SpaceSite Lab.

A Full-Scale Moon and Mars Test and Research Facility

Final Presentation, December 2024

Danish Technological Institute:

1,100
Specialized employees

39,000
Specific solutions

10,600
Satisfied customers

94%
Ideal workplace*

9th
Most attractive place to work**

4,7
High customer satisfaction***

Danish Technological Institute is a self-owned and not-for-profit institution. DTI is approved as a Research and Technology Organisation by the Danish Minister of Higher Education and Science.

*In the Institute's employee satisfaction survey, 94% agree or strongly agree with the statement "Overall, I am satisfied as an employee at Danish Technological Institute." The total survey was responded to by 825 employees.

**In 2023, the Institute was ranked as the 9th most attractive workplace in Universum's image survey. The survey is based on responses from 1,347 active professionals in engineering and natural sciences.

***The rating is based on responses from 1,793 customers in 2023 and indicates customer satisfaction on a scale from 1-5. Source: Institute's Customer Satisfaction Survey.

Gantt Chart

PROJECT PLANNING

2nd Round: SpaceSite Lab. - A Full Scale Moon and Mars Test and Research Facility

Task 1: Facility Configuration

- WP1100 GAP Assessment for Analoque Facilities
- WP1200 Req. for Installation, Instruments and Operation
- WP1300 Facility Architecture and Visualization
  - Deliverables:
    - TN1: Facility Specification Document ✓
    - TN1-A: GAP Assessment for Analogue Facilities ✓

Task 2: Preliminary Business Analysis

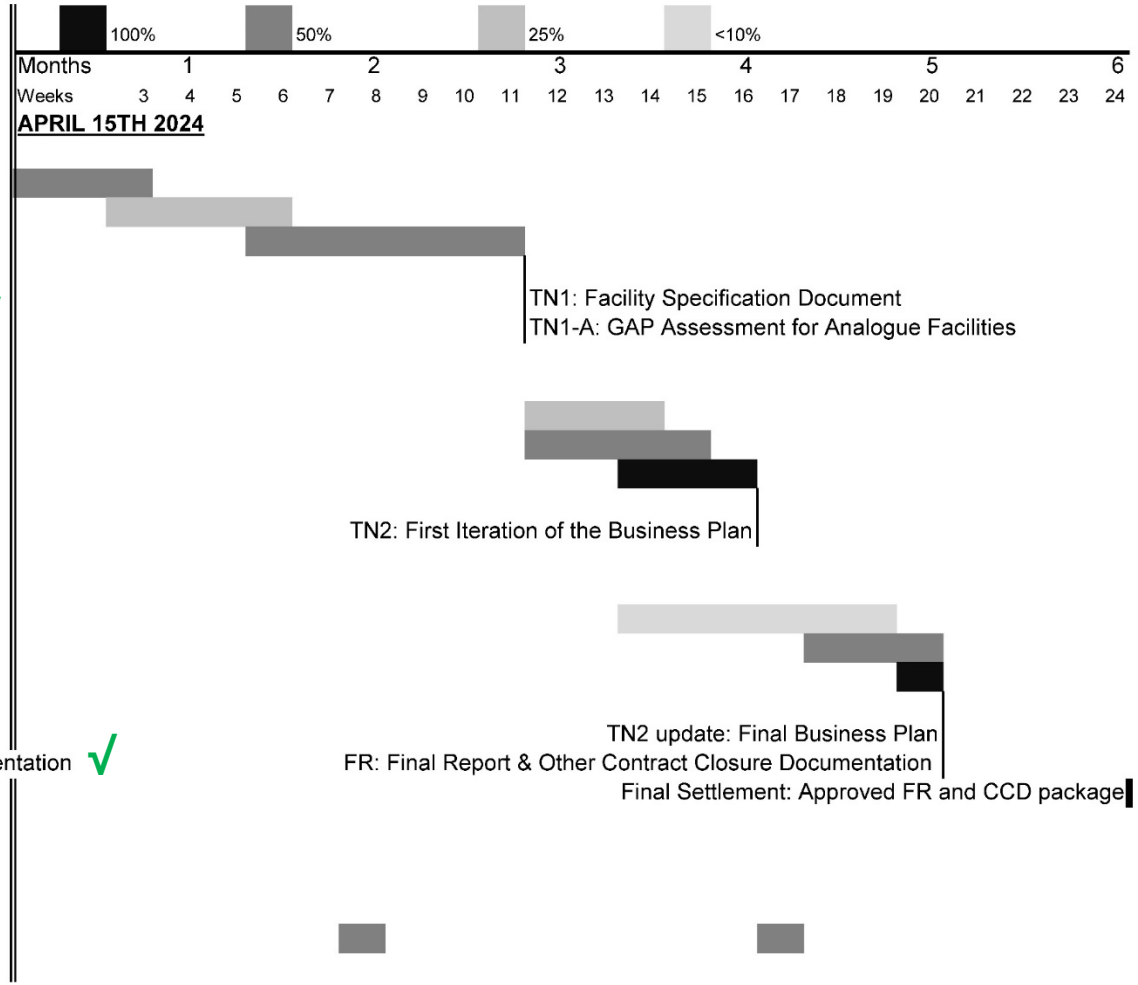
- WP2100 Competitive Landscape Analysis
- WP2200 Stakeholder Analysis
- WP2300 Economic Projections for Cost and ROI
  - Deliverables:
    - TN2: First Iteration of the Business Plan ✓

Task 3: Roadmap for Realization

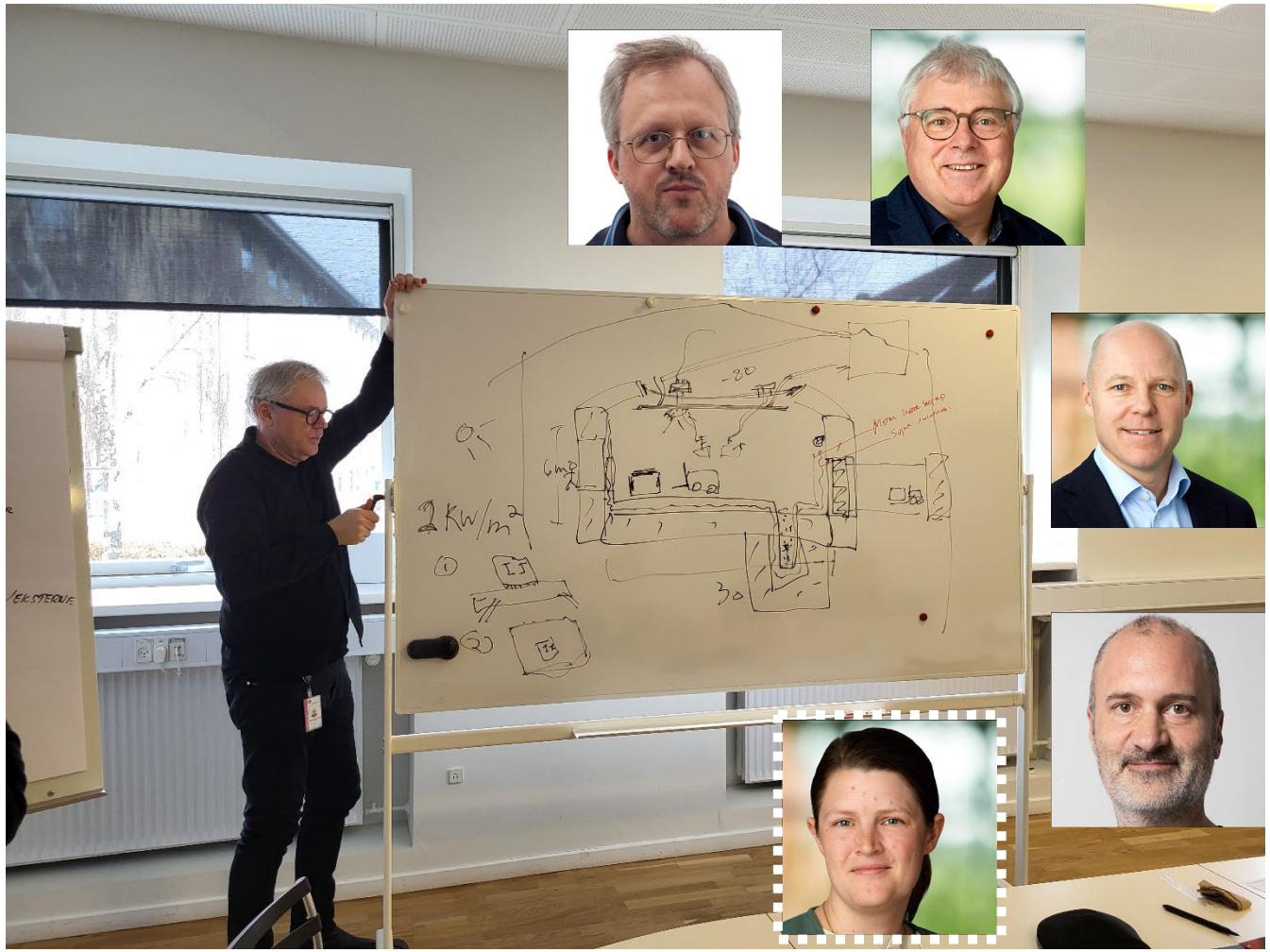
- WP3100 Civil Engineering Peer Review
- WP3200 Funding and Investment Opportunities
- WP3300 Finalization and Dissemination Activities
  - Deliverables:
    - TN2 update: Final Business Plan ✓
    - FR: Final Report & Other Contract Closure Documentation ✓
  - Final Settlement: Approved FR and CCD package

Task 4: Management

- WP4100 Project planning and coordination of activities
  - Deliverables:
    - Bi Monthly reports



Workshop April 2nd, 2024



DTI:

- Christian Dalsgaard (Lead)
- Kristian Skaarup (Robotics)
- Christina M. Zeuthen (3D Print)
- Niels Christian Nielsen (Building)

Aarhus University:

- Jonathan Marrison
- Jens Jacob Iversen


PROJEKTBESKRIVELSE / FORUNDERSØGELSE
ESA STAR RCP 5-50065/24/NL/GLC/ov
SpaceSite Lab. – A Full Scale Moon and Mars Test and Research Facility
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DANISH TECHNOLOGICAL INSTITUTE

PROJEKTBESKRIVELSE / FORUNDERSØGELSE

SpaceSite Lab.
A Full-Scale Mars and Moon Test and Research Facility
(Dansk version)

Space Exploration Network, August 30th, 2024

Brug rummet
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Space Exploration Danmark partnerskabet holdt fredag den 30. august sin årlige partnerskabsdag på Københavns Universitet - University of Copenhagen

40 virksomheder og forskere, som arbejder med at forberede fremtidens rummissioner til Månen og Mars, var samlet i Mærsk tårnet til den årlige partnerskabsdag for Space Exploration Danmark.

Space Exploration Danmark partnerskabet blev lancereret af Ministry of Higher Education and Science i 2020 med det formål at samle kræfterne om det krævende og langsigtede arbejde omkring fremtidens rummissioner til Månen og Mars.

Dagen bød på masser af netværk og præsentationer af Mani – et nyt dansk ledet Måneprojekt - ved lektor ved Globe Instituttet på KU Jens Frydenvang. Et projekt som ESA netop har vurderet som 3. bedst. https://lnkd.in/dWKey-sv

Seniorkonsulent ved Danish Technological Institute Christian Dalsgaard og Jakob Lange fra BIG - Bjarke Ingels Group præsenterede planerne om en ny stor testfacilitet i Aarhus til stort udstyr, der skal med på Måne eller Mars missioner https://lnkd.in/d8YxfWUj

Vært ved partnerskabsdagen Jens Frydenvang fortæller:
"Uden partnerskabet havde vi aldrig kunne samle de rigtige partnere til Mani på så kort tid. Partnerskabet giver os desuden kritisk vigtig og tidlig information om mulighederne hos ESA, sådan at vi kan fokusere vores sparsomme tid og ressourcer. Derfor er jeg meget glad for, at Københavns Universitet, som en aktiv partner, kan samle så mange danske kapaciteter, og jeg ser frem til at flere nyskabende danske missioner ser dagens lys."

Partnerskabet er åbent for alle interesserede og håber at kunne styrke mulighederne for, at danske forskere og virksomheder deltager i fremtidens spændende missioner

Læs mere om partnerskabet:
https://lnkd.in/dF6WUdHq

Peter Mandix Sehestedt Alexandra Martinussen Vikner Sebastian Aristotelis
#brugrummet #spaceexplorationdanmark

Show translation

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Reactions +61

Like Comment Repost Send

LUNA Visit September 3rd 2024

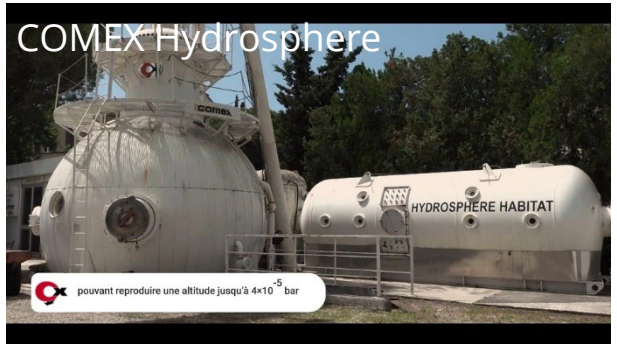
From left:

- Kristian Skaarup (DTI, Robotics)
- Christina M. Zeuthen (DTI, 3D Print)
- Andreas Mogensen (ESA Astronaut)
- Aidan Cowley (ESA Project Officer)
- Niels Christian Nielsen (DTI, Buildings)
- Jonathan Marrison (Aarhus University)
- Christian Dalsgaard (DTI, Functional Materials. photographer)

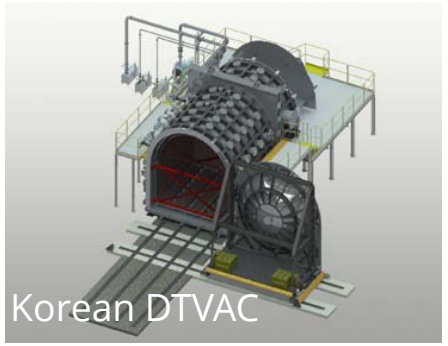
Artificial Analogue Facilities for Moon/Mars Exploration – State of the Art

- ESA-DLR LUNA in Cologne, Germany, is a facility designed to recreate the lunar surface. It will provide a training ground for astronauts, with no vacuum or temperature analogous to those on the moon.
- The COMEX Hydrosphere in France features a moon surface simulator within a vacuum cylinder that is five meters in diameter.
- Korean DTVAC, a 4m (W) × 4m (H) × 4m (D) space environment for the lunar surface at 10-4 mbar pressure, -190 ~ + 150 ℃ temperature cycles with 25 tons of soil.
- ESRIC Dusty Thermal Vacuum Chamber (DTVC) is capable of testing subsystem components (Luxembourg-based) from 2025.


ESA-DLR LUNA



COMEX Hydrosphere


Korean DTVAC


ESRIC

Gap Analysis Summary

Categories of Existing Facility

- Conventional large thermal vacuum (TVAC) systems
- Terrestrial regolith simulators
- Dirty-TVAC systems (‘medium-large’)

Key Gaps

- Full scale environmental testing (Mars/Moon)
- Full scale dust exposure (Mars/Moon)
- In-Situ Resource Utilization (ISRU) simulation

Key facility capabilities

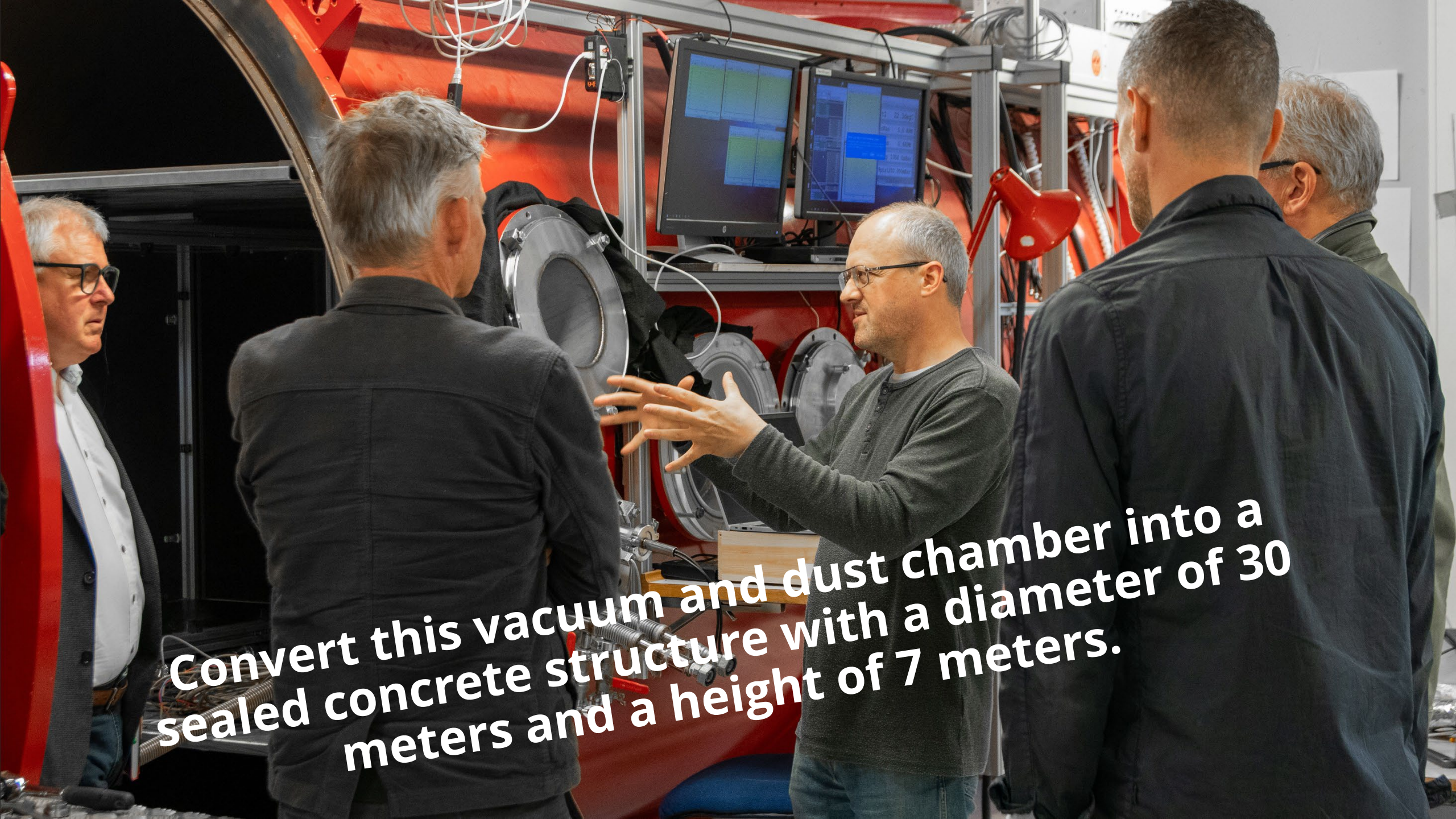
- Facility size (full-scale)
- Environmental control (TVAC) Moon/Mars
- Regolith / Dust exposure

Examples of Untested Scenarios:
MOON LANDER, APEX 1.0 ISPACE
LUNAR MARTIAN LANDER
MOON ROVER, HiveR NEURO SPACE

Artificial Analogue Facilities for Moon/Mars Exploration

Facility		Scale m3 Full Scale	TVAC	Dust	Regolith
ESRIC Dusty Thermal Vacuum Chamber, Luxembourg	ESA	10	YES	YES	YES
University of Glasgow, Glasgow UK	ESA	12	YES	NO	YES
COMEX hydrosphere, Marseille FR	ESA	20	YES	NO	YES
KICT Dirty Thermal Vacuum Chamber, Korean	KASA	50	YES	NO	YES
Planetary Environment Facility (PEF), Aarhus University DK	ESA	42	YES	YES	YES
LUNA, European Astronaut Centre (EAC), Cologne GE	ESA	3000	NO	NO	YES
Large Space Simulator (LSS), Noordwijk NL	ESA	2300	YES	NO	NO
NASA's Glenn Research Center, Space Environments Complex (SEC), Ohio US	NASA	27000	YES	NO	NO
Proposed Large Scale Mars and Moon, Aarhus, DK	ESA	5000	YES	YES	YES

Existing and Planned Analogue Facilities for Mars and the Moon.
The Proposed Aarhus Facility adresses the gap for Large-Scale Dusty Windy Thermal Vacuum Chamber (DWTVC >5000 m^3)


Convert this vacuum and dust chamber into a sealed concrete structure with a diameter of 30 meters and a height of 7 meters.

Big Collaboration with BIG Architects

BIG - Bjarke Ingels Group is a leading name in space architecture. Their role is to:

- Elevate our vision and visualize a **leading landmark** for space initiatives in Europe.
- Present an **attractive workplace** for space development in Denmark.
- Develop an **architectural framework** that aligns with identified needs and is practical for construction.
- Embrace a commitment to using **recycled building materials** and circularity principles to the greatest extent possible.

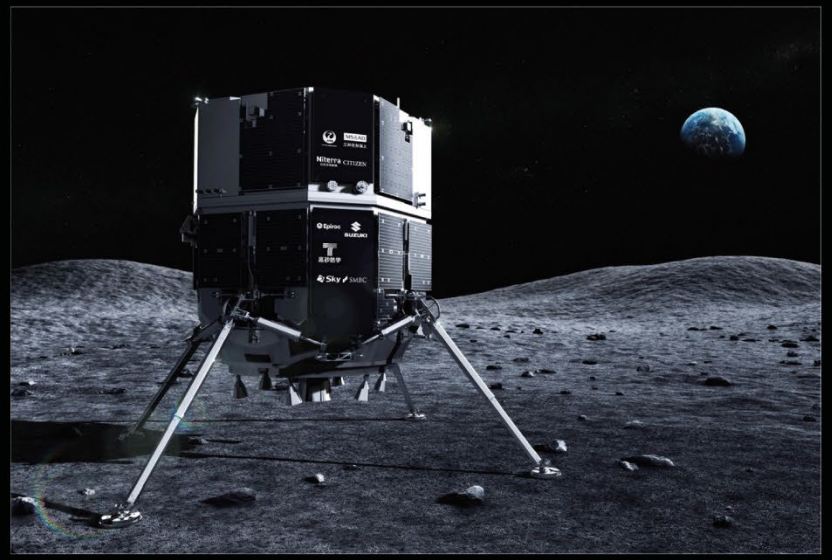
DTI's four guiding principles

EXPERTISE
We know what we are talking about

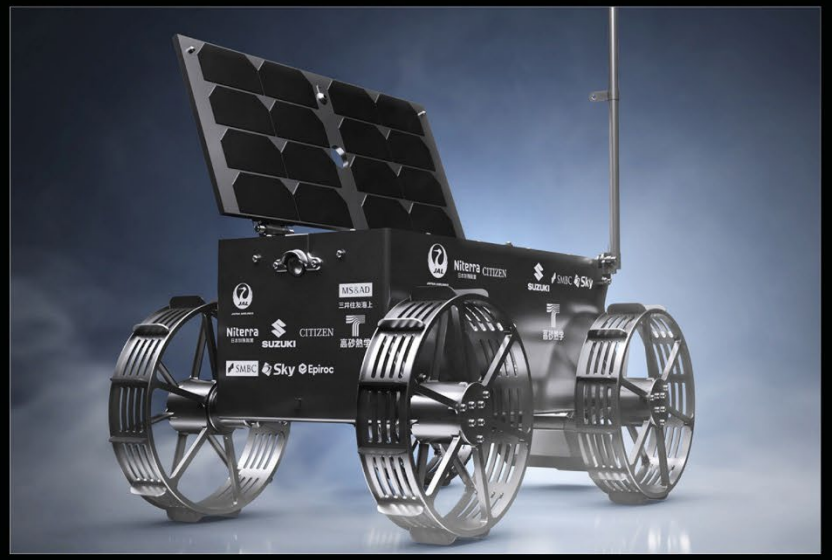
ACHIEVING RESULTS
We find the best solution

INTEGRITY
We live up to our promises

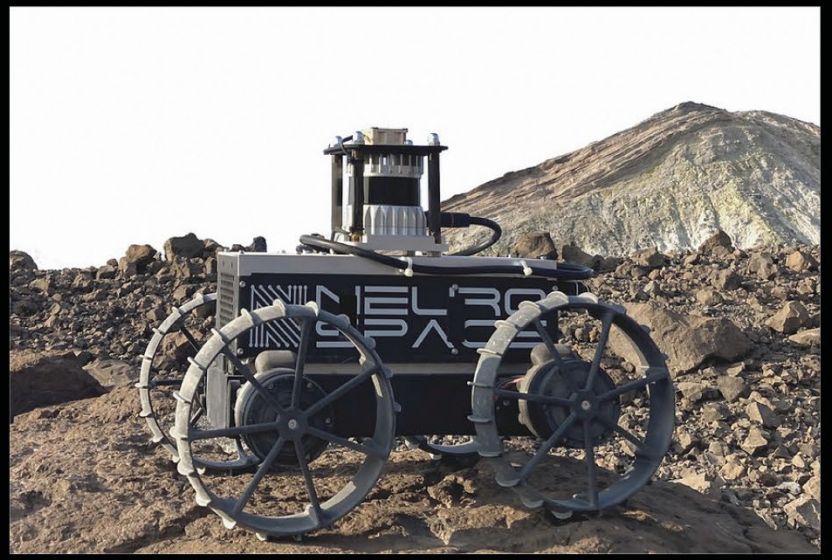
GROUND-BREAKING
We are at the cutting edge of development



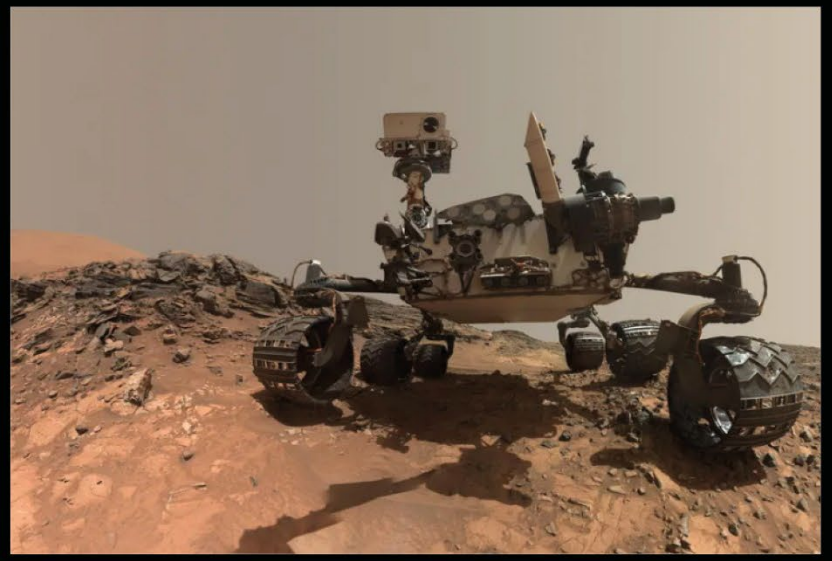
MOON LANDER
APEX 1.0 ISPACE



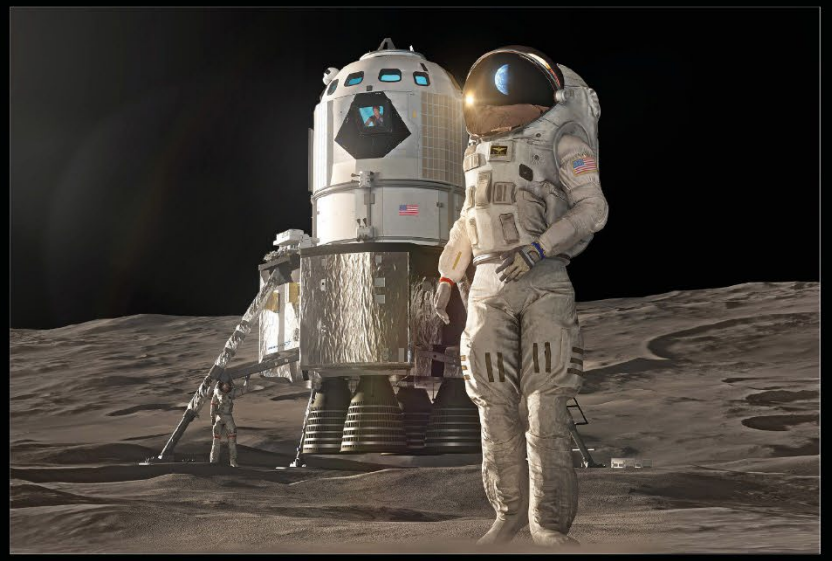
MOON ROVER
M1 ISPACE



MOON ROVER
HiveR NEURO SPACE



MARS ROVER
PERSEVERANCE NASA



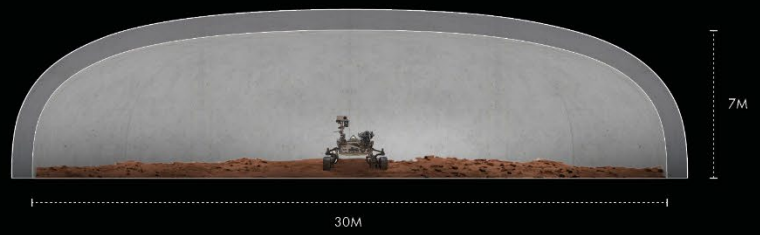
EVA, SUITS FOR EXTRAVEHICULAR ACTIVITY
LUNAR MARTIAN LANDER

TESTING REAL SCALE MARS OR LUNAR HABITATS, LANDED MISSIONS
ODYSSEUS SPACECRAFT, LUNAR SUFACE LANDING BY THE U.S, 2023

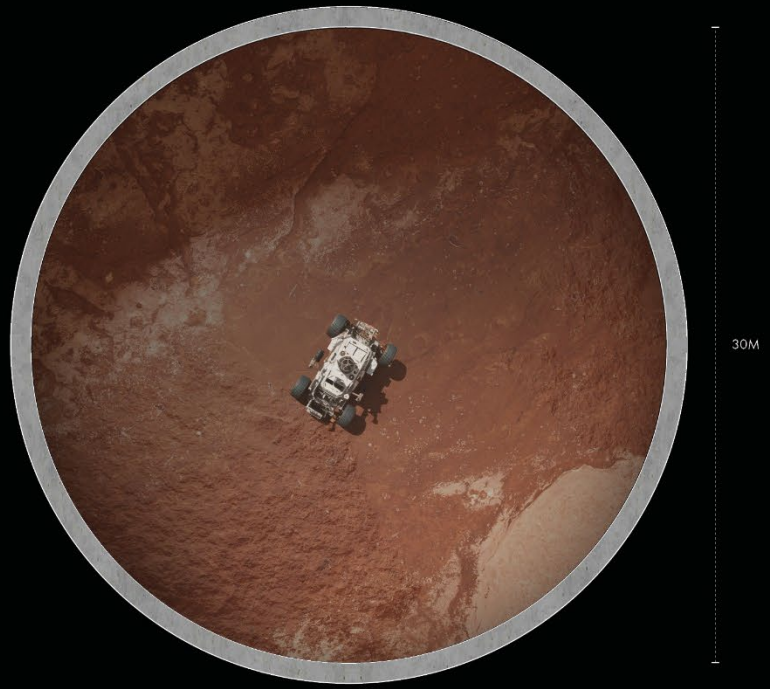
EXAMPLES OF LARGE SCALE TEST OBJECTS

VACUUM CHAMBER

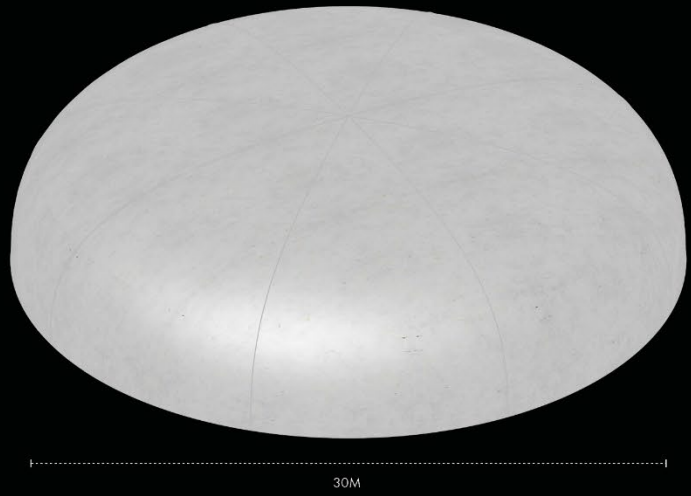
BIG, BJARKE INGELS GROUP



SECTION



PLAN

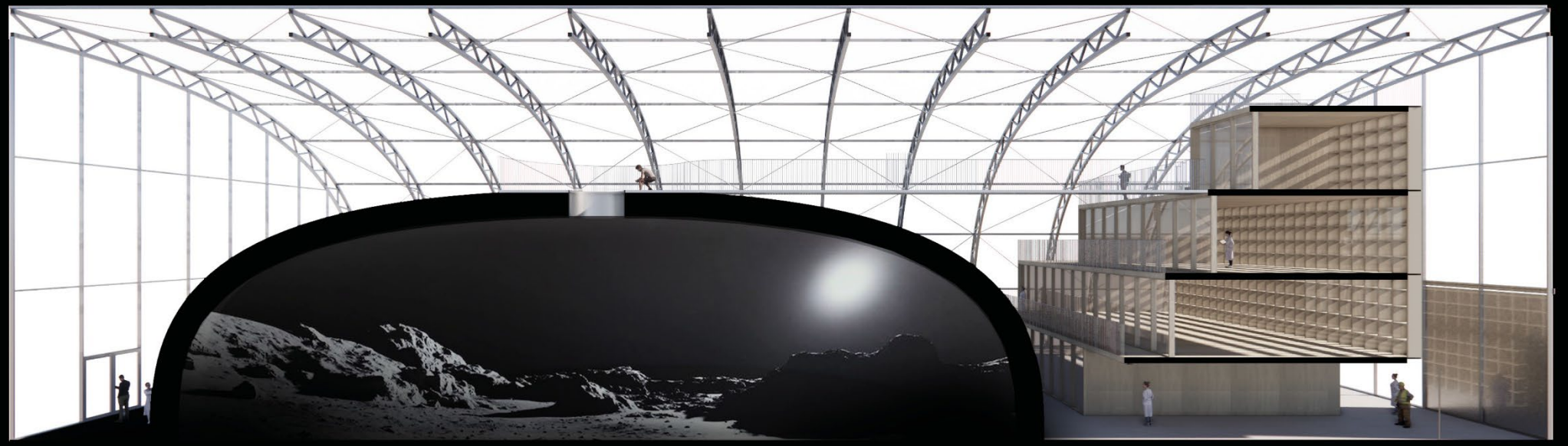


AXO

VACUUM CHAMBER

GEOMETRY REQUIREMENTS

BIG, BJARKE INGELS GROUP



SECTION

NORTH / SOUTH

BIG, BJARKE INGELS GROUP

LECTURE CORNER

VACUUM CHAMBER EXTERIOR

BIG, BJARKE INGELS GROUP

ELEVATED TERRACE / OFFICE CORRIDOR

OFFICE / BOH

BIG, BJARKE INGELS GROUP

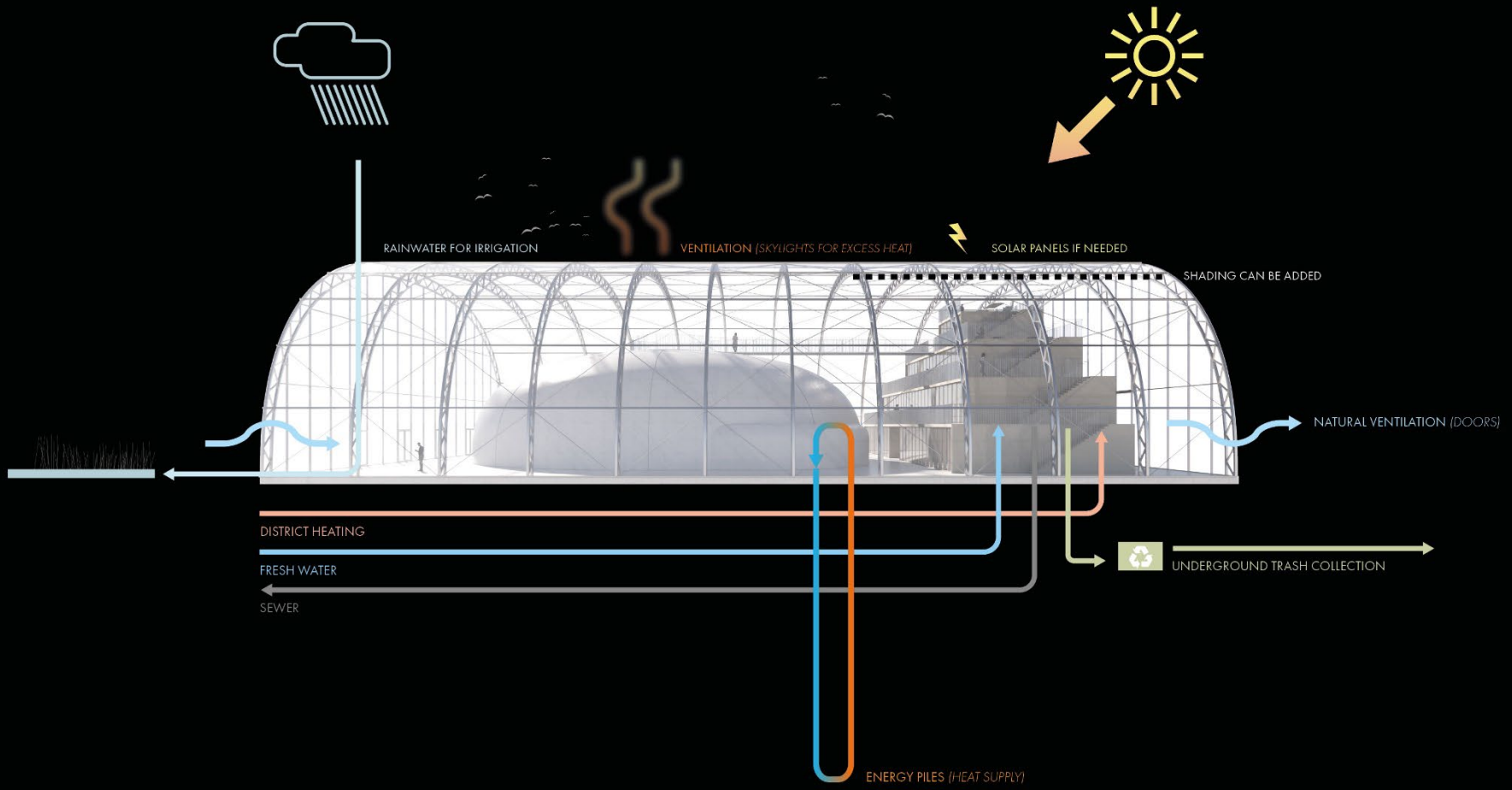
BRIDGE CONNECTION TO THE VACUUM CHAMBER TOP

STEEL STRUCTURE

BIG, BJARKE INGELS GROUP

SITE CONDITION TODAY

AARHUS DENMARK

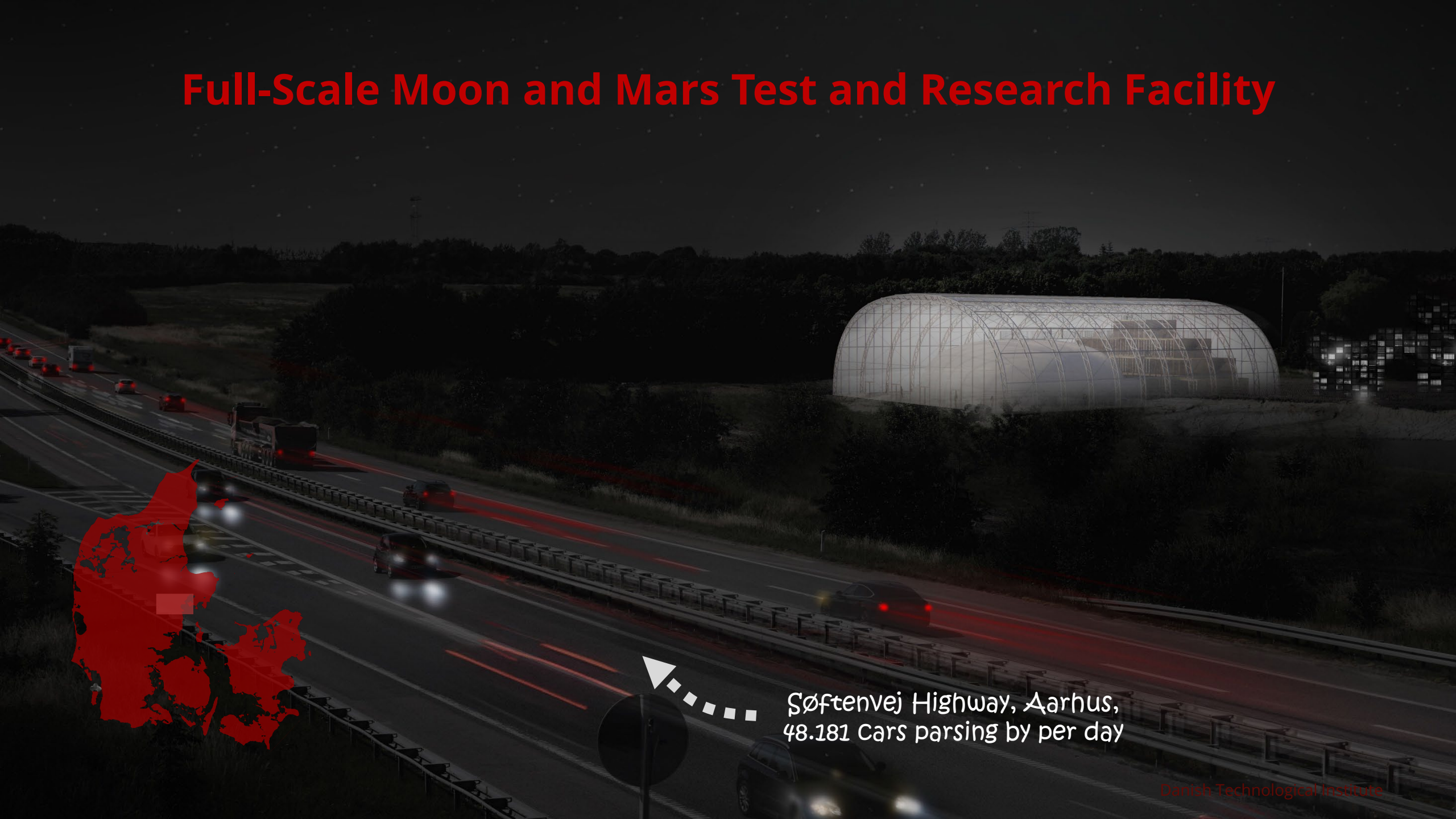


SUSTAINABILITY

SYSTEMS FOR FURTHER DISCUSSION

BIG, BJARKE INGELS GROUP

Full-Scale Moon and Mars Test and Research Facility



Danish Technological Institute

Terrestrial Synergies

SpaceSite Lab.

Applied Research

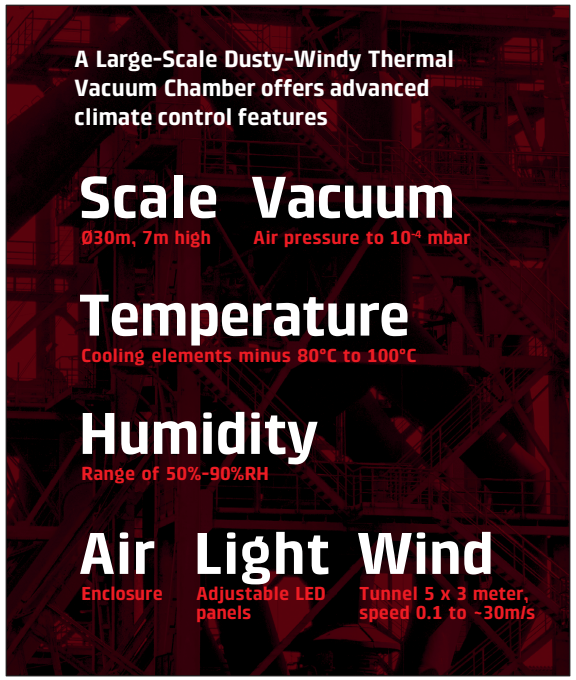
Meteorology: Conduct simulations and studies of various weather phenomena.

Aeronautics: Recreate wind and temperature conditions to test instruments designed for high-altitude balloons, drones, and scaled wind turbine blades.

Materials: Test advanced materials for tribology, 3D printing, and printed electronics, i.e with locally recyclable resources.

Large Climate Chamber

Arctic Research: Simulate operational situations under extreme arctic conditions.



> New clients can be served with a large dusty climate chamber mimicking real life scenarios
>
> *Stig Koust, ph.d, Business Manager, DTI, Air and Sensor Technology*

Utilizing the Closed Chamber as a Large Test Room

- **Environmental Studies:** Measure aerosol emissions from vehicles (cars, buses) and heating appliances (stoves, etc.).
- **Protective Gear Evaluation:** Assess the effectiveness of tents in maintaining an airtight environment.
- **Ventilation Systems:** Test and evaluate the performance of large ventilation systems.
- **Agricultural Studies:** Examine the response of plants and crops to specific atmospheric conditions and articifical sunlight.

Terrestrial Use Cases for Large Test Facility

Use Case	Maturity of Use Case	Special Requirements	Required capabilities	Possible issues
Test of larger outdoor air-cleaning facilities (Plant walls, outdoor air purifiers etc.)	Existing project that lack controlled environ- ments for testing	Lights that replicate sunlight	Closed chamber	
Document active dust mitigation me- thods	Client request, lack of suitable testing facility		Closed chamber, Dust	
Air Quality Sensor Network – Development and Calibration	Client request, declined due to absence of a suitable testing facility.		Closed chamber	
Electric vehicles + battery / charging performance with varying temperatu- res	Business opportunity proposed for the team	Access to EV charger within facility	Temperature control	Dust residuals can cau- se issues
Test of tribological surfaces for arctic vehicles	Client requests, turned down due to lack of testing facility	Usage of snow (or simulant) in chamber	Temperature control	Require snow in cham- ber
Test of drones in arctic conditions	Various proposed projects, missing testing facility		Temperature control, low pressure	
Upper atmosphere simulation for we- ather balloons	Collaboration with existing customer		Vacuum, Temperature	
Wind tunnel tests of trucks and air- crafts	Business oppertunity proposed for the team	Large gate (height 4,5 m x width 4 m)	Wind tunnel, Dust	Size is an issue
Wind tunnel tests of wind turbine blades	Customers (blade producer) existing wind tun- nel of 1,35x2,7x7,0 m (WxHxL) is too small	Wind tunnel capabilities up to 100 m/s	Wind tunnel, tempera- ture control	Gate to allow a long elements to enter
Test of jet engines in dusty environ- ments	Commercial client request, turned down due to lack of testing facility		Wind tunnel, Dust	
Test of large pipes	Existing project lacking testing facility		Closed chamber	A price sensitive indu- stry

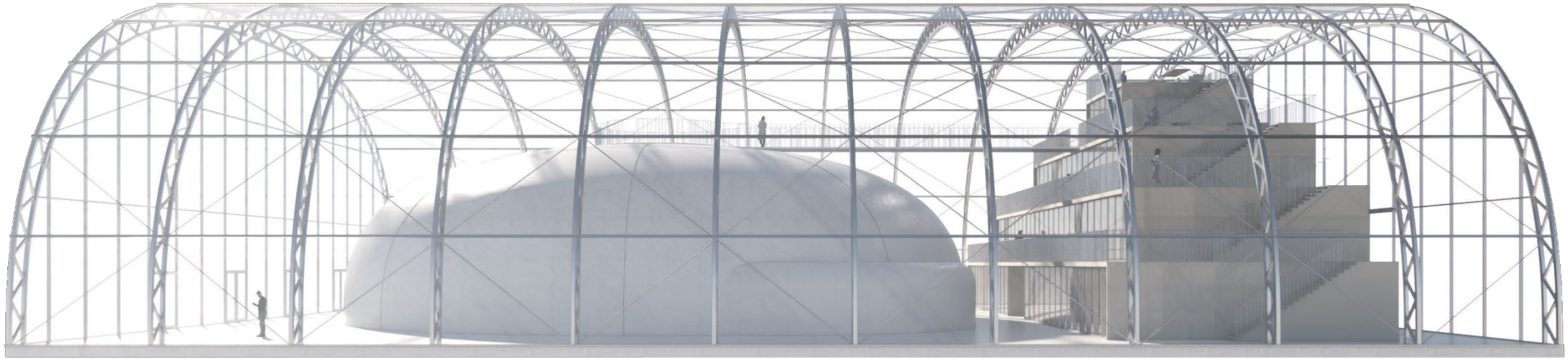
Estimated Construction Costs for the Complex

Cost Estimation

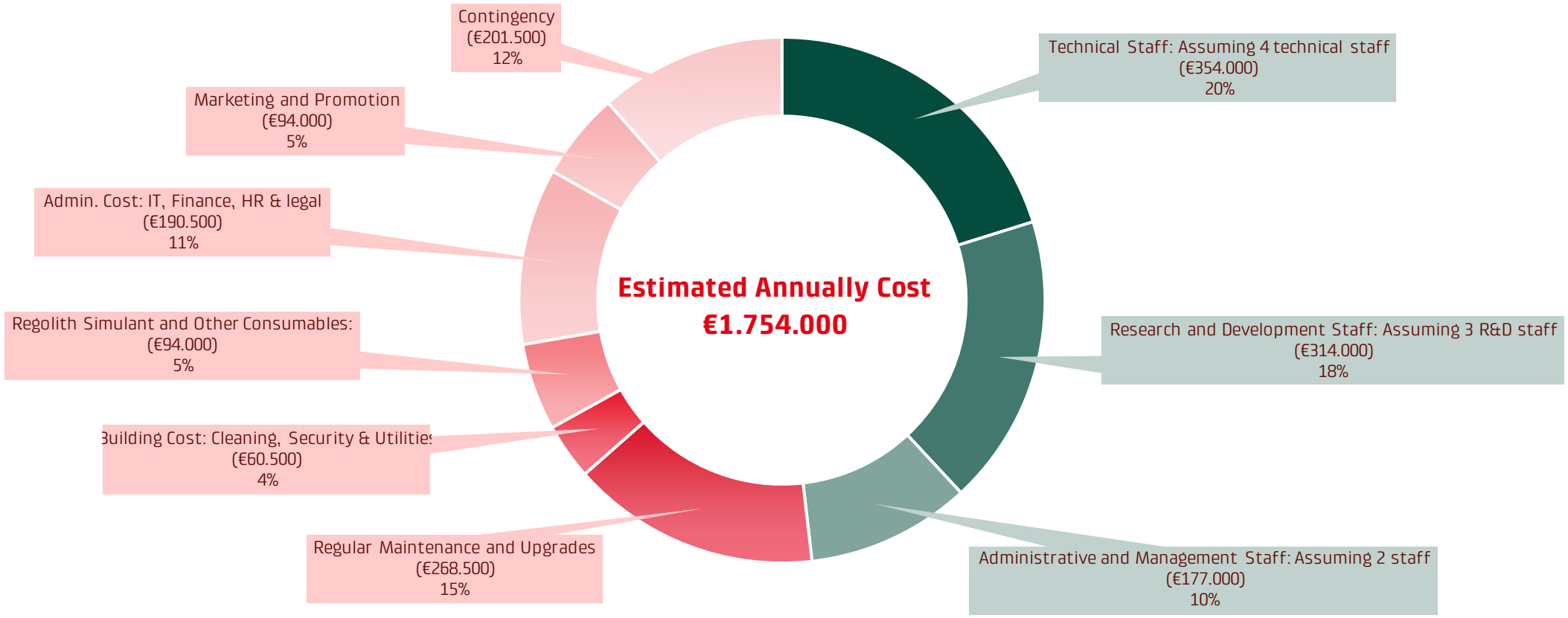
Based on our calculations, the total estimated cost for the SpaceSite Lab facility is approximately **27.5 million euros**, with the thermal vacuum chamber contributing 35% and having the highest uncertainty.

Basic Operational Costs

The annual operational cost is estimated **at €1,754,000** which equates to approximately minimum rate of €8.800 per day.



Basic Operational Costs for a Full-Scale Moon and Mars Test and Research Facility



Revenue Estimates for the Facility

Space Projects

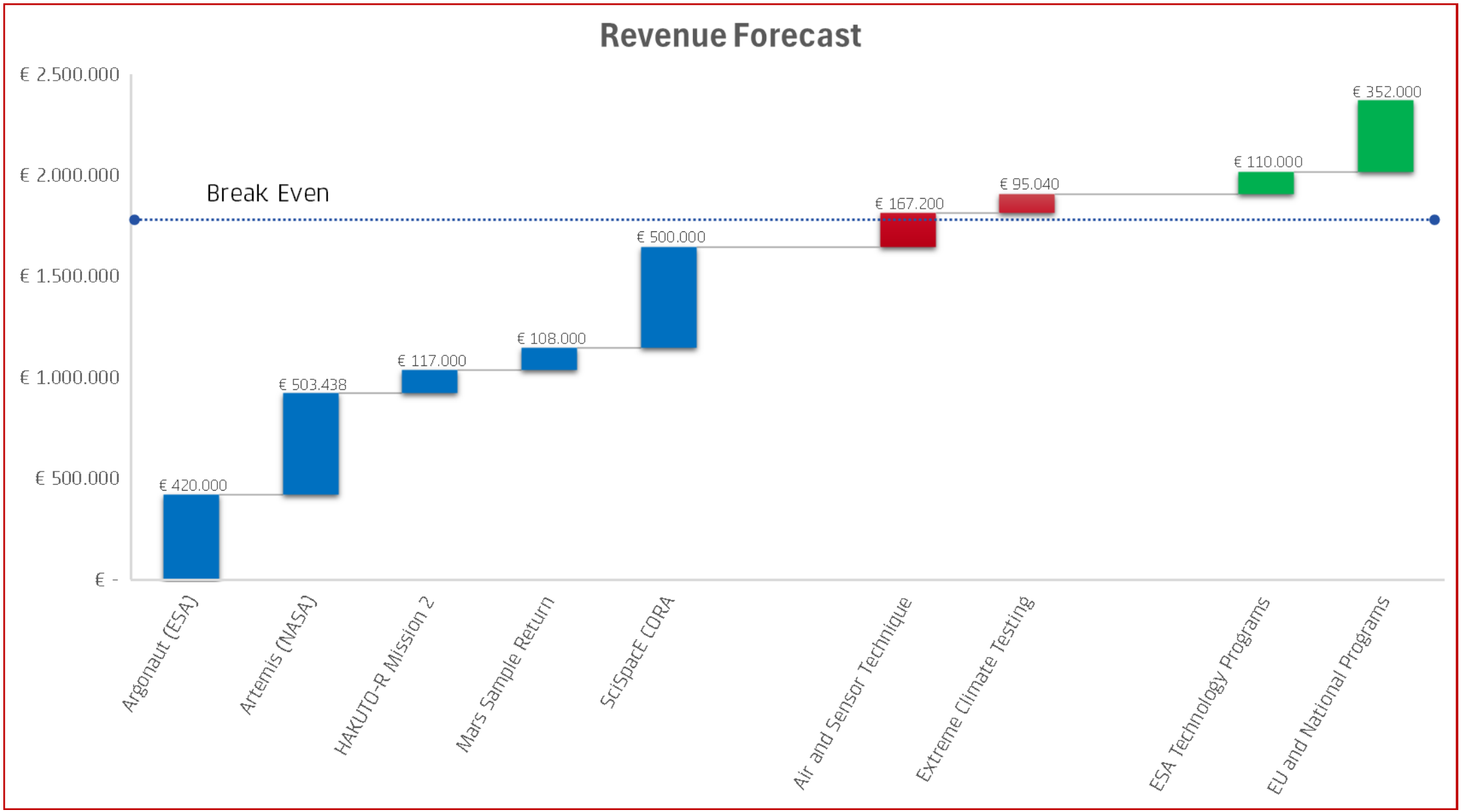
Program			Yearly Revenue
Argonaut (ESA)			€ 420.000
Lunar Descent Element (lander)	€	96.000	
Cargo Platform Elements	€	180.000	
Payloads	€	144.000	
Artemis (NASA)			€ 503.438
Artemis Lunar Terrain Vehicle	€	45.000	
Griffin Mission One - Astrobotic	€	84.375	
Intuitive Machines PRIME-1	€	126.563	
Commercial Lunar Payloads (CLPS)	€	202.500	
EVA Suits	€	45.000	
HAKUTO-R Mission 2			€ 117.000
RESILIENCE Lander	€	72.000	
Lunar Cruiser	€	45.000	
Mars Sample Return			€ 108.000
Sample Return Continuation	€	18.000	
Sample Fetch Rover	€	90.000	
SciSpacE CORA			€ 500.000
Physical Science	€	125.000	
Life Science	€	125.000	
Moon & Mars Science	€	250.000	
			€ 1.648.438

Terrestial Projects

Types			Yearly Revenue
Air and Sensor Technique			€ 167.200
Test & Certification	€	61.600	
R&D	€	105.600	
Extreme Climate Testing			€ 95.040
Environmental Testing	€	52.800	
Larger Machineries	€	42.240	
			€ 262.240

Funded Projects

Programs			Yearly Revenue
ESA Technology Programs			€ 110.000
TDE, GSTP, Prodex	€	110.000	
EU and National Programs			€ 352.000
Horison Europe	€	176.000	
National Funding	€	176.000	
Ph.D Program	€	-	
			€ 462.000


Revenue Forecast
€ 2.500.000
€ 2.000.000
€ 1.500.000
€ 1.000.000
€ 500.000
€ -
Break Even
€ 420.000
€ 503.438
€ 117.000
€ 108.000
€ 500.000
€ 167.200
€ 95.040
€ 110.000
€ 352.000
Argonaut (ESA)
Artemis (NASA)
HAKUTO-R Mission 2
Mars Sample Return
SciSpacE CORA
Air and Sensor Technique
Extreme Climate Testing
ESA Technology Programs
EU and National Programs

Proposed Financial Business Model

Funding and Investment

- **Government Grants and Space Agency Funding:** Significant funding will be sourced from national and international space agencies, supporting the primary construction costs.
- **Public-Private Partnerships:** Collaborations with private companies interested in space technology and terrestrial applications in extreme environments will provide additional funding and investment for having pre-reserved access.
- **Enterprise Foundations:** Danish foundations that support scientific initiatives and strengthen competitiveness within Danish businesses, particularly in the industrial sector, are also expected to provide funding.

Revenue Streams

- **Service Fees:** Fees for using the facility will be a primary revenue source. This includes testing services for space assets, terrestrial equipment, and environmental studies across various sectors such as transportation, appliances, agricultural, and meteorological.
- **Collaborative Project**s: Joint projects with industry partners can bring in additional revenue, often involving co-development of technologies and services.
- **Consultancy and Expertise:** Offering consultancy services in space simulation, environmental testing, and other specialized areas can generate importent revenue.
- **Incubation Services:** Offering access to experienced mentors, affordable office space, and test facilities for space developments. *This activity is self-sustaining and does not contribute to net profi.*

Costs

The total estimated construction costs for the facility, primarily funded via grants, are €27,557,000.

The annual operational cost is estimated at €1,754,000 which equates to approximately minimum €8.800 per day.

Annual Revenue Contributing to Operations

- Space Assets Testing and Certification: €1.7 million (hereof large scale ~50%)
- Terrestial Application: €0,3 million (all large scale installations)
- Collaborative Funded Projects: €0,5 million
- Incubation Services: self-sustaining

Depreciation Margin per Year

€1.7 + €0,3 + €0,5 - €1.75 millon = €0.75 millon per year

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TECHNOLOGICAL
INSTITUTE

Thank you

first sketch of the SpaceSite Lab facility 14/9-2023

This work is being carried out under a programme of, and funded by, the European Space Agency.
ESA Contract No. 4000144360/24/NL/GLC/ov
SpaceSite Lab – A Full Scale Moon and Mars Test and Research Facility

The views expressed in this brief do not necessarily reflect the official opinion of the European Space Agency.

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