TALLINN UNIVERSITY OF TECHNOLOGY
School of Information Technologies

Silver Lodi 210741IAAM

Creation of the Aggregated Marketplace for Ground Station Services for Spaceit OÜ

Master's thesis

Supervisor: Paul Leis
PhD
External supervisor: Lauri Kimmel
MSc

Tallinn 2022

TALLINNA TEHNIKAÜLIKOOL
Infotehnoloogia teaduskond

Silver Lodi 210741IAAM

Maajaamateenuste agregeerimise platvormi väljatöötamine Spaceit OÜ-le

Magistritöö

Juhendaja: Paul Leis
PhD
Väline juhendaja: Lauri Kimmel
MSc

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Author’s declaration of originality

I hereby certify that I am the sole author of this thesis. All the used materials, references to the literature and the work of others have been referred to. This thesis has not been presented for examination anywhere else.

Author: Silver Lodi

18.05.2022

Abstract

This master's thesis is based on the Estonian space start-up Spaceit. The company provides infrastructure for satellite operations as a service including a cloud-based platform for satellite mission control, ground station services and cyber defence exercises[1]. The thesis is focused on the space part of the company's activities, and not on the cyber, security or defence one.

Mission control is the set of tools (software) and activities (everyday satellite operations) needed to operate satellites. Each and every satellite mission needs one.

A ground station is a terrestrial radio station designed for extraplanetary[2] telecommunication with spacecraft[3], or reception of radio waves from astronomical radio sources. Ground stations may be located either on the surface of the Earth, or in its atmosphere [1].

Satellite connection to additional ground station networks requires high integration costs regarding time, personnel, and licenses. The market is fragmented in terms of providers, locations, and legal issues and due to that real time radio communication with satellites is still impossible. This has become problem for the space industry where the need for extra communication options or low latency[4] is increasing due to to higher data rates and development of space technology.

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[1] In the cyber defense exercises, the scenarios that are simulated closest to reality which provides very important contributions by bringing together the necessity of making the best decisions and management capabilities under the cyber crisis by handling stress and coordinated movement as a team [32].

[2] Situated or originating outside the region of the planetary orbits; also relating to space outside this region.

[3] A spacecraft is a vehicle or machine designed to fly in outer space. A type of artificial satellite, spacecraft are used for a variety of purposes, including communications, Earth observation, meteorology, navigation, space colonization, planetary exploration, and transportation of humans and cargo.

[4] Latency, from a general point of view, is a time delay between the cause and the effect of some physical change in the system being observed.

Based on the market needs, Spaceit is developing an Aggregated Marketplace for Ground Station Services (hereinafter also referred as the Marketplace, the Solution), a single platform for ground station services. It is an additional feature of Spaceit's cloud-based Mission Control System (hereinafter also referred as MCS), and it will combine standalone ground stations, as well as virtual and physical networks into one unified ecosystem.

The aggregator business model is basically a network model which organizes the related unorganized service providers in one huge platform under one brand name. This platform also connects service providers with their customers but under one brand [2].

The marketplace business model is basically a website or mobile application which contains different products from multiple vendors and allow sellers to promote their business in one vast platform. The marketplace model acts as a bridge by connecting sellers and buyers in one platform and does not own any products of their own [2].

This master's thesis gives an economic rationale and IT architecture for the Aggregated Marketplace for Ground Station Services activity. Capability-Based Planning (CBP) method was used for the alignment between business strategy and the architecture. Specifically, the focus is on the next topics:

- Overview of Spaceit
- Actuality of the topic
- Market analysis
- Overview of the Aggregated Marketplace for Ground Station Services solution
- Business model of the Marketplace
- Financial forecast of the Marketplace
- Business capabilities of Spaceit
- Strategic goals of Spaceit
- Business motivation
- Value streams of the Marketplace
- Overview of the main processes and actors
- Requirement analysis
- Components of the system
- Prototype

- Development logic.

Due to the above-mentioned focus, the thesis will not focus on the cyber security aspects of the industry, company nor the solution being created. Spaceit MCS security features or measures are not presented in the paper.

An overall goal of the thesis is to provice a valuable input for the business as well as technical personnel for the business and development activities of the Aggregated Marketplace for Ground Station Services solution.

The paper is written in English and is 76 pages long, including 8 chapters, 17 figures and 17 tables.

Annotatsioon

Maajaamateenuste agregeerimise platvormi väljatöötamine Spaceit OÜ-le

Käesolev magistritöö baseerub Eesti kosmosevaldkonna idufirma Spaceit näitel. Ettevõte pakub satelliitsiderakendusi teenusena. Spaceiti arendatud pilvepõhine platvorm võimaldab satelliitide juhtimist ning infovahetust läbi erinevates geograafilistes asukohtades olevate maajaamade, kõrvaldades olemasolevate kosmosesidelahenduste mitmed olulised skaleerimise, turvalisuse, koostöö ja toimekindluse probleemid, samal ajal vähendades satelliidimissioonide eelarvet. Lisaks kasutatakse ettevõtte rakendusel baseeruvaid simulaatoreid küberõppustel (nagu näiteks Locked Shields). Antud töö keskendub Spaceiti kosmoseside ning mitte küberturbe ärisuunale. Arvestades magistritöö fookust ning ettevõtte konfidentsiaalsuse põhimõtteid, pole töös mainitud ka Spaceiti platvormi turvalisust puudutavat infot.

Magistritöö eesmärgiks on Spaceiti platvormile uue liidese, maajaamateenuste agregeerimise platvormi, majandusliku otstarbekuse hindamine, äriplaani loomine ning infotehnoloogilise (IT) lahenduse pakkumine. Magistritöö ei keskendu rakenduse ega üldiselt valdkonda puudutavale küberturvalisusele. Täpsemalt kätkeb magistritöö järgmisi teemasid:

- Ettevõtte lühiülevaadet
- Kosmosesektori ning turu analüüsi
- Loodava rakenduse kirjeldust ning peamisi funktsioone
- Rakendusega loodavat lisandväärtust seotud osapooltele
- Ärimudeli koostamist kasutades ärimudeli lõuendit
- Finantsprognoosi
- Spaceiti ärivõimekusi
- Strateegilisi eesmärke
- Motivatsiooni- ja strateegiamudelit
- Loodava rakenduse väärtusvoogu

- Ülevaadet peamistet kasutajatest ning kasutusmallidest
- Funktsionaalseid ning mittefunktsionaalseid nõudeid
- Süsteemi komponente
- Prototüüpi
- Arenduse loogikat ning peamisi tegevusi.

Kosmosesektor on viimastel aastatel läbi teinud kiire arengu. Kui 2017 saadeti kosmosesse umbes 300 satelliiti, siis 2022 prognoos on juba 2000 [3]. Sektori väärtus ulatus 2021. lõpu seisuga orienteeruvalt 350 miljardi euroni. Globaalne kosmosemajanduse kasv võib ulatuda 75%-ni 2030. aastaks ehk 612 miljardi euroni [4].

Seoses eelkõige side- ja kaugseiresatelliitide arvu kasvu ning tehnoloogia arenguga (näiteks kõrge kvaliteediga satelliidifotod), on vajadus üha paremaid rakendusi kvaliteetseks ja vahetuks kommunikatsiooniks Maal asuvate süsteemide ning orbiidil tiirlevate satelliitide vahel. Üks maajaam võimaldab keskmiselt vaid ühe tunni kasulikku sideaega satelliidiga ööpäevas. Satelliidimissioon on tavaliselt ühendatud ühe maajaama või -võrgustikuga, kuna integratsioon täiendavatega on aegenõudev ning kulukas. Tulenevalt teenusepakkujate rohkusest ning seadusandlusest erinevates riikides (seal hulgas kosmoseside sagedusload), on maajaamateenuste turg üsna fragmenteeritud. Samal ajal seisab osa kosmosesidet võimaldavast riistvarast jõude, kuna pakutavat ressurssi ei osata piisavalt hästi turustada.

Spaceiti kavandatav uudne lahendus püüab probleemi nii satelliidioperaatorite kui maajaamade jaoks leevendada luues maajaamateenuste agregeerimise platvormi. Ettevõtte pilvepõhise platvormile arendatav rakendus ühendab satelliidid erinevate maajaamade ning nende võrgustikega üle maailma.

Muu hulgas kätkeb rakendus endas järgmisi funktsioone:

- Maajaamavõrgustike-ülene side satelliidiga
- Satelliidikontaktide (infovahetus satelliidi ja maajaama vahel) broneerimine
- Sateliidikontaktide haldamine (inglise keeles management)
- Hindade koondamine (agregeerimine)
- Sateliidikontaktide optimeerimine vastavalt erinevatele kriteeriumitele
- Ühtlustatud kasutajaliides ülalpool mainitud võimaluste kasutamiseks.

Ettevõtte visiooniks on pakkuda reaalajas sidet Maa ja satelliitide vahel. Käesolev lõputöö peaks andma väärtusliku sisendi selle saavutamiseks.

Magistritöö sisaldab teksti 76 leheküljel. See on kirjutatud inglise keeles, kätkeb endas 17 joonist, 17 tabelit ning on jaotatud 8 peatükki. Esimene ja seitsmes on vastavalt sissejuhatus ning kokkuvõte. Teine kätkeb ettevõtte lühiülevaadet. Kolmas tööstusharu ja maajaamateenustega seonduvate probleemide kirjeldust. Neljas peatükk võtab vaatluse alla arendatava süsteemi funktsionaalsuse ning lisandväärtuse seotud osapooltele. Viiendas peatükis analüüsitakse rakenduse majanduslikku mõttekust ning kuuendas esitatakse selle IT arhitektuur, nõuded, prototüüp ja arenduse loogika.

List of abbreviations and terms

API	Application Programming Interface
As a Service	The ‘As a service’ business model is an emerging business model that shifts the customer - supplier relationship from the traditional model of ownership to a model that evolves around providing a service on a non-ownership basis [5].
AWS	Amazon Web Services
B2C	Business to Consumer
BCM	Business Capability Model
BMM	Business Motivation Model
BPMN	Business Process Model and Notation
CAPEX	Capital Expenditures
CAGR	Compound Annual Growth Rate
CBP	Capability-Based Planning, is a method is a solution for the alignment between business strategy and Enterprise Architecture [6].
COBIT	Control Objectives for Information and Related Technologies
CTO	Chief Technology Officer
DB	Data Base
EA	Enterprise Architecture. Enterprise architecture is an analytical discipline that provides methods to comprehensively define, organize, standardize, and document an organization’s structure and interrelationships in terms of certain critical business domains characterizing the entity under analysis [7]
EHF	Extremely High Frequency
EO	Earth Observation
ESA	European Space Agency
ESOP	Employee Stock Ownership Plan
Extraplanetary	Situated or originating outside the region of the planetary orbits; also relating to space outside this region
GNSS	Global Navigation Satellite System
GS	Ground Station. A ground station is a terrestrial radio station designed for extraplanetary telecommunication with spacecraft,

	or reception of radio waves from astronomical radio sources. Ground stations may be located either on the surface of the Earth, or in its atmosphere [1].
ICD	Interface Control Document
Infrastructure Software	Infrastructure software is a type of enterprise software or program specifically designed to help business organizations perform basic tasks such as workforce support, business transactions and internal services and processes [8].
IT	Information Technology
ITIL	Information Technology Infrastructure Library
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LEO	Low Earth Orbit
MCS	Mission Control System. Mission control is the set of tools (software) and activities (everyday satellite operations) needed to operate satellites. Each and every satellite mission needs one
MRR	Monthly Recurring Revenue
MOU	Memorandum of Understanding
Operations Automation	Operations automation in IT is the use of automated applications and systems to manage key operations processes without the need for human intervention.
OPEX	Operational Expenditures
REST	Representational State Transfer
RF	Radio Frequency
SAM	Serviceable Available Market
SAFe	The Scaled Agile Framework
Satcom	Satellite Communication. Satellite communication, in telecommunications, the use of artificial satellites to provide communication links between various points on Earth. Satellite communications play a vital role in the global telecommunications system [9].
Satellite Payload	Satellite payload is defined as modules carried on satellites with the ability to perform certain functionalities. Satellite consists of the payload and the bus.
Satnav	Satellite Navigation
SDR	Software Defined Radio
SHF	Super High Frequency
SLA	Service Level Agreement

Spacecraft	A spacecraft is a vehicle or machine designed to fly in outer space. A type of artificial satellite, spacecraft are used for a variety of purposes, including communications, Earth observation, meteorology, navigation, space colonization, planetary exploration, and transportation of humans and cargo.
TAM	Total Available Market
Telecommand	A telecommand or telecontrol is a command sent to control a remote system or systems not directly connected (e.g. via wires) to the place from which the telecommand is sent [10].
Telemetry	Telemetry is the in-situ collection of measurements or other data at remote points and their automatic transmission to receiving equipment (telecommunication) for monitoring [11].
TM/TC	Telemetry and Telecommand
UI	User Interface
UHF	Ultra High Frequency
UX	User Experience

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1 Introduction

This master's thesis is based on the Estonian space start-up Spaceit. The company provides an infrastructure[1] for satellite communications[2] as a service[3] including a cloud-based platform for satellite mission control, ground station services and cyber defence exercises.

The global space market has been increasing in recent years and as of 2021 is valued at $337 billion. It will continue to grow and is expected almost to double to $642 billion by 2030 [4]. Operating any satellite requires software and ground station services. Despite revenue growth and heavy investments in the industry, real time communication with satellites is still impossible because of the fragmentation of the market and technical difficulties in integrations between satellite command and control software with ground station networks. This has become problem for the space industry where the need for low latency and extra communication options is increasing due to to higher data rates and development of technology.

Based on the market needs, Spaceit is developing an Aggregated Marketplace for Ground Station Services (the Marketplace, the Solution), a single platform for ground station services. It is an additional feature of Spaceit's cloud-based Mission Control System (MCS) and it will combine standalone ground stations, as well as virtual and physical networks into one unified ecosystem. The Solution will allow to book, manage contacts, and communicate with satellites in one cross network environment.

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[1] Infrastructure software is a type of enterprise software or program specifically designed to help business organizations perform basic tasks such as workforce support, business transactions and internal services and processes [8].

[2] Satellite communication, in telecommunications, the use of artificial satellites to provide communication links between various points on Earth. Satellite communications play a vital role in the global telecommunications system [9].

[3] The 'As a service' business model is an emerging business model that shifts the customer - supplier relationship from the traditional model of ownership to a model that evolves around providing a service on a non-ownership basis [5].

The initial idea of the Marketplace was developed by the author and Spaceit's CTO Lauri Kimmel (also the external supervisor of the thesis) already in around 2016-2017. Due to limited funding (and personnel), it did not materialized back then other than in a form of a prototype. Nevertheless, by now the activity is supported and largely financed by the European Space Agency (ESA) and Estonian delegation at ESA.

In the next following paragraphs an economic rationale, and IT architecture for the Aggregated Marketplace for Ground Station Services is presented. It should provice a valuable input for Spaceit to strive towards its vision of providing operators[1] a near real-time communication with spacecrafts.

[1] Satellite Operator means the Person licensed by a Party to operate a Satellite Space Station to provide Satellite Transmission Capacity.

2 Overview of the Company

Founded in 2015 and being a spin-off of Estonia's first student satellite mission ESTCube-1[1], Spaceit provides an infrastructure as a service for satellite operations. The company focuses on making access to space simple and affordable. Spaceit offers a single cloud-based platform called Spaceit Mission Control System (MCS) and accompanying services for satellite mission control, ground station services, and cyber defence exercises.

Spaceit has had a space flight heritage since 2019. The platform is integrated with one ground station network today. The aim is to be connected with several additional ones in the coming years to meet the market needs. Spaceit is an alumnus of ESA BIC Estonia and Starburst Accelerator (since 2019 and 2020, respectively).

The company has been a contractual partner of the European Space Agency (ESA) since 2020 when it successfully led a consortium of companies (Spaceit, CybExer Technologies, and CGI Estonia) which developed a satellite operations simulator for cyber exercises for ESA.

Furthermore, Spaceit has successfully fundraised of €1 million in 2021. There are 10 people working in the company at the moment. If to include advisors (including Mr. Jean-Jacques Dordain, former Director General of ESA) and part time employees, the team is 14. The company has offices in Tallinn and Tartu. There are a small number of people acting as advisors for the company, including. As for the founders, Mr. Kimmel's experience includes mission control system development lead in successful ESTCube-1 mission.

[1] For further information: https://en.wikipedia.org/wiki/ESTCube-1

3 Actuality of the Topic

This paragraph will give and overview of the global space market, description of problem related with the Marketplace activity and how it affects Spaceit's customers and partners.

3.1 Global Space Market

According to Euroconsult, the global space market is valued at $337 billion in 2021 up 6% v. 2020 i.e., a market value comparable to 2019 prior to covid crisis which impacted satellite service revenues in 2020. The largest revenue drivers remain satellite navigation and communications which account for 50% and 41% of the total market value respectively, driven by Business to Consumer (B2C) applications. In comparison, Earth Observation (EO) still accounts for a marginal 5% of the total value but with a much higher proportion upstream. Satellite Navigation (satnav) has surpassed Satellite Communication (satcom), growing from about 37% of the total revenues in 2016 to over 50% in 2021, largely due to services enabled by Global Navigation Satellite System (GNSS) services and their related devices [4].

The space economy is expected to grow by 74% by 2030 to reach $642 billion (6.3% Compound Annual Growth Rate, CAGR) renewing its strong growth pattern following a 4% decrease in 2020 under the effect of the Covid crisis impact on commercial space services [4].

In 2021, government space budgets accelerated their growth trajectories to an unprecedented, an 8% increase over 2020. Despite (or perhaps because of) Covid, governments have doubled down in support for their national space industries, highlighting the critical strategic and commercial value of space [12].

Civil budgets represent 58% of total spending in 2021, at $53,5 billion, with spending boosted by more ambitious space programs by mature powers as well as the vibrant private space sector attracting large amounts of public and private funding [12].

Looking forward, a clear forecast is difficult. A more optimistic scenario with the current budget growth drivers persisting over the decade would see governments worldwide investing over $1 trillion in space programs over the next 10 years. A more pessimistic scenario with public finances strained by Covid and reduced space ambitions would see about $85 billion invested over the decade [12].

The total revenues for EO data in 2021 accumulate to €536 million across all segments. From 2021, the EO data market will see a CAGR of 3,5% by 2031, resulting in €797 million total revenues. The EO value-added services market is considerably larger and accumulated globally a total of €2,2 billion in 2021 within the same scope of market segments. With revenues set to double from roughly €2,8 billion to over €5,5 billion over the next decade, the market for Earth Observation applications is boosted by a large pool of value-added services (i.e. 85% of global revenue). These contribute across all segments, though especially in those of Climate Services, Urban Development and Cultural Heritage, Agriculture, Energy and Raw Materials and the Insurance and Finance segment [13].

When it comes to the sale of EO data (worth €0,8 billion in 2031, 15% of global revenue), the top five of segments is made up of Urban Development and Cultural heritage, Agriculture, Insurance and Finance, Energy and Raw Materials as well as Consumer Solutions, Tourism and Health [13].

3.2 Description of the Problem

Operating any satellite requires **mission control software** and **ground station services** over its lifetime.

Mission control is the set of tools (software) and activities (satellite management) needed to operate satellites. Ground station services are terrestrial radio stations and related services to communicate with a spacecraft [1].

Satellite operation costs can amount to over 2/3 of a satellite mission budget (see Figure 1. Cost Breakdown of a Satellite Mission, page 22).

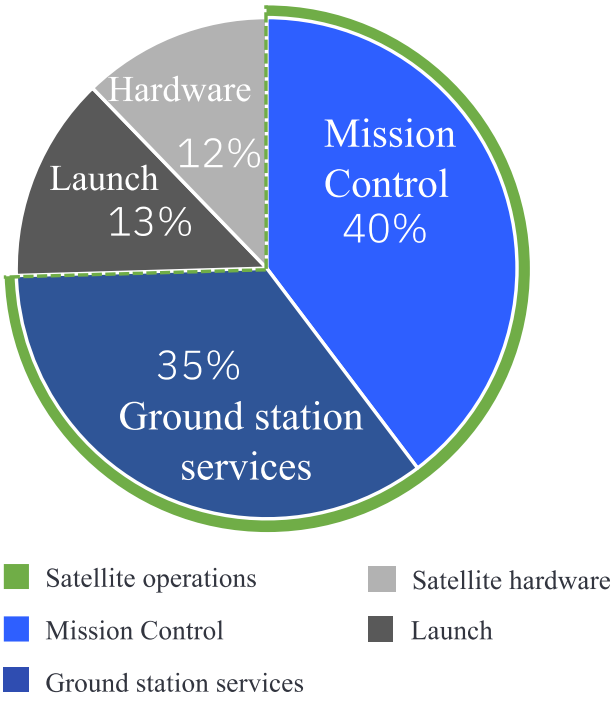

Figure 1. Cost Breakdown of a Satellite Mission.

3.2.1 Pains for Satellite Operators

Concerning mission control and ground station services, satellite operators are facing the following difficulties often:

- The number of EO satellites is increasing (25 launched in Q4 2020 alone). In correlation with imaging instrument improvements, the volume of data is increasing, and resolution are improving. Due to that, a rising number of satellites require less latency and more contact options to communicate with the Earth to transmit large quantities of data.
- Despite recent developments, 24/7 radio communication with satellites is still impossible because ground station service is fragmented.
- One ground station enables only approx. 1 hour of communication with a satellite in a low Earth orbit (LEO)[1] per day.
- A mission is usually utilizing services from a single ground station network.
- Connection to additional ground station networks requires high integration costs in terms of time, personnel, and licenses.

[1] For further information: https://en.wikipedia.org/wiki/Low_Earth_orbit

- The market is fragmented in terms of providers, locations, and legal issues.

Although in terms of hardware, radio communication with satellites has been constantly improving in recent years (e.g., development of omnidirectional antennas, software defined ratios (SDRs), longer lifespan of satellites), the pains and costs regarding satellite integrations with ground stations have remained basically unchanged. Partly due to that and the fact ground station services market is fragmented (see Figure 2 below), **24/7 radio communication with satellites is still impossible.**

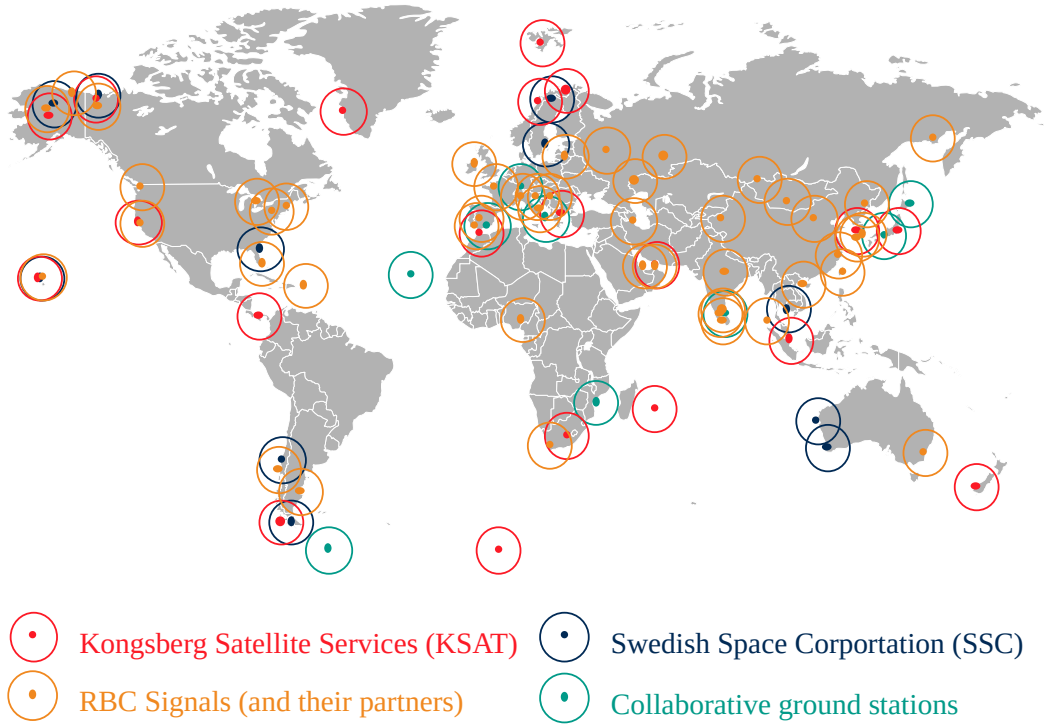

Figure 2. Fragmentation of the Ground Station Services Market in an Example of Four Biggest Networks.

3.2.2 Pains for Ground Stations Operators

A ground station, Earth station, or Earth terminal is a terrestrial radio station designed for extraplanetary telecommunication with spacecraft (constituting part of the ground segment of the spacecraft system), or reception of radio waves from astronomical radio sources. Ground stations may be located either on the surface of the Earth, or in its atmosphere. Earth stations communicate with spacecraft by transmitting and receiving radio waves in the super high frequency (SHF) or extremely high frequency (EHF) bands (e.g., microwaves). When a ground station successfully transmits radio waves to a

spacecraft (or vice versa), it establishes a telecommunications link. A principal telecommunications device of the ground station is the parabolic antenna.[1]

Similarly to satellite operators, ground station owners are facing some of the difficulties on their own:

- Underutilized resources (approximately 1 hour of communication time with a single satellite in LEO per day).
- Integration with satellites is complicated (custom solutions with every new customer).

[1] For further information: https://en.wikipedia.org/wiki/Ground_station

4 Overview of the Aggregated Marketplace for Ground Station Services

Based on the market needs, Spaceit is creating an Aggregated Marketplace for Ground Station Services, a single platform for ground station services. The new solution will combine standalone ground stations, as well as virtual and physical networks into one unified ecosystem. It will allow to book (using MCS to send a command to a spacecraft through a ground station to exchange information between them when the satellite is in a range of the ground station), manage contacts, and communicate with satellites in one cross network environment.

4.1 Starting Point of the Activity

The starting point of the activity is an existing product – Spaceit's cloud-based MCS. The Marketplace will be its additional feature and overall, an integral part the company’s end-to-end mission control as a service offering.

Currently Spaceit MCS is integrated with one ground station network (Infostellar, Japan). The company’s aim is to integrate with at least 3 new networks in 2022 and additional 4 in 2023. Various agreements have been signed with ground station services providers such as Leaf Space, KSAT, RBC Signals, Endurosat, Amazon Web Services (AWS) etc. An overall interest and feedback from the providers have been very positive. This is evidence that inter network aggregation of services is possible, creating a marketplace functionality and setting ground for potentially near real time coverage for satellite operators.

Spaceit considers integration with 3-4 networks, which means over 200 separate ground stations, to have sufficient coverage with low latency to demonstrate main capabilities of the Solution.

4.2 Key Features

The key features of the Aggregated Marketplace for Ground Station Services will be:

- Cross network connectivity
- Aggregation of services and prices from different providers
- Satellite-ground station contact management and contact booking via different ground stations
- Optimisation of satellite-ground station bookings according to different criteria (availability, price, quality, etc.)
- Unified user interface (UI) for the above-mentioned features
- Near real-time satellite communication capability as a long-term vision.

4.3 Benefits for Users

The main users of the Solutions will be satellite operators (customers) and ground station operators (partners).

Gains for satellite operators will be as follows:

- Seamless pre-integration with various ground station networks – over 2 times shorter integration time with a satellite and a ground station[1].
- Over 20% more communication sessions between the Earth and satellites (especially the EO ones) within the same mission budget[2].
- Access to a worldwide network of over 300 antennas (including Spaceit's partnering networks KSAT, Leaf Space, AWS, InfoStellar, RBC Signals etc.)
- One gateway of booking and scheduling contacts with satellites using combined network of ground stations.
- Potentially up to 24/7 radio coverage.

[1] If to use more than one ground station (network). On average, an integration between a ground station (network) and a small satellite could take at least one calendar month with two full time employees (FTEs). If to use more than one ground station (network), an additional integration is needed i.e., integration time at least two calendar months. It takes only one integration with Spaceit MCS to have access to numerous different ground stations (network) worldwide.

[2] There are two assumptions: a) depending on complexity but an integration with Spaceit's Platform costs 5000 euros which is 50% less than a ground station network charges. That amount equals to approximetely to 200 passes. If one ground station enables one pass per day and an average lifespan of a smallsat is approximetely two years, the total amount of passes amounts to 730 over two years. Using Spaceit MCS, the operator could purchase 27% more passes for 5000 euros; b) with a critical number of users, Spaceit is aiming to purchase available ground station resources in advance (with a discount), add its premium and sell it to the operators. In overall, the operators will benefit from the lower passes and minute prices, as well as integration costs.

- A marketplace to purchase ground station services (higher competition, lower costs).

Gains for ground stations:

- Extra sales channel
- Increased efficiency (reduced integration costs)
- Pre-integration to mission control platform.

4.4 Innovation with Respect to What is Available in the Market

Currently there is a shortage of single one-point-of-entry ground communication solutions which are integrated with different ground station networks. The closest ones are virtual networks such as Infostellar, RBC Signals, Satnogs etc. The main differences between the Marketplace and virtual networks are the latter combine different stand-alone ground stations not ground station networks (including several different ground stations) and they do not have mission control nor satellite operations simulations capabilities.

Spaceit's Marketplace will bring together satellite operators and ground station networks in a one unified platform. The Solution changes the space communication as follows:

- It aggregates both virtual and physical networks creating a unified ecosystem for ground station services. It allows booking and managing contacts and communicating with satellites in one environment.
- For satellite operators, it requires only one integration with Spaceit's platform to get an access to an extended number of ground stations worldwide, thus saving time and cost.
- For ground station networks, it is an extra sales channel to access customers and monetize operations.

- It supports very high frequency (VHF)[1], ultra high frequency (UHF)[2], S band[3], X band[4], KA band[5] and optical communication. The goal is to support different standards (including Consultative Committee for Space Data Systems – CCSDS[6]) and broker a full spectrum of services related to telemetry and telecommand (TM/TC[7]) and payload communications.
- Potentially it is possible to create a live 24/7 coverage with a satellite. This helps to minimize the latency, download more data from EO satellites or establish a constant link with communication.

4.5 Key Stakeholders Involved in the Activity

Customers

Spaceit's customers are satellite operators who are classified into two main categories:

- commercial operators (private companies)
- public operators (space agencies, universities, R&D organisations).

As for the Marketplace, the focus is on the private companies and the European Space Agency (ESA), the latter financing the project.

Spaceit has signed memorandum of understandings (MOUs) with different satellite operators to test the Marketplace with their satellites. From the sample, one potential customer is planning to launch an EO satellite is equipped with a hyperspectral optical instrument and an on-board computer allowing for advanced data processing through convolutional neural networks. As a part of the project, the company is planning to

[1] For further information: https://en.wikipedia.org/wiki/Very_high_frequency

[2] For further information: https://en.wikipedia.org/wiki/Ultra_high_frequency

[3] For further information: https://en.wikipedia.org/wiki/S_band

[4] For further information: https://en.wikipedia.org/wiki/X_band

[5] For further information: https://en.wikipedia.org/wiki/Ka_band

[6] For further information: https://en.wikipedia.org/wiki/Consultative_Committee_for_Space_Data_Systems

[7] For further information: https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Onboard_Computers_and_Data_Handling/Telemetry_Telecommand

establish their own ground station, as well as to purchase the services from external providers. This is one example of a potential lead customer who could use a range of Spaceit's services and offer its resources though the Platform. In short, more specific activites are planned as follows:

- Spaceit will test the command and control features of its platform with a customer satellite mission. The focus will be on satellite telemetry[1] reception, telecommand[2] preparation and delivery, satellite payload[3] data reception, and operations automation[4].
- Spaceit will integrate the client's ground station to its Marketplace. It would allow 3rd parties to use the ground station and increase its utilization. At the same time the customer will have access to different other gound stations for a wider coverage using Spaceit's solution.

Since Spaceit's MCS is already integrated with Aalto University's satellite Aalto-1, the Marketplace will be tested in space with this satellite as well.

Furthermore, some of the ground station providers (e.g., AWS) are supporting integration process by enabling connectivity with well known free-to-listen test satellites.

Partners

Currently, Spaceit's MCS is integrated with one ground station network – Infostellar, Japan. Target is to integrate as many ground stations as possible in the coming years. Different level agreements have been signed with 7 providers. Potential partners' interest in Spaceit's technology is high because it allows them to add an extra sales channel for their services. Spaceit has forecasted that depending on the technology (frequency band,

[1] Telemetry is the in-situ collection of measurements or other data at remote points and their automatic transmission to receiving equipment (telecommunication) for monitoring [11].

[2] A telecommand or telecontrol is a command sent to control a remote system or systems not directly connected (e.g. via wires) to the place from which the telecommand is sent [10].

[3] Satellite payload is defined as modules carried on satellites with the ability to perform certain functionalities. Satellite consists of the payload and the bus.

[4] Operations automation in IT is the use of automated applications and systems to manage key operations processes without the need for human intervention.

standards/protocols), it takes 2-6 weeks on average to integrate with a ground station network.

Besides ground station networks, other partners include cloud and telecommunication (internet connection) providers.

Regulators

Spaceit MCS nor the Marketplace are not subject to any regulators. The company's customers (satellite operators) are subject to International Telecommunication Union's (ITU)[1] regulations and national laws of the country of origin. Similarly, the partners (ground stations) are subject to their national laws.

A valid ITU filing is a prerequisite for radiating radio frequency (RF) signals over a service area. The responsibility for the ITU filing is with the spacecraft owner (i.e., Spaceit's customer). An ITU filing is a cumbersome and lengthy process and depending on the nature of the spacecraft and purpose of the mission, the license is granted for a specific geographical location (i.e., over a country x up and downlink are allowed, over a country y they are not allowed).

According to information gathered from the Estonian Consumer Protection and Technical Regulatory Authority[2], satellite operators and ground station networks, once ITU has issued the license, the domestic licenses for ground stations are regulated locally by national authorities. That means each customer (satellite operator) does not have to file for each potential ground station from Spaceit's pool with the ITU (to operate in the regions initially allowed).

Applying for a frequency band license from responsible national authorities can be a lengthy process as well. The lead time depends heavily on a country, band, bandwidth, nature of the communication, and other factors. Some countries may require the adherence to the exact earth station characteristics in the ITU filing. Also, further requirements (such as pre-coordination with other network operators) may be stipulated

[1] For further information: https://www.itu.int/en/Pages/default.aspx

[2] For further informaion: https://www.ttja.ee/en

by individual countries. All in all, this process can take from a few weeks to months but similarly with ITU filing it is not a showstopper for Spaceit's business.

Investors

Besides the founders, Spaceit has 3 investors – Icebreaker Fund II Ky, UG Investments OÜ and Starburst PTE Ltd. Their interest is the value of Spaceit to grow and are supporting the Marketplace activity.

National delegation at ESA

Estonian delegation at ESA is supporting the activity and has issued a letter of support to confirm it.

Spaceit personnel

The company will allocate necessary amount of people for the activity. It has been communicated internally.

5 Business Rationale of the Activity

To evaluate economical viability of the Marketplace business model analysis was conducted (including financial forecast). Market insights were already given in the 4 paragraph of the thesis. This paragraph elaborates more on the microeconomical perspective. The analysis proves the activity in overall being very beneficial to Spaceit and the other related stakeholders.

5.1 Business Model Canvas

The Business Model Canvas is a strategic management template used for developing new business models and documenting existing ones. It offers a visual chart with elements describing a firm's or product's value proposition, infrastructure, customers, and finances, assisting businesses to align their activities by illustrating potential trade-offs [14].The Business Model Canvas divided the canvas into nine sections, each responsible for the most vital business elements of every organization [15]:

- Customer Segments
- Key Partnerships
- Key Activities
- Revenue Streams
- Value Propositions
- Channels
- Key Resources
- Customer Relationships
- Cost Structure [15].

Table 1. Business Model Canvas of Spaceit As-Is.

<table>
<tr>
<td rowspan="2">Key Partners
Satellite manufacturers
Supplementary tools and services providers
Cloud providers
Software developers
Industry event organizers
Government
Space agencies (ESA)</td>
<td>Key Activities
Sales of products and services (mission control system, simulators, SaaS)
Integration with ground stations
Integration with satellites
Digital marketing of services
Participation in public procurements
Testing and validation</td>
<td rowspan="2">Value Proposition
Spaceit offers mission control as a service…
… a single cloud-based platform for satellite command and control.
It enables lower satellite communication costs for satellite operators.</td>
<td>Customer Relationships
Binding and non-binding agreements
Customer feedback for product development
Help of customers in their developments</td>
<td rowspan="2">Customer Segments
Commercial satellite operators (EO, R&D)
Public operators (space agencies, ESA)
Academic and research org-s (universities, non-profit etc.)</td>
</tr>
<tr>
<td>Key Resources
Product software developers
Sales team
Marketing team
Cloud platform
Access to investments, working capital
Freedom to operate in the industry</td>
<td>Channels
Space technology exhibitions
Digital channels
Partners
Public procurements
System integrators</td>
</tr>
<tr>
<td colspan="3">Cost Structure
Software development (in-house, outsourced)
Cloud platform
Insurance and banking
Legal (IP, contracts)
Additional services providers
Company's fixed costs</td>
<td colspan="3">Revenue Streams
Subscription of the service (SaaS)
Sales of additional tools (e.g., satellite operations simulator)
Satellite management (dedicated personnel managing client’s satellites)
One-off fees (integration with satellites)
ESA procurements</td>
</tr>
</table>

Table 2. Business Model Canvas of Spaceit To-Be (Changes Highlighted).

<table>
<tr>
<td rowspan="2">Key Partners
Ground station networks
Stand-alone ground stations
Satellite manufacturers
Supplementary tools and services providers
Cloud providers
Software developers
Industry event organizers
Government
Space agencies (ESA)</td>
<td>Key Activities
Sales of products and services (mission control system, ground station services, simulators, SaaS, end-to-end)
Integration with ground station networks
Integration with satellites
Digital marketing of services
Participation in public procurements
Testing and validation</td>
<td rowspan="2">Value Proposition
Spaceit offers an end-to-end infrastructure for satellite operations…
… a single cloud-based platform for satellite command and control, and ground station services.
It enables low latency, communication costs for satellite operators, and…
…creates an extra sales channel for ground stations, helping to utilize their assets more efficiently.</td>
<td>Customer Relationships
Binding and non-binding agreements
Customer feedback for product development
Help of customers in their developments</td>
<td rowspan="2">Customer Segments
Commercial satellite operators (EO, R&D)
Public operators (space agencies, ESA)
Academic and research org-s (universities, non-profit etc.)</td>
</tr>
<tr>
<td>Key Resources
Product software developers
Sales team
Marketing team
Cloud platform
Access to investments, working capital
Freedom to operate in the industry</td>
<td>Channels
Space technology exhibitions
Digital channels
Partners
Public procurements
System integrators</td>
</tr>
<tr>
<td colspan="3">Cost Structure
Software development (in-house, outsourced)
Ground station services fees
Cloud platform
Insurance and banking
Legal (IP, contracts)
Additional services providers
Company's fixed costs</td>
<td colspan="3">Revenue Streams
Subscription of the service (SaaS)
Brokerage of ground station services (cost-plus, revenue sharing)
Sales of additional tools (e.g., satellite operations simulator)
Satellite management (dedicated personnel managing client’s satellites)
One-off fees (integration with satellites and ground stations, licensing)
ESA procurements</td>
</tr>
</table>

Comparing the As-Is of the Business Model Canvas of Spaceit with the To-Be one, it is clearly visible that addition of the Marketplace widens the value proposition of the company. Still, at the same time potential customers and partners will remain basically unchanged which means the company should gain an additional competitive advantage to succeed in the industry.

5.1.1 Customer Segments

The key customer segments targeted by the Solution are (please see Table 3 below for their problems/needs):

- Commercial operators - medium-sized satellite operators (EO, broadband)
- Public operators - space agencies (ESA)
- Academic and research - universities (R&D).

Table 3. Customer Segments and Their Problems/Needs.

Segment	**Needs**	**Pain**	**Gain**
Commercial operator	Reliable infrastructure	Mission managers and operators cannot take risks on unreliable infrastructure, due diligence of provider takes time, operative customers support must be available	All ground station service providers from one place, alternative options, pre-integrated, evaluation according to different criteria (ground station provider, antenna location, price etc.)
	Low costs	Integration with multiple ground stations is expensive and time consuming, potentially higher prices due to cooperation with one provider	With the Marketplace solution, integration costs will decrease since there is only one integration with Spaceit's solution required to get an access to different providers, price competition, freedom to choose and shop across different options
	Wide coverage	GS market is fragmented, which implies costly integrations, local legal constraints, no real-time coverage	One integration to gain access to different ground stations, using services across providers could enable a near 24/7 coverage with EO satellites

Segment	Needs	Pain	Gain
	Inconvenient access to ground station resources -> simple usage	Widely used legacy systems can be complicated for newspace companies, in-house developments costly	Spaceit's solution provides a user friendly modern UI/UX and managed cloud-based service
Public operator	Innovative solutions to advance the industry	To find innovative solutions which could utilize existing infrastructure	Utilization of established ground infrastructure, lower prices, and increased usage for end-users
	Competitive price	Public procurements are related to specific territory, policies, but also must be competitive in terms of pricing	With the Marketplace solution, integration and legal costs will decrease since there is only one integration with Spaceit's solution required to get an access to different providers, price competition, freedom to choose and shop across different options
	Inconvenient access to ground station resources -> simple usage	Widely used legacy systems can be complicated for newspace companies, in-house developments costly	Spaceit's solution provides a user friendly modern UI/UX and managed cloud-based service
Academic and research operator	Inconvenient access to ground station resources -> simple usage	Widely used legacy systems can be complicated for newspace companies, in-house developments costly, constellation support not always in place	Spaceit's solution provides a user friendly modern UI/UX and managed cloud-based service
	Low price	Integration with multiple ground stations is expensive and time consuming, potentially higher prices due to cooperation with one provider	With the Marketplace solution, integration costs will decrease since there is only one integration with Spaceit's solution required to get an access to different providers, price competition, freedom to choose and shop across different options

5.1.2 Value Proposition

Table 4 below identifies the specific key features of our product that will address a subset of previously identified customer problems/needs and define its value proposition i.e., the benefits that the Marketplace offers to its customers.

Table 4. Key Product Features and Benefits.

Customer Segment Problem/Need	**Feature Description**	**Benefit for the Customer/Added Value**		
		Benefit 1	**Benefit 2**	**Benefit 3**
Satellite operators have inconvenient access to ground station services from multiple providers	Aggregation of ground stations services	More options for communication services	Competition between providers result in better services and price	
Ground stations operators have access to limited customer base	Aggregated marketplace	Better visibility to potential customers	Better utilization of resources	
Satellite operators must implement complicated integration with each ground station service provider	Pre-integration with ground station service providers	Reduced effort for integration	Better quality	Lower integration costs (one time integration fee of apx. €10,000 instead of multiple fees)
Satellite operators have limited radio coverage when communicating with satellites	Brokerage of communications between satellites and ground station service providers	Wider coverage	More ground station services options	Potentially improved coverage through more streamlined planning and purchasing process

Customer Segment Problem/Need	Feature Description	Benefit for the Customer/Added Value		
		Benefit 1	**Benefit 2**	**Benefit 3**
Satellite operators have difficulties with ground station licence applications	Ground station license application support	Potentially shorter application times since local ground station frequency license process is managed by a ground station provider using local expertise (not satellite operator itself)		
Satellite operators must manually select and book contacts in ground stations	Contact optimizer	Selects optimal contact plan according to user preferences (best price, max communication time, longest communication window, etc)	Automated contact booking	Reduced manual work decreases human errors

5.1.3 Revenue Streams

Spaceit's revenue model is based on the following items:

- Subscription of Spaceit MCS (cloud-based platform, SaaS)
- Brokerage of ground station services (two options for customers: cost-plus, revenue sharing)
- Sales of add-on functionalities of the Spaceit MCS (satellite operations simulator, integrated 3rd party solutions, SaaS)
- Satellite management (dedicated personnel managing client's satellites)
- One-off fees for the integration with the platform, ground station licensing

Spaceit MCS can be subscribed as a standalone (the platform without ground station services or simulator) or in packages consisting of several modules:

- MCS + ground station services

- MCS + ground station services + simulators
- MCS + ground station services + simulators + satellite management.

SaaS is a periodical subscription based on the number of satellites and users. Depending on a customer, Spaceit is aiming for a yearly subscription paid in advance.

If a customer chooses to use ground station services, Spaceit will include the MCS platform subscription, integration and ground station licensing costs into the ground station fees (price per pass or minute).

Satellite management fee is charged when Spaceit's dedicated personnel manages its customers satellites daily.

Additional tools could be in-house or external ones integrated with the MCS.

The financial forecast presented in this thesis includes revenues and costs related only with the Marketplace. It does not include additional products or services. The economic advantage of the Marketplace derives from the reduced integration costs and the advance purchase of bulk resources from the ground stations sufficient to cover the resale mark-up.

In the commercial exploitation stage, the Marketplace will be sold to the customers as described in the Table 5 below.

Table 5. Product Pricing in Euros.

Satellite Operator Type	**Product Installation Fee Per Unit**	**Recurring Service Fee Per Product Per Year**	**MCS Subscription Fee Per Satellite Per Month**	**Ground Sstation Licencing Fee Per Satellite Per Month**	**Sales Price Per Pass**
Commercial operator	3000	287300	2500	150	25
Public operator	2000	95675	2500	150	25
Academic and research	1000	40125	0	150	15

In the more advance financial model, churn rate is kept 0% but an average lifetime of 2 years per satellite is considered (see Table 6, page 40).

Table 6. Cumulative Volume Sales, Satellites Using Spaceit MCS.

Estimated Cost of Sales		**Commercial Exploitation Phase**					
		0	**1**	**2**	**3**	**4**	**5**
Cumulative volume sales	Commercial operator	2	6	13	25	46	78
	Public operator	1	1	2	3	4	5
	Academic and research	1	3	4	5	6	7

The forecasted turnover is based on the following assumptions:

- Subscription fee per satellite per month: €2500 for commerical and public operators, €0 for academic and research (based on market averages)
- Product installation charge per new mission onboarded: €3000 for commercial, €2000 for public and €1000 for academic operators
- Ground station licensing per satellite per month: €150
- Number of ground stations used per satellite: 4 for commercial, 1 for public and academic satellites
- Number of passes per day per satellite per ground station: 7
- Days operational per year: 365
- Sales price per pass: €25 for commercial and public, €15 for academic missions (based on market averages and signed agreements)
- 10% markup is included to price per pass, integration, and licencing fees, all what Spaceit is outsourcing from ground station networks

Current financial model is based only cost-plus pricing (see the markup in the assumptions), revenue or profit sharing are not included. Furthermore, the presented model includes only revenue from the Marketplace and related services, all other streams have been excluded.

Considering Table 7 on page 41, the forecast shows rather positive outlook for the additional sales generated by the Marketplace.

Table 7. Forecasted Total Sales Generated by the Marketplace in Euros.

Total Revenues	**Commercial Exploitation Phase**					
	0	**1**	**2**	**3**	**4**	**5**
Commercial operator	580600	1729800	3743900	7194500	13230800	22427400
Public operator		97675	193350	291025	386700	484375
Academic and research	41125	122375	162500	203625	243750	284875
TOTAL	621725	1949850	4099750	7689150	13861250	23196650

5.1.4 Cost Structure

Since Spaceit will be brokering ground station services, most of the cost of sales are related to purchasing the services from partnering networks and stand-alone stations.

Personnel costs are mainly related to continuous development of the Marketplace, including:

- New features
- Integrations with ground stations
- Integrations with satellites
- Sales and marketing.

The key elements of cost for realizing the value proposition during the commercial/operational stage are presented in Table 8 below and Table 9 on page 42.

Table 8. Forecasted Cost of Sales of the Marketplace in Euros

Cost Item	**Commercial Exploitation Phase**					
	0	**1**	**2**	**3**	**4**	**5**
Radio communication brokerage	498736	1055471	2215441	3932145	7180061	11448700
Ground station networks integrations	6364	9091	11818	17273	20000	25455
Licencing	58909	137455	235636	412364	687273	1080000
Hosting expenses	6000	12000	24000	36000	48000	60000

Assumptions of the cost of sales are as follows:

- Cost per pass: €22,7 for commercial and public missions, €13,6 for academic ones
- Integration costs: €4500 for commercial & public missions, €2273 for academic ones. The integration costs depend on the new missions (customers onboarded)
- Licensing costs: €1636 for all missions
- In all cases Spaceit's markup is 10% and the costs base on market averages and signed agreements.

Table 9. Forecasted Operational Expenditures (OPEX) of the Marketplace in Euros

Estimated OPEX		**Commercial Exploitation Phase**					
		0	**1**	**2**	**3**	**4**	**5**
Sales and marketing staff cost		0	75000	75000	75000	75000	75000
Uplift	2%	0	1500	1500	1500	1500	1500
Sales staff		0	1,5	4	8	8	12
Product development		84000	84000	84000	84000	84000	84000
Uplift	2%	1680	1680	1680	1680	1680	1680
Development staff		3	8	10	11	12	12
Admin staff cost		84000	84000	84000	84000	84000	84000
Uplift	2%	1680	1680	1680	1680	1680	1680
Admin staff		1	1	2	2	2	2
Back office, finance, accounting, legal		1000	50000	90000	150000	175000	180000
Estimated OPEX		**Commercial Exploitation Phase**					
		0	**1**	**2**	**3**	**4**	**5**
General expenses		34683	94562	144466	191429	205583	241350
Financial and taxes		3109	9749	20499	38446	69306	115983

Assumptions of the OPEX are as follows:

- Payroll based on market averages and Spaceit's current profit and loss structure
- Number of sales staffs is in correlation with missions onboarded
- Admin staff is kept minimum (2 full time employees)
- For back office, finance etc., external service is used, later according to revenue and personnel growth
- General expenses are considered 10% of all other OPEX

- Financial and taxes include mainly bank fees, no dividends (and its tax) are not considered.

The Marketplace does not require any capital expenditures (CAPEX). It is a cloud-based software solution. Ground station services are outsourced. The company is not planning to invest into any physical assets.

5.1.5 Channels

In the commercial exploitation stage, the Marketplace will be sold to the customer segments via these channels:

- Personal direct sales – industry exhibitions (previously Spaceit has attended to approximately 12 exhibitions per year) and personal meetings with customers.
- Digital sale channels – company's website, social media (LinkedIn and Twitter).
- Partners – satellite manufacturers (invites to participate in tenders), ground station networks (forwarding customers to use Spaceit MCS), cyber exercise organizers (several exercises in 2021 and 2022).
- Public procurements – ESA and national procurements.
- System integrators – applies mainly for a stand-alone MCS and satellite operations simulator sales.

These sales channels have already been established. The focus is set more on the sales through partners and system integrators (more personal meetings). Furthermore, although Google visibility has worked well for the sales, an extra sale on social media (LinkedIn) and content marketing will be considered.

5.1.6 Customer Relationships

Spaceit's relationships with the key customer segments already exist. MOUs have been signed with different satellite operations across the World.

The following fees are being negotiated with one of the potential customers:

- €2500 for the Platform subscription for 1-3 satellites in average
- €5000 for the integration with Spaceit's MCS
- Price per pass around €25 depending on ground station and frequency band.

5.1.7 Key Activities

To make the business model work, Spaceit needs to perform the key activities identified in Table 10 below.

Table 10. Overview of Key Activities

Key Activity	When Are Going to Be Performed (During or After the Activity)
Sales of products and services	During and after the activity. The Company is already selling mission control (incl. ground station) services. The initial pricing is set, first agreements are being negotiated.
Integration with ground stations	During and after the activity. Spaceit is integrated with one ground station network today (Infostellar). The aim is to be connected with 3 additional ones during the project. It would bring the total amount of antennas over 200 and give the service sufficient coverage and competitive advantage. The integrations will continue after the activity.
Software development	During and after the activity. The development of the MCS (including the Markerplace) is already in works and will continue after the current project. The development activities during the activity will result in: • capability to book contacts in different ground stations / ground station networks • capability to manage contact bookings in different ground stations / ground station networks • capability to optimize contact booking according to user selected constraints • capability to conduct satellite communications through different ground stations / ground station networks • complete required functionality (telemetry processing, telecommanding, payload data reception) for validation of marketplace functionality.
Promotion of products through digital marketing	During and after the activity. Being visible in the digital channels is one of the key activities in times of COVID-19 which has paused most of physical meetings and industry events. Spaceit launched the new webpage in 2020 and has been active in promoting its services on different social media platforms. More content marketing would be beneficial (depends on the overall sales and marketing budget).
Participation in public procurements	During and after the activity. Spaceit is active in ESA tenders, but also offering its stand-alone products (MCS, simulators) with cyber exercises in different other procurements.
Participation in consortiums	During and after the activity. Spaceit is leading a couple of ESA tender consortiums currently. Also, the company is acting as a sub in one of the biggest ongoing ones.
Public appearances (conferences, speeches etc.)	During and after the activity. Depending on the COVID-19 situation but the goal is to make at least 12 public appearances (conferences, speeches etc.) per year (on tract as of 04.2022).

5.1.8 Key Resources

The key resources are presented in Table 11 below which are cruisal for the Marketplace activity to succeed.

Table 11. Key Resources of the Marketplace

Required Resource	In Place	Potential Issues
Product software developers	Yes	Change of personnel.
Sales team	Yes (partially)	Long lead times to find required personnel (in different continents).
Marketing team	Yes (partially)	Long lead times to find required personnel.
Cloud platform	Yes	Some clients are not confident with AWS (e.g., for security reasons) – recommended solution being end-to-end encryption (potential partner selected).
Access to investment and working capital	Yes	Pre-seed fundraising conducted successful in 2021. Operational cash flow from existing agreements.
Freedom to operate in the industry	Yes	Additional restrictions could apply in the future

5.1.9 Key Partners

Spaceit's main partners are ground stations looking for an extra sales channel. Currently, Spaceit MCS is integrated with one ground station network - Infostellar, Japan. The company's aim is to integrate with several other networks. Different level agreements have been signed with 8 additional ones. In general, the ground station networks are interested in the cooperation with Spaceit since the Marketplace will create them an extra sales channel.

Spaceit's Marketplace will introduce a cross-network aggregation of ground station services to the existing value chain. So far, the closes services are virtual networks (such as Infostellar or RBC Signals) aggregating stand-alone ground stations.

5.2 Market Analysis

An overview of the global space market has been described in the paragraph 3.1. The Marketplace is addressing the subsector of ground station services which has the following characteristics:

- One ground station enables only one hour of communication with a satellite a day
- One satellite is usually connected to a single ground station network
- Connection to additional ground station networks requires high integration costs
- The market is fragmented in terms of providers, locations, and legal issues
- Ground station networks are not offering their own mission control software
- KSAT alone had a €100 million turnover in 2020, 50000 passes in December 2020 (backlog €350 million as of Q4 2020).

The Total Available Market (TAM) of the targeted product is €1,4 billion[1] and the Serviceable Available Market (SAM) of the targeted product is €839[2] million. Depending on a country, market barriers could include the following issues:

- Legal (ground station licenses, space insurance)
- Political (tensions between countries concerning the space)
- Industry (not enough knowledge regarding space industry)
- Financial (less funding)
- Technological (less opportunities to test space technology).

5.3 Competitive Landscape

Spaceit's main competitors and the nature of the competition are identified in Table 12 page 47. Leaving aside system integrators who are covering the space value chain vertically (and are Spaceit's partners), the main competitors include Kubos, Bright Ascension and Sfera Technologies.

[1] In LEO: launch of approx. 1060 satellites per year, 8 passes per ground station per satellite per year, 6 ground stations servicing 1 satellite, lifetime of 3 years of satellite, price per pass of €25.

[2] In LEO: approx. 1060 satellites per year, Spaceit servicing 40% of them i.e. 638 satellites, 8 passes per ground station per satellite per year, 6 ground stations servicing 1 satellite, lifetime of 3 years of a satellite, price per pass of €25.

Table 12. Summary of the Competition

Name	**Country**	**Nature of Competition**	**Competitor Product**	**Strengths**	**Weaknesses**	**Advantages & Differentiating Features of the Spaceit Marketplace for the End-User**
Sfera Technologies	Bulgaria	Aggregation of ground station services	Currently only an idea and no integrations with ground stations	Relatively lower development costs in Bulgaria	At very early stages	All-in-one: aggregation of different ground station networks, combined with MCS, simulator and cyber exercise. Cloud-based, tested in space.
Kubos, Bright Ascension, enable.space	various	MCS, its integration with ground station networks	Kubos has similar MCS as Spaceit, Bright does not have full cloud support	Better funding than Spaceit, might have more traction	Not always a clear focus on offerings, higher personnel costs	Aggregation of different ground station networks, combined with MCS, simulator and cyber exercise. Cloud-based, tested in space. Scalability .
Telespazio, Airbus, OHB, Nano Avionics, Open Cosmos, D-Orbit	various	Mission management	Focus on end-to-end mission management, separate products occasionally	Traction, funding, know-how, wide range of products and services	High price, not always focused on the newspace market nor selling products separately, legacy software, high personnel costs etc.	Focus on the ground communication: aggregation of different ground station networks, combined with MCS, simulator and cyber exercise. Cloud-based. Scalability. Agility.
CGI, GMV, Scisys, Braxton	various	MCS, other space related software development	Focus on selling different apps and providing s/w outsourcing, legacy systems	Traction, funding, know-how, wide range of products and services	Not focused as a service offering. High price, not always focused on the newspace market, expensive legacy software developments.	Spaceit offers the Platform which combines different MCS, cybersecurity and ground station services features as-as-service, low overhead, scalability, agility.

The Marketplace should give Spaceit an additional competitive advantage over them due to a possibility for an end-to-end offering in space communications.

5.4 Value Chain

Figure 3 and Figure 4, both describe Spaceit's composition within the value chain and the company's role in the commercial exploitation phase of the Solution As-Is and To-Be.

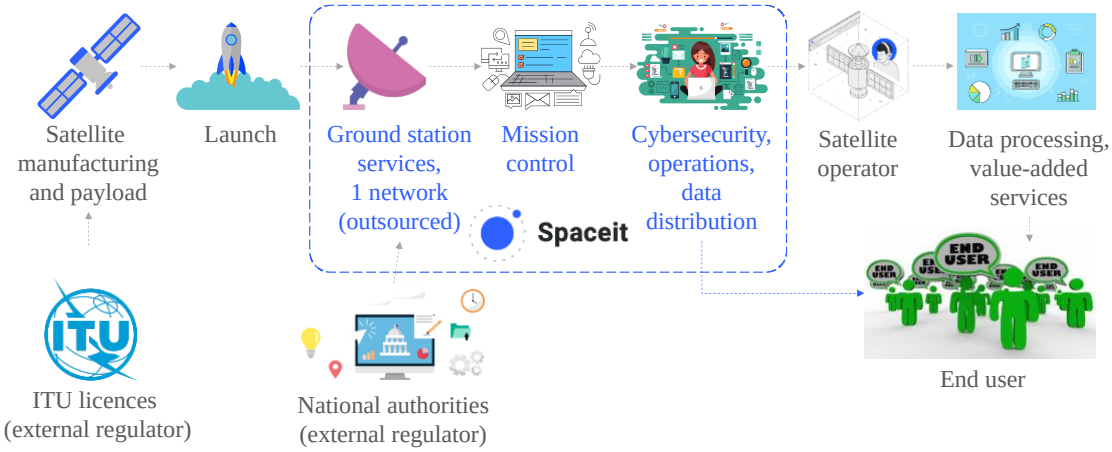

Figure 3. As-Is of Spaceit's Value Proposition in the Value Chain.

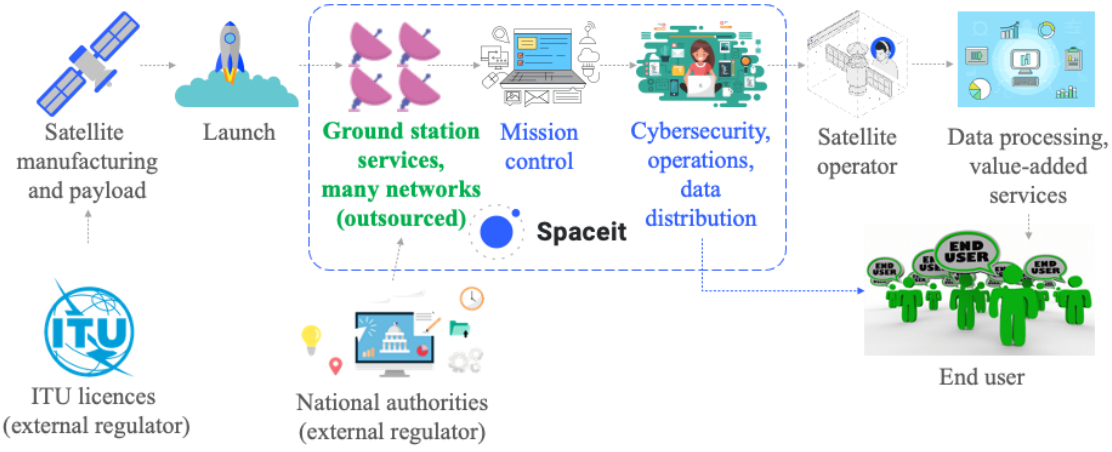

Figure 4. To-Be of Spaceit's Value Proposition in the Value Chain (Changes Highlighted).

Next Spaceit's activities are analyzed using Porter's Value Chain (see Figure 5, page 49). It works by breaking an organization's activities down into strategically relevant pieces, so that it is possible to see a fuller picture of the cost drivers and sources of differentiation, and then make changes appropriately [16].

In case for Spaceit, the Marketplace activity will add several strategic activities (revenue sources) to Spaceit business such as:

- Sale of ground station services,
- Possibility to offer an end-to-end service in satellite communication (MCS, ground station services, simulatorsm satellite management)
- Additional opetions for one-off fees (ground station integrations, licencing fees).

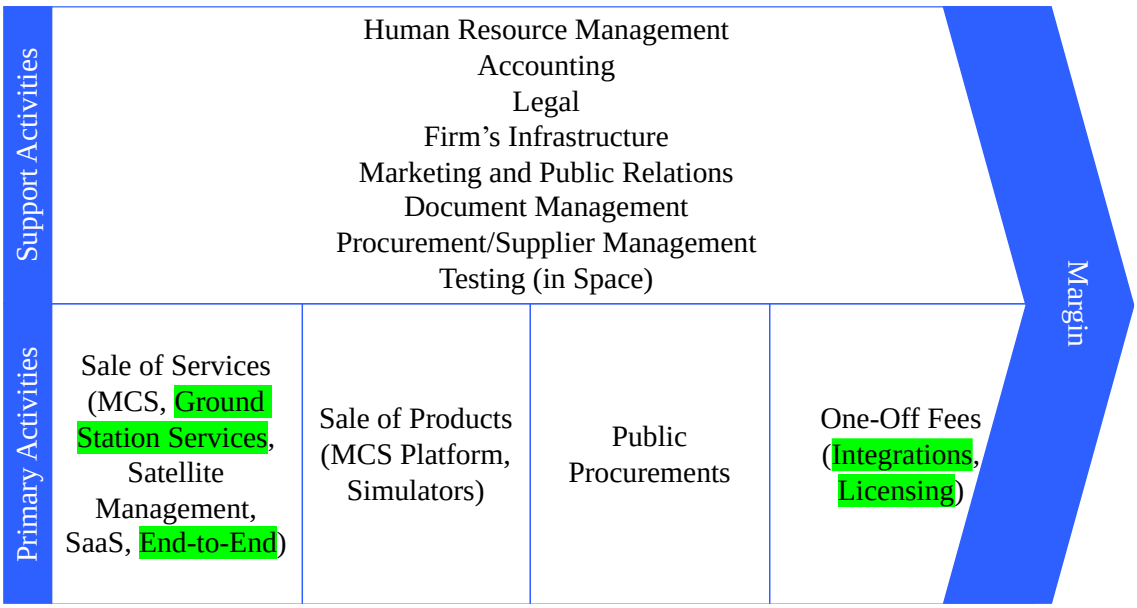

Figure 5. Porter's Value Chain of Spaceit (Added Features Highlighted).

6 Business Motivation and Capabilities of Spaceit

In this paragraph, Spaceit's strategic goals and current business capabilities (latter As-Is and To-Be) are presented together with the business motivation model to provides a scheme and structure for developing, communicating, and managing business plans of the Marketplace in an organized manner.

6.1 Strategic Goals

The outcome of the Marketplace activity (and this thesis) is that the strategic goals of Spaceit, set by the management of the company in cooperation with the investors, have to be amended. The new set of goals are presented in table Table 13.

Table 13. Strategic Goals of Spaceit (To-Be)

Criteria Menu	**Criteria for Defining Goals**	**Define Goals**
Financial stability	Monthly Recurring Revenue (MRR)	MRR > 0. Continuous income from SaaS business (not only from one-off ESA procurements)
Increase of customers	Yearly increase of commercial satellite operators	2 new commercial satellite operators contracted by the end of 2022, additional 3 in 2023, and 4 in 2024
Increase of satellites serviced	Yearly increase of commercial satellites serviced	2 satellites by the end of 2022, 8 in 2023, and 30 in 2024
Continuous partnership with ESA	Number of ongoing ESA projects on a rolling basis per year	4 in 2022-2024
Improving platform	New ground station networks integrations per year	3 new ground station network integrations in 2022, additional 4 in 2023
Best workplace	People retained per year	95% of the personnel retained i.e. <5% left by keeping them happy, trained and offering competitive remuneration

6.2 Business Capability Model As-Is

Business capability models (or business capability maps, BCMs) provide structured graphical representations of all organizational business capabilities, their relationship and hierarchy. BCMs represent high-level views of an organization from the perspective of its business capabilities. Essentially, they briefly describe everything that an organization can do. Business capability models are very stable and organizationally neutral in nature. They are largely independent of specific organizational structures, reporting relationships, political agendas and cultural aspects of individual business leaders, current initiatives, and projects. Furthermore, most changes happening in organizations do not affect the fundamental structure of their business capability models [17].

As-Is BCM analysis of Spaceit (Figure 6) shows main improvement areas are related with Spaceit MCS, ground station services and third party applications. Ground station services capability needs development in majority. Previously resources (money and personnel) have been preventing development of the capability but now with the ESA and investor funding, all barriers have been lifted.

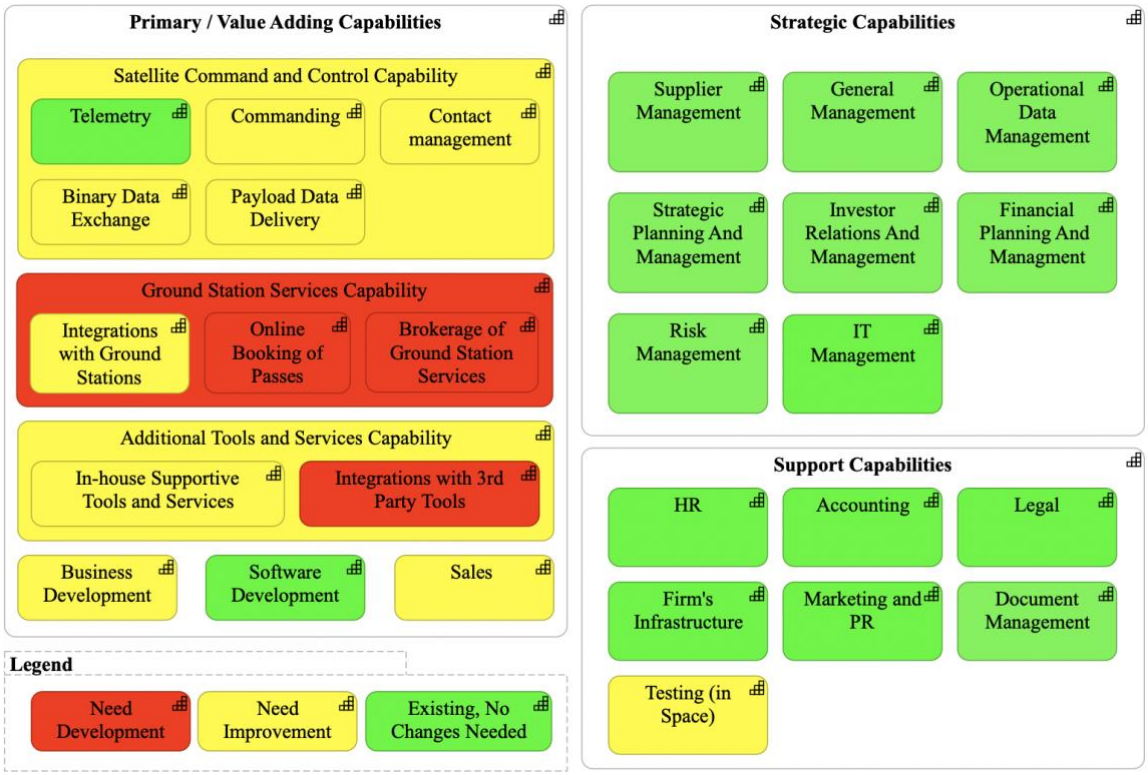

Figure 6. Business Capability Map of Spaceit (As-Is).

Despite the areas in a need for an improvement or development, Spaceit MCS platform has most of the necessary features needed for satellite communication and thus the service in overall is marketable. Nevertheless, this thesis has identified the impact of the Marketplace on many critical areas of Spaceit business and strategic goals. Its implementation should provide an additional competitive advantage to the company. It has been elaborated more in the following paragraphs.

6.3 Business Motivation Model and Capabilities To-Be

The Business Motivation Model (BMM) in enterprise architecture provides a scheme and structure for developing, communicating, and managing business plans in an organized manner. Specifically, the Business Motivation Model does all of the following [18]:

- identifies factors that motivate the establishing of business plans
- identifies and defines the elements of business plans, and
- indicates how all these factors and elements inter-relate [18].

Spaceit BMM and the capabilities To-Be are presented in the following page in Figure 7 on page 53. The key take-aways from the model are as follows:

- Customers are seeking an affordable, scalable, reliable mission control software which is highy automated and has wide coverage with ground station networks (the problem the Marketplace is solving)
- Investors and management are focusing on increasing the value of the company through increase of customers and monthly recurring revenue (MRR[1])
- Ground stations want to utilize their assets better (the Marketplace focus)
- Employees would like to have challenging assignments and be owners of the company through Employee Stock Ownership Plan (ESOP[2])
- Estonian national delegation at ESA is expecting a good performance and development of the company
- Spaceit has set rather straightforward metrics the reach the desired strategic goals

[1] For further information: https://baremetrics.com/academy/saas-calculate-mrr

[2] For further informaion: https://www.investopedia.com/terms/e/esop.asp

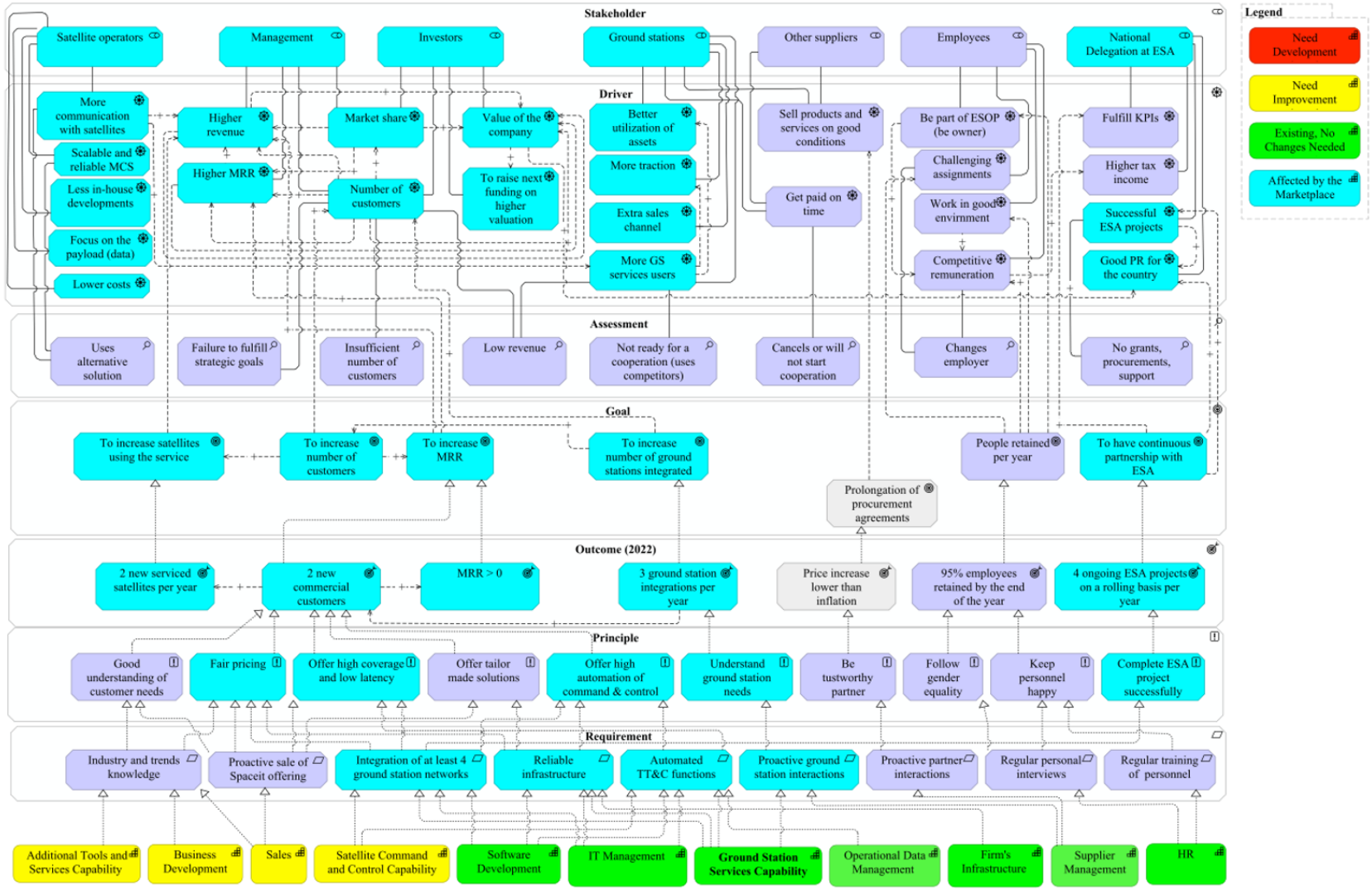

Figure 7. Business Motivation Model and Capabilities (To-Be) of Spaceit.

Additional key take-aways from the model are as follows:

- Many important capabilities of the company (e.g., IT management, firm's infrastructure) are already in place to support different business requirements.
- At the same time some of the critial capabilities to succeed are still in a need for development or improvement, best examples being the ground station services and (automated) satellite command and control respectively.
- The ground station services capability will be developed with the implementation of the Marketplace activity thus likely improving the other critical areas and an overall performance of the company as well.

Based on the BCM and BMM, the thesis shows the importance of the development of the ground station services through the Marketplace activity which creates additional capabilities to Spaceit's end-to-end offering, eventually impoving the potential reaching the strategic goals of the company (see Figure 8 below).

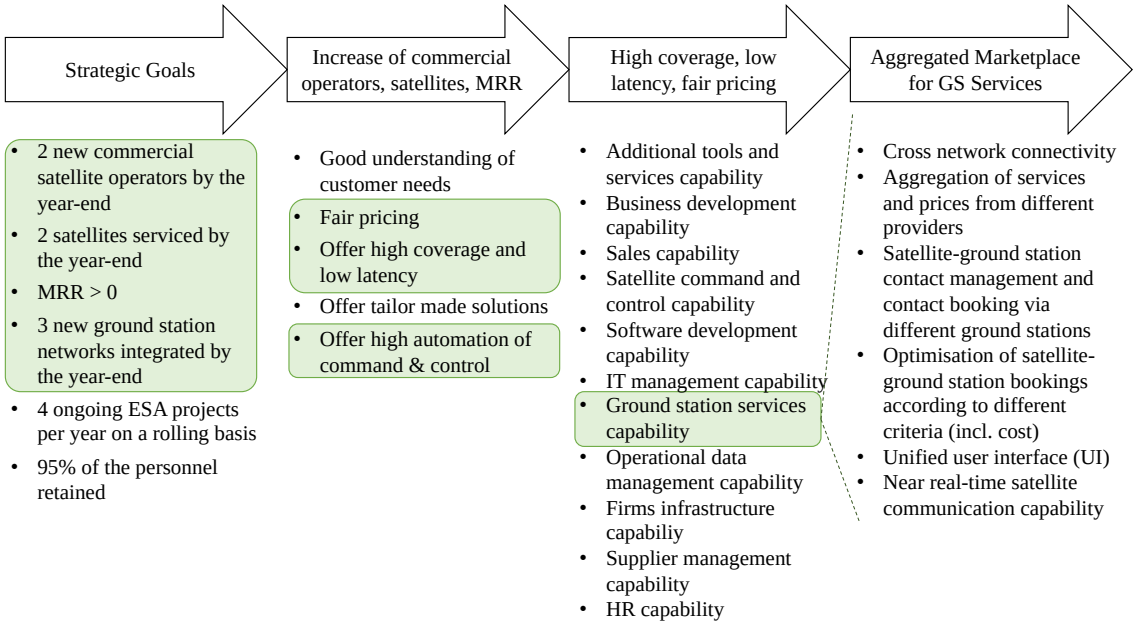

Figure 8. Business Capabilities Required to Meet Strategic Goals of Spaceit.

6.4 Value Streams

By implementing the Marketplace activity, it creates value to customers by high radio coverage and low latency with satellites, and eventually Spaceit should have better chances to meet its strategic goal of increasing the number of commercial satellite

operators (i.e. customers), satellites services and have eventually monthly recurring revenue.

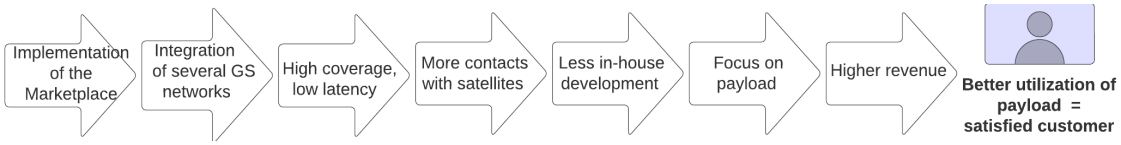

Figure 9. Creating High Coverage and Low Latency with the Marketplace.

Furthermore, value is created by competitive pricing – the aggregation of difference service providers should mean more transparency on ground station costs.

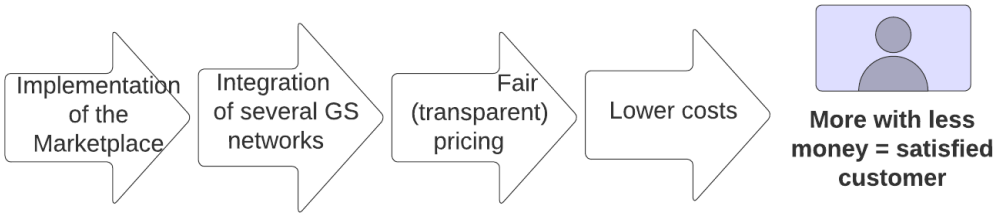

Figure 10. Creating Competitive Pricing Environment with the Marketplace.

The value stream analysis confirms again the necessity of the development of the Aggregated Marketplace of the Ground Station Services.

7 Development of the System Architecture for the Marketplace

Based on the market analysis, company resources and business case, the Marketplace should be a successful activity in overall. In the following paragraph, the system architecture will be developed for the Marketplace. The following methodology is used:

- Business Process Model and Notation (BPMN) to present and specify main process of the Marketplace (contact booking) As-Is and To-Be
- Use-cases incl. diagram to describe user's possible interactions with the system
- Functional and non-functional requirements
- Components of the Marketplace
- Prototyping

Also, development logic and activities are presented to give an overview of next steps.

7.1 Business Process Model and Notation

Business Process Model and Notation (BPMN) is a graphical representation for specifying business processes in a business process model [19]. The primary goal of BPMN is to provide a notation that is readily understandable by all business users, from the business analysts that create the initial drafts of the processes, to the technical developers responsible for implementing the technology that will perform those processes, and finally, to the business people who will manage and monitor those processes. Thus, BPMN creates a standardized bridge for the gap between the business process design and process implementation [20].

In Spaceit's case, the aim for the BPMN is to give an overview one of the main processes – contact booking with a satellite – before and after the Marketplace activity.

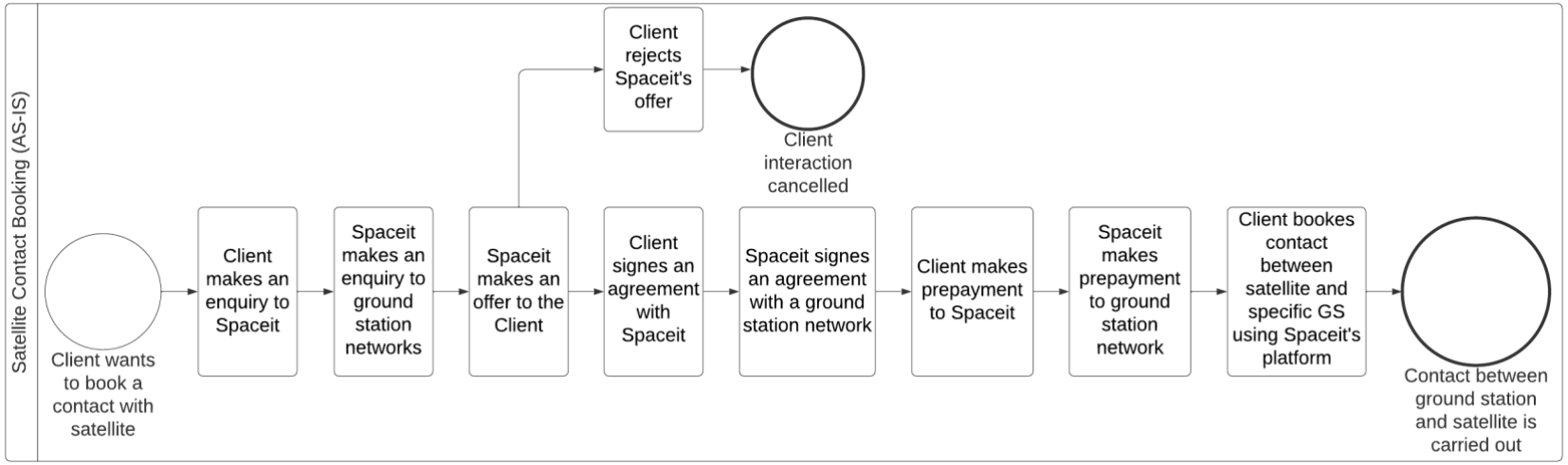

Figure 11. Satellite Contact Booking As-Is.

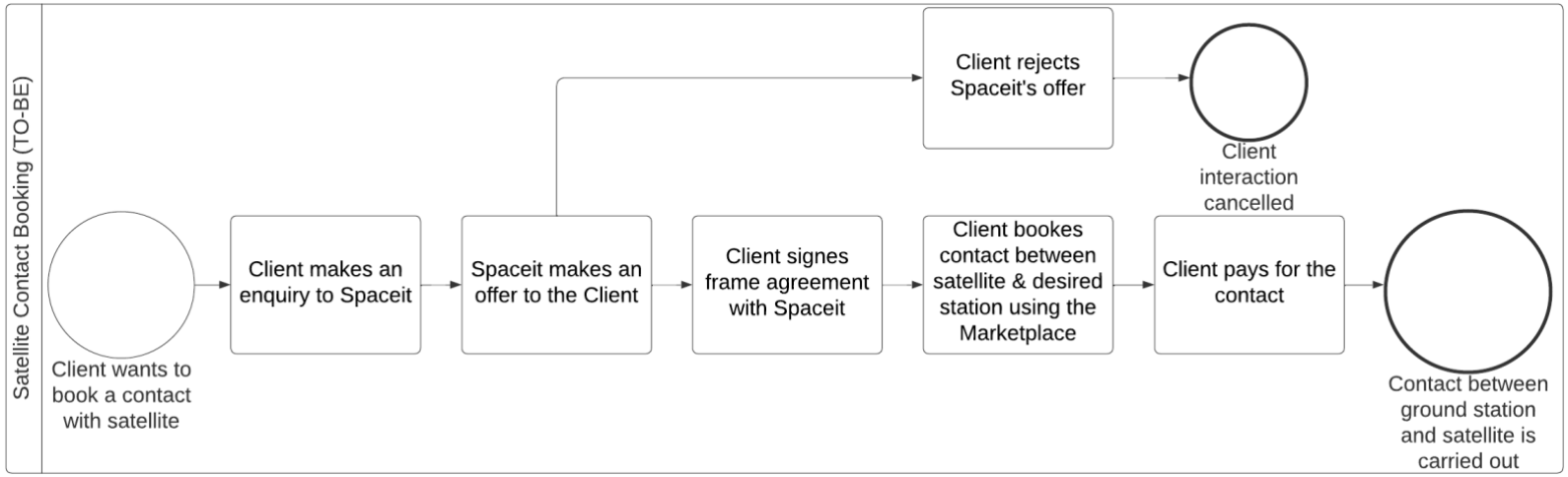

Figure 12. Satellite Contact Booking To-Be.

As it is seen from the BPMN diagrams (Figure 11 and Figure 12, page 57), the process of contact booking will be much more efficient with the Marketplace feature. For the future, an internet payment functionality could be considered to improve it even more.

7.2 Use Cases

In software and systems engineering, the phrase use case is a polyseme with two senses [21]:

1. A usage scenario for a piece of software; often used in the plural to suggest situations where a piece of software may be useful.
2. A potential scenario in which a system receives an external request and responds to it.

A use case diagram is a graphical depiction of a user's possible interactions with a system. A use case diagram shows various use cases and different types of users the system has and will often be accompanied by other types of diagrams as well. The use cases are represented by either circles or ellipses. The actors are often shown as stick figures [22].

The main actors in the Marketplace include:

- Satellite operator (client)
- Ground station operator (partner)
- Spaceit employee [22].

The main external systems include:

- Satellite
- Ground station [22].

There were all together 17 use cases created which are shown in Figure 13 on page 59.

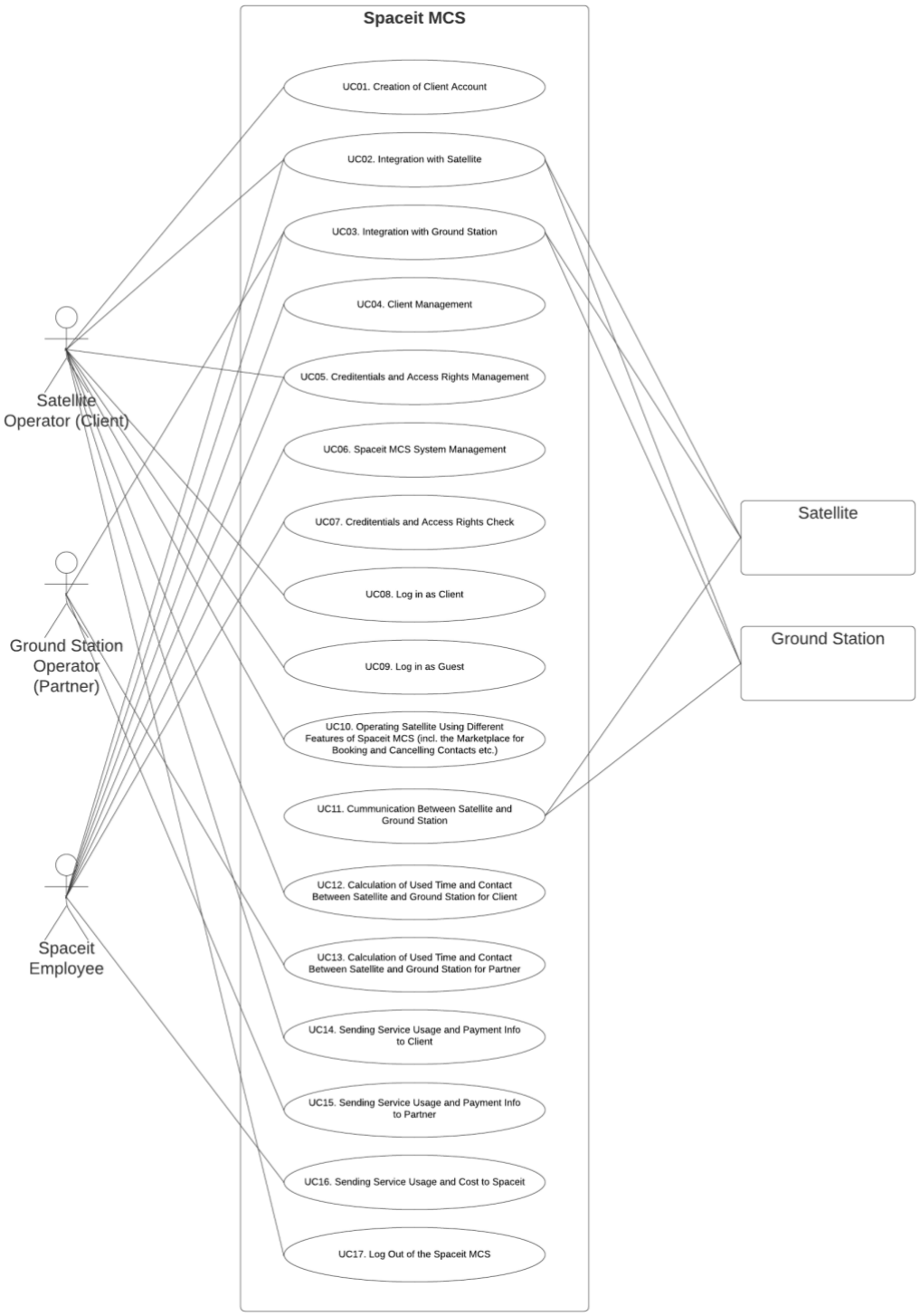

Figure 13. Use Case Diagram of Spaceit MCS (Including the Marketplace).

7.3 Requirements Analysis

Requirements analysis is very critical process that enables the success of a system or software project to be assessed. Requirements are generally split into two types: functional and non-functional requirements [23].

Functional requirements are the requirements that the end user specifically demands as basic facilities that the system should offer. All these functionalities need to be necessarily incorporated into the system. These are represented or stated in the form of input to be given to the system, the operation performed and the output expected. They are basically the requirements stated by the user which one can see directly in the final product, unlike the non-functional requirements [23].

Non-functional requirements: these are basically the quality constraints that the system must satisfy. The priority or extent to which these factors are implemented varies from one project to other. They are also called non-behavioral requirements. They basically deal with issues like: portability, security, maintainability, reliability, scalability, performance, reusability, flexibility [23].

Based on the industry know-how, client and partner meetings, and market trends there were all together 53 functional requirements set for the Marketplace together with Spaceit's Chief Technology Officer (CTO) Lauri Kimmel. 5 key functional requirements are presented in Table 14 below, other 47 can be found in Appendix 1 on page 72.

Table 14. Key Functional Requirements Requirements of Spaceit MCS (Including the Marketplace). Authors: Lauri Kimmel, Silver Lodi.

Requirement ID	**Requirement Description**	**Description of criticality**
KR-FUN-01	The Marketplace should aggregate available satellite contacts from available service providers	Must have
KR-FUN-02	The Marketplace should present available satellite contacts in user interface	Must have
KR-FUN-03	The Marketplace should provide means to book upcoming satellite contacts directly from the user interface	Must have
KR-FUN-04	The Marketplace should provide means to cancel booked satellite contacts considering service provider constraints	Must have

Requirement ID	Requirement Description	Description of criticality
KR-FUN-05	Contact optimizer should create optimal contact plan considering user preferences (best price, max time, etc.)	Must have
KR-FUN-06	Spaceit MCS should conduct communication sessions for booked satellite contacts	Must have

The key non-functional requirements To-Be are shown in Table 14 below.

Table 15. To-Be Functional Requirements of Spaceit MCS (including the Marketplace).

Requirement ID	Requirement Description
NFUN-01	Users must change the initially assigned login password immediately after the first successful login. Moreover, the initial should never be reused.
NFUN-02	Spaceit MCS should be capable enough to handle 100 satellite missions with affecting its performance
NFUN-03	Spaceit MCS should be capable enough to handle 1000 satellites simultanously with affecting its performance
NFUN-04	Spaceit MCS should be capable enough to handle 500 operators simultanously with affecting its performance
NFUN-05	Spaceit MCS should be capable enough to support connectivity with 500 separate ground stations
NFUN-06	Spaceit MCS should be portable. Moving from one cloud to other cloud should be possible
NFUN-07	The Marketplace should have one user interface
NFUN-08	The Marketplace should be able to switch to next best available ground station if the initial one is not responding
NFUN-09	The Marketplace should allow cross network connectivity between satellites and ground stations
NFUN-10	Spaceit MCS should comply with all the EU and US reglations

7.4 System Components

This paragraph is divided into two sections: first describing Spaceit MCS As-Is current architecture, and second To-Be one with the Marketplace.

7.4.1 Spaceit MCS

Aggregated Marketplace of Ground Station Services is implemented as an integral part of Spaceit's cloud-based Mission Control System (MCS).

Spaceit's MCS frontend is a single page web application. Additional views, controls and dashboard widgets are added to the frontend to enable end user interaction with the ground station marketplace functionality [24].

Spaceit's MCS backend is based on loosely coupled microservices. Each microservice is focused on a single business function and has limited dependencies to the rest of the MCS services. Interaction with other microservices is implemented by using predefined interfaces – RESTful[1] APIs and messaging.

7.4.2 Aggregated Marketplace of Ground Station Services

Additional microservices are added to the overall Spaceit MCS deployment to provide the Marketplace functionality to users. Most notable microservices to be added or significantly modified are [25]:

- Contact manager – is responsible for consolidating satellite contact information from different service providers. Since each service provider is using propearitary API, contact manager has to adapt to each of them. Most common implementations are based on REST and GRPC. Every provider defines its own data model and contact manager has to consolidate them into an internal data model. Interface control document published by the providers are proprietary and not publicly available. Spaceit has access to ICDs on contractual basis. Contact manager provides RESTFul API for MCS UI and other relevant services. Message queue is used to request scheduling and cancellation of session services.
- Session orchestrator – responsible for starting, stopping and removing session services on defined time. It has no in-depth knowledge of communication sessions nor service provider interfaces. The orchestrator is using underlying software container runtime for most of its functions. Furthermore, it is using a message queue to listen for requests to schedule and cancel session services.

[1] For further informaion: https://en.wikipedia.org/wiki/Representational_state_transfer

- Contact optimizer – responsible for calculating and managing most optimal contact plans for the satellite missions according to user selected constraints.
- Ground station network gateway – responsible for communicating with the ground station provider resources using supplied APIs to conduct communication sessions with the satellites. At minimum supplied APIs should enable functionality mentioned above and accessible for MCS over network [25].

The role of the product in the context of the overall system of its target users is to provide a satellite operation platform using ground station services from available providers according to constraints set by the user [25].

The Marketplace will be integrated into Spaceit's MCS. Satellite operators will have a satellite monitoring and control functionality side by side with communication planning and management [25].

A component diagram, also known as a UML component diagram, describes the organization and wiring of the physical components in a system. Component diagrams are often drawn to help model implementation details and double-check that every aspect of the system's required functions is covered by planned development [26].

Component diagram of the Marketplace was developed under the guidance of Spaceit CTO Lauri Kimmel and is presented in Figure 14 on page 64.

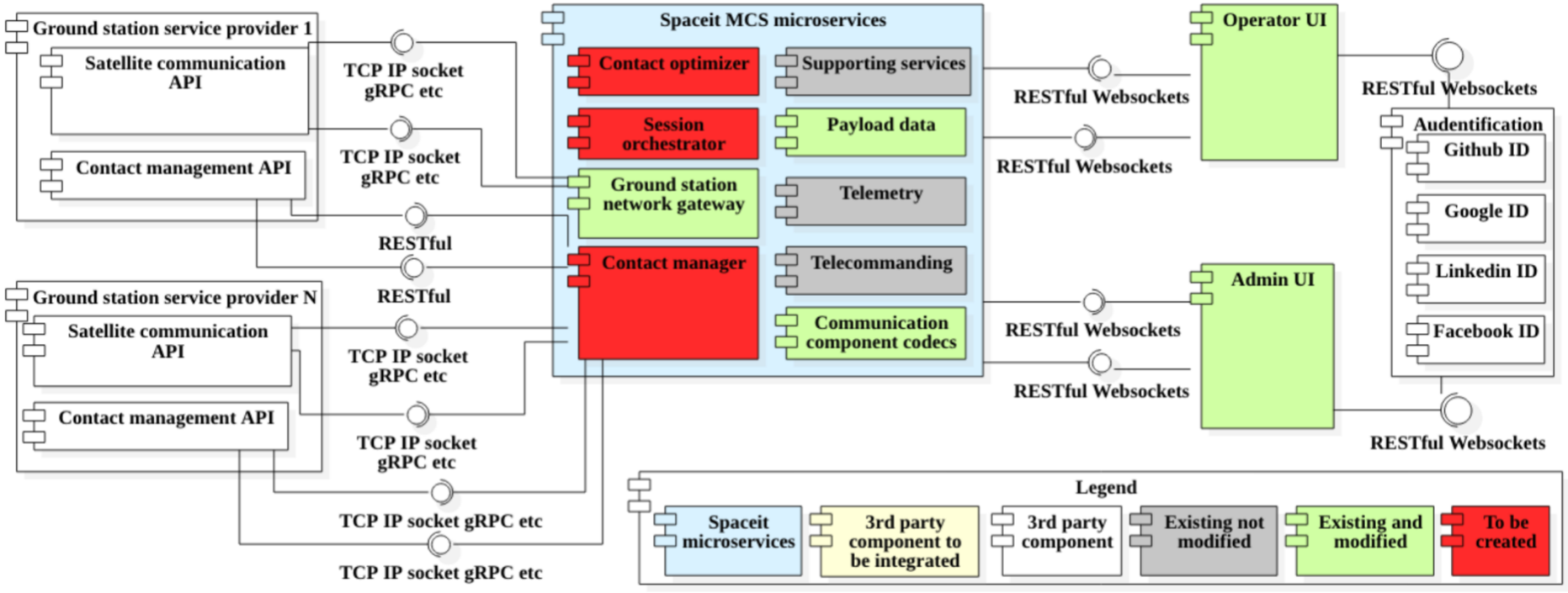

Figure 14. Component Diagram of Spaceit MCS (Including the Marketplace). Authors: Lauri Kimmel, Silver Lodi.

7.5 Prototype

Customer journey maps are used to map the relationship between a customer and an organization over time and across all channels on which they interact with the business. Design teams use customer journey maps to see how customer experiences meet customers' expectations and find areas where they need to improve designs [27].

Software prototyping is the activity of creating prototypes of software applications, i.e., incomplete versions of the software program being developed. It is an activity that can occur in software development and is comparable to prototyping as known from other fields, such as mechanical engineering or manufacturing [28]. Testing prototypes with end-users enables UX teams to visualize and optimize the user experience during the design process [29].

Before the Marketplace activity officially begun in December 2020, a work on the new user interface (UI) of Spaceit MCS (including the Marketplace features) had already been ongoing (though very slowly) for a couple of years. Back in 2018 all together 6 interviews with potential users were conducted by Spaceit team to gather input for the UI. Afterwards 2 additional customer journey mappings were proceeded. Based on the information preliminary axure and figma wireframes were created (presented in Appendix 3 page 75). Using the wireframes 7 views were created in cooperation with a design company (Appendix 4 page 76).

During the Marketplace activity, the following steps will be taken in terms of the UX/UI[1]:

- Additional interviews with 3 ground station networks
- Additional interviews with 4 satellite operators
- Additional in-depth customer journey mappings with 4 users
- Adjustment of wireframes based on the findings
- Creation of new views for the Marketplace functionality of Spaceit MCS.

[1] For further informaion: https://xd.adobe.com/ideas/process/ui-design/ui-vs-ux-design-understanding-similarities-and-differences/

7.6 Development Logic of the Marketplace

Development of the Marketplace will follow agile development methodology and best practices. Scrum guidelines will be used and enhanced continuously during the project to achieve best possible results. Everyday communication between team members will be conducted in person, using emails and online channels like Slack, Zoom or similar.

The project team will use JIRA as an issue tracker and agile management tool. Project documentation will be managed using wiki (Confluence or similar) and shared files (Google Drive or similar). Bitbucket will be used as a central Git repository. Accompanying Pipelines feature will be utilised as continuous integration and delivery (CI/CD) tool. Software components developed during the project are packaged as Docker images and stored in Docker repository. Main development activitiesare in Table 16.

Table 16. Main Development Activities of the Marketplace [24].

Item	**Development Activities**
Telemetry handling	Agile development to complete telemetry data handling functionality including limit checking, alerting, advanced configuration capabilities
Telecommanding	Agile development to complete telecommanding functionality including command repository and advanced configuration capabilities
CCSDS	Consultative Committee for Space Data Systems
Communication protocol codecs	Agile development to add support for required communication protocols including relevant CCSDS and mission specific implementations
Contact manager	Agile development to aggregate and present services from multiple ground station network providers
Ground station network gateway	Agile development to integrate data relay services from multiple ground station network providers
Contact optimization	Agile development to implement contact optimization functionality based on user selectable constraints
Payload data	Agile development to address shortcomings in payload data handling
User Interface	Agile development to enable user interaction with the Marketplace

8 Summary

The purpose of the master's thesis was to create:

- An economic rationale, and
- System architecture for the Aggregated Marketplace for Ground Station Services.

To achieve the goal the author:

- Analysed the company, problems, and demand on the market
- Gave and overview of the developed solution, its main functions and value-add
- Created a business model using business model canvas
- Created a financial forecast of the Marketplace
- Analysed strategic goals, business motivation, business capabilities of Spaceit
- Value strams of the Marketplace
- Main process, use cases and actors of the Marketplace
- Created functional and non-functional requirements
- System architecture of its main components
- Gave a short overview of potential prototype, and
- Development logic of the Marketplace activity.

Eventually the master's thesis became quite voluminous. It is due to the actuality (booming industry), good foundation (ongoing activity, author involved), as well as the complexity of the topic (more explanation to people unfamiliar with the space industry).

Based on the author's opinion, initial goals were succeeded. Based on the master's thesis, it was proven the Marketplace activity to be valuable to the market, Spaceit, as well as other stakeholders. Furthermore, the Solution should improve different strategic capabilities and goals of the company which were identified in the thesis. In overall, the thesis should a valuable input for ongoing and further development of the Aggregated Marketplace for Ground Station Services solution and to Spaceit in general.

References

[1] Various authors, „Wikipedia,“ [Võrgumaterjal]. Available: https://en.wikipedia.org/wiki/Ground_station. [Kasutatud 15 5 2022].

[2] Infinijith Apps and Technologies Pvt Ltd, „Aggregator vs Marketplace Business Model: Their Pros & Cons,“ Infinijith Apps and Technologies Pvt Ltd , 8 7 2020. [Võrgumaterjal]. Available: https://www.purchasecommerce.com/blog/aggregator-businessmodel-vs-marketplace-businessmodel. [Kasutatud 15 5 2022].

[3] Satellite Applications Catapult Limited, “The Small Satellite Market Intelligence Report,” 19 11 2021. [Online]. Available: https://sa.catapult.org.uk/wp-content/uploads/2021/11/Q3_2021_Small_Sat_Report.pdf. [Accessed 28 4 2022].

[4] Euroconsult, „Free Extract - Space Economy Report - 2021 Edition,“ 22 1 2022. [Võrgumaterjal]. Available: https://mailchi.mp/euroconsult-ec/sp_economy. [Kasutatud 28 4 2022].

[5] Consultancy.eu, „‘As a service’ business models: What it is and its benefits,“ 3 3 2022. [Võrgumaterjal]. Available: https://www.consultancy.eu/news/7350/as-a-service-business-models-what-it-is-and-its-benefits. [Kasutatud 15 5 2022].

[6] M. E. I. M. L. D. Q. B. W. Adina Aldea, „Capability-Based Planning. The Link between Strategy and Enterprise Architecture,“ The Open Group, Berkshire, 2016.

[7] Various authors, „Wikipedia,“ [Võrgumaterjal]. Available: https://en.wikipedia.org/wiki/Enterprise_architecture. [Kasutatud 15 5 2022].

[8] Various authors, „Technopedia,“ 2022. [Võrgumaterjal]. Available: https://www.techopedia.com/definition/26477/infrastructure-software. [Kasutatud 15 5 2022].

[9] V. Labrador, „Britannica,“ [Võrgumaterjal]. Available: https://www.britannica.com/technology/satellite-communication. [Kasutatud 15 5 2022].

[10] Various authors, „Wikipedia,“ [Võrgumaterjal]. Available: https://en.wikipedia.org/wiki/Telecommand. [Kasutatud 15 5 2022].

[11] Various authors, „Wikipedia,“ [Võrgumaterjal]. Available: https://en.wikipedia.org/wiki/Telemetry. [Kasutatud 15 5 2022].

[12] Euroconsult, „Free Extract - Government Space Programs, 21st edition,“ 29 1 2022. [Võrgumaterjal]. Available: https://digital-platform.euroconsult-ec.com/product/government-space-programs/. [Kasutatud 28 4 2022].

[13] European Union Agency for the Space Programme, „The EUSPA Earth Observation (EO) & Global Navigation Satellite System (GNSS) Market Report,“ 26 1 2022. [Võrgumaterjal]. Available: https://www.euspa.europa.eu/sites/default/files/uploads/euspa_market_report_2022.pdf. [Kasutatud 28 4 2022].

[14] Vairous authors, „Wikipedia,“ [Võrgumaterjal]. Available: https://en.wikipedia.org/wiki/Business_Model_Canvas. [Kasutatud 28 4 2022].

[15] Altexsoft, „Using Business Model Canvas to Launch a Technology Startup or Improve Established Operating Model,“ Altexsoft, 23 12 2021. [Võrgumaterjal]. Available: https://www.altexsoft.com/blog/business/using-business-model-canvas-to-launch-a-technology-startup-or-improve-established-operating-model/. [Kasutatud 28 4 2022].

[16] Mind Tools, „Porter's Value Chain,“ Mind Tools, [Võrgumaterjal]. Available: https://www.mindtools.com/pages/article/newSTR_66.htm. [Kasutatud 13 5 2022].

[17] Various authors, „Wikipedia,“ [Võrgumaterjal]. Available: https://en.wikipedia.org/wiki/Business_capability_model. [Kasutatud 30 4 2022].

[18] Various authors, „Wikipedia,“ [Võrgumaterjal]. Available: https://en.wikipedia.org/wiki/Business_Motivation_Model. [Kasutatud 30 4 2022].

[19] Various authors, „Wikipedia,“ Wikipedia, [Võrgumaterjal]. Available: https://en.wikipedia.org/wiki/Business_Process_Model_and_Notation. [Kasutatud 29 4 2022].

[20] Object Management Group, „Business Process Model and Notation (BPMN), Version 2.0,“ 3 1 2011. [Võrgumaterjal]. Available: https://www.omg.org/spec/BPMN/2.0/PDF. [Kasutatud 29 4 2022].

[21] Various authors, „Wikipedia,“ [Võrgumaterjal]. Available: https://en.wikipedia.org/wiki/Use_case. [Kasutatud 30 4 2022].

[22] Various authors, „Wikipedia,“ [Võrgumaterjal]. Available: https://en.wikipedia.org/wiki/Use_case_diagram. [Kasutatud 30 4 2022].

[23] GeeksforGeeks, „Functional vs Non Functional Requirements,“ GeeksforGeeks, 29 4 2020. [Võrgumaterjal]. Available: https://www.geeksforgeeks.org/functional-vs-non-functional-requirements/. [Kasutatud 1 5 2022].

[24] L. Kimmel, *Spaceit MCS,* Tartu: Spaceit OÜ, 2015-2022.

[25] Spaceit OÜ, „Aggregated Marketplace for Ground Station Services,“ Spaceit OÜ, Tartu, 2021.

[26] SmartDraw, LLC, „Component Diagram,“ SmartDraw, LLC, 1994-2022. [Võrgumaterjal]. Available: https://www.smartdraw.com/component-diagram/. [Kasutatud 1 5 2022].

[27] Salesforce UK, „Customer Journey Map: What is Customer Journey Mapping & Why is it Important?,“ Salesforce UK, 30 6 2020. [Võrgumaterjal]. Available: https://www.salesforce.com/uk/blog/2016/03/customer-journey-mapping-explained.html. [Kasutatud 1 5 2022].

[28] Various authors, „Wikipedia,“ [Võrgumaterjal]. Available: https://en.wikipedia.org/wiki/Software_prototyping. [Kasutatud 1 5 2022].

[29] UXPin Sp. z o.o., „What Is a Prototype: A Guide to Functional UX,“ What Is a Prototype: A Guide to Functional UX, 2020-2022. [Võrgumaterjal]. Available: https://www.uxpin.com/studio/blog/what-is-a-prototype-a-guide-to-functional-ux/. [Kasutatud 1 5 2022].

[30] Van Haren Publishing, „The Open Group IT4IT™ Standard – In 3 Minutes,“ Van Haren Publishing, 2 5 2017. [Võrgumaterjal]. Available: https://www.vanharen.net/blog/it4it-in-3-minutes/. [Kasutatud 1 5 2022].

[31] Interaction Design Foundation, „Customer Journey Maps,“ Interaction Design Foundation, [Võrgumaterjal]. Available: https://www.interaction-design.org/literature/topics/customer-journey-map. [Kasutatud 1 5 2022].

[32] H. H. O. Ensar Seker, „The Concept of Cyber Defence Exercises (CDX): Planning, Execution, Evaluation,“ IEEE Xplore, 11 6 2018. [Võrgumaterjal]. Available: https://ieeexplore.ieee.org/document/8560673. [Kasutatud 15 5 2022].

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Appendix 2 – Functional Requirements of the Marketplace

Table 2-17. Functional Requirements of Spaceit MCS (Including the Marketplace). Authors: Lauri Kimmel, Silver Lodi.

Requirement ID	Requirement Description	Description of criticality
PR-FUN-001	Contact manager must be able to interact with service provider proprietary APIs to list upcoming contacts with a given satellite	Must have requirement
PR-FUN-002	Contact manager must be able to interact with service provider proprietary APIs to book an upcoming contact with a given satellite	Must have requirement
PR-FUN-003	Contact manager must be able to interact with service provider proprietary APIs to list booked contacts with a given satellite	Must have requirement
PR-FUN-004	Contact manager must be able to interact with service provider proprietary APIs to cancel already booked contact according to provider specification	Must have requirement
PR-FUN-005	Contact manager must be able to collect and present list of all available contacts for the given satellite across service providers	Must have requirement
PR-FUN-006	Contact manager must schedule communication sessions in Spaceit MCS for given satellite and ground station on demand	Must have requirement
PR-FUN-007	Contact manager must cancel scheduled communication sessions in Spaceit MCS on demand	Must have requirement
PR-FUN-008	Contact manager must collect operational metrics related to communication sessions in Spaceit MCS	Must have requirement
PR-FUN-009	Contact manager must store detailed history of booked contacts	Must have requirement
PR-FUN-010	Contact manager must prevent conflicting schedules	Must have requirement
PR-FUN-011	Contact manager must provide RESTful API for its services	Must have requirement
PR-FUN-012	Contact manager must be stateless	Must have requirement

Requirement ID	Requirement Description	Description of criticality
PR-FUN-013	Contact manager must support deployment of multiple parallel instances	Must have requirement
PR-FUN-014	Contact manager restart must not affect functionality of unrelated services in Spaceit MCS	Must have requirement
PR-FUN-015	Contact manager must use authentication and authorization provided by Spaceit MCS	Must have requirement
PR-FUN-016	Contact manager must manage its database schema	Must have requirement
PR-FUN-017	Contact manager must respond to Spaceit MCS internal health checks	Must have requirement
PR-FUN-018	Contact manager must collect and report operational metrics	Must have requirement
PR-FUN-019	Contact manager must be deployable as Docker container	Must have requirement
PR-FUN-020	Ground station network gateway must conduct communication sessions with satellites using ground station provider interface	Must have requirement
PR-FUN-021	Ground station network gateway must be able to receive telemetry data from the satellite	Must have requirement
PR-FUN-022	Ground station network gateway must be able to receive payload data from the satellite	Must have requirement
PR-FUN-023	Ground station network gateway must be able to transmit telecommands to the satellite	Must have requirement
PR-FUN-024	Ground station network gateway must be able to restart communication session with the ground station in case of failure	Must have requirement
PR-FUN-025	Ground station network gateway must terminate connection with service provider when satellite contact is completed	Must have requirement
PR-FUN-026	Ground station network gateway must support deployment of multiple parallel instances	Must have requirement
PR-FUN-027	Ground station network gateway restart must not affect functionality of unrelated services in Spaceit MCS	Must have requirement
PR-FUN-028	Ground station network gateway must use authentication and authorization provided by Spaceit MCS	Must have requirement
PR-FUN-029	Ground station network gateway should manage its database schema	Must have requirement
PR-FUN-030	Ground station network gateway must respond to Spaceit MCS internal health checks	Must have requirement

Requirement ID	Requirement Description	Description of criticality
PR-FUN-031	Ground station network gateway must collect and report operational metrics	Must have requirement
PR-FUN-032	Ground station network gateway must be deployable as Docker container	Must have requirement
PR-FUN-033	Contact optimizer must use data from Contact manager to calculate optimal communication plan	Must have requirement
PR-FUN-034	Contact optimizer must allow user to select optimization criteria according to best price, best quality of contact within time window, most time within budget, longest continuous contact	Must have requirement
PR-FUN-035	Contact optimizer must provide list of contacts to user upon optimization request	Must have requirement
PR-FUN-036	Contact optimizer must use data from Contact manager to calculate optimal communication plan	Must have requirement
PR-FUN-037	Contact optimizer must support deployment of multiple parallel instances	Must have requirement
PR-FUN-038	Contact optimizer restart must not affect functionality of unrelated services in Spaceit MCS	Must have requirement
PR-FUN-039	Contact optimizer must use authentication and authorization provided by Spaceit MCS	Must have requirement
PR-FUN-040	Contact optimizer must manage its database schema	Must have requirement
PR-FUN-041	Contact optimizer must respond to Spaceit MCS internal health checks	Must have requirement
PR-FUN-042	Contact optimizer must collect operational metrics. Preliminary list of metrics: performance, resource utilization, throughput, latency, response time, etc.	Must have requirement
PR-FUN-043	Contact optimizer must be deployable as Docker container	Must have requirement
PR-FUN-044	Spaceit MCS must be able to handle important telemetry data from the satellite	Must have requirement
PR-FUN-045	Spaceit MCS must be able to deliver important telecommands	Must have requirement
PR-FUN-046	Spaceit MCS must be able to handle payload data from the satellite	Must have requirement
PR-FUN-047	Spaceit MCS must provide user interface to interact with aggregated marketplace of ground station services	Must have requirement

Appendix 3 – Wireframe Example of the Marketplace

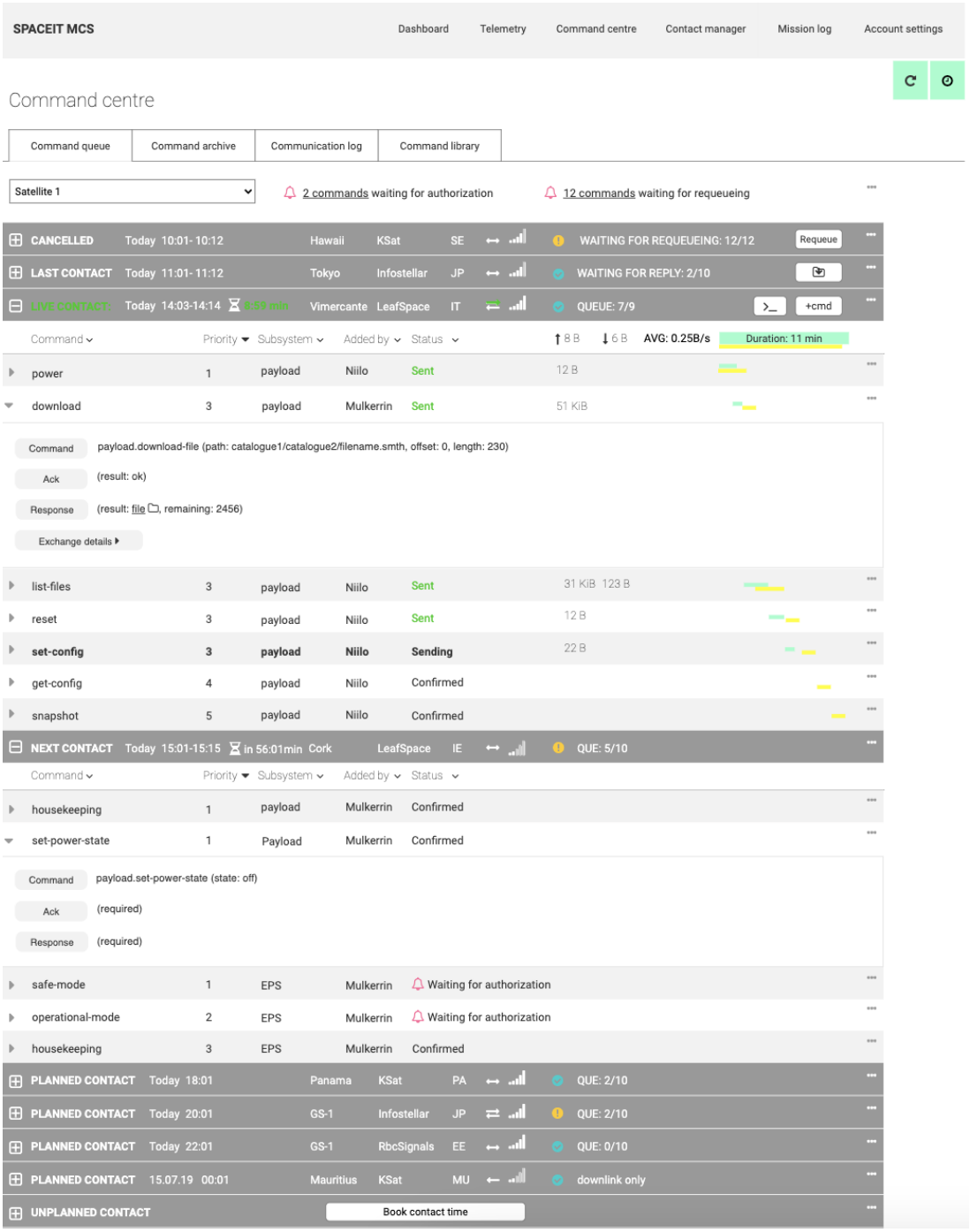

Figure 151. Axure Wireframe Example of the Command Centre View of the Spaceit MCS. Author: Hanna-Liisa Pender.

Appendix 4 – Initial UI prototypes of the Marketplace

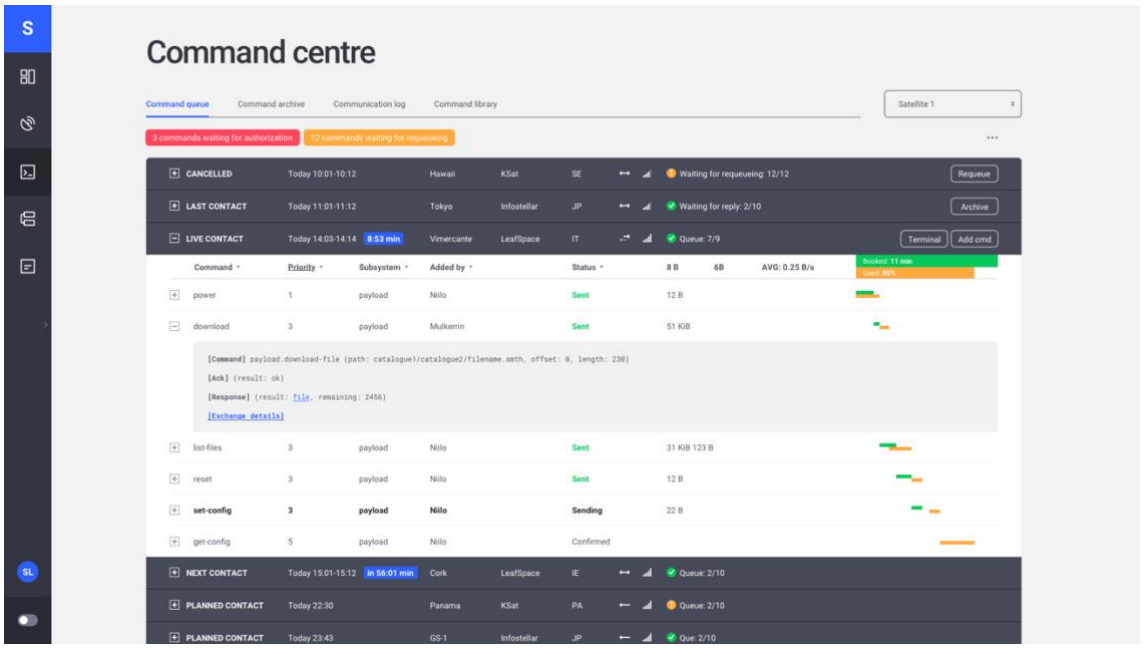

Figure 161. UI Prototype of the Command Centre View of the Spaceit MCS.

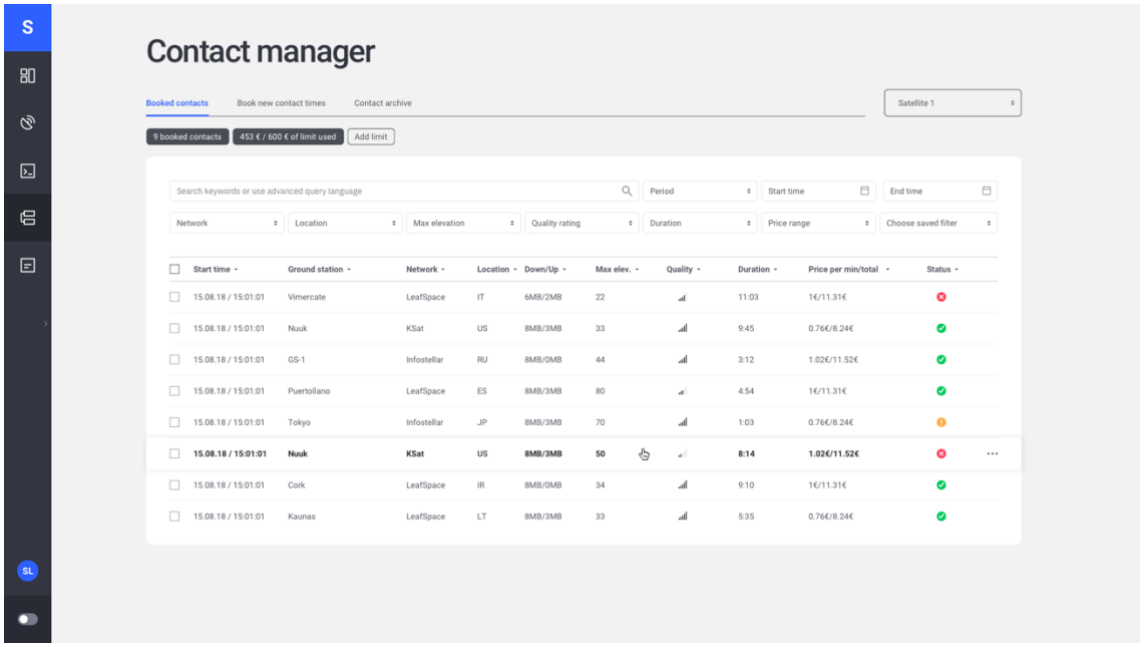

Figure 172. UI Prototype of the Contact Manager View of the Spaceit MCS.