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ASSIMILATING REQUIREMENTS SPECIFICATION FOR SPACE MANNED MISSIONS: A NOVEL APPROACH

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This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science in Software Engineering

Under the Supervision of Dr. Sofia Ouhbi

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Declaration of Original Work

I, Khalfan Mohamed Al Remeithi, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*Assimilating Requirements Specification for Space Manned Missions: A Novel Approach"*, hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Dr. Sofia Ouhbi, in the College of Information Technology at UAEU. This work has not previously formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

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Abstract

Aligned with the UAE Space Strategy 2117, which aims to establish the first inhabitable human on the Martian Surface by 2117, and with the current enthuse toward space tourism, the thesis proposes a novel framework to assimilate the process of requirement specification for a Manned Mission to Mars surface. Deep Space manned missions are unique and characterized by a set of specific requirements that should be elicited from different sources and stakeholders to ensure the missions' success. In addition, these missions are highly dependent on the software components in the Command and Data Handling System (CDHS), which is used to control the spacecraft and interact with the astronauts. Thesis contribution consists of: (i) surveying current trends in space system requirements engineering from requirements elicitation to requirements specification; and (ii) introducing a new set of requirements for CDHS in space missions that are related to astronauts, particularly emotional requirements for deep space manned missions, which have not been considered before. Moreover, the contribution introduces a modular requirement model to ensure the modularity and reusability of these requirements in several manned space missions. The thesis contribution will strengthen the position of UAE as one of the top countries in the world that invest in space sciences.

Keywords: Requirements Engineering, Requirements Specification, Space Mission Requirements, Emotional Requirements.

Title and Abstract (in Arabic)

أسلوب مستحدث في إستيعاب مواصفات متطلبات البرمجيات للمهمات الفضائية المأهولة

الملخص

تماشيا مع توجهات دولة الإمارات العربية المتحدة في قطاع الفضاء و مشروع إستكشاف المريخ 2117، بالإضافة إلى الحماس العالمي لقطاع الضيافة و الفنادق الفضائية، تمت دراسة متطلبات البرمجيات للمهمات الفضائية المأهولة لإستحداث إطار العمل لإستيعاب المواصفات المتعلقة بالمهمات الفضائية المأهولة التي تتمتع بخصائص و متطلبات فريدة يتم وضعها من خلال مصادر مختلفة وبالتعاون مع أصحاب المصلحة المختلفين. إضافة إلى ذلك، هذه المهمات الفضائية تعتمد بشكل كبير على أنظمة القيادة ومعالجة البيانات التي تقوم بالتحكم بالمركبة الفضائية و يتم من خلالها التفاعل مع رواد الفضاء. تساهم الرسال (أ) بمسح التوجهات الحديثة في هندسة المتطلبات المتعلقة بالمركبات الفضائية من إستنباط و تخصيص، كما تساهم (ب) بتقديم مجموعة من المتطلبات المتعلقة بأنظمة القيادة ومعالجة البيانات للمركبات الفضائية المتعلقة برواد الفضاء، خصوصا المتطلبات العاطفية لهمات الفضاء المأهولة، حيث أنه لم يتم تخصيصها من قبل. أيضا، تقوم الرسالة بتقديم نموذج معياري للمتطلبات يضمن تقديم مواصفات معيارية يمكن إعادة إستخدامها في عدد من المهمات الفضائية المختلفة. تساهم الرسالة في إبراز موقع الإمارات كواحدة من الدول الرائدة في الإستثمار في علوم الفضاء.

مفاهيم البحث الرئيسية: هندسة المتطلبات البرمجية، مواصفات المتطلبات البرمجية، المتطلبات العاطفية للبرمجيات، متطلبات الجودة للبرمجيات، متطلبات المهمات الفضائية.

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I would like to thank my committee for their guidance, support, and assistance throughout my preparation of this thesis, especially my advisor Dr. Sofia Oubi whose endless support was integral in completing the work. I would like to thank the chair and all members of the Department of Computer Science and Software Engineering at the United Arab Emirates University for assisting me all over my studies and research. Special thanks to the Library Research Desk for providing me with the relevant reference material.

I would like to extend my immense gratefulness to my mother and wife who have both helped me throughout this journey and who at some point thought it was an endless one.

Dedication

To my beloved parents and family

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List of Abbreviations

AIT	Assembly, Integration and Testing
BDD	Behavior Driven Development
CAN	Controller Area Network
CDHS	Command and Data Handling
COMM	Communications
ConOps	Concept of Operations
DC	Domain Characteristic
ECSS	European Cooperation for Space Standardization
ER	Emotional Requirements
ESA	European Space Agency
Exp	Expert
FA	Functional Analysis
FSM	Finite State Machines
GDRD	General Design Requirements Documents
GPS	Global Positioning System
HCI	Human Computer Interaction
HK	Housekeeping
HMI	Human Machine Interaction
I2C	Serial Communication Protocol
LR	Legal Requirements
MARTE	Modeling and Analysis of Real-time and Embedded
NASA	National Aeronautics and Space Administration
NSSTC	National Space Science Technology Center

PPS	Pulse Per Second
R&D	Research and Development
RAM	Random Access Memory
RE	Requirements Engineering
RQ	Research Questions
RTOS	Real-Time Operation System
S/C	Spacecraft
SCATA	Service-based Context-awareness Tourism Application
SH	Stakeholder
SR	Source
SRE	Software in Regulated Environment
SRS	Software Requirements Specification
SyRS	System Requirements Specification
ST	Stakeholders Statement
SW	Software
SysML	Systems Modeling Language
TBC	To be Confirmed
TBD	To be Defined
TS	Trigger Scenarios
UNOOSA	United Nations Office for Outer Space Affairs

Chapter 1: Introduction

1.1 Overview

Recently, there has been a promising growth of the space tourism market and the international global enthusiasm about space. The United Arab Emirates (UAE) established its Mars Exploration Program with the first Mars Probe (Hope) in July 2020, with an important involvement of UAE scientists and engineers specialized in Space Explorations (Zheng, 2020). Moreover, the UAE plans to collaborate in building the First Human Settlement on Mars by 2117 (Murphy, 2019). There is therefore a need to consider an approach to define and specify requirements, particularly those concerned with human factors, for space manned missions. The following thesis attempts to investigate and build an understanding of domain-specific Software Requirement Specification (SRS) and System Requirement Specification (SyRS) framework for Command and Data Handling Systems (CDHS), which are used in space manned missions. This framework will help create a modular set of requirements that is aligned with different stakeholders' needs and concerns, technical and legal guidelines, and astronauts' emotional and cognitive needs. Moreover, this framework will help reduce time, cost, and effort in initiating space manned missions while ensuring a high quality of astronauts' work.

The proposed methodology fused to achieve this contribution is composed of five main steps. First, different requirements sources and references related to space manned missions were selected. Reference models are documents that will be used as references to align the selected requirements. These references have been selected in a way that contributes to the national and local efforts of improving the space sector by identifying possible local collaborators such as the National Space Science and

Technology Center (NSSTC) and the UAE Space Agency. The output of this step resulted in defining statements that can be translated into requirements to be used in the framework. After that, domain characteristics were introduced domain characteristics to the different sources to ensure that the reference is well-matched with the domain characteristics. After matching the SRS reference with the domain characteristics, the thesis introduced the environmental regulation. This step ensures that the SRS reference is according to the domain characteristics and regulations. The fourth step of the methodology consisted of introducing emotional requirements. The thesis introduced emotional requirements into the space manned missions and consider them a key factor in the success of the development of new software systems that satisfy astronauts' emotional preferences (Kuo et al., 2016). In the last step, different stakeholders have been consulted to ensure their participation in initiating the framework.

The proposed framework has been refined and validated with experts from the NSSTC and the space domain to ensure the quality of the work. This work can be used as a reference framework for defining requirements for CDHSs for future missions by the NSSTC or other stakeholders in the space sector. Moreover, it is a contribution toward the UAE National Space Strategy and Mars 2117 project by defining a reference framework and introducing Emotional Requirements to the developers' community to ensure a high quality of future software systems in space manned missions. As it is foresighted that the habitants will be built for long-duration manned missions on the Martian surface the importance and a need for a framework is increased.

1.2 Statement of the Problem

As the UAE joined the Space Exploration activities recently, the need to have frameworks to serve the space exploration projects has emerged, particularly as different countries have their frameworks that are applied locally. Moreover, the need to ensure the high quality of space manned missions raises the issue of having requirements that are compliant with domain characteristics and with environmental and local regulations. The aim of this thesis is therefore to propose a framework that will ensure the compliance of UAE space manned missions with these characteristics and regulations. This thesis will also introduce emotional requirements to improve the user experience of astronauts and to increase the quality of the proposed framework. To fulfill these objectives, the thesis addresses the following Research Questions (RQs):

RQ.1 What are the best practices and used approaches to specify requirements for space missions?

RQ.2 How to define the emotional requirements to be included in the framework?

RQ.1 will be answered by looking at related literature and reference models from space agencies that have a legacy and a heritage in Human Space flights. This will help to collect accumulative knowledge based on past experiences.

RQ.2 will be answered by looking at different possible candidate emotional models that can be used to derive from as there are no emotional requirements models that are used in the space sector explicitly.

1.3 Relevant Literature

This is a multidisciplinary thesis dealing with different disciplines as shown in Figure 1.

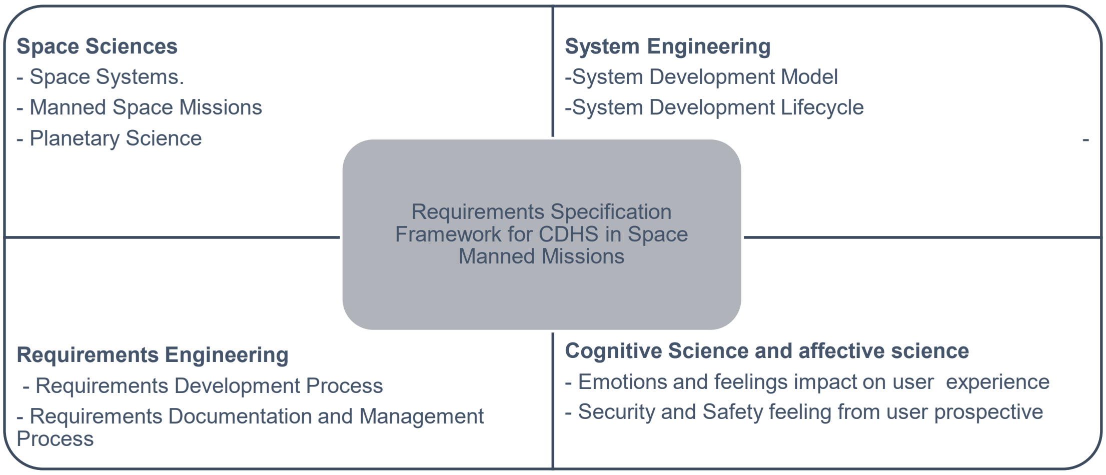

Figure 1: Collaborative Domains Covered by the Proposed Framework

1.3.1 Definitions

1.3.1.1 Requirements Engineering

Every software product is designed to serve a set of needs; these needs are known in the industry as Requirements and the set of activities, tasks, and techniques that are practiced to understand these needs are called Requirements Engineering (RE) (Pressman, 2010). RE includes a set of activities that defines the process of RE that are Requirement Elicitation, Requirement Analysis, Requirement Documentation, and Requirement Validation (Ramingwong et al., 2012) as shown in Figure 2.

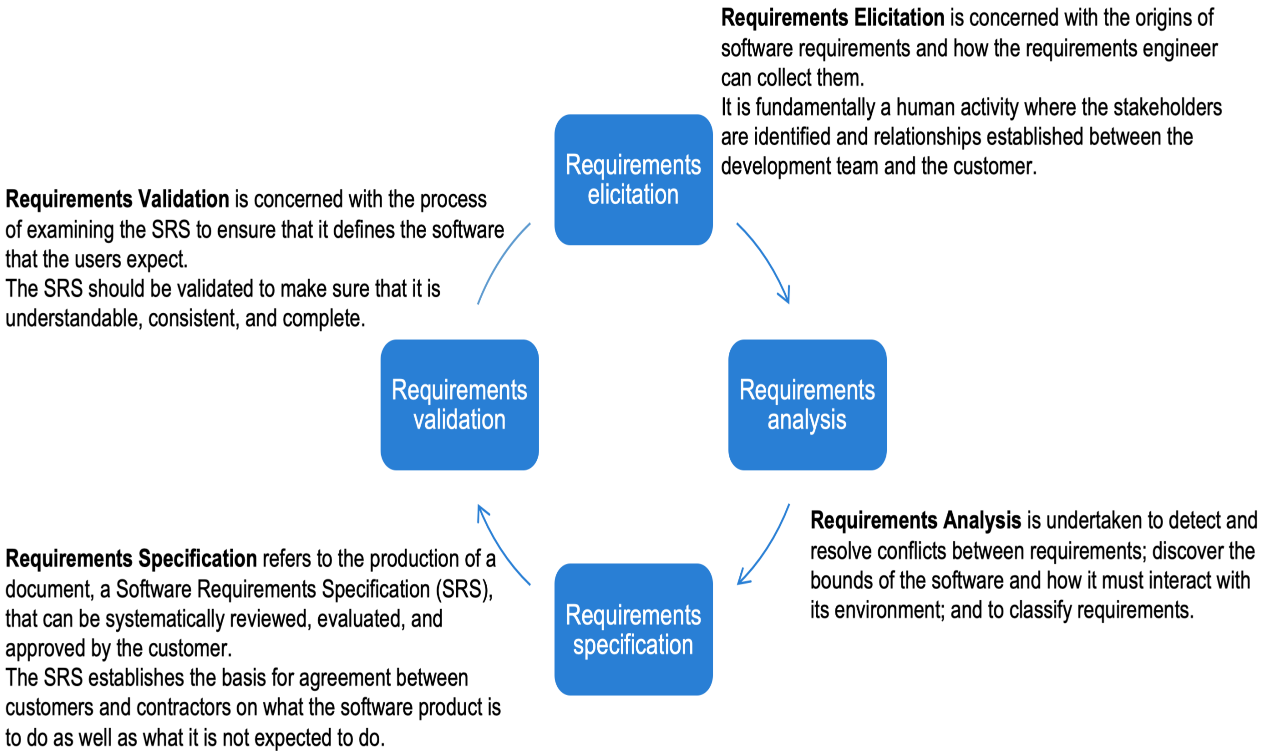

Figure 2: Requirements Development Process

RE could also be defined as a set of activities involved in creation, managing, documenting, and maintaining a requirement set for a product (Marques & Yelisetty, 2019). The Importance of RE resides in the fact that it is one of the main reasons to successfully build the software:

• Requirement ambiguity is considered one of the top reasons leading to projects failure (Ramingwong, 2012),

• RE allows the engineers to examine the software context, the tasks to be performed and the priority of these tasks to be done in order (Pressman, 2010),

• RE is one of the key processes in the creation and customization of software products (Spijkman et al., 2019),

• Poor requirement management can complicate software development projects (Spijkman et al., 2019).

In this thesis, the team focused on the Requirement Documentation and Specification that is the set of documents, graphical and mathematical models that are used as a combination to produce an SRS and SyRS (Pressman, 2010). Moreover, the thesis plan to introduce Emotional Requirements into the Space manned missions as it is a key factor in the success of the development of new software that satisfies the astronaut emotional preferences (Kuo et al., 2016). Emotional Requirements are requirements that aim to fulfill the various beliefs and desires of the end-users (Dirin, 2018).

1.3.1.2 Cognitive Science

Cognitive Science demand is increasing and becoming a trend infused with Human-Computer Interaction (HCI) (Boring, 2002). Cognitive Science is a bit hard to define but it may be introduced as the sciences related to the mind, humans as information processors, behavioral science, and cognitive psychology (Boring, 2002). Moreover, affects that are parts of the cognitive sciences are defined as simpler feelings than emotions that are featured by valence and arousal while emotions are invisible constructs by the human brain based on experience such as love and passion (Taveter et al., 2019). Emotions do affect the product quality, user experience, and user satisfaction more than just a product's functionality (Kuo et al., 2016).

1.3.2 Related Work

To understand the state of the art of the field of RE, particularly requirement specification, a systematic search was done in the fields of SRS models, space software specification, and emotional requirements in literature. A search has been conducted in SCOPUS and Google Scholar to identify relevant studies for this section. It should be noted that only studies that have been published after 2015 were considered in this section to ensure including up-to-date relevant approaches. The selection process is shown in Figure 3.

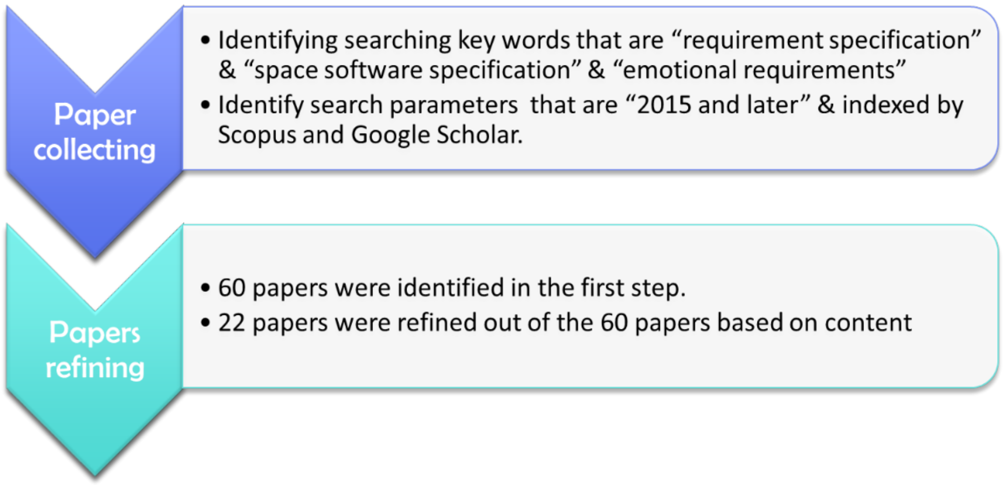

Figure 3: Research Process

1.3.2.1 Requirements Specification for Real-Time Operation Systems

Operation System (OS) that has constraints on time, memory and performance, is one of the pillars in the development of spacecraft software systems, which are time-constrained and critical in space missions. Thus, understanding the process of generating requirements specifications for a generic Real-Time Operation Systems (RTOS) is the first step in developing CDHS requirements for space manned missions. Boukir and his team presented a requirement verification approach that is based on model-checking. The paper's objective was to pinpoint subtle issues in the implementation of scheduling policies for RTOS. These requirements were carried in a modular approach to verify each component separately. The verification approach was based on examining the implementation correctness during the execution of the OS model. The authors provided verification scenarios for each component to verify the requirements. Furthermore, they provided counter-example scenarios to detect possible scheduling errors (Boukir et al., 2020).

Ribeiro and his team introduced the Systems Modeling Language (SysML) requirements diagram and Modeling and Analysis of Real-time and Embedded (MARTE) design model. The SysML shows explicit relationships between requirements, increasing the spectrum of understanding and defining real-time system requirements. However, the SysML profile by itself does not provide concepts for representing temporal, behavioral, and performance requirements, nor provide elements for explicit representation of system configurations. The authors introduced also the MARTE profile that provides key resources to specify non-functional requirements for real-time systems, generally time requirements. Few approaches were proposed with a focus on applying MARTE and SysML together to design RTOS, and even less with a focus on requirements modeling (Ribeiro et al., 2016).

The MARTE design model provides support to conduct a detailed specification of an RTOS through the following packages:

- Time modeling that allows modeling of time and related structures.
- Non-functional properties modeling, which offers paths to specify nonfunctional properties of RTOS.
- Core elements, which provide basic elements for behavioral modeling and semantic representation of its running time.
- Allocation modeling, an application element in MARTE can be a service, computation, or a function of the OS.
- Generic resource modeling, which provides stereotypes and tagged values to represent generic features.

SysML is a UML profile applicable to various types of engineering applications, enabling specification, analysis, design, verification, and validation of complex systems. The meta-model proposed in this paper is to combine SysML and MARTE. Thus, the paper needed to define extended requirements; requirements that had been extended to allow additional relationships and representation taking into consideration the specifications of the IEEE 830-1998 standard for documenting software requirements. The strong points of the paper are:

1- Clustering of requirements,
2- Classification of requirements,
3- Expressive and partial modeling.

Understanding the modeling challenges with UML and the need to extend the requirements to cover SysML and MARTE is an approach that can be used in Space Missions Systems Requirements Modeling. This helped the paper to bear in mind these challenges and proposed solutions to improve the extended requirement to be able to express the needs of the clients and end-users.

1.3.2.2 Requirement Specification for Domain-Specific Systems

Space software systems are domain-specific systems. Understanding how domain-specific Software Systems are defined is, therefore an important challenge in this thesis. Takoshima and Aoyama proposed an approach that can be used to derive a Space-domain-specific model of SRS shown in Figure 4. The authors investigated society's requirements on software technologies as they become more sophisticated and complex with time. They highlighted that RE is a key success factor in the development of complex software with such sophisticated and diverse requirements (Takoshima & Aoyama, 2018).

In addition, increasing the quality of the SRS is required to satisfy the quality and the development cost and time by representing more diverse requirements.

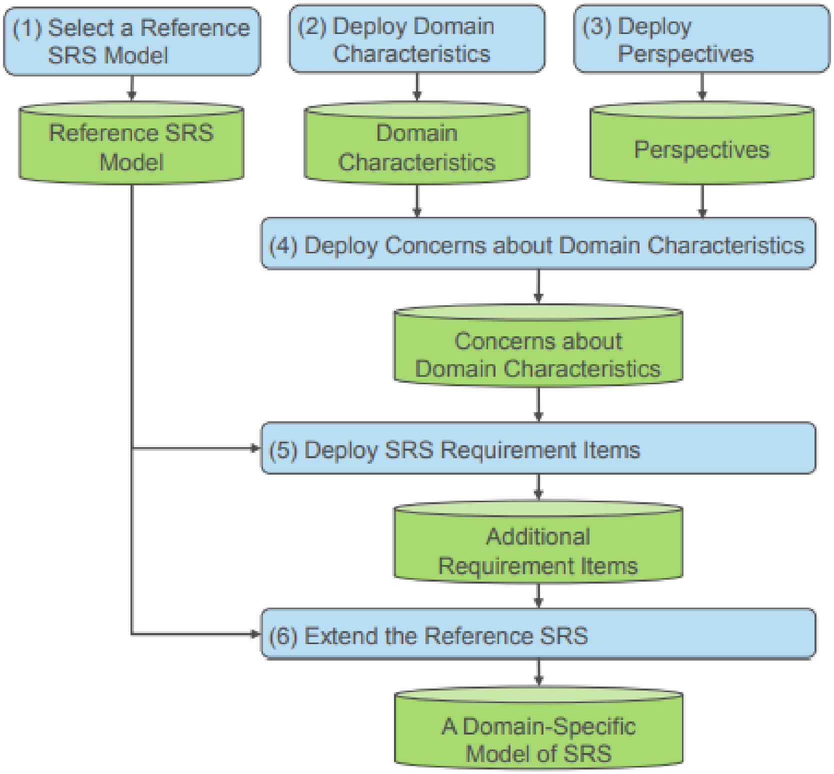

Figure 4: Domain-Specific Model (Takoshima & Aoyama, 2018)

Moreover, the paper attempted to establish how to extend a reference model of SRS and design a domain-specific model of SRS. The paper aimed to represent stakeholder concerns and needs by focusing on domain characteristics and apply them to design the proposed method for the automotive domain to evaluate its effectiveness. Its proposed method starts with defining the meta-model of the requirements items based on the stakeholder concerns about the domain characteristics. Then, derive domain-specific model of SRS by mixing in domain-dependent requirements to domain-independent requirements and inherit common requirements for references model. The results of evaluating the method conclude that: 1- The high-level requirements represent requirements stemming from the domain characteristics. 2- The low-level requirements represent non-functional requirements that reflect the characteristics of software belonging to a certain domain.

The paper's main findings are listed below:

1- SRS model with appropriate organizations is necessary for eliciting and representing stakeholders' concerns.

2- No research has proposed a domain-specific SRS model for automotive software.

Takoshima & Aoyama (2018) proposed a systematic method for clarifying excess and deficiencies of the required items of a reference model of SRS. The authors plan to evaluate the validity of the designed automotive-domain-specific model by applying it to the actual product. Understanding the approach can help the work to be done and enhance it based on the findings, results and minimizing the challenges and obstacles.

1.3.2.3 SRS Characteristics in Regulated Environments

Space-domain is a regulated environment that needs to follow a certain standard in requirements specification, documentation, and management. Marques & Yelisetty addressed the factors that influence the details of SRS such as organizational thinking; existing specification standards; and regulatory needs. The authors presented and analyzed the following SRS characteristics in regulated environments: consistency, unambiguity, verifiability, and traceability. Moreover, the paper addressed Safety-Critical Software that is software that has been developed to meet stringent certification requirements to prevent errors that can indirectly cause losses of human lives or have other catastrophic consequences (Marques & Yelisetty, 2019). In addition, Marques & Yelisetty addressed the issues that are faced when developing SRS for Software in Regulated Environment (SRE) such as incomplete, incorrect, ambiguous, conflicting, or inconsistent requirements. The paper also mentioned that SRE consists of many different development cultures, which have common characteristics that allow them to be correlated.

Marques & Yelisetty aimed to provide an analysis of SRS characteristics in regulated environments such as aeronautics, railway, automotive, nuclear, medical, military, and aerospace. The paper compared the mentioned standards based on: internal and external consistency, unambiguity, verifiability, and traceability. The paper addressed the similarities between the SRE Standards to find a standardized global framework for SREs. Understanding the practices in different regulated-environment software development helps to build a generic model for domain-specific SRS model. This can be integrated with the domain-specific SRS model in the paper (Takoshima & Aoyama, 2018) to provide a list of global characteristics that are applied to the domain-specific SRS model and apply it to the space domain.

1.3.2.4 Requirements Definition through Functional Analysis

Understanding the approach that is used by space agencies improves the ability to apply other models or modify it to accommodate other models of SRS or use the specific domain models. Viscio and his team represented the description of a flexible methodology with particular emphasis on requirements definition to support space mission design. The results showed that a significant number of papers considered Functional Analysis (FA) and Concept of Operations (ConOps) as fundamental activities to capture requirements. The paper’s methodology followed the classic approach of systems engineering that consists of the mission statement. Figure 5 shows the mission objectives through the stakeholder analysis and definition of requirements through FA and ConOps (Viscio et al., 2015).

Additionally, Space mission analysis and design shall be regarded as an iterative and recursive process, permitting a continuous refinement of requirements and constraints leading to a deeper component definition level. This starts with defining the mission statement through a properly executed activity that will result in a complete, clear, and concise mission statement. The mission objective shall also be thought through and defined clearly at the early stage, as the mission will be built on these foundations. The process is recursive and lower levels shall inherit from higher-level repeatedly and this nature of the process will be highlighted in Viscio's work.

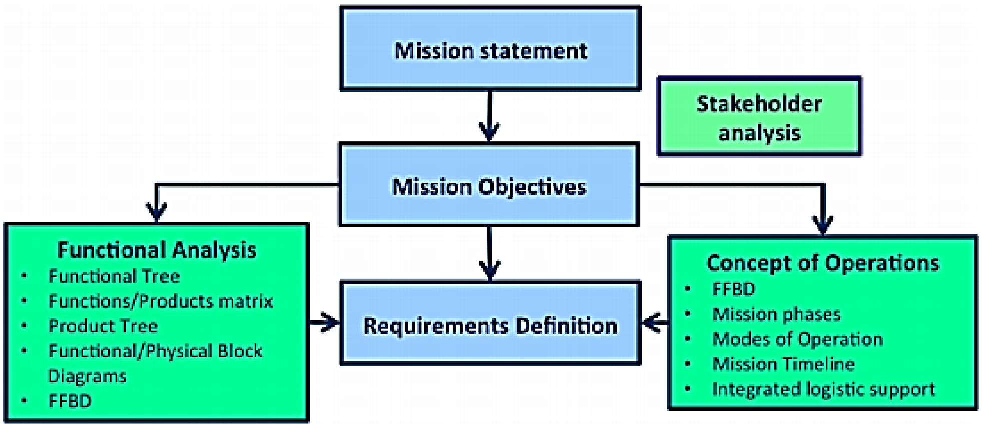

Figure 5: General Methodology Overview (Viscio, et al, 2015)

Viscio and his team discussed the FA and its tools that allow defining the mission systems, configurations, and Interfaces that are needed to accomplishing the space mission. FA starts with the functional tree that defines and splits higher-level complex functionalities into lower-level functions by breakdown the systems into subsystems, and components into processes and functions. From that, the

Function/Products matrix is created with the scope to identify the lower elements and building blocks that are needed to achieve the functionalities needed to accomplish the mission. At the end of the process, the complex system is defined by these building components and the process of grouping them to produce the product tree. FA is considered by the National Aeronautics and Space Administration (NASA) and The European Space Agency (ESA) as the systematic process of identifying, describing, and relating the functions a system has to be able to perform the mission functionality successfully (Viscio et al., 2015). The main output of the FA process is:

1- The definition of the building blocks of the system functional architecture.
2- The identification of configuration requirements through the functions/products matrix.

Moreover, the paper defined a demo mission to describe in detail the tools of the FA methodology. The mission proposed a demonstration mission of the inflatable technology. The need for inflatable technology resides in the capability of allowing a large volume/mass ratio and increase volume in orbit. The paper started with defining the mission statement and primary objectives. After that, the authors continued with the Stakeholders Analysis, which is an important step as it defines the main actors at the space mission to be able to design it. The authors discussed also the FA and produced a functional tree. Following that the authors came out with the different matrices needed that are:

• Functional/device matrix.

• Connection matrix.

• Functional block diagram.

Out of the listed product, the authors build a Concept of operation for the mission that includes:

- Mission phases,
- Modes of operations,
- Mission timeline and
- Functional flow block diagram.

The authors used the FA and ConOps to define the top-level requirement of the mission. In conclusion, the paper presented the recursive methodology of FA to design future space missions. In this model, FA, Functional Tree, and Product Tree can be used to improve a generic domain-specific model or for a complex system model.

1.3.2.5 Behavior-Driven Requirements Specification

The Space Manned Mission is interactive and led by the behavior of the astronaut. Requirements engineers need to understand and derive the behavior model of the interaction between the spacecraft and the astronaut to be able to increase the quality of the SRS. Similarly, Silva in the paper focused on clients' behavior to model requirements specification. Moreover, end-users were always ardent to introduce new requirements after each successful iteration, which led to new challenges that affect the future development and the produced software. This also introduced complications in tracing the artifacts and many software tools were developed to address this challenge. In addition, failing to trace requirements is one of the most effective ways to fail the project. The authors then introduced the Behavior Driven Development (BDD) than aims to develop requirements specification based on User Stories in a comprehensive natural language format (Silva, 2016). This approach:

- Allows specifying executable requirements.
- Makes it easier for the clients to set their final acceptance tests.
- Guides the system development.

On the other hand, there are several limitations of using BBD, such as:

- The technique is currently limited, which allows testing requirements only against a Final User Interface.
- Specifications using only Scenarios are not self-sufficient to provide a concrete perception.

The paper's contribution can be summed as:

- Definition of an ontological model that describes only behaviors that report Steps performing common actions directly in the User Interface through Interaction Elements.
- Presentation of a conceptual model using User Stories.
- Testing Multi-artifacts that compose the requirements specification.

1.3.2.6 Ways of Requirements Description

Additionally, Ali and his team addressed the commonly used expression of requirement specification by different graphical scenario description languages. The paper introduced the characteristic of such languages such as simplicity and graphical representation. These characteristics facilitate stakeholder involvement and elicitation of requirements. The paper introduced behavior synthesis processes that are applied to transform these scenario specifications and properties into behavioral models in the form of State Machines (Ali et al., 2015).

These description languages were categorized into two generations; the first generation that provides syntactic and semantic support for writing scenario specifications in the form of existential statements, and a second generation that provides support for existential and universal statements. The paper addressed the related background and works that have been done in the area of Trigger Scenarios (TS) and extended the TS by adding construct that enhances the expressive of the TS and described them with a pre-chart and main chart. In addition, the deriving of Behavior models was done in 3 phases that are:

1- Scenario Preparation: after documenting the system specification the authors use it to prepare scenarios based on them.
2- Construct Finite State Machines FSMs from annotated scenarios: the behavior is derived from the scenarios prepared in the earlier phase and transformed into FSM.
3- Merging FSM components: merging different FSMs by identifying identical terminal and starting states. The paper focuses on the analysis of software quality attributes as the current software systems come with a complex nature.

Ali and his team (2015) concluded by emphasizing the required outline to derive a behavioral model in form of FSM and highlighted the importance of its output in estimating the reliability, evaluating the utility, and validating the improvements by TS. This contribution can be used to adhere to the process of creating a model for requirements specification by introducing the FSM of the Space Software System and build a behavioral model for the astronauts to give the requirements engineers more insights into the product and increase the quality of the SRS.

1.3.2.7 Emotional Requirements Specification

The requirements engineers need to understand how the space systems emotionally affect the user. This can help in understanding the need of the end-user of the system and deriving requirements in a way that will increase the astronaut's feeling of security and trust.

Kuo and his team highlighted that emotional requirement are a key to success in the development of new products as they satisfy the customer's emotional preferences. The paper introduced Kano's model that emphasizes the fact that functional products are not enough to reach customer satisfaction. The quality requirements are the requirements that delight the customers. In the paper, the researcher stated that emotional requirements are very subjective based on personal experience, background, and experiences. Thus, it is difficult to elicit Emotional requirements and predict whether the new product will be joyful or not. The paper emphasized that quantitative and qualitative data needed to be collected to understand the customers' attitudes toward the products. The paper discussed 5 different methods to deal with customer perceptions that are: exploratory factor analysis, procruste analysis, cluster analysis, principal component analysis, and fuzzy theory. The paper contributed with a case study on an experiment where emotional requirements were elicited using two semantics are Sport Emotion and Product Personality. The paper found that the senses that interact with the product have a bigger effect on user satisfaction more than others that did not. This can help to understand how the interaction between the end-user and the software can affect the end-user emotions based on the senses that interact with the system (Kuo et al., 2016).

Dirin highlighted the importance of emotional requirements in creating a robust tourism application to empower the tourism sector that is a major source of employment and revenue. The context is the development of a mobile application for tourism. The paper highlighted the lack of emotional requirements and user experience requirements in several tourism applications. The paper addressed the increased usage of smartphone applications by tourists in their travels. Applications are used mainly for informing, contextualizing, personalizing, and translation purposes. The paper highlighted the challenges of designing tourism software to promote the tourism sector. The paper discussed the user experience and divided it into 3 parts: emotional requirements, system design aspect, and product context. Emotional requirements are non-functional requirements that aim to fulfill the various beliefs and desires of the end-user. Embedding emotional and cognitive needs is necessary to ensure the acceptance of mobile services. Three approaches to elicited and measure emotional requirements are subjective, behavioral, and physiological. Behavioral approaches measure the end-user behavior such as facial poses or people interactions. Physiological approaches are the approaches that measure and identify how the body behaves when the emotional experience changes. The paper analyzed user experience and emotional engagement of the Service-based Context-awareness Tourism Application (SCATA). The assessment was based on two main questions- How do travelers trust and rely on it when traveling? And how secure do travelers when they do use the SCATA? The paper emphasized the tourist's feeling to trust the application and found that if it does not satisfy the essential emotional requirements the tourist will tend to neglect the application. This paper showed why it is important for the systems to be trusted to be used (Dirin, 2018).

Moreover, Taveter and his team focused on the importance of emotional requirements for RE to ensure the productivity of software that is emotionally acceptable. To achieve this the software engineer needs to understand the basic theories about emotions and brain construction and needs methods to explicitly elicited and represent emotional requirements. The paper discussed how requirements engineers used psychological frameworks based on basic emotions such as fear, anger, and joy or other frameworks that divide the emotions into simpler feelings with two features that are valence and arousal. The paper focused on Motivational Modelling that is a method that allows requirements engineers to elicit and represent emotional requirements in sociotechnical systems. Motivational Modeling includes two main methods of requirements elicitation that are structured interviews and workshops and the requirement elicited in the structured interviews and workshops are converted into a motivational goal model. The paper included two case studies that represent Motivational Modeling. The first case study "Application for Self-Managing Health" was done using structured interviews and the second case "Systems for Supporting Decisions by e-Healthcare" used workshops. The paper contributed by eliciting two Motivational Models for the two aforementioned cases (Taveter et al., 2019).

By projecting the aforementioned results on the work, it is therefore important to introduce emotional requirements that can keep the astronaut feeling secure and help design for a good user experience.

Chapter 2: Methods

2.1 Research Design

The proposed methodology for the thesis shown in Figure 6 starts with choosing reference SRS documents to start with. The proposed solution starts with the NSSTC SRS model as a reference document. NSSTC is the UAE University arm in space Research and Development (R&D), The Reference Model phase then will go through three-stage of refining. The first stage will be applying the domain requirements. It will start by defining a domain requirement reference to align the domain requirements on the SRS model. The proposed Domain requirements reference is a document from NASA. The second stage of refinement will be applying the Environment Regulations and aligning the SRS with them. The proposed environment regulation reference is the space law that is derived from the United Nations Office for Outer Space Affairs (UNOOSA). The thesis will also consider UAE Space Agency references if possible. The third step will be about integrating emotional requirements in the SRS framework. Emotional requirements are not investigated in the space industry. Therefore, the thesis investigates different models from other industries such as the gaming industry to be used as a reference for the emotional requirements. The introduction of emotional requirements as part of the Space SRS documentation is part of the novelty of the thesis. The fourth stage is concerned with the stakeholders' immersion. It includes meeting and discussing the refined SRS with different stakeholders to align it with their needs and expectations.

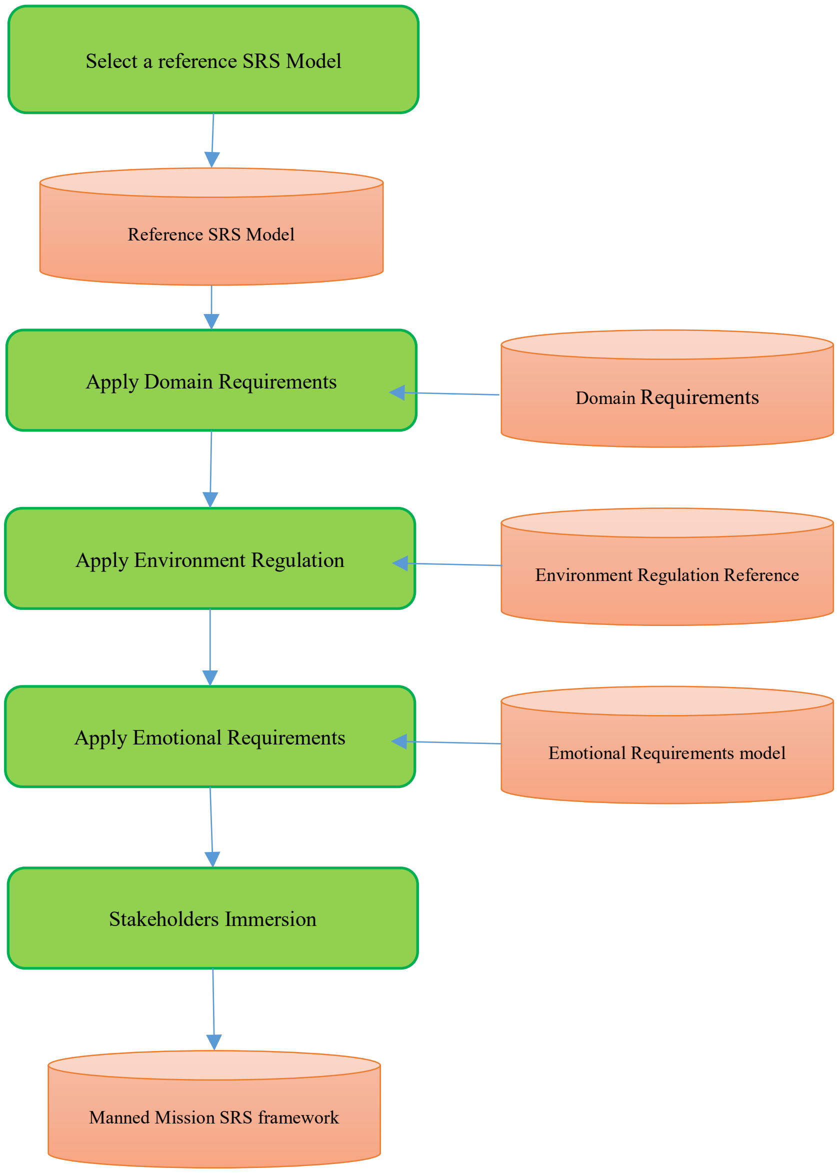

Figure 6: Thesis Methodology

2.2 Data Collection

For the Domain requirements Reference Models, the thesis started with two reference models for domain requirements that are: (i) the Europeans Cooperation for Space Standardizations - Human factors engineering (ECSS-E-ST-10-11C) that is ESA reference for used for s Standard defines requirements for the integration of the human in the loop for space system products, and (ii) NASA Human Integration Design Handbook (NASA/SP-2010-3407) that is the guide for the crew health, habitability, environment, and human factors design of all NASA human space flight programs and projects.

For the Legal Reference Models, the thesis will include two legal references to ensure compliance with legal frameworks that are: (i) the UAE Space Federal Law, Federal Law No. 12 that regulates the space activities, and (ii) the UNOOSA Space Law that is the International treatment that formalizes the use of the outer space activities for civil use between the countries.

For the Emotional Requirements Model, the thesis will investigate the best practices in including the emotional requirements in the framework. The thesis will derive emotional requirements from the domain requirements reference model and legal reference model if possible. In addition, a case study by Eudy (2018) investigates the emotional experience of astronauts. Moreover, the thesis looks at published papers about emotional requirements in different industries such as gaming industries.

For the Stakeholder involvement, the thesis will take into consideration the stakeholder concerns and needs. The involvement will start with the beginning of the work to adapt a co-design approach to ensure the quality of the framework. However, there will be a step of stakeholder immersion at the end to increase the involvement of the stakeholders by reviews and workshops if possible.

2.2.1 Examples of Statements from Reference Models

Table 1 presents examples of statements collected from different reference models that can serve to specify requirements in this thesis. An extensive list of statements will be included in the final thesis manuscript.

Table 1: Examples of Statements from Reference Models Used in this Thesis

ID	Statement	Page
NASA.001	The users' expectations as to how the system will perform, and familiarity with similar systems, should be considered in system development.	900
NASA.002	The user should be in control of the system following the user's allocated function and responsibilities so that the user is playing an active and not a passive role in the outcomes of the system operations.	901
NASA.003	The environmental conditions in which the system will be operated should be considered in the design of the system.	901
NASA.004	Usability testing should be performed on all hardware, software, procedures, and training materials with which a crewmember will interact. Depending on the size of the system, testing can be scoped using task analysis to determine the critical tasks/systems to be tested.	901
NASA.005	Systems must be usable under conditions of high stress (i.e., an emergency), with minimal cognitive effort	901
NASA.006	Interface Consistency, the knowledge users have learned using one part of the system or a subsystem can be applied to the rest of the interface	902
NASA.007	Crew interfaces that perform different functions should be designed to have distinct visual designs and methods of interaction.	904
NASA.008	If items have a high probability of being confused, then they should differ in two or more dimensions.	905
NASA.009	Displays should be legible under all expected spaceflight conditions where reading/interpretation of the displayed information will be required.	905
NASA.010	The ambient luminance, contrast, and color gamut of displays should be estimated for the intensity levels and SPDs expected in the display application environment.	913
NASA.011	Specular front-surface reflections are often the most intense and troublesome and should be avoided as much as possible by placement and shielding of the display and adjustments of the viewing geometry.	913
NASA.012	Where front-surface reflections cannot be mitigated by such means, anti-reflection and/or anti-glare surface treatments should be used.	913
ECSS.01	The design of human-machine systems shall conform to the Human-Centered Design process	19
ECSS.02	Safety-related issues shall be characterized for on-board activities: 1. Mechanical Safety, 2. Electrical Safety, 3. Environmental Safety, 4. Operational Safety, and 5. Psycho-physiological Safety.	24
ECSS.03	Safety shall also characterize all mission-related ground activities and possible cumulative effects on the users	24

Table 1: Examples of Statements from Reference Models Used in this Thesis (Continued)

ID	Statement	Page
ECSS.04	For hardware ergonomics system design, the following factors shall be characterized: 1. Anthropometrical characteristics of the user population, 2. Human capabilities and skill, 3. Environment, 4. Tasks complexity and constraints and inherent or collateral physical stress that can be generated, and 5. Machine capabilities and autonomy level.	24
ECSS.05	For hardware ergonomics, human-machine interface design shall provide: 1. Visual, audio or tactile cues and information on the interface characteristics and task performance, 2. Interface customization, and 3. Identification of safety-related controls.	24
ECSS.06	For environmental ergonomics, to create an environment that supports and maintains human health, safety and well-being all relevant functions and resources shall be provided as specified in ECSS-E-ST-34.	24
ECSS.07	For environmental ergonomics, to create an environment that supports and maintains a positive psycho-sociological attitude of the on-board crew both as an individual and as group-specific functions shall be identified according to the mission profile and resources and implemented.	24
ECSS.08	For cognitive ergonomics, to achieve the most effective overall system design, the following factors shall be characterized: 1. Human capabilities and knowledge profiles and boundaries, 2. Environment, 3. Tasks complexity and constraints and inherent or collateral stress that can be generated, and 4. Machine capabilities and autonomy level.	25
ECSS.09	For cognitive ergonomics, the fit between human cognitive abilities and limitations for safety related data and controls shall be characterized.	25
ECSS.10	For operations ergonomics, the job design shall identify working hours, off-duty hours, and rest days.	25
ECSS.11	For Operations ergonomics, physical exercise shall be counted as working hours.	25
ECSS.12	For habitable environment, the habitable pressurized environment design shall include: 1. living areas organization, 2. human-related equipment arrangement, and 3. harmonization of compartments and crew stations.	26
UAELAW.01	A proof that the natural person is aware and well informed of the risks associated with Spaceflight.	Article 16 page 11
UAELAW.02	Written consent of the natural person to participate in the Spaceflight	Article 16 page 11
UAELAW.03	A proof that the person has completed the necessary training, physical and health fitness to participate in the Spaceflight.	Article 16 page 11
UAELAW.04	A proof that Operator has performed all necessary risk and safety assessments, and that there is an appropriate emergency plan.	Article 16 page 11
UAELAW.05	Any requirements or conditions issued by a resolution of the Board of Directors.	Article 16 page 11
UAELAW.06	Operator authorized to conduct a human Spaceflight activity shall immediately inform the Agency of any Incident or Accident encountered, or the risks faced, and any measures are undertaken thereby to reduce the same or the effects thereof	Article 16 page 11
UNOOSA.01	States Parties to the Treaty shall regard astronauts as envoys of mankind in outer space and shall render to them all possible assistance in the event of accident, distress, or emergency landing on the territory of another State Party or on the high seas	Article V, page 5

Chapter 3: Implementation

In this section, the discerption of the approach step by step to specify requirements. This includes surveying sources, extracting statements from surveyed sources, identifying areas of interest for each step, and eliciting requirements based on these areas.

3.1 NSSTC CDHS Requirements Document

3.1.1 Statement Extraction

The first step was to extract statements from the NSSTC requirements document. 51 statements found and grouped into 10 groups. These groups are identified into areas of services that the software provides to the spacecraft.

3.1.2 Statements Analysis

10 groups of statements were analyzed to understand the coverage of the source document and initialize a baseline of the refined document that will be the result of the approach. Each statement was identified by the prefix (SR) for source.

3.1.2.1 Operational

The first group of requirements is operational statements. These are statements that are related to the software operations. Table 2 presents the collected operational statements.

Table 2: Operational Statements

ID	Statement	Source	Page
SR.01	When the two CDHSs computers are powered, only one of them shall do normal CDHS operations. The other one shall only be able to do configuration, diagnostic, and file transfer.	NSSTC CDHS requirements	5
SR.02	The CDHS shall have security mechanisms that avoid unauthorized parties from successfully executing functionality on-board.	NSSTC CDHS requirements	5
SR.03	The CDHS shall be operational within the temperature interval of -30°C to 85°C	NSSTC CDHS requirements	5

This group of statements organizes the operational roles, responsibilities, and boundaries for the Spacecraft software to be operable in a certain environment and certain behavior.

3.1.2.2 Equipment Manager

The second group of statements is equipment manager statements. This group of statements, presented in Table 3, illustrates the role of the software in managing the equipment. It specifies the way of handling and monitoring the equipment.

Table 3: Equipment Manager Statements

ID	Statement	Source	Page
SR.04	The CDHS shall be able to send commands to other subsystems as required by Spacecraft (S/C) operations.	NSSTC CDHS requirements	6
SR.05	The CDHS shall collect housekeeping (HK) data from equipment periodically at configurable rates (maximum rate: 1 sample every 5 seconds).	NSSTC CDHS requirements	6

3.1.2.3 Implementation

Table 4 presents statements related to software implementation. They specify the way of middleware and hardware that the software shall support and the software architecture.

Table 4: Implementation Statements

ID	Statement	Source	Page
SR.06	The CDHS SW shall be designed to be modular and reusable means through isolating mission-specific functionality and hardware from general architecture and functionality.	NSSTC CDHS requirements	12
SR.07	The CDHS shall be able to support an RTOS.	NSSTC CDHS requirements	12
SR.08	The development of the CDHS SW shall use widely supported tools.	NSSTC CDHS requirements	12
SR.09	The CDHS shall include the capability to update any of the CDHS software images while in orbit.	NSSTC CDHS requirements	12

3.1.2.4 Interface

Table 5 presents statements that are related to the software interfaces. They provide interfaces for debugging, integration with the spacecraft, and different type of interfaces.

Table 5: Interfaces Statements

ID	Statement	Source	Page
SR.10	The CDHS shall provide a debugging interfaces	NSSTC CDHS requirements	11
SR.11	The CDHS shall feature a connection with I2C, Controller Area Network (CAN), and Pulse Per Second (PPS) wire.	NSSTC CDHS requirements	11
SR.12	The CDHS shall feature 2 (TBD) interfaces	NSSTC CDHS requirements	11
SR.13	The CDHS shall be compliant with accommodation mechanisms foreseen for the S/C	NSSTC CDHS requirements	11

3.1.2.5 Performance

Table 6 presents statements related to the software performance. This includes the response time, estimated life expectancy, memory size, memory types, and computational resources.

Table 6: Performance Statements

ID	Statement	Source	Page
SR.14	The CDHS shall have persistent storage adequate of storing for 1 week worth of HK data sampled at a 30 sec interval (TBC).	NSSTC CDHS requirements	10
SR.15	The CDHS shall have adequate computational resources to perform the required onboard functions	NSSTC CDHS requirements	10
SR.16	The CDHS shall resist vibrations during Assembly, Integration, and Testing (AIT), transport, launch, and operation	NSSTC CDHS requirements	10
SR.17	The CDHS computer shall be radiation resistant to operate in low earth orbit for 5 years	NSSTC CDHS requirements	10
SR.18	The CDHS power consumption shall be kept as low as possible with a target of not more than 1W maximum	NSSTC CDHS requirements	10
SR.19	The CDHS shall have TBD RAM (Random Access Memory) to permit the execution of Onboard software.	NSSTC CDHS requirements	10
SR.20	The CDHS shall have sufficient non-volatile memory to store the onboard software. (3 MB estimated)	NSSTC CDHS requirements	11
SR.21	The CDHS shall at least be able to perform at 100 CoreMark	NSSTC CDHS requirements	11
SR.22	The CDHS Shall comply with the General Design Requirements Documents (GDRD)	NSSTC CDHS requirements	11

3.1.2.6 Safety and Security

Table 7 presents extracted statements related to the safety and security of the software and the communications.

Table 7: Safety and Security Statements

ID	Statement	Source	Page
SR.23	The CDHS shall use only accepted telecommand from an authorized source (e.g. through a key)	NSSTC CDHS requirements	6
SR.24	The CDHS shall automatically resort to load a recovery stored software image when the boot counter reaches a configurable threshold	NSSTC CDHS requirements	6

3.1.2.7 Services

Table 8 presents statements that illustrate the service the software shall provide to the spacecraft such as equipment status, file systems, data monitoring, and configurations.

Table 8: Services Statements

ID	Statement	Source	Page
SR.25	The CDHS shall provide an S/C Configuration Vector which tracks the status of each onboard equipment	NSSTC CDHS requirements	7
SR.26	The CDHS shall allow selected parameters to be configurable and persistently stored	NSSTC CDHS requirements	7
SR.27	(The exhaustive list of parameters will be provided in lower level requirements)	NSSTC CDHS requirements	7
SR.28	The CDHS shall allow the user to upload/download files and delete files.	NSSTC CDHS requirements	7
SR.29	The CDHS shall allow the execution of user defined scripts	NSSTC CDHS requirements	7
SR.30	The CDHS shall be able to periodically generate packets of data containing S/C HK elements	NSSTC CDHS requirements	7
SR.31	The CDHS shall log in the persistent memory at any telemetry generated by itself without causing the on-board storage to run out of storage space (e.g. implementing a circular buffer with configurable quotas)	NSSTC CDHS requirements	7
SR.32	The CDHS shall allow the user to configure commands that are sent (to the CDHS or equipment) that will be triggered by onboard events.	NSSTC CDHS requirements	7
SR.33	The CDHS shall allow the user to schedule commands that are sent (to the CDHS or equipment) at a pre-programmed time.	NSSTC CDHS requirements	8
SR.34	The CDHS shall allow the user to configure commands that are sent (to the CDHS or equipment) as a result of or calculated geometric events (such as eclipse and overfly of a point of interest).	NSSTC CDHS requirements	8
SR.35	The CDHS shall allow the user to configure monitors of data coming from the equipment.	NSSTC CDHS requirements	8

3.1.2.8 System Manager

Table 9 presents statements that illustrate the software's role in managing the system such as when to enter or exit the "Safe Mode", fault investigation mechanisms, ways to interchange the modes, command issuing, and payload management.

Table 9: System Manager Statements

ID	Statement	Source	Page
SR.36	The CDHS software shall exit "Safe Mode" only after receiving a protected command from the Ground.	NSSTC CDHS requirements	8
SR.37	The CDHS software shall include a "Safe Mode", which the Satellite shall enter once a fault is detected (e.g. loss of attitude).	NSSTC CDHS requirements	8
SR.38	The CDHS shall provide mechanisms that allow investigating the causes why it entered Safe Mode	NSSTC CDHS requirements	8
SR.39	The CDHS shall be able to switch between operating modes by telecommand and/or autonomously	NSSTC CDHS requirements	8
SR.40	The CDHS shall support mode transitions as specified in the Spacecraft Requirements Document.	NSSTC CDHS requirements	9
SR.41	The CDHS shall be able to issue commands to the equipment to perform spacecraft commissioning activities such as the deployment of antennas and solar arrays	NSSTC CDHS requirements	9
SR.42	The CDHS shall perform the execution of the survival thermal control of the Primary Payload.	NSSTC CDHS requirements	9
SR.43	The CDHS SW shall include mechanisms that prevent unintentional infinite loops, computational errors, and possible lockups as well as stack overflow.	NSSTC CDHS requirements	9
SR.44	The CDHS shall autonomously and periodically command the communications (COMM) system to transmit to the ground a packet of data (beacon) containing representative data of the state and health of the spacecraft	NSSTC CDHS requirements	9

3.1.2.9 Time Management

Table 10 presents statements that are related to time management to ensure the onboard clock synchronization such as soft reset and GPS synchronization.

Table 10: Time Management Statements

ID	Statement	Source	Page
SR.45	The CDHS shall have in place a mechanism that will prevent a soft reset to affect the on-board time	NSSTC CDHS requirements	9
SR.46	The CDHS shall keep track of time and allow time synchronization with the ground and onboard sources such as the Global Positioning System (GPS) (inclusively precise synchronization with the GPS PPS signal)	NSSTC CDHS requirements	10
SR.47	The CDHS shall feature a watchdog timer for processor supervision.	NSSTC CDHS requirements	10
SR.48	The CDHS shall be able to synchronize itself with the GPS PPS signal and distribute the PPS time reference to other equipment that needs it.	NSSTC CDHS requirements	10

3.1.2.10 Validation

Table 11 presents the software process to validate the user telecommand.

Table 11: Validation Statements

ID	Statement	Source	Page
SR.49	The CDHS shall be validated with invalid data in user telecommand (robustness testing)	NSSTC CDHS requirements	12

3.1.3 Requirements Elicitation

As a result of the earlier illustrations, it can be seen that the NSSTC CDHS requirements document covers the following areas of requirements:

A1.1: Operational Requirements: requirements that illustrate the role, responsibilities, and boundaries of software operations.

A1.2: Equipment Manager Requirements: requirements that illustrate the software's role in monitoring and managing the spacecraft equipment.

A1.3: Implementation Requirements: requirements that illustrate the way of development, tools to support, and software architecture.

A1.4: Interfaces Requirements: requirements that illustrate the type and role of the software system interfaces.

A1.5: Performance Requirements: requirements that specify the software system capabilities, computational resources, response time, and memory types and sizes.

A1.6: Security and Safety Requirements: requirements that illustrate requirements that ensure software security and safety.

A1.7: Service Requirements: requirements that state the services that the software system shall provide such as data monitoring, file systems and configurations.

A1.8: System Manager Requirements: requirements that illustrate the role of the software in managing the software system.

A1.9: Time Management Requirements: requirements that state the way to manage the time onboard the spacecraft to ensure time synchronization.

A1.10: Validation Requirements: requirements about validation processes.

Table 12 presents the requirements that are elicited from the aforementioned statement analysis.

Table 12: Source Document Requirements

ID	Requirements	Justification
R.001	The software shall operate in the range of temperatures that is decided by the mission team.	A1.1
R.002	The software shall provide housekeeping reports about the spacecraft equipment and software itself every 30 seconds.	A1.2
R.003	The software shall be design in a modular way to increase the level of reusability.	A1.3
R.004	The software shall have an interface connection with I2C, CAN, and PPS wire.	A1.3 & A1.4
R.005	The software shall have a life expectancy of the designed mission.	A1.5 & A1.1
R.006	The software shall accept only commands by authorized users.	A1.6
R.007	The software shall change the authorization key repeatedly at a minimum of 48 times a day.	A1.6
R.008	The system shall provide a mechanism to investigate incidents on the spacecraft through logs.	A1.7 & A1.6
R.009	The software shall provide a mechanism to leave the safe mode through astronaut approval and ground command.	A1.8 & A1.4
R.010	The software shall provide interfaces to state and modify the time for the astronauts.	A1.9
R.011	The software shall be able to validate invalid data from the astronaut.	A1.10

3.2 Domain Requirements

3.2.1 Statement Extraction

The first step in this phase is to survey the space domain to identify possible sources, which could be used to identify possible guidelines or statements that define the domain-specific requirements and characteristics for the space manned missions. The thesis surveyed NASA and ESA references and identified two possible references: NASA Human Integration Handbook, and ESA Human Factor Engineering. The thesis extracted statements that are related to manned space missions and identified 275 statements that can be used to derive domain requirements. Then, the statements were grouped the extracted statements into 7 groups based on the nature of the requirements.

3.2.2 Statements Analysis

The thesis analyzed the 7 groups of statements to derive domain-specific requirements based on the nature of statements: Usability, Environments, Health, Integrity and Security, Training, Design, and Availability. Each statement was identified by the prefix (DC) for domain characteristics.

3.2.2.1 Usability

142 statements were found that can be used as domain-specific requirements. Table 13 presents 23 out of the 142 statements that illustrate the usability experience.

Table 13: Usability Statements

ID	Statement	Source	Page
DC.01	The user should be in control of the system following the user's allocated function and responsibilities so that the user is playing an active and not a passive role in the outcomes of the system operations.	NASA-HMI	901
DC.02	Usability testing should be performed on all hardware, software, procedures, and training materials with which a crewmember will interact. Depending on the size of the system, testing can be scoped using task analysis to determine the critical tasks/systems be tested.	NASA-HMI	901
DC.03	The ambient luminance, contrast, and color gamut of displays should be estimated for the intensity levels and SPDs expected in the display application environment.	NASA-HMI	913
DC.04	Specular front-surface reflections are often the most intense and troublesome and should be avoided as much as possible by placement and shielding of the display and adjustments of the viewing geometry.	NASA-HMI	913
DC.05	The size of control should ensure optimal operation by the expected body part (e.g., finger, hand, foot) of the smallest and largest crewmember, including the expected clothing such as a spacesuit, boots, and gloves.	NASA-HMI	968
DC.06	Push buttons should be used when control or an array of controls is needed for momentary contact or for actuating a locking circuit, particularly in high-frequency-of-use situations.	NASA-HMI	969
DC.07	Push buttons should not be used for discrete control where the function status is determined exclusively by the position of the switch.	NASA-HMI	969
DC.08	The push-button surface should be concave (indented) to fit the finger. When this is impractical, the surface should provide a high degree of frictional resistance.	NASA-HMI	969
DC.09	A positive indication of control activation must be provided (e.g., snap feel, audible click, or integral light).	NASA-HMI	969
DC.10	Foot-operated switches are useful when the hands are occupied, but should not be used for frequent or critical operations, or when foot restraints are needed.	NASA-HMI	970
DC.11	Footswitches should be designed for operation by the toe and the ball of the foot rather than by the heel.	NASA-HMI	971
DC.12	Arrangements of push buttons in the form of keyboards should be used when alphabetic, numeric, or special function information is to be entered into a system.	NASA-HMI	971

Table 13: Usability Statements (Continued)

ID	Statement	Source	Page
DC.13	The switch should not be capable of being stopped between positions.	NASA-HMI	976
DC.14	The use of a coding mode (e.g., size and color) for a particular application should be governed by the relative advantages and disadvantages of each type of coding	NASA-HMI	1015
DC.15	Shared displays should be located within the required viewing angles and viewing	NASA-HMI	1020
DC.16	The name of a control, display, piece of equipment, or process should reflect its function and what it does in the mission.	NASA-HMI	1027
DC.17	Graphical representations should avoid clutter and high density.	NASA-HMI	1032
DC.18	Careful consideration should be given to the choice of graphics, to ensure that the meaning is obvious. For example, photographs sometimes display too much information, which can confuse them. A line drawing can eliminate extraneous information and allow the user to focus on the purpose of the illustration.	NASA-HMI	1032
DC.19	Auditory cues should be used to remind the user to perform a task, convey alerting messages, and/or provide redundant information when used in conjunction with visual cues.	NASA-HMI	1034
DC.20	The user should have access to the status of the system at all times.	NASA-HMI	1044
DC.21	The user should be provided timely and precise status information.	NASA-HMI	1044
DC.22	Master alarm lights should have the capability to be energized simultaneously.	NASA-HMI	1052
DC.23	Master alarm status lights should be visible from any location in the open volume of a module.	NASA-HMI	1052

As it is shown in Table 13, the group of statements identifies the usability level of the system and how it can be used in the spacecraft to ensure the quality of the experience for the astronauts.

3.2.2.2 Environment

72 statements were found that can be used as domain-specific requirements. Table 14 presents 29 out of the 72 statements that identify the environment in the space manned mission.

Table 14: Environment Statements

ID	Statement	Source	Page
DC.24	The environmental conditions in which the system will be operated should be considered in the design of the system.	NASA-HMI	901
DC.25	Whereas sunglasses can be a very effective aid to vision and promote visual comfort in very bright environments, they should generally be of a neutral-density type to avoid significant changes in the chromaticity of displays	NASA-HMI	914
DC.26	The use of polarized sunglasses should generally be avoided in display application environments that use LCDs that produce linearly polarized light output or in displays that use circular polarizing filters for control of front-surface reflections.	NASA-HMI	914
DC.27	If the switch may become wet and slippery, the switch cap surface should provide a high degree of frictional resistance.	NASA-HMI	971
DC.28	Channel guards, lift-to-unlock switches, or other equivalent prevention mechanisms should be provided to prevent inadvertent activation.	NASA-HMI	975
DC.29	Resistance of lift-to-unlock mechanisms should not exceed 13 N (3 lb).	NASA-HMI	975
DC.30	The crew should have a means of reacting to any required control input forces without letting those forces push him or her away from the control. This helps the crew maintain position and apply required control forces.	NASA-HMI	1018
DC.31	Above 3 g, controls should be operable by a restrained, suited operator.	NASA-HMI	1018
DC.32	Between 2 g and 3 g, controls should be operable by a restrained, suited operator.	NASA-HMI	1018
DC.33	The operator's arms/legs should be supported and/or restrained to allow for accurate control inputs to remain within task performance limits during elevated g conditions and to prevent inadvertent control inputs during high-g nominal and abort scenarios.	NASA-HMI	1019
DC.34	Requiring crewmembers to reach out for displays or controls or to assume an uncomfortable position to use any device should be avoided whenever possible.	NASA-HMI	1021
DC.35	Controls should be spaced so that they can be accessed and operated by crewmembers who are suited for all expected operational environments.	NASA-HMI	1022
DC.36	Controls designed to be out of view while being operated should be spaced or shaped/textured such that the control can be identified with a pressurized gloved hand without a line of sight	NASA-HMI	1023
DC.37	Where system engineering necessitates speech transmission bandwidths narrower than 200 to 6,100 Hz, the minimum acceptable frequency range should be 250 to 4,000 Hz	NASA-HMI	1038
DC.38	The dynamic range of microphones and other input devices should be great enough to admit variations in signal input of at least 50 dB.	NASA-HMI	1038
DC.39	Noise-canceling microphones and other input devices are required for high-noise environments (85 dBA or above) and are preferred in all areas.	NASA-HMI	1038
DC.40	If listeners will be working in high ambient noise (85 dBA or above), binaural rather than monaural headsets should be provided	NASA-HMI	1039

Table 14: Environment Statements (Continued)

ID	Statement	Source	Page
DC.41	Provide fixed or portable writing and working surfaces	NASA-HMI	1069
DC.42	Provide writing instruments and supplies required for documentation update	NASA-HMI	1069
DC.43	Consolidated stowage for writing instruments, supplies, and documents in locations that are easily accessible	NASA-HMI	1070
DC.44	Provide easily accessed equipment and supplies for data transfer connections, power activation, operation, resupply, and inventory	NASA-HMI	1070
DC.45	Safety-related issues shall be characterized for on-board activities: 1. Mechanical Safety, 2. Electrical Safety, 3. Environmental Safety, 4. Operational Safety, and 5. Psycho-physiological Safety.	ECSS	24
DC.46	For hardware ergonomics Human-machine interface design shall provide: 1. Visual, audio or tactile cues and information on interface characteristics and task performance, 2. Interface customization, and 3. Identification of safety-related controls.	ECSS	24
DC.47	For Operations ergonomics, The job design shall identify working hours, off-duty hours, and rest days.	ECSS	25
DC.48	For Operations ergonomics, Physical exercise shall be counted as working hours.	ECSS	25
DC.49	For habitable environment, The habitable pressurized environment design shall include: 1. Living areas organization, 2. Human related equipment arrangement, and 3. Harmonization of compartments and crew stations.	ECSS	26
DC.50	The limitation and constraint of the EVA suit shall be included in designing the spacecraft and habitat and its mission.	ECSS	29
DC.51	For external operations, the work station and exclusions zones or primary and secondary translation path shall be defined.	ECSS	29
DC.52	Equipment, tools, restraints and mobility aids and any other systems that have to interface with the crew members wearing the EVA Suit shall be designed accordingly to their context of use.	ECSS	29

As it is shown in Table 14, the statements illustrate the environment of the spacecraft and how it affects the interactions between the astronauts and the software systems. This group of statements can be used to enhance the design of interfaces (A1.4) to include human interaction-related statements.

3.2.2.3 Availability

Table 15 presents 11 statements that can be used as domain-specific requirements that discuss the availability of the system.

Table 15: Availability Statements

ID	Statement	source	Page
DC.53	The feedback should be delivered to the user promptly.	NASA-HMI	1042
DC.54	Since information management systems operate on electronic hardware, the system should provide a mechanism for backing up data on a regular or periodic basis.	NASA-HMI	1068
DC.55	The system should provide an automatic backup function for safety-critical data	NASA-HMI	1068
DC.56	The system should provide a selective data backup function.	NASA-HMI	1069
DC.57	The system must provide a "data restore" function	NASA-HMI	1069
DC.58	A secure viewing environment for electronically displayed private information such as medical data and e-mails	NASA-HMI	1069
DC.59	Ground access to perform all onboard database functions without crew intervention	NASA-HMI	1069
DC.60	The ability to exchange information electronically (e.g., by e-mail) with personnel on the ground	NASA-HMI	1070
DC.61	Automation should be provided when crewmembers cannot reliably and safely perform assigned tasks.	NASA-HMI	1076
DC.62	Automation interfaces should enable the operator to understand exactly how and what was done by the automation and how successfully the task was accomplished	NASA-HMI	1076
DC.63	Accomplishing the process of paying close and continuous (sustained) attention while watching for something rare to happen can depend on time available, alertness, and expertise.	NASA-HMI	1081

Availability is an important aspect of the spacecraft, it is important to ensure the availability of the system and the ground access to ensure the ability to sustain the space manned mission. It is noticed that these statements can be used to improve the operational statements (A1.1) to ensure the availability of the operations.

3.2.2.4 System Design

Table 16 presents 20 statements that can be used as domain-specific requirements that discuss the system design requirements.

Table 16: System Design Statements

ID	Statement	Source	Page
DC.64	The design of human-machine systems shall conform to the Human-Centered Design process	ECSS	19
DC.65	Analyses shall be performed and included in the design documentation to decide which of the below-listed workstation shall be implemented and with which characteristics. 1. Element control and communication workstation, 2. Maintenance and servicing work station, 3. Payload work station, and 4. Windows work station	ECSS	28
DC.66	A board of stakeholders shall define and control the process (including validation) and products through the procedures' life cycle.	ECSS	30
DC.67	Operations nomenclature shall apply to procedures and HMI development.	ECSS	30
DC.68	Boundary conditions, scheduled procedures usage, flight rules, medical and safety regulations shall be reflected in a timeline.	ECSS	31
DC.69	The timeline shall contain system and experiment operations, attitude and pointing, dataflow operations.	ECSS	31
DC.70	All resources and boundary conditions shall be compatible with the work/rest cycles of the crew as defined according to clause 4.5.4.	ECSS	31
DC.71	The design of the display products shall comply with the output of the task analysis.	ECSS	31
DC.72	Clause 4.4 shall apply for display product development	ECSS	31
DC.73	Displays and procedure development shall be coordinated.	ECSS	31
DC.74	The project-specific operations nomenclature shall be used.	ECSS	31
DC.75	A project-specific display standard shall be developed before the manufacturing of any displays.	ECSS	32
DC.76	Stakeholders including users (or their representatives) shall assess the system being designed according to the human-centered design approach.	ECSS	32
DC.77	Continuous assessment (iterative process) shall be supported by techniques of rapid prototyping.	ECSS	32
DC.78	A continuous assessment plan (part of the human-centered design process plan) shall be established.	ECSS	32
DC.79	The continuous assessment plan shall include the planned evaluation events (e.g. usability reviews).	ECSS	32
DC.80	The continuous assessment plan shall be maintained.	ECSS	33
DC.81	After each evaluation event, a report shall be issued	ECSS	33
DC.82	The technique and the models used for the continuous assessment shall be analyzed for their quality of representativeness before each assessment is made.	ECSS	33
DC.83	The model used for the assessment shall be capable to be incrementally updated to represent the achieved definition of the system under evaluation.	ECSS	33

In Table 16, it can be seen how important is to consider human in the design aspect of space missions. System design can be used to enhance the implementation statements (A1.3) to be more human-centered design.

3.2.2.5 Health

3 statements were found that can be used as domain-specific requirements that discuss astronauts' heath. Table 17 presents statements that illustrate requirements to be considered for astronauts' health. These requirements emphasize on the importance of including astronaut health in the design aspect.

Table 17: Health Statements

ID	Statement	Source	Page
DC.84	The physical exercise facility to maintain crew health and well-being shall be classified as a duty station.	ECSS	29
DC.85	It shall be demonstrated that medical facilities and provisions including the capability to handle specific illness or injuries shall satisfy the need for the number of crew members, mission duration, and related mission constraints.	ECSS	29
DC.86	Analyses shall be performed and included in the design documentation to decide which of the below listed medical facilities and provisions shall be implemented and with which characteristics. 1. Monitor and control crew health and well-being, 2. Monitor and treat one or more injured crew persons, 3. Monitor, isolate and treat one or more ill crew persons, 4. Quarantine one or more crew person, and 5. isolate/handle at least one or more deceased crew person	ECSS	29

The health area (A2.5) is another area that can be used to introduce a section of requirements that concern astronauts' well-being in the spacecraft.

3.2.2.6 Integrity and Security

4 statements were found that can be used as domain-specific requirements about integrity and security. Table 18 presents statements that are related to the Integrity and Security aspects.

Table 18: Integrity and Security

ID	Statement	Source	Page
DC.87	Ability to add digital signatures to all database traffic between spacecraft and with the ground, to allow the receiving system to verify the sender's authenticity	NASA-HMI	1069
DC.88	To prevent security breaches, eavesdropping, and tampering with sensitive or private data	NASA-HMI	1070
DC.89	The ability to add digital signatures to all electronic communications between spacecraft and with the ground, to allow the receiver to verify the sender's authenticity	NASA-HMI	1070
DC.90	The ability of crewmembers to exchange information of a personal nature (e.g., medical information or family communications) in such a way that only the intended recipients (e.g., flight surgeon or family member) can read the message or view any attachments	NASA-HMI	1070

It is noticed that this area is in collaboration with the Security and Safety (A1.6) to ensure the cybersecurity aspect of the software systems.

3.2.2.7 Training

3 statements were found that can be used as domain-specific requirements that discuss the training aspect. Table 19 presents statements that illustrate statements that are related to training.

Table 19: Training Statements

ID	Statement	Source	Page
DC.91	Training objectives and requirements for ground and flight personnel shall be established and specified.	ECSS	32
DC.92	Training requirements shall be developed in parallel with the design process.	ECSS	32
DC.93	Training curriculum and related training models and simulators shall be specified.	ECSS	32

As the software system will be interactively used by astronauts, it is important to include training requirements (A2.7) to ensure that astronauts are prepared to use the software system in the space environment.

3.2.3 Domain Requirements Elicitation

Understanding the nature of the statements found in the selected references, the thesis considered 7 important areas that contribute to the domain requirements. Table 20 presents the elicited requirements.

A2.1: Usability: requirements that improve the usability of the software system in the space manned mission domain.

A2.2: Environment: requirements about the effects of the environment on the human-computer interaction in the domain.

A2.3: Availability: requirements that are related to the availability of the software system.

A2.4: Design: requirements that illustrate the way to design the software system, processes, procedures, and interactions.

A2.5: Health: requirements that help sustain the astronauts’ health.

A2.6: Integrity and Security: requirements that are related to the security and integrity of the system.

A2.7: Training Experience: requirements that are directly related to astronauts' training so they can be able to use the software systems.

Table 20: Domain Requirements

ID	Requirements	Justification
R.12	The system shall consider the ambient luminance, contrast, and color gamut of displays when designing the software interfaces and displays.	A2.1 & A2.2
R.13	The system shall consider the environment as part of the human-computer interactions to eliminate errors and risks.	A2.1 & A2.2
R.14	The system shall prevent astronauts from misusing the system interfaces to eliminate errors and risks.	A2.1 & A2.6
R.15	The system shall be designed in a human-centered approach.	A2.4 & A2.2
R.16	The system shall provide different options for data restoration such as soft and hard copies.	A2.3 & A2.6
R.17	The system shall have a redundant source of power to ensure system availability.	A2.3
R.18	The system shall provide interfaces to track astronaut health and condition.	A2.5
R.19	The training shall consider the interactions between the software and the astronauts to ensure the astronauts' readiness.	A2.7

3.3 Environment Regulation

3.3.1 Statement Extraction

The first step in the phase is to survey the space domain to identify possible sources, which could be used to identify possible guidelines or statements that regulate and bind the space-manned missions. The thesis surveyed the UAE Federal Law and international binding treaties by the United Nations UNOOSA Space Law. The team extracted statements that are related to manned space missions. The team identified 11 statements that can be used to derive regulation requirements. Then, the team grouped the extracted statements into 4 groups based on the liabilities of the stakeholders.

3.3.2 Statements Analysis

4 groups of statements were analyzed to derive regulated requirements based on liabilities that are assigned to different stakeholders in the space manned missions. This allowed to define the role of the stakeholders in the space manned mission as a

set of regulatory requirements. The thesis presents the statements that were extracted and grouped in the following categories: Astronauts Liabilities, Operator Liabilities, State Liabilities, and International Cooperation. Each statement was identified by the prefix (LR) for Legal Requirements.

3.3.2.1 Astronauts Liabilities

The group of statements that is related to the liabilities to the astronauts were analyzed. It is important to understand the liabilities of the Astronauts to ensure the mutual understanding between the stakeholders' liabilities and that the rights of all parties are preserved. These statements are presented in Table 21.

Table 21: Astronauts Liabilities

ID	Statement	Source	Reference
LR.01	A proof that the natural person is aware and well informed of the risks associated with Spaceflight.	UAE Law	Article 16 page 11
LR.02	Written consent of the natural person to participate in the Spaceflight	UAE Law	Article 16 page 11
LR.03	A proof that the person has completed the necessary training, physical and health fitness to participate in the Spaceflight.	UAE Law	Article 16 page 11

It is identified that the requirements framework shall include requirements that ensure the understanding of the astronauts' role, responsibilities, the risk associated, physical preparation, and training associated. This area can be integrated with health (A2.5) as they are related to the astronaut's well-being.

3.3.2.2 Operator Liabilities

The group of statements that is related to the operator's liabilities were analyzed. It is important to understand the liabilities of the operators to ensure the mutual understanding between the stakeholders' liabilities and that the rights of all parties are preserved. These statements are grouped in Table 22.

Table 22: Operator Liabilities

ID	Statement	Source	Reference
LR.04	A proof that Operator has performed all necessary risk and safety assessments, and that there is an appropriate emergency plan.	UAE Law	Article 16 page 11
LR.05	Operator authorized to conduct a human Spaceflight activity shall immediately inform the Agency of any Incident or Accident encountered, or the risks faced, and any measures are undertaken thereby to reduce the same or the effects thereof	UAE Law	Article 16 page 11

Analyzing the role of the operator in the space manned mission shows the importance of understanding the nature of the technical capabilities. It also illustrates how to perform the operator roles and responsibility to assess, manage, and monitor space manned flights. Moreover, it provides cooperation between different operators to ensure the safety of the space-manned missions. Using the statements mentioned above, the thesis can derive requirements into the implementation area (A1.3) to ensure the compatibility of the design and being able to work with another manned spacecraft.

3.3.2.3 State Liabilities

The group of statements that are related to the state's liabilities were analyzed. It is important to understand the liabilities of the States to ensure the mutual understanding between the stakeholders' liabilities and that the rights of all parties are preserved. These statements are grouped in Table 23.

Table 23: State Liabilities

ID	Statement	Source	Reference
LR.06	Any requirements or conditions issued by a resolution of the Board of Directors.	UAE Law	Article 16 page 11
LR.07	The conditions and terms of liability related to the activities of human Spaceflight shall be determined by a resolution of the Board of Directors, in cooperation with the concerned Government Entities, and in particular those related to Sub-Orbital Flights.	UAE Law	Article 16 page 12
LR.08	States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that those national activities are carried out in conformity with the provisions outlined in the present Treaty	UNOOSA, International Law	Article VI, page 5

Analyzing the statements shows two roles for the states. The first is an internal role to govern the space manned mission and to define the roles and responsibilities of each stakeholder to ensure mutual understanding between the parties. The second, is an external role that ensures the cooperation with the international society to ensure that the activities carried are considered as human expedition and bear with the international responsibilities. These statements can be injected into the operational area (A1.1) to ensure empowering the inter-operations of the space software systems.

3.3.2.4 International Cooperation

The group of statements that is related to the liabilities to the international space society towards the space manned mission were analyzed. Space manned mission is a result of international cooperation at the highest levels. These statements are grouped in Table 24.

Table 24: International Cooperation

ID	Statement	Surce	Reference
LR.09	States Parties to the Treaty shall regard astronauts as envoys of mankind in outer space and shall render to them all possible assistance in the event of accident, distress, or emergency landing on the territory of another State Party or the high seas	UNOOSA, International Law	Article V, page 5
LR.10	States Parties to the Treaty shall be guided by the principle of cooperation and mutual assistance and shall conduct all their activities in outer space, including the Moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty.	UNOOSA, International Law	Article IX, page 6
LR.11	The States Parties to the Treaty shall consider on a basis of equality any requests by other States Parties to the Treaty to be allowed to observe the flight of space objects launched by those States.	UNOOSA, International Law	Article X, page 6

The international cooperation statements are focusing on considering any manned space mission as a mankind activity and all countries shall provide full cooperation to ensure their safety, mutual understanding, and international efforts. These statements can be used to enhance the operational area (A1.1) to ensure the compatibility of the operation to improve the collaborations between the different software.

3.3.3 Legal Requirements Elicitation

Legal requirements can be elicited and specified based on 4 areas of interest:

A3.1: Astronaut: requirements that are related to Astronaut's roles and responsibilities and ensure the full implementation of these roles in the requirements.

A3.2: Operator: requirements that are related to the operator role and ensure that operators are fulfilling their role in the space manned missions.

A3.3: State: requirements that are related to the liabilities of the state and ensure that the requirements represent the roles and the responsibilities of the state toward the space manned missions.

A3.4: International Cooperation: requirements on different stakeholders in space manned missions to ensure international cooperation on all levels.

Each of these 4 areas is needed to be in the space manned mission requirements to ensure that the roles and responsibilities of each stakeholder are covered from a technical perspective as illustrated in Table 25.

Table 25: Legal Requirements

ID	Requirements	Justification
R.20	The system shall prompt the astronaut confirmation of risks associated with certain tasks before proceeding.	A3.1
R.21	The system shall assess the physical health conditions of the astronaut before proceeding with tasks that need a certain level of physical readiness.	A3.1
R.22	The system shall not allow the astronaut from taking action that might affect the spacecraft condition without ground approval.	A3.1 & A3.2
R.23	The system shall be able to work with different operating systems such as RTEMS, FREE RTOS, Leon, and Ubuntu to ensure cooperation possibilities.	A3.2 & A3.4
R.24	The system shall monitor and assess the spacecraft condition and provide the information to the ground operators.	A3.2 & A3.1
R.25	The system shall allow a ground operator for managing the spacecraft remotely when requested.	A3.2 & A3.3 & A3.4

3.4 Emotional Requirements

3.4.1 Statement Extraction

The first step in this phase is to survey the space domain to identify possible sources that could be used to identify possible guidelines or statements that define the emotional experience of the astronauts. The thesis surveyed NASA and ESA and identified two possible references that are NASA Human Integration Handbook and ESA Human Factor Engineering. Moreover, the thesis analyzed results reported in the Morgan case study (Eudy, 2018), which is a study conducted on 533 astronauts who orbited the Earth investigating their emotional experience in the space manned missions including the effect of their isolation, the crew attitude and behavior, the stress of being in a critical environment and the scheduled operations and tasks that needed to be operated in a timely manner. The thesis extracted statements that are related to emotional requirements. The thesis identified 60 statements that can be used to derive emotional requirements. Then, the thesis grouped the extracted statements into 7 groups based on their cognitive efforts to facilitate their analysis.

3.4.2 Statements Analysis

The 7 groups of requirements were analyzed to derive emotional requirements based on the effects of these statements on the emotional/cognitive experience of the astronauts. This allowed to define the effect of these statements on the astronauts' emotional experience as a set of emotional requirements. The thesis present the statements that were extracted and grouped in the following categories: memory, other mental loads, flow, perception, attention, learning, and emotional experience. Each statement was identified by the prefix (ER) as Emotional Requirements.

3.4.2.1 Mental Load – Memory

Table 26 presents statements that are focusing on memorizing activities. They highlight the importance of minimizing the effort of the astronauts to memorize words, items, and steps. It is important to not stress the astronauts into memorizing different items, increasing the mental load by memorizing things that can lead to frustration for the astronauts and lead to error making and misjudgment.

Table 26: Memory Statements

ID	Statement	Reference	Page
ER.01	Labels and cues shall be provided in all spacecraft areas regardless if crew operations (either nominal or contingency) are performed.	ECSS	26
ER.02	Cue cards shall be provided as a reminder for task execution.	ECSS	31
ER.03	The number of shapes to be identified by each operator based on absolute discrimination should be not more than 10.	NASA-HMI	1017
ER.04	Information should be displayed only within the limits and precision required for specific operator actions or decisions.	NASA-HMI	1025
ER.05	The display of information at any one time should be as simple and minimal as possible	NASA-HMI	1026
ER.06	Abbreviations should be used as sparingly as possible. If they must be used, make sure that target users are familiar with them.	NASA-HMI	1026
ER.07	The verbiage used on a display should be simple and common.	NASA-HMI	1026
ER.08	If domain-specific verbiage is needed, it should be common to that domain, so that it can be understood by a person with minimal training.	NASA-HMI	1026
ER.09	User interfaces should reduce the demand on user memory through the use of prompts, labels, menus, and other salient cues.	NASA-HMI	1033

3.4.2.2 Mental Load – Others

Statements were grouped in Table 27 that are related to the mental load but not directly related to the memory. It is important to understand the mental load to prevent overworking the astronauts with mental activities such as learning, mastering tasks, and decision making. It will consume the astronaut's energy and will lead to aggressiveness, misjudgment, and error making. This is important to enhance the astronaut well-being and can be used collaboratively with the health area (A2.5)

Table 27: Mental Load Statements

ID	Statement	Reference	Page
ER.10	Safety shall also characterize all mission-related ground activities and possible cumulative effects on the users.	ECSS	24
ER.11	For environmental ergonomics, To create an environment that supports and maintains human health, safety, and well-being all relevant functions and resources shall be provided as specified in ECSS-E-ST-34 (Environmental control and life support standards).	ECSS	24
ER.12	Labels and cues shall be provided as memory aids for the user.	ECSS	26
ER.13	Systems must be usable under conditions of high stress (i.e., an emergency), with minimal cognitive effort.	NASA-HMI	901
ER.14	Controls that are used during high acceleration or vibration should be located and designed so that the operator can make accurate control inputs.	NASA-HMI	1024
ER.15	Information should be sufficient to allow the operator to perform the intended mission, but limited to information necessary to perform specific actions or to make decisions.	NASA-HMI	1025
ER.16	The unit of measure presented should be the one required for the task.	NASA-HMI	1025
ER.17	Information required for flight, docking, systems, and other critical activities, should be integrated to reduce scan, resolve ambiguity, and improve interpretation during a full range of flight-related tasks.	NASA-HMI	1026
ER.18	The amount of information on a given display should be necessary and sufficient to complete the current task.	NASA-HMI	1027

3.4.2.3 Flow of Tasks

Statements were grouped in Table 28 are related to the flow of tasks and activities. These statements illustrate the importance of considering the environment, hardware, and cognitive ergonomics, in addition to the astronaut capabilities and skills needed to be in mind when designing the astronaut experience. These considerations will ease the flow of the tasks that will help the astronaut to learn the tasks. This will likely decrease the frustration of the astronaut and will decrease the possibility of misjudgment and error making. This area can be used to enhance the Implementation area (A1.3) to ensure that flow of tasks is captured in the design process.

Table 28: Flow of Tasks Statements

ID	Statement	Reference	Page
ER.19	For hardware ergonomics system design, the following factors shall be characterized: 1. Anthropomorphic characteristics of the user population, 2. Human capabilities and skill, 3. Environment, 4. Tasks complexity and constraints and inherent or collateral physical stress that can be generated, and 5. Machine capabilities and autonomy level.	ECSS	24
ER.20	For cognitive ergonomics, to achieve the most effective overall system design, the following factors shall be characterized: 1. Human capabilities and knowledge profiles and boundaries, 2. Environment, 3. Tasks complexity and constraints and inherent or collateral stress that can be generated, and 4. Machine capabilities and autonomy level.	ECSS	25
ER.21	For cognitive ergonomics, the fit between human cognitive abilities and limitations for safety-related data and controls shall be characterized.	ECSS	25
ER.22	The color vision capabilities of the crew should be considered in the design.	NASA-HMI	1033
ER.23	The lack of a consistent, reliable organizational framework generated a sort of frustration	Morgan Study	53
ER.24	The pressure to complete the highly scheduled mission timeline contributed to stress and frustration.	Morgan Study	60
ER.25	Operations required significant cognitive resources with an extremely low margin for error.	Morgan Study	60

3.4.2.4 Cognitive Effort – Perception

Statements that are grouped in Table 29 are related to the cognitive effort of building the astronaut perception. The astronaut's perception is an important pillar in the emotional experience. Being able to understand the environment surrounding the astronaut and immerse with it helps the astronaut to feel secure and confident when interacting with the system. Thus, it is important to create the experience in a way that the system gains the astronaut's trust. This area will be an enhancement of the usability area (A2.1) to understand how the astronaut will be affected by the system when using it.

Table 29: Perception Statements

ID	Statement	Reference	Page
ER.26	Shapes must be tactually identifiable when gloves must be worn.	NASA-HMI	1017
ER.27	If color-coding is required, not more than five colors should be used. Only the following colors should be selected for control coding.	NASA-HMI	1017
ER.28	Color coding should be compatible with anticipated ambient light during the mission.	NASA-HMI	1018
ER.29	Coding for emergency controls should allow the operator to distinguish them from other controls.	NASA-HMI	1018
ER.30	The orientation of displays and controls should be as consistent as possible and be designed to be compatible with crew orientation during procedures.	NASA-HMI	1020
ER.31	To make an interface simple for the user, related items should be grouped.	NASA-HMI	1022
ER.32	Where sequential operations follow a fixed pattern, controls should be arranged to facilitate operation.	NASA-HMI	1022
ER.33	Related items should be grouped, either in a logical sequence in time or in a similar location in space.	NASA-HMI	1022
ER.34	Displays and controls should be arranged concerning one another according to their sequence of use or the functional relations of the components they represent.	NASA-HMI	1022
ER.35	Whenever possible, displays and controls should be arranged in sequence within functional groups and provide a flow from left to right or top to bottom.	NASA-HMI	1023
ER.36	The name of a control, display, piece of equipment, or process should reflect its function and what it does in the mission.	NASA-HMI	1027
ER.37	Displays and controls should have features such as color and shape that make them sufficiently different from each other.	NASA-HMI	1028
ER.38	The use of too many colors should be avoided to prevent the so-called “Christmas tree” effect that can distract users from their main task.	NASA-HMI	1033
ER.39	Extreme environments engender cognitive and behavioral changes that may increase perceptions	Morgan Study	24

3.4.2.5 Cognitive Effort – Attention

Statements in Table 30 are related to the astronaut cognitive effort related to attention. Analyzing the statements that are provided in Table 30 is important to consider when designing the interfaces and interactions between the system and the astronaut. Location of the interfaces and the way interfaces are grouped, displayed, or colored. With the perception built-in Table 29, these statements could help guide the attention of the astronaut to identify the interfaces and the relation between the interfaces that will help to relieve the cognitive stress. This area also can be a second enhancement for the usability area (A2.1) to understand and improve the usability experience when trying to grab the astronaut's attention.

Table 30: Attention Statements

ID	Statement	Reference	Page
ER.40	Work station shall be either outfitted with equipment (including lights) and tools (including restrains) to support the foreseen crew activities or shall be provided with the necessary restraints and hook points to enable their outfitting.	ECSS	28
ER.41	Crew interfaces that perform different functions should be designed to have distinct visual designs and methods of interaction.	NASA-HMI	904
ER.42	If items have a high probability of being confused, then they should differ in two or more dimensions.	NASA-HMI	905
ER.43	Large, hand- or fist-operated, mushroom-shaped buttons should be used only as “emergency stop” controls.	NASA-HMI	969
ER.44	Tactile feedback is preferred in space environments because the background noise may prevent the crew member from hearing auditory feedback.	NASA-HMI	973
ER.45	Only displays and controls that are necessary and sufficient for the completion of the task should be placed in the main visual field of the user.	NASA-HMI	1020
ER.46	If there is a likelihood that two commands will be confused with each other, operational distinction should be used. Operational distinction involves requiring the user to perform different manual actions or procedures to initiate each command.	NASA-HMI	1028
ER.47	Navigation should be consistent across the software in color, label, positioning, and other features.	NASA-HMI	1030
ER.48	The color vision capabilities of the crew should be considered in the design. Careful consideration should be given to the choice of graphics, to ensure that the meaning is obvious. For example, photographs sometimes display too much information, which can confuse them. A line drawing can eliminate extraneous information and allow the user to focus on the purpose of the illustration.	NASA-HMI	1033

3.4.2.6 Cognitive effort – Learning

Statements were grouped in Table 31 are related to the process of learning. These statements show the importance of considering the astronaut learning process and build on it in different tasks. Consistency of interfaces, color coding, displays, keys groups, and languages used in the interactions between the astronaut and the system helps the astronaut to get confident and decrease the frustration that will lead to a better judgment from the astronaut side. This area can be used in collaboration with the training area (A2.7) to consider the learning process in the training and prepare the astronaut to be more comfortable with it to ensure their adaptability.

Table 31: Learning Statements

ID	Statement	Reference	Page
ER.49	Interface Consistency, the knowledge users have learned using one part of the system or a subsystem can be applied to the rest of the interface.	NASA-HMI	902
ER.50	Displays should be legible under all expected spaceflight conditions where reading/interpretation of the displayed information will be required.	NASA-HMI	905
ER.51	Keys should be grouped according to their function, based on convention. Groupings can include numeric keys, alphabetical keys, and function keys.	NASA-HMI	972
ER.52	The nomenclature, or verbiage, used to describe each item of a system, the syntax, and procedure presentation should be consistent across all aspects of the system.	NASA-HMI	1027
ER.53	The language used in dialog boxes should be simple, natural language that is easy for users to understand.	NASA-HMI	1031
ER.54	Color usage should be consistent across the system.	NASA-HMI	1053

3.4.2.7 Emotional Experience

Table 32 presents statements that are identified as a direct emotional requirement. From the statement, it is obvious that when engineering the astronaut experience, it is important to ensure a quality emotional experience that helps to reduce the negativity in the environment to help the astronaut to keep a positive psycho-sociological attitude. This area can be injected into the astronauts' well-being and health (A2.5) to ensure the well-being of the astronaut from an emotional aspect.

Table 32: Emotional Experience Statements

ID	Statement	Reference	Page
ER.55	For environmental ergonomics, to create an environment that supports and maintains a positive psycho-sociological attitude of the on-board crew both as an individual and as group-specific functions shall be identified according to the mission profile and resources and implemented.	ECSS	24
ER.56	Astronauts report globally that self-awareness and group harmony are major concerns and training for these experiences may help to improve their social skills and capabilities	Morgan Study	25
ER.57	The social and physical environments of isolation and confinement contribute to irritability, depression, and interpersonal conflict during the period of isolation and confinement in multiple contexts	Morgan Study	29
ER.58	Selecting-in individuals who are task-oriented problem solvers, who have high assertiveness, positive expressivity, and interpersonal awareness are key to future success for missions in these environments	Morgan Study	30
ER.59	Efficient teamwork and concise, clear interpersonal communication were crucial for safety and success.	Morgan Study	46
ER.60	The importance of good crew discipline, especially during off-nominal events.	Morgan Study	47

3.4.3 Emotional Requirements Elicitation

To understand the nature of the statements found in the selected references, the thesis considered the following 7 important areas, which contribute to each other.

A4.1: Memory requirements that will minimize the memorizing efforts to decrease the stress on the astronauts and help them to have a better judgment.

A4.2: Mental Load requirements about understanding the mental load of the astronauts to decrease their frustration and errors.

A4.3: Flow requirements that are related to the flow of tasks. These requirements are about helping astronauts feel confident and secure when executing tasks.

A4.4: Perception requirements that are about helping astronauts build a perception about the surrounding environment and understand it.

A4.5: Attention requirements that are about helping astronauts identify the interfaces and interactions with the system to build confidence and trust.

A4.6: Learning requirements that are related to the learning process of the interaction and interfaces that help the astronauts to interact with the system and build a better judgment.

A4.7: Emotional Experience requirements that are directly related to the astronauts' emotions and direct the engineers to design the system in a way that helps astronauts to stay emotionally stable to build a positive attitude between the crew members.

Each area that is mentioned above is required to ensure the quality of the astronauts' experience by decreasing their cognitive stress, mental load, and frustration, and increasing their confidence and trust in the system. This is important for the overall quality of the astronauts' experience and helps astronauts to be in control of the space mission that will ensure the success of the exploration missions. Table 33 regroups high-level requirements that are needed to be addressed in every manned space mission.

Table 33: Emotional Requirements

ID	Statement	Justification
R.26	The system shall reduce the dependency on the astronauts' memory as much as possible by adapting alternative tools to remind the astronauts such as labels and cues	A4.1 & A4.2
R.27	The system shall not use abbreviations and verbiage unless it is a must to use it and in case it was used, it is needed to be clarified and introduced earlier	A4.1 & A4.2 & A4.6
R.28	The system shall use a limited number of identifiers such as color or shape, not more than 10	A4.1
R.29	The system shall display a limited number of information or instructions	A4.2 & A4.6
R.30	The engineers Shall consider human capabilities, skills, knowledge profile, and task complexity when developing a flow of tasks	A4.3
R.31	When possible, the system interfaces shall be designed and grouped in a way related to the flow of tasks	A4.3 & A4.6
R.32	The system interfaces shall not be designed in a way that confuses the astronauts	A4.3 & A4.6
R.33	The system interfaces shall be consistent all over the spacecraft	A4.4 & A4.5
R.34	The system navigation shall be consistent all over the spacecraft	A4.4 & A4.5
R.35	The engineers shall ensure the consistency of graphics, labels, cues all over the spacecraft	A4.1 & A4.4 & A4.5
R.36	The engineers shall ensure a quality level of the environment that help astronauts to be emotionally stable to ensure a positive attitude	A4.7

Chapter 4: Model Evaluation and Validation

4.1 Model Evaluation

In this section, the thesis discussed the quality of the software system based on the relative influence between the requirements areas. As shown in Figure 7, the requirements areas are categorized into 4 main quality sections. The first is the implementation quality, which contains requirements areas that baseline the process of design, implementation, and interfaces between implemented design, service design, and validation. These are the most important set of requirements as they influence all the other layers of quality sections. The second section is integration quality, which includes requirement areas that affect the integration of the system itself, different equipment that is added to the system, and the time management in between the system components and added equipment. This layer depends on the implementation quality section and influences the product quality section as it ensures the integration and synchronization between the software system components and added equipment. The third layer is the product quality section, this section collects the set of requirements that define the quality of the product such as operational, compatibility, interoperability, performance, security, and safety requirements. This layer is a result of the quality of the implementation and integration requirements. By enhancing the product quality it influences the last layer that is the quality in use. The quality in use section is the set of requirements that depends on all the other quality sections collaboratively and it is the layer that will show the effort in developing the system as it will define the interactions between the astronaut and the system from different aspects such as and not limited to perception, learning, usability, and human-machine interfaces. This shows the importance of ensuring the quality of different requirements areas as they are influenced by each other and dependent of each other.

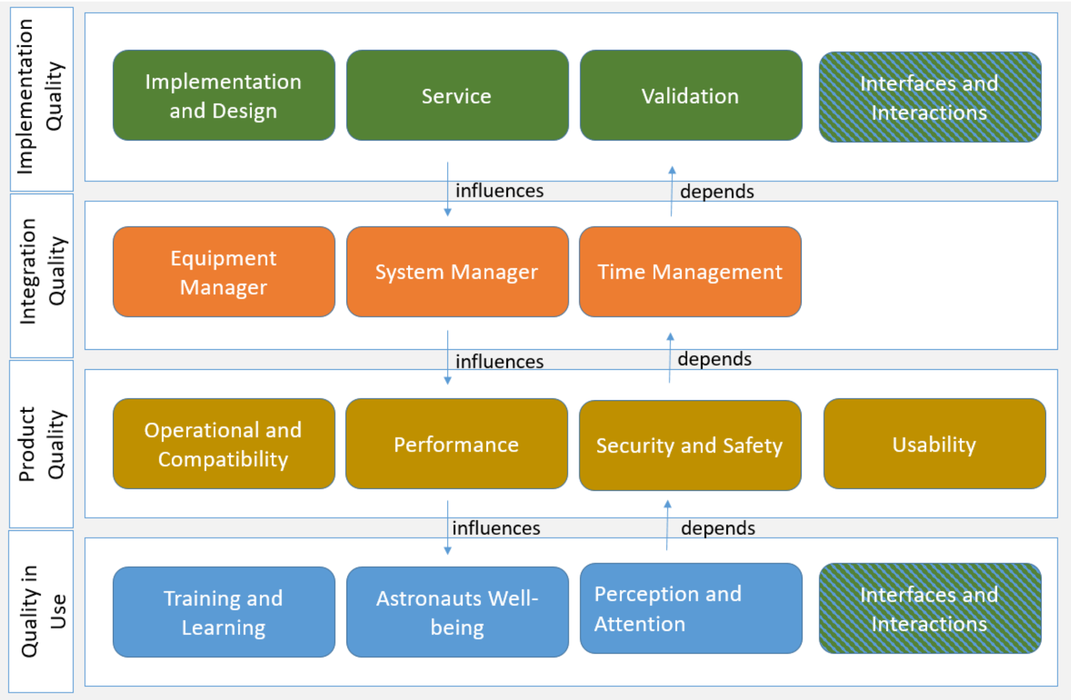

Figure 7: Requirements Evaluation Model

4.2 Stakeholders Immersion

In this section, the thesis discussed the stakeholders' involvement in the approach. It is important to include the stakeholders in the requirements process to be able to collect their inputs to elicit more requirements. For this reason, the thesis injected a stakeholders' immersion step to ensure their involvement. The thesis created a list of different stakeholders that are potentially involved in the space manned missions as mentioned in Table 34. Each stakeholder is referred to in this table by the acronym (SH).

Table 34: Stakeholders

ID	Role	Entity
SH.01	Mission Operations Engineer	Research centers
SH.02	Astronaut	UAE astronauts Program
SH.03	System Engineer	Commercial Entity
SH.04	System Engineer	UAE government (space agency)
SH.05	System Engineer	UAE government (space agency)

4.2.1 Involvement Preparations

In this section, the thesis present the preparation steps to collect the requirements from different stakeholders by initiating focus groups, interviews, and questionnaires (presented in Appendix B). These groups and interviews are defined in a way to cover different stakeholders and different end-users of the software system. The groups are presented in Table 35.

Table 35: Stakeholders Groups

Stakeholders	Elicitation technique	Subject
Research centers (SH.01)	Mission Operator Interview	Software experts and engineers' technical input.
Astronaut (SH.02)	Astronaut Interview	End-user input
Software engineer (SH.03)	Commercial Sector Interview	Commercial and private sector input.
UAE Space Agency (SH.04, SH.05)	UAE Space Agency focus group	Domain experts and government input.

The team had tried to interview an astronaut, but with no success. The team had applied for the interview and gone through all the required steps to interview the astronaut. Unfortunately, the timing to interview the astronaut is not decided yet as the astronauts are in special training in the United States and are not available with their loaded schedule and the limited time to prepare the thesis.

4.2.2 Methods of Involvement

To involve the stakeholders in the model evaluation, a slide presentation, online workshops and electronic questionnaires were prepared to be able to get feedback and collect comments from stakeholders. In light of the precautionary measures taken due to the Covid-19 pandemic, most workshops, meetings, and interviews were held virtually and all communications related were completed via email. First, the slides were presented (shown in Appendix B) to discuss the model then circulate the questionnaire to collect the feedback from the attendees. After that, all responses were collected in a single table for analysis.

4.2.3 Statement Collection

Different statements have been collected from different stakeholders were grouped and organized to prepare them for analysis and requirement elicitation. Each statement is identified by the prefix (ST) as a stakeholder's statement. Table 36 presents the statements that were collected through this process.

Table 36: Stakeholders Statements

ID	Statement	Source
ST.001	The system shall have automated and autonomies responses that define the automated operations of the software systems.	SH.01
ST.002	The system shall have software configuration management requirements that ensure maintaining consistency of the software performance, functional, and physical attributes.	SH.01
ST.003	The system interfaces shall include a requirement to test all interfaces between different elements interfaces.	SH.01
ST.004	If an astronaut and ground operator commanded the spacecraft. Astronaut priority in command as the commands will be in real-time and with more understanding of the environment.	SH.01
ST.005	Their system shall simulate the commands to ensure the consequences before executing the commands	SH.01
ST.006	Process of discussion making through project team, mission team, operation team, and astronaut that specify the role, responsibilities, and authority.	SH.01
ST.007	The roles of Artificial intelligence in Software automation should be defined	SH.04
ST.008	The Testing Process and Validation process should be defined.	SH.05
ST.009	There must be a statement that requires testing through the hardware-in-the-loop test.	SH.05
ST.010	There must be a product assurance requirement on the software to assure that the processes, procedures, and products used to produce and sustain the software system meet all requirements.	SH.04
ST.011	The process of training on the software processes and task sequences.	SH.03
ST.012	International standards for software development, testing, and operations.	SH.03
ST.013	Milestones and reviews to ensure tracking of the requirements throughout the project and operation.	SH.03
ST.014	To reflect the interfaces processes with different standards/stakeholders in the requirements	SH.03
ST.015	To reflect risk associated with the software or project management in the requirements	SH.03
ST.016	To reflect requirements, change management processes in the requirements	SH.03

In the process of stakeholder immersion, it is noticed that experts representing different stakeholders had different points of view in the discussion of the requirements elicitation. Experts from the government focused on testing and product assurance, experts from the commercial sector focused on the project and requirement management aspect to ensure continuous effort in satisfying the customer, experts from operations centers focused on the operation, maintenance, roles, and responsibilities throughout the space mission. This illustrates the importance of involving the stakeholders in the process of the requirements development process to ensure alignment with different points of view and aspects.

4.2.4 Statement Analysis

In this section, 16 statements were collected and divided into 5 requirement areas that are covered in the next subsections.

4.2.4.1 Operational and Compatibility

Table 37 presents 4 statements that are related to operations and compatibility areas.

Table 37: Operational - Stakeholder Statements

ID	Statement	Source
ST.001	The system shall have automated and autonomies responses that define the automated operations of the software systems.	SH.01
ST.004	If an astronaut and ground operator commanded the spacecraft. Astronaut priority in command as the commands will be in real-time and with more understanding of the environment.	SH.01
ST.005	Their system shall simulate the commands to ensure the consequences before executing the commands.	SH.01
ST.007	The roles of Artificial intelligence in Software automation should be defined.	SH.04

4.2.4.2 Design and Implementation

Table 38 presents 7 statements that are related to design and implementation processes.

Table 38: Implementation and Design - Stakeholder Statements

ID	Statement	Source
ST.002	The system shall have software configuration management requirements that ensure maintaining consistency of the software performance, functional, and physical attributes.	SH.01
ST.006	Process of discussion making through project team, mission team, operation team, and astronaut that specify the role, responsibilities, and authority.	SH.01
ST.010	There must be a product assurance requirement on the software to assure that the processes, procedures, and products used to produce and sustain the software system meet all requirements.	SH.04
ST.012	International standards for software development, testing, and operations.	SH.03
ST.013	Milestones and reviews to ensure tracking of the requirements throughout the project and operation.	SH.03
ST.015	To reflect the risk associated with the software or project management in the requirements.	SH.03
ST.016	To reflect requirements change management processes in the requirements.	SH.03

4.2.4.3 Testing and Validation

Table 39 presents 3 statements that are related to testing and validation processes.

Table 39: Testing and Validation - Stakeholders Statements

ID	Statement	Source
ST.003	The system interfaces shall include a requirement to test all interfaces between different elements interfaces.	SH.01
ST.008	The testing process and validation process should be defined.	SH.05
ST.009	There must be a statement that requires testing through the hardware-in-the-loop test.	SH.05

4.2.4.4 Training and Learning Process

Table 40 presents one statement that is related to the training and learning process.

Table 40: Training and Learning Process - Stakeholder Statements

ID	Statement	Source
ST.011	The process of training on the software processes and task sequences.	SH.03

4.2.4.5 Interfaces and Interactions

Table 41 presents 2 statements that are related to interfaces and interactions. It focuses on interface processes and testing to ensure interfaces are communicated to all stakeholders with their standards.

Table 41: Interfaces and Interactions - Stakeholder Statements

ID	Statement	Source
ST.003	The system interfaces shall include a requirement to test all interfaces between different elements interfaces.	SH.01
ST.014	To reflect the interfaces processes with different standards/stakeholders in the requirements	SH.03

4.2.5 Stakeholders Requirements Elicitation

Table 42 presents 14 requirements based on the statements collected from the stakeholders above to cover the different needs of the projects. These requirements are bonded to the requirements area illustrated in Section 4.4.

Table 42: Stakeholders Requirements

ID	Requirements	Area
R.37	The System shall define the automated response scenarios based on the Mission requirements and Concept of Operations.	A1
R.38	The System shall design shall include a configuration management plan based on the Mission requirements to ensure maintaining consistency of the software performance, functional, and physical attributes.	A3
R.39	All system interfaces and interactions shall be tested and validated based on System Testing and Validation Plan	A10
R.40	Command and control priorities shall be programmed in the system based on the Mission Concept of Operations.	A1
R.41	The System shall be able to simulate commands and illustrate consequences when never requested.	A1
R.42	All the roles, responsibilities, and authorities shall be programmed based on the Mission Concept Operations.	A3
R.43	All Testing and Validation processes and procedures shall be aligned and compliant with the System Testing and Validation Plan.	A10
R.44	The System process and procedures shall be aligned and compliant with the Product Assurance Plan	A3
R.45	The software learning process and flow of tasks shall be designed in alignment with the training process and plan.	A13
R.46	International Standards shall be decided and documented in all the Software product life cycle: Design, Implementation, Testing and Validation, Operations, and maintenance.	A3
R.47	Software requirements shall be aligned with the project milestones aligned with the Mission Concept of Operations.	A3
R.48	The system interfaces shall be designed based on international standards that are aligned with the Mission Concept of Operations.	A4
R.49	The Software Development Plan shall include a risks management plan that is aligned with Mission Risk Management Plan.	A3
R.50	The Software Development Plan shall include a requirement management plan that defines the process of change management to ensure tracking of requirements changes throughout the mission.	A3

4.3 Expert Feedback

In this section, the proposed model is discussed to ensure the quality of the framework and to refine the SRS document. Figure 8 shows how the validation started with the expert team creation, collecting expert preference and feedback interviews and email to collect more requirements based on their experience.

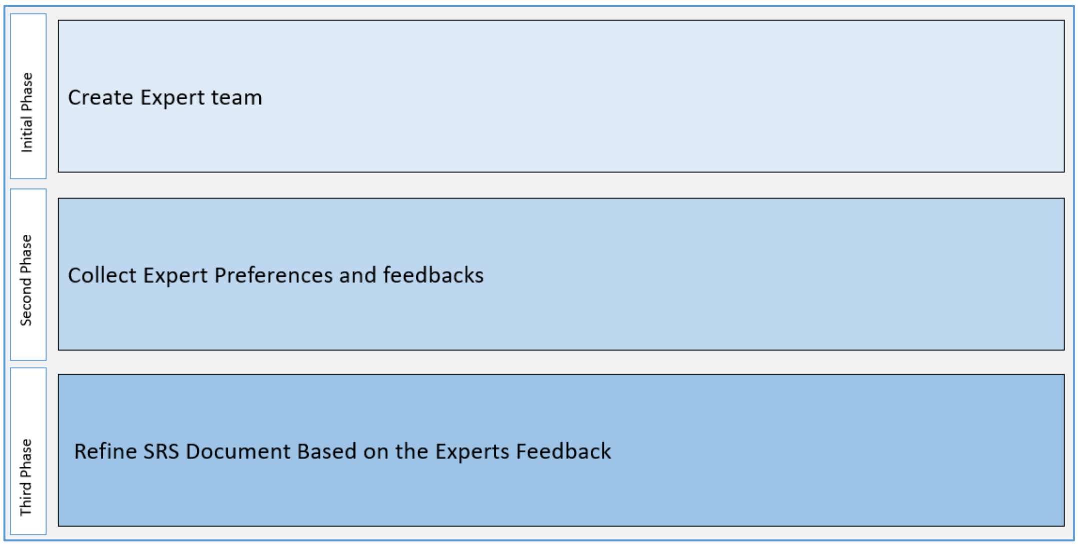

Figure 8: Expert Involvement Steps

4.3.1 Statements Collection

Table 43 presents the statements that were raised by the field experts with prefix (Exp) as Experts statements.

Table 43: Expert Statements

Number	Statement	Justification
Exp.01	The system shall be designed to never use more than 80% of the computing resources (processor power, temporary storage, and memory)	This is a safety margin so that if some algorithm uses more resources than needed, it does not compromise the rest
Exp.02	I didn't see any requirement for software watchdogs: i.e. the system shall automatically detect its failures – such as infinite loops – and automatically recover (kill the task or reboot)	
Exp.03	The reboot time shall not exceed mission parameters – i.e. if the integrity of the spacecraft is compromised if the system does not work for more than X seconds, then the booting time shall not exceed this.	
Exp.04	Requirements for radiation tolerance/hardness	
Exp.05	Requirements for storage integrity: e.g. most flash drives only allow a maximum X number of write operations – so you need to set a requirement to avoid selecting a flash drive that only supports very few write operations	
Exp.06	Requirements for in-flight updates of the software	
Exp.07	If you are also thinking of requirements for the physical part then: - Buttons shall be usable with big astronaut gloves - Buttons shall not press themselves e.g. because of g-forces and vibrations	

4.3.2 Expert Requirements Elicitation

Table 44 presents 8 requirements based on the statements collected from the experts above to cover the different needs of the projects.

Table 44: Experts Requirements

ID	Requirements	Area
R.51	The system shall be designed to never use more than 80% of the computing resources (processor power, temporary storage, and memory)	A.3
R.52	The system shall automatically detect its failures – such as infinite loops – and automatically recover (kill the task or reboot)	A.8
R.53	The reboot time shall not exceed mission parameters based on the Mission Concept of Operations.	A.1
R.54	The System Shall be tolerating radiation effects up to the mission parameters based on the Mission Concept of Operations.	A.6
R.55	The System storage at a minimum shall support writing operations as mentioned in the mission parameters based on the Mission Concept of Operations.	A.5
R.56	The System shall be able to update the software in flight or deep space habitats.	A.8
R.57	The System interfaces shall not be triggered by environmental factors such as g-forces and vibrations.	A.4
R.58	The Software shall have defined APIs for communicating with other components.	A3 & A4

4.4 Refined SRS Content

In this step, the thesis incorporates the input from each earlier step to refine all the inputs. This is done through Refined Area Table (Table 45) that defines each area and the components from the framework related to it.

Table 45: Refined Area Table

Source Areas	Domain Areas	Regulation Areas	Emotional Areas	Refined Areas
A1.1 Operational	A2.3 Availability	A3.4 International Cooperation A3.3 State		Operational and Compatibility
A1.2 Equipment Manager				Equipment Manager
A1.3 Implementation	A2.4 Design	A3.2 Operator	A4.3 Flow	Design and Implementation
A1.4 Interfaces	A2.2 Environment			Interfaces and Interactions
A1.5 Performance				Performance
A1.6 Security and Safety	A2.6 Integrity and Security			Security and Safety
A1.7 Service				Service
A1.8 System Manager				System Manager
A1.9 Time Management				Time Management
A1.10 Validation				Testing and Validation
	A2.1 Usability			Usability
			A4.4 Perception A4.5 Attention	Perception and Attention
	A2.5 Health	A3.1 Astronaut	A4.2 Mental Load A4.7 Emotional experience	Astronauts Well-being
	A2.7 Training		A4.1 Memory A4.6 Learning	Training and Learning

The new refined SRS Includes 14 requirements area that covers different requirements areas from each step to ensure that all areas mentioned in the framework are illustrated and aligned with other related requirements areas. For instance, requirements areas that are related to the astronauts A2.5, A3.1, A4.2, and A4.7 are collaborating in the interest of the astronauts' well-being. Table 46 presents these 14 requirements areas.

Table 46: Refined Requirements Area Definitions

ID	Requirements Area	Definition
A.1	Operational and Compatibility	Requirements that ensure the operations and availability of the software systems in the space environment and compatibility with different space software systems to ensure cooperation through different systems.
A.2	Equipment Manager	Requirements that illustrate the role of the software in managing the equipment.
A.3	Design and Implementation	Requirements that specify the way of development, system design, system architecture, and flow of tasks.
A.4	Interfaces and Interactions	Requirements that specify the type of interfaces, role of interfaces, type of interaction, and environmental conditions for the interactions between the astronaut and the software system.
A.5	Performance	Requirements that are related to the software system performance include response time, estimated life expectancy, memory size, memory types, and computational resources.
A.6	Security and Safety	Requirements that ensure software security, communication security, system safety, and integrity.
A.7	Service	Requirements that illustrate the service that the software shall provide to the spacecraft such as equipment status, file systems, data monitoring, and configurations
A.8	System Manager	Requirements that are illustrating the software's role in managing the software system such as when to enter or exit the "Safe Mode", fault investigation mechanisms, ways to interchange the modes, command issuing, and payload management.
A.9	Time Management	Requirements that are related to time management to ensure the onboard clock synchronization such as soft reset, GPS synchronization and modify it
A.10	Testing and Validation	Requirements that illustrate the process of validating the software systems.
A.11	Usability	Requirements that ensure the usability of the software system
A.12	Perception and Attention	The requirement is related to the perception and attention of the astronaut.
A.13	Astronauts Well-being	Requirements that are related to the astronauts' health, roles, responsibility, mental and emotional experience.
A.14	Training and Learning	Requirements that specify the training and learning process.

4.5 Refined Requirements

Table 47 presents the cumulative elicited requirements that were elicited in this work. These requirements are refined based on the experts' feedbacks and can be used as a part of an SRS and as a seed for different Manned Space Missions.

Table 47: Elicited Requirements

ID	Statement	Justification
R.01	The System shall operate in the range of temperatures that is decided by the mission team.	A1
R.02	The software shall provide housekeeping reports about the spacecraft equipment and software itself every 30 seconds.	A2
R.03	The software shall be design in a modular way to increase the level of reusability	A3
R.04	The System shall have an interface connection with I2C, CAN, and PPS wire.	A3 & A4
R.05	The software shall have a life expectancy of the designed mission.	A5 & A1
R.06	The software shall only accept only commands by authorized users.	A6
R.07	The software shall change the authorization key repeatedly at a minimum of 48 times a day.	A6
R.08	The system shall provide a mechanism to investigate incidents on the spacecraft.	A7 & A6
R.09	The software shall provide a mechanism to leave the safe mode through astronaut approval and ground command	A8 & A4
R.10	The software shall provide interfaces to state and modify the time for the astronauts.	A9
R.11	The software shall be able to validate invalid data from the astronaut.	A10
R.12	The system shall consider the ambient luminance, contrast, and color gamut of displays when designing the software interfaces and displays.	A11 & A4
R.13	The system shall consider the environment as part of human-computer interactions to eliminate errors and risks.	A11 & A4
R.14	The system shall prevent astronauts from misusing the system interfaces to eliminate errors and risks.	A11 & A6
R.15	The system shall be designed in a human-centered approach.	A3 & A4
R.16	The system shall provide different options for data restoration such as soft and hard copies.	A1 & A6
R.17	The system shall restart from the same point following a restart after a power interruption	A1
R.18	The system shall provide interfaces to track astronaut health and condition.	A12
R.19	The training on the software shall consider the interactions between the software and the astronauts to ensure the astronauts' readiness	A13
R.20	The system shall prompt the astronaut confirmation of risks associated with certain tasks before proceeding.	A12
R.21	The system shall assess the physical health conditions of the astronaut before proceeding with tasks that need a certain level of physical readiness.	A12
R.22	The system shall not allow the astronaut from taking action that might affect the spacecraft condition without ground approval.	A12 & A3
R.23	The system shall be able to work with different operating systems such as RTEMS, FREE RTOS to ensure cooperation possibilities.	A3 &A1
R.24	The system shall monitor the spacecraft condition and provide the information to the ground operators.	A3 & A12
R.25	The system shall assess the spacecraft condition and provide the information to the ground operators.	A3 & A12
R.26	The system shall allow a ground operator for managing the spacecraft remotely based on the mission concept of operations.	A3 & A1
R.27	The system Shall reduce the dependency on the astronauts' memory as much as possible by adapting alternative tools to remind the astronauts such as labels and cues	A13 & A12
R.28	The system shall not use abbreviations and verbiage unless it is a must to use it and in case it was used, it is needed to be clarified and introduced earlier	A13 & A12
R.29	The system shall use a limited number of identifiers such as color or shape, not more than 10.	A13 & A11
R.30	The system shall display a minimum number of information or instructions and not more than 10	A12 & A13

Table 47: Elicited Requirements (Continued)

ID	Statement	Justification
R.31	The engineers Shall consider human capabilities, skills, knowledge profile, and task complexity when developing a flow of tasks	A3
R.32	the system interfaces should be designed and grouped in a way related to the flow of tasks	A3 & A13
R.33	The system interfaces shall not be designed in a way that confuses the astronauts	A3 & A13
R.34	The system interfaces shall be consistent all over the spacecraft	A12
R.35	The Software shall ensure the consistency of graphics, labels, cues all over the spacecraft	A11 & A12
R.36	The Software shall ensure a quality level of the environment that help astronauts to be emotionally stable to ensure a positive attitude	A12
R.37	The System Shall define the automated response scenarios based on the Mission requirements and Concept of Operations.	A1
R.38	The System shall design shall include a configuration management plan based on the Mission requirements to ensure maintaining consistency of the software performance, functional, and physical attributes.	A3
R.39	All system interfaces and interactions shall be tested and validated based on System Testing and Validation Plan	A10
R.40	Command and control priorities shall be programmed in the system based on the Mission Concept of Operations.	A1
R.41	The System Shall be able to simulate command and illustrate consequences when never requested.	A1
R.42	All the roles, responsibilities and authorities shall be programmed based on the Mission Concept Operations.	A3
R.43	All Testing and Validation processes and procedures shall be aligned and compliant with the System Testing and Validation Plan.	A10
R.44	The System process and procedures shall be aligned and compliant with the Product Assurance Plan	A3
R.45	The software learning process and flow of tasks shall be designed in alignment with the training process and plan.	A13
R.46	International Standards shall be decided and documented in all the Software product life cycles: Design, Implementation, Testing and Validation, Operations, and maintenance.	A3
R.47	Software requirements shall be aligned with the project milestones aligned with the Mission Concept of Operations.	A3
R.48	The system interfaces shall be designed based on international standards that are aligned with the Mission Concept of Operations.	A4
R.49	The Software Development Plan shall include a risks management plan that is aligned with Mission Risk Management Plan.	A3
R.50	The Software Development Plan shall include a requirement management plan that defines the process of change management to ensure tracking of requirements changes throughout the mission.	A3
R.51	The system shall be designed to never use more than 80% of the computing resources (processor power, temporary storage, and memory)	A.3
R.52	The system shall automatically detect its failures – such as infinite loops – and automatically recover (kill the task or reboot)	A.8
R.53	The reboot time shall not exceed mission parameters based on the Mission Concept of Operations.	A.1
R.54	The System Shall be tolerating radiation effects up to the mission parameters based on the Mission Concept of Operations.	A.6
R.55	The System storage at a minimum shall support writing operations as mentioned in the mission parameters based on the Mission Concept of Operations.	A.5
R.56	The System shall be able to update the software in flight or deep space habitats.	A.8
R.57	The System interfaces shall not be triggered by environmental factors such as g-forces and vibrations.	A.4
R.58	The Software shall have defined APIs for communicating with other components.	A3 & A4

Chapter 5: Conclusion

In summary, this work will help establish the requirements specification framework for long-duration manned missions aligned with the UAE Space Sector strategy and MARS2117 visionary project. This work could be considered a stepping stone towards space manned missions that are engineered in a way that takes into consideration the domain requirements and local legal framework. Moreover, it includes a novel part about emotional requirements to be engineered throughout the mission requirements phase and the design phase. This work was done through several stages to ensure the quality of the framework to be used in the space industry by local space actors.

The framework initiates a modular 14 requirements areas with 58 initial requirements statements that can be used as a seed for a SyRS for manned space missions with an augmented Human-Centered design approach to increase the quality of the user experience to help astronaut stay longer in space and to increase the tourist experience as an end-user.

The framework model was discussed with different stakeholders to include their interests and concerns to incorporate input from the space sector. In addition, the framework model was reviewed with experts' to get their feedback to ensure the quality of the SyRS framework model by enhancing the existing requirements and close any gaps that they've foreseen.

As a future work for the thesis, the developed framework can be used to develop a space manned mission reusable requirements catalog. This can help to ensure the quality of the SyRS, the modularity, and reusability to decrease the effort in the mission requirements studying phase.

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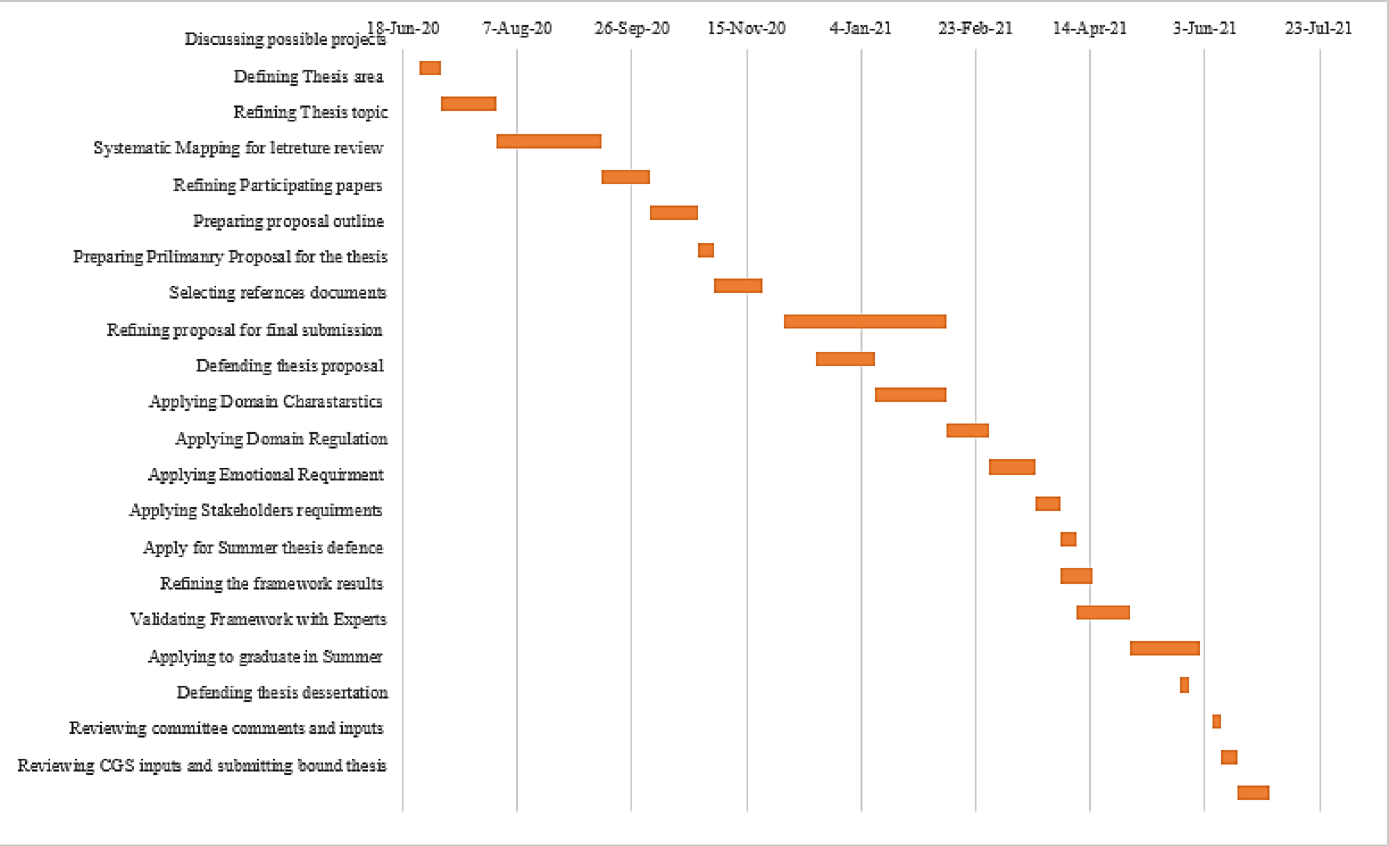
Appendices

Appendix A - Gantt chart



Task	Start	End	Duration
Discussing possible projects	25-Jun-20	5-Jul-20	10
Defining Thesis area	5-Jul-20	29-Jul-20	24
Drafting the first draft	6-Aug-20	29-Aug-20	23
Systematic Mapping for literature review	13-Sep-20	4-Oct-20	21
Refining Participating papers	4-Oct-20	25-Oct-20	21
Preparing proposal outline	25-Oct	1-Nov-20	7
Preparing Preliminary Proposal for the thesis	1-Nov-20	22-Nov-20	21
Defending thesis proposal	10-Jan-21	10-Feb-21	31
Applying Emotional Requirement	21-Mar-21	1-Apr-21	11
Applying Stakeholders requirements	1-Apr-21	8-Apr-21	7
Apply for Summer thesis defense	1-Apr-21	15-Apr-21	14
Refining the framework results	8-Apr-21	1-May-21	23
Validating Framework with Experts	1-May-21	1-Jun-21	31
Applying to graduate in Summer	23-May-21	27-May-21	4
Defending thesis dissertation	6-Jun-21	10-Jun-21	4
Reviewing committee comments and inputs	10-Jun-21	17-Jun-21	7
Reviewing CGS inputs and submitting a bound thesis	17-Jun-21	1-Jul-21	14

The work on the thesis started in early July 2020. The first phase of the thesis was the preproposal. The work started with exploring the research areas, possible thesis and different contribution can be added to the thesis. The work continued till September to define a preliminary thesis. In September, the second phase of defining the proposal started. The first step was a systematic mapping for a literature review were done to collect all possible references to create the technical background and literature review. In October, these collected articles were refined to define the set of articles that will be used from the other such as unrelated domains, the narrowness of the articles, and the relativity for the thesis work. The work also included the writing of the literature review and a proposed outline for the thesis proposal. In November, the thesis proposal has defined that cover the literature review for technical background, related work, and the methodology that is presented to achieve the aim of this proposal.

As the formal work of the thesis starts in January, the team decided to use December to refine the proposal and submit it by early January. The third stage of defining the framework starts with selecting references Model in January. As the NSSTC is part of the UAE University society, it is preferred to choose Local resources to be developed and available for local use and future developments. Thus, the thesis proposed The NSSTC SRS Model be developed through the thesis work and introduce a framework that can be kept for their use. Moreover, the reference Model for Domain requirements will be the NASA SRS model (human integration design handbook) and European Space Agency (ESA) SRS model (ECSS HMI). The Regulation Framework is preferred to be UAE Space Agency framework as it is the National Regulatory Authority for the space sector and The United Nations Office for Outer Space Affairs (UNOOSA) International Space Law. Similarly, a model for Emotional Requirements will be used to introduce the novelty of the work. The work on each stage of inputs is expected to take 3 weeks starting from mid-February to Mid-April. After that, the stage of stakeholder immersion will take place for a week. The stakeholders' involvement will start with a short walk-through session through the refined SRS model. After that, the discussed Modeled will be shared for them to review separately. The involvement will end with a workshop to integrate the stakeholders' review, inputs to be embedded in the Framework.

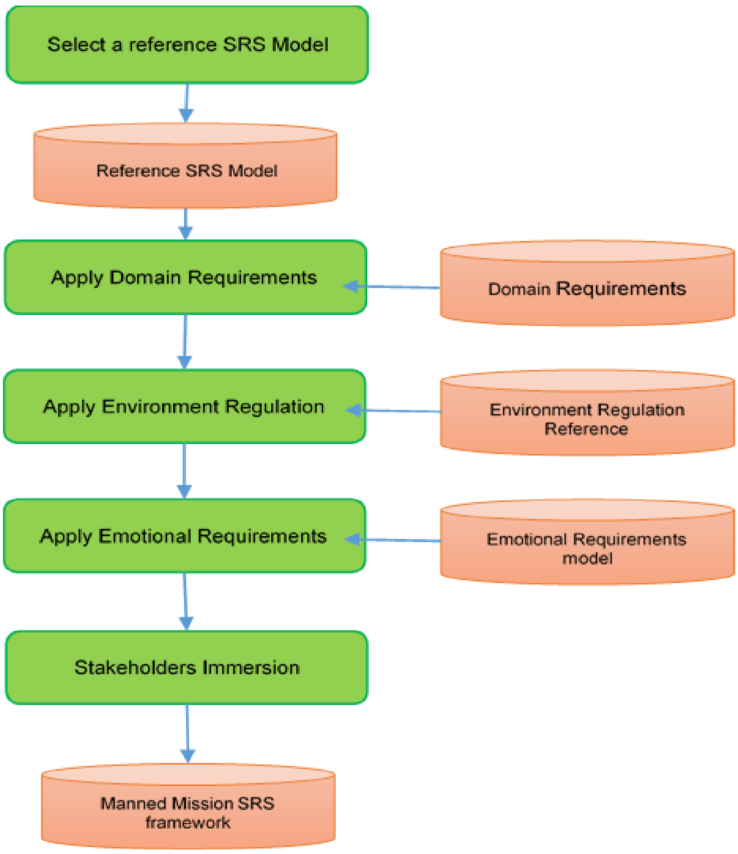
After that, there will be two weeks of refining the work of the resulted framework. If possible, the thesis will validate the framework with experts in the Space Domain. The Last Stage of the thesis will be defending the thesis. It is anticipated that the thesis will be ready to defend by early June to match with the University Deadlines. And be able to submit the bounded thesis by end of June.

Appendix B

Questionnaire

Introduction

The objective of this questionnaire is to collect the stakeholders input on the Manned Spacecraft Software Requirements. The next table introduce the requirements areas that is introduced by the thesis and it represent the information gathered from domain technical sources, federal law and international agreements.



Number	Requirements Area	Definition
A.1	Operational and Compatibility	Requirements that ensure the operations and availability of the software systems in space environment and compatibility with different space software systems to ensure cooperation through different systems.
A.2	Equipment Manager	Requirements that illustrate the role of the software in managing the equipment.
A.3	Implementation and Design	Requirements that specify the way of development, system design, system architecture and flow of tasks.
A.4	Interfaces and Interactions	Requirements that specify the type of interfaces, role of interfaces, type of interaction and environment conditions for the interactions between the astronaut and the software system.
A.5	Performance	Requirements that are related to the software system performance that includes response time, estimated life expectancy, memory size, memory types and computational resources.
A.6	Security and Safety	Requirements that ensure the software security, communication security, system safety and integrity.
A.7	Service	Requirements that illustrate the service that the software shall provide to the spacecraft such as equipment status, file systems, data monitoring and configurations
A.8	System Manager	Requirements that are illustrating the software role in managing the software system such as when to enter or exit the "Safe Mode", fault investigation mechanisms, ways to interchange the modes, command issuing and payload management.
A.9	Time Management	Requirements that are related to time management to ensure the onboard clock synchronization such as soft reset, GPS synchronization and modify it
A.10	Validation	Requirements that illustrate the process of validating the software systems.
A.11	Usability and perception	Requirements that ensure the usability of the software system and specify the way to build the astronaut perception.
A.12	Astronauts Well-being	Requirements that are related to the astronauts' health, roles, responsibility, mental and emotional experience.
A.13	Training and Learning	Requirements that specify the training and learning process.

Elicited Requirements

In the next table these are the elicited requirements by applying the mentioned approach to cover the mentioned area above.

Number	Statement	Justification
S.001	The software shall operate in the range of temperatures that is decided by the mission team.	A1
S.002	The software shall provide housekeeping reports about the spacecraft equipment.	A2
S.003	The software shall be design in a modular way to increase the level of reusability	A3
S.004	The software shall have interface connection with I2C, CAN and PPS wire.	A3 & A4
S.005	The software shall have a life expectancy of the designed mission.	A5 & A1
S.006	The software shall only accept authorized commands that is authenticated using a key	A6
S.007	The software shall change the authorization key repeatedly at minimum 48 times a day.	A6
S.008	The system shall provide mechanism to investigate incidents on the spacecraft through logs.	A7 & A6
S.009	The software shall provide mechanism to leave the safe mode through astronaut approval and ground command	A8 & A4
S.010	The software shall provide interfaces to state and modify the time for the astronauts.	A9
S.011	The software shall be able to validate with invalid data from the astronaut.	A10
D.001	The system shall consider the ambient luminance, contrast, and color gamut of displays when designing the software interfaces and displays.	A11 & A4
D.002	The system shall consider the environment as part of the human computer interactions in order to eliminate errors and risks.	A11 & A4
D.003	The system shall prevent astronaut from miss-using the system interfaces to eliminate errors and risks.	A11 & A6
D.004	The system shall be designed in a human-centered approach.	A3 & A4
D.005	The system shall provide different options for data restoration such as soft and hard copies.	A1 & 6
D.006	The system shall have redundant source of power to ensure the system availability.	A1
D.007	The system shall provide interfaces to track astronaut health and condition.	A12
D.008	The training shall consider the interactions between the software and the astronauts to ensure the astronauts readiness	A13

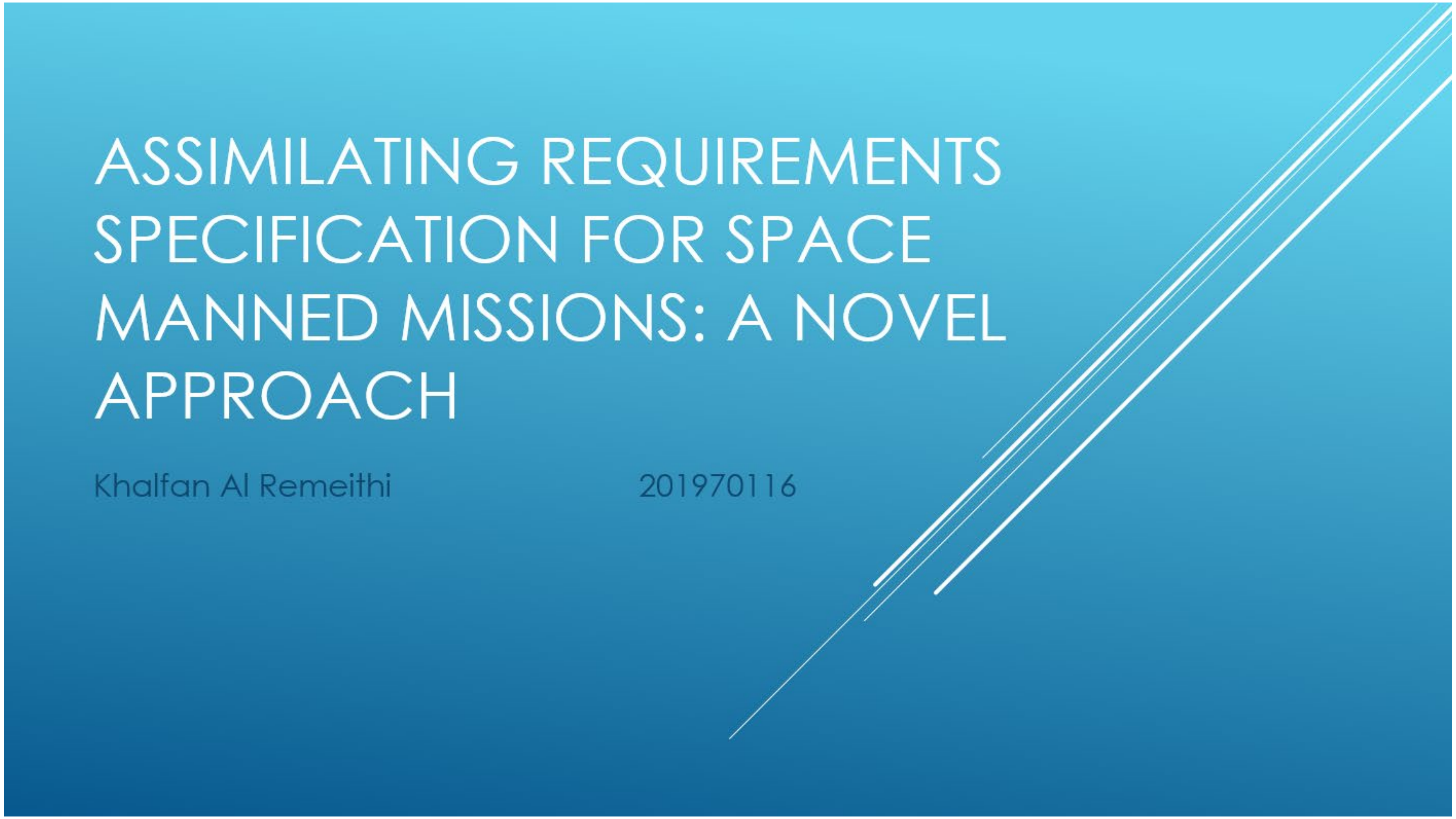
L.001	The system shall prompt the astronaut confirmation of risks associated with certain tasks before proceeding.	A12
L.002	The system shall assess the physical health conditions of the astronaut before proceeding with tasks that needs certain level of physical readiness.	A12
L.003	The system shall not allow the astronaut from taking action that might affect the spacecraft condition without ground approval.	A12 & A3
L.004	The system shall be able to work with different operators system such as RTEMS, FREE RTOS, Leon and Ubuntu to ensure cooperation possibilities.	A3 &A1
L.005	The system shall monitor and assess the spacecraft condition and provide the information to the ground operators.	A3 & A12
L.006	The system shall allow ground operator of managing the spacecraft remotely when requested.	A3 & A1
E.001	The system Shall reduce the dependency on the astronauts memory as much as possible by adapting alternative tools to remind the astronauts such as labels and cues	A13 & A12
E.002	The system shall not use abbreviations and verbiage unless it is a must to use it and in case it was used, it is needed to be clarified and introduced earlier	A13 & A12
E.003	The system shall use limited number of identifiers such as color or shape not more than 10	A13 & A11
E.004	The system shall display limited number of information or instructions	A12 & A13
E.005	The engineers Shall consider human capabilities, skills, knowledge profile and task complexity when developing a flow of tasks	A3
E.006	When possible, the system interfaces shall be designed and grouped in a way related to the flow of tasks	A3 & A13
E.007	The system interfaces shall not be designed in a way that confuse the astronauts	A3 & A13
E.008	The system interfaces shall be consistent all over the spacecraft	A12
E.009	The system navigation shall be consistent all over the spacecraft	A12
E.010	The engineers shall ensure the consistency of graphics, labels, cues all over the spacecraft	A11 & A12
E.011	The engineers shall ensure a quality level of environment that help astronauts to be emotional stable to ensure positive attitude	A12

Question one

In the next table, kindly add statements that can be used as requirements with the justification.

Number	Statement	Justification

Slides


ASSIMILATING REQUIREMENTS SPECIFICATION FOR SPACE MANNED MISSIONS: A NOVEL APPROACH
Khalfan Al Remeithi
201970116

ABSTRACT

- Aligned with the UAE Space Strategy 2117, which aims to establish the first inhabitable human on the Martian Surface by 2117, and with the current enthuse toward space tourism, we propose a novel Framework to assimilate the process of requirement specification for a Manned Mission to Mars surface. Deep Space manned missions are unique and characterized with a set of specific requirements that should be elicited from different sources and stakeholders to ensure the missions' success. In addition, these missions are highly dependent on the software components in the command and data handling system (CDHS), which is used to control the spacecraft and interact with the astronauts. Our contribution consists of: (i) surveying current trends in space system requirements engineering from requirements elicitation to requirements specification; and (ii) introducing a new set of requirements for CDHS in space missions that are related to astronauts, particularly emotional requirements for deep space manned missions, which to the best of our knowledge have not been considered before. Moreover, our contribution introduces a modular requirement model to ensure the modularity and reusability of these requirements in several manned space missions. We do believe that this contribution will strengthen the position of UAE as one of the top countries in the world that invest in space sciences.

- The proposed methodology for the thesis starts with choosing reference SRS documents to start with:
- The proposed solution starts with the NSSTC SRS model as a reference document.
- The first stage will be applying the domain requirements The proposed Domain requirements reference is a document from NASA.
- The second stage of refinement will be applying the Environment Regulations and aligning the SRS with them that re the space law of United Nations Office for Outer Space Affairs (UNOOSA) and UAE Space Federal Law.
- The third step will be about integrating emotional requirement in the SRS framework
- The fourth stage is concerned with the stakeholders' immersion. It includes meeting and discussing the refined SRS with different stakeholders to align it with their needs and expectations.

METHODOLOGY

ID	Requirements Area	Definition
A.1	Operational and Compatibility	Requirements that ensure the operations and availability of the software systems in space environment and compatibility with different space software systems to ensure cooperation through different systems.
A.2	Equipment Manager	Requirements that illustrate the role of the software in managing the equipment.
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A.5	Performance	Requirements that are related to the software system performance that includes response time, estimated life expectancy, memory size, memory types and computational resources.
A.6	Security and Safety	Requirements that ensure the software security, communication security, system safety and integrity.
A.7	Service	Requirements that illustrate the service that the software shall provide to the spacecraft such as equipment status, file systems, data monitoring and configurations
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A.9	Time Management	Requirements that are related to time management to ensure the onboard clock synchronization such as soft reset, GPS synchronization and modify it
A.10	Testing and Validation	Requirements that illustrate the process of validating the software systems.
A.11	Usability	Requirements that ensure the usability of the software system
A.12	Perception and Attention	Requirement that are related to the perception and attention of the astronaut.
A.13	Astronauts Well-being	Requirements that are related to the astronauts' health, roles, responsibility, mental and emotional experience.
A.14	Training and Learning	Requirements that specify the training and learning process.

RESULT REQUIREMENTS AREA

ID	Statement	Justification
S.001	The software shall operate in the range of temperatures that is decided by the mission team.	A1
S.002	The software shall provide housekeeping reports about the spacecraft equipment.	A2
S.003	The software shall be design in a modular way to increase the level of reusability	A3
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D.003	The system shall prevent astronaut from miss-using the system interfaces to eliminate errors and risks.	A11 & A6
D.004	The system shall be designed in a human-centered approach.	A3 & A4
D.005	The system shall provide different options for data restoration such as soft and hard copies.	A1 & 6
D.006	The system shall have redundant source of power to ensure the system availability.	A1

REQUIREMENT STATEMENTS

ID	Statement	Justification
D.007	The system shall provide interfaces to track astronaut health and condition.	A12
D.008	The training shall consider the interactions between the software and the astronauts to ensure the astronauts readiness	A13
L.001	The system shall prompt the astronaut confirmation of risks associated with certain tasks before proceeding.	A12
L.002	The system shall assess the physical health conditions of the astronaut before proceeding with tasks that needs certain level of physical readiness.	A12
L.003	The system shall not allow the astronaut from taking action that might affect the spacecraft condition without ground approval.	A12 & A3
L.004	The system shall be able to work with different operators system such as RTEMS, FREE RTOS, Leon and Ubuntu to ensure cooperation possibilities.	A3 &A1
L.005	The system shall monitor and assess the spacecraft condition and provide the information to the ground operators.	A3 & A12
L.006	The system shall allow ground operator of managing the spacecraft remotely when requested.	A3 & A1
E.001	The system Shall reduce the dependency on the astronauts memory as much as possible by adapting alternative tools to remind the astronauts such as labels and cues	A13 & A12
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E.005	The engineers Shall consider human capabilities, skills, knowledge profile and task complexity when developing a flow of tasks	A3
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E.007	The system interfaces shall not be designed in a way that confuse the astronauts	A3 & A13
E.008	The system interfaces shall be consistent all over the spacecraft	A12
E.009	The system navigation shall be consistent all over the spacecraft	A12

REQUIREMENT STATEMENTS

REQUIREMENT STATEMENTS

ID	Statement	Justification
H.001	The System Shall define the automated responses scenarios based on the *Mission requirements* and *concept of Operations*.	A1
H.002	The System shall design shall include a configuration management plan based on the *Mission requirements* to ensure maintaining consistency of the software performance, functional, and physical attributes.	A3
H.003	All system interfaces and interactions shall be tested and validated based on *System Testing and Validation Plan*	A10
H.004	Command and control priorities shall be programmed in the system based on the *Mission Concept of Operations*.	A1
H.005	The System Shall be able to simulate command and illustrate consequences when never requested.	A1
H.006	All the role, responsibilities and the authorities shall be programmed based on the *Mission Concept Operations*.	A3
H.007	All Testing and Validation processes and procedures shall be aligned and complaint with the *System Testing and Validation Plan*.	A10
H.008	The System process and procedures shall be aligned and complaint with *Product Assurance Plan*	A3
H.009	Software learning process and flow of tasks shall be designed in alignment with the training process and plan.	A13
H.010	International Standards shall be decided and documented in all the Software product life cycle: Design, Implementation, Testing and Validation, Operations and maintenance.	A3
H.011	Software requirement shall be aligned with the project milestones aligned with the *Mission Concept of Operations*.	A3
H.012	The system interfaces shall be designed based on international standards that are aligned with the *Mission Concept of Operations*.	A4
H.013	The *Software Development Plan* shall include risks management plan that is aligned with *Mission Risk Management Plan*.	A3
H.014	The Software Development Plan shall include requirement management plan that define the process of change management to ensure tracking of requirements changes throughout the mission.	A3

QUESTION

- In the next table, kindly add statements that can be used as requirements with the justification.