DOI: 10.13009/EUCASS2022-4832
9TH EUROPEAN CONFERENCE FOR AERONAUTICS AND SPACE SCIENCES (EUCASS)

SAMMBA H2020: Ground Services based on 4.0 technologies for NewSpace launch systems

Sophie MISSONNIER, Eduard DIEZ* **, Christopher CHAFFARDON***, Olivier WEITTEN****, Marcelus LIMA*****
and Norbert FRISCHAUF******

**CT Ingenierie,*

Immeuble Arago 1, 41 bvd Vauban, 78280 Guyancourt, France, sophie.missonnier@ctingenierie.com

***GTD Sistemas de Informacion SA,*

Passeig Garcia Faria 17, 08005 Barcelona, Spain, eduard.diez@gtd.eu

****MT Aerospace*

Franz-Josef-Strauß-Str. 5 D- 86153 Augsburg, Germany, christopher.chaffardon@mt-aerospace.de

*****Air Liquide Advanced Technologies*

2 rue de Clémencière, BP 15, 38360 Sassenage, France, olivier.weitten@airliquide.com

******EURECAT*

23, Universitat Autònoma Avenue, 08290 Cerdanyola del Vallès, Spain, circe.serra@eurecat.org

*******SpaceTec Partners SPRL*

Avenue Louise 66, 1050, Brussels, Belgium, frischauf@spacetecpartners.eu

Abstract
Launch service provider (LSP) initiatives aim to provide responsive, flexible and affordable orbiting services to new generations of satellites. Consequently, spaceports operators (SPO) enter the NewSpace business by providing base services, infrastructures and operations, under cost and campaign requirements. SAMMBA, "Standard And Modular Microlauncher BAse services" designs base services relying on 4.0 technological building blocks, which tackle multiplicity through standardisation and scalability: enabling SPO to handle multiple launchers and a LSP operating from multiple spaceports. SAMMBA performs techno-economical design loops in synergy with market survey, regulatory frame and costumers' feedback, outcoming prototype demonstrators of added-value solutions.

1. Introduction

The boom of the NewSpace market and the continuous growth of the small satellites sector lead to a whole new family of launch concepts: the microlaunchers. The microlaunchers define a whole new frame for Spaceports providing base services, where cost, responsiveness and launch rate are a must to those who aim to shape and lead the future space market. Europe seeks to adapt to this new technological, methodological, and economic scenario. The key concept to this new paradigm is multiplicity: the spaceports, to develop their business model, aim to attract multiple microlaunch concepts available on the market, while microlaunch services plan to launch from multiple spaceports seeking an expanded launch scope at a wider range of azimuths and increase their potential launch rate that enable their own business plan goals. SAMMBA's answer is to endow SPO with technologies and services providing standard and modular Base Services (Standard And Modular Microlaunchers BAse services).

The SAMMBA objective is to develop launch base services that enable cost-effective, agile and flexible launch campaigns, empowering future spaceports to operate multiple launch concepts while fitting in the cost and the launch rate targeted in the small payload market. This goal is tackled through two main axes: the design of base services

DOI: 10.13009/EUCASS2022-4832

through model engineering systems (MBSE) and the development and deployment of innovative 4.0 technologies. That approach provides standard, instantiation and modular base services with the capability of being replicated at several spaceports, opening launch concepts to a multi-spaceport scenario. SAMMBA main outcomes are: the deployment of demonstrators and prototypes at spaceports in the Strategic Advisory Board and the presentation of a business plan to exploit and implement those base services at operational level. As a result, SAMMBA contributes to the major goal of increasing European competitiveness in access to space, allowing European Spaceports to offer affordable ground services competing technologically and economically for the launch services and payload market.

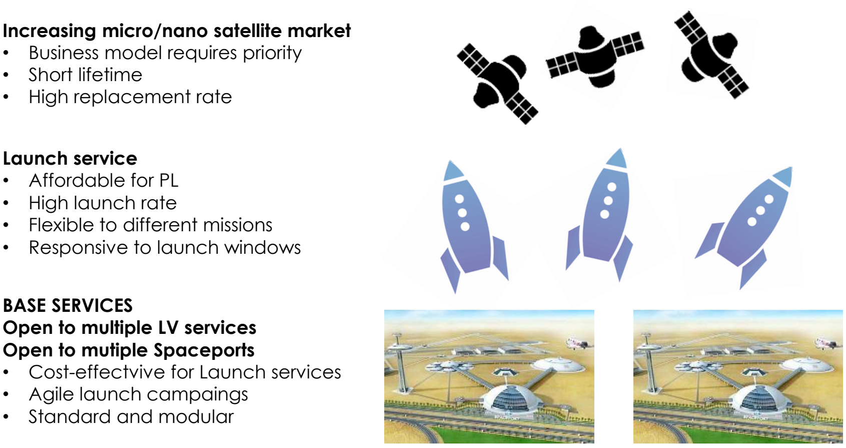

Figure 1: Spaceports to provide services to multiple launchers and payloads

Table 1: Consortium partners

	Expertise	Contribution to SAMMBA
gtd	Information Technologies (IT) systems Control & Command Ground checkout systems	IT virtualization On-board autonomous flight safety Modular control benches
MT AEROSPACE	Structures and mechanical systems	Autonomous operations at launch pad through intelligent launcher IF Modular Mechanical assembly IF's
CT	Multi-physics modelling, techno-economic optimisation, systems design	Innovation Management Functional & operational Analysis
eurecat Centre Tecnològic de Catalunya	Research centre on 4.0 technologies	Autonomous transportation Virtual/augmented reality CBM and real-time scheduling
space·tec PARTNERS	Business Development and Communication	Dissemination of outputs Regulatory survey Market and business case User Manual for clients and investors
Air Liquide creative oxygen	Fluids and propellant systems	Autonomous Wireless sensors CBM and real-time monitoring Mobile propellant storages

Objectives

1. Technological, the design of the Base Services relying on 4.0 technologies to cope with NewSpace requirements:
    - SCALABLE, STANDARD and MODULAR to target multi-launcher and adapting to market evolution and needs
    - DEMONSTRATION of prototypes for new concepts and technologies
    - RELIABLE and SAFE systems and operations allowing high launch rate and responsiveness

DOI: 10.13009/EUCASS2022-4832

2. Business
SAMMBA Business plan is aiming to attract microlaunch market to Europe and to implement operational base services to active Spaceports initiatives during the development and by the end of the project. SAMMBA will take advantage of main Spaceports initiatives in Europe (Andøya [Norway], Azores [Portugal], Esrange [Sweden], CSG-Kourou [France], Grottaglie [Italy]) which are involved as Advisory Board from the beginning of the proposal and actively during the project at two phases: first, in synergy and collaboration during the definition of high level requirements; secondly, providing feedback and review for project outcomes (prototypes deployment and business plan) at the end of the project.

3. Service -oriented vs. launch-centred approach
One of the key factors that have been identified is the legacy of custom designed base services that were specifically developed to comply with a set of requirements coming from the launcher itself. In mirror of this tradition, the targeted objectives of SAMMBA as a Base Service consider the Spaceports and their business objectives on top priority, to attract launch services to their facilities. Follow, in order of priority, the interfaces with the LSPs systems and operations and the payload operators

2. Market analysis

Small satellites (satellites with a mass <500 kg) are disrupting the traditional space practices, enabling new satellite missions such as the deployment of satellite constellations for communication and Earth observation applications into Low Earth Orbit (LEO). These projects have already attracted the attention of numerous players from the Information Technology (IT) and the big data analytics world with financial back-up from public institutions and a prospering ecosystem of Venture Capital (VC) funds. Currently, more than 200 satellite constellations have been announced. However, it is highly unlikely that all of them are going to succeed. Yet, out of the total planned constellations, roughly a third of them already have at least one satellite in orbit and around 10 constellations have been fully deployed. The number of operational satellites is expected to rise from more than 2500 units in March 2020 to more than 13,000 by 2030, driving up the demand for space launches. The growth of the space market is mainly led by the proliferation of mega-constellations (constellations of thousands of satellites such as SpaceX's Starlink), at least one of which is expected to prosper and be fully deployed by 2030. Small satellites below 200 kg will generate an average launch demand of more than 20 tonnes per year in the 2020-2030 timeframe [1], which will be addressed by microlaunchers (<500kg payload capacity) or heavier-lift rockets. Most of the commercial payload demand originates hereby from North America, while European constellations only account for less than 17%. Around half of the commercial payloads are expected to rely on the flexible launch services offered by microlaunchers, resulting in a forecasted demand of 128 orbital microlaunches each year by 2030 [2] (in a medium forecast scenario). This is an important consideration for SAMMBA, as it implies that only a few rockets will be launched at high launch rates. The few microlaunchers that will capture a large market share will be those with high heritage, low production costs and that can be rapidly mass-produced to offer higher frequency. At the same time, we expect many other players to win a small stake in the market, particularly for the launch of governmental payloads. Most spaceports have a single or a few launch pads, often dedicated to a single launch vehicle. Since most launchers are sent into orbit once a year or at even lower cadences, operations at spaceports are currently very limited.

The new microlaunchers will require at least one spaceport to operate. Their selection of the spaceport will be influenced by the spaceport's capabilities to support microlaunch missions, reachable orbits and the regulatory framework (achievable launch rate, the complexity of obtaining licenses, licensing costs, the rigidity of the launch regulations, etc.). Many of the spaceports under development (e.g. Sutherland Space Centre, now SaxaVord - United Kingdom, Whalers Way Orbital - Australia, etc.) and some already operational spaceports (e.g. Launch Complex 1 by Rocket Lab) are assessing how to address these needs, but no flexible launch method compatible with multiple microlaunchers has been successfully implemented yet. SAMMBA should strive to meet the needs of microlaunchers and provide modular services that allow frequent launch services and are compatible with multiple microlaunchers. At the same time, SAMMBA services should be compliant with international regulations, allowing for prompt deployment at different spaceports. The advantages of SAMMBA modular services are manifold. The possibility to support multiple microlaunchers will enable spaceports to drastically expand their operations. By moving to an economy of scale strategy, the spaceport will be able to generate a continuous flow of revenues coming from various commercial launchers. The operational costs for each launch mission will drop with the increased use of spaceport facilities.

[1] SpaceTec Partner analysis

[2] The Chinese demand for space launches is excluded from the study, as considered not addressable by microlaunchers potentially using SAMMBA services

DOI: 10.13009/EUCASS2022-4832

SAMMBA services shall indeed also aim at reducing the costs of the space launch mission, since costs will continue to be a priority for all space stakeholders (spaceport managers, microlaunchers, and satellite operators). SAMMBA intends to enhance the efficiency of the launch mission by providing innovative solutions through model engineering systems and the implantation of innovative 4.0 technologies - thus replacing the need for a dedicated R&D budget for spaceport operators, reducing the complexity of a launch mission and automating certain tasks. SAMMBA will therefore provide a competitive advantage to the spaceport that will adopt its services, enabling them to expand and thrive in the space launcher market.

3. Design approach

To design systems that meet the needs and requirements of the NewSpace emerging market, the consortium drew on its expertise to leverage the benefits of collaboration through the use of relevant methodologies presented hereafter:

- Model-Based System Engineering (MBSE) to dynamically manage the system requirements, functions breakdown, design and allocation to components, usage scenarios and compliance checks,
- high-level requirements definition and functional analysis of services to develop
- survey of innovative technologies, assessed and ranked from a technical and economical point of view

3.1 MBSE modelling approach ARCADIA/CAPELLA

Model-based systems engineering (MBSE) is the formalized application of modelling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing through development and later life cycle phases (INCOSE 2007). A distinguishing characteristic of a MBSE approach is that the model constitutes a primary artifact of the systems engineering process. The focus on developing, managing and controlling a model of the system is a shift from the traditional document-based approach to systems engineering, where the emphasis is on producing and controlling documentation about the system. By leveraging the system model as a primary artifact, MBSE offers the potential to enhance product quality, enhance reuse of the system modelling artifacts, and improve communications among the systems development team. This, in turn, offers the potential to reduce the time and cost to integrate and test the system, and significantly reduce cost, schedule, and risks in fielding a system. The MBSE provides with the following advantages:

- Unification of Design Point, the methodology provides a unified modelling environment for collaborative system development, maintenance and update.
- Traceability within the design by clearly stating the relationships between all system elements
- Automation, the language standardisation allows mass manipulation of the design data through automated scripts
- Granularity, between Abstraction (metamodeling) and instantiation (specific model):

The MBSE method/tool selected for SAMMBA is the ARCADIA/CAPELLA, as the model-based engineering method for systems, hardware and software architectural design. ARCADIA/CAPELLA define the following levels in modelling a system:

- Operational Analysis: This perspective aims to define the user needs and goals,
- System Analysis: This perspective defines what the system needs to accomplish in order to satisfy the user needs defined in the previous level. Functions of the system are defined in this level. Interoperability and interaction between the system and the users/external systems are also defined at this level.
- Logical Architecture: This perspective aims at building a component breakdown of the system carrying the most important architectural decisions. It therefore defines the form of the system (decomposition of the system in components), as well as the function to form mapping (which component carries out which function).
- Physical Architecture: This perspective defines the “final” architecture of the system. Once it is done, it is considered “ready to develop”. It also defines the form and function of the system components, introducing further details and design decisions.

3.2 Perimeter and high-level requirements

The first task on SAMMBA consortium’s hands was to define the scope of the project. Once the scope is defined, the functional analysis methodology could be used to identify and specify high level requirements. SAMMBA perimeter was determined considering the services to which the project could bring the most added value, along with partners’ expertise and a market analysis consolidated by spaceports from the Strategic Advisory Board. The perimeter identifies

DOI: 10.13009/EUCASS2022-4832

the systems and services in the scope of the concept, and at the same time the spaceports and launch service providers most likely to be interested by them: in the end, SAMMBA considers in its scope all European spaceports including the Kourou launch base, New-Zealand and American spaceports. Concerning launchers, European microlauncher vehicles (MLVs) currently in development aiming to put payloads from 200kg to 500kg and from 1 to 1.5 ton in low earth orbit (LEO) are considered (see table below).

Table 2: Spaceports and launch service providers (LSP) inside SAMMBA perimeter

Spaceports in SAMMBA scope	**Microlaunchers in SAMMBA scope**
El Arenosillo (ESP)	Isar Aerospace
Kourou (FRA)	RFA
SaxaVord Spaceport (UK)	HyImpulse
German off-shore platform (GER)	PLD space
Azores (POR)	ENVOL
Andoya (NOR)	AVIO
Esrange (SWE)	Orbex
Sutherland (UK)	Skyrora

SAMMBA perimeter includes most parts of the launch sequence services, and systems associated. The launch sequence starts the moment the assembled launcher leaves the final integration building, and ends with the payload in orbit. SAMMBA focuses on ground segment, so the launch sequence considered for the project actually ends with the launcher firing its engines and lifting-off.
Chronologically speaking, the launcher would leave the integration building horizontally placed on a transport mean. Alongside, a conditioning system would be plugged into the fairing to ensure proper temperature, pressure and cleanliness for the payload. There are usually several kilometres and at least hundreds of meters between the integration building and the launchpad. Once the launcher reaches the launchpad, an erection mean would set the launcher vertically, and position it on the launchpad. The launcher would then be maintained in adequate position, so that the rest of the launch sequence could unfold safely. A battery of tests is then performed on the launchpad, to check the transport did not break anything, and more generally to check that everything is working as expected. The batteries embedded in the launcher would be charged at the same time. Once the tests are validated, the launcher would be filled with propellants, stored until then in tanks near the launchpad and brought to the launcher thanks to fluid lines. Once the launcher filled, the countdown would start and the launcher would lift-off at the end of it. During the launch sequence, a lot of data on the launcher but also on the ground equipment is collected and analysed, including video footage of what is happening. Once the launcher has lift-off, telemetry data would also be collected and analysed. Telemetry, telecommand and tracking (TT&C) means are out of SAMMBA scope but not the data processing.
There are also some services outside the launch sequence that are considered inside the perimeter: maintenance operations on ground segment are part of the scope, along with training of personnel.

With a scope properly defined, the functional analysis methodology leads to SAMMBA high level requirements. These define, in terms of expectations, safety and security measures to follow, the type of fluids handled, the cost of systems, the duration of operations… The main high-level services under SAMMBA, called capabilities in CAPELLA, are:

- Transport the MLV (within the launch site)
- Position the MLV (in launching position)
- Provide conditioning to the MLV for the payload
- Protect MLV from outer environment
- Provide power to the MLV
- Provide launch sequence management solution
- Enable to fill MLV with fluids
- Communicate with the MLV
- Track the MLV
- Ensure the safety of operations
- Test the MLV
- Manage and train spaceport staff
- Maintain the ground equipment in operating condition

The scope being defined and the functions identified, following sections are devoted to the research and trade-off between the different technologies able to answer these requirements.

DOI: 10.13009/EUCASS2022-4832

3.3 Technology survey

CT organised a technology survey among partners, not only to find the most interesting technologies to answer the needs, but also in a system perspective, from an overall ground segment view, which technologies would best fit together. To do so, CT first led creativity sessions on generic topics: Launch sequence management, Fluid systems, Mechanical systems, IT systems and Utilities.
Then, ideas that emerged from these sessions were evaluated in terms of raw potential before being ordered in relevant specific categories (as opposed to generic topic, such as transport mean, fluid storage, data handling, etc.), resulting into 16 building blocks corresponding to functional modules.
The arrangement of ideas for each function to answer inside each block (see Figure 2) resulted into several possible solutions for each block, called an option for the block.

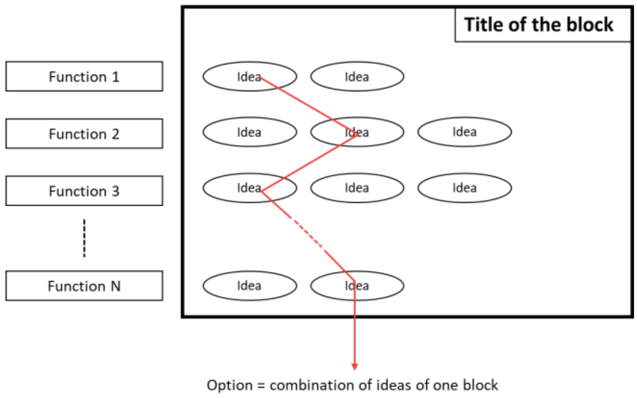

Figure 2: Technology survey methodology: combination of ideas

Several options were defined for each block, evaluated according to four considerations:
- Performance (derived from market requirements, among which genericity, interference with spaceport, ability to reach high launch rate, modularity and deployment ease)
- Cost (CAPEX, OPEX either launch-related or recurring even in the event of no launch, development cost)
- Time (impact on launch sequence duration and spaceport responsiveness, development time)
- Risks (related to feasibility, market, regulations)

Then options were classified inside each block to determine the ones with the most added value for SAMMBA, synergies and incompatibilities between options were looked at, specific and global solutions were thought of.
As a matter of fact, some technologies work best together, some need more time to be developed, some cost more, and a ground segment solution has to consider the association of technologies rather than considering them individually. Some, however, stand out and seem to be of particular interest.
Here is an overview of the most promising technologies identified:
- Launch tower with a set of adapted physical interface between launchers and the tower
- Launcher erection thanks to a counterweight
- Generic clamping interface on the launch pad to maintain the launcher
- Autonomous docking of the tower – launcher set to the launchpad
- Standard fluid interface and set of adaptors between launchers and fluids umbilical
- Innovative sensors to detect fluid leaks and accurately measure fluid levels inside the tanks
- Autonomous guided vehicles for monitoring and surveillance though imagery in real-time
- Blockchain technology to secure data exchanges among the stakeholders during a launch campaign and between several parallel campaigns
- Store launch campaign data in a data lake with the idea of setting-up an AI solution trained with this data to have predictive maintenance
- Virtualised IT infrastructure providing service to operators
- Scheduler bade on AI optimisation algorithms to manage SPO campaigns and operations
- Monitoring and control system compatible with IoT technologies
- Independent and mobile fairing conditioning system
- AR/VR for personnel training and maintenance operations

DOI: 10.13009/EUCASS2022-4832

CT synthesised the work done in a system perspective, and identified the most promising groups of technologies for SAMMBA, or the best compromises for the system to develop. As a counterpart of innovation some technological options not being mature enough to use them as they are today, a demonstrating phase follows the technology survey to reduce their feasibility uncertainty and prove their potential benefit. The systems being demonstrated in the framework of SAMMBA are described in section 4.

4. Demonstrators and proof-of-concepts

4.1 Global demonstrator architecture and use cases

SAMMBA targets a global demonstration to ensure that the selected systems in the technology survey tackle the main goals of the project: the modularity, flexibility and scalability of the technologies, allowing the deployment and operability at spaceports of multi-domain systems and services. Therefore, the initial activity is to define the demonstrator architecture, interfaces and use cases.

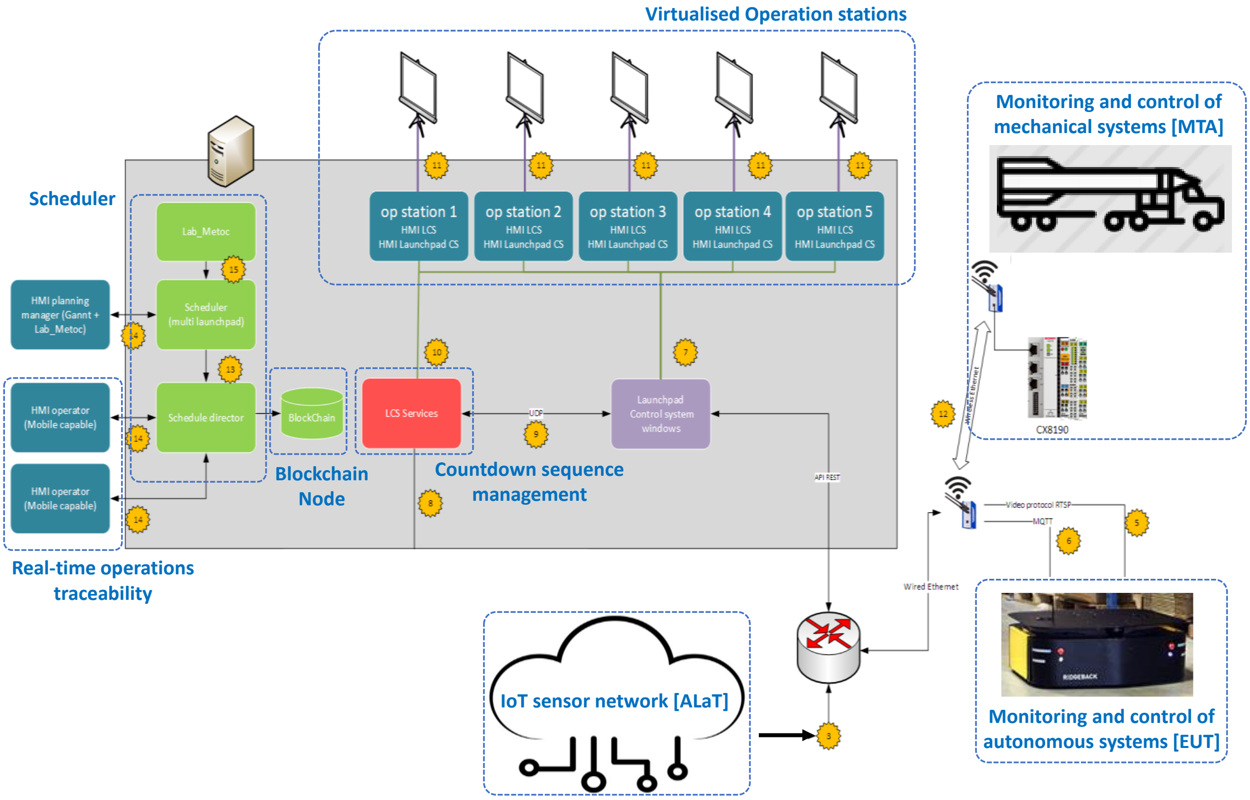

Figure 3: Virtualised IT platform interfaces

The following sections are devoted to the technologies selected for demonstration purposes. The selection is based on the technology survey implemented in synergy with the market survey and cost analysis, obtaining as a result the technological building blocks requiring a demonstration. The objective is to assess their performances, risks, maturity (TRL) and the compatibility with spaceports requirements and development plan. Figure 3 illustrates the SAMMBA services and systems architecture, interfacing the IT, fluids and mechanical building blocks outcome from the technology survey activity in synergy with the market survey. Once the architecture and the interfaces are designed, the use cases define how the services and systems interact with one another in specific scenarios which are representative of the NewSpace operations. The use cases then provide the dynamic context where to test and demonstrate these technologies, as mentioned before, in terms of performance, risk and maturity. The use cases are defined as procedures following steps at which in each of them a function or a service is triggered and the performance can be measured by KPI (Key Performance Indicators). The use cases and the KPI are defined to fulfil the NewSpace expectations:

DOI: 10.13009/EUCASS2022-4832

- Launch Rate and Campaign duration
    - Operations Flexibility and responsiveness in front of failure
    - System validation procedures without holding Launch Base operations
    - Safer and more performant maintenance operations
    - Distributed data in real-time performance: Infrastructure as a service (IaaS) towards->operators)
    - Agile operations and optimal use of resources
- Competitive costs and business model enabler
    - Less operators on-site
    - Less infrastructure
    - Decentralised systems
    - Multi-launcher configuration

There are two main use cases that provide context to the demonstrations:

1. the launch range and launch complex systems monitoring and control (Figure 4)
2. the data handling, traceability and scheduling of operations (Figure 5).

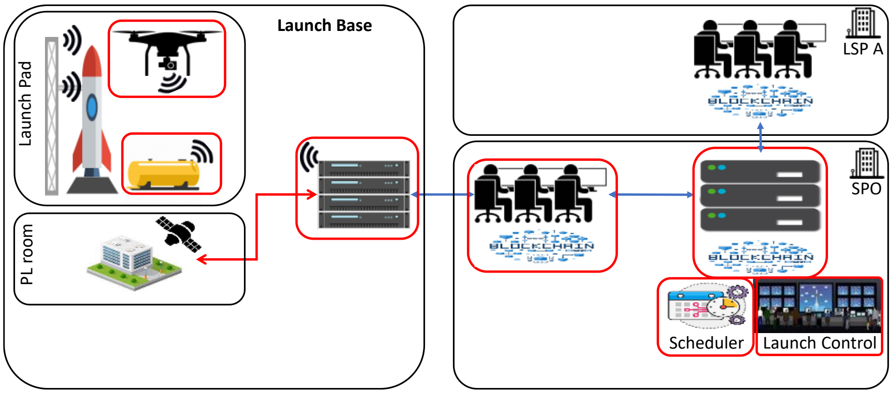

Figure 4: Launch Range and launch complex systems monitoring and control

The fluid systems and the mechanical systems (see 4.2 Fluid systems monitoring and 4.3 Transport and erection systems respectively) in the launch complex interface the IT virtualised architecture (see 4.4.1. Virtualised IT platform) through the monitoring and control system. The monitoring and control architecture (M&C) is based on PLC HW/SW COTS and IoT standards aiming to test the wireless communications between the M&C and the surveyed equipment. Moreover, the IT infrastructure is centralised to ease the maintenance while the services are provided to operators in real-time disregard their location. The real-time performance for operators, the orchestration capabilities of different versions of IT architectures and the monitoring and control of distant systems are the KPIs of this use case.

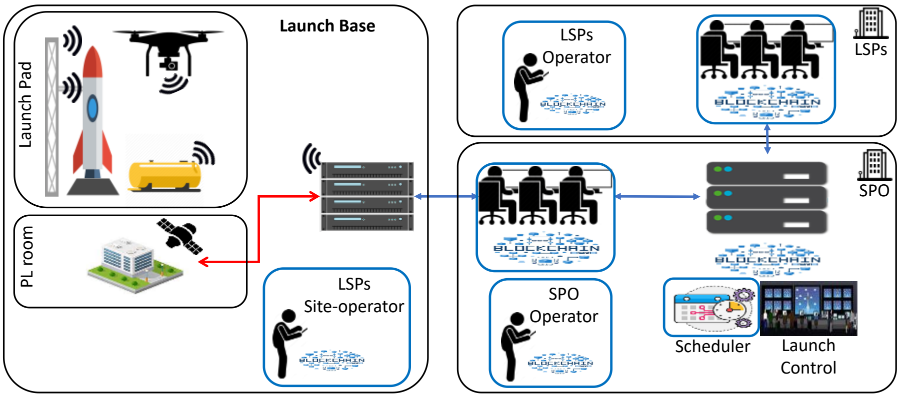

Figure 5: Data handling, traceability and scheduling of operations

The data handling, traceability and scheduling use case assess the communications between different stakeholders with different levels of confidentiality while all of them shall share common data and contribute to the same launch campaign at a spaceport. The management of the alarms, anomalies, nominal and non-nominal events in that scenario represents a challenge. In that use case, campaign events, either nominal or non-nominal, such as the meteorological conditions (see 4.4.2 Environmental situation awareness Tool) and alarms coming from the fluids and mechanical systems through the M&C, are processed in the AI scheduler that optimises the spaceport and campaign operations

DOI: 10.13009/EUCASS2022-4832

(see 4.4.3 Multi-campaign scheduler). The information flow is shared in a private and distributed ledger data base based on Blockchain. The performance in real-time, the confidentiality and security and the capability of global planning of spaceport activities are the basic KPI's of that use case.

4.2 Fluid systems monitoring

Fluid systems monitoring represents a challenge from a risk and operations point of view in infrastructures spread on large surfaces as the spaceports. Two main innovations are proposed in the frame of SAMMBA: automation using drones and massive data collection using IoT technologies. One of the innovations that we aim to implement within the SAMMBA service modules is to provide on-demand inspection of launch campaign operations involving fluid operations with the help of next-generation drones. Thanks to ALaT extensive experience in working with propellants, we are looking forward to ensure the operations involved during a SAMMBA launch campaign are seamless and can be monitored at any point in time during the launch campaign with a limited number of personnel involved in the process. To do so, SAMMBA service modules will be equipped with the required sensors to enable autonomous inspection with the help of drones. The sensors integrated with SAMMBA service modules will communicate with the drones in order to exchange information about the status of operations and infrastructures, mainly leakages. Due to the generic nature of the module, it will be compatible with several launch campaigns regardless of the microlauncher design. With the help of this innovation, SAMMBA aims to reduce the time required for a launch campaign as well as the chances of a launch being delayed. This will in turn help spaceports operate effectively and reduce their operating expenses (OPEX). In essence, SAMMBA will allow spaceports to have a higher profit margin or to offer attractive services to their clients. At the same time new generation of sensors are being tested (pressure, ultrasound and temperature sensors). The objective is to supervise fluid infrastructure and equipment for predictive maintenance purposes by collecting data under IoT technology from launch zone, outside the launch zone and even outside the spaceport. The system monitors in a single point data from facilities, equipment at the base and equipment from stakeholders contributing to the campaign operations even before being at the spaceport facilities themselves, e.g. tracking the supply chain for transport and delivery of propellant storages from the production facilities to the spaceport.

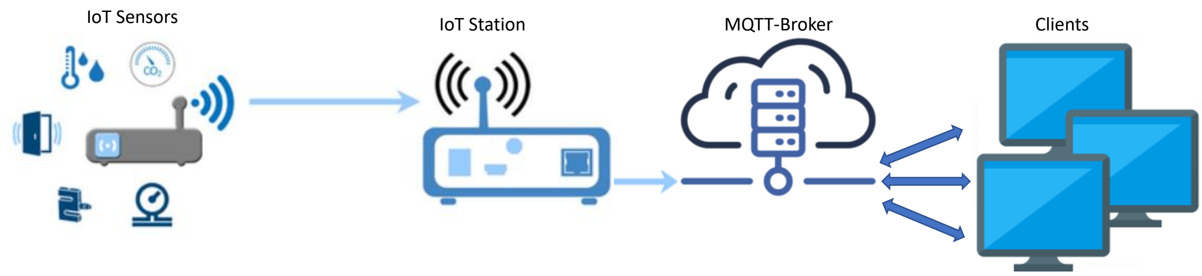

Figure 6: Fluid systems supervision with IoT technology

The supervision of these operations provides with critical information and awareness to other stakeholders, the spaceport operator (SPO) the most, in order to decrease risks and time of operations (e.g. share efficiently equipment and resources). This could allow as well the service providers move boundary for CAPEX cost: necessary equipment could be more easily included (or not) in CAPEX cost.
Figure 6 illustrates how the data is collected wireless from sensors to an IoT station. The data can be transmitted via IoT network (MQTT broker), even some applications allow to communicate via satellite link between the station and the network. The IoT standard communication protocols provide subscribe/publish capabilities to/from several clients under several platforms allowing different stakeholders in the spaceport operations to interface the data via HMI disregard their location. Fluids KPI's are the real-time performance of new sensors for equipment monitoring, the capacity to centralise monitoring of delocalised equipment and the performance of UAV on-board sensor to provide consistent and reliable data through imagery

4.3 Transport and erection systems

Among the demonstrators of the mechanical systems built by MT Aerospace AG (MTA) in the frame of SAMMBA, the erection system is described. The purpose of this demonstrator is to elaborate a pragmatic, pertinent, and modular system to tackle future challenges for mini-launchers, which particularly concern costs, energy consumption, maintenance, safety, logistics, and inspection. Additionally, the demonstrator aims to increase the Technology Readiness Level (TRL) and prove the functionality of the design. This demonstrator has been developed at MTA in an agile and NewSpace industry frame, using MTA's strong heritage in the design and manufacturing of mechanical

DOI: 10.13009/EUCASS2022-4832

ground systems. The demonstrator is using only standard parts, which are easier and faster to purchase compared to special parts. The system aims to demonstrate the viability of a full-scale demonstrator using only standard components, for which inspection, maintenance and purchasing costs are fairly low. In Figure 7, the demonstrator for the erector is shown. The erector consists of a transport frame, a swing frame, and a base frame. The transport frame is specific and therefore depends on the rocket and its configuration, while the other frames (and the interfaces to the transport frame) are generic and therefore designed in such a way that any rocket within the framework considered by the SAMMBA project can use this erector without modifying them.

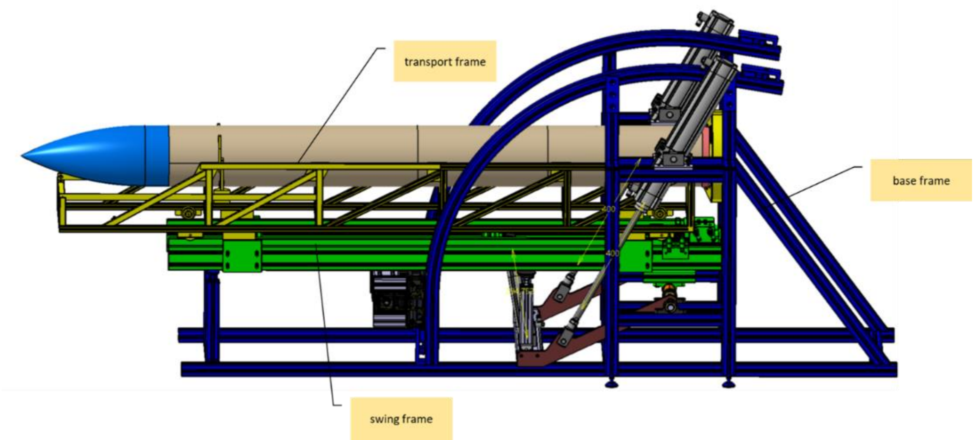

Figure 7: design of the erector demonstrator

The erector is scaled and has a length of approximately 2.2 m and a width of approximately 0.75 m. The rocket dummy used for the demonstration is about 2.4 m in length and has a mass distribution comparable to a representative rocket within the frame of SAMMBA. With this setup, the most critical steps of the preliminary launch sequence are to be simulated. However, the transport and the docking sequence are deemed to be covered by other demonstrators and will therefore not be simulated here.

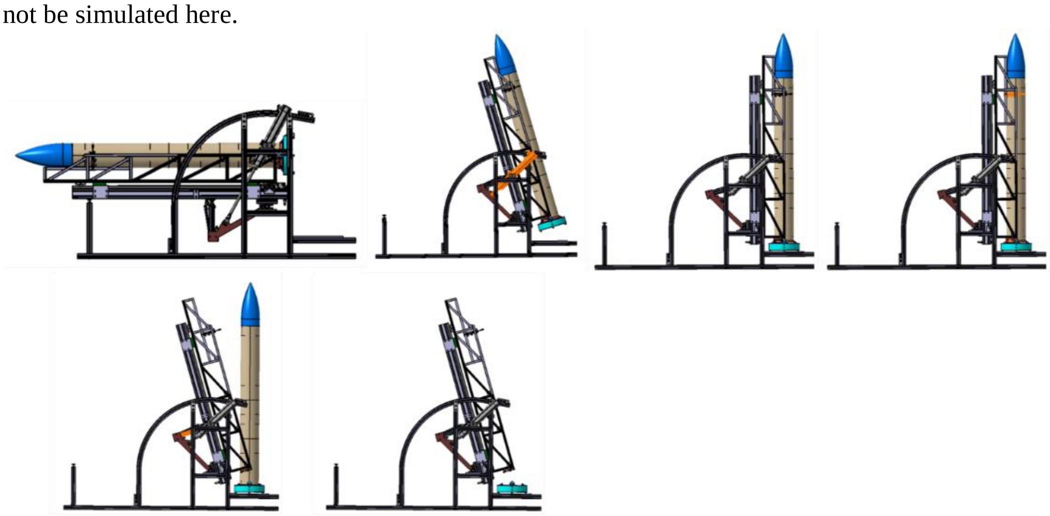

Figure 8:nominal test sequence

The demonstration sequence of the erector is divided into two use cases: the nominal launch sequence and the contingency case of a launch abort. The nominal launch sequence test is:

1. Erection
2. Connection base frame / table
3. Arms opening and cut of energy / data provision on tower
4. Tilting until angle defined by launch procedure (rocket dummy removed manually)
5. Tower moved to vertical position
6. Tower tilted to horizontal position

The contingency case is simulated in the same way, except that the rocket dummy is not removed after tower tilting and therefore is to be tilted back to horizontal position. That procedure also means that the dummy rocket needs reconnection to the tower. With these test procedures the functionality of the developed design is proven. The tests also show that the interactions with other subsystems (e.g. fluidic system) are crucial and thus require to be considered

DOI: 10.13009/EUCASS2022-4832

in the setup design. Furthermore, a full-scale model based on the demonstrator's design will require adaptations that are still under investigation. This demonstrator is designed to demonstrate and test a scaled version of an erector for the future mini-launcher requirements that are foreseen within the SAMMBA project. The KPI's for the erection and transport system are the docking precision, the duration and RAMS of the operation.

4.4 IT systems

4.4.1. Virtualised IT platform

Spaceports embracing the NewSpace paradigm tend to present themselves as infrastructures hosting operations from multiple stakeholders, either sharing the ground infrastructures or contributing to operations during a campaign in a multi-launcher scenario. That scenario creates an increased need for agile monitoring and control operations, and for seamlessly distributing the information to operators and stakeholders involved in the operations in a secure way. The virtualised IT architecture does not only target the operations during the campaign but also enables the management and deployment of multiple architecture instantiations during campaign preparation, post campaign reconfiguration and maintenance phases. For these purposes, SAMMBA has developed a demonstrator that features a virtualised architecture providing services to operators irrespective of their location (IaaS). Its architecture is based on standard components and interfaces and allows to operate and maintain the systems in a more agile way, reducing the required infrastructure, operators on site and both CAPEX/OPEX costs.

The virtual cluster provides operators the information and services for the operations. This cluster runs on standard HW and OS, hence reducing complexity. The systems in the virtual cluster are:

- The Launch Control System provides real-time track processing and flight safety information for the launch base. It centralizes Launch Vehicle Tracking data or situation awareness information such as sea traffic surveillance events or hazard areas. It manages the countdown time & sequence as well as the Enable Launch or Safe Flight criteria and sends the command Flight Termination when needed.
- The Launchpad Control System monitors and controls the status of the launchpad and related facilities. It collects status data and sends commands either through data interfaces (fluid system) or through electrical interfaces (mechanical system). It provides the operators with a highly ergonomic Human Machine Interface that allows a fast reaction to events and failures in the monitored facilities.
- The Scheduling System handles the schedules for all the launch campaigns planned in the spaceport. The scheduler considers requested tasks, needed resources and constraints of each launcher type to propose an optimized schedule to the planning manager. Once the schedule is approved, the system tracks each task via a blockchain database that ensures the immutability of the exchanges between the operators and the system
- LAB_METOC provides information about the weather forecast so that the scheduler system can take its impact into consideration for future spaceport planning of operations

The data and information are shared in a Blockchain private network so operators from different entities can access the information necessary to their shared operations, guaranteeing the traceability of each one's responsibility while securing confidential information between different stakeholders (Spaceport Operator SPO and Launch Service Providers, LSP's, operating at the spaceport infrastructure). The following points describe the main concepts of the architecture and their benefits to the operations at SPO:

Cost-benefit: The optimisation of hardware procurement contributes to simplifying the installation and to reducing the room needed for the platform and its maintenance costs, thus helping minimise the CAPEX due to reduced infrastructure requirements. SAMMBA deployable architecture also helps reduce the on-site operators hence minimizing operating costs (OPEX). The virtualisation of server and computer devices enhances scalability (multi-launcher campaign management) and enables delocalised operations and operators (distributed systems).
Reduced risk: The contribution regarding risk reduction relates to the risk of system unavailability and campaign delay, thanks to more efficient SW maintenance operations and monitoring.
Data Security: Data security is guaranteed through the Blockchain technology proposed for databases, in the format of a private network in which all stakeholders are identified along with their level of access to information channels. Moreover, data security is addressed in operational systems through more classic cybersecurity methodologies and approaches.
Simplified operations: The availability of information, distributed in real-time among the involved stakeholders, makes operations agile thus contributing to a reduction of the time consumed by operations and decision-making procedures. The use of standard technologies and protocols simplifies the IV&V procedures and ensures long-term

DOI: 10.13009/EUCASS2022-4832

durability (increased infrastructures availability, reliability and reduced maintenance) hence also contributing to reduced operating expenses (OPEX).
Universality: System version management/orchestration for SW architecture allows parallelisation of operations and systems configuration for multi-launcher campaigns during campaign preparation and during the campaign itself. Multiple virtualised architectures can be maintained with no increase of HW or operations effort, deploying the appropriate version during campaign preparation, even off-site.
The architecture of the monitoring and control system is generic, thus contributing to the increased versatility of spaceports deploying SAMMBA systems. Applications that run in the virtual cluster in the SAMMBA system may be adapted to each spaceport. Moreover, virtualised architectures from different spaceports can be installed in standard HW with no specific procurement.
Remote operation: Delocalisation of operators and operations from the site itself allows the monitoring and support of operations off-site.

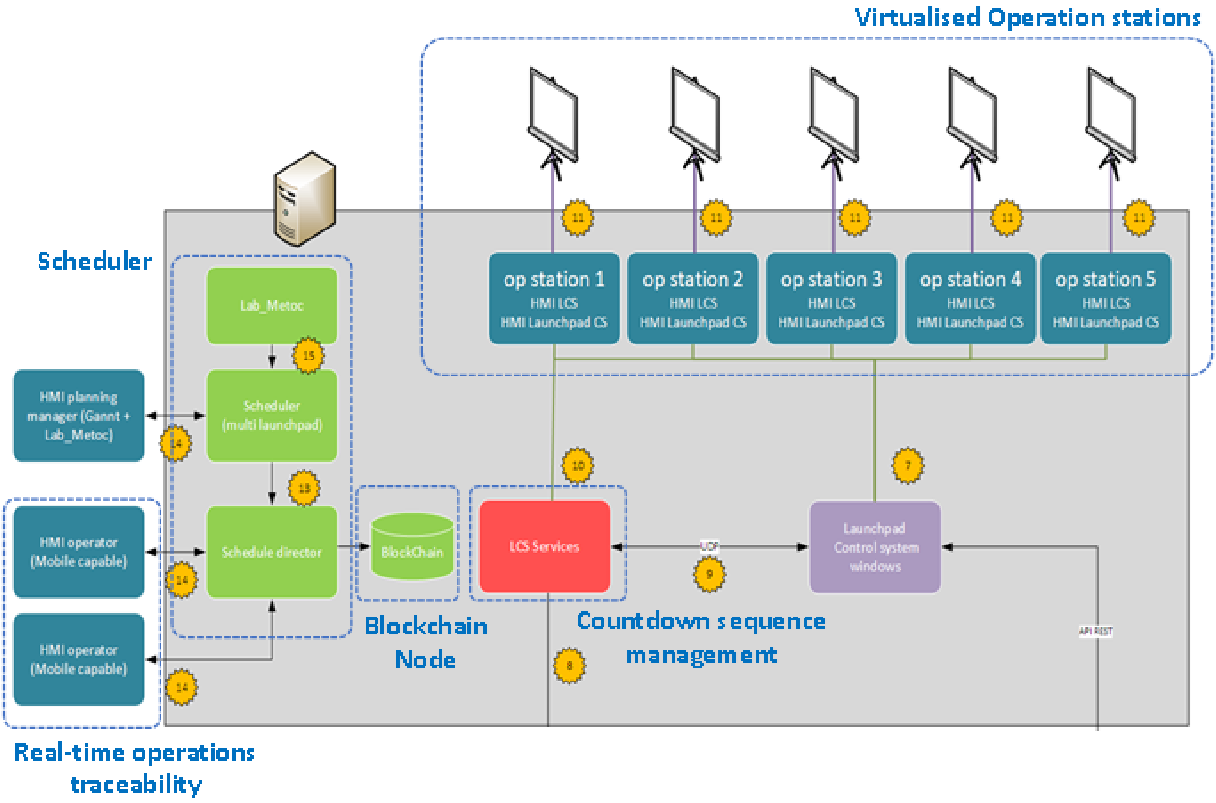

Figure 9: Virtualised IT platform functions

4.4.2 Environmental situation awareness Tool

As part of the work carried out in the SAMMBA project, the Environmental Situation Awareness is a very important topic that meets the requirements of safety and security, autonomy, standardization and reduction of operating costs attached to the future bases. The environmental conditions having an impact on the operations are mainly of a meteorological nature but can also be related to the sea state for the recovery of the launcher components, or of a hydrographic nature for the risk of flooding, or of another nature: forest fires, presence of aerosols in the atmosphere caused by sandstorms or volcanic eruptions, etc. In this context, CT developed the LAB_METOC Decision Aid Platform to assess all the risks related to environmental conditions likely to degrade the overall level of success of an operation. LAB_METOC expresses these risks in terms of factors of impact of environmental conditions on operations, each factor having its own level of importance depending on the considered operation.

This approach applies both to a complete launch campaign and to a specific operation carried out on the base. In all cases, it is a matter of breaking down a complex operation into several simple activities for which relevant impact factors are expressed. Finally, LAB_METOC assesses the overall risk relating to the operation by combining and weighting the various impact factors considered. The objective of LAB_METOC is to provide decisive support for mastering the chronology of a launch campaign, by providing all the concerned players with knowledge of the risks

DOI: 10.13009/EUCASS2022-4832

linked to environmental conditions and by contributing to building a reliable picture of the Operational Situation of the base.

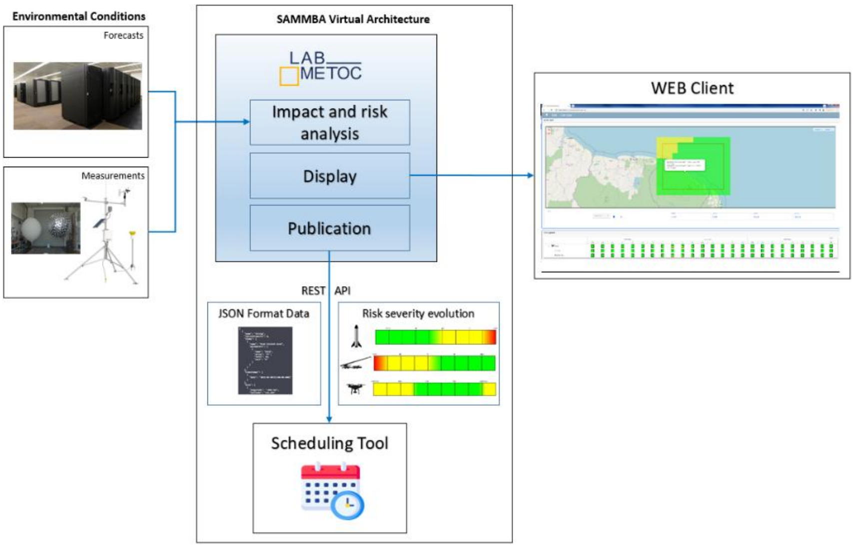

Figure 10: LAB_METOC in the SAMMBA virtual architecture

A Decision Support Approach by LAB_METOC during the duration of a campaign makes possible to anticipate variations in the risks that weigh on operations, over a period from the present moment to several days or weeks in the future, by exploiting forecast data. During the final phase of the chronology, LAB_METOC changes pace to better respond to the particular constraints of rocket firing and flight. LAB_METOC then integrates the measurements of the observations made locally, as well as the data describing the state of the air column above the launch pad. The Decision Aids produced by LAB_METOC are intended for flight directors, persons responsible for the various activities carried out on the ground during a campaign and more generally, all persons involved in safety on the launch base.

The LAB_METOC outputs are presented in the form of dashboards, timelines and impact maps, trend curves and briefings. The clarity and conciseness of the information presented is essential so that the picture of the Environmental Situation is understandable at a glance. LAB_METOC is integrated into the virtualized SAMMBA platform (see section 4.4.1) and offers a Publication Service for its products via a REST API, in particular for the SAMMBA scheduling tool (see section 4.4.3).

After the analysis and the processing of the input meteorological data, LAB_METOC provides a risk assessment on each site representing on the map the aggregation of the risks of all the activities considered on each site, at each time step of the considered period. Thresholds are defined in order to represent the level of severity of each risk: Thus, the decision maker can understand at a glance if the planned activities involve risks related to environmental conditions, what are the evolutions of these risks in the period of interest considered, and make the necessary decisions.

4.4.3 Multi-campaign scheduler

The spaceports of the future are intended to reduce campaign times by increasing the number of launches per year. In addition, they seek to share infrastructures at the same time, increasing the launch rate and minimising waiting times. However, this new concurrent approach, where contracts fight for resources, brings new management difficulties at the global level. Numerous constraints such as contract priorities, launch deadlines or slots, launch types with different environmental or infrastructure constraints, create a complex puzzle to manage manually. In addition, changes in ongoing spaceport operations (e.g. delay of a launch due to bad weather) or the acquisition of new contracts can greatly affect the planning of future launches, requiring new schedules.
The spaceport scheduler is intended to automatically provide the most appropriate global campaign planning in a multi-campaign scenario, considering the constraints of the type of launch, its needs and limitations. The spaceport scheduler takes advantage of the benefits of AI to return optimal planning in a reasonable time (order of minutes) providing a valuable support for the decision-making at spaceport management level. The spaceport scheduler is a global service which interfaces and collects any service/tool that provide information about possible changes in the scenarios. The performance of the scheduler (KPI) is assessed by the optimisation of the resource in front of those different scenarios

DOI: 10.13009/EUCASS2022-4832

in a spaceport, either nominal (new contracts) or non-nominal (aborted launches, failures in operations), form either autonomous systems or operators.

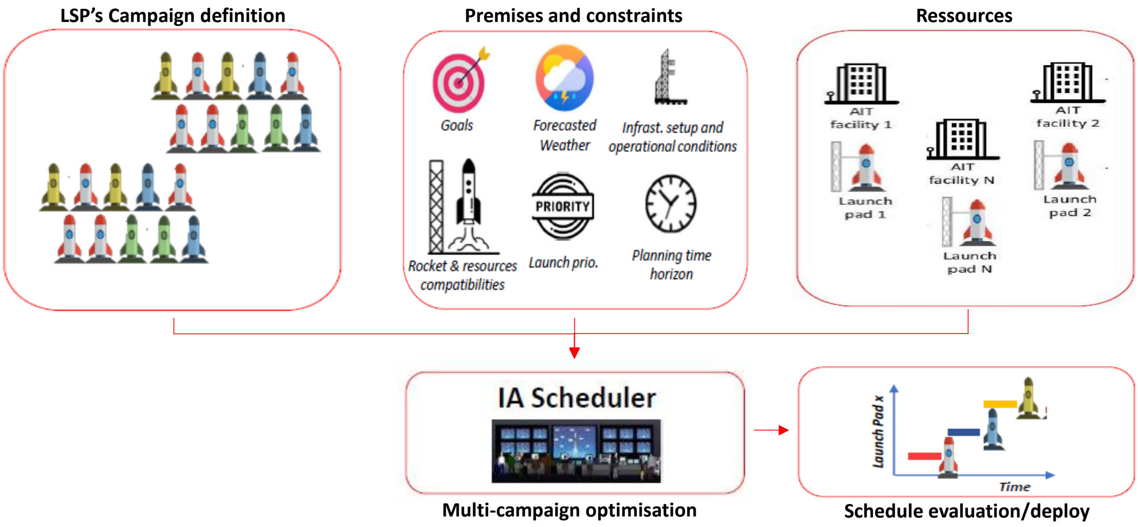

Figure 11: Scheduler definition and configuration

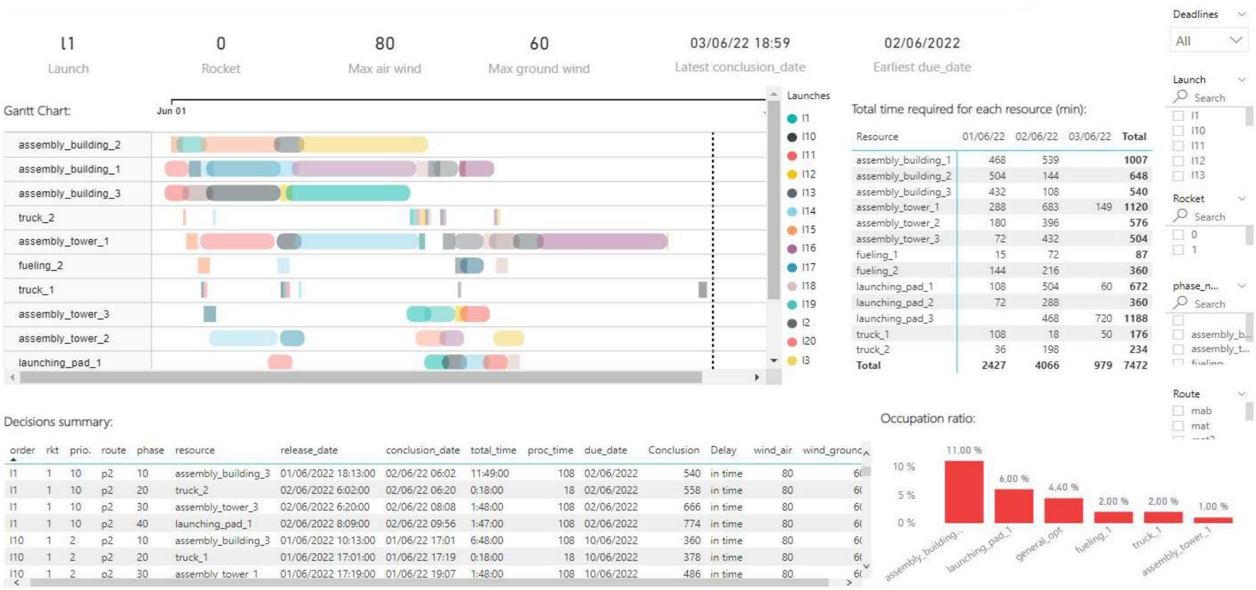

Figure 12: Scheduler operator station view

As a result, a global scheduler/planner provides a holistic and optimal use of spaceports resources and operations:
Costs: the system helps reducing cost by optimizing the campaign times in a scenario with multiple launchers sharing resources. The system increases the performance of the spaceport by better aligning the use of resources. Mainly the improvements offered are aimed at helping to reduce both CAPEX and OPEX costs. CAPEX by optimising the use of infrastructure and resources, reducing the need to acquire new ones. OPEX by optimising the use of operations, reducing the need to hire more staff.
Automation: the sequencer automates manual processes such as the sequencing of campaigns and their stages at a global level. However, it should be noted that the results of this automated process will be supervised by an operator responsible for the final decision
Risk: the system helps mitigate risks because the Spaceport Scheduler considers multiple constraints and assumptions during the optimisation process, minimising possible inconsistencies in campaign planning that can occur during manual planning.
Campaign time: in a scenario with multiple launchers on the same special port, the recommender helps to reduce time by minimising waiting times between the use of shared resources in operations like launch sequence, reconditioning, maintenance.

DOI: 10.13009/EUCASS2022-4832

Genericity/scalability: it is a generic system to support special ports, it is compatible with different spaceports and considers multiple launchers.

5.Conclusions and future work

The prototypes presented in this paper are under development looking forward to being pitched at the end of the project (December 2022 at GBSF2022 conference) to spaceports initiatives under development. The market studies and the feedback received place the outcomes of SAMMBA at the right timing to become operational and deployed in future spaceports operating in the NewSpace context. Moreover, the modularity and scalability of the concepts demonstrated allow to align further developments with the spaceports roadmap, upgrading the functionalities and capabilities of the services from basic for first maiden flights towards full-operational capabilities (FOC). As a result, SPOs can implement an incremental approach to adapt to their market needs of the LSPs. SAMMBA is currently in contact with several spaceports such as CSG, ESRANGE and ASC, in the frame of near future projects that would allow to push forward the concepts towards operational.

Acknowledgments

The European Union's Horizon 2020 SAMMBA project is being implemented by a consortium of six European partners: Air Liquide Advanced Technologies (France), CT Ingénierie Paris (France), EURECAT (Technology Center of Catalonia, Spain), GTD Sistemas de Información (Spain), MT Aerospace (Germany) and SpaceTec Partners (Belgium). The project has commenced in January 2020 and will last for a total of three years.
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 870451 (follow us at https://www.linkedin.com/company/sammba-h2020/ and more https://sammba.eu/)

References

[1] Diez, E., et al. 2021. SAMMBA’s standard and modular services: smart use of 4.0 technologies to fit ground operations for NewSpace challenges. In: *ESAW ESA workshop on operations*.

[2] Diez, E., Perrel, F. 2017. Base location selection and ground segment architecture design devoted to ALTAIR new airborne launcher service for payloads. In: *GBSF Ground-Based Space Facilities symposium*