AMPERE

Autonomous Moon Power & Environmental Research Element

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MOON SURFACE IMAGE FROM: NICOLAS LEFAUDEUX (2021)

Agenda

- Operating on the Moon: the energy gap
- Introducing AMPERE
- A 3-module architecture
- Eagle: Energy Generation & Storage
- Power Distribution and Demonstration
- From AMPERE to a lunar power grid
- Conclusion and questions

Operating on the Moon: the energy gap

“Exploration” ——— **POWER DEFICIT** ⟶ “Utilization”

- Industrial ISRU plants & construction are extremely power hungry: oxygen extraction plants require 30-70kW alone [1]
- **Lunar Night**: 120 to 354 hours of darkness
- **Current model is not Scalable:** every asset brings its own power

Continuous power demand of 20 - 100 kW [1]

[1] J. ZHENG ET AL., ”ELECTRICITY GENERATION FOR LUNAR BASES DURING CONSTRUCTION AND OPERATION: KEY TECHNOLOGIES, CHALLENGES AND DEVELOPMENT ROADMAP,” ACTA ASTRONAUTICA.

Introducing AMPERE

The first step toward a lunar power grid.

What is it?

A demonstrative platform for power generation, storage and distribution on the lunar surface, while collecting environmental data

Mission Objectives

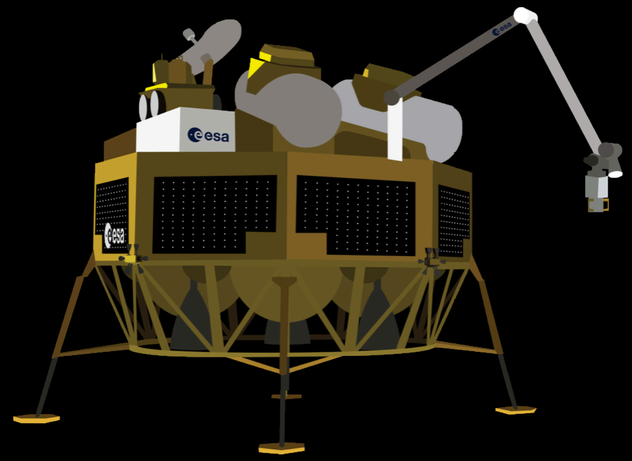
DEMONSTRATE THE GENERATION AND STORAGE AT SOUTH POLE
Generate and Store Energy

DEMONSTRATE THE FEASIBILITY OF POWER DISTRIBUTION
Distribute Power

VALIDATE LUNAR ENVIRONMENTAL MODELS
Research

Introducing AMPERE

The first step toward a lunar power grid.



ESA ARGONAUT LANDER. [2]

🇪🇺 European asset

- Ariane 6 launcher
- Argonaut lander
- Moonlight constellation

Mission constraints

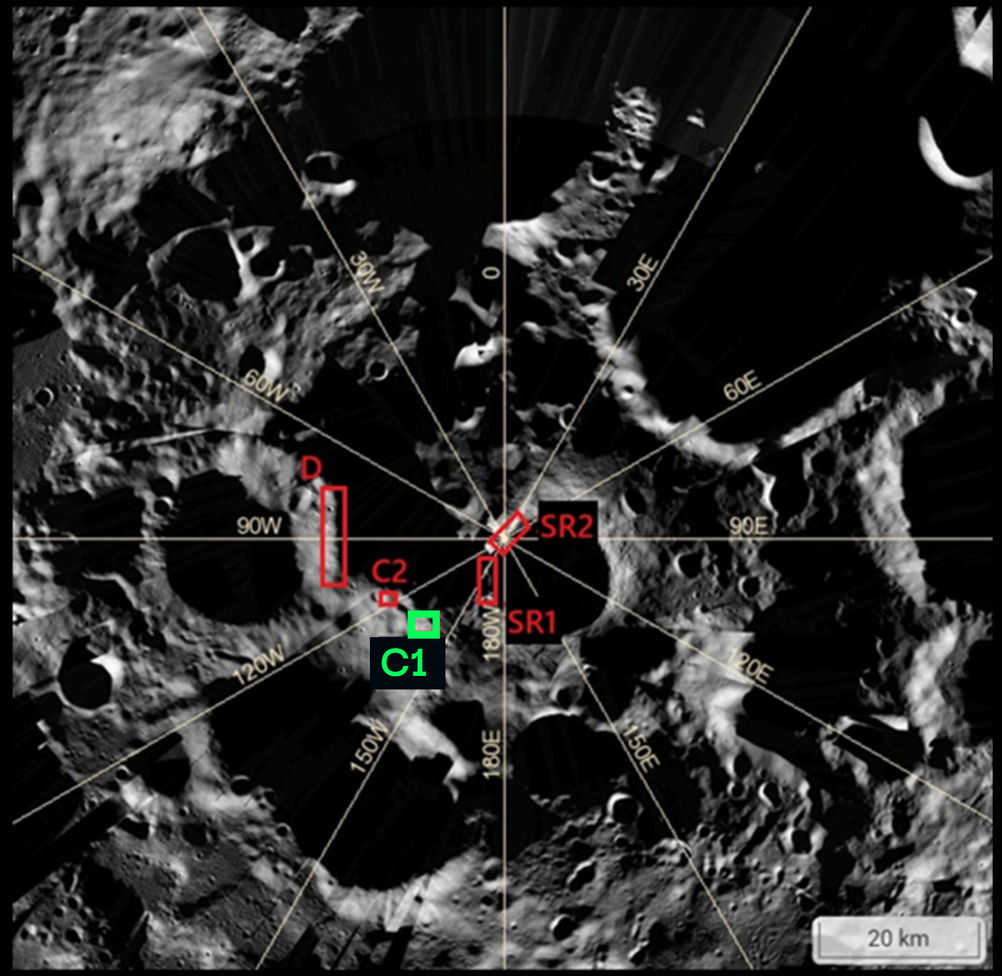
Mass	800 kg
Base surface	4 m^2
Height	1.8 m

[2]: European Space Agency, “What is Argonaut?,” infographic, ESA, Oct. 2020

Introducing AMPERE

Landing and Operational Site

- Safe Landing Conditions
- Critical Aspect for Payload Survival and Operativity
- Average Illumination of 88% p.y. and 120 h of continuous darkness
- Interest in Lunar South Pole



CANDIDATE LANDING SPOTS AT SOUTH POLE (RED)
SELECTED LANDING SPOT CR1 (GREEN).[3]

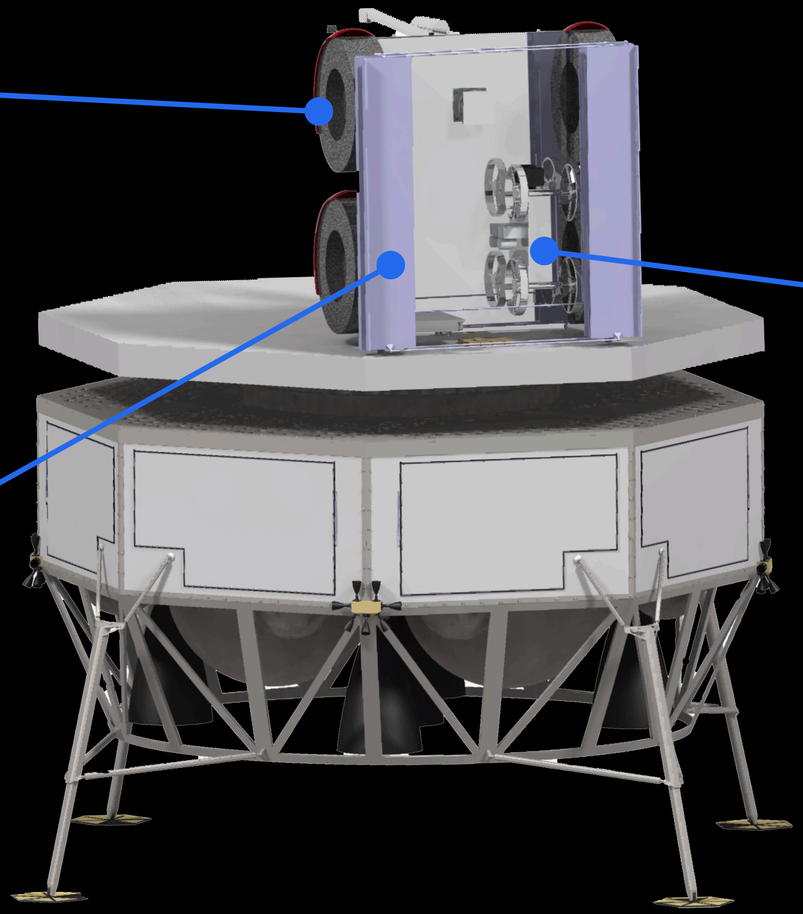
[3]: NASA, “Moon Trek — A web portal for lunar data,” Moon Trek. [Online]. Available: https://trek.nasa.gov/moon/

A 3-Module Architecture

STATIONARY POWER HUB

EAGLE

- ~ 500 KG
- 5 KW OF GENERATED POWER
- 48 KWH OF STORAGE



DEMONSTRATIVE ROVER

SCOTT

- 41 KG
- 297 WH BATTERY
- MOVES AT 6.5 CM/S
- 9 H DUTY CYCLE

PAYLOAD DELIVERY SYSTEM

PDS

- 6.86 M FOLDABLE RAMP @ 26° SLOPE
- 5 FOLDABLE PANELS
- 5 MECHANICAL HINGES
- ALUMINUM HONEYCOMB COVERED WITH CARBON FIBER REINFORCED POLYMER (CFRP) STRIPS

SCHEMATIC VIEW OF AMPERE ALLOCATED ON ARGOANUT

EAGLE: Energy Generation and Storage

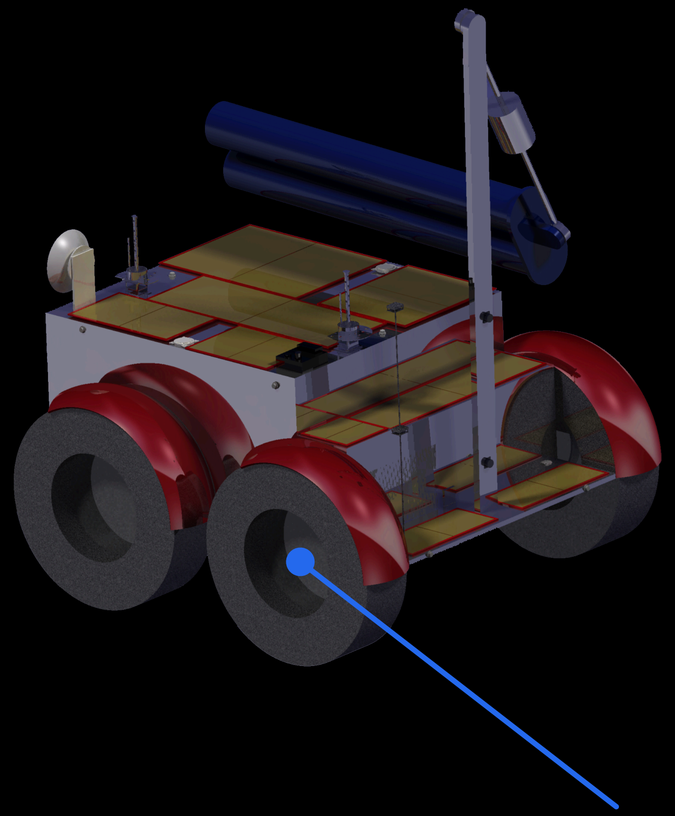
Meet EAGLE

- Structurally built on honeycomb aluminum cart
- Dual-mission: generate and store energy to survive the 14-days or darkness

LUNAR PAYLOAD MODULE
LPM

LUNAR SENSOR MODULE - STATIONARY
LSM-S

ROVER DELIVERY SYSTEM
RDS



WHEELS
FOR DEPLOYMENT STABILITY
AND POTENTIAL MICRO-POSITIONING

EAGLE: Energy Generation and Storage

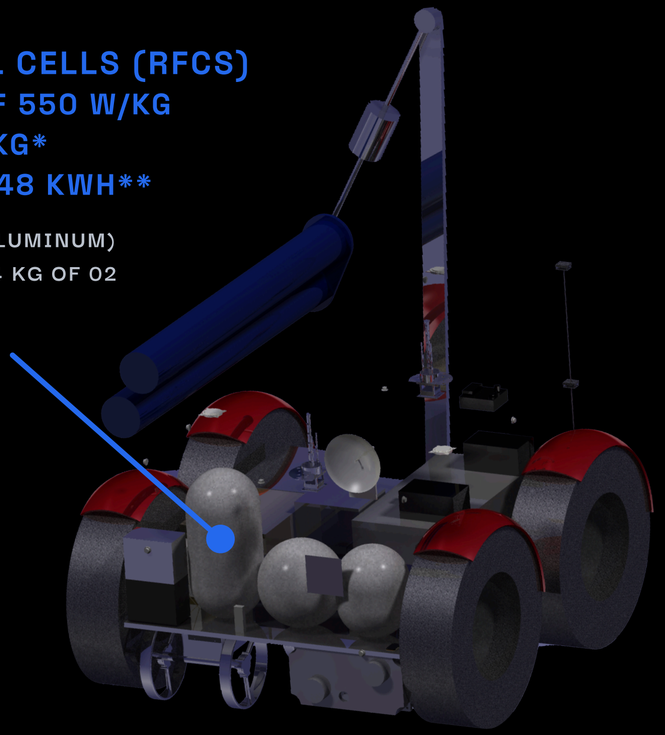
Meet EAGLE

REGENERATIVE FUEL CELLS (RFCS)

- POWER DENSITY OF 550 W/KG
- TOTAL MASS: 140 KG*
- TOTAL CAPACITY: 48 KWH**

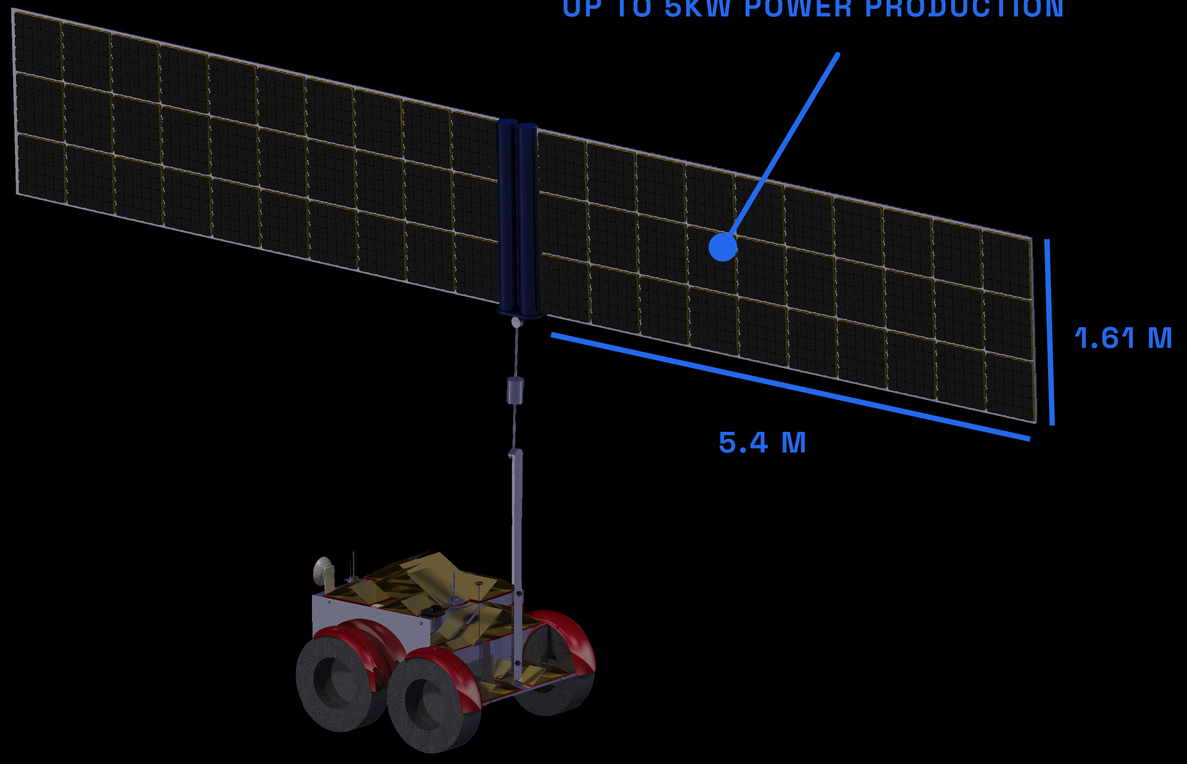
*INCLUDING TANKS MASS (ALUMINUM)

**USING 1.22 KG OF H2 + 9.74 KG OF O2



EAGLE INTERNAL COMPONENTS ARRANGEMENT
(CLOSED PANELS CONFIGURATION)

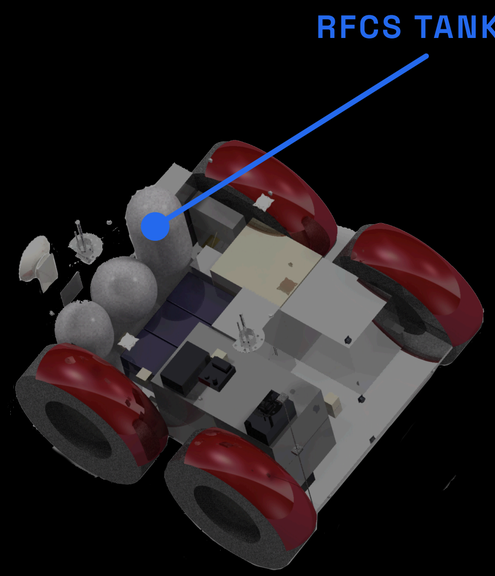
ROLL-OUT SOLAR ARRAYS (ROSA)
TOTAL SURFACE: 17.34 SQM
QJ GAAS CELLS
UP TO 5KW POWER PRODUCTION



EAGLE SOLAR PANELS DEPLOYED CONFIGURATION

EAGLE: Energy Generation and Storage

Meet EAGLE



EAGLE INTERNAL COMPONENTS.
(UP-VIEW)

RADIATOR WITH TWO VANE
BLADE LOUVERS [3]

Thermal Control System

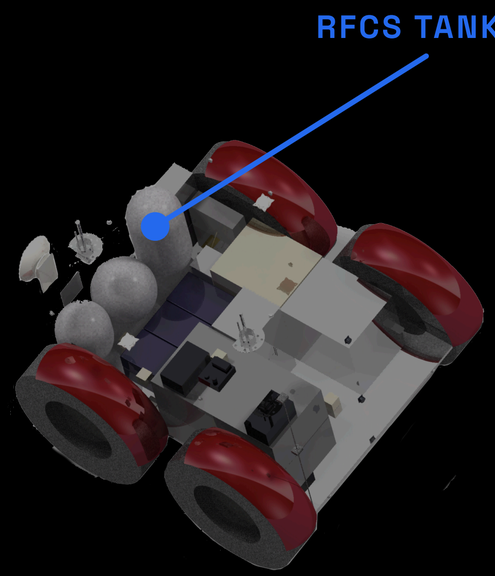
Operative range: 273 K and 320 K

- RFCS thermal synergy:
  at 50% electrical efficiency they allow to recover waste heat
- Smart Multi-Layer Insulation (SMLI) with variable emissivity and Loop Heat Pipes (LHP)
  POWER CONSUMED: 108.6 W
- Passive radiators plus blade louvers dissipate heat during daytime

[3]: VANOV, Dmitri; FERNANDES, Domingos. Lunar dust tolerant thermal louver development for a light-weight rover system. Lunar dust tolerant thermal louver development for a light-weight rover system

EAGLE: Energy Generation and Storage

Meet EAGLE



EAGLE INTERNAL COMPONENTS.
(UP-VIEW)

RADIATOR WITH TWO VANE
BLADE LOUVERS [3]

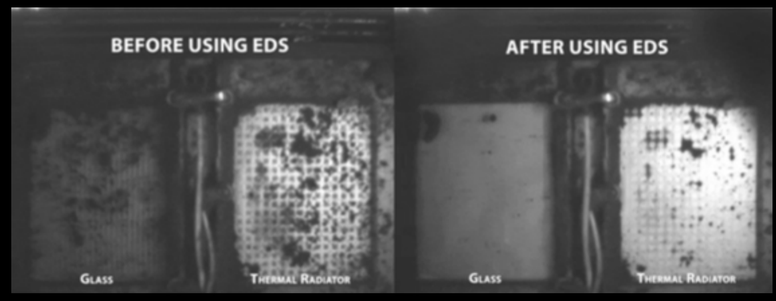
Thermal Control System

Hybrid thermal control

ACTIVE DUST MITIGATION:

Electro-dynamic Dust Shield (EDS) prevents regolith accumulation on radiators and MLI to maintain thermo-optical properties

POWER CONSUMED: 49.5 W



EDS EFFECT ON GLASS AND THERMAL RADIATORS.

[3]: VANOV, Dmitri; FERNANDES, Domingos. Lunar dust tolerant thermal louver development for a light-weight rover system. Lunar dust tolerant thermal louver development for a light-weight rover system

[4]: NASA. NASA's Dust Shield Successfully Repels Lunar Regolith on Moon [online]. NASA, 2024. Available: https://www.nasa.gov/image-article/nasas-dust-shield-successfully-repels-lunar-regolith-on-moon/

EAGLE: Energy Generation and Storage

LUNAR PAYLOAD MODULE
LPM

LUNAR SENSOR MODULE - STATIONARY
LSM-S

ROVER DELIVERY SYSTEM
RDS

Sensors on-board

To evaluate environment and elimination of movement:

Measurements:

- Total ionizing dose
- Radiation (with NGRM*)
- 3-axis fluxgate magnetometer
- PRT (Platinum Resistance Thermometer)

*NEW GENERATION RADIATION MONITOR

Power distribution and demonstration

How does EAGLE transfer power?

Two standards are selected:

WIRELESS

UFPC

125 W @ 8A
VIA INDUCTIVE COUPLING.
NO EXPOSED CONTACTS, NO DUST RISK

FROM LEFT TO RIGHT: TRANSMITTER, TRANSMITTER COIL, ON BOARD CHARGER, RECEIVER COIL [5]

WIRED

LESSH

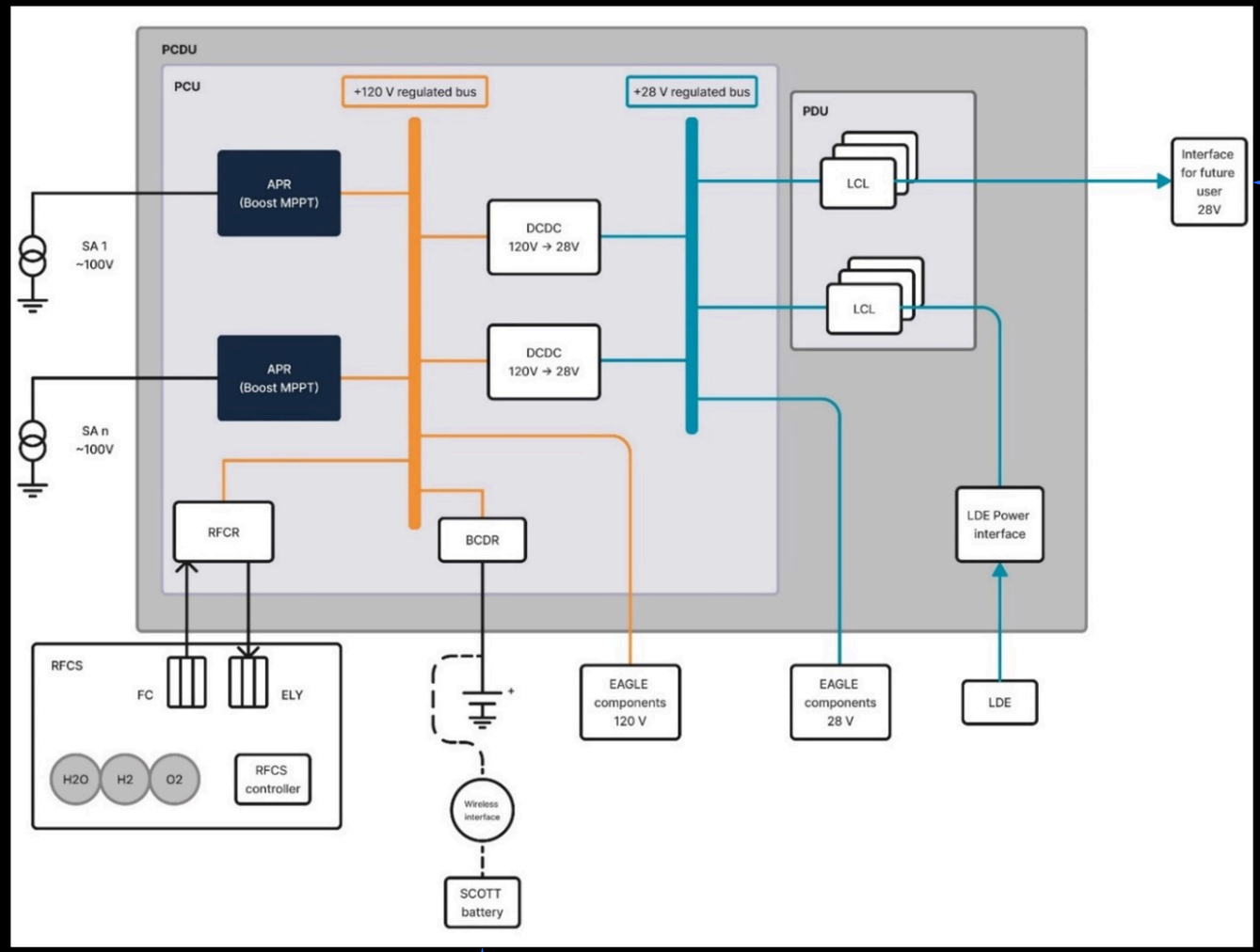
215 W @ 9.4 A
WIRED INTERFACE
FOR FUTURE HEAVY ASSETS

LESSH BCM [6]

[5]: Ultra Fast Proximity Charger: Wireless Power for the Moon," Astrobotic, Pittsburgh, PA, Nov. 2023. [Online]. Available: https://science.nasa.gov/wp-content/uploads/2023/11/astrobotic-wireless-charger.pdf
[6]: Amato, Michael, et al. "LESSH Lunar Experiment Support System and Handling Battery Charger Module." Lunar Surface Innovation Consortium. 2024.

EAGLE: Energy Generation and Storage

- EAGLE's PCDU scheme fully integrated with LDE
- 1.6 kW are used to sustain the platform during daytime
- 3.4 kW available to charge other asset
- Future assets will use the 28V bus, while SCOTT uses the 120V



EAGLE PCDU SCHEME

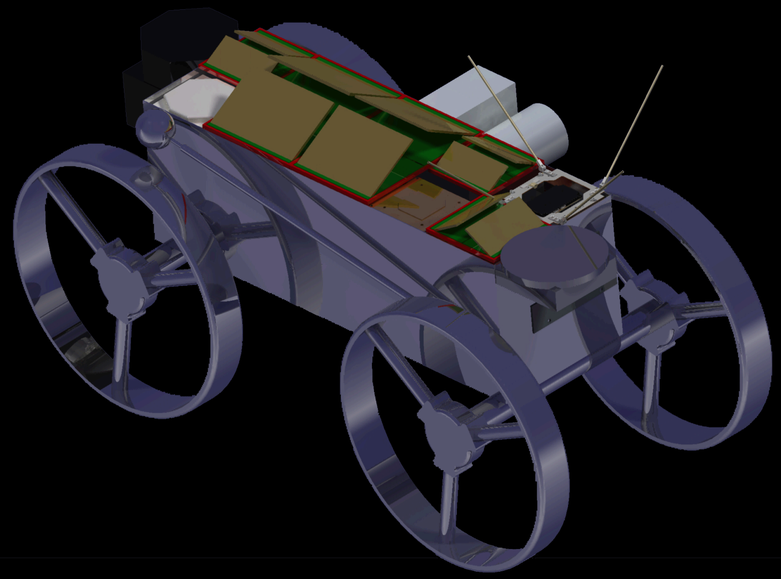
Power distribution and demonstration

Scott: Demonstrative Rover acting as future customer

- 24U CubeRover equipped with a 297Wh battery
- Capable of moving at 6.5 cm/s

Primary job

Traverse 50 to 75 m, perform scientific readings and return to Eagle to recharge

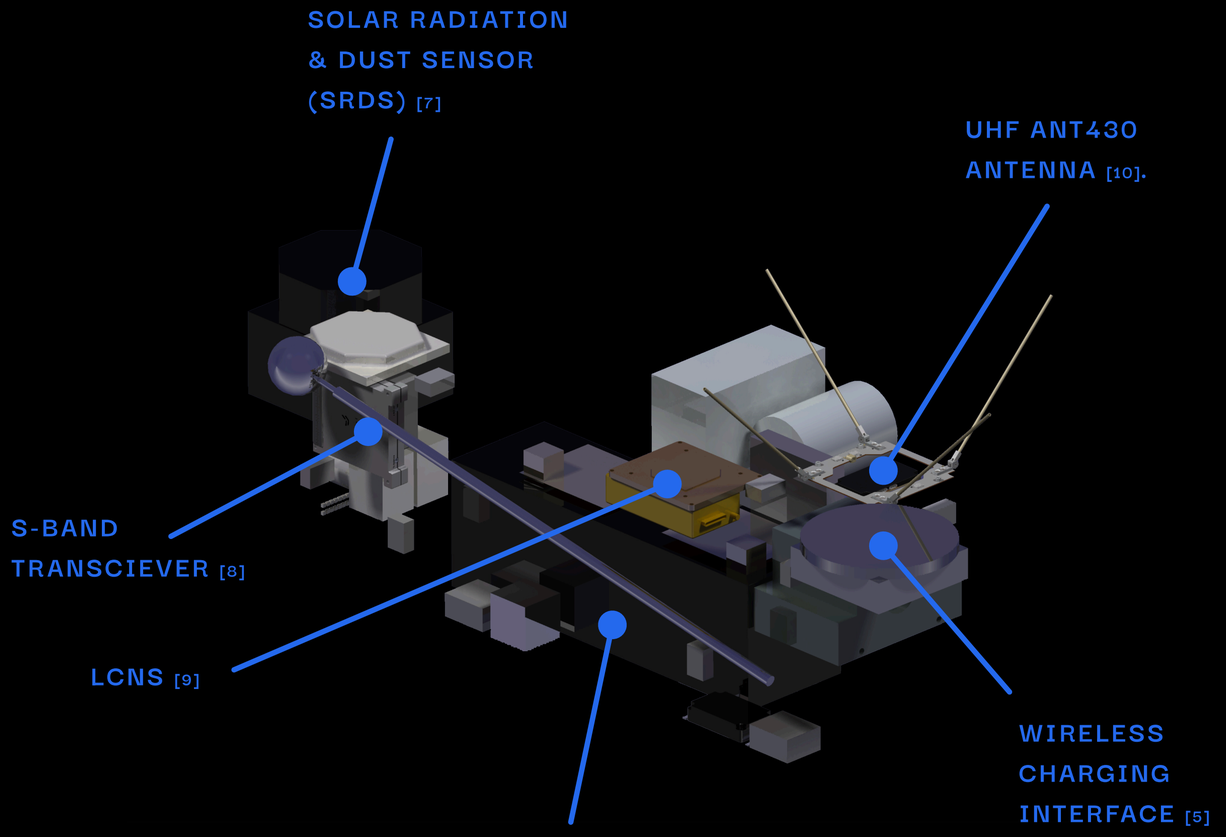


SCOTT ROVER.
EXTERNAL VIEW

Power distribution and demonstration

Scott: Demonstrative Rover acting as future customer

- Operational cycle of 9 hours:
  - 2 h for complete charging
  - 7 h for moving and data acquisition
- Equipped with:
  - Dosimeter
  - Radiation monitor
  - Temperature sensor
  - 3-axis magnetometer



SCOTT ROVER INTERNAL COMPONENTS ARRANGEMENT

[7]: UJ. A. Rodriguez-Manfredi et al., “The Mars Environmental Dynamics Analyzer (MEDA): A suite of environmental sensors for the Mars 2020 mission,” *Space Science Reviews*, vol. 217, no. 48, 2021
[8]: EnduroSat, “S-Band Transceiver for CubeSat and SmallSat Communication,” EnduroSat. [Online]. Available: https://www.endurosat.com/products/s-band-transceiver/
[9]: SpaceQuest, Ltd., “GNSS-700 Series: Satellite GNSS Receiver,” ver 2019-08-09, Fairfax, VA, USA, Aug. 9, 2019. [Online]. Available: [https://www.aac-clyde.space/product/gnss-700-series]
[10]: GomSpace, “NanoCom ANT430 — Wire Antenna,” SatCatalog (ora SatBase). [Online]. Available: https://www.satcatalog.com/component/nanocom-ant430/

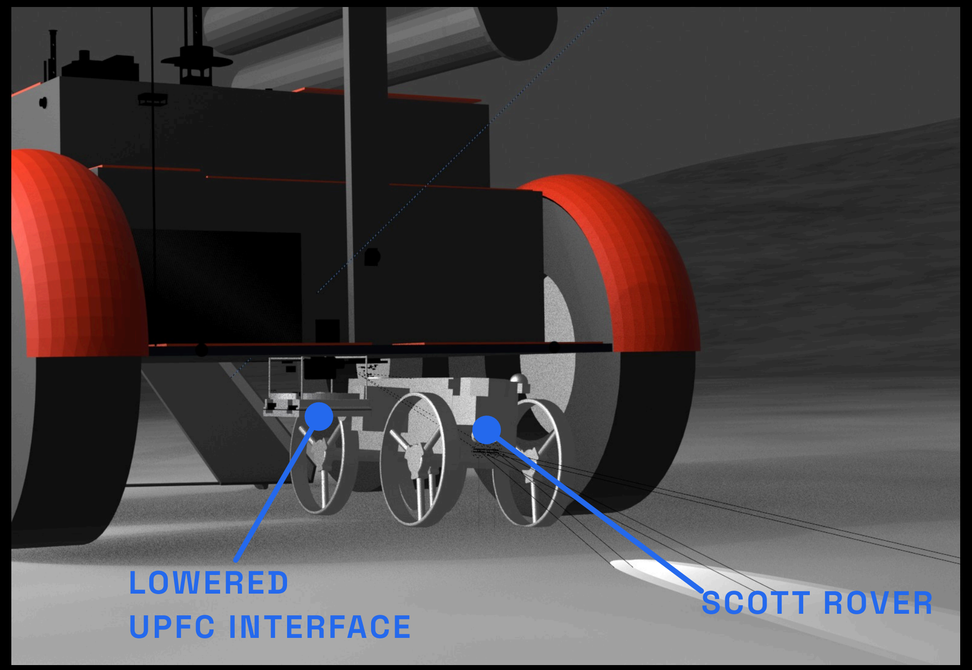
Scott: Demonstrative Rover acting as future customer

Released on the Moon surface thank to RDS:

- located underside EAGLE's chassis
- uses Ejector Release Mechanism (ERM) to drop Scott (10 cm, absorbed by wheels)

RDS also:

- Lowers the Wireless Power Transmitter from Eagle to a precise height of 35 cm a.g.



RENDER OF LOWERED UFPC AND SCOTT.

From AMPERE to a lunar power grid.

Not a one-off mission.

- AMPERE is designed to survive 12 months and validate the technology by setting a standard for power distribution.
- Other assets can use EAGLE to charge during the mission period
- EAGLE is a single block. More blocks can be used to form a Micro Power Grid and meet the energy demand

MOON VILLAGE ASSOCIATION

Lowering the barrier for lunar surface

Thank You

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AMPERE mission