LUVMI: low-mass, low-footprint, payload and robotic system for the sampling of volatiles at the Lunar poles

Space Resources Roundtable, Golden, CO

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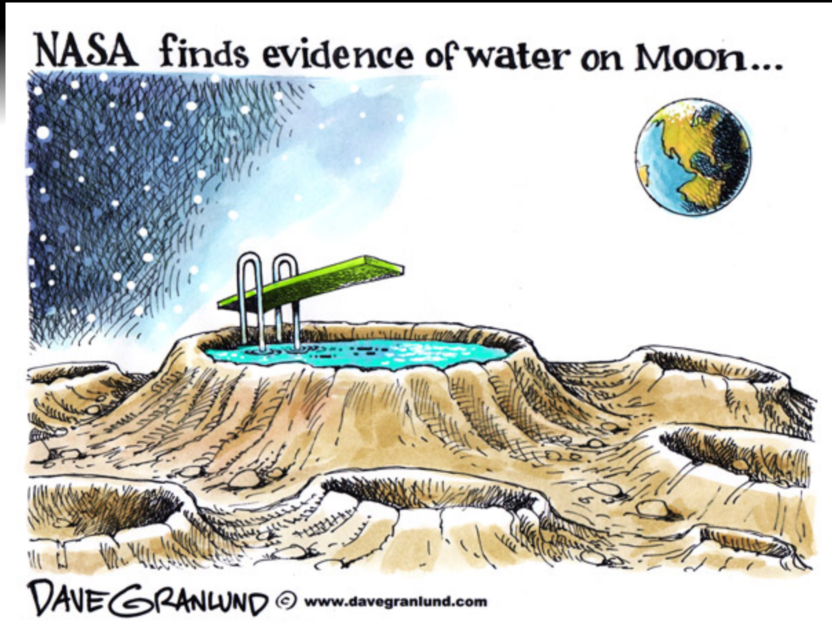
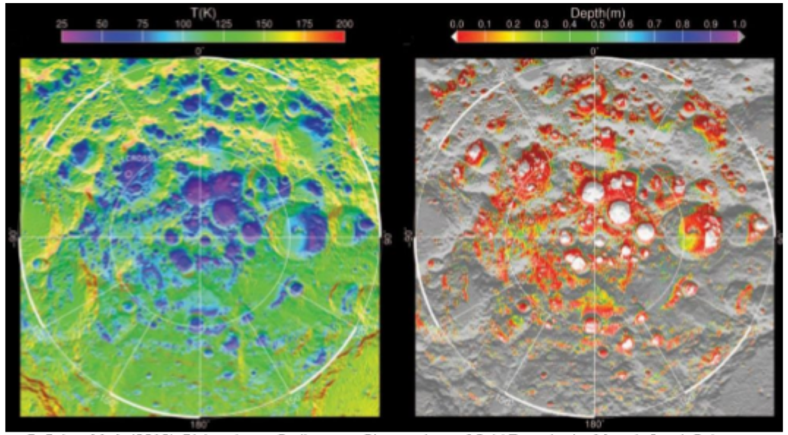
Context & motivation

- Lunar volatiles – untapped resource to kick start the space economy
- H, H2O, N, CO2, others … but where, how much?
- Prospecting missions planned but heavy-> few, far in between
- Use low-mass robotic payload





D. Paige, M. A. (2010). Diviner Lunar Radiometer Observations of Cold Traps in the Moon's South Polar Region. *Science*, 479-482.

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LUVMI

- LUVMI: LUnar Volatiles Mobile Instrumentation
- Project H2020 (COMPET-5-2016: scientific instrumentation)
- 24 months

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Objectives

- Objectives:
  - Determine variability of volatile distribution (VSAT obj. 1)
  - *Identification of chemical phase of volatile elements* (VSAT obj. 2)
  - Analysis of physical & chemical behavior of lunar soil with T° (VSAT obj. 3)
  - Determine geotechnical properties (VSAT obj. 4)
  - Current volatile flux (VSAT obj. 5)

- A small mobile payload addresses 4 objectives (+1 partially)

	Static lander with limited subsurface access	Static Lander with drill	Rover		
			Surface sampling only	Limited subsurface access (<20 cm)	drill (>1 m)
Variability of volatile distribution	1	2			
Chemical Phase of Volatile Elements	3		4	5	
Chemical and physical behavior of polar soil with temperature			6		
Geotechnical properties			7		
Current volatile flux					

Credits LEAG VSAT

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Scientific objectives

- Scientific objectives:
  - Detect/quantify abundance of loosely bound volatiles
  - Identify chemical phase of detected volatiles
  - Investigate migration of volatiles over lunar surface
  - Determine engineering properties of regolith in polar regions.

- Expected detection:
  - Water
  - Volatiles observed during LCROSS

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Mission Baseline

- Landing site:
  - 1km distance to PSR
  - >80 deg latitude
  - 40% solar illumination [avg. time]
  - 40% Earth visibility [avg. time]
  - No major obstacle in 250m radius
- Mission
  - 14 days
  - Increasing order of risk
  - Hibernation possible for 48h
- Sampling locations:
  - Vicinity of landing site
  - Regular illumination sites
  - Non-permanent shadow region
  - Night/day termination event
  - Vicinity of PSR
  - PSR

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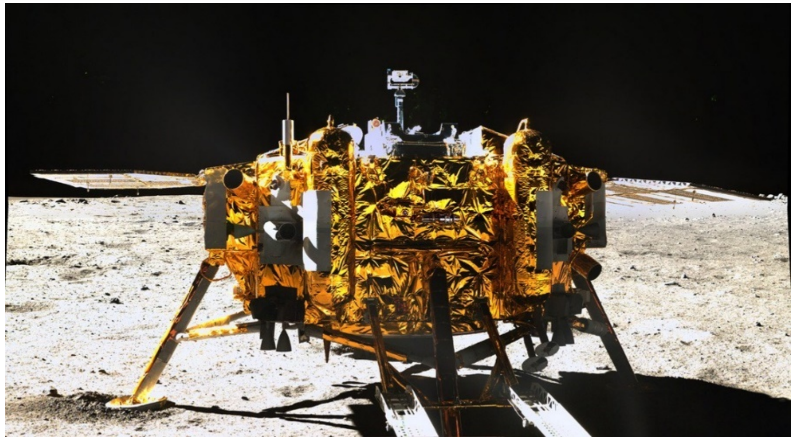
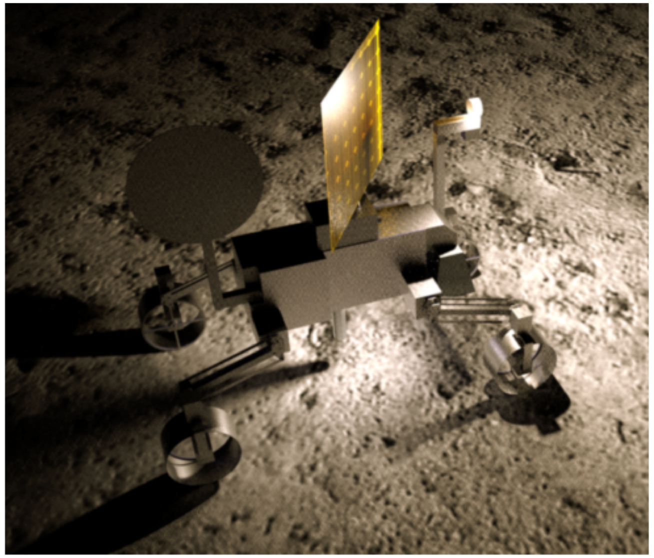
Mission Baseline

- Flight: Design LUVMI to accommodate most landers
  - Piggy back(Change’e, Luna-[25,27,28,29], NASA Resource Prospector)
  - Commercial lander (Astrobotic , PTScientists…)



- Design LUVMI to withstand PSR environment



- Independent from Lander

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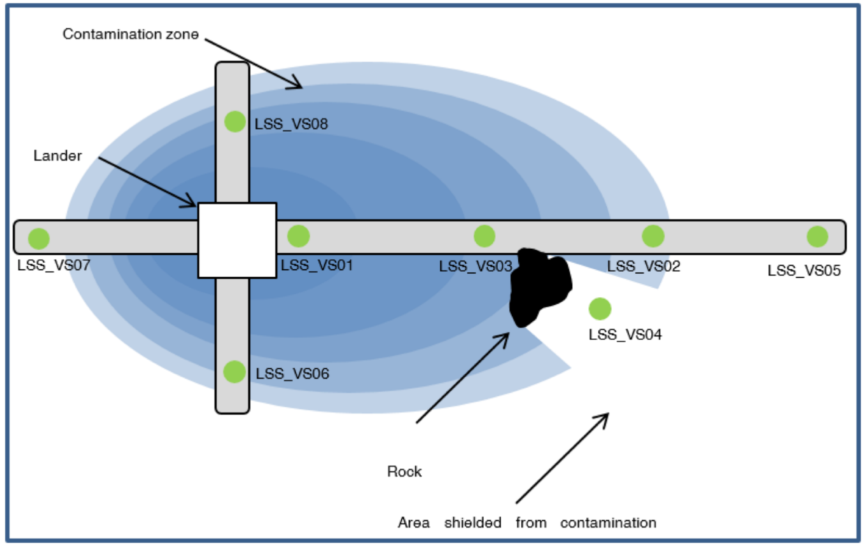
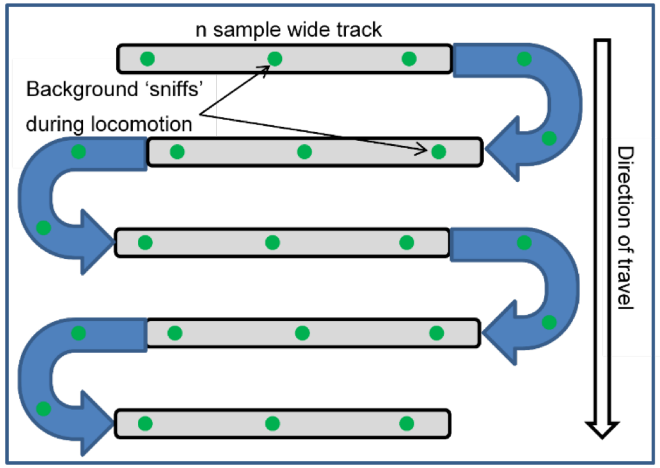
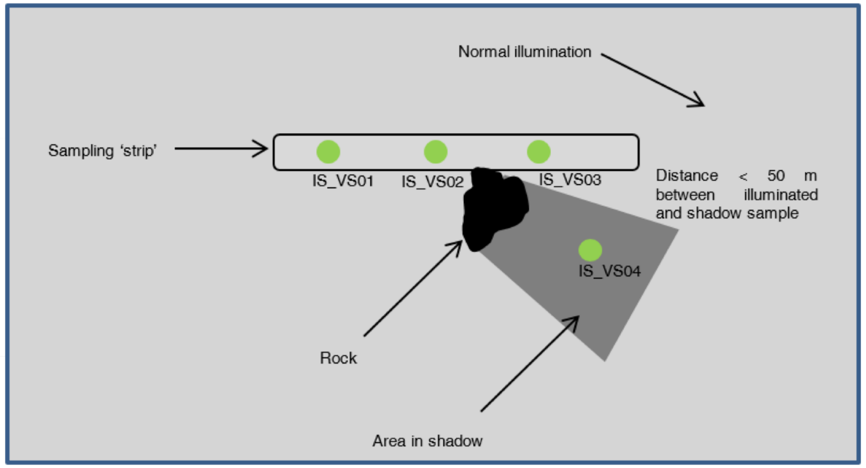
Concept of operation

- Post landing-checkout
- Rover egress
- Landing survey
- Wide field area survey
- Terminator passage survey
- PSR survey







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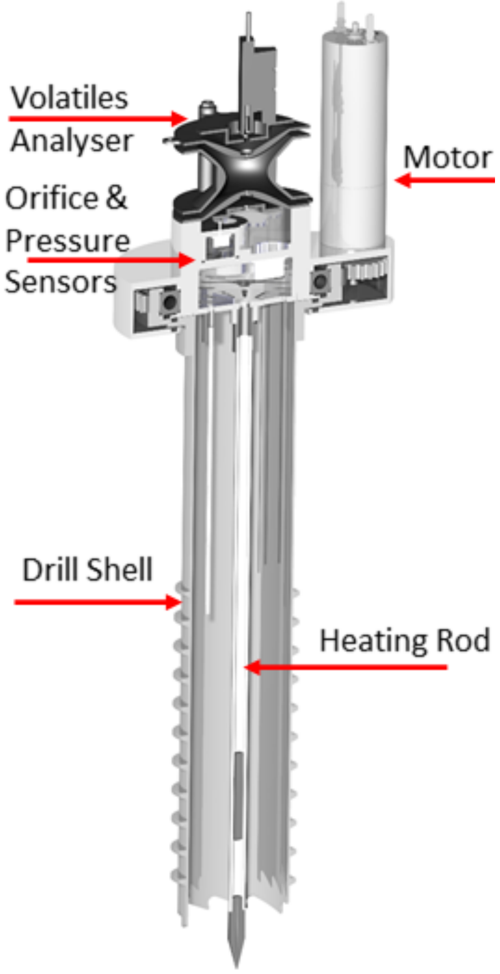
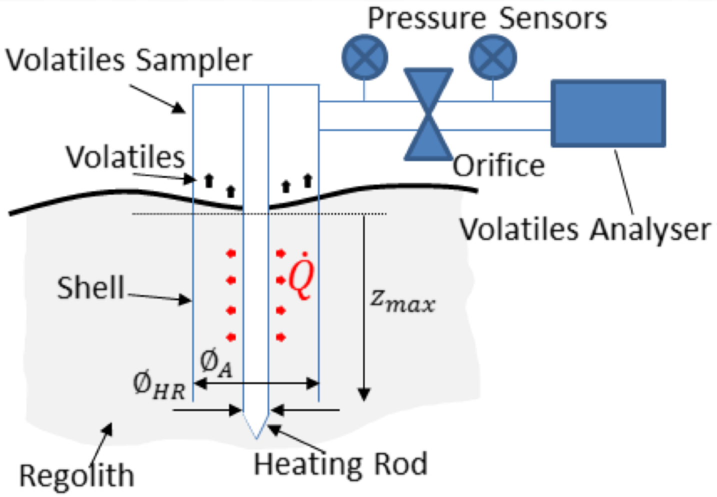
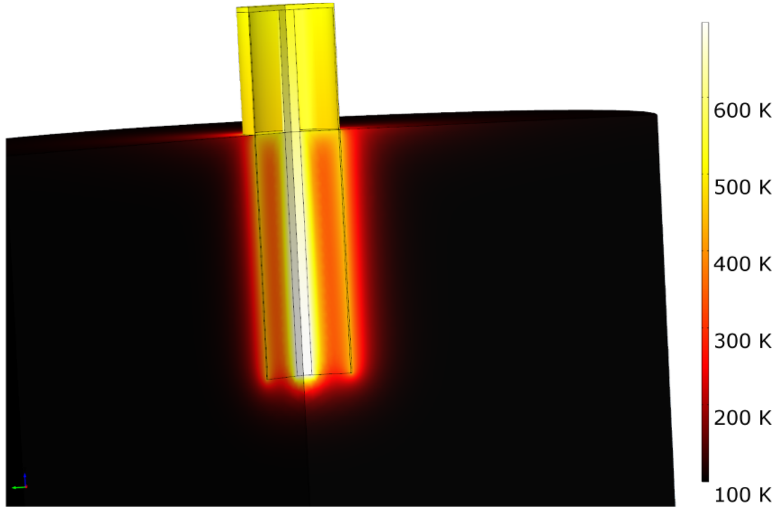
Instruments: Volatile Sampler

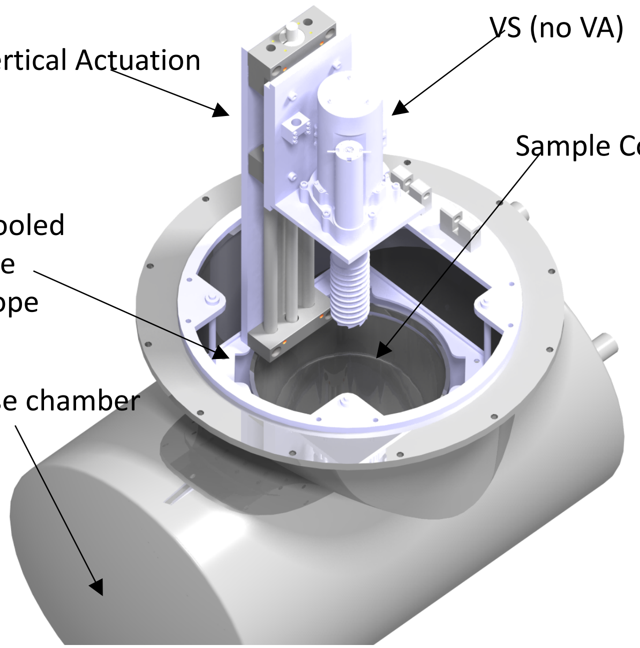
- Drill + sample preparation + gas extraction
- Operation:
  - Get rover into drilling position
  - Drill (10 cm deep, possibly up to 20 cm)
  - Heat central rod
  - Extract/analyze trapped volatiles
- Low heat conductivity of Regolith
  - High gradient







Instruments: Volatile Sampler



Volatiles Extraction Test

#	Description	Status
Test 1	Mechanism Functionality Test (OHB)	Successful
Test 2	Penetration Test (OHB)	Ongoing
Test 3	Materials Outgassing Test (OHB)	Ongoing
Test 4	Volatiles Extraction Test	In preparation
Test 5	E2E VA/VS Integrated Gas Extraction & Analysis	In preparation
Test 6	Rover Demonstration	-

Penetration test

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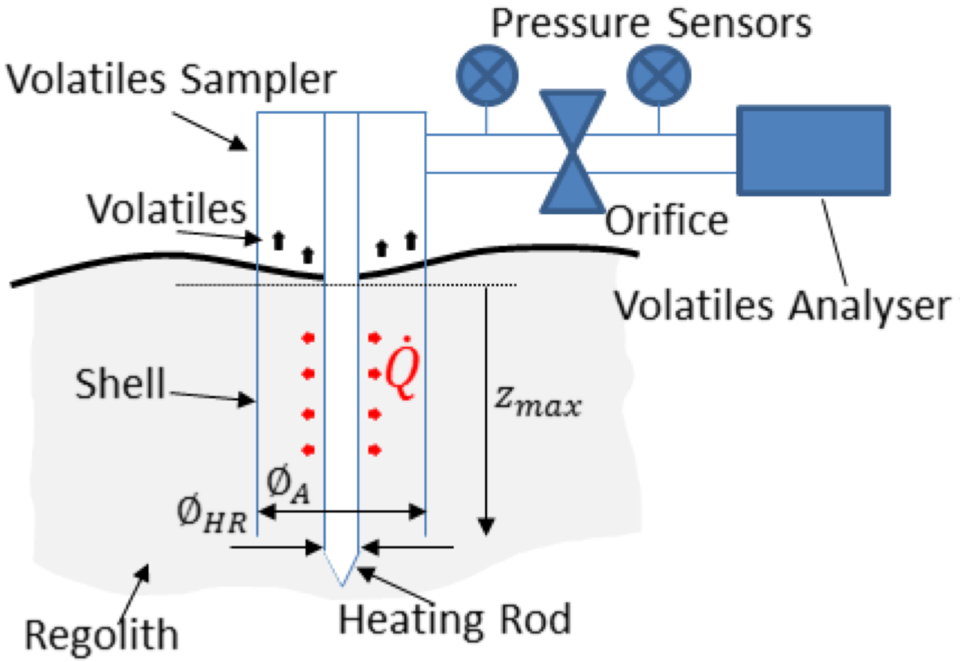
Instruments: Volatile Analyzer

- Placed on top of Volatile sampler
- Ion trap mass spectrometer
- Based on heritage of Rosetta mission and on UK MoonLite mission instrument



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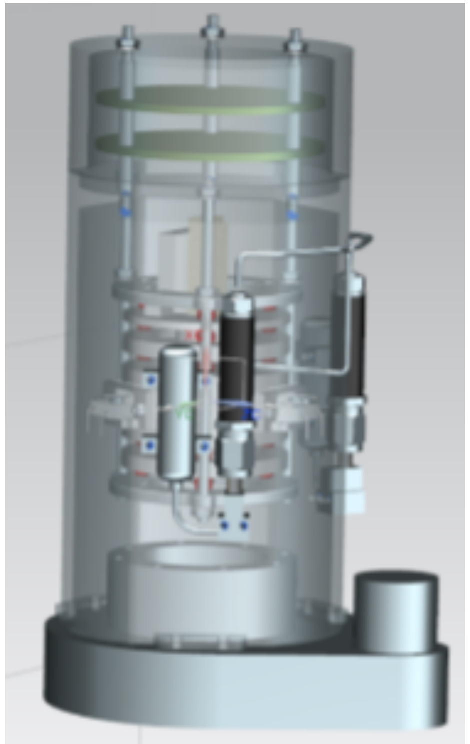
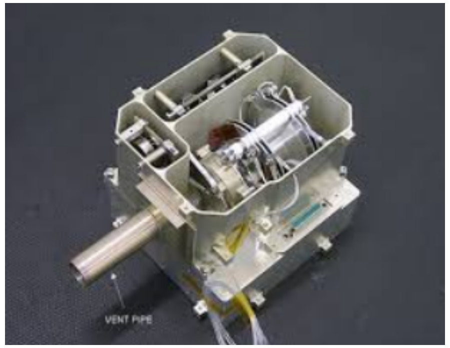
Instruments: Volatile Analyzer

- Detect: H_2S, NH_3, SO_2, C_2H_4, CO_2, CH_3OH, CH_4

- Simple, low mass, compact
- Low detection levels

- Reference gas system, in-situ calibration





Rosetta ptolemy mass spec

LUVMI mass spec (VA)

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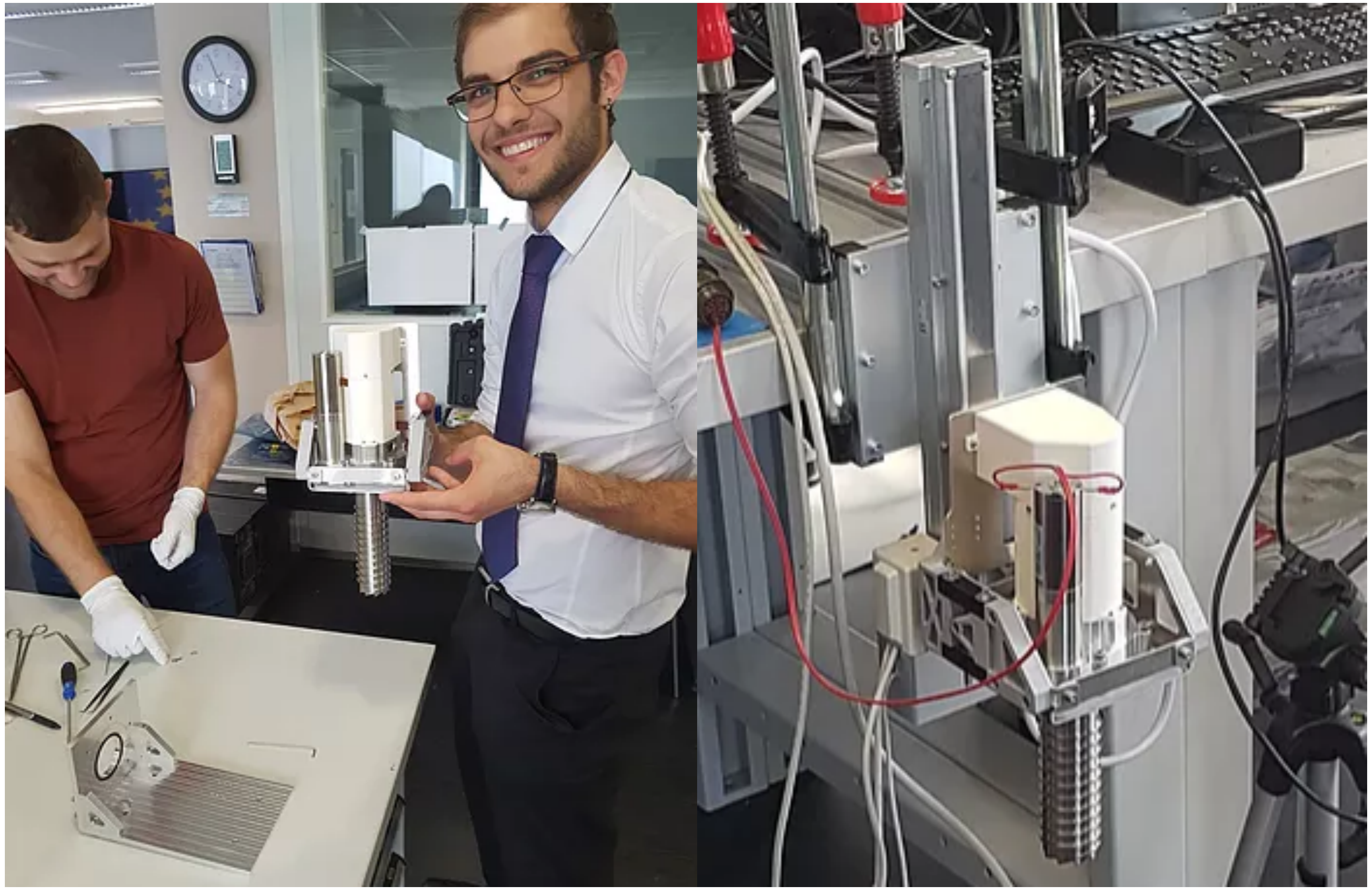
VA-VS assembly (payload)

- For prototype:
  - Mass VS+VA= 1,8 kg plus margins
  - Mass VS+VA electronics= 1 kg plus margins
  - Max Power during Analysis VS+VA= 26 W



Preliminary integration (End of May 2018)

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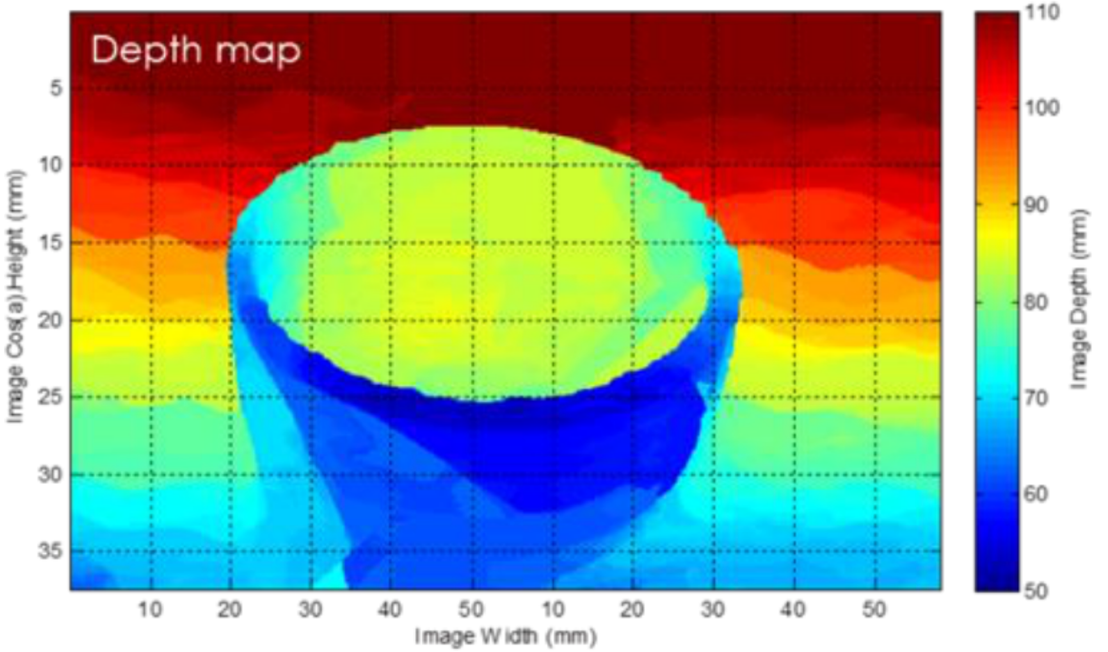
Instruments: Imager

Technology

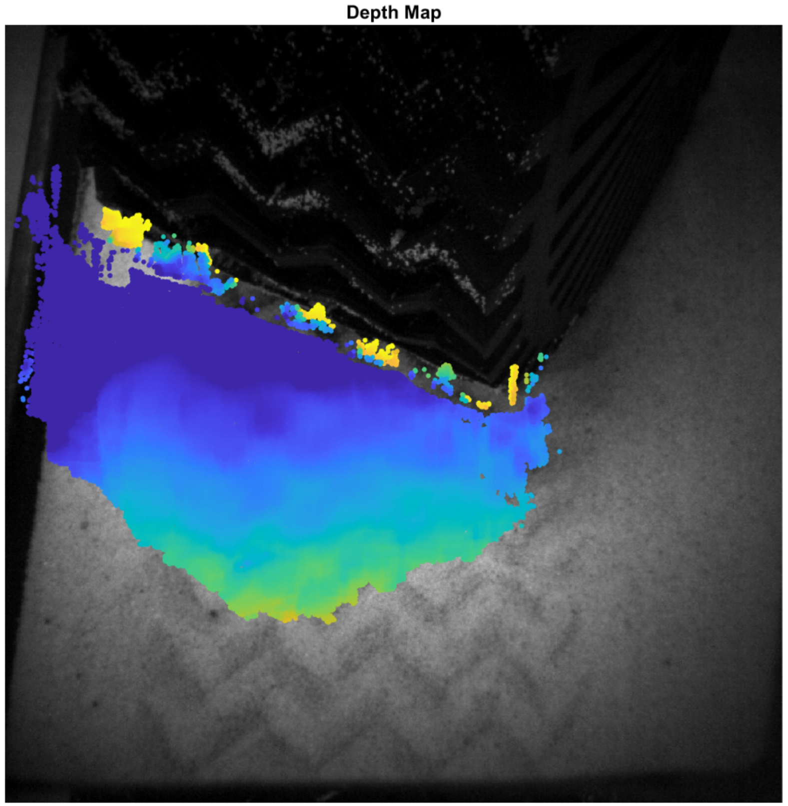
- Light-field imaging
- Micro-lens array
- Extracts depth map

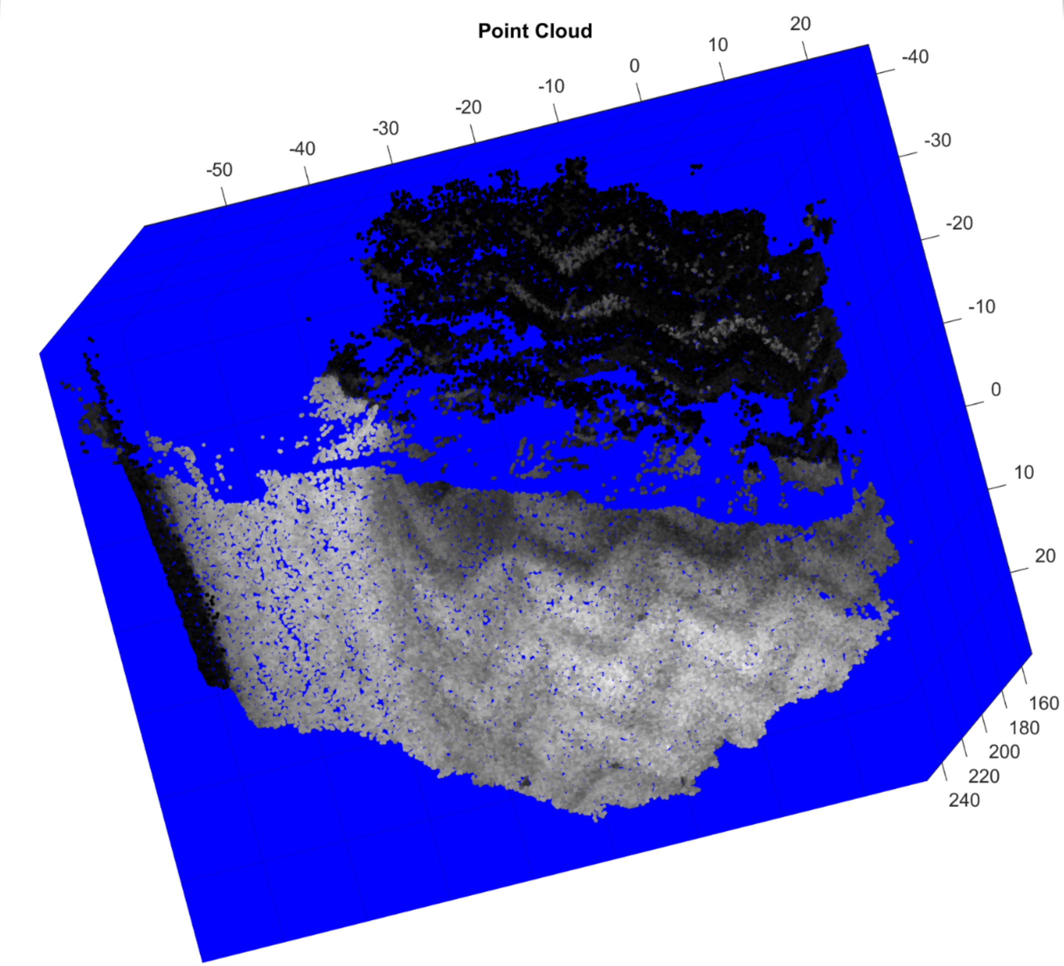


Provides

- Info on rover's environment
- For navigation, teleoperation and science

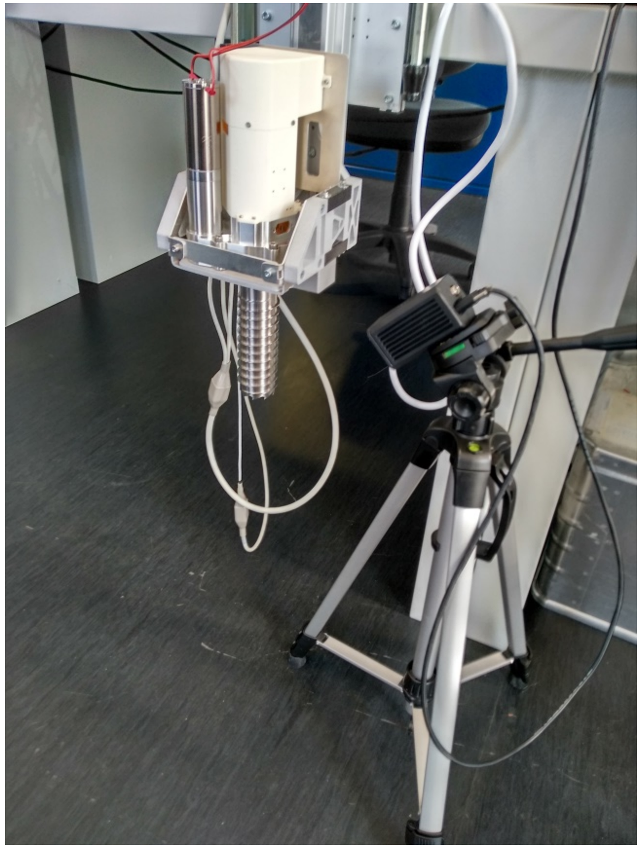
Instruments: Imager

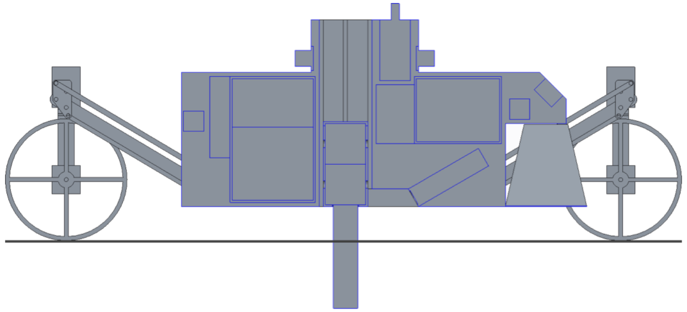




Instruments: Imager

- Imager in mast (navigation)
- Imager under chassis
  - Monitor sampling process
  - Measure geotechnical properties





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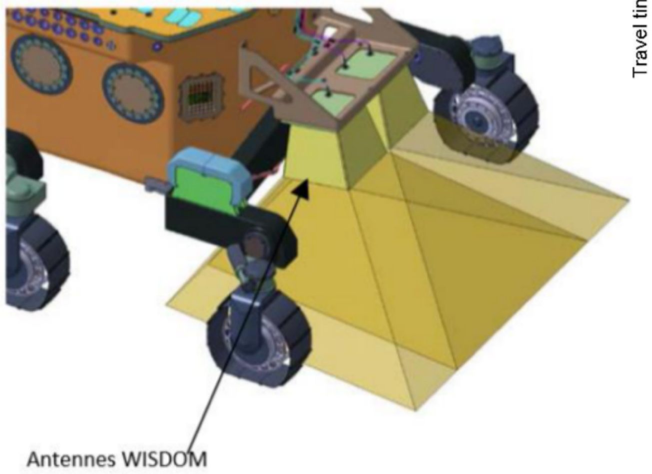
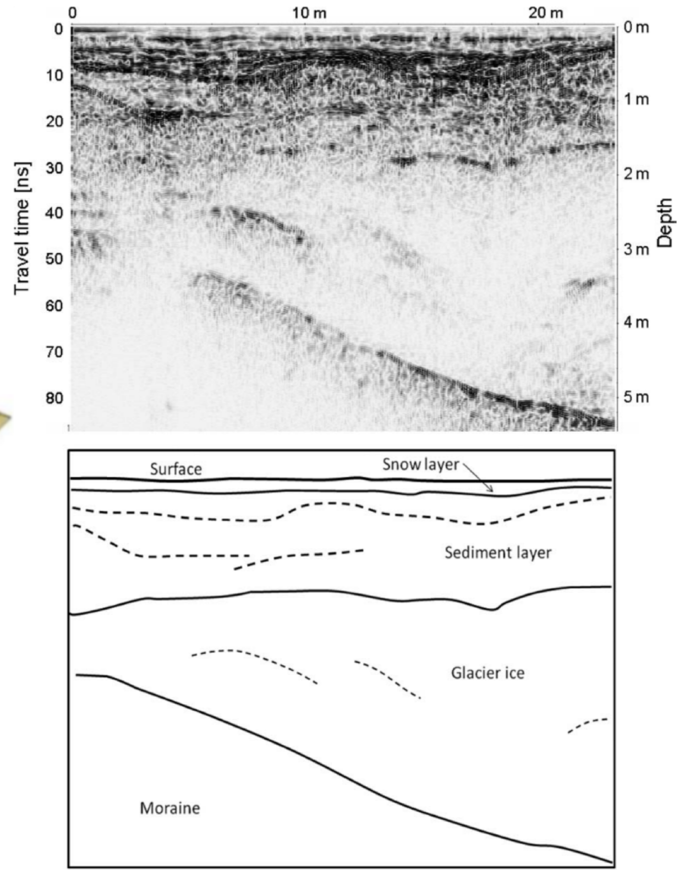
Instruments: Ground penetrating radar

- Possible Secondary payload
  - WISDOM - based on exoMars heritage
- Get subsurface context + correlate with measured volatiles
- Information before drilling
  - Hardness

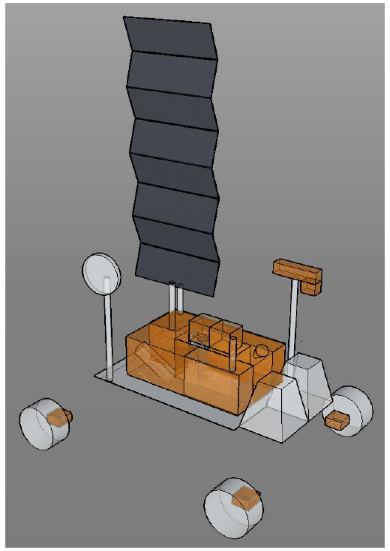


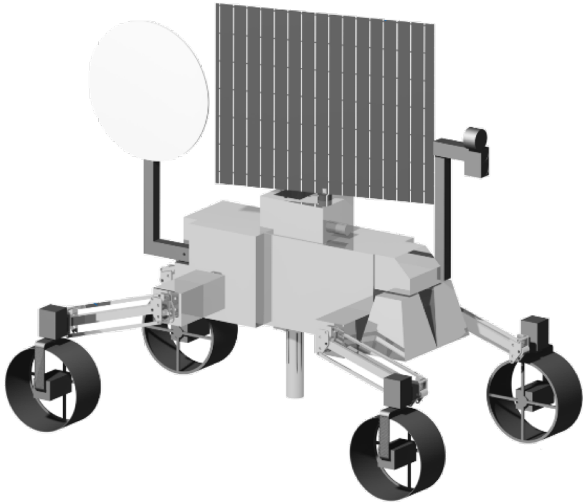
WISDOM on ExoMars rover: Image courtesy of LATMOS

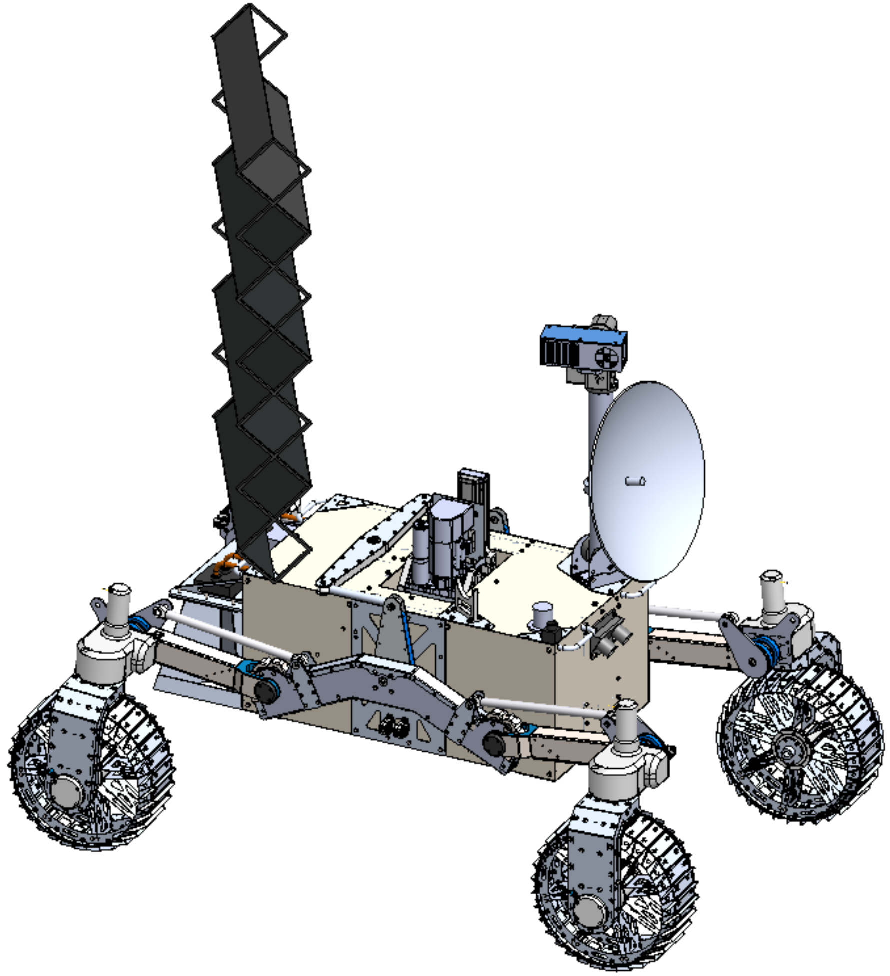


Mobile platform

- Flight Model -> preliminary design
- Ground Model -> prototype
  - Demonstrate critical functions
  - Test in earth-based analogues







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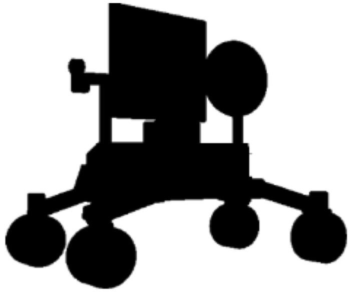
Mobile platform

NASA LRP: 1.5m x 1.5m x 2.0m
Weighs about 300kg



LUVMI: 1.5m x 1m x 1.6m (deployed)
Weighs about 40 kg

1m x .7m x .7m (stowed)

- Note LRP has/had many functional differences: sealed manifold, controlled heating, quantitative measurements, water droplet experiment, ilmenite reduction (?), deep access
- LUVMI is conceived as an “LRP LITE” w/ reasonable compromises, achieving a much lighter payload and rover

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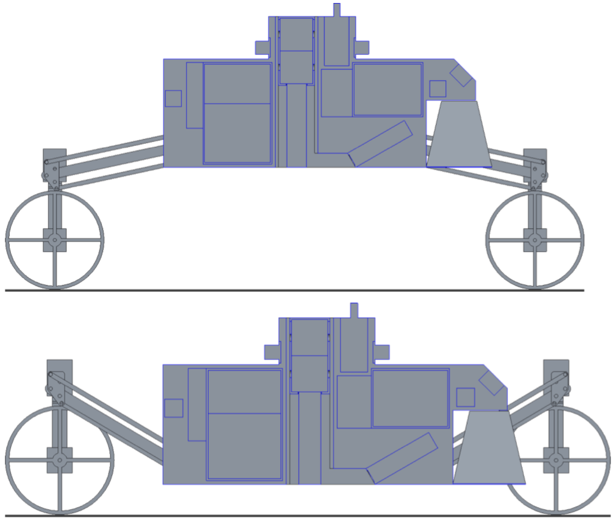
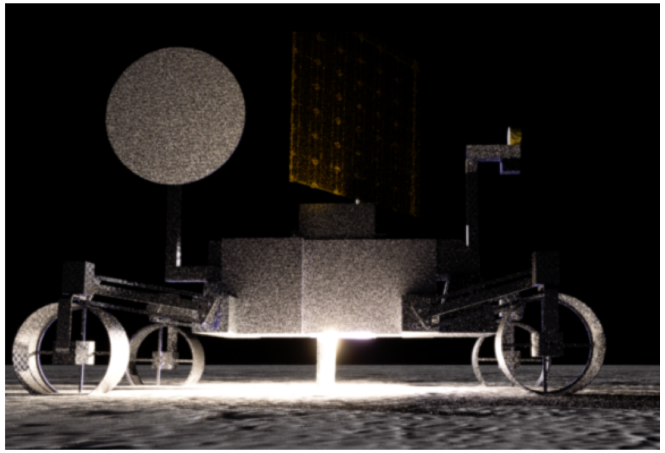
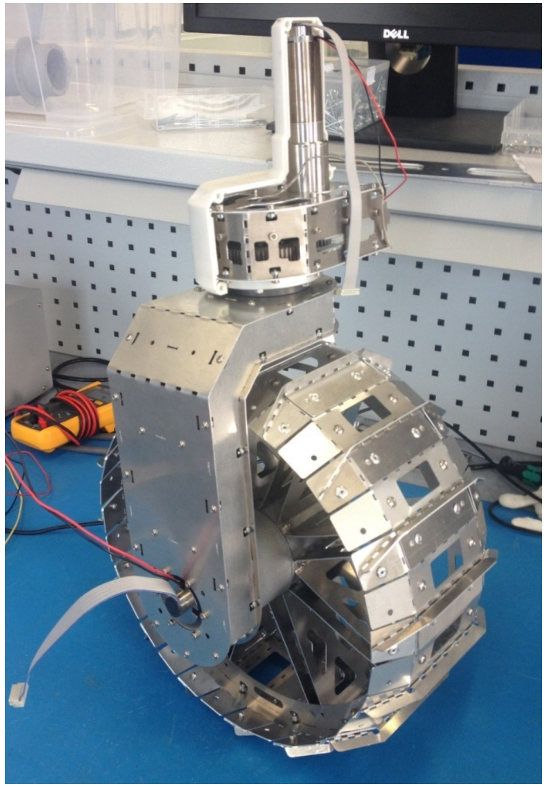
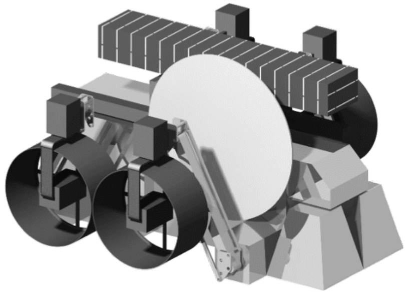
Mobile platform

- Active suspension
- Enables drilling operation
- Used for facilitating stowage in lander
- Compact system in lander
- Large wheelbase & front track
- Larger ground clearance









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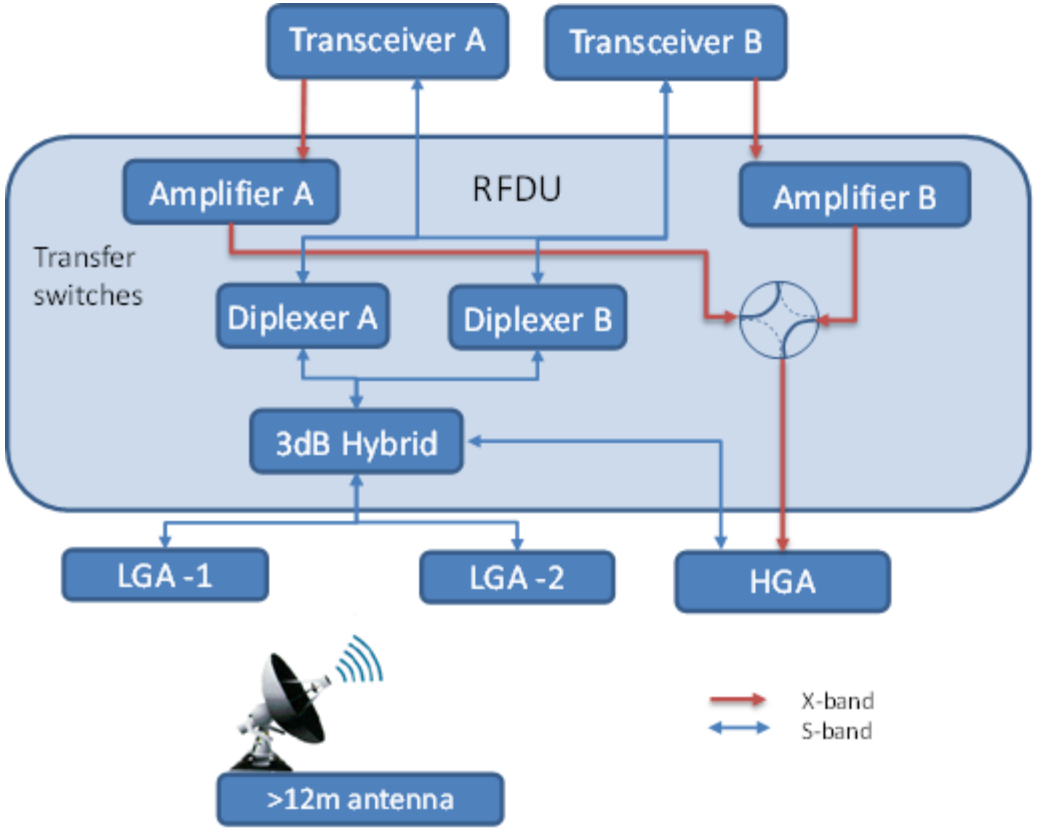
Mobile platform sub-systems

- Communication
  - High/low gain: Direct-To-Earth communication
  - Lander or orbiter comms possible when and if available (not req'd)
- Power
  - Plan to use high-density batteries (Li-S)
  - Will be changed if TRL low by time of building system/ if low temperature battery-less architecture feasible
- Thermal
  - Provide heat to keep system alive
  - in PSR
  - During hibernation



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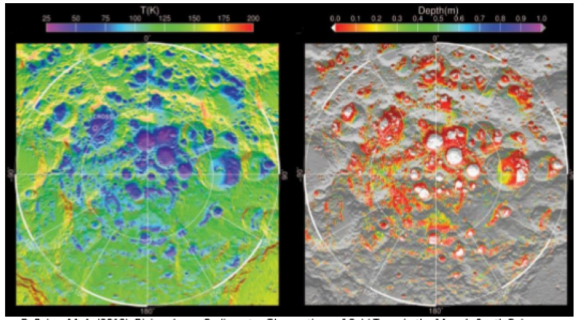
Conclusion & future work

- Sum-up:
  - 40-kg high-mobility rover, survives PSRs. State of the art miniature analyser and sampler, GPR, lightfield imager.
  - Flexible design, can piggyback in agency, commercial missions
  - **Additional payloads welcome**
- On-going and future work
  - Building instrument and mobile platform system
  - Test instruments in vacuum
  - Test integrated system in earth-based analogue
  - **BLTAS: ESA GSP project**
    - **Studies battery-less “low-temperature” architecture**
    - **Using LUVMI as case study**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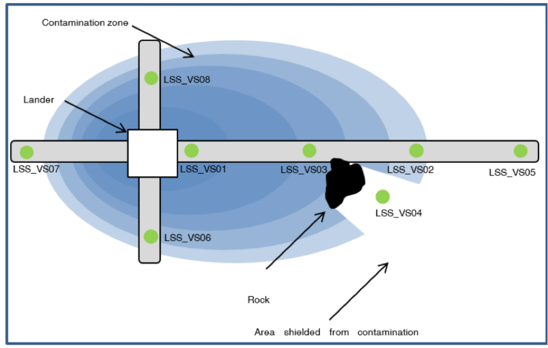

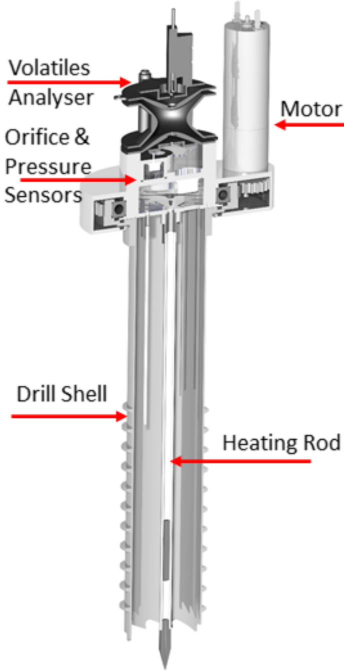

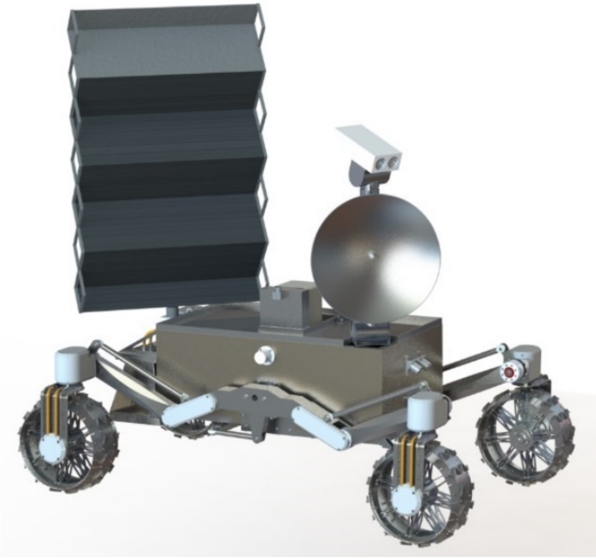

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