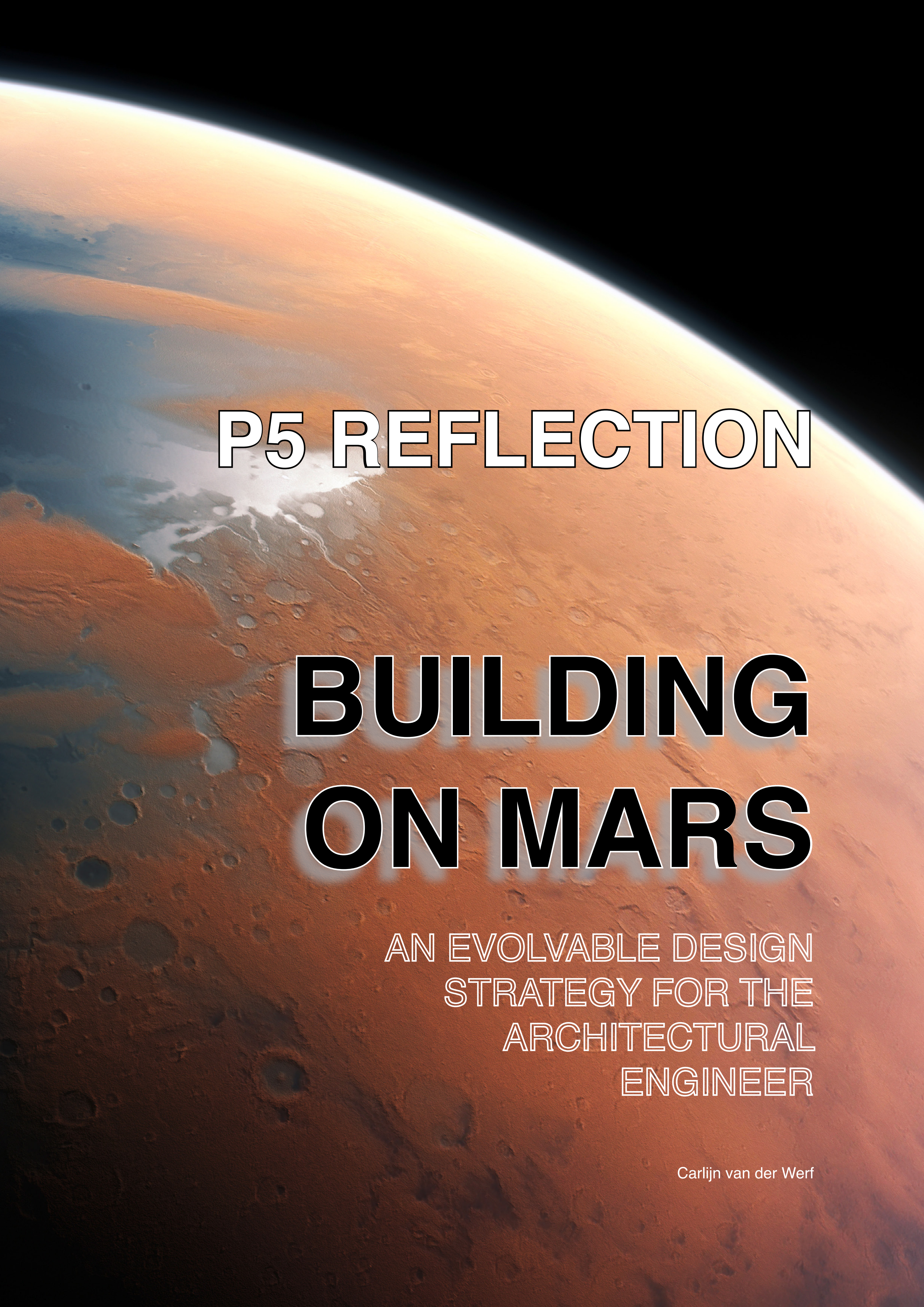

P5 REFLECTION

BUILDING ON MARS

AN EVOLVABLE DESIGN STRATEGY FOR THE ARCHITECTURAL ENGINEER

Carlijn van der Werf

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P5 reflection
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Author:
Bsc. Carlijn van der Werf

In cooperation with:
Bsc. Nihat Mert Ogut
Bsc. Layla van Ellen

First tutor:
Prof.dr.ing. Ulrich Knaack

Second tutor:
Dr.MScArch. Michela Turrin

Delegate examiner:
Dr.ir. Alexander Koutamanis
Dr. Ilir Nase

Consulted experts:
Ir. Kevin Cowan MBA
DArch. Tristan Bassingthwaigthe
Dipl.-Ing. Dr.-Ing. Sandra Hauplik-Meusburger
PhD Lic. Eng. Olga Bannova
Dr. Angelo Vermeulen

1. INTRODUCTION

1.1. SURFACE HABITAT DESIGN FOR MARS

To start with designing habitats for Mars a 3D-printed habitat design challenge was organised in 2015 by NASA in collaboration with Berkeley University and America Makes (NASA, 2017). The competition led to some initial concept designs for martian surface habitats. Several lessons can be drawn from the designs, but still the question rises whether these designs will meet all the necessary requirements. As long as there is no clear mission defined it is hard to define the leading parameters for the brief.

This is where Space Architecture comes in. The Space Architect is positioned between the architect and the engineer, trained to balance qualitative and quantitative requirements for space design. (Bannova et al., 2016) Space architecture is concerned with designing habitability for missions in Isolated and Confined Environments (ICE) (Suedfeld, 2000) to orbit, Moon, Mars and beyond.

Yet, it is a relatively new discipline officially developed as an education in 2003 (Duerk, 2004). Due to it’s recent establishment, it is not widely known to be a certified profession. Space Architecture is currently taught at ten universities around the world. (Bannova et al., 2016) Clear manuals on Space Archicture barely exist. A profound knowledge of both architectural design and space mission design is required. (Bannova, 2011)

1.2. OBJECTIVE

The objective of this research is to come up with a strategy to develop a feasible surface habitat for a human mission to Mars. The architectural engineer is trained in balancing quantity and quality to serve the design goal. In order to check if the suggested approach works, it ought to be tested with a design. The desired outcome is to develop a list of criteria to establish a feasible martian architecture and a framework with highlighted problem areas in the habitat system design. These challenges can stimulate further research in the field of Building Technology, with the ultimate goal of a faster advancement in habitat development and mission succes.

To narrow the domain of research, several boundaries and assumptions are defined. The focus is put on developing a suitable habitat for the first human settlement on Mars. Planning for this mission assumes immediate development and application of state of the art technologies. Future technological developments are likely to have a major impact on the design outcome. These alterations have to be taken into account for future value of the research outcome.

MAIN RESEARCH QUESTION:

What aspects are to be considered when developing a habitat for the first human settlement on Mars?

Several sub-questions:

What are the conditions on Mars?
- what are the differences compared to Earth?
- what are major issues concerning habitat design?

What will the mission look like?
- what will be the mission objective?
- what is the schedule?
- what are logistical constraints to consider?

What team will go and what will they need?
- what is the crew size?
- what are the psychological needs?
- what architectural means can be applied in addressing these needs?

What habitat will they need and how should it be build?
- what is the brief for programmatic functions?
- what is the site?
- what does the habitat system look like?

1.4. APPROACH

Before starting with research into mission design and space architecture, the conditions and characteristics of Mars will be studied and explained. The first chapter of the thesis, will form a brief introduction to Planet Mars.

In order to come up with a realisation strategy for a martian surface habitat, it is necessary to define the mission context as a baseline. Understanding the keydrivers and decision parameters in Mission Design for a manned mission to Mars, is critical in habitat development as the technical constraints form an integral part of the mission's system architecture.

Apart from these technical constraints, the qualitative needs for the crew are to be identified as important architectural design parameters. Space Psychology plays a leading role. Research in this field has generated leading insights in the crew's composition and psychological processes that occur during a mission.

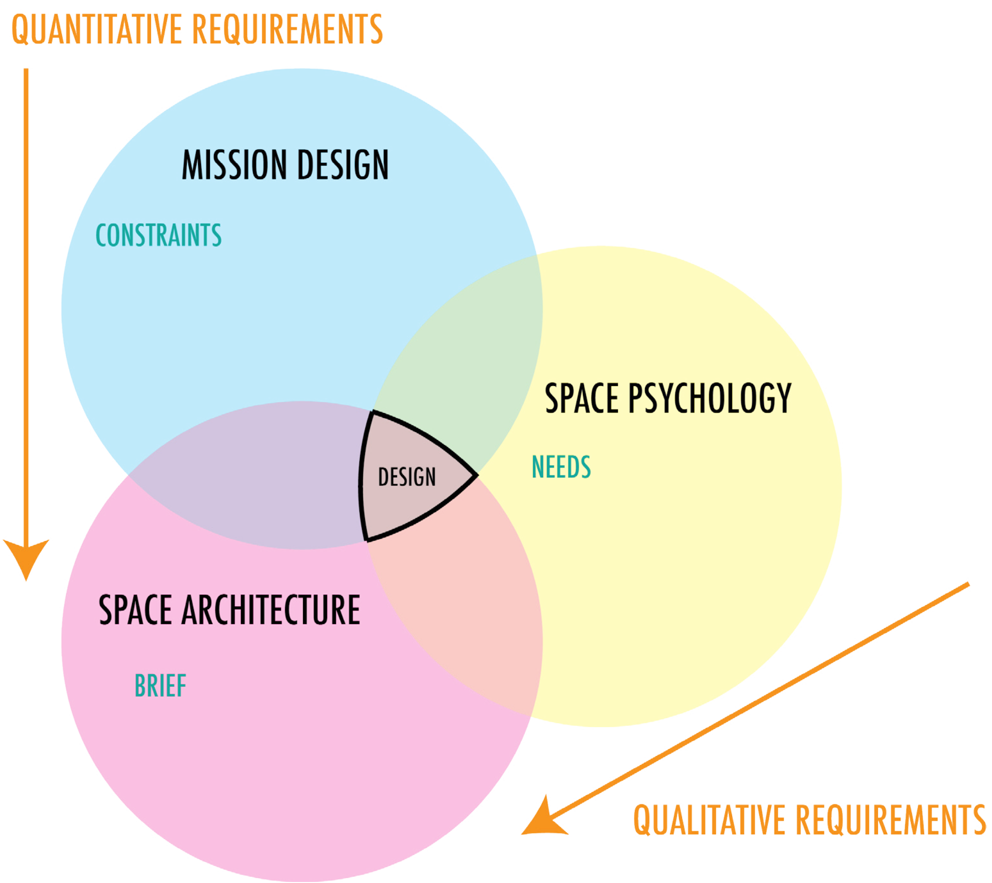
In addition, a lot can be learned from former Space Architecture research and the designs. Findings from design analysis, will contribute to building a comprehensive brief as a baseline for the assignment. The brief will serve as a checklist in the first stages of development to check to what extend the habitat intends to add value and to identify points for improvement.

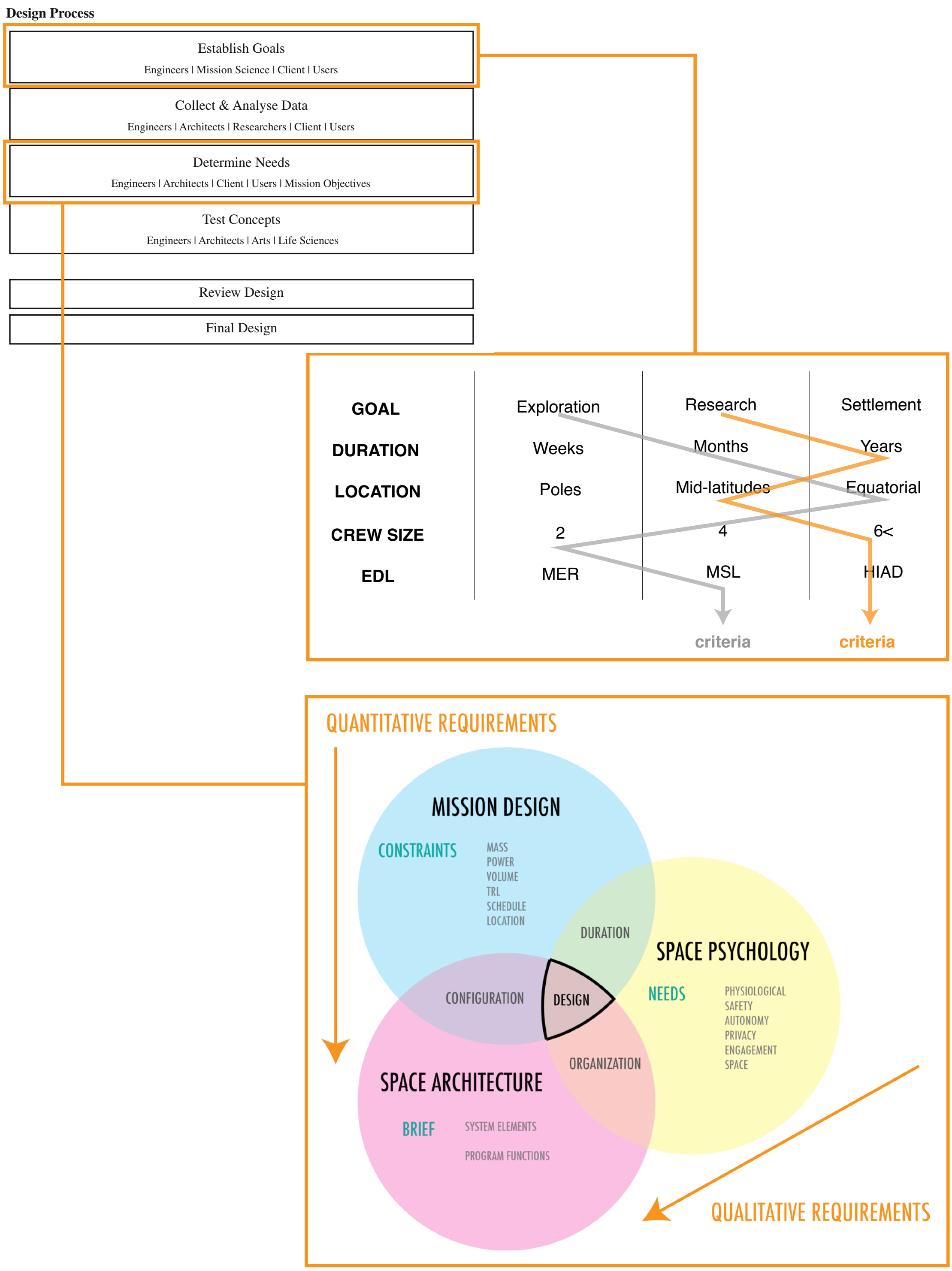
The outcome of this research will be a strategy to approach a problem of this size in these extreme circumstances where the stakes are high. Also a design will be developed intended to get a first grasp on the size of the challenge in meeting the formulated list of requirements. The list can serve as a starting point for defining the parameters in the equation to guarantee mission success. These parameters can then be updated according to developments in other areas of the mission's system architecture.

Information is gathered based on literature research and interviews with various experts. The chapter on Mission Design will be peer reviewed by Kevin Cowan, professor in Space Systems Engineering at the faculty of Aerospace Engineering from Delft University of Technology. The chapter on Space Psychology will be peer reviewed by Tristan Bassingthwaithe, who received his doctorate in Space Architecture in May 2017 on designing for Long-Term Health of Inhabitants of Extreme Environments.

1.5. THESIS STRUCTURE

The research is set up according to three leading disciplines: Mission Design, Space Psychology and Space Architecture. The history, progress and most recent findings will be explained and evaluated. Findings from this research will add up to a conceptual brief that enholds, but is not limited to, some first basic requirements. As a result, overlapping design drivers for a human mission to Mars will be identified and used for the baseline habitat's system architecture. A sketch design will be made and weighed against the criteria. Conclusions are drawn in the final chapter, followed by recommendations for future research.





Design Process
Establish Goals
Engineers | Mission Science | Client | Users
Collect & Analyse Data
Engineers | Architects | Researchers | Client | Users
Determine Needs
Engineers | Architects | Client | Users | Mission Objectives
Test Concepts
Engineers | Architects | Arts | Life Sciences
Review Design
Final Design
GOAL
DURATION
LOCATION
CREW SIZE
EDL
Exploration
Weeks
Poles
2
MER
Research
Months
Mid-latitudes
4
MSL
Settlement
Years
Equatorial
6<
HIAD
criteria
criteria
QUANTITATIVE REQUIREMENTS
MISSION DESIGN
CONSTRAINTS
MASS
POWER
VOLUME
TRL
SCHEDULE
LOCATION
DURATION
SPACE PSYCHOLOGY
NEEDS
PHYSIOLOGICAL
SAFETY
AUTONOMY
PRIVACY
ENGAGEMENT
SPACE
CONFIGURATION
DESIGN
ORGANIZATION
SPACE ARCHITECTURE
BRIEF
SYSTEM ELEMENTS
PROGRAM FUNCTIONS
QUALITATIVE REQUIREMENTS

2. CONCLUSION

2.1. TOWARDS AN EVOLVABLE DESIGN STRATEGY

The architect has to synthesize quantitative constraints and qualitative requirements into one integrated design. For extreme circumstances, such as a mission to Mars, it was found that the mission architecture forms the baseline for the design parameters that the architect has to consider. The mission architecture will result in the baseline assumptions for mission objectives, duration, crew size, location, logistics and functional activities. Based on these assumptions the criteria for constructability of the surface habitat can be quantified. In addition, the characteristics of the crew and their psychological and physical needs can be defined. These requirements will then form the driving parameters for the space architect.

During habitat development a continuous design iteration will be necessary between the architect and mission engineers as well as space psychology experts. The architect will develop the habitat's configuration of system elements and organization of functional activities. In turn, the other experts will evaluate the proposal based on the constructability and habitability of the habitat system, therefore qualifying the design in terms of its feasibility.

Some preliminary criteria for the design evaluation have been defined. The criteria related to constructability enhold, but are not limited to, fitting the budgets of mass, power, volume and the schedule as well as having the chosen sub-systems to meet the required TRL's and the building construction to meet the requirements for technical performance based on characteristics of the chosen location.

The criteria related to habitability enhold, but are not limited to, meeting the physiological needs and safety measures for psychological well-being, facilitating privacy, engagement opportunities and autonomy in organizing the physical and psychological perception of the environment as well as a creating a positive perception of the enclosed space.

The objective of the research was to formulate a list of requirements as a brief for the habitat. A quantified brief was found to be a difficult task to complete within the set time frame, as the mission architecture forms the baseline assumption for formulating exact design requirements. Defining a quantified mission architecture, was a difficult and complex task and is normally allocated to mission engineering experts. However, based on extensive analysis of mission architectural design and engineering, some preliminary parameters could be defined.

Finally, a design exercise was conducted to test application of the design parameters based on the formulated quantitative constraints and qualitative criteria. The result of the preliminary design revealed insight in the complexity of the design task at hand and the need for a continuous interdisciplinary design iteration between experts from both mission engineering and space psychology. These iterations will be of vital importance in order to come to a final habitat design which will be feasible in terms of constructability and habitability and add to achieving mission success. The defined framework will form a starting point in shaping this design process, thus resulting in an evolvable design strategy.

3. REFLECTION

3.1. RELATIONSHIP BETWEEN PROJECT AND WIDER SOCIAL CONTEXT

In the past decade, I witnessed the development and increased global awareness for many crises in the world: the financial crisis, the refugee crisis and perhaps the most important of all, the climate crisis. After choosing the take up the challenge on engaging in the latter one, I decided in 2014 to go for the master track in Building Technology, which focussed on sustainable building development. In the master track a heavy emphasis was put on managing and optimising the use of Earth's resources.

For my graduation research, I decided not to fixate on the problems we've created in the past and present, but to focus on hopeful future solutions and ideas that ignite motivation and excitement. An inspiring vision is likely to result in a more effective and successful journey towards the end goal. I'm convinced that exploration induces innovation and generates new perspectives on these problems. This is why I chose to design for Mars.

3.2. RELATIONSHIP BETWEEN RESEARCH AND DESIGN

In a later stage, after the P3, my first tutor pushed me towards starting with a design. I was deep into the process of research and he reminded me that it would have to result in a design. He asked me to chose a decision method that could help me with defining driving design parameters. This is when I came to the conclusion, that the scope of the research was too big. It would not be possible to come to a quantified brief based on the interests from the perspective of mission engineering and also space psychology. As a result, I had to alter my approach and structure in order to come to tangible results within the given timeframe.

This process taught me about the complexity of the formulated design task. When I started designing from the driving parameter of system sizing according to quantitative and qualitative criteria, I realised that the design process would required many iterations between disciplines. It also made me realise that an architect just has to start at a certain point somewhere with a design, in order to start this process of iteration.

The research was valuable and necessary to start the process of designing. During the design I realised that this complex design task could not be merely a single person job. A constant evaluation is necessary from various disciplinary perspective and requires time and precision.

3.3. RELATIONSHIP BETWEEN BUILDING TECHNOLOGY AND BUILDING ON MARS

Space is a hostile and inhabitable environment and doesn't have a forgiving nature. A space exploration mission calls for extremely rigourous planning, with many built-in failure-safety scenarios in order to achieve mission success. Designing for space enforces an efficient, effective and flexible approach for product development. Past exploration missions have led to radical technical innovations beneficial for earth application, such as development of the solar panel. Research in the field of extreme, deep-space architecture, can advance innovative development for new building systems, advancing current knowledge about Building Technology.

3.4. REFLECTION ON APPROACH

In januari 2017, as part of my P2, I handed in a graduation plan with a conceptual draft of the process and chosen methodology. The original research question was posed as:

> *"What is a suitable facade design for a Mars habitat, using automated construction, to mitigate psychological and radiation exposure risks for human health?"*

The original objective was formulated as:

> *"The objective of this research is to develop a facade design and construction methodology that is adequate to mitigate the risks for psychological health and radiation exposure for a manned mission to Mars. This objective unfolds itself in the following sub-objectives.*
>
> 1. *Definition of constraints and required technical performance based on literature for the construction of a Martian facade with ISRU-technologies.*
> 2. *Development of design guidelines for a facade construction that meet the constraints and technical performance criteria for a Martian surface habitat.*
> 3. *Evaluation of current architectural Mars surface habitat proposals whether they will or will not be expected to have a negative effect on the crew's psychological health.*
> 4. *Assessment of the facade designs for the proposed surface habitats whether the expected technical performance is sufficient to shield against radiation.*
> 5. *An assessment of the automated construction methodologies for a surface habitat and it's expected feasibility for a Mars mission.*
> 6. *Combined evaluation of architectural performance, expected technical performance and construction methodology for a Mars surface habitat.*
>
> *It is likely, that an ultimate facade design proposal can not be found. The use of ISRU-technologies will influence the materialisation of the habitat, thus it's expected technical performance. This research intends to expose a suitable design methodology to balance the human risks related to deep space architectural design."*

During the process of looking at facade considerations, I got stuck on the question whether the facade would need a window. Then, I drifted of to psychological considerations to mitigate the Behavioral Health and Performance risks for a human mission to Mars. A feedback session in early March with both my two tutors resulted in a shift in the research approach.

We figured that the primary interest was to figure out how design decisions concerning behavioral health and designing for habitable quality interfere with the strategy of habitat construction. This perspective on a complex design issue might reveal some interesting insights for a wider application in circumstances and design tasks on Earth.

In all, I changed my methodology which led to the results as described in the previous chapters. Looking back on the orginal question and objectives, I can tell that I did find some of the answers. As a result, I have formulated a starting point for objective 1 and 2. Apart from that, I did do the 3rd and 4th objective: I have assessed other designs, though I did not document and include all the results and findings in the report. However, the 5th objective was not achieved due to time limitations. Objective 6 was only achieved by a certain preliminary extend in the design evaluation in Chapter 6 of the report.

3.5. REFLECTION ON COLLABORATION

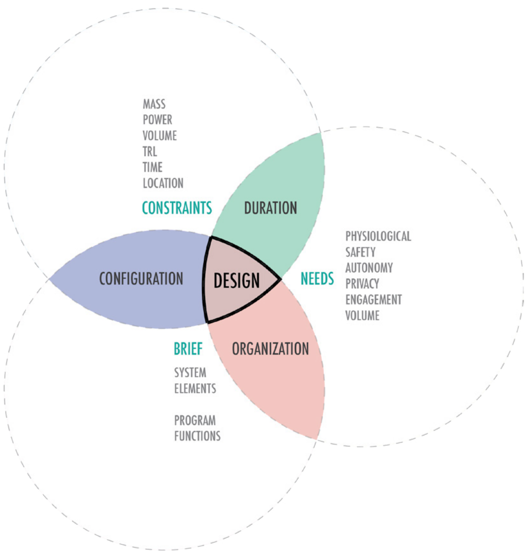
In november 2016, Nihat and I started the research on the topic together. At the P2, the external examiner set the rule that we'd continue with individual research trajectories and not be dependent on each other. The collaboration would have to be complementary to each other and not hold each other back. In hindsight, I am very glad that I was able to focus on my own research. The collaboration took up a lot of extra energy.

In the spring of 2017, Layla started her graduation thesis on the topic Building on Mars. She has been working on developing an ISRU ice structure in martian conditions. Our collaboration has been very fruitful and motivating. We reflected on each others findings a lot, we've read eachother's thesis and gave me some very constructive feedback. What I learned, is that the best collaboration is based on management of expectations.

3.6. FINAL REFLECTION ON RESEARCH OUTCOME

As a result I have developed a framework applicable for designing architecture for Isolated and Confined Environments, such as capsule habitats, applicable for extreme circumstances in either full or partial gravity. The case study of designing a martian surface habitat was used as a means to develop this framework. This framework should be tested in other design cases for validation.

During the process of research, I investigated the perspective of various disciplines and identified some areas in which they overlap. These overlapping design drivers were defined as mission duration and habitat system configuration and system organization. The latter two formed the leading parameters from the perspective of the space architect in the conducted design exercise. The configuration was then evaluated based on the formulated technical criteria, defined as constraints for constructability. And the organization was evaluated based on the formulated qualitative criteria, defined as needs for habitability. In order to validate the formulated criteria and design drivers, further research has to be done on other design cases.



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