ALCHEMIST

A LUNAR CHEMICAL IN-SITU RESOURCE UTILISATION TEST PLANT

ISRU DEMONSTRATION MISSION

SINCE 1987

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SPACE APPLICATIONS SERVICES

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- Human Spaceflight and Robotic Exploration
- Earth Observation
- Navigation
- Launchers
- Commercial space
- The European Commission's H2020 Space programme

HEALTH – ENVIRONMENT - SECURITY

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BELGIAN COMPANY WITH INTERNATIONAL OFFICES

FOUNDED IN 1987

10M+€ ANNUAL TURNOVER

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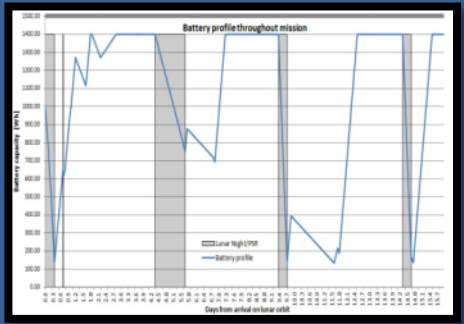
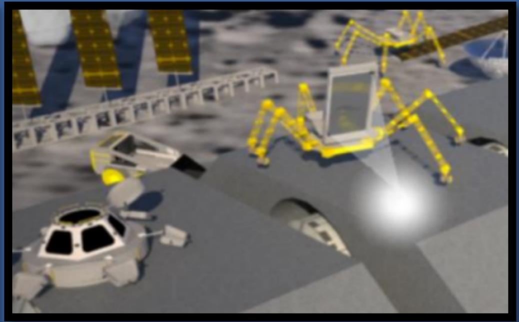
European Space Research & Technology Center
NL

OUR ISRU-RELATED WORK

- 2009- In-Situ Resources Utilisation (ISRU) Architecture and Technology Study: extraction of water from regolith
- 2011- Autonomous Planetary Payload Support System: architectural and system design of a non-nuclear system to provide survival and servicing support to a planetary payload element
- 2014- Lunar Polar Sample Return Mission Phase A: mobile element definition
- 2015- Sintering Regolith with Solar Light: breadboard demonstrator in vacuum including 3-axis table and regolith feeder
- 2016- Lunar Volatiles Mobile Instrumentation: development of a lunar rover for volatiles mapping, including volatiles sampling, extraction and analysis
- 2017- Battery less Low Temperature Avionics and System Study: lunar rover application
- 2017- Study to assess the future potential market and value-chain of space resources utilisation (ESA/spaceresources.lu/PwC)
- 2017- Awarded Study of oxygen extraction demonstrator (ESA)





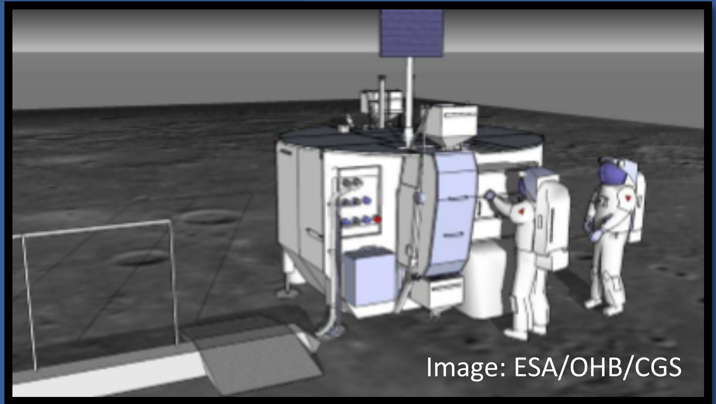


Image: ESA/OHB/CGS

ISRU DEMONSTRATION MISSION

- Mission is in preparation to demonstrate the feasibility of ISRU processes on the lunar surface not later than 2025
- Focus on closing strategic knowledge gaps for ISRU processes, complementing ESA PROSPECT payload (scheduled 2022)
- Goal:

"Produce potable water or breathable oxygen on the Moon before 2025 and for less than 250 M Euro"

- Lunar communication and transportation services to be procured from the private sector
- Envisaged to engage in a simplified mission scenario without surface mobility and to rely on ubiquitous resources (e.g. oxygen from silicate or metal oxides) rather than volatile deposits

STRUCTURE OF THE PARALLEL STUDIES

- 2 parallel on-going studies:
  - **Team Hydrogen Reduction**
  - Team Carbothermal Reduction

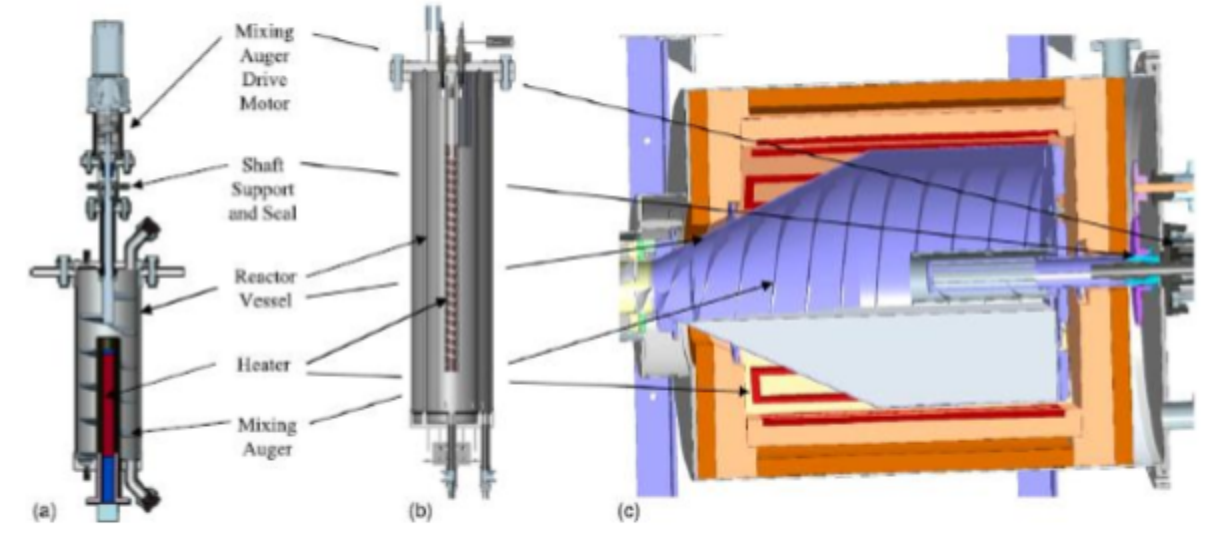
- Each of the 2 study teams is composed of 3 segments
  - Payload Segment
  - (Commercial) Delivery Segment
  - (Commercial) Communications Segment

  - With ESA acting as a Mission Integrator

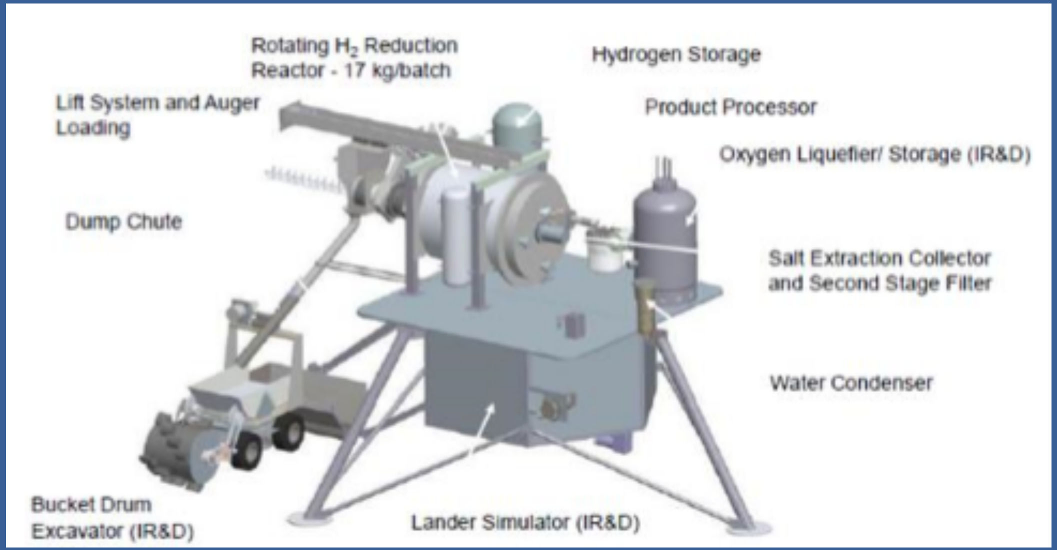
- Team Hydrogen Reduction
  - **Payload: Space Applications Services (prime)**
  - Delivery: Thales Alenia Space Italia (prime)
  - Communications: Thales Alenia Space UK (prime)

- One of the processes will be down-selected for the payload in the future

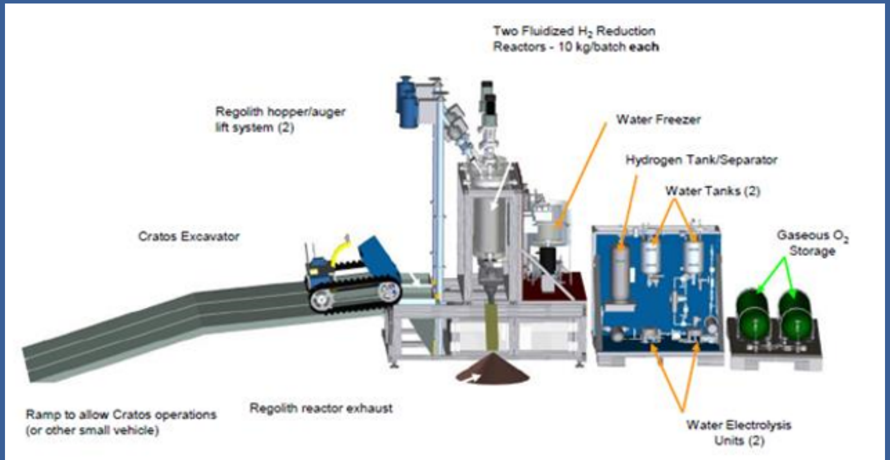
HYDROGEN REDUCTION



ROxygen, ROxygen II, (NASA) PILOT Reactors (NASA, LM)



PILOT (NASA, LM)



ROxygen plant (NASA)

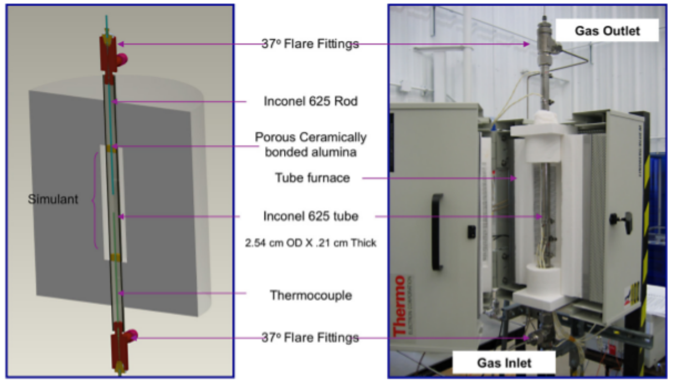
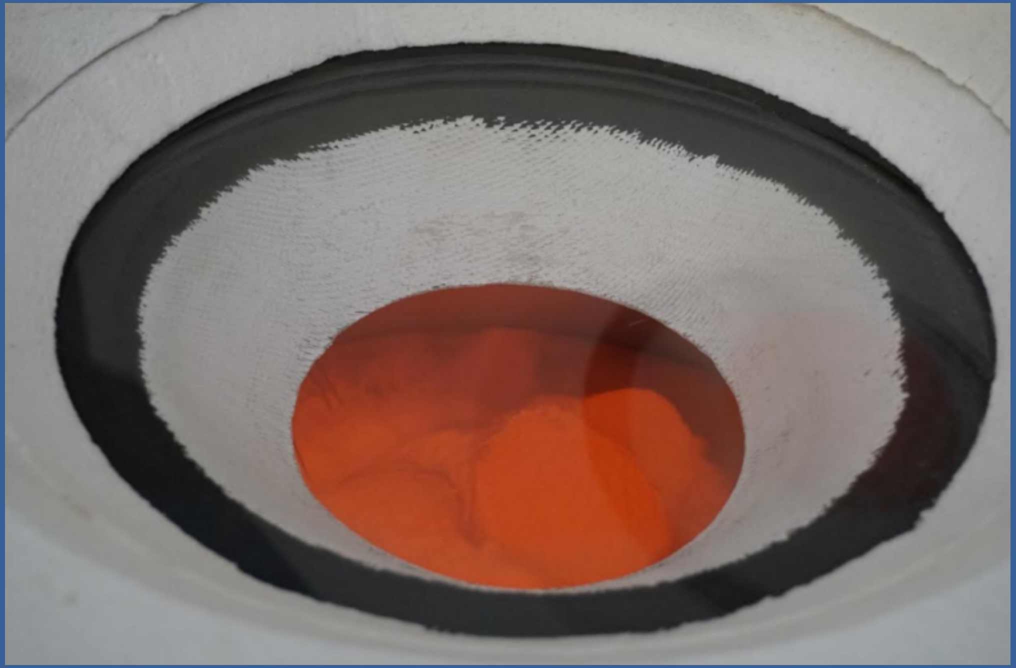


Figure 2.—Reactor schematic and experimental set-up.

Lab setups Hegde et al. (NASA)

PSA-CIEMAT ORESOL PLANT

- Outpost-scale H2 reduction system
- Tested with pure ilmenite and inert gas+ hydrogen



Images: Thorsten Denk, Plataforma Solar de Almeria - Ciemat

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
PSA

PSA-CIEMAT ORESOL PLANT

- Low quantity (due to low H_2 feed)
- H_2 -conv. -> 100%
- Water very acidic (pH=3) and contaminated (NH_4^+ , Cl^- , …)

- Water was obtained
- Water separator worked well

ALCHEMIST

- ALCHEMIST: building upon the Oresol experience, miniaturize the H2 reduction system to produce a demonstration-scale amount of water, on the Moon, before 2025

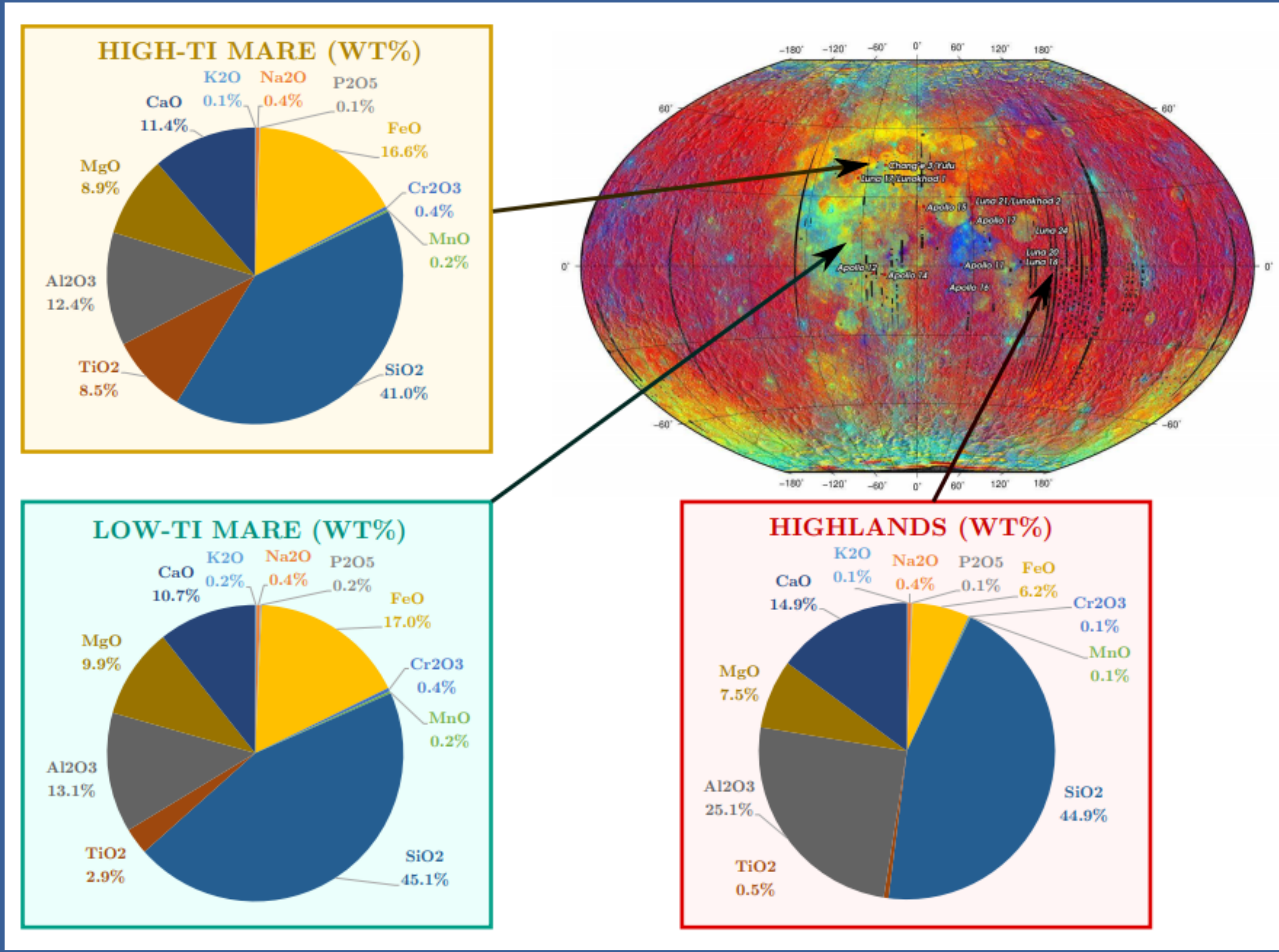
The payload is to

- Extract Oxygen/obtain water through H2 reduction
- Beneficiate the material as needed and/or for demo purposes

- **Water production (total – ESA requirement)**
  - 10 g minimum
  - 100g goal

esa

IRON OXIDE ON THE MOON



LANDING SITES

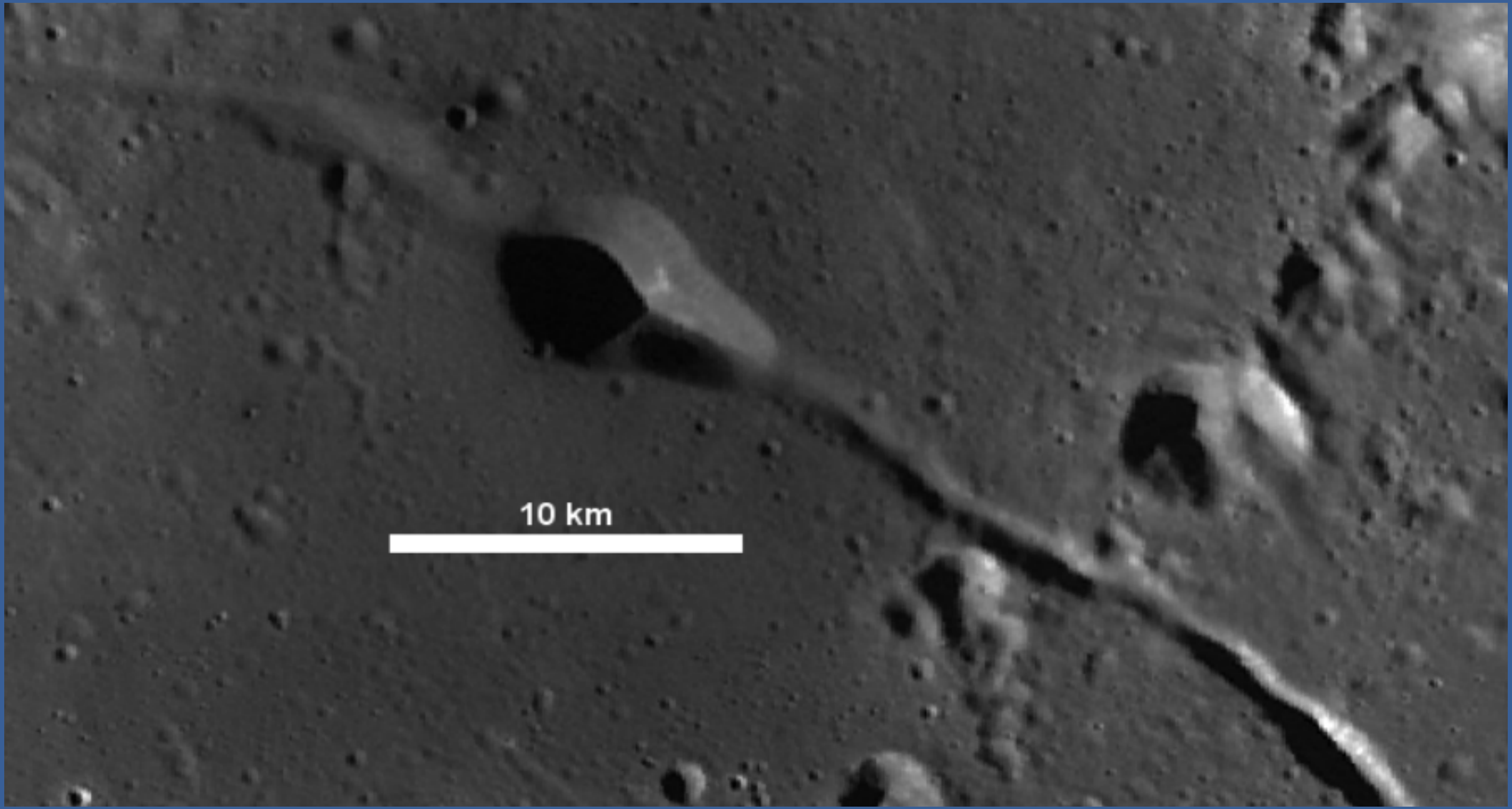
- **Water production (total)**
  - 10 g minimum
  - 100g goal
- Independent of beneficiation results.
- Sites preselected (1,2) reduce performance requirements and risk, however all sites are preliminarily considered feasible
- Schroedinger Pyroclastic Flow - scientifically more interesting
- Since MI-025 stresses Shackleton connecting ridge, we keep track of other main locations (e.g.highlands) in our models

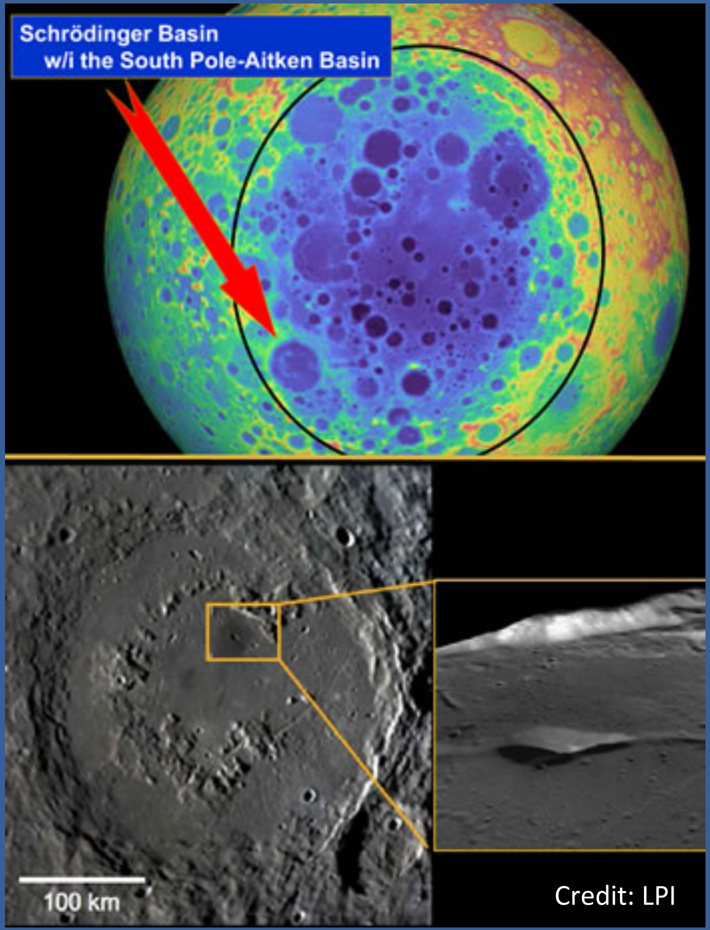
Site	Type	Lat, Long	Comms	Implications for P/L
Shackleton Connecting Ridge	Highland	Shackleton, 125 E, 88 S	DTE comms TBC	• Likely low FeO • Potentially more difficult fluidization (particle shape) • Material somewhat better characterized (particle size, shape, separation) (general highlands) • Comms constraints not assessed but possibly good conditions
Schroedinger Pyroclastic Flow (1)	Pyroclastic deposit	Schroedinger, 139 E, 75 S	No DTE comms	• Likely high FeO content. • Potential easier fluidization (if glass beads content) • Material particle size, shape known to lesser degree, no tests on separation are known • Additional constraints in comms (delay, bandwidth, access)
Shoemaker Faustini Connecting Peak	Highland	Peak around 77 E, 87 S	DTE comms TBC	• Likely low FeO • Potentially more difficult fluidization (particle shape) • Material somewhat better characterized (particle size, shape, separation) (general highlands) • Comms constraints not yet assessed but possibly good conditions
Near side site, Orientale (TBC) (2)	Mare	TBC	DTE comms	• Likely high FeO Potentially more difficult fluidization (particle shape) • Material somewhat better characterized (particle size, shape, separation) (general Maria) • Comms – likely good conditions

SCHRODINGER PYROCLASTIC FLOW

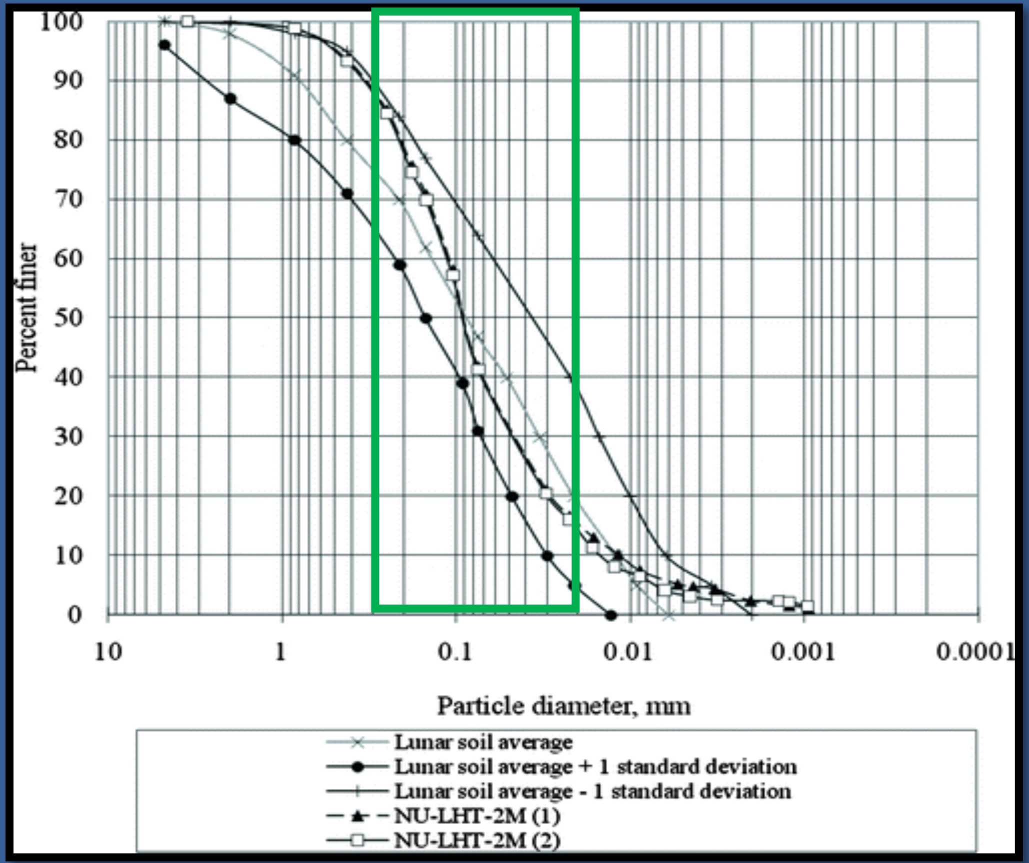
FeO content

- Known very high FeO content (working assumption landing areas with FeO>=10.5% and up to 14%)





PARTICLE DISTRIBUTION



SOME OF THE CASES EXPLORED FOR PYROCLASTIC FLOW, EXCAVATION REQS

Case PM1-D

	Highlands (NU-LHT-2M) – Full beneficiation (M)	Shroedinger Pyroclastic Flow with full beneficiation (M)– Case PM1-D	Shroedinger Pyroclastic Flow partial beneficiation– Case PM1-C
Excavation Mass	35 kg	58.4 kg	4.1 kg

ACCOMMODATION

Accommodation

- On top deck
- Core of lander discarded due to propellant tank and avionics accommodation
- Current maximum height: ~~1.030~~ m

Local communications

- Provided by lander
- Low data rate (TM/TC): MIL bus
- High data rate (imagery): Spacewire

Payload avionics

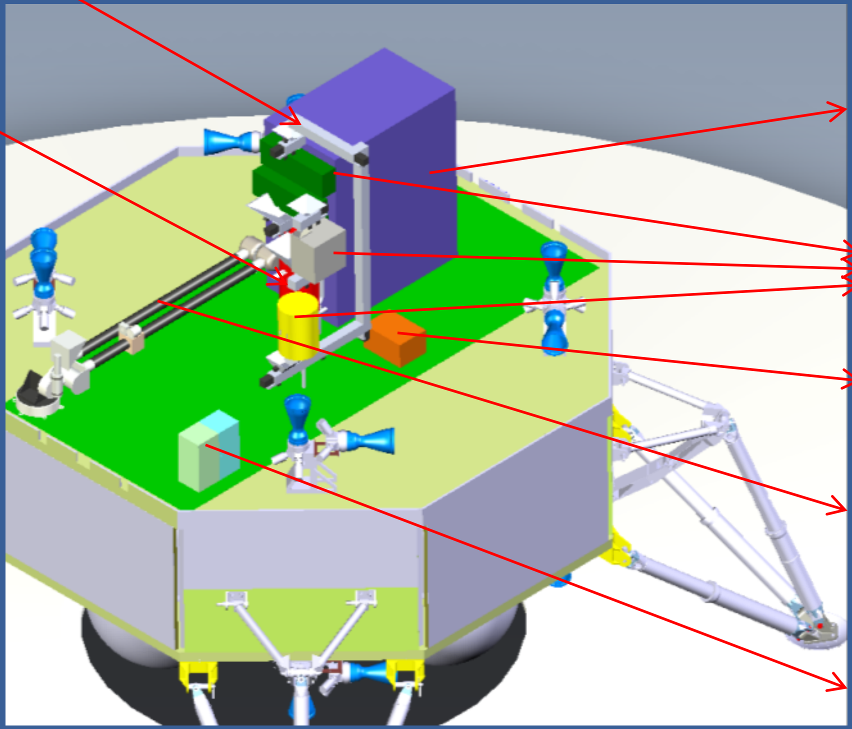
- All processing done by payload avionics

Thermal control

- Done by payload Thermal control subsystem

Power generation and storage

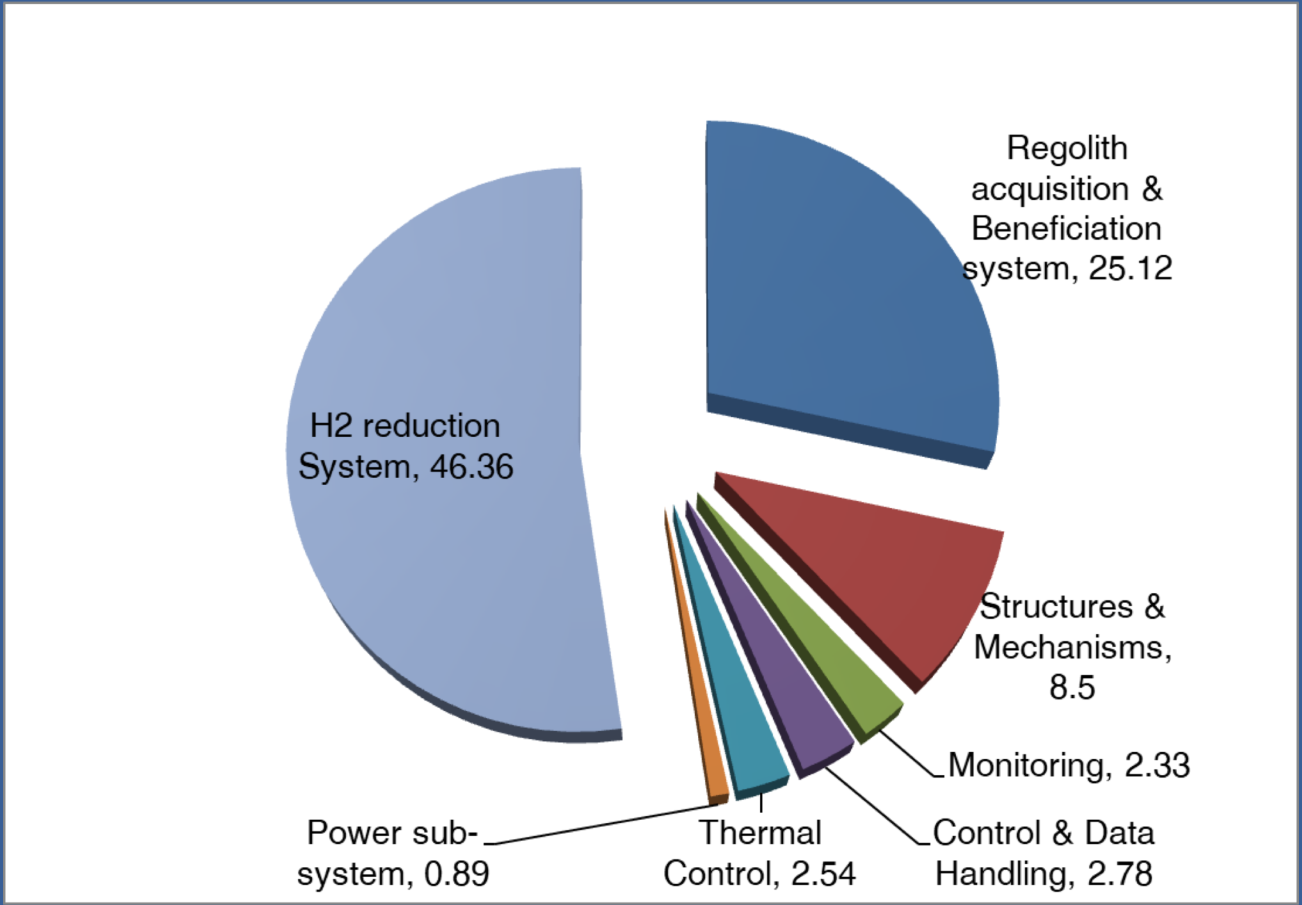
- Provided by lander



Not depicted: Thermal management system, tailings pipes

MASS BREAKDOWN

Mass ~100 kgs



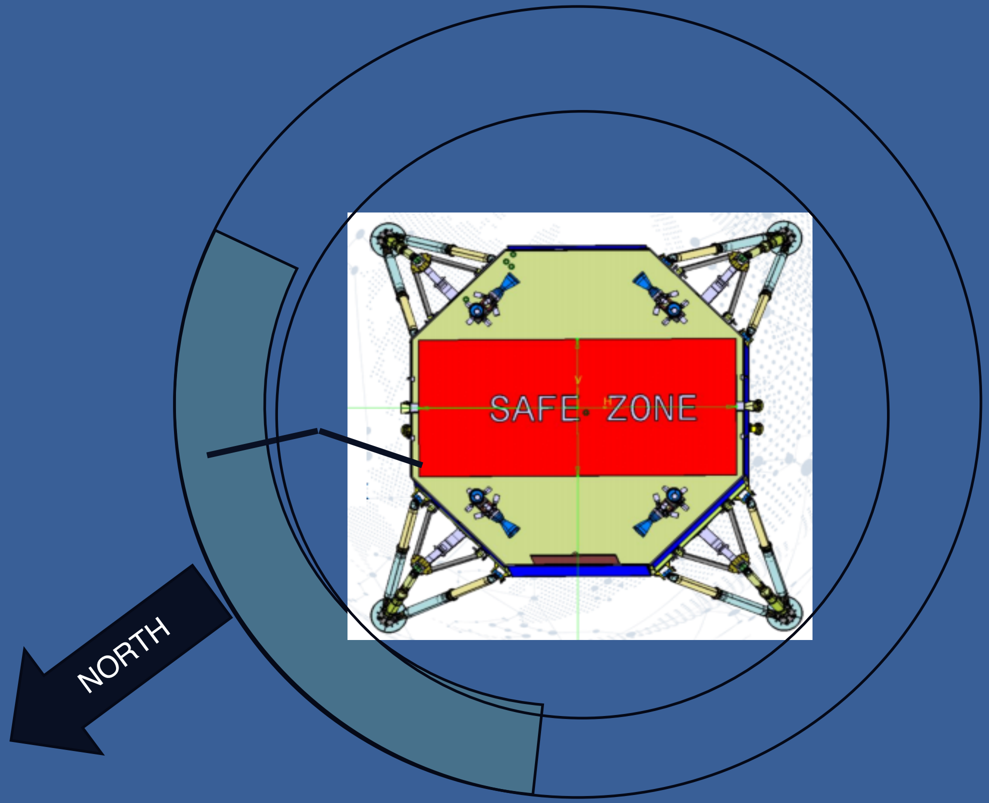
EXCAVATOR SYSTEM

Assumptions:

- End effector capacity: 0.8-1.2 kg
- Assumed adjacent surface to lander at landing site is : 0 - 5 degrees (θ)
- Depth of excavation: 30 mm maximum
- At least 3 cms of loose material available at 2 m from thruster

Performance:

- Area of excavation: 3.26 m2 – 4.76 m2
- Max volume of excavation: 98-143 litres



SPECS

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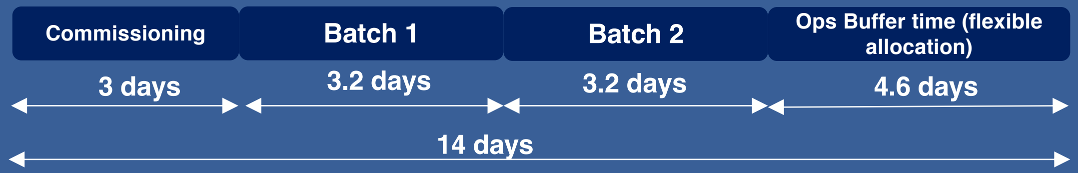
- Process cycles:
  - 1 cycle in ~3.5 days
- Power
  - Various operational modes – most demanding is heating (~630 W x 4.5 hours)
  - Total energy ~60000 W-h full mission
- Data
  - Downlink
    - TM: ~100 kbps
    - Cameras: ~400 kbps (only 1 at a time)
    - 222 Gb full mission
  - Uplink:
    - TC: ~10 kbps
  - Relay available for 4.8 hrs, unavailable for ~2 hrs.
  - Comms delay ~5 seconds
- Thermal
  - Currently use own TCS for process (cooling down the gas)
  - Reactor highly insulated
- Dust
  - Regolith tailings progressively piled up underneath lander
  - Excavator + beneficiation would likely produce some dust in the top deck

Timeline (case PM1-D – full beneficiation)



Mode (Nominal Phase batch cycle)	Duration [min]	Low data rare [Duty cycle %]	High data rare [Duty cycle %]	Data volume [Gb]
Excavation + beneficiation modes	3194.6	100%	54%	59.9
Excavation Mode	1711.4	100%	100%	
Beneficiation Mode A	3194.6	100%	0%	
Beneficiation Mode B	308.2	100%	0%	1.8
Heating_Process mode	259.5 Additional 50 min during 1st batch	100%	0%	1.6
Reaction mode + gas cooling mode	503.0	100%	10%	4.2
Total				67.5

FUTURE WORK + ANNOUNCEMENTS

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- Continuation/finalization of the study
- Earth-based demonstrator of the H2-reduction system will start implementation in August
- Phase A/B study/breadboarding

Image: Markus Reugels

- RFI from ESA closed a few days ago (was open to all regardless of geo location), science payloads, ISRU components
- **The consortium is investigating interested parties to form partnerships (Eureopean or foreign) these could be in kind exchanges/contributions or sponsorships**

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At Space Applications:

- Upcoming job opening(s) - ISRU related
- Upcoming internship opportunity(ies) – ISRU related

Stay tuned!

www.spaceapplications.com

Image: Scott Listfield