Reflection paper

This is a reflection on the graduation project:
Building on Mars. A *Research on In Situ Research Utilisation (ISRU) for a sustainable habitat which protects the crew on a Martian surface mission against the harsh environment.*

Relationship between research and design

The research question this thesis aims to answers is:
Which **in situ materials** and **forming techniques** are suitable to create an outer shell for a **sustainable habitat** on Mars which protects the crew from **the harsh Martian environment?**

The answer to this question is focussed on research in the field of material science (in situ materials) and on process technology (forming techniques), and is divided into different steps. The first step is a literature study on the subject of traveling to space, mission design, architecture in space, sustainability in space and an analysis of the design location: Jezero crater, Mars. This literature study forms the base to generate a programme of requirements for a sustainable habitat on Mars. This programme of requirements is leading for the following research and design as most currently available technologies are not complying to the high requirements. Therefore the programme of requirements is divided into three topics: material, process and structural design and further research is done. The research is done in a methodological way, starting with a literature study specific on the subject to identify the missing gaps. Then an experimental approach is used to create more empirical values. For example, ice composites were made as no current material complied to the high set of requirements. The composites were tested on mixing, melting and compressive strength to try to achieve a material which complies to the requirements. This led to the conclusion that adding sodium chloride (NaCl) to purified water adds strength, redundancy, still lets light through and is 100% ISRU, therefore meeting all the requirement regarding building materials.

When the three topics specific requirements are met, a design for a habitat is made to test the new technologies.
Hence research and design are closely related in this graduation thesis in an iterative process. For example, a research is done on material requirements, then a new ice composite is designed based on this literature study. To verify that the design of the material complies to the requirements, research in the form of experiments is made. Although both aspects are in constant iteration, this thesis has a clear focus on research and the design of the habitat is considered as another test for the research done rather than as the end goal.

Relationship between the theme of the graduation lab and the subject/case study

Within the Building Technology (BT) master track, every student graduates within the same studio: sustainable graduation studio. Throughout the whole master, sustainability has played an important role during design and research projects. This thesis has a clear focus on sustainability as it is part of the TISD (Technology in Sustainable Design) annotation. Sustainability is already a broad and controversial topic in the building environment here on Earth but building a sustainable habitat on Mars is even more vague. Therefore, the first sustainable aim of this project is to define sustainability on Mars. The term sustainability and the need for ecological measures on Earth became an urgency mainly due to climate change.

As Mars does not have a population yet and it is thus not currently experiencing climate change. As a matter of fact, the Red Planet was hotter and wetter some 3,6 gigayears (Gyr) ago and has therefore already experienced “climate change”. It is therefore nonsense to apply sustainable principles used on Earth to counteract climate change to design a sustainable habitat on Mars. The core concept behind sustainability is “to be able to sustain”. This concept is closely linked to the concept of redundancy which are both essential if a crew is sent to Mars. This crew will have to survive the harsh Martian environment having only 22 min delay communications with Earth and a possibility for a voyage every 26 months at best. This distance between Earth and the Martian surface is why redundancy and sustainability are not only important but are crucial for the crew’s survival and the completion of the mission.

Following this logic, to be able to sustain would mean being as much independent from Earth as possible, therefore allowing problems and potentials to be handled in situ without any time delay. Hence being sustainable on Mars means being independent from Earth and its resources. This concept of sustainability on Mars is translated into concrete design requirements.

The use of ISRU for the design of a habitat can be divided in five classes with class V indicating a complete independency from Earth. The analysed precedent designs are all categorized as class III habitats: an ISRU derived structure with integrated Earth components. Each of these classes can be compared to the technology readiness level (TRL), with the lower the class the higher the TRL. Therefore, as those two aspects need to be taken into account, the requirements set for this research is to have a habitat in between class III and IV, meaning that a class III habitat is designed with some class IV technologies which are tested in situ. This enables the class IV technology to have a higher TRL for the next Martian surface habitat as more missions will probably be sent after the first one. Combining technologies from both classes allow redundancy and possible sustainable expansion of the habitat following the principles set by Häuplik-Meusburger and Bannova (2016).

Relationship between the methodology of Building Technology & the chosen method

Within the master building technology, every project is a constant iteration between the design chairs: façade design, structural design, climate design and computational design. All of these disciplines are used to answer a technological challenge within the built environment. Although this method often leads to innovative ideas, I do think that the building industry often stays within known paths on specific aspects. Hence, I choose a new challenge which can't be answered using only the design chairs from the BT master track. When building a habitat on Mars, mission design is a huge design driver and therefore the complex matters of space travel, EDL, space architecture, etc. have to be understood in order to respond with an adequate habitat design.
Hence this thesis is based on knowledge from the other fields of aerospace engineering, material sciences and civil engineering and is then combined with my own knowledge within the build environment. This multi-disciplinary aspect influenced the design and design decisions, making this graduation project quite different from other projects within the BT master track. Outside the learning environment of the University, projects are often an iteration between different disciplines. Therefore, I think the methodology chosen for this project taught me valuable concepts which can be used in the future.

Relationship between the project and the broader social context

Societal relevance

This graduation research offers a new perspective for architects and building engineers on outer space architecture and sustainability. Usually sustainability is about preserving our planet because we live on it. As asteroids and other planets aren't inhabited by humans (yet), sustainability isn't believed to be an important factor when designing structures. However, as humans are starting to colonize space, maintaining and sustaining the resources as well as the current situation becomes more important. Especially as space isn't owned by a specific party (e.g. a state, a company, etc.) it is important to maintain this environment for everyone interested in space exploration. Moreover, just like Earth is our only Earth, the solar system is our only solar system. Building for a sustainable long term habitat has also economical relevance as the costs will greatly be reduced for follow-up missions.

Scientific relevance

The information gathered in this research can help design a new habitat for manned missions to Mars for interested parties. As some large space agencies (e.g. NASA, SpaceX) are planning to send manned missions onto Mars, the success of the mission depends on the wellbeing of the crew and on whether they survive the trip and stay on the planet. As outer space architecture isn't fully developed yet, every piece of information on how a habitat can be built will help protect the manned mission's crew.

● (green) Full utilization in relevant environment ● Sufficient risk reduction in relevant environment ⊙ Initial feasibility validation/partial validation	Earth	ISS/Low-Earth Orbit	Lunar Vicinity (Earth-Moon Lagrange Point (EML), Moon Orbit)	Moon Surface	Mars Vicinity	Mars Surface (Robotic Mission)
Beyond Low-Earth Orbit Crew Transportation			●	●	● (green)	
Heavy Lift Launch			⊙	●	● (green)	
Reduced Supply Chain		⊙	●	●	● (green)	
Autonomous Crew Operations	⊙	⊙	●	●	● (green)	
Deep Space Staging Operations			● (green)		● (green)	
Mars Ascent	⊙			⊙		⊙
Space Radiation Protection/Shielding		⊙	●	●	● (green)	
Life Support & Habitation Systems		●	●	●	● (green)	
Entry, Descent, & Landing Systems	⊙			⊙		●
Surface Power and Energy Management	⊙			● (green)		● (green)
Surface Mobility	⊙			●		●
Human Robotic Integration	⊙	●	● (green)	● (green)	● (green)	● (green)
Mars In-Situ Resource Utilization	⊙			⊙		●
Long Duration Human Health	⊙	●	●	●	●	
Deep Space Operation Techniques	⊙	⊙	●		● (green)	

Note: This table assumes critical capabilities will be provided by multiple agencies.

Figure 1. Risks of space exploration (ISECG, 2013, p. 21).

Relevance at TU Delft Building Technology

This research takes into account the research of two other TU Delft Building Technology students: Nihat Mert Ögüt and Carlijn van der Werf who both started their graduation project in November 2016 on building on Mars focussing on radiation shielding and on the program of requirements, respectively. This research is focussing on a different aspect (ISRU materials and process with regard to sustainability) of the overall task which is: building on Mars. In a way this research is complementary to the two other master theses.

Ethical aspects

Building on Mars, or even sending humans to Mars, is a complex issue especially combined with sustainability concepts. As one of the reasons to go to Mars is mining, some people think we shouldn't go. Their main argument is that we create problems on our own planet (climate change, material scarcity, water scarcity, etc.) and therefore shouldn't go and create problems to another planet like Mars. Especially because mining Mars would possibly mean to completely "destroy" the planet to satisfy the needs of humans. This thinking leans towards finding a solution within our planet as we are the ones who created the problem.
On the other hand, people think that we past the point where a solution can be provided within Earth and that mining other planets would help our planet as this planet is the only friendly environment to humans. Their main argument is thus that it is better to destroy another less habitable planet than our planet Earth.
Both arguments are for sustainability and show how broad and open to interpretation the term sustainability is. This ethical question is at the core of my thesis on whether we should or shouldn't send humans to Mars.

Sources:

Häuplik-Meusburger, S., & Bannova, O. (2016). *Space Architecture Education for Engineers and Architects: designing and planning beyond earth*. Cham: Springer.

ISECG, (2013). The global Exploration Roadmap. *National Aeronautics and Space Administration*. Washington.