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Self-deployable Habitat for Extreme Environments (SHEE) - An investigation of design principles

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IAC 2013, Beijing, September 23

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Particular focus on self-deployment and performance in extreme environments on Earth.

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OBJECTIVES

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To develop a self-deployable autonomous architecture and technology test-bed for simulating terrestrial analogues of extreme environments.

MARS BASE 10

Habitat will serve:

- To exterior and interior **operations tests** in extreme environments analogues and laboratory conditions *(deployment, operations safety, habitability, ingress /egress, ergonomics, functions allocation)*
- As **platform for** exterior and interior habitat **hardware tests**, its utilization and integration with emphasis on systems coupling *(communication hardware, robotic systems, rovers, EVA suits, Human Machine Interfaces, Environmental Control and Life Support Systems)*
- **Mission simulations** in laboratory or analogue conditions (TBD: up to x day autonomy, up to 28 days operations)
- **Outreach and education** (Space studies, Architecture, Aerospace engineering, System engineering, Industrial design etc.)
- The SHEE design principles and compact architecture may influence future buildings in **daily life**.

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SCOPE – Extreme Environments

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SCOPE – Extreme Environments

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Keeping in mind the space applications, the addressed extreme environments are narrowed down to those important on Earth (similar to space but less extreme) for the actual SHEE hardware development.

The project is addressing some of the highest extremes on Earth which are defined by following criteria and are relevant to planetary (gravity driven) architecture:

- **Missing or insufficient building infrastructure** (construction machinery, power, water, drainage)
- **Missing or unavailable workforce**
- **Contaminated, un-breathable** or **absent atmosphere**
- **Exposure to extreme temperatures** (below -50°C or above +50°C)
- **Logistics** - High requirements on ease of habitat transport rapid deployment and folding of the habitat

Doule, 2006, ARCHITEKTURA V EXTRÉMNÍM PROSTŘEDÍ, FA CVUT

Grosch, E., Antarctic field camp with Istund Peak in the background

RESEARCH

DFID - UK Department for International Development: Houses destroyed by tsunami

DISASTERS

Habitat Demonstration Unit, NASA

ANALOGUES

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Self-deployable

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Reasons for self-deployable function

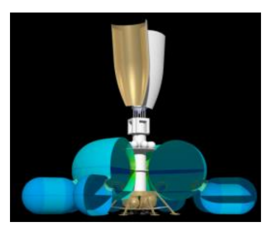
SAFETY – Building construction in extreme environments on Earth and in space is risky and dangerous. Self-deployment mitigates this risk and danger by excluding human from the construction process.

SPEED – Building construction in extreme environments on Earth and in space is risky and dangerous. Self-deployment mitigates this risk and danger.

COST EFFICIENCY – Building construction is a complex process composed of repetitive tasks that can be programmed. Robotics and/or rigid or inflatable structures can be combined and integrated in building to avoid utilisation of heavy machinery i.e., structure has „inbuilt“ construction workforce and machinery

AVAILABILITY – The packed habitats (folded buildings) can be produced in advance and stored as any other goods. In case of necessity, such buildings can be deployed in large quantity at once.

(VOLUME/LOGISTICS) – Packed and deployed ratio enables efficient transportation and habitat interior utilization



LUNAR BASE10 – Self-deployable base for 10 people on lunar pole – deployable structures analysis.Credit: Space Innovations, Sobriety

Robotics in architecture - 1910

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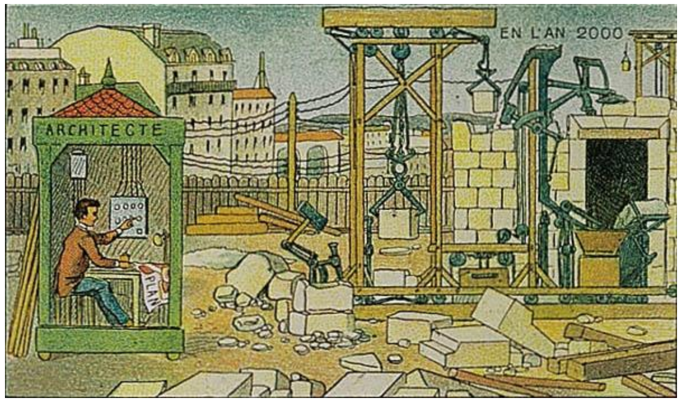

Electric construction 1910

Robotics in architecture – Concordia (ESA)

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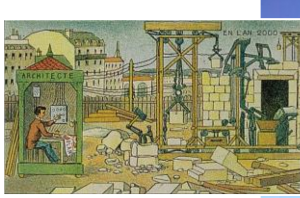

Concordia station

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Robotics in architecture – 1964

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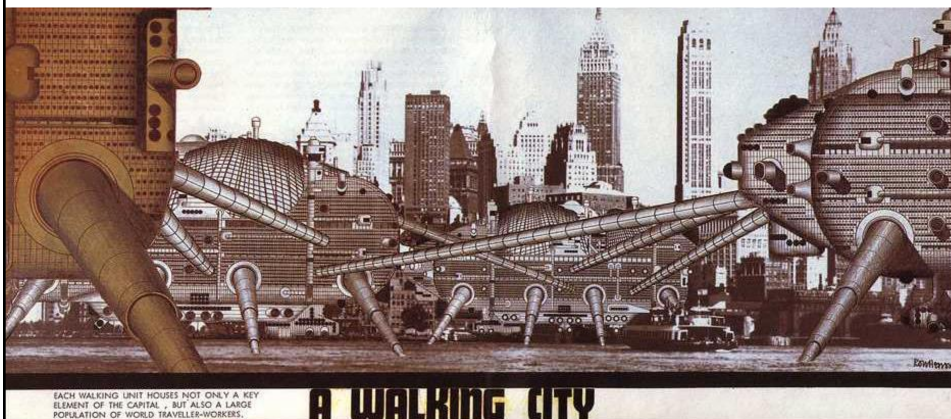

A WALKING CITY Credit: Archigram, 1964

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Robotics in architecture – Athlete (NASA)

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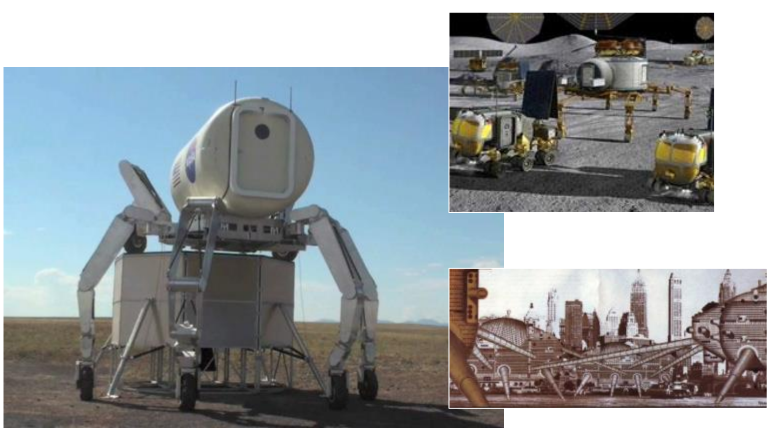

ATHLETE platform carrying cylindrical habitat, NASA

Robotics in architecture - NASA

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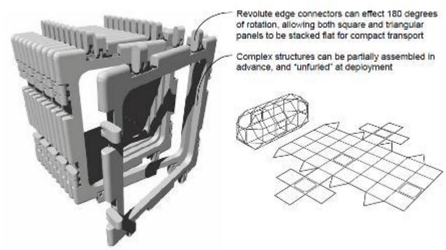
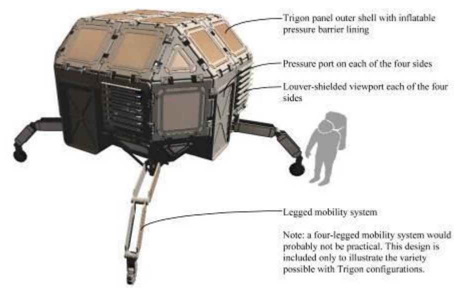
Self-deployable concept





TRIGON, Scott Howe

Inflatable architecture - Earth

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Sports hall – pressurized/airlock needed

Self-deployable concept in 1 minute

Crystal – Inflatable walls and windows/ no airlock

Eden Project – inflatable domes pressure corrections needed

Inflatable architecture - Space

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TransHab concept NASA JPL

Toroidal habitat NASA JSC, ILC Dover

Bigelow Expandable Activity Module

SHEE Design Drivers

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- SPACE (Moon, Mars): Living quarters, Laboratory, greenhouse
  - Logistics (payload shroud integration, surface deployment)
  - Safe and effective construction = self-deployment (autonomous deployment)
  - Gravity driven architecture
  - Radiation, micrometeoroids and dust protection
  - Life support systems
  - Power generation and thermal control
- Earth: Post-disaster management, areas without technical infrastructure and with harsh climate
  - Logistics (shipping cargo integration, ease of transport, surface deployment)
  - Safe and effective construction = self-deployment
  - Rapid and easy deployment, availability
  - Water, air filtration, waste management
  - Power generation and thermal control

Final - Design drivers for analogue base

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Develop a hybrid (rigid/inflatable) structure system for a self-deployable, autonomous habitat integrating robotics into architecture

- Self-deployable structure
- Efficient packed-deployed ratio
  - space logistics prefer a vertical cylinder configuration while terrestrial prefer a horizontal cylinder configuration
  - Operations and testing facilities capacity constraint
- Logistics (payload shroud integration, surface deployment, low mass)
  - Two person habitat capacity for up to two weeks depending on the environment
- Safe and effective construction = self-deployment (autonomous deployment)
- Gravity driven architecture
- Water and power autonomy
- ELCSS integration – airtight structure

Regulation of some design drivers by research focus and funding

- Level of autonomy during deployment
- Level of performance of ECLSS and waste management
- Lifetime of 5 years
- Power generation – not implemented

Design Drivers Trade-offs

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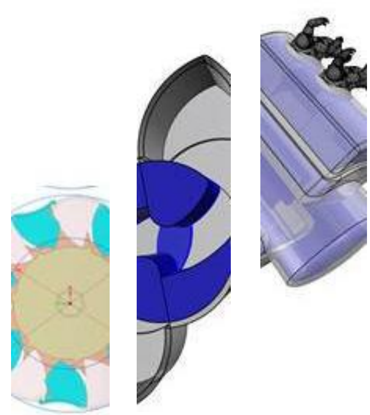
- Architecture trade-offs:
  - Low complexity structure
  - Simple deployment
  - Both space and terrestrial logistics requirements
  - Pressurizable shape – geometry efficiency
- Engineering trade-offs
  - Will be provided by mathematical modelling for space and terrestrial applications
  - For extreme temperatures and atmospheric pressure differences
  - ECLSS test-bed integrated



Design strategy outcomes

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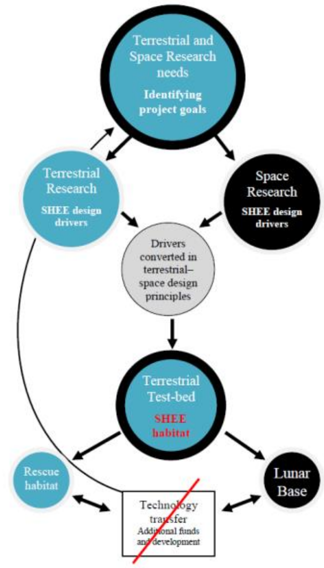
- **Interconnection of space and terrestrial architecture** is demonstrated on the SHEE project.
- Its benefits may be numerous in both terrestrial and space environments:
  - Autonomous habitation systems
  - Faster and safer construction
  - Enabling human-spaceflight by novel design strategies (ways how to approach space habitats designs)
  - Providing base for planetary settlements
  - Providing know-how for post-disaster camps
- Economic benefits from connecting space and terrestrial architecture
  - Terrestrial research platform for space
  - Dual use technology development (dual use - dual market)
  - Commercial implications for smart homes and smart appliances
  - Cost reduction and greater efficiency in the commercial and residential construction markets



SHEE selected concept visualization

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Credit: SHEE Consortium 2013

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