Orbit Recycling

Turning Waste Into Value

Frank Koch

Founder Orbit Recycling

Berlin, 09/2022

Orbit Recycling

Wertstoff aus dem All

BUILD Recycling & Waste Management Awards

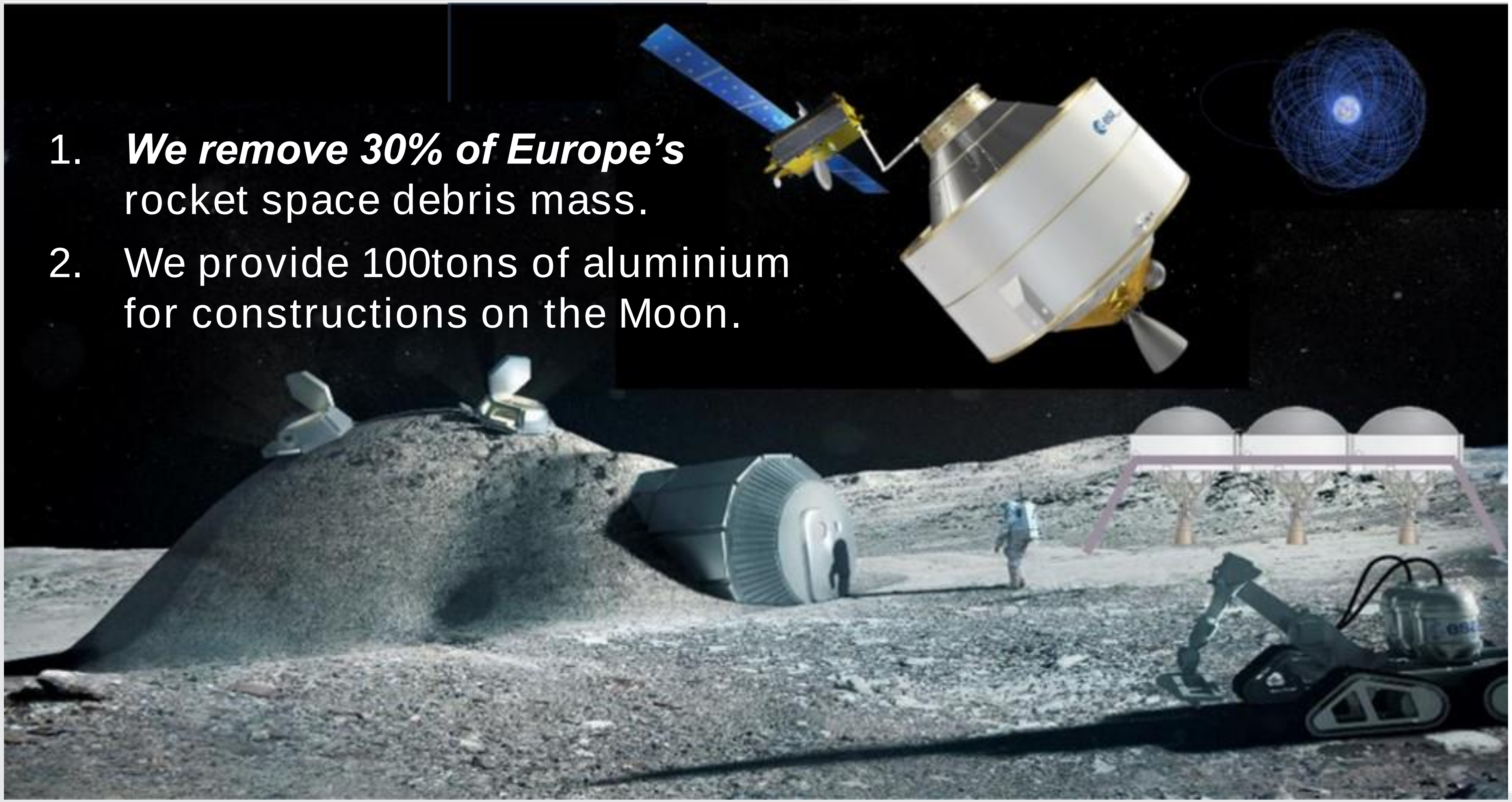
Orbit Recycling

Most Pioneering Aluminium Recycling Company 2020

CorporateLiveWire INNOVATION & EXCELLENCE AWARDS 2021

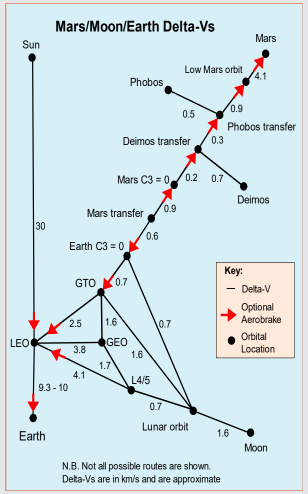
3rd Place 2021 Airbus Challenge

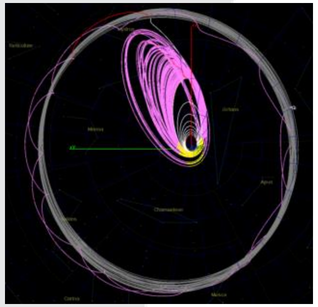
Orbit Recycling turns waste into value to start a circular economy in space.



Our approach & technical details were validated in an ESA study 2020 / 2021.

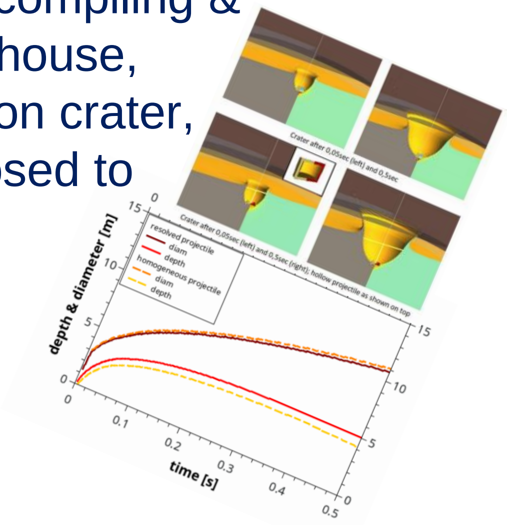
Proprietary database of debris objects, orbits tumbling rates, …





Trajectory simulations, delta-v calculation & propulsion sizing & grabbing concepts

Proprietary landing concept incl. object decompiling & dynamic warehouse, registered Moon crater, concept proposed to COPUOS



The aluminum would be cast in regolith to produce wall segments for the Moon station.
https://doi.org/10.1016/j.actaastro.2021.01.045

Our melting & casting process independent from debris; ISRU or Earth transports fine, too.

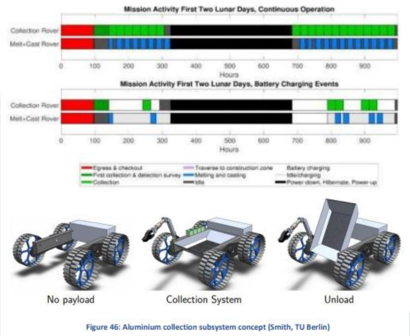


Figure 46: Aluminium collection subsystem concept (Smith, TU Berlin)

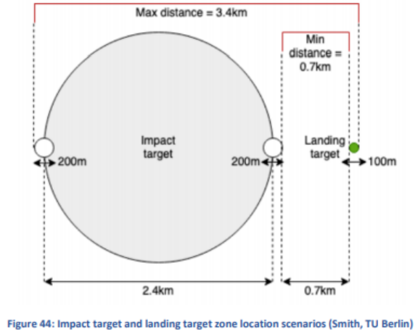


Figure 44: Impact target and landing target zone location scenarios (Smith, TU Berlin)

Material retrieval via rover or partner technology (NDA / contract in place)

Business case for 100t recycled aluminium (EUR)

	Small lander	EL3 mission	SLS mission	Recycling mission
Payload / Recycling mass	200kg	1500kg	4000kg	2200kg
Number of missions (100 tons)	500	67	25	55
Price per ton / per recycling tug	1 billion (1 million per kg)	500 million (750 million per 1,5t)	250 million (1.000 million per 4t)	150 million
Avg. launch cost per mission	Incl.	Incl.	1.000 million	60 million
Mission operation costs	1 million	1 million	1 million	4 million
Total price for 100 tons	100,5 billion	50,3 billion	25 billion	11,8 billion
Costs for Moon infrastructure				50 million
Replacement costs (1 EL3 mission)				750 million
No. of replacements over 10y				5 (2y lifetime)
Total costs lunar infrastructure (10y)				4 billion (2y)
Total price per option	100,5 billion	50,3 billion	25 billion	15,8 billion (2y)
Price per kg Al	1 million	503.000	200.000	158.000
Total Savings	84,7 billion	34,5 billion	9,2 billion	/

In addition, 30% of the European rocket debris mass is removed.

Our timeline is aligned with the official Moon exploration program of the space agencies.

Precursor Missions
2022 – 2025

Visual inspection of upper stage
- Tumbling rate, material aging, …

Validate Technologies
- 8K-camera (PTS), Grabbing tools

Terrestrial Melting & Casting Tests
- Solar melting & dust prevention

Demonstration Missions
2026 – 2030

GTO Recovery
- Tug upper stage to Moon

Lunar Melting & Casting
- Test lunar lander
- Test lunar rover
- Execute AL recycling

Commercial Recycling
2031 – 20xx

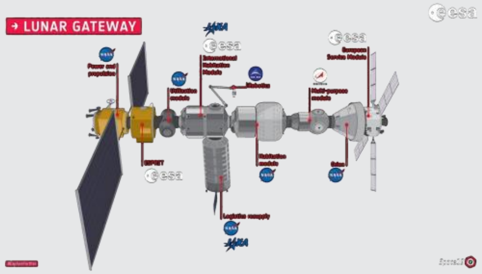
Serial Production
- Space tugs, landers, rovers…

Space Debris Removal
- 100+ upper stages in GTO

Lunar Recycling Industry
- Raw material supply for ESA

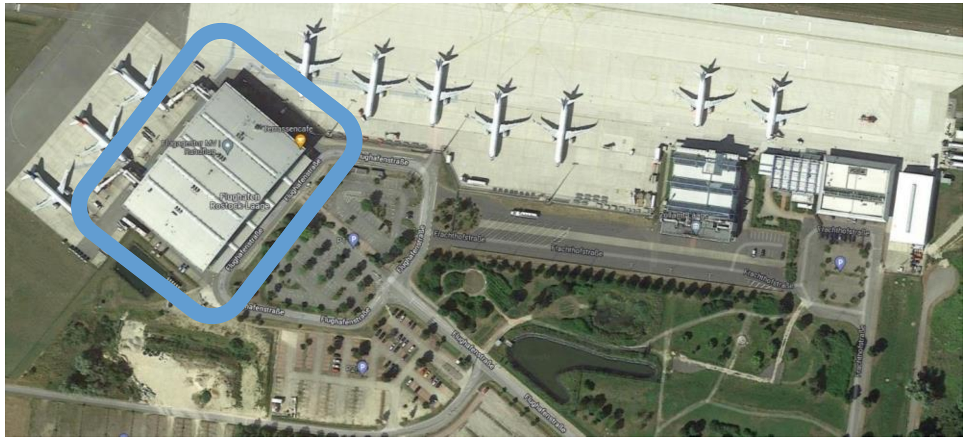
2025-28
Lunar Surface Visit

2028+
Lunar Orbit Gateway



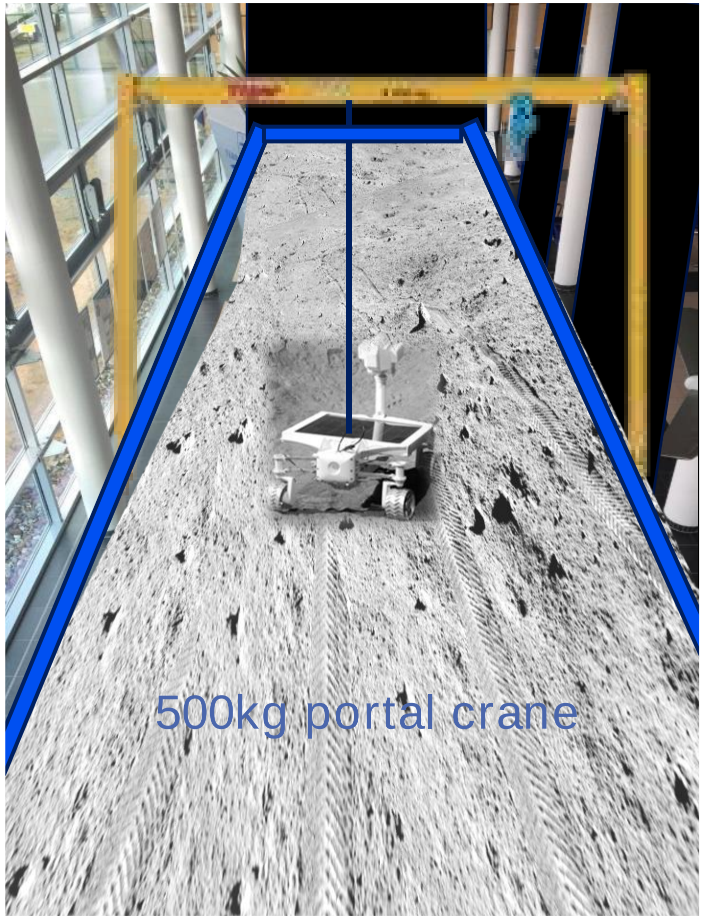
2030+
Lunar Surface Station

This fall, we open our Moon Testbed.



- Located at Airport Rostock
  - 90m² of “moon dust” simulant
  - Ideally suited for rover & ground tests
  - In close partnership with PTS, Berlin
- Open to industry & research institutes
  - Book your slot at https://TestingFor.Space
- Solar melting technology enhancements (TRL 5/6) till 2023
  - Partnership with EAC, Cologne
- Rover maturation & industrialization (TRL 7/8) till 2024
  - Partnership with PTS, Berlin

Public airport terminal



500kg portal crane

Awards and Partner Network

Awards

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Space Observations

Fraunhofer FHR

GAUSS – Group of Astrodynamics for the Use of Space Systems

ОРДЕНА ЛЕНИНА им. М.В. КЕЛДЫША РАН

Research

Technische Universität Berlin

Museum für Naturkunde Berlin

Technische Universität Braunschweig – Institute of Space Systems

Spaceship EAC

Universität Stuttgart

Business Networks

Paris Peace Forum – NET ZERO SPACE – Sustainable outer space by 2030

esric

Moon Village Association

PromoMoon Initiative

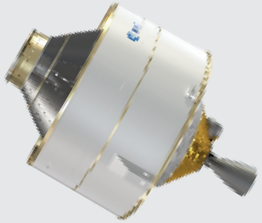
Technical Details (Overview)

Orbit Recycling

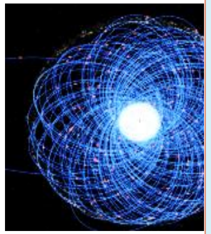
Wertstoff aus dem All

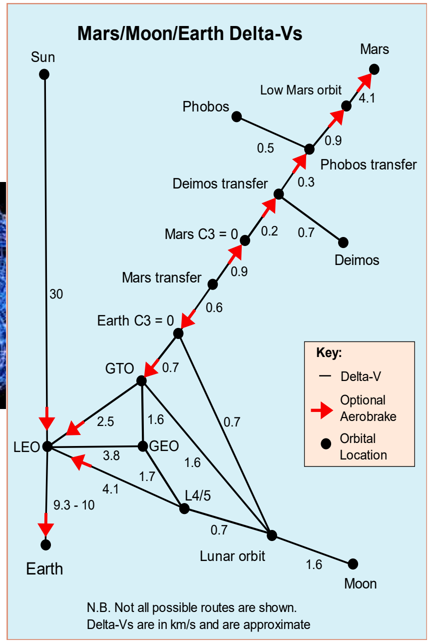
Space Debris: Threat & Opportunity

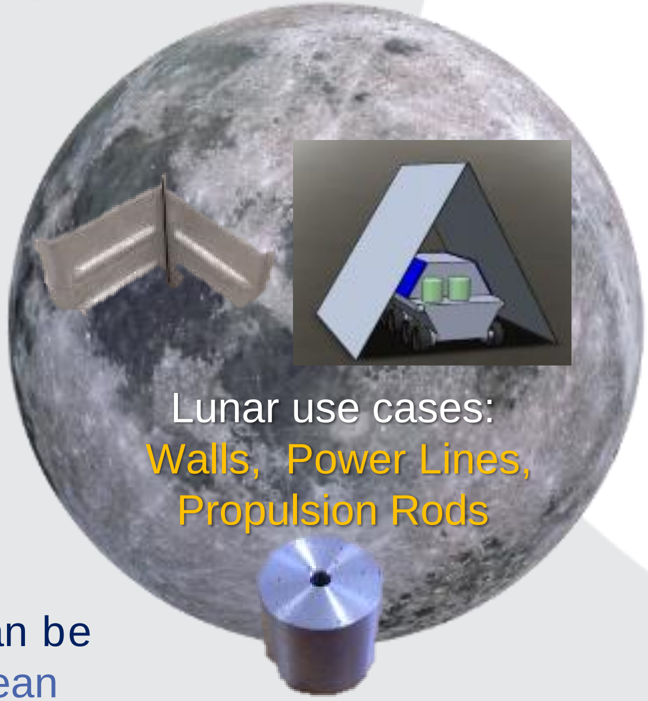
Space debris, like Ariane 5 upper stages, are a great source of raw materials.



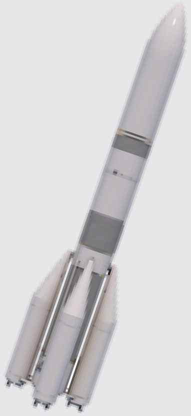
The upper stages are located in GTO. Roughly 75% of the Moon transfer energy (delta-v) is already paid.





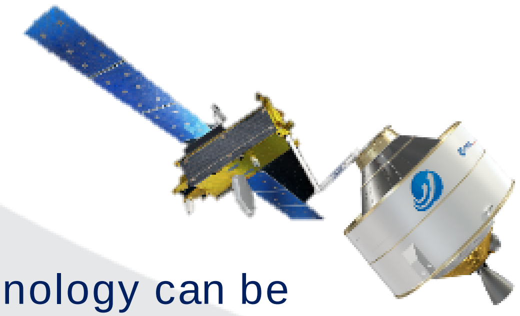


Lunar use cases:
Walls, Power Lines, Propulsion Rods



© ESA

The lunar recycling Infrastructure can be launched & transported with European launcher (Ariane 6) & landers (EL3).

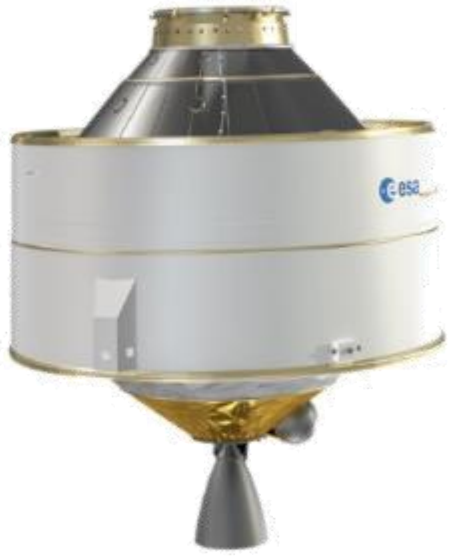


The required technology can be derived from existing mission concepts, like ClearSpace-1 and others.

Selecting the ideal debris for recycling

Criteria / Target	Satellite (mega) constellation (LEO)	"Galileo" satellite fleet (MEO)	Large GEO satellites	Ariane 5 ESC-A upper stages
Object Composition	Known, not public.	Known, not public.	Known, not public.	Known, not public.
Identified Recycling Material (RM)	Metal / Aluminium	Metal / Aluminium	Metal / Aluminium	Metal / Aluminium
RM ratio vs. total (dry) weight	<15%	<20%	<25%	>60%
RM amount per object	<50kg	<140kg	<250kg	>2,000kg
Object orbit	LEO	MEO	GEO	(Mainly) GTO
Object traceable from	Earth & space	Earth & space	Earth & space	Earth & space
Object interfaces for connecting	Proprietary	Payload Adapter	Payload Adapter Nozzle	Nozzle Payload Adapter
Scaling benefits (no. of objects)	Hundreds to Thousands	Dozens (~26)	Dozens (~20-50 per bus)	Dozens (~60 ESC-A,)

Table 1: Evaluation of Space Debris Criteria



Tumbling rates of upper stages in GTO

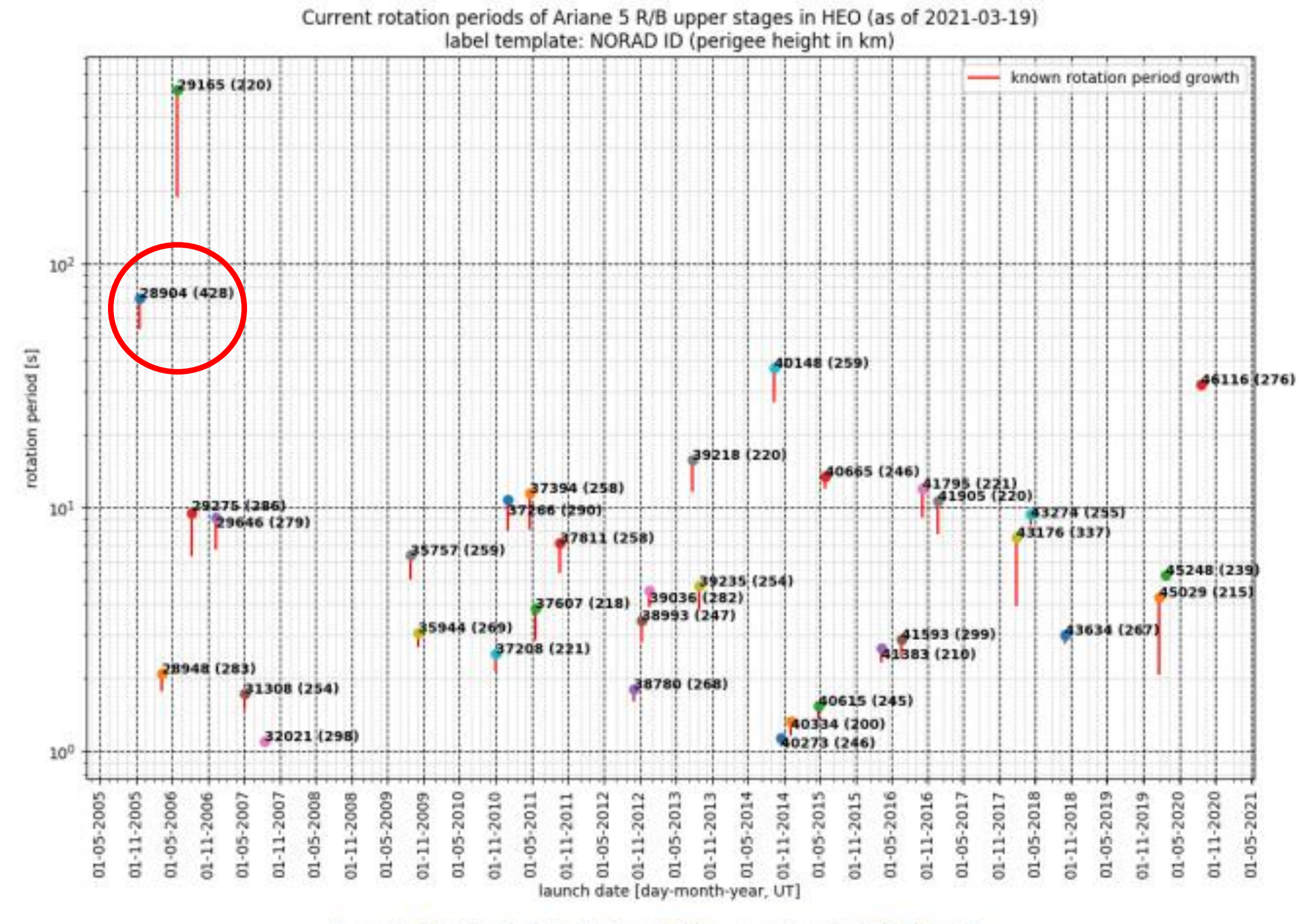
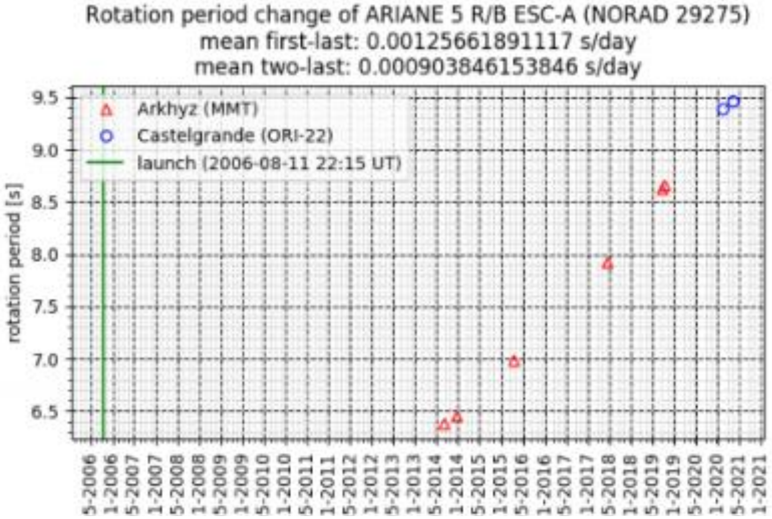
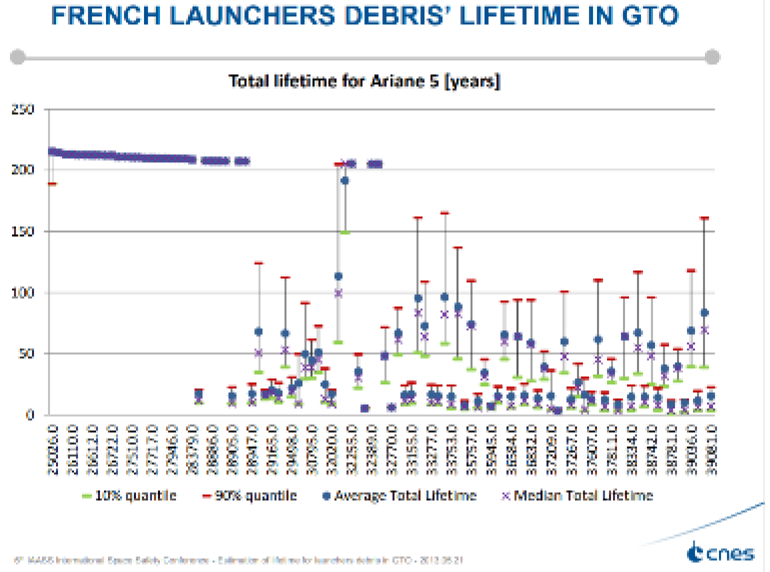


Figure 14: Rotation Periods of Ariane 5 ESC-A upper stages in GTO (Schmalz)





Kindly supported by Sergei Schmalz, Castelgrande Observatory

Gripping concepts for upper stages

- Worldwide research on gripping solutions (top, bottom, side)

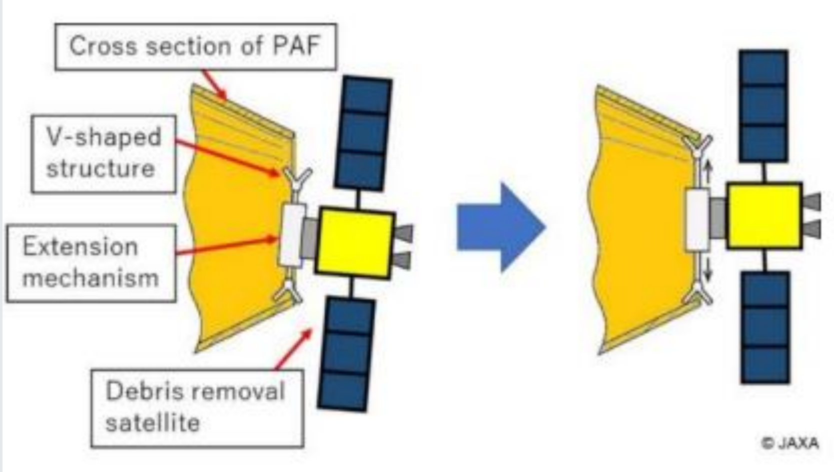


Figure 26: PAF capturing method of developed end-effector (JAXA, (181))

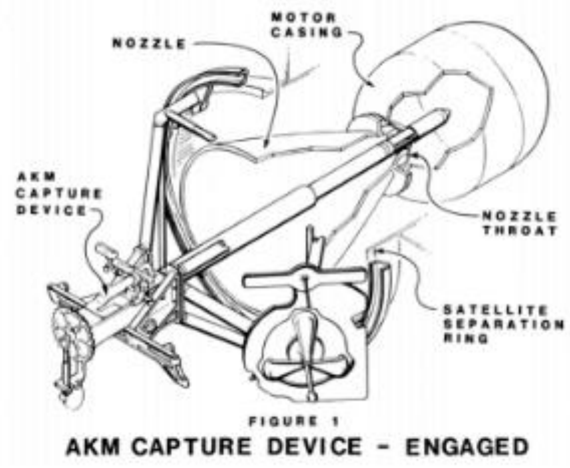


Figure 27: Apogee Kick Motor capture device (NASA, (182))

Ongoing Research with TU Berlin

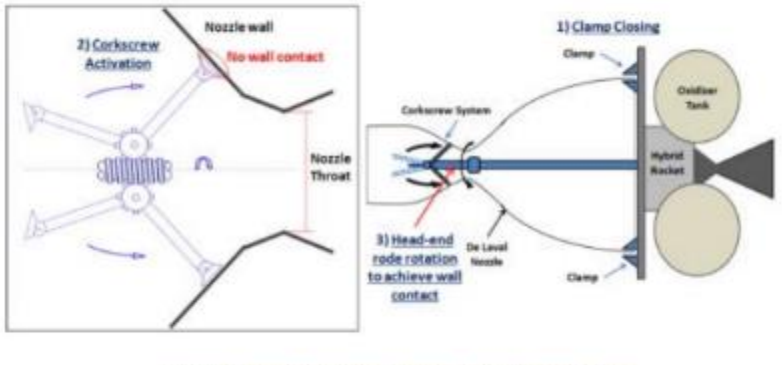
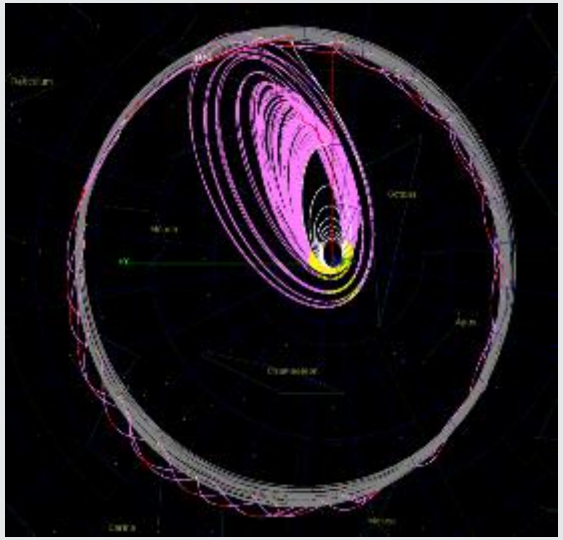


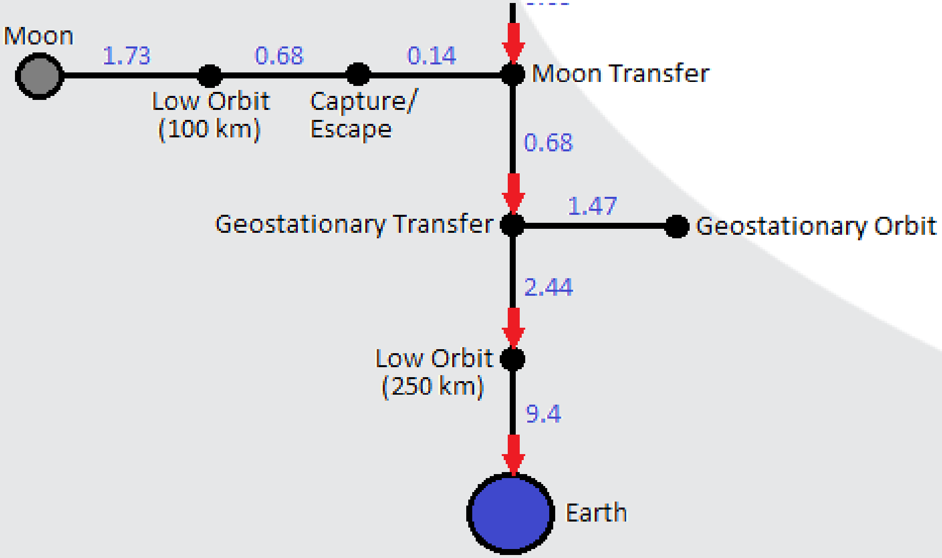
Figure 28: Nozzle-based "corkscrew" docking solution (DeLuca et.al., (183))

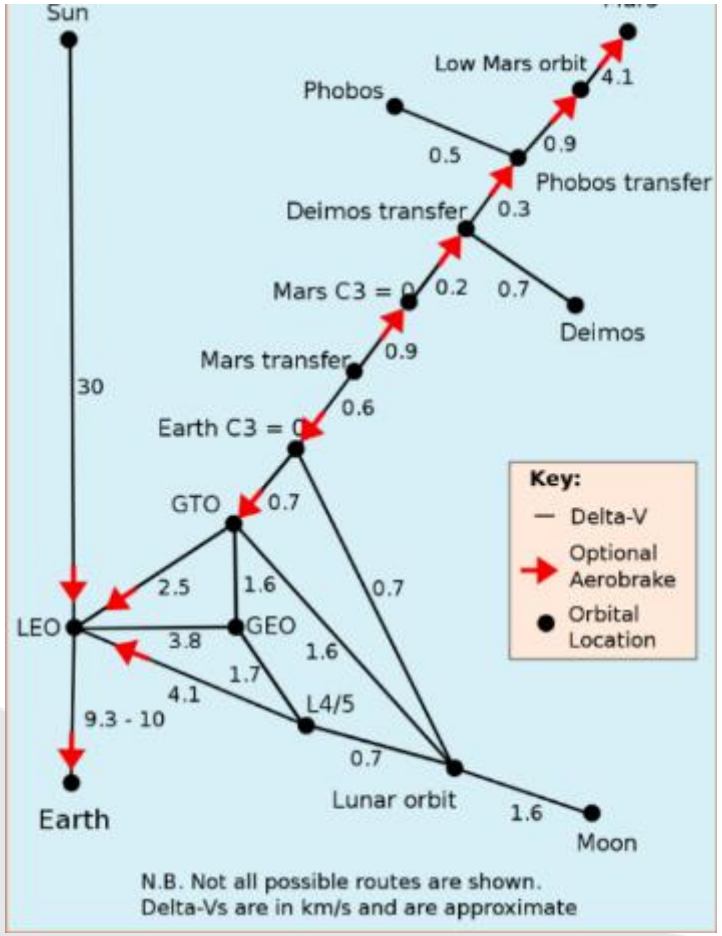
Figure 30 ClearSpace' four-arms removal concept (ClearSpace, (9))

Various trajectory concepts to the Moon

- Tugging upper stage to the Moon with hybrid propulsion
  1. Trajectory studies with University Stuttgart
  2. Needed: 1.6KM/s + 1.6 KM/s
  3. Chem. prop. to quickly cross radiation belt, continue with e-prop. to safe overall weight







Preliminary space tug summary

Mission duration of >320 days:

- 1 day for the launch into GTO
- 4 days for approaching the GTO target (Manthey)
- (60 days to detumble the target with eddy current)
- 1 day to grab and connect
- 180-580 days for the Moon transfer
- 70 days for lunar orbit and crash (Kochler)

Mission can be shortened down to 240 by carrying out the detumbling separately (-60d) and by optimizing Moon transfer & lunar orbit (-20d)

Figure 38: Artist's view of Orbit Recycling Space Tug (Manthey, Orbit Recycling)

Figure 32: Vega-C based space tug design (Kochler, IRS)

“Soft” landing on the Moon

- “Soft”-landing on the Moon with 0.8 – 1.8km/s
    - LCROSS: Centaur upper stage with 2.5 KM/s at 75°
        - 28m wide, 5m deep crater
    - E-propulsion break (SMART-1, 800m/s)
    - Concept: add. “booster”-break
        - Chem. propulsion from space tug (500kg)
        - Deformation energy of space tug

Lunar impact & crater simulation

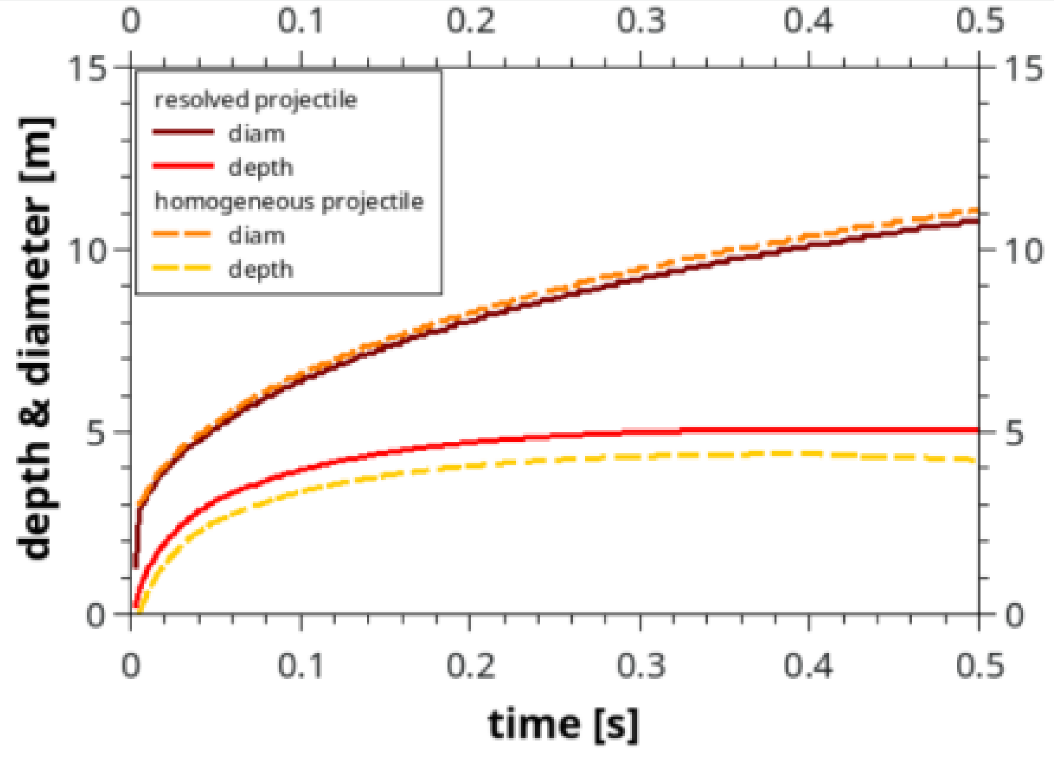


Figure 40: Impact crater development over time (Luther, MfN)

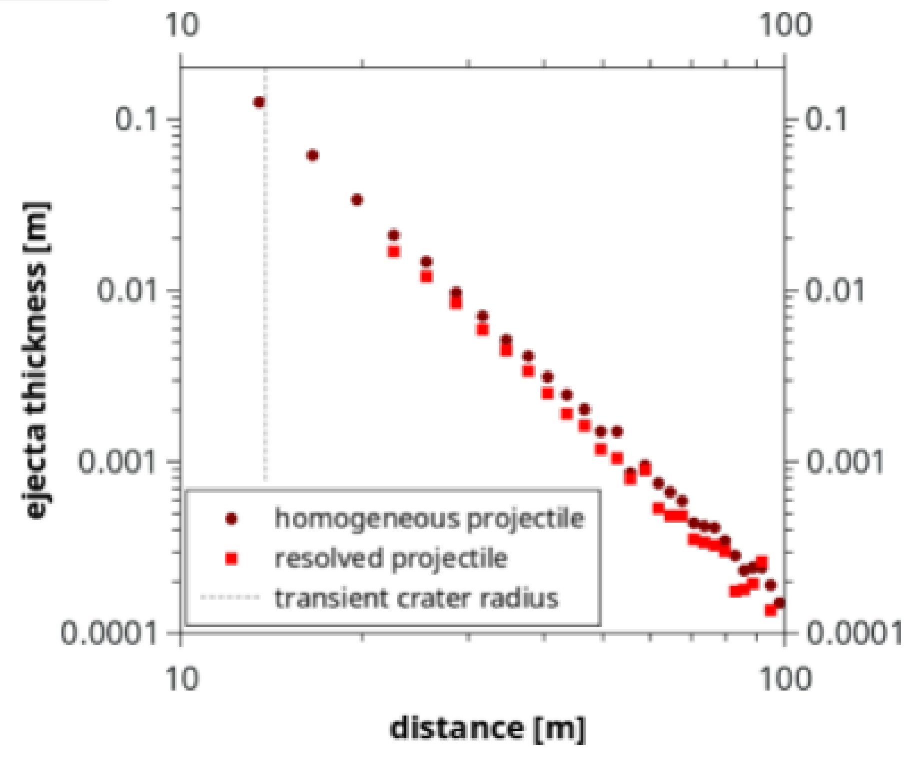


Figure 41: Impact ejecta thickness over distance (Luther, MfN)

Kindly supported by Luther & Wünnemann, Museum für Naturkunde – Leibnitz Institut für Evolutions- und Biodiversitätsforschung, Berlin

Impact velocity: 800m/s. Crater diameter: 11m, depth: 5m

Recovery of debris fragments on the Moon

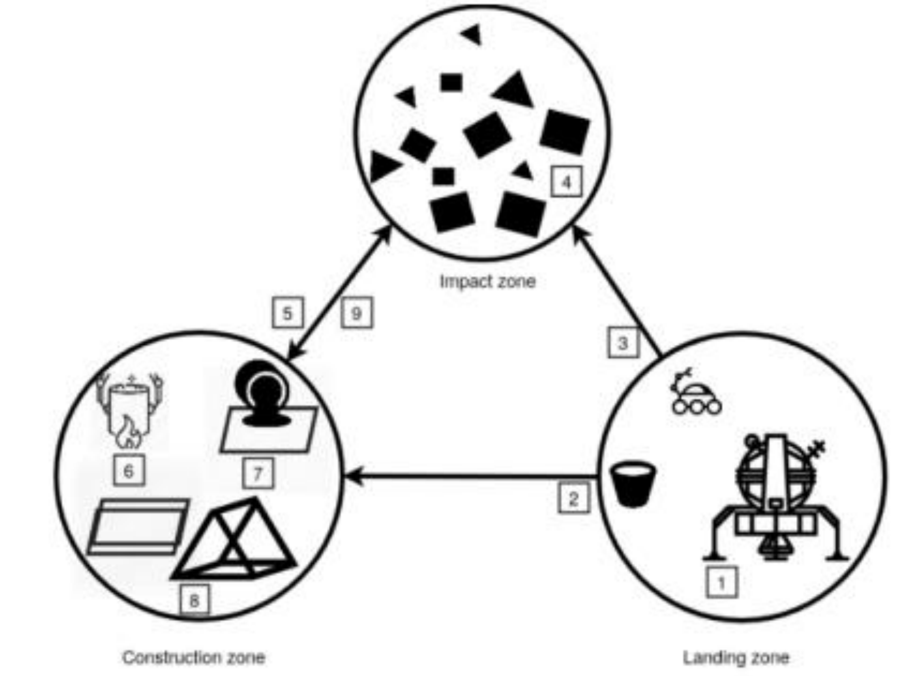


Figure 42: Aluminium recycling process on the Moon (Smith, TU Berlin)

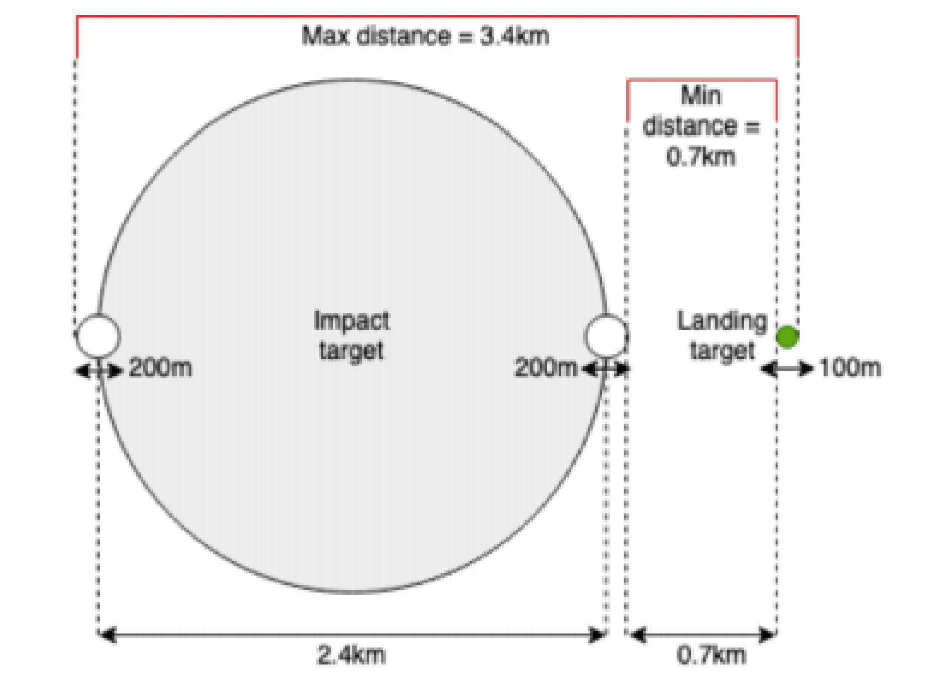
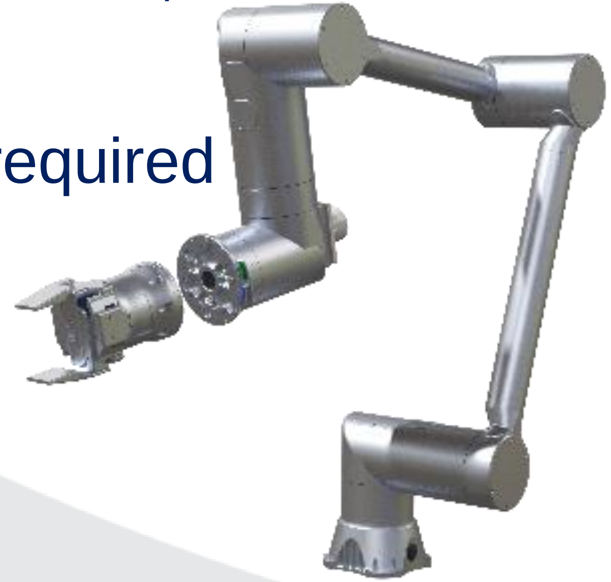


Figure 44: Impact target and landing target zone location scenarios (Smith, TU Berlin)

Figure 46: Aluminium collection subsystem concept (Smith, TU Berlin)

Recovery of debris fragments (continued)

- Metal will be collected by rover and brought to melting station
  - Partnership with TU Berlin & PTS, Berlin
- Rover tests with metal detector coil in autumn 2020
  - Further studies from this fall onwards in new lunar testbed, Rostock
- Manipulator (pic: Made In Space Europe)
  - Further studies to recover (partly) buried fragments required



Recovery of Debris Fragments (continued)

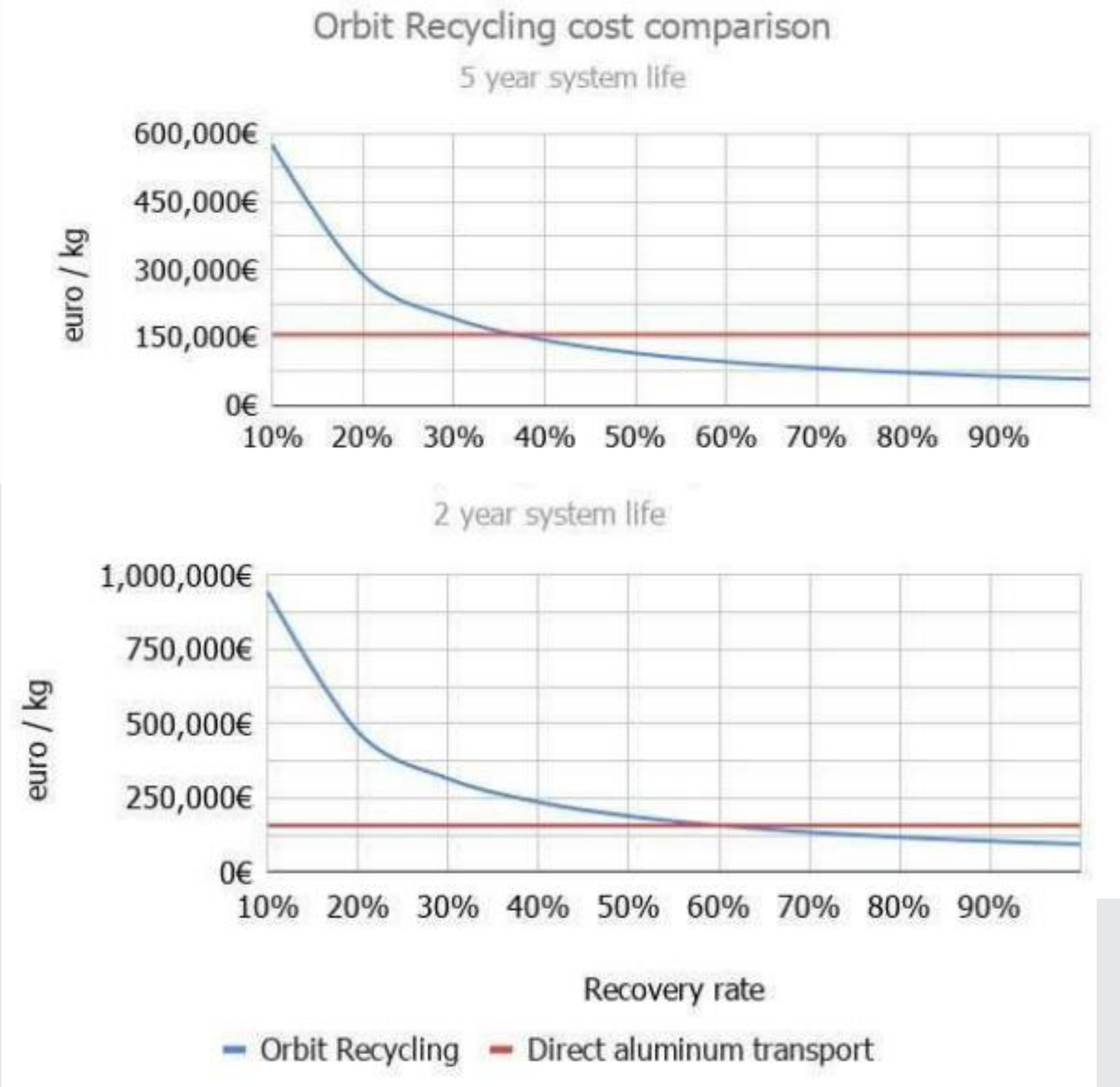
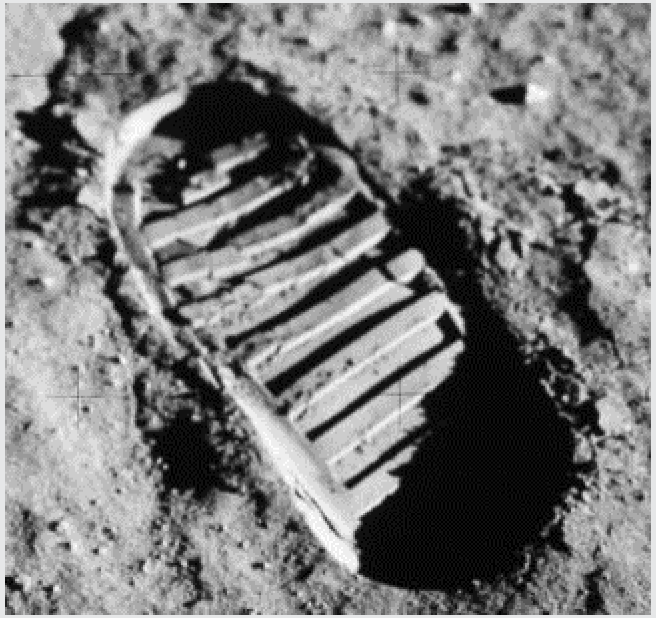


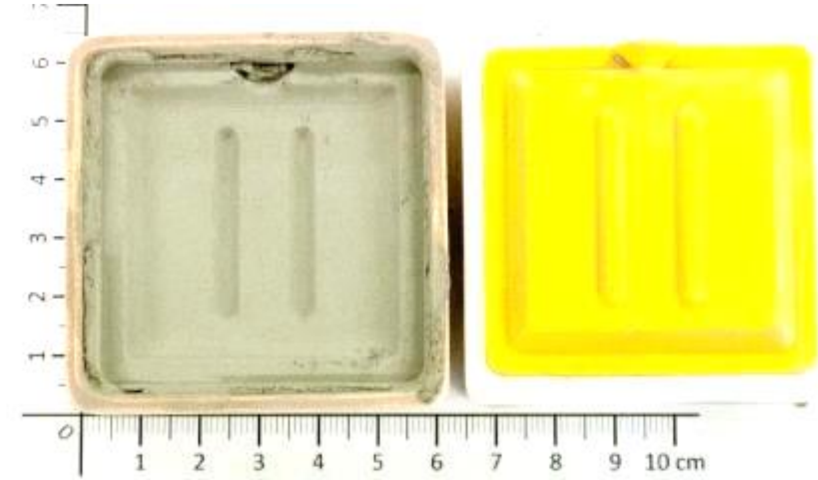
Figure 49: Orbit Recycling cost per kilogram per ESC-A, 60% recovery rate. (Smith, TU Berlin)

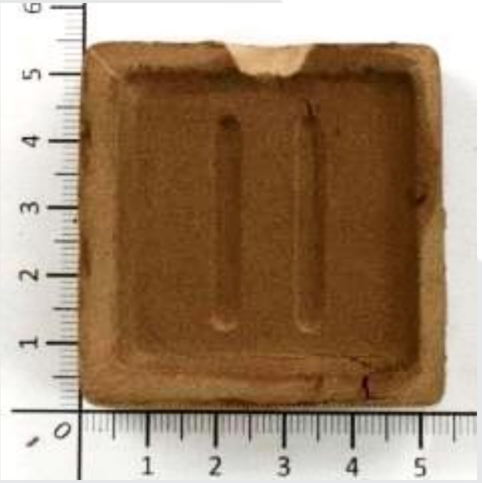
Direct metal casting in lunar regolith

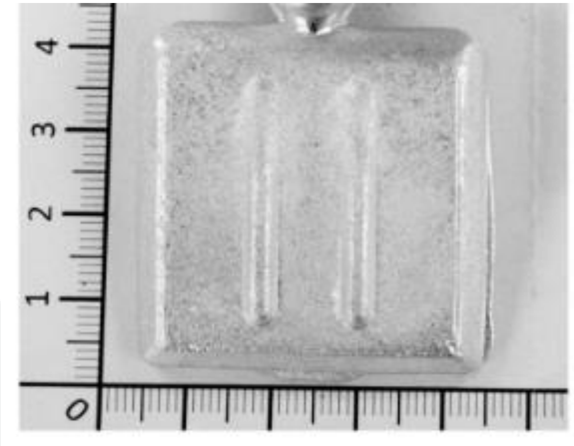


NASA

Casting requires a mould –
Why not using regolith for it?



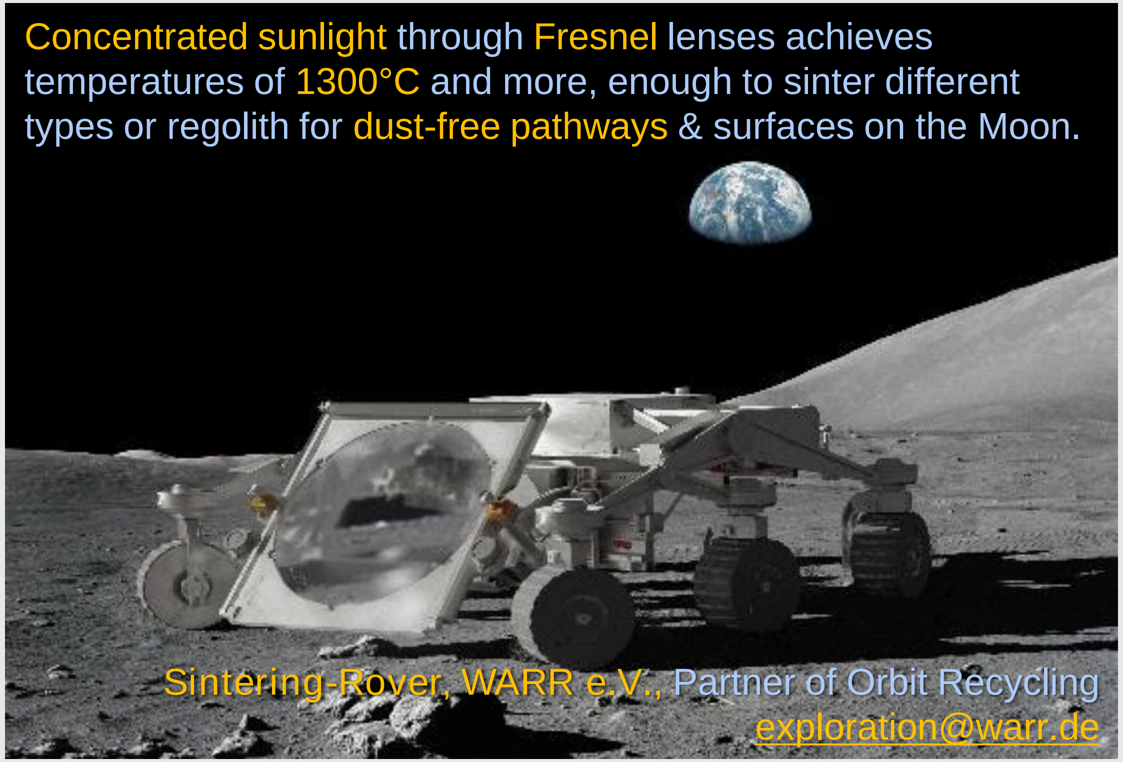


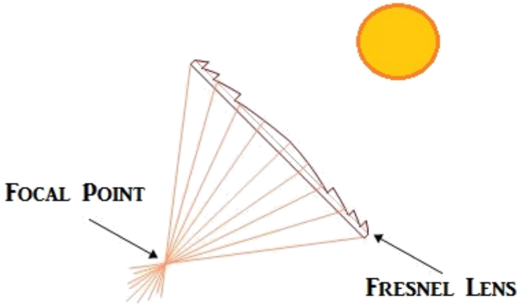


Sintered mould

Acta Astronautica Vol. 182: https://doi.org/10.1016/j.actaastro.2021.01.045

Aluminium melting on the Moon

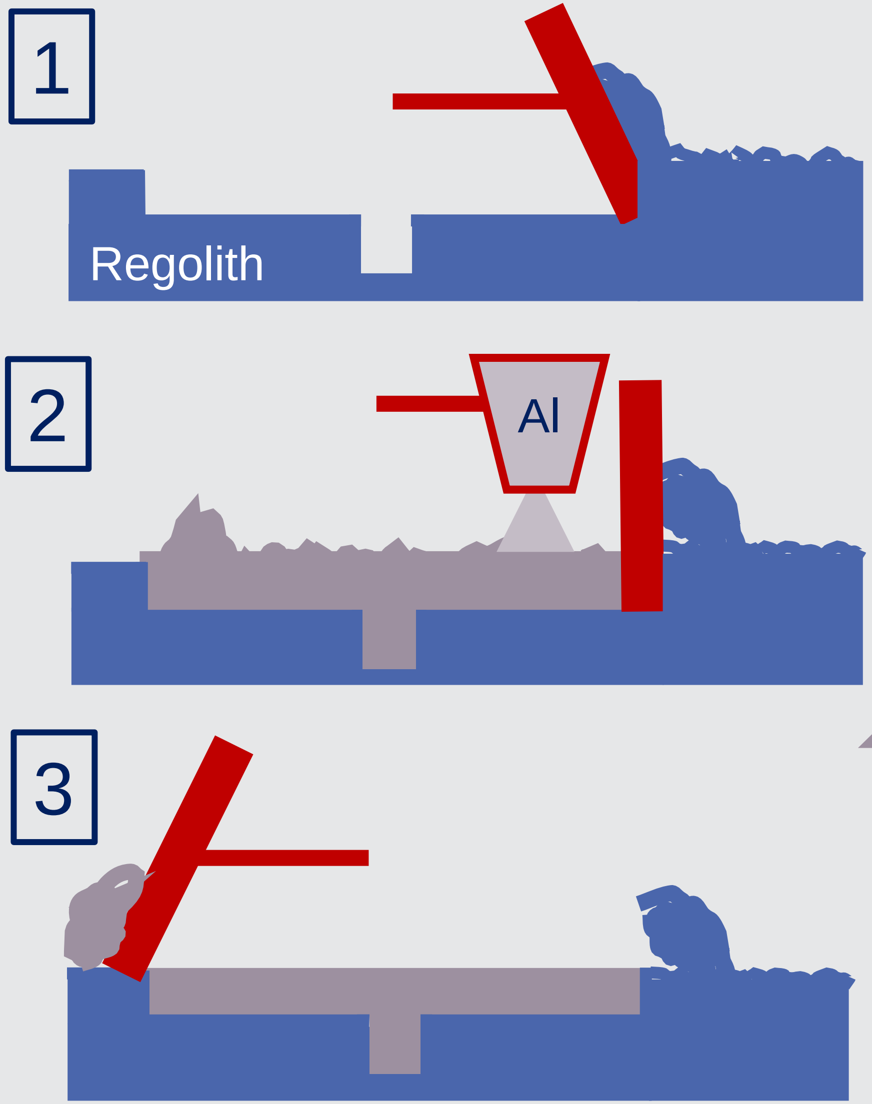


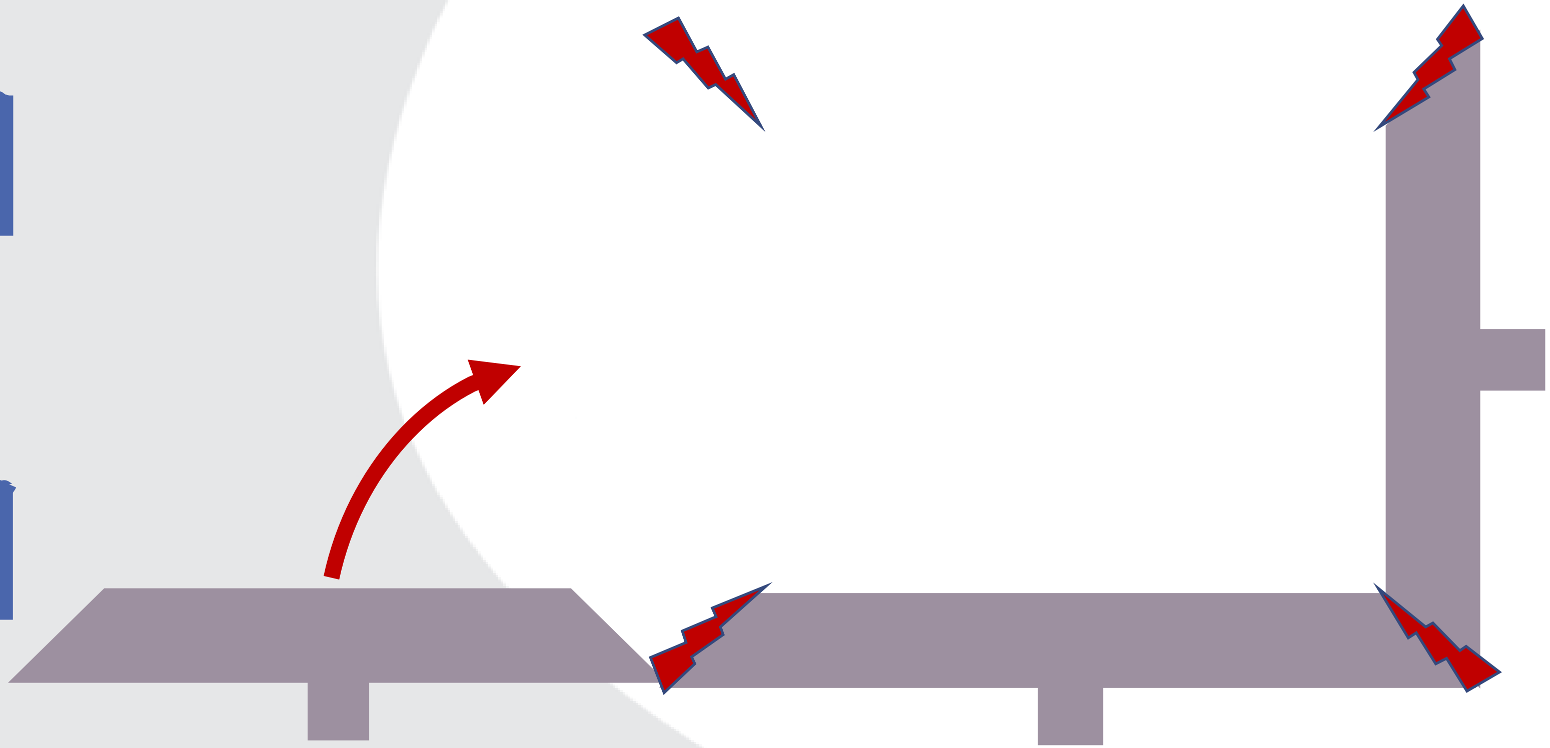


Glowing regolith (orange)
Glazed regolith (black)
Melted aluminum “blob”

https://doi.org/10.1016/j.actaastro.2021.01.045

Automated construction (concept)





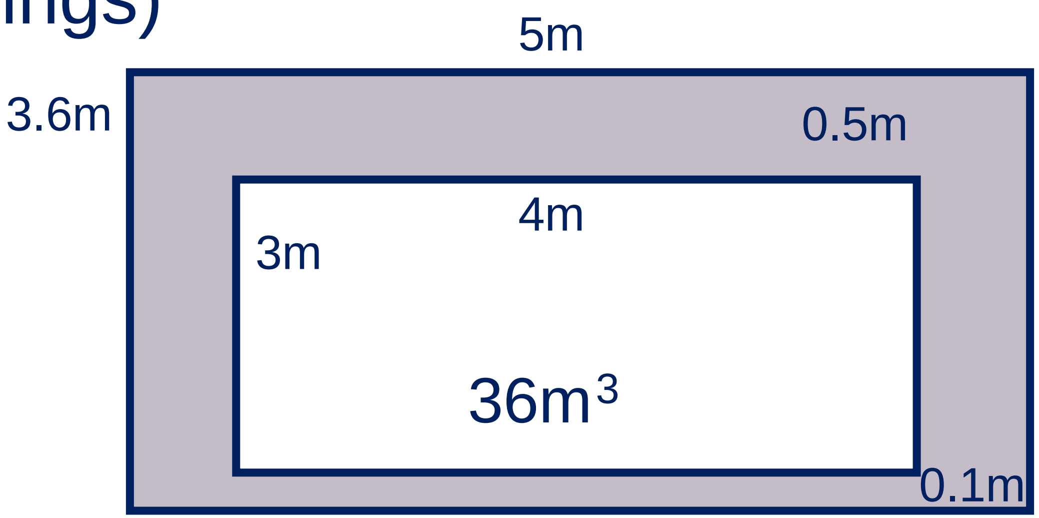
Moon station (concept: Orbit Recycling)

Concept building (raised floor, 2 ceilings)

- Inner building (36m³)
  - 4 walls (4m x 3m) + 2 fronts (3m x 3m)
- Outer building (72m³)
  - 2 sides (5m x 3.6m) + 2 fronts (4m x 3.6m) + 2 tops (5m x 4m)
- Total wall size: 104.8m²
  - Per ESC-A: ca. 163m²* overall

With 55 ESC-A: 1980m³ habitat

- For comparison: 916m³ at ISS



Max. weight inner walls: 162kg
ca. 27kg on the Moon
Max. weight outer walls: 270kg
ca. 45kg on the Moon

* Per ESC-A upper stage: 2200kg aluminum (density: 2,7g/cm³)
100m² with 0,5cm thickness = 1350kg (2700kg x 0.5)
163m² with 0,5cm thickness = 2200kg

Thank You!

Questions & Comments

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2021 Award Winner

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