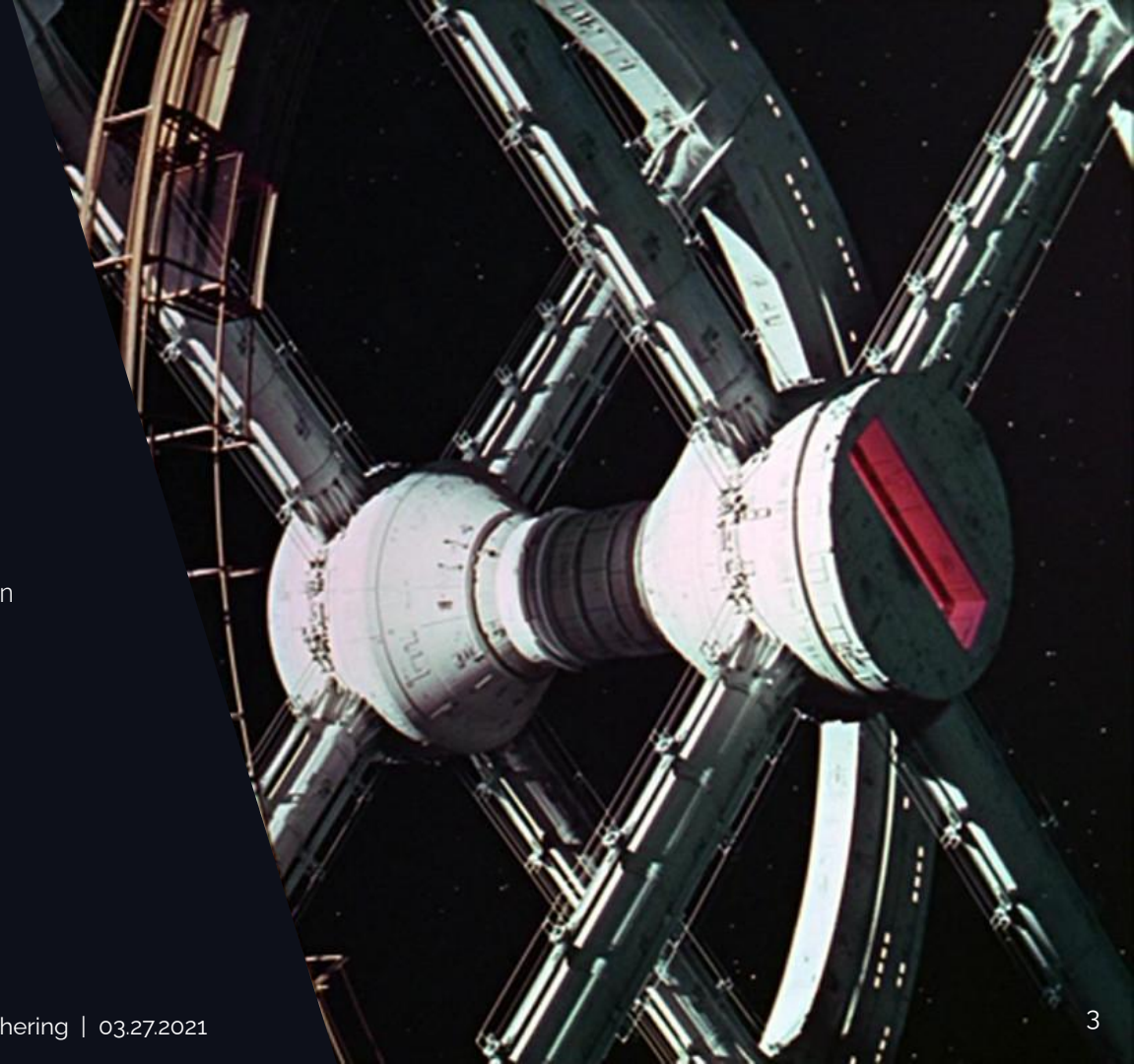
> M.Arch Architecture *(IUAV)*

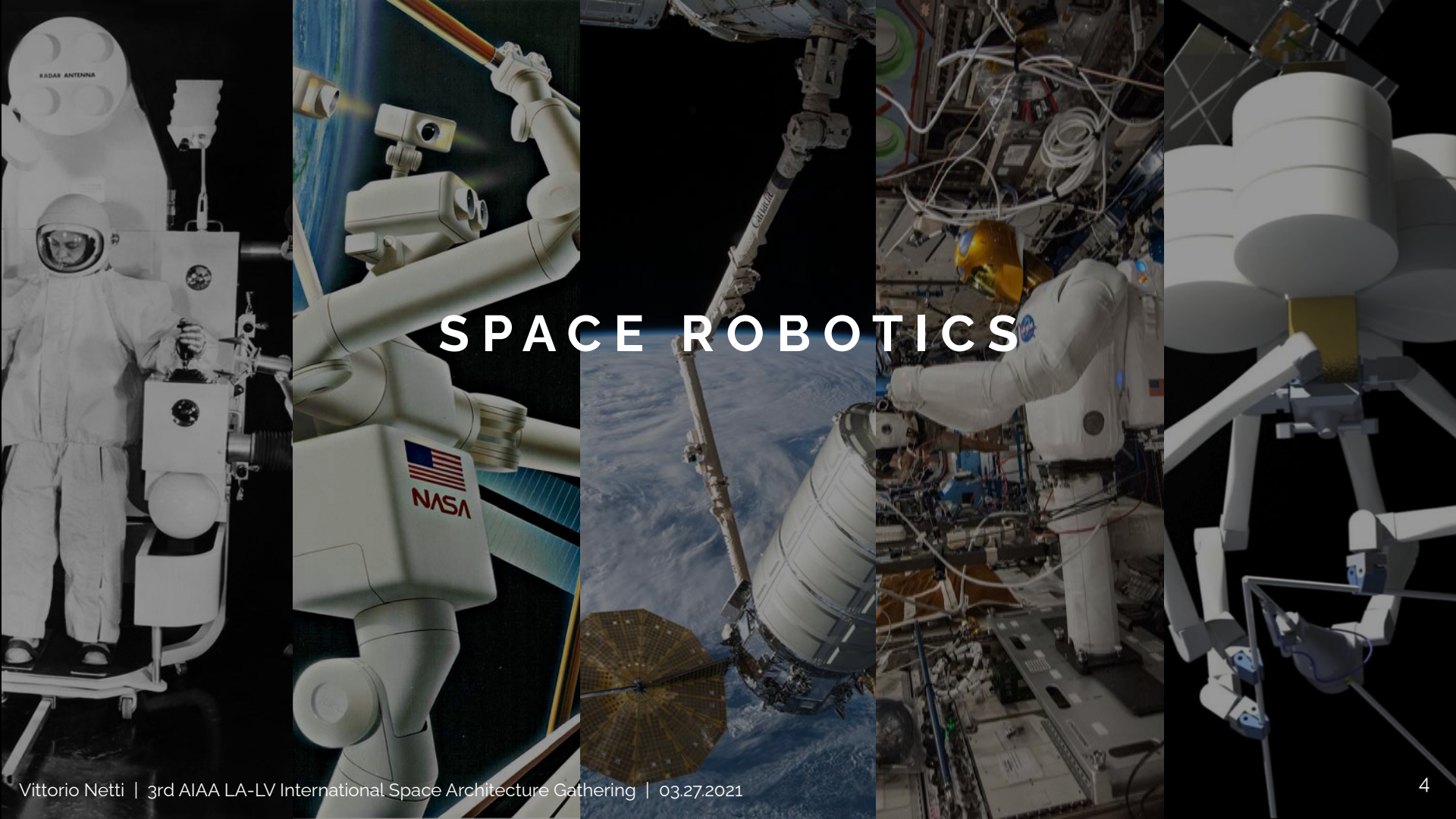
> B.Sc Architectural Sciences *(IUAV)*

Politecnico di Bari
SICSA
vector robotics
UNIVERSITY of HOUSTON
POLITECNICO DI MILANO
SEArch+

A SAFE AND ACCESSIBILE SPACE ENVIRONMENT

Rising automation levels in space missions will enable the future-proof maintenance and integration capability that is needed to boost the larger scale applications.

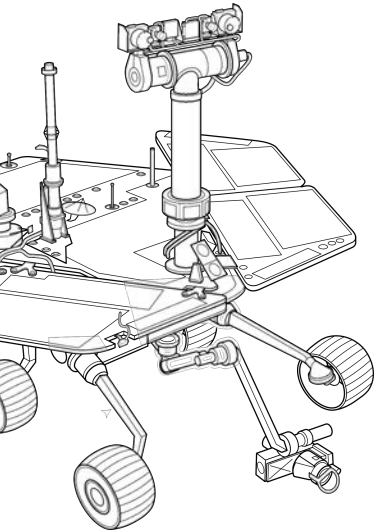




SPACE ROBOTICS

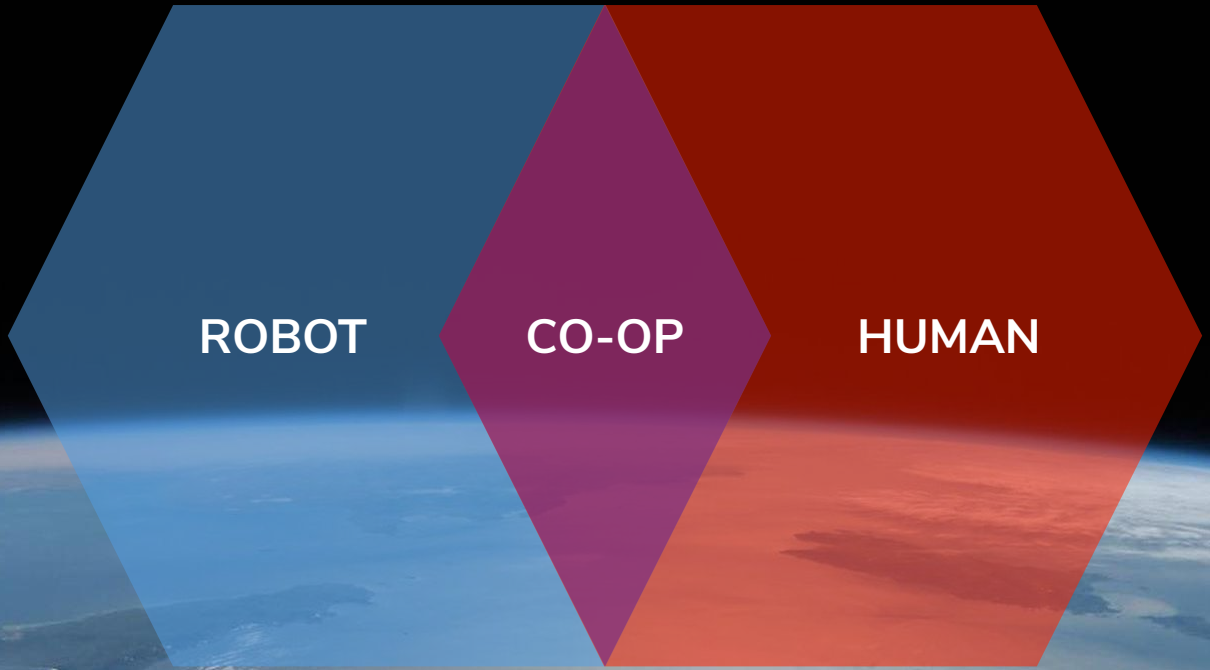
HUMAN VS ROBOTICS CAPABILITIES IN EVA OPERATIONS

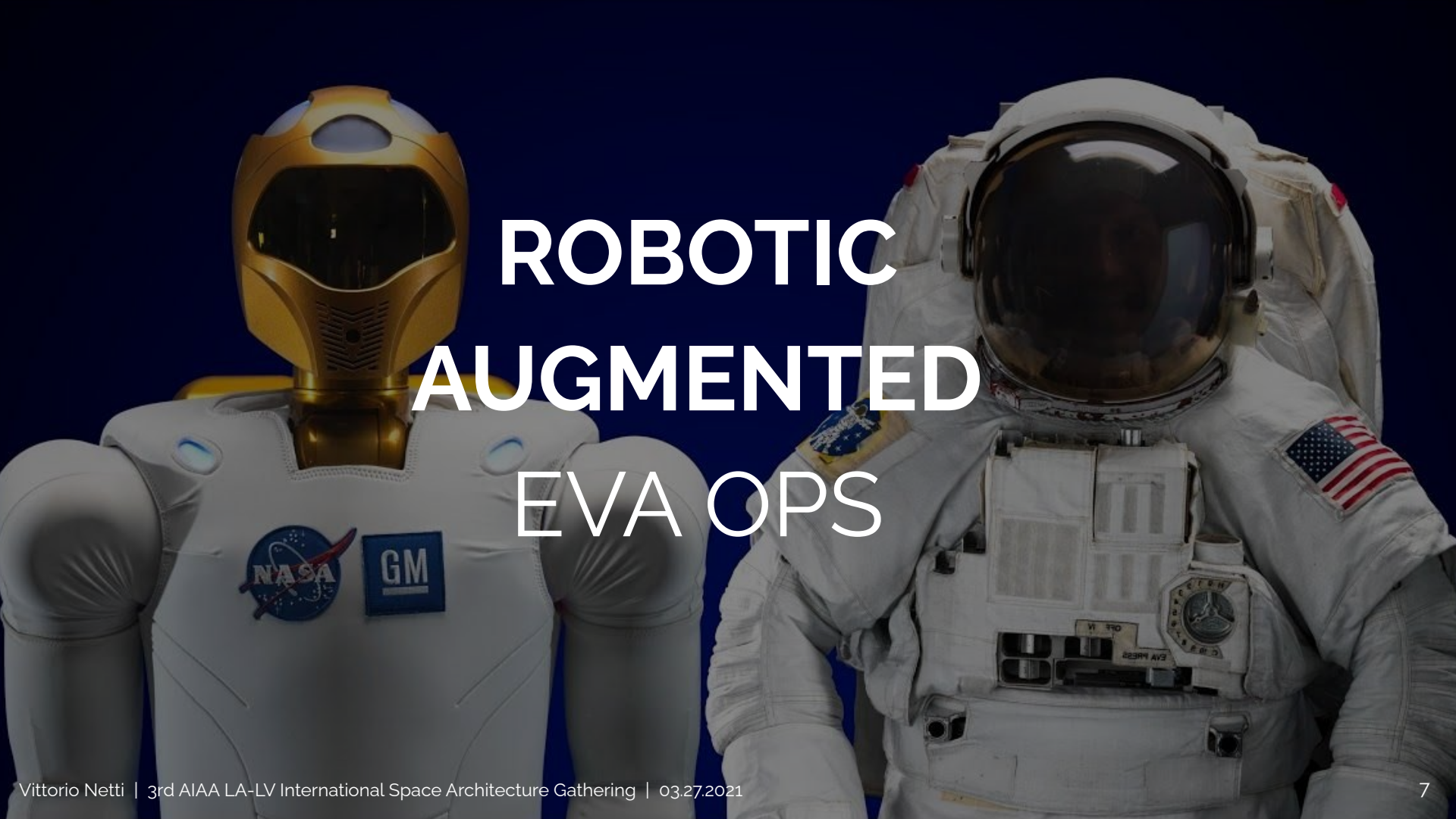
Source: J.B Garvin 2005



ROBOT	SKILL	HUMANS
28%	STRENGHT	72%
15%	ENDURANCE	85%
90%	PRECISION	10%
2%	COGNITION	98%
6%	PERCEPTION	94%
84%	DETECTION	16%
21%	SPEED	79%
17%	RESPONSE TIME	83%
34%	REALIBILITY	66%
14%	AGILITY	86%
9%	VERSATILITY	91%
78%	EXPENDABILITY	22%

VISION

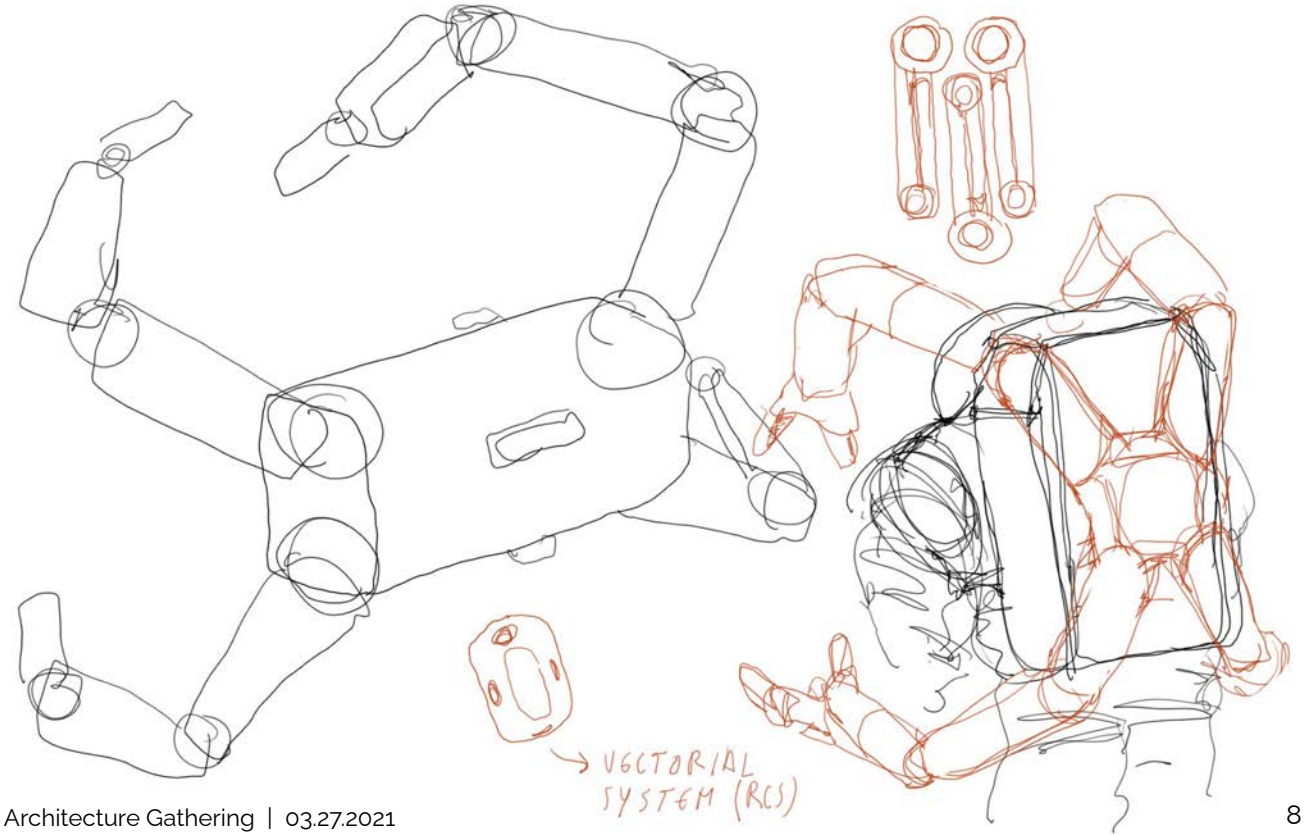




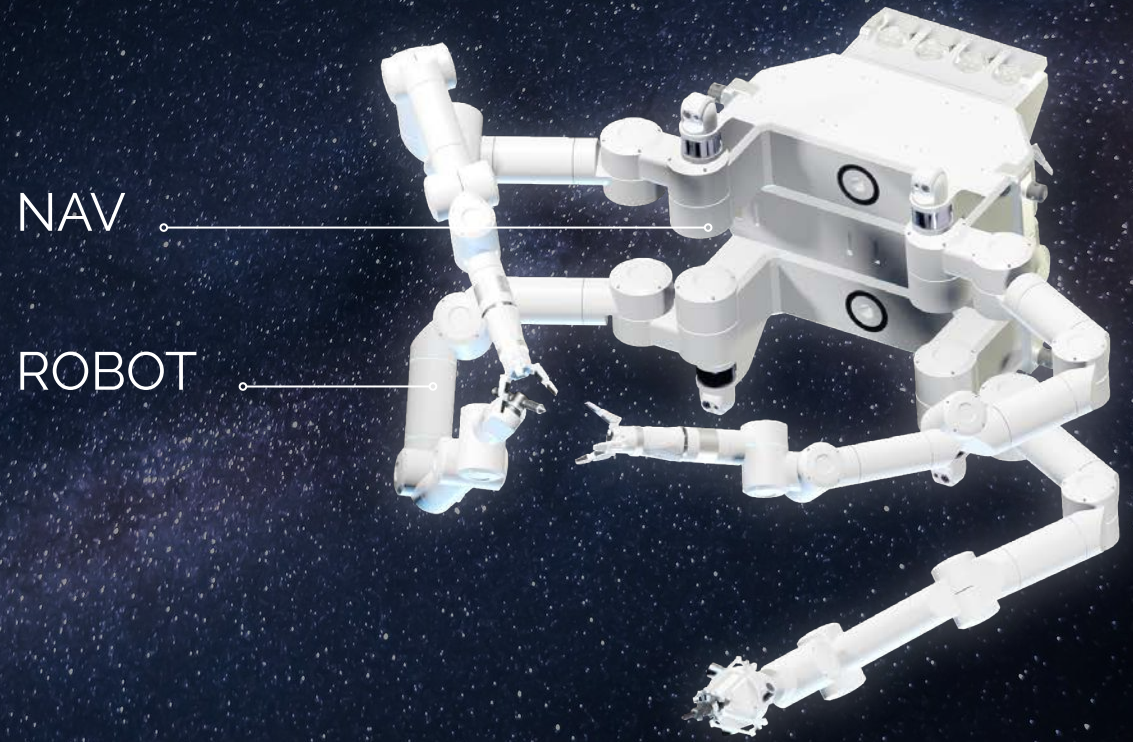
ROBOTIC AUGMENTED EVA OPS

MMEVR

MULTI-MISSION
EXTRA-VEHICULAR
ROBOT



MMEVR | AUTONOMOUS



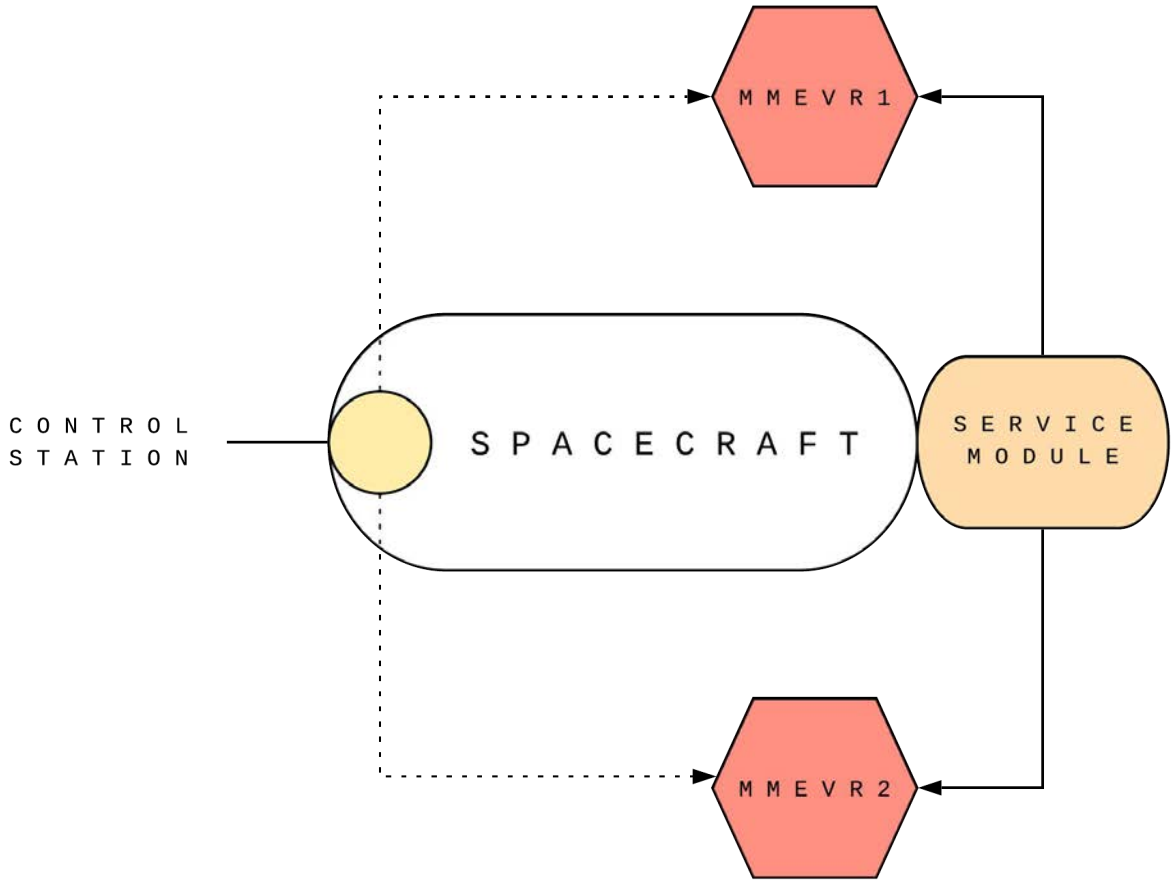
MMEVR | COOPERATIVE

MMU

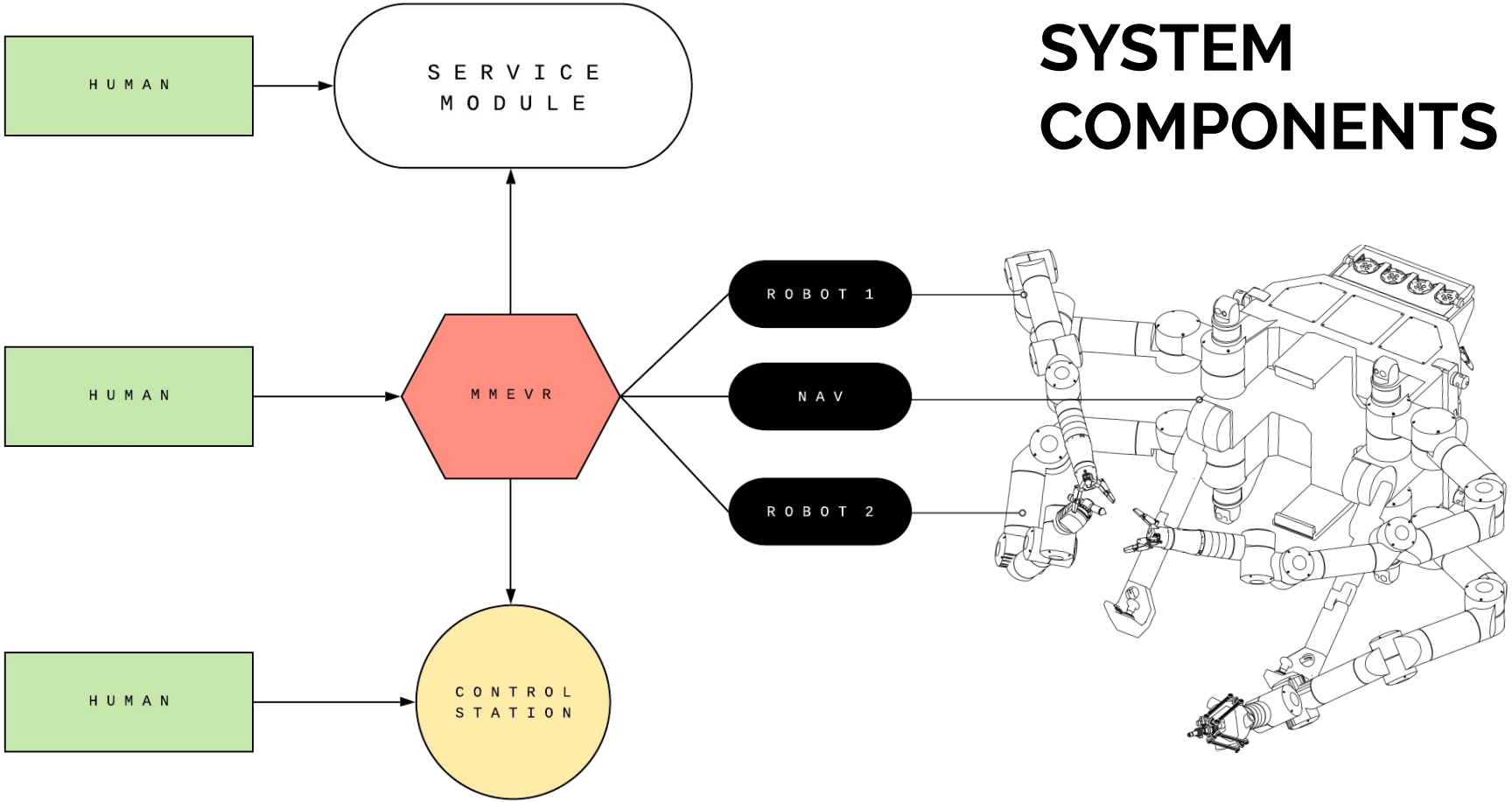
MANNED
MANEUVERING
UNIT

SMM Retrieval, 1984

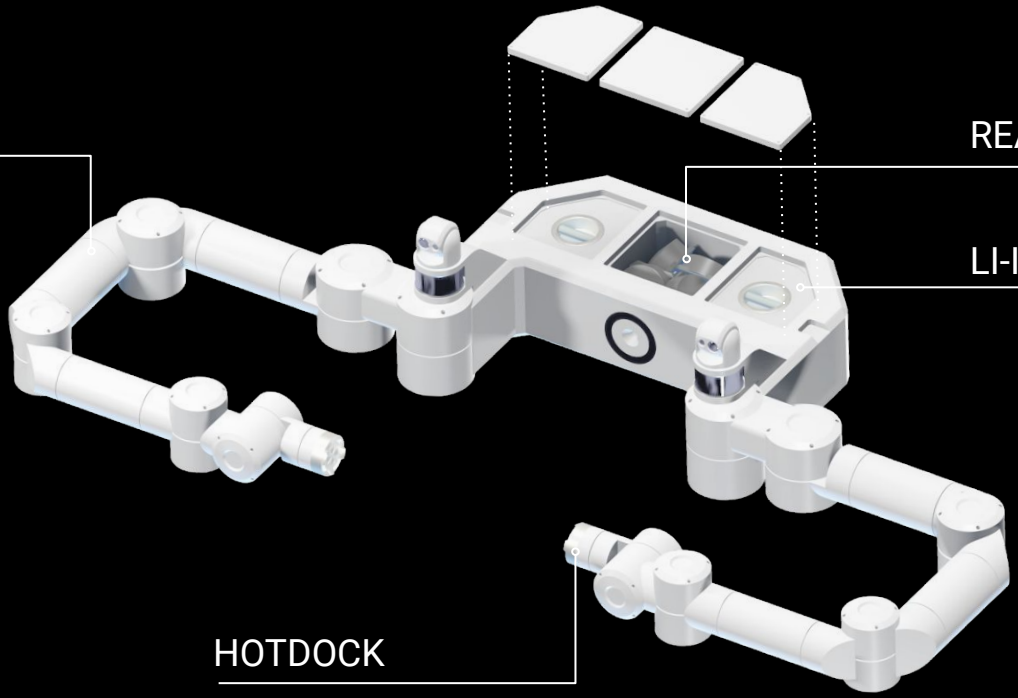
SYSTEM ARCHITECTURE



SYSTEM COMPONENTS



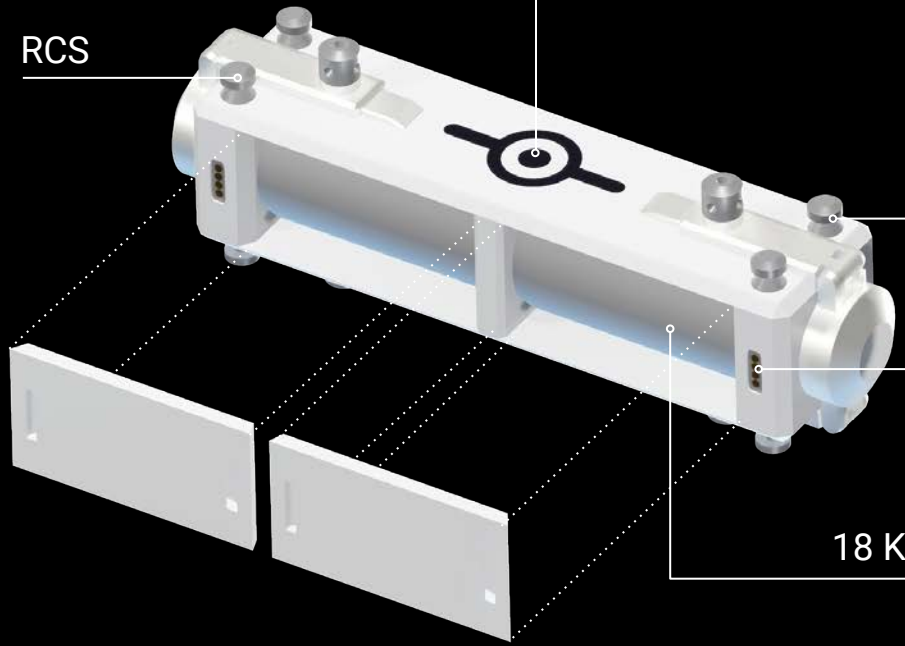
MMEVR | ROBOT



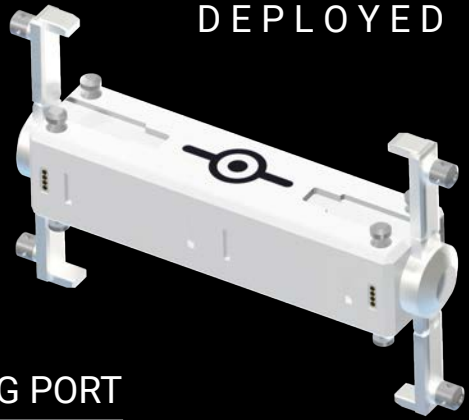
DRY MASS
80 KG

MMEVR | NAV

STOWED

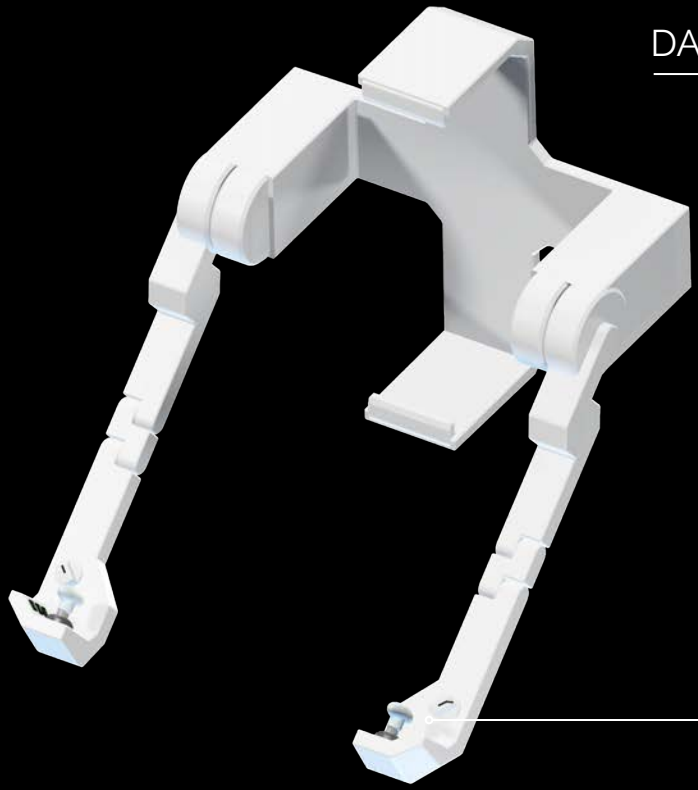


DEPLOYED

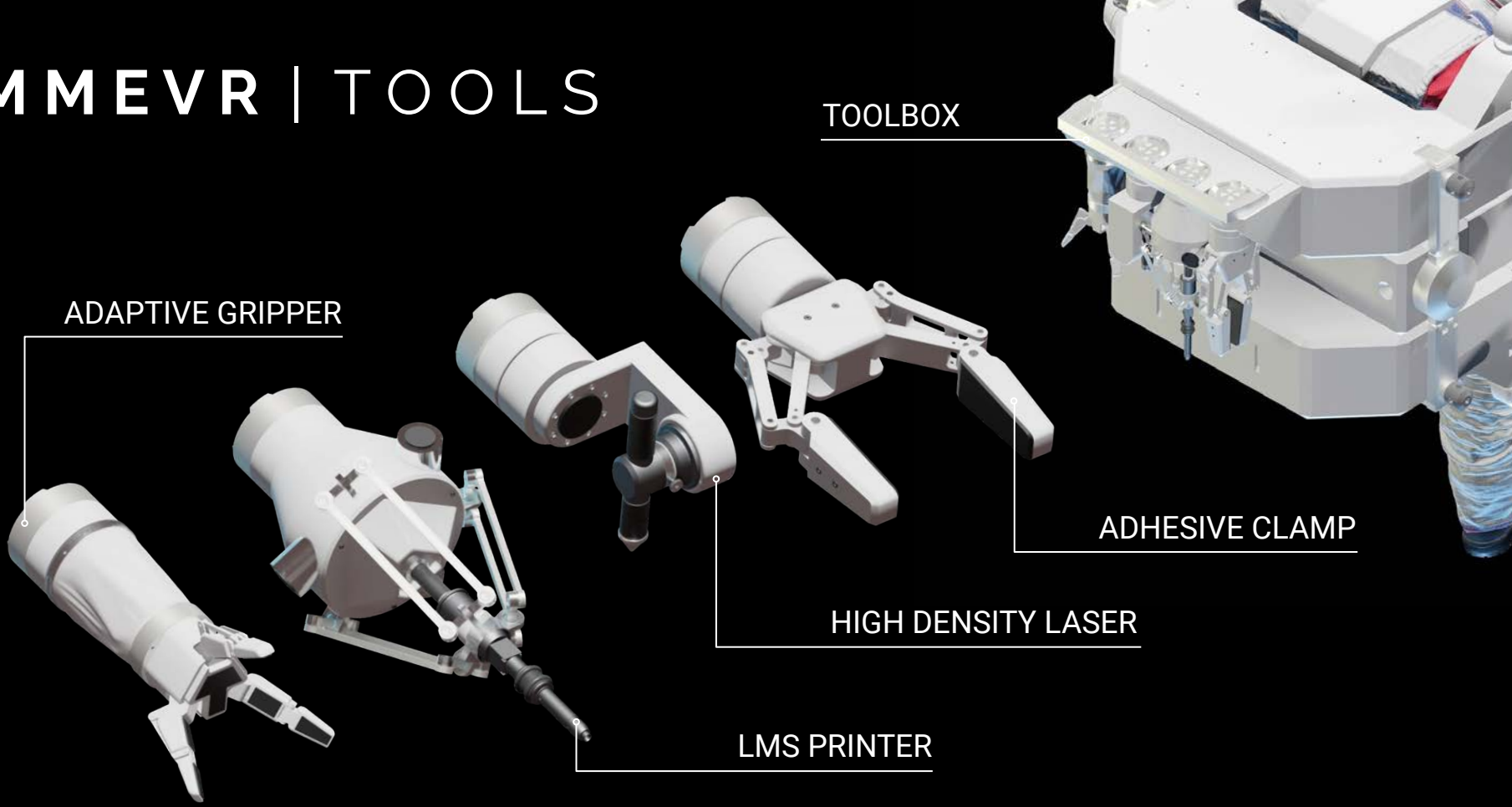


DRY MASS
25 KG

MMEVR | HARNESS



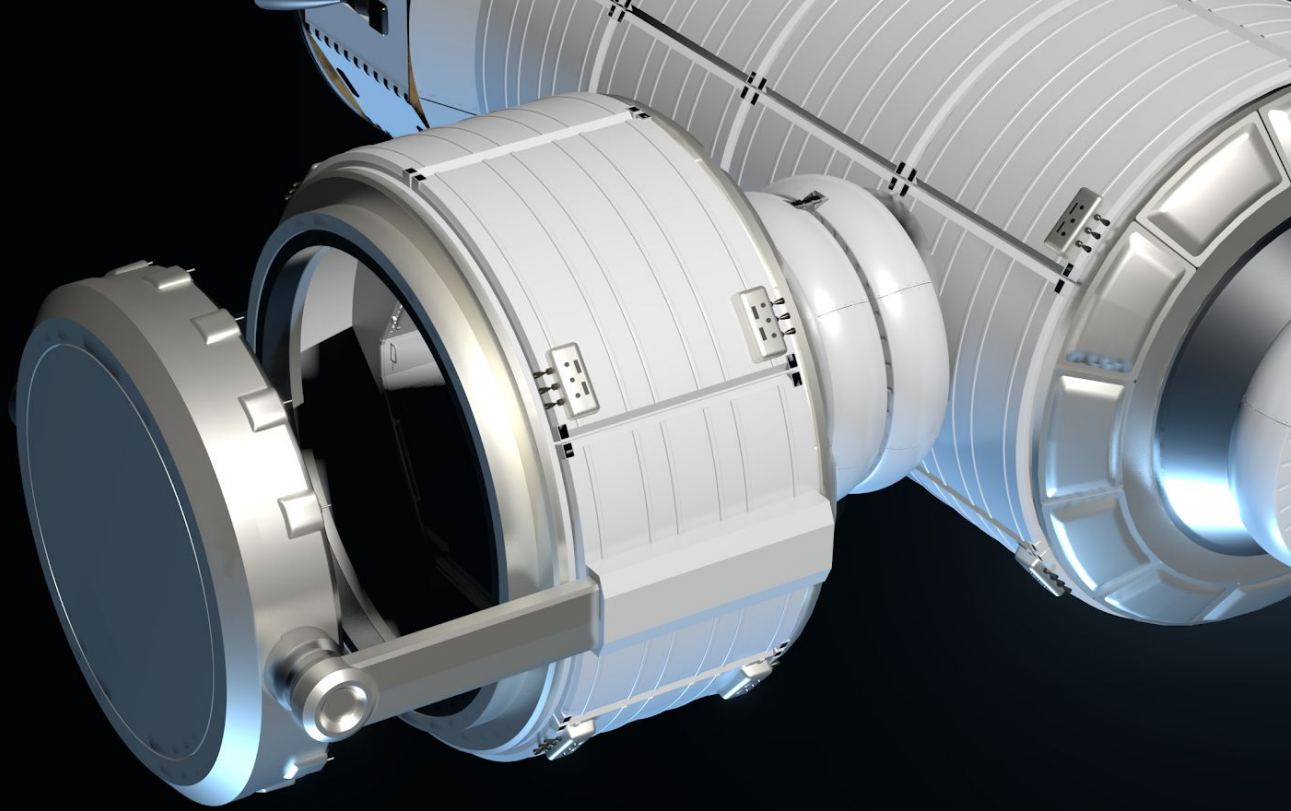
MMEVR | TOOLS


TOOLBOX
ADAPTIVE GRIPPER
ADHESIVE CLAMP
HIGH DENSITY LASER
LMS PRINTER

SERVICE MODULE

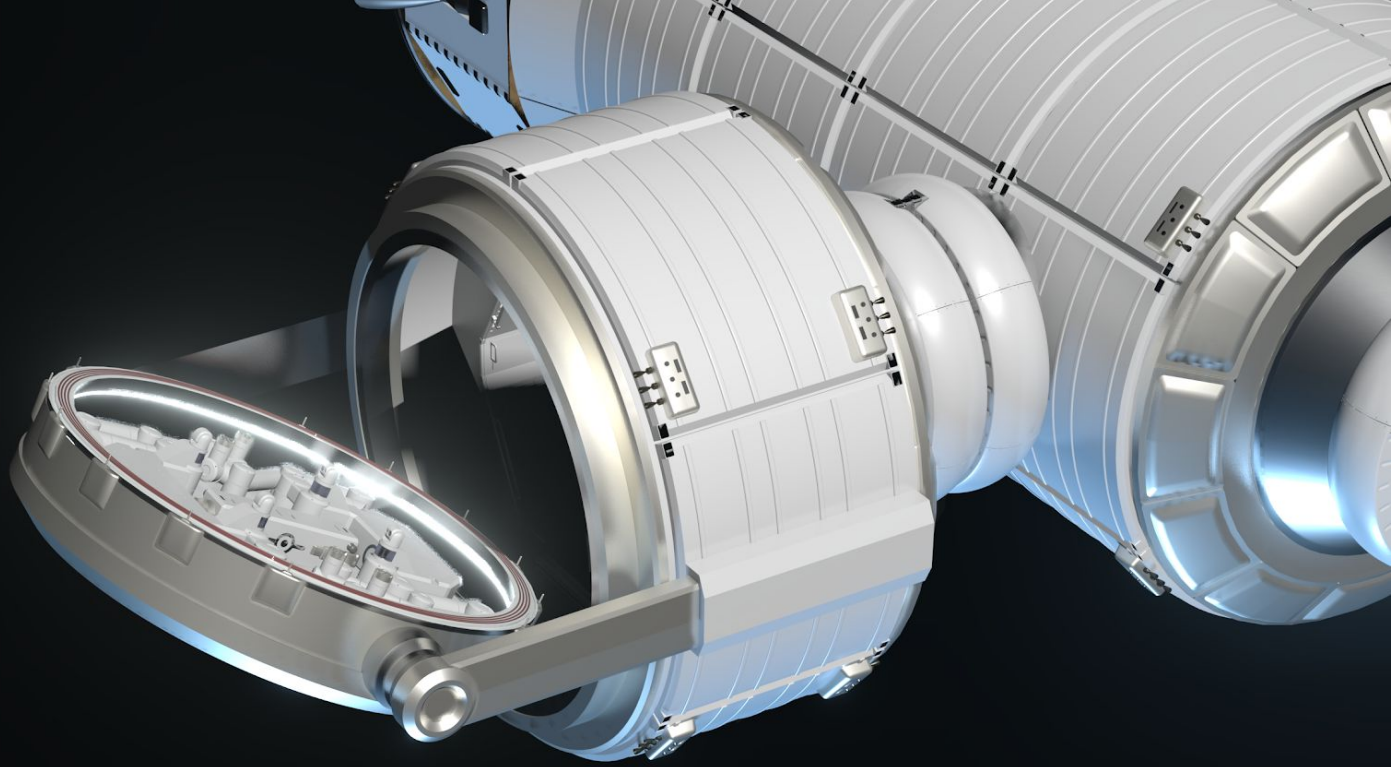
SPACEX DRAGON XL

SERVICE MODULE



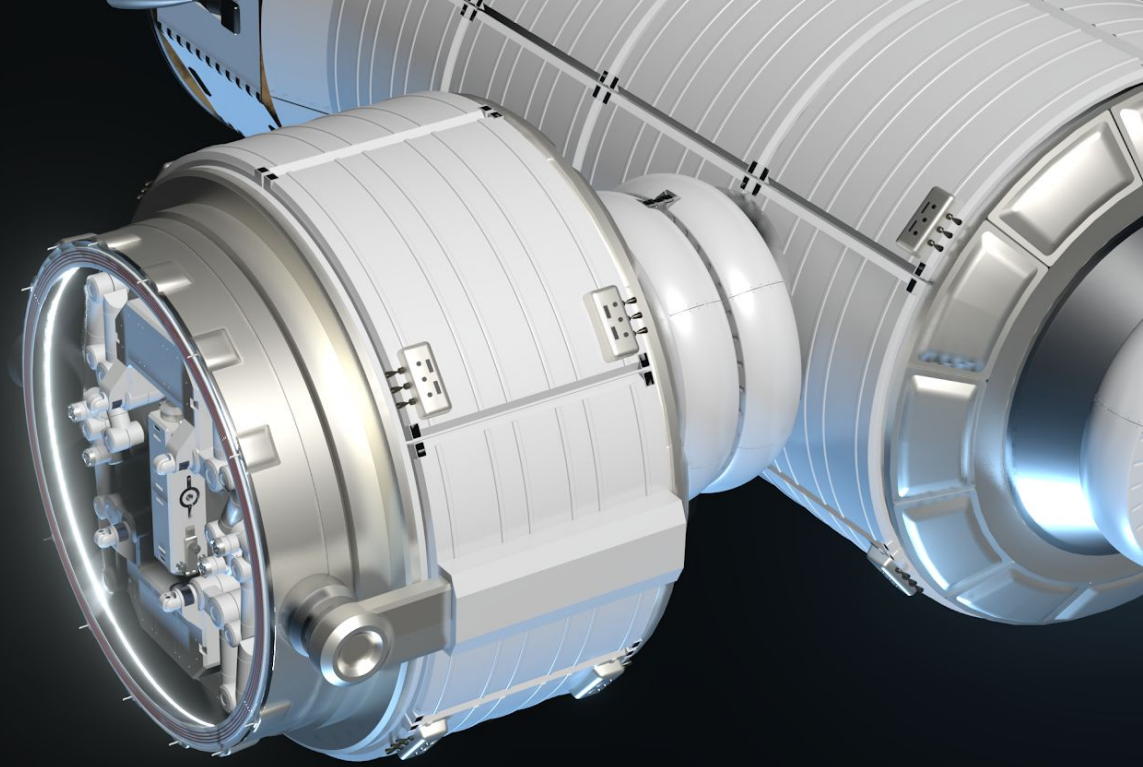
DRY MASS:
4700 Kg

SERVICE MODULE

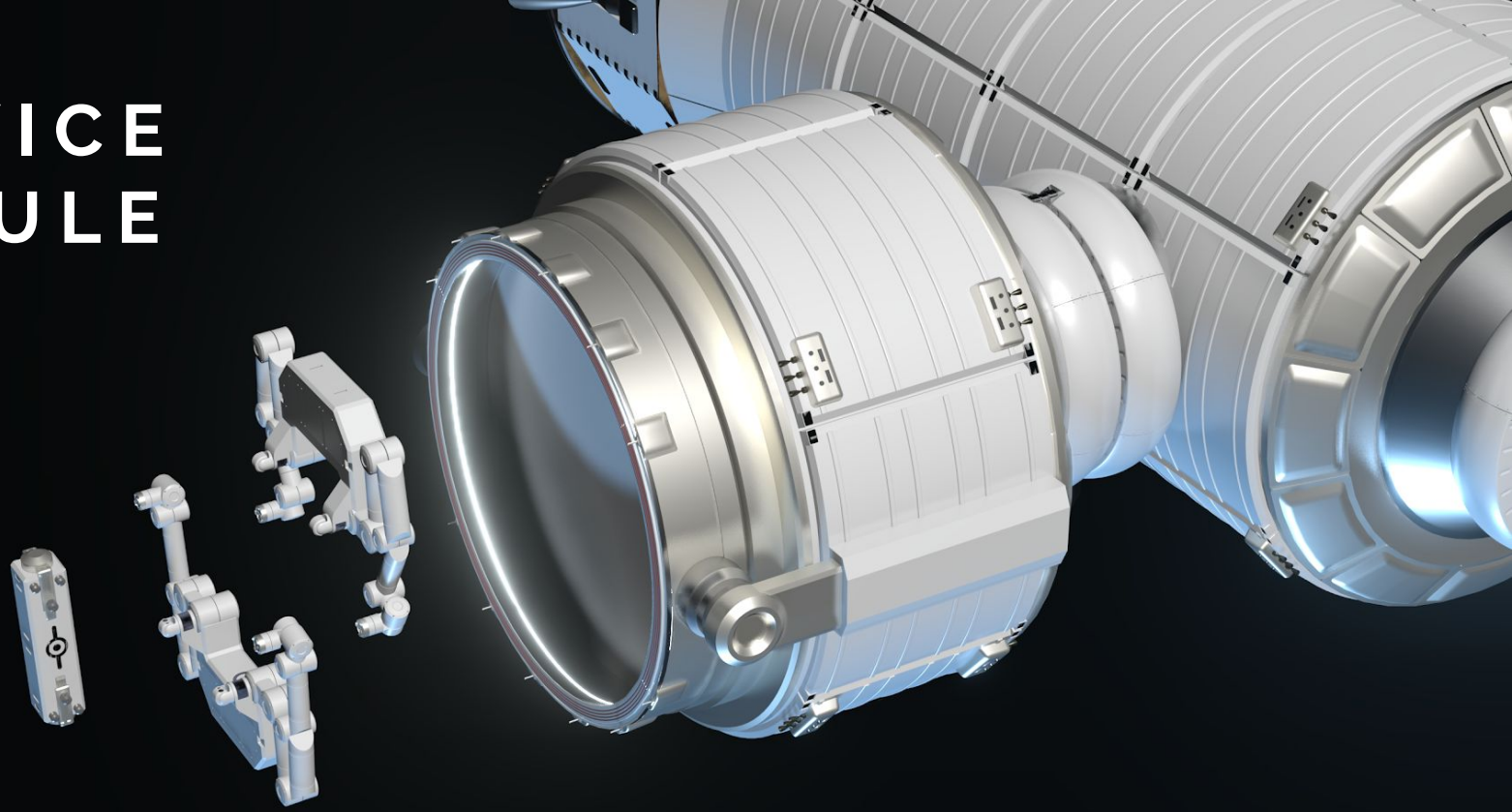


SERVICE MODULE

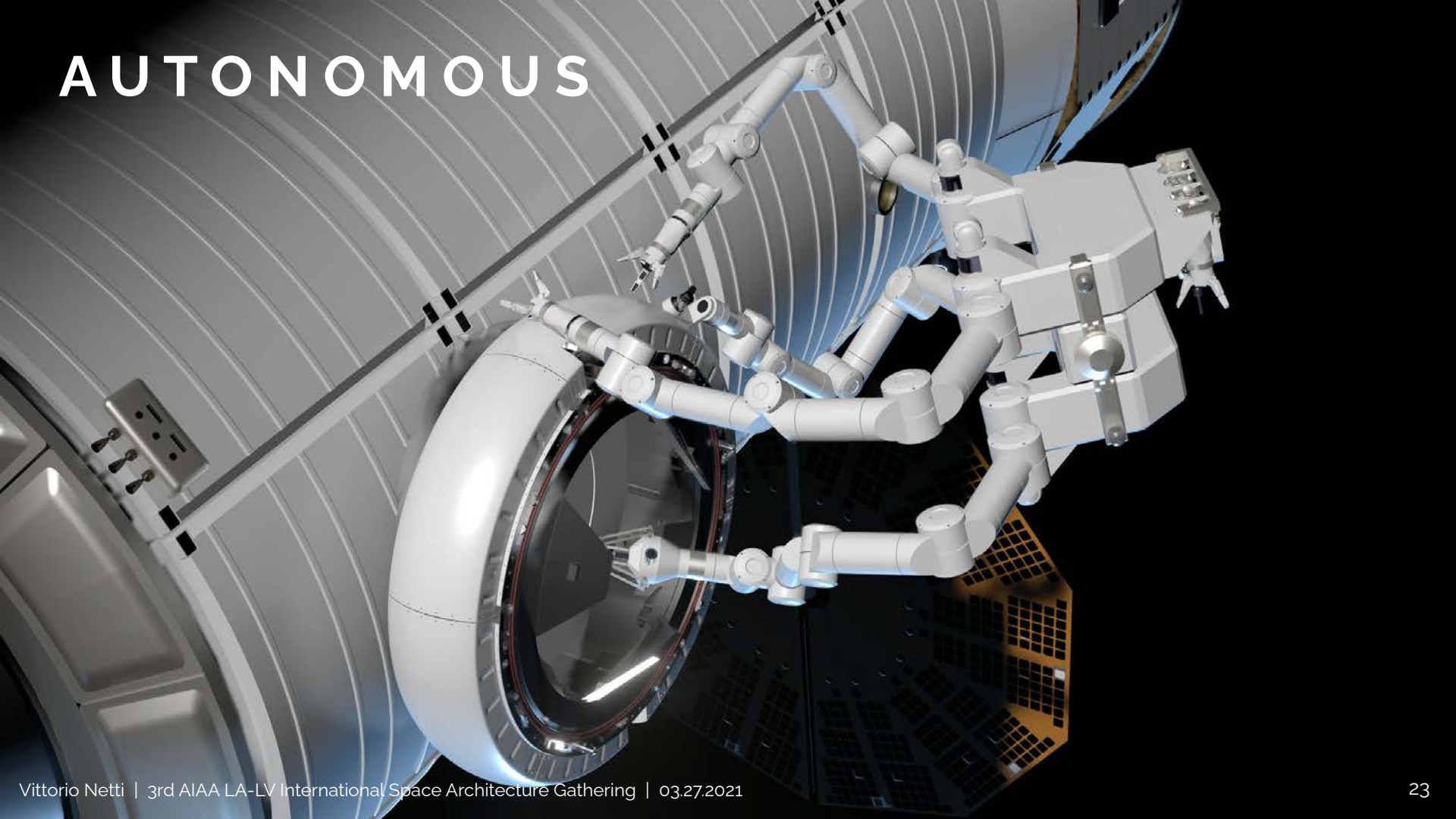
Multipurpose
Payload Airlock



SERVICE MODULE

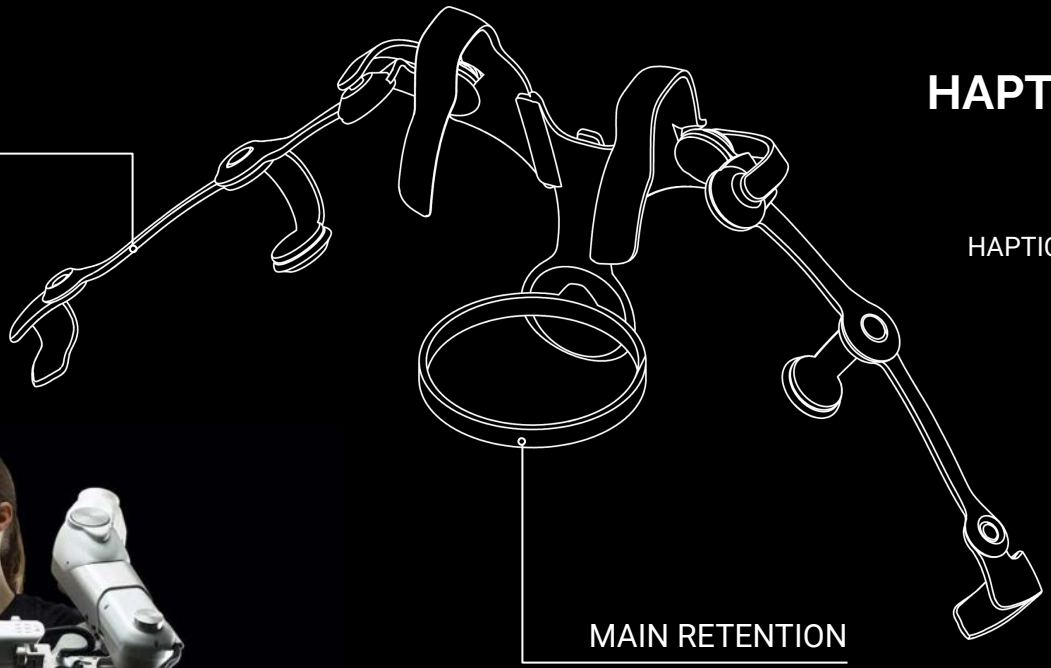


AUTONOMOUS



AUGMENTED

CONTROL STATION



HAPTIC EXOSKELETON

HAPTIC FEEDBACK FOR INTERACTION <

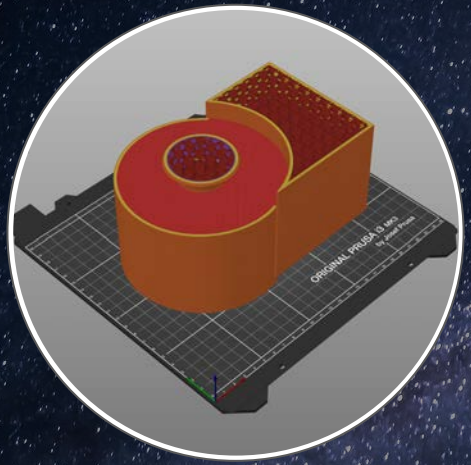
MIXED REALITY HEADSET <

UPPER BODY CONTROL <

SAFETY TRIGGER <

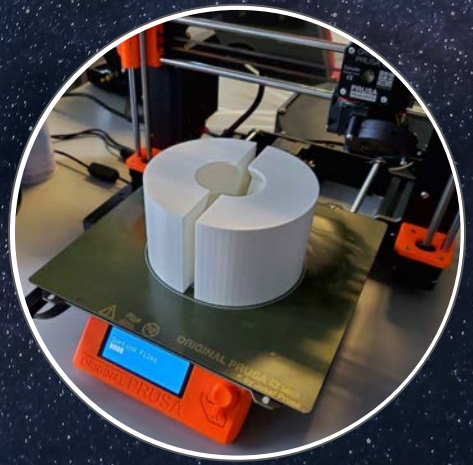
5 DoF LIMBS <

PROTOTYPE | PROCESS



1 | MODELLING

INVENTOR | PRUSA SLICER



2 | PRODUCTION

3D PRINTING | LASER CUT

3 | TESTING

ASSEMBLY | INTERACTION

PROTOTYPE | DESIGN

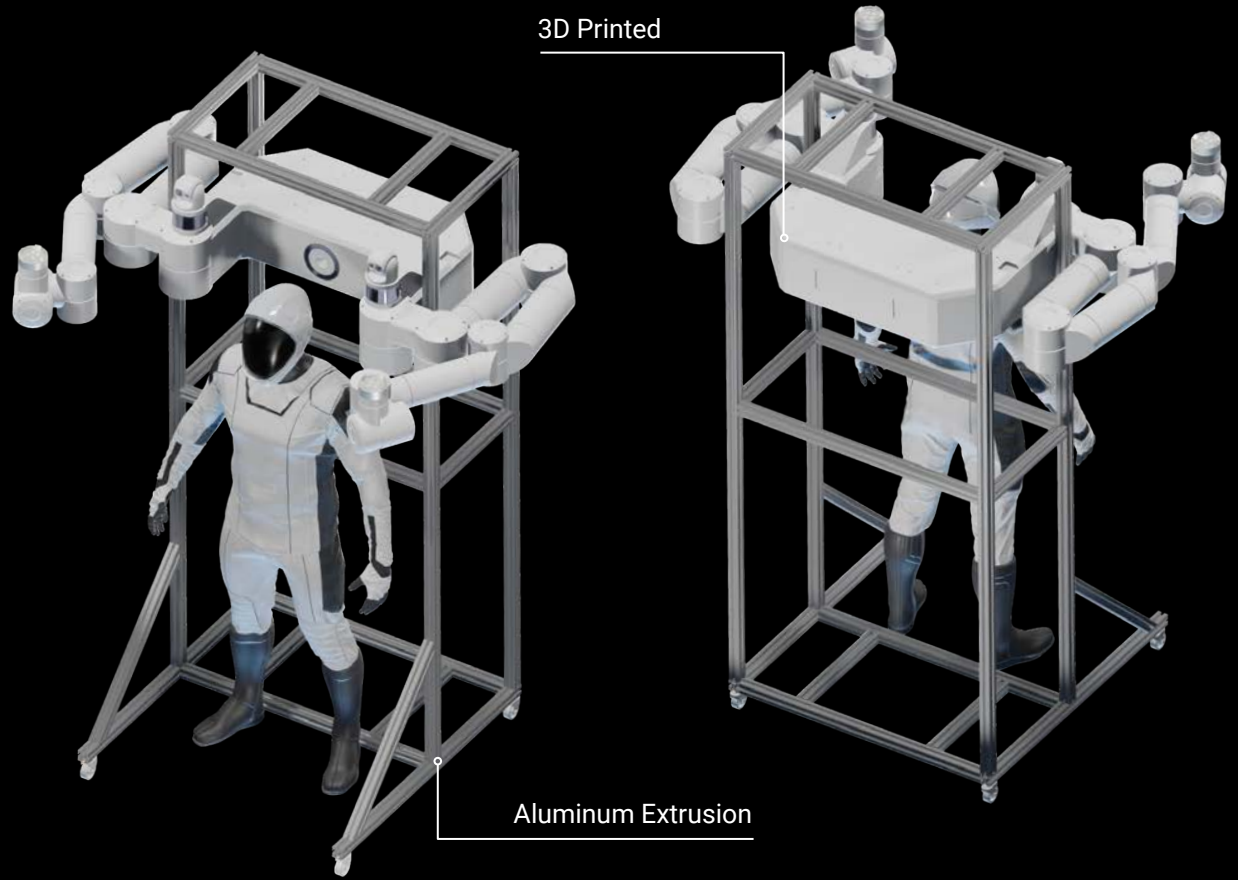
> 1:1 SCALE

> ACQUISITION SYSTEM

> 10 DoF

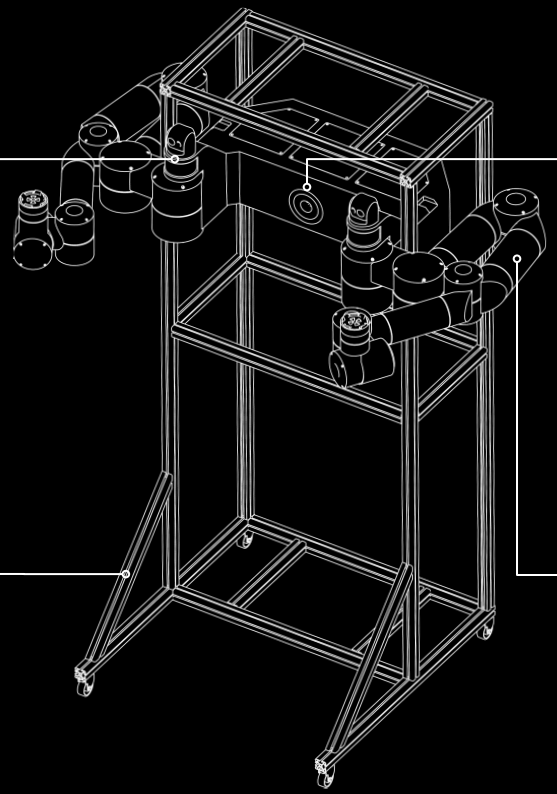
> FIT 99th PERCENTILE

> BUDGET 5000$



PROTOTYPE | PRODUCTION

VISION

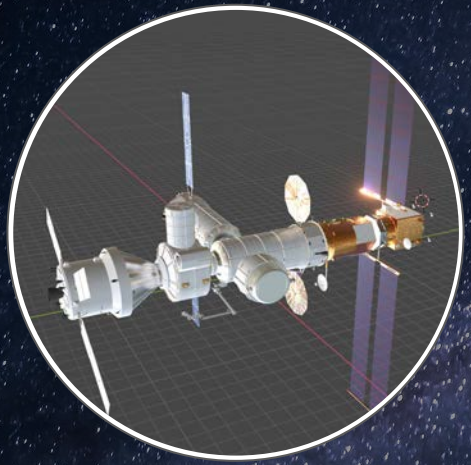


BODY

STAND

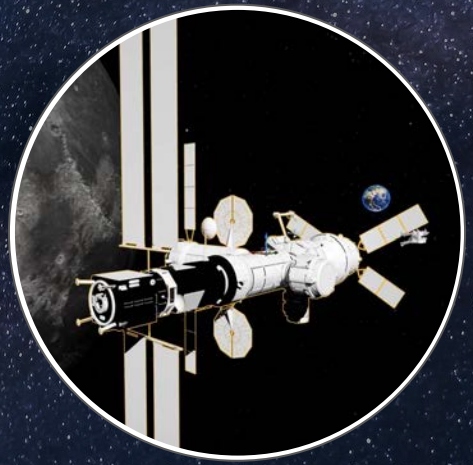
LIMBS

SIMULATION | PROCESS



1 | MODELLING

BLENDER



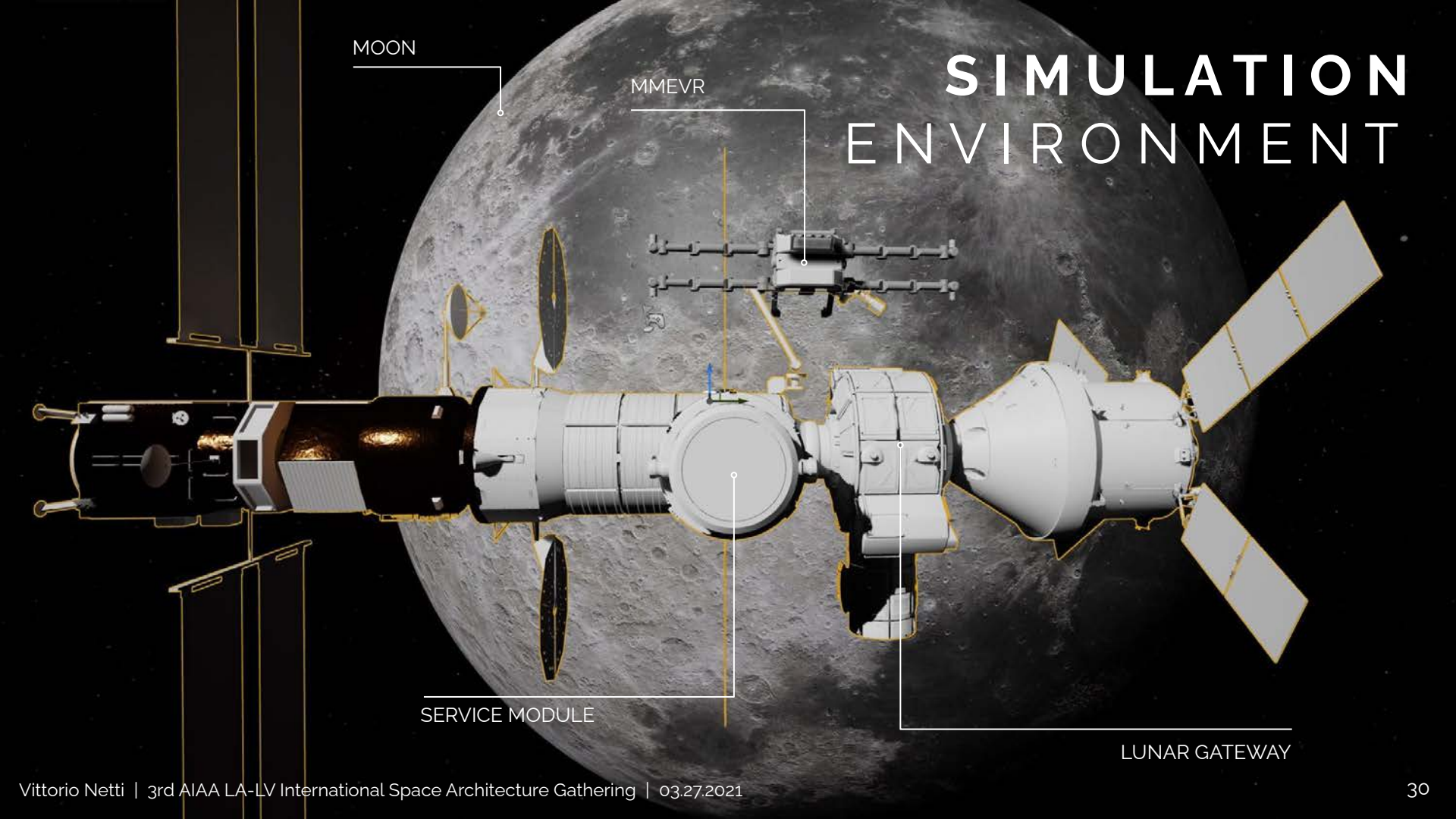
2 | PRODUCTION

UNREAL ENGINE

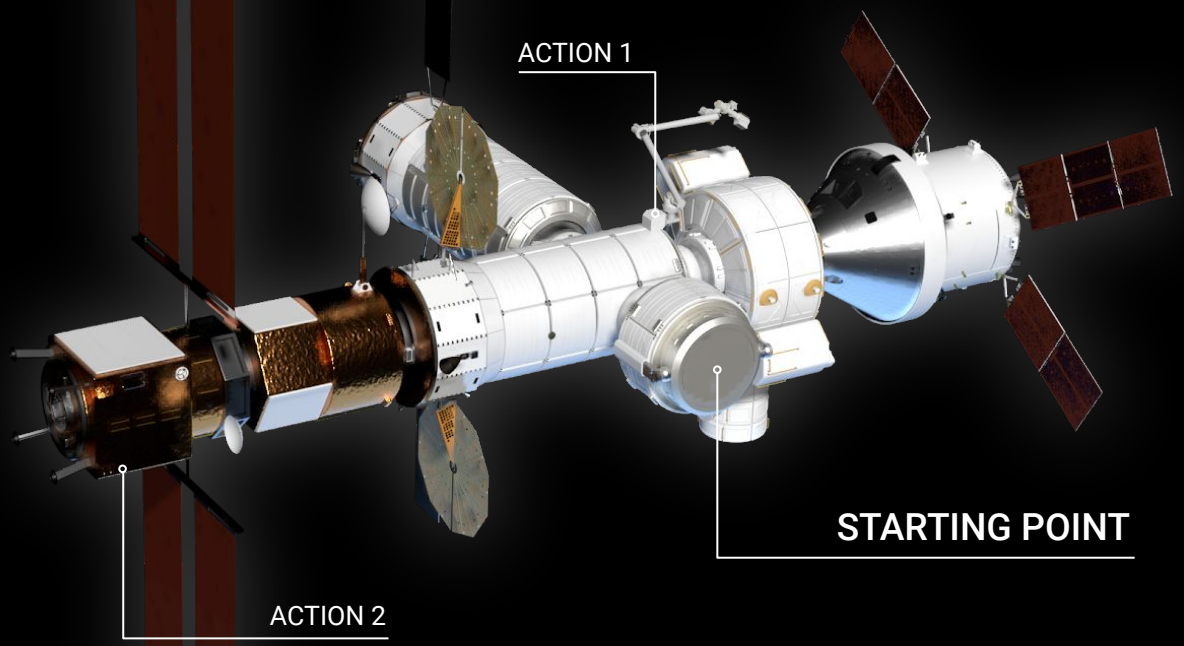
3 | TESTING

HTC COSMOS

SIMULATION ENVIRONMENT



SIMULATION | DESIGN



SIMULATION OVERVIEW

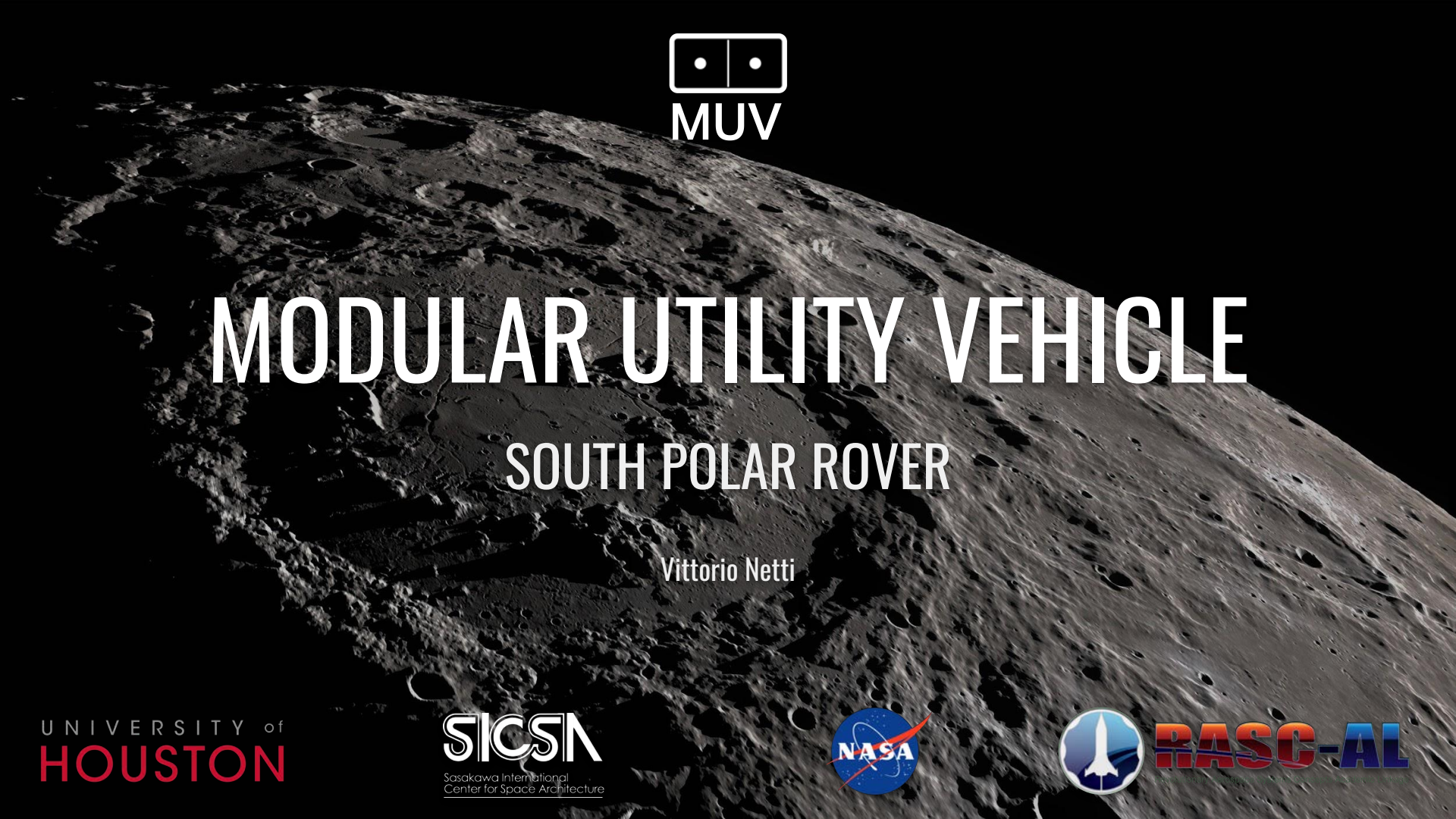
2 AVAILABLE MISSIONS <

TELEOPERATED | AUGMENTED MODE <

6 DIFFERENT TASKS FOR MISSION <

COMPATIBLE WITH DIFFERENT HEADSET <

VECTORIAL MOVEMENT (RCS) <


MUV
MODULAR UTILITY VEHICLE
SOUTH POLAR ROVER
Vittorio Netti
UNIVERSITY of HOUSTON
SICSA
Sasakawa International Center for Space Architecture
NASA
RASC-AL

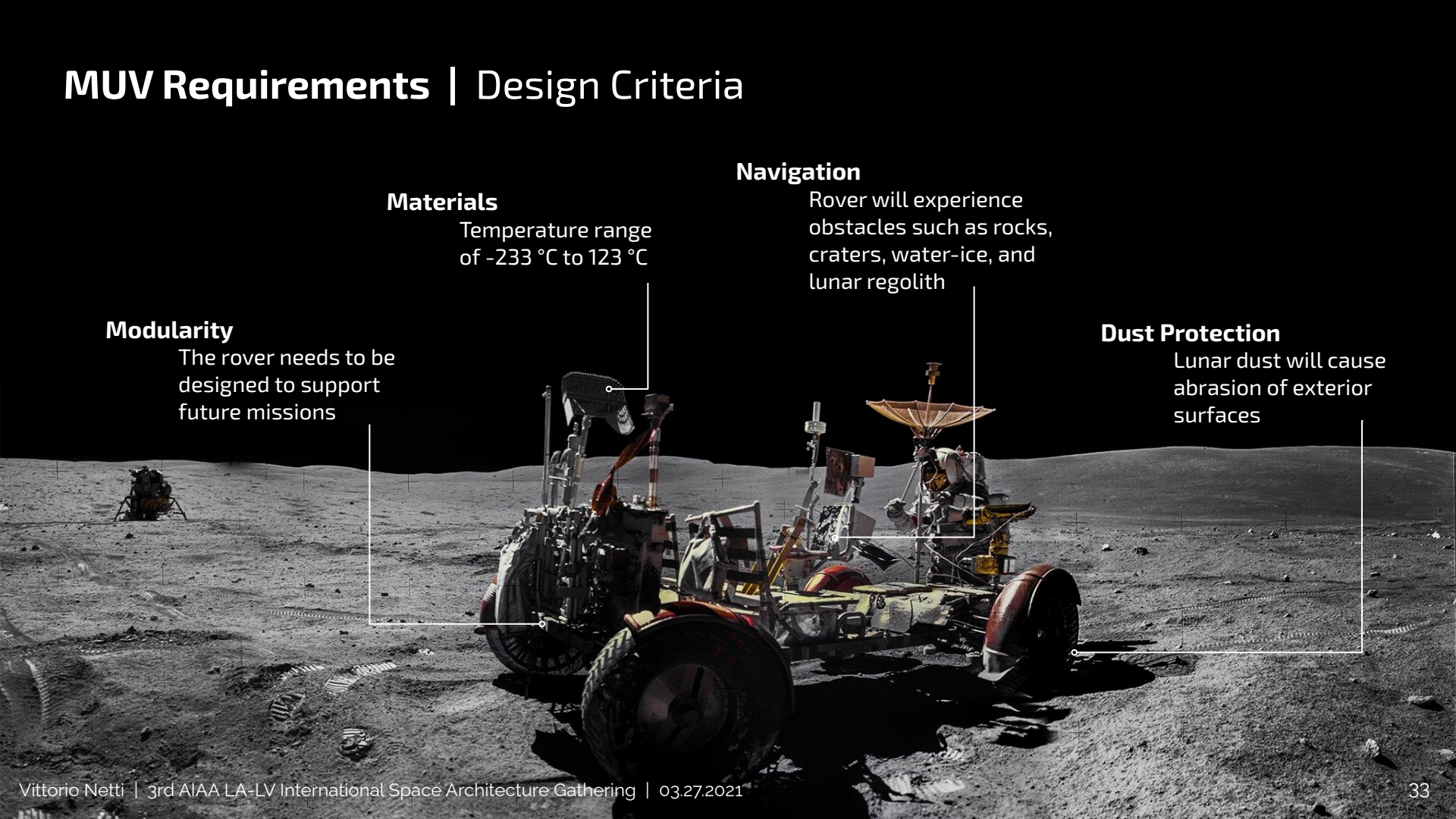
MUV Requirements | Design Criteria

Navigation
Rover will experience obstacles such as rocks, craters, water-ice, and lunar regolith

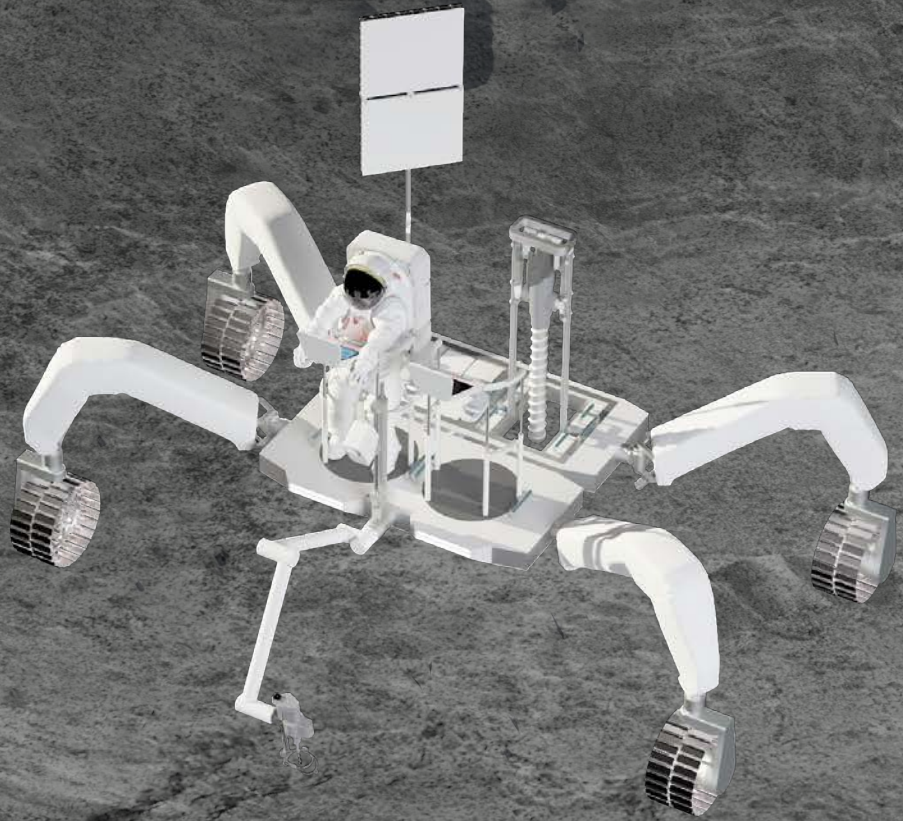
Materials
Temperature range of -233 °C to 123 °C

Modularity
The rover needs to be designed to support future missions

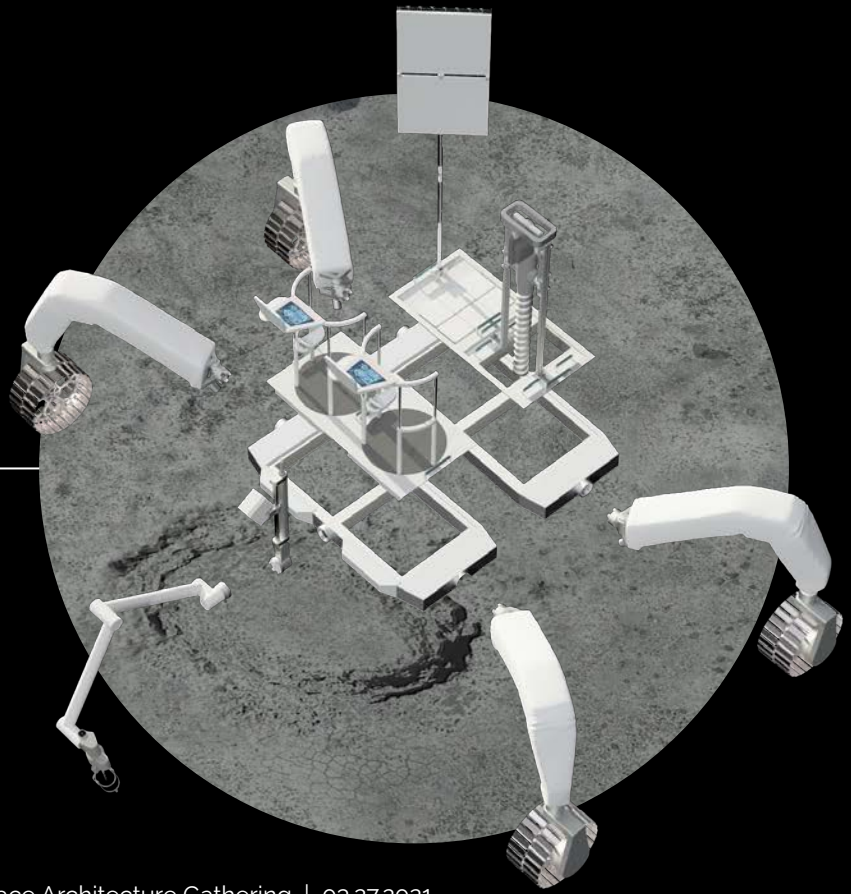
Dust Protection
Lunar dust will cause abrasion of exterior surfaces



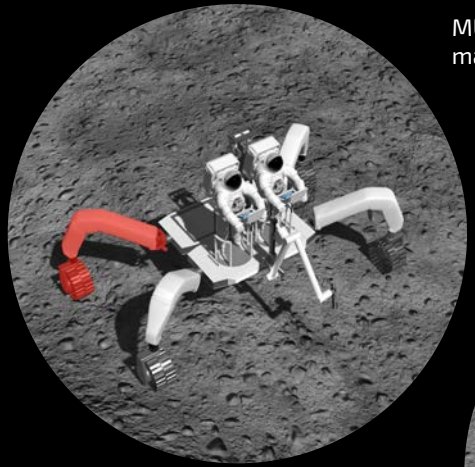
Design Concept | Modular Utility Vehicle



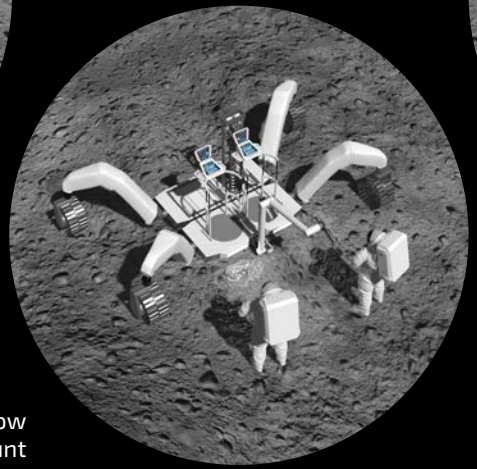
Design Concept | Modularity



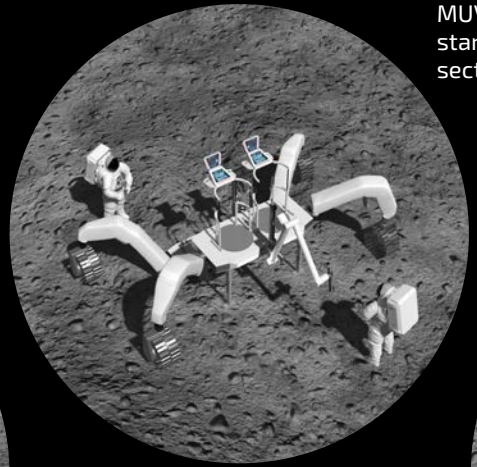
Design Concept | Field Stripping



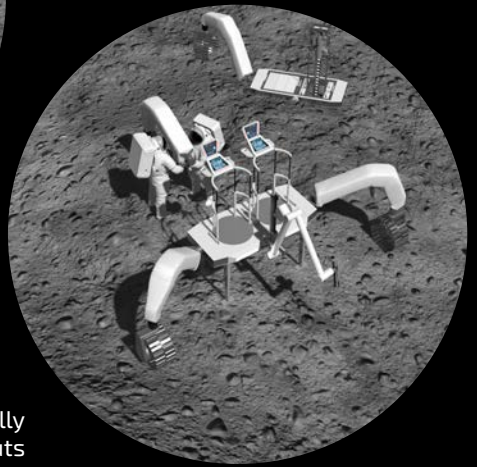
MUV Software recognize a malfunctioning module



MUV is lowered to allow astronauts to dismount

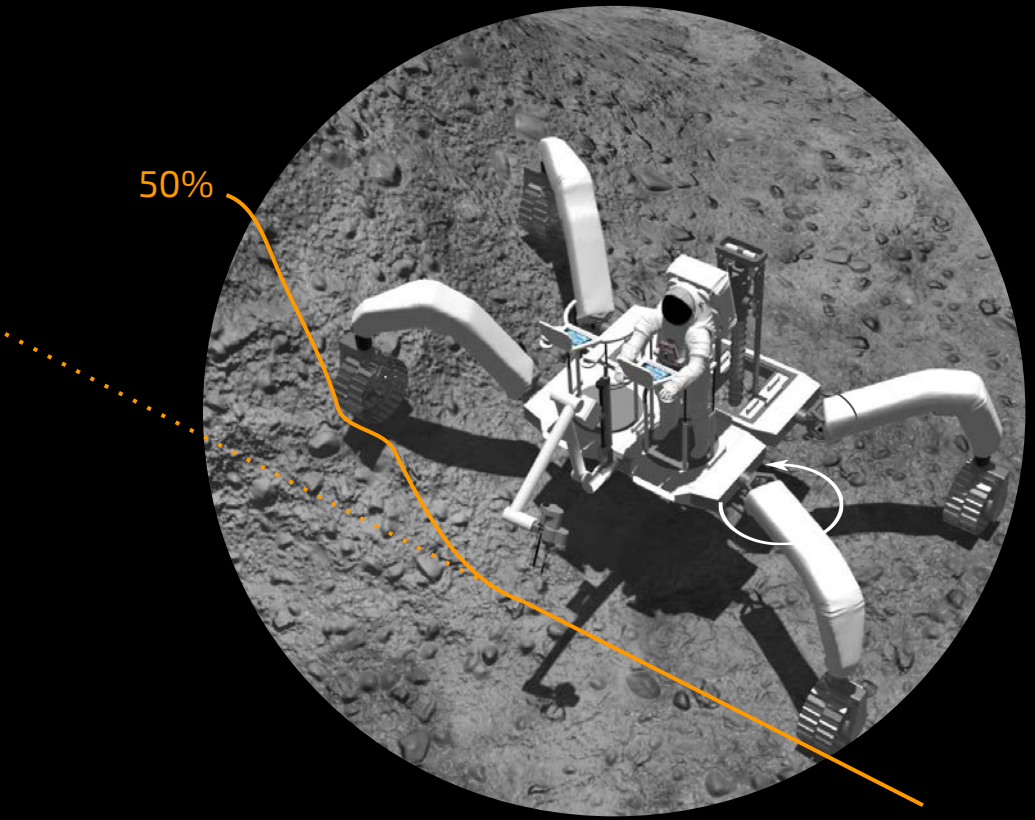


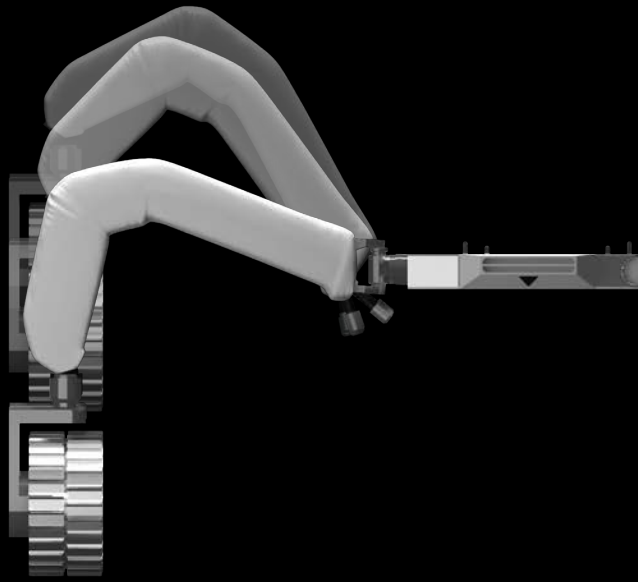
MUV is lifted on its deployable stands and the malfunctioning section is abandoned.



MUV is reconfigured manually by the astronauts

Design Concept | Attitude Control



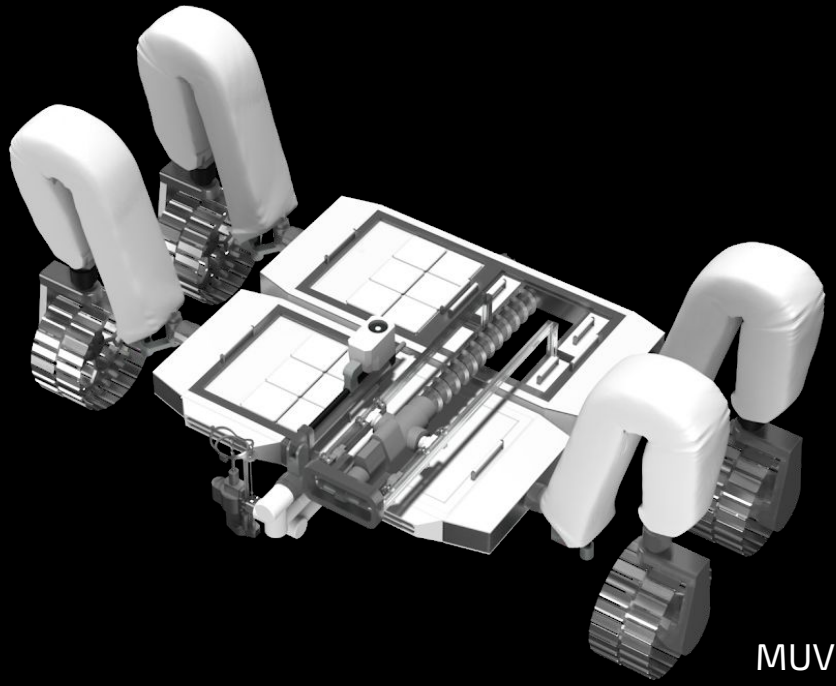


45° Max Gradient

Operations Concept | Initial Deployment

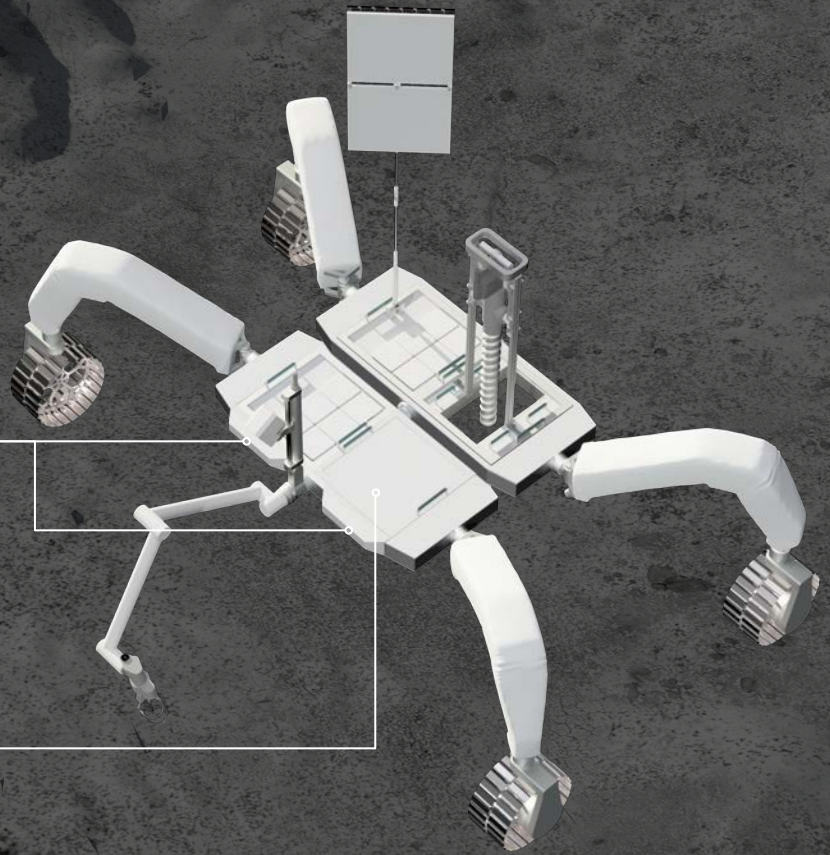
VIPER Lander

Blue Moon Lander

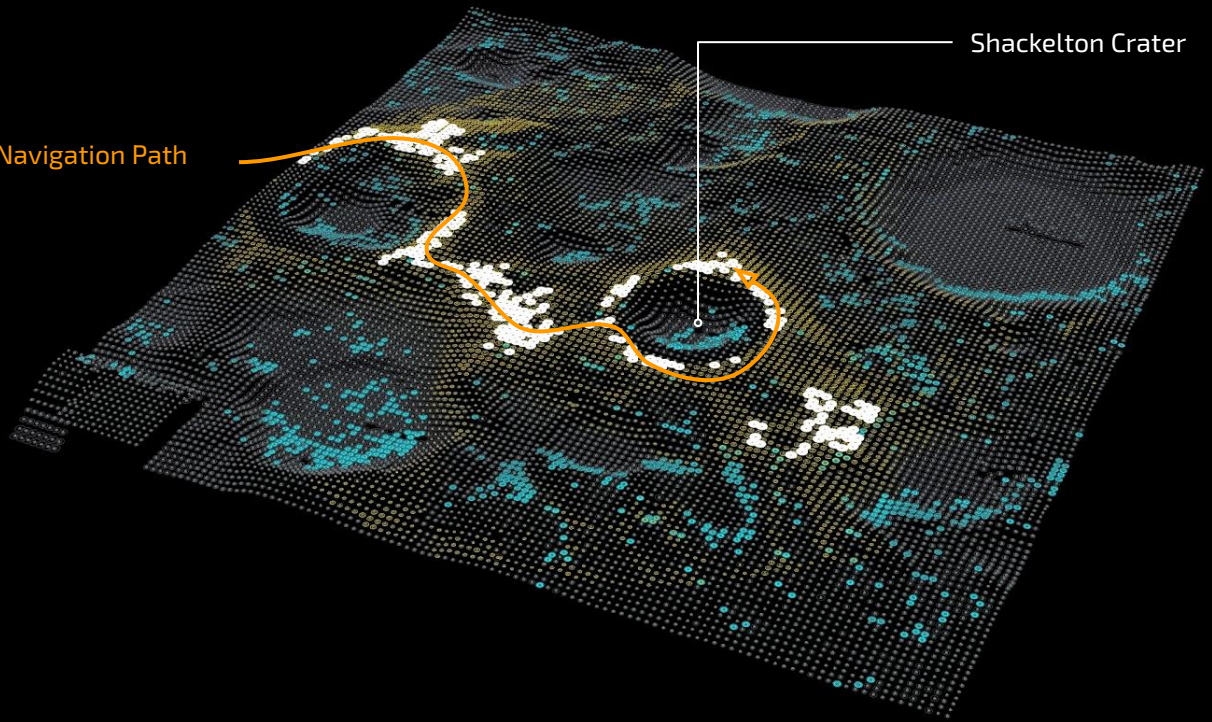


MUV Rover in
stowed configuration

Operations Concept | Autonomous Operations



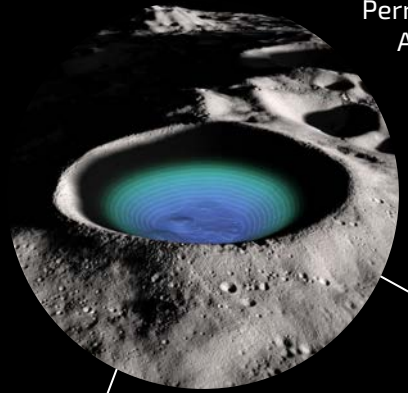
Operations Concept | Autonomous Navigation



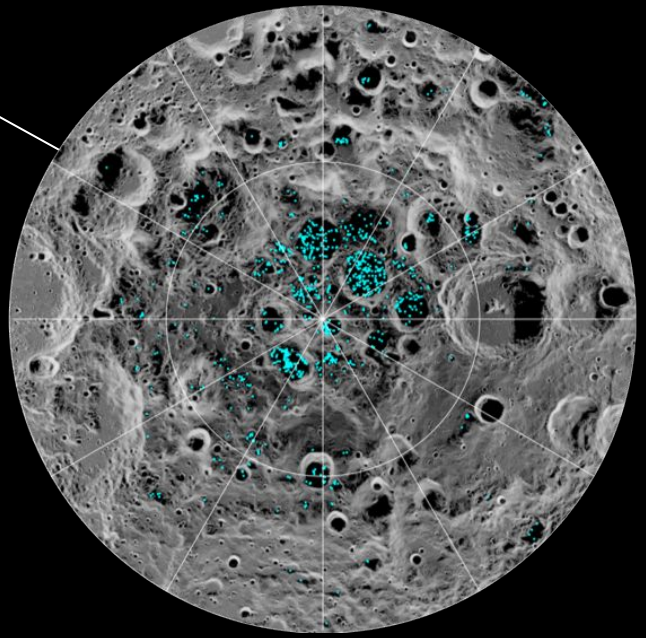
LRO Illuminance map of the Lunar South Pole

Operations Concept | Autonomous Science

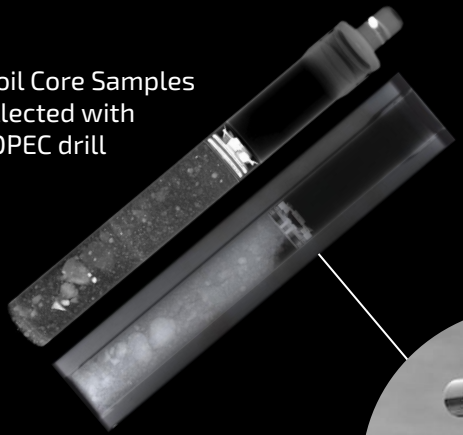
Permanent Shadowed Area of the Shackleton crater

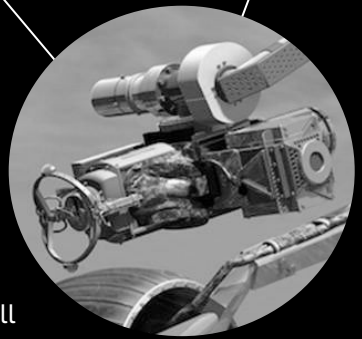


Water-Ice mapping of the Lunar South Pole



Soil Core Samples Collected with the ROPEC drill

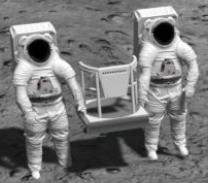


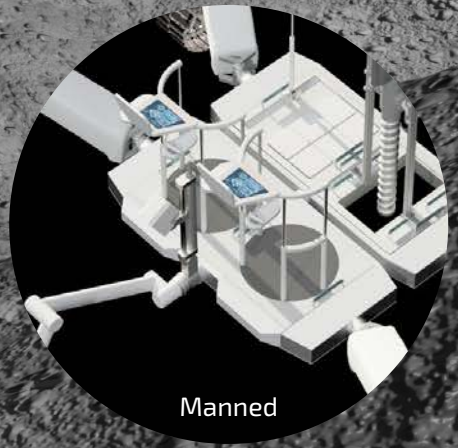


ROPEC drill

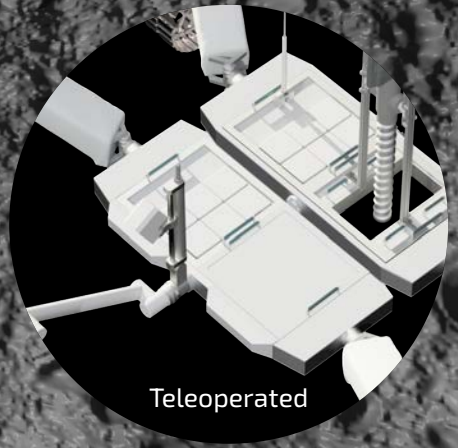
Operations Concept | Mode Switch

As soon as they land, astronauts will reconfigure MUV as manned transport



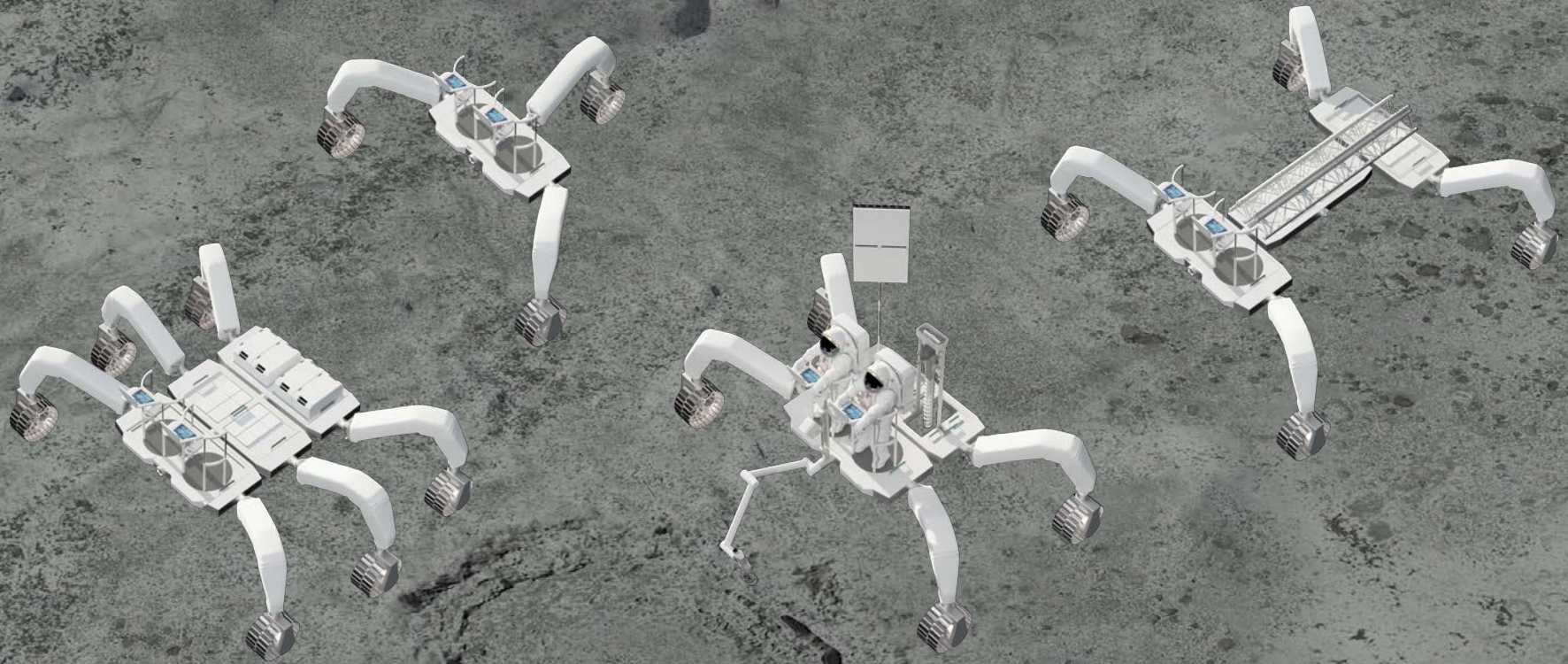


Manned

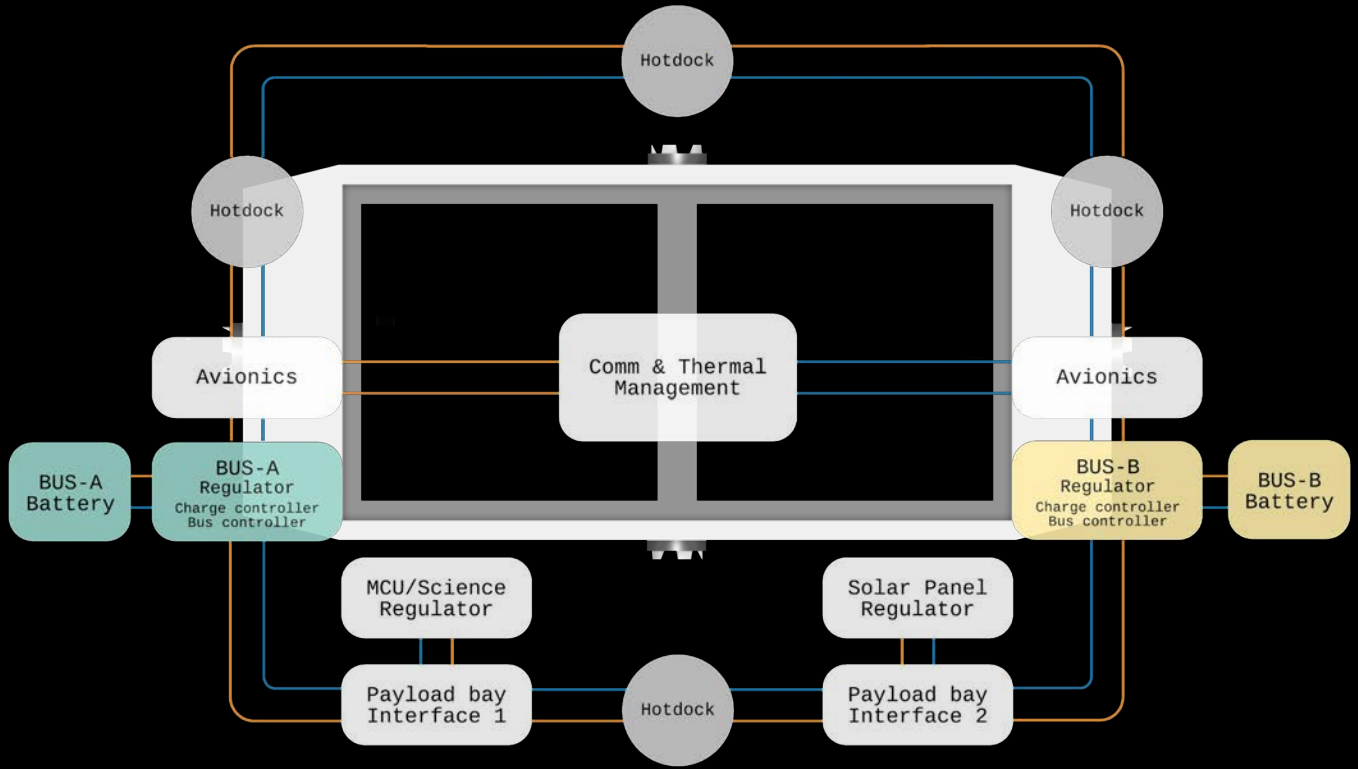


Teleoperated

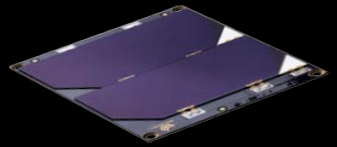
Extended Operations | Designed for Flexibility



Vehicle Specifications | Power Management

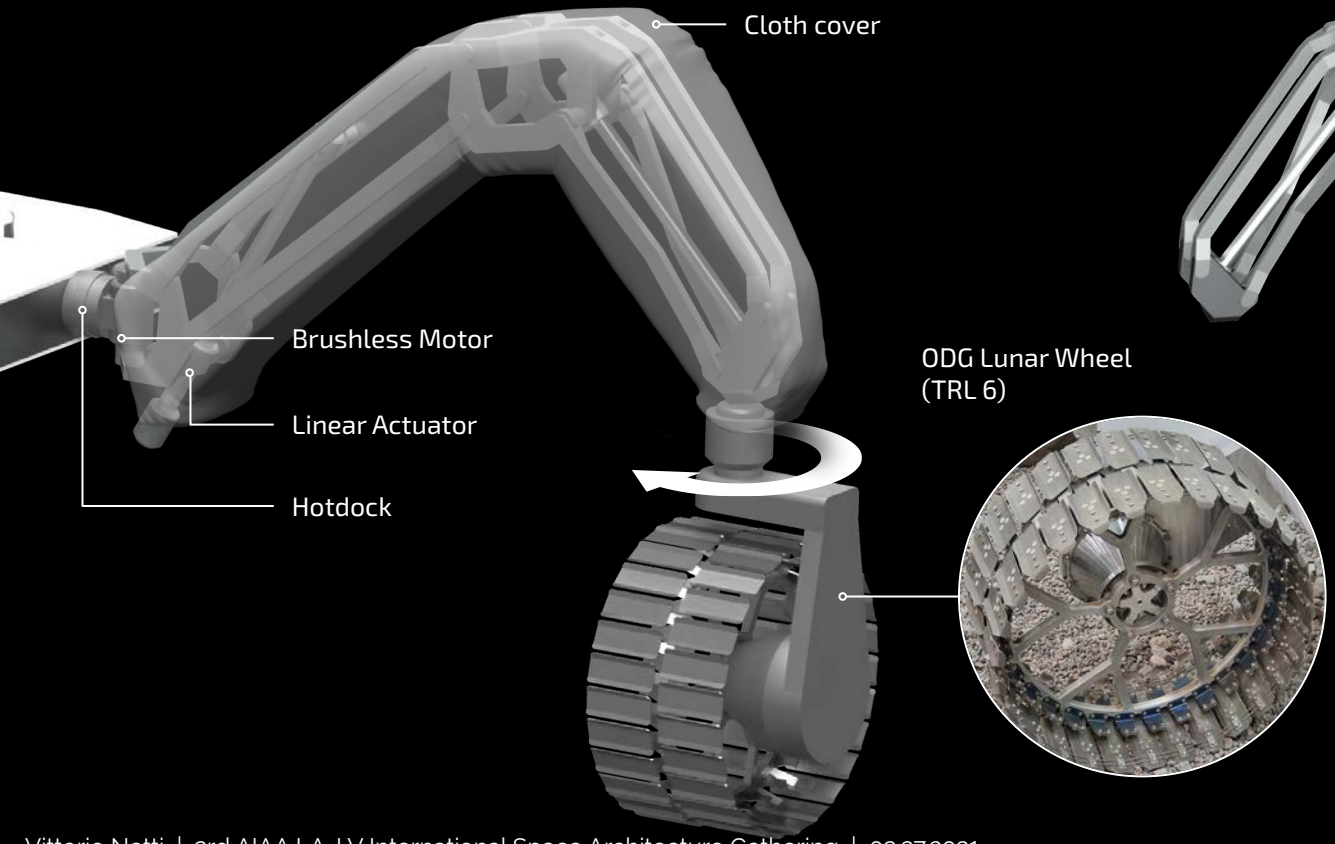


Li-ion Battery Pack
(TRL 9)



Triple-Junction Solar Cell
(TRL 9)

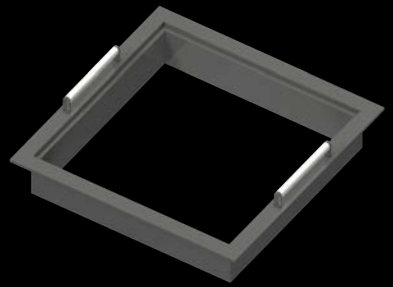
Vehicle Subsystems | Mobility Unit



ODG Lunar Wheel
(TRL 6)

Mobility Unit
5 DoF robotic limb
attitude control

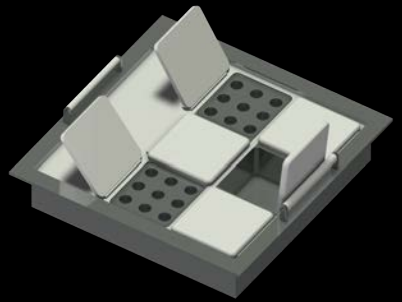
Vehicle Subsystems | Payload Box



Payload Box (Frame)

Manned Control Unit (MCU)

Volatile Extractor + Analyzer



Sample collector + Analyzer

Vehicle Subsystems | Manned Control Unit

1. MCU is connected to MUV in stowed configuration
2. MCU is deployed and powered on
3. Platform rotate to allow astronaut to step on the MCU from the front of MUV
4. Astronaut connects to the handle and take control of MUV, platform rotate again

Planetary construction with ISRU on Moon and Mars: form factor and automation of the construction processes.

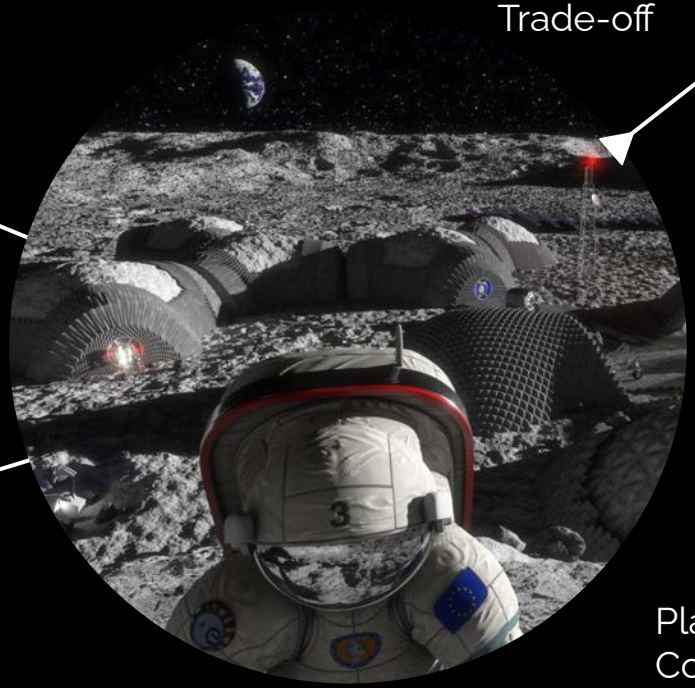
ICON

SEArch+

ROBOTIC CONSTRUCTION

Additive Manufacturing

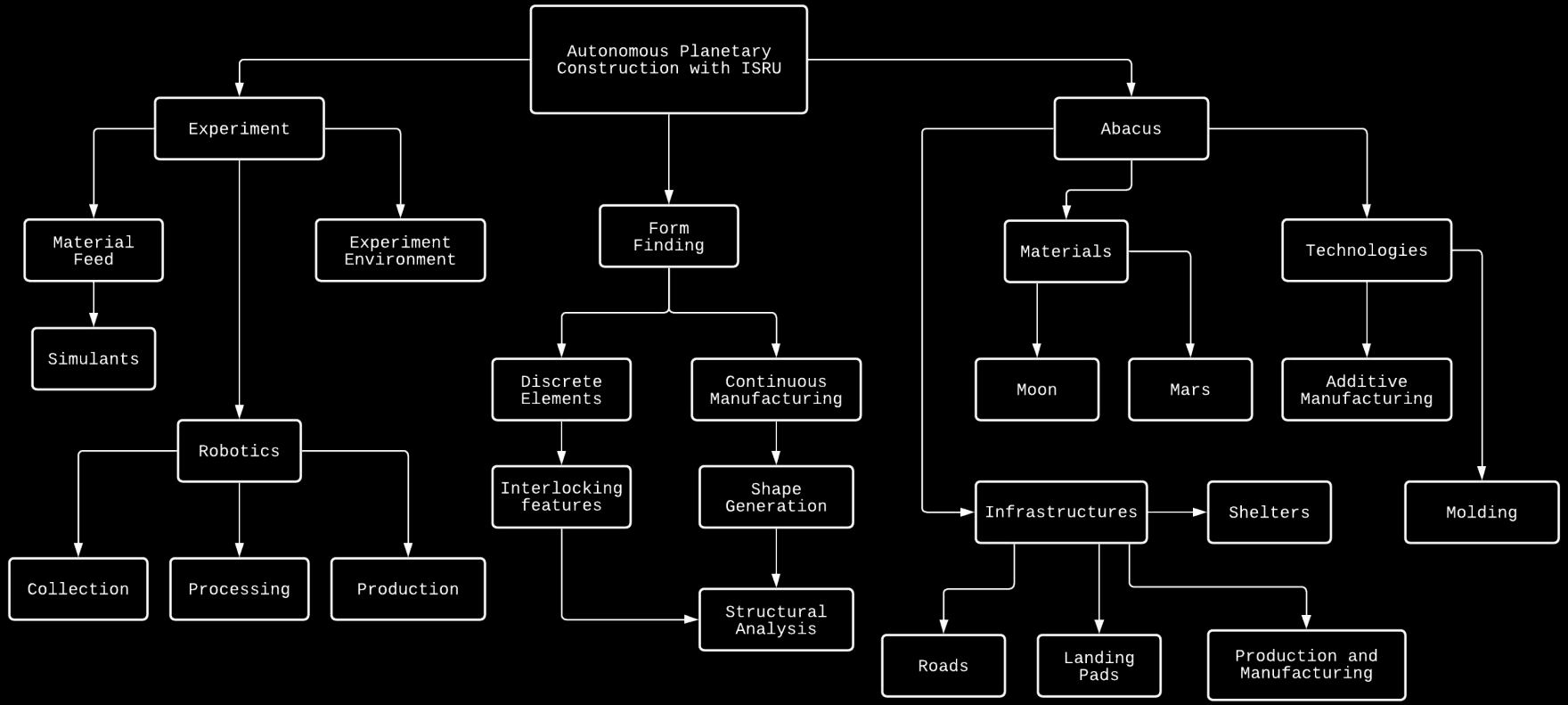
Discrete elements *(forming)*



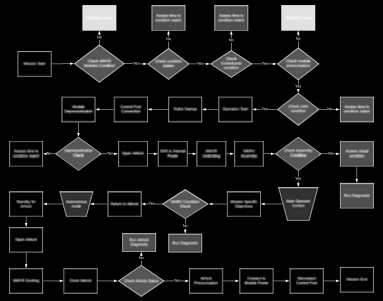
Earth Construction Trade-off

Planetary Construction

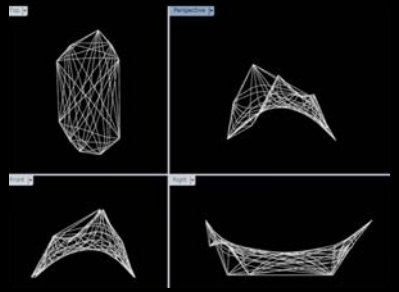
METHODOLOGY



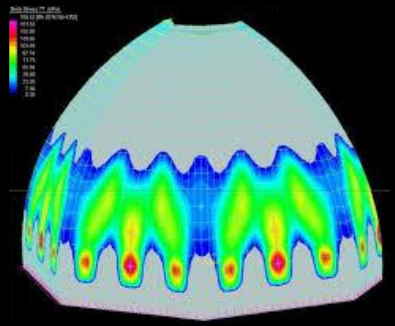
DEVELOPMENT



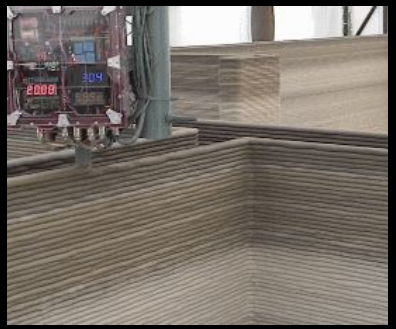
1. Experiment ConOps



2. Form Finding



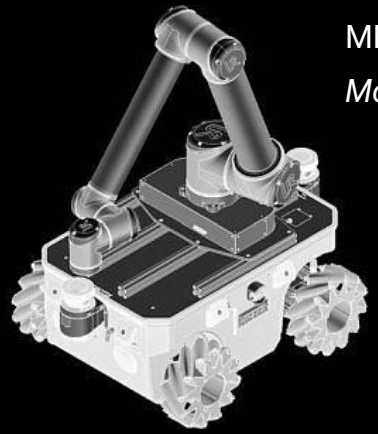
3. Structural Analysis



4. Experiment execution

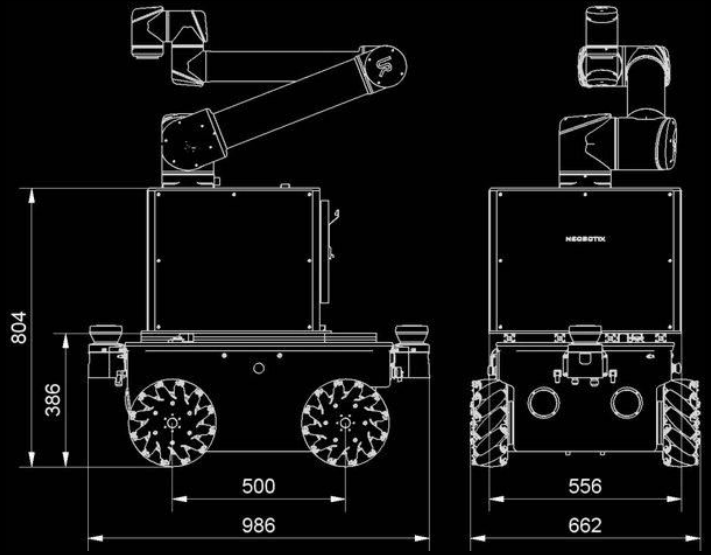
EXPERIMENT

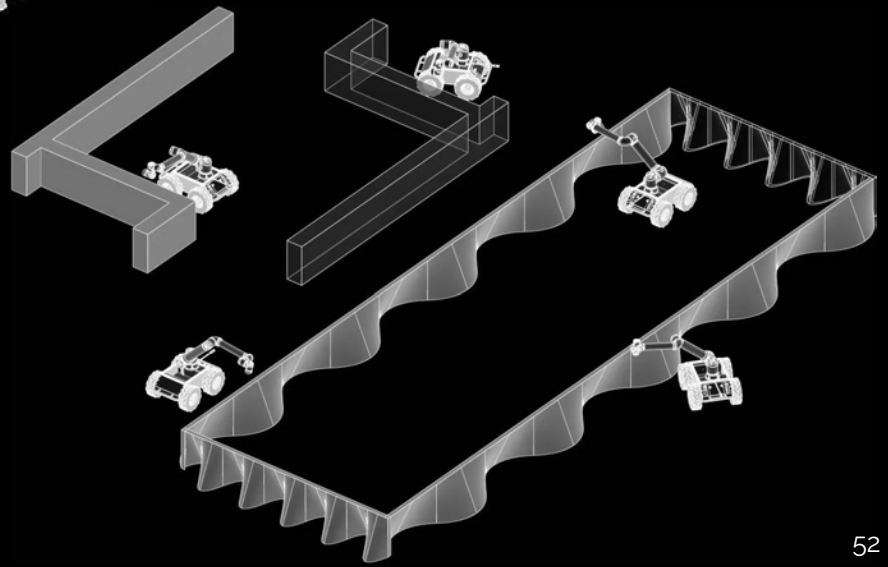
Testing collaborative mobile regolith printer in a closed-loop environment



MMO-500

Mobile Manipulator





THANK YOU

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