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Development of Automation Tools for In-Orbit Operations

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Abstract

Founded in 2015, In-Space Missions (ISM) has grown rapidly; ISM's Faraday-Phoenix satellite was launched in 2021 and further missions are scheduled to launch in the near future. Spacecraft operations has played a fundamental role in the company's offering requiring significant development of the internal infrastructure. Initially, software was sourced through various third parties which allowed for a rapid turnaround given the limited timeframe of LEO CubeSat missions. However, the complexity of the ISM rideshare missions highlighted the need for flexible and robust systems that would provide increased automation but with the option for manual operator intervention at all stages. The paper describes the roadmap for ISM's development and enhancement of the underpinning automation tools to complement third party operations software.
Keywords: Ground Segment, Architecture, Automation, Optimisation, Software, Roadmap

Acronyms/Abbreviations
CDP: Client Data Portal
ConOps: Concept of Operations
CSPS: Contact Schedule Planning System
GS: Ground Segment
ISM: In-Space Missions
KPI: Key Performance Indicator
LEO: Low Earth orbit
LEOP: Launch & Early Operations Phase
S/C: Spacecraft
SMT: Service Management Tool
TLM: Telemetry

1. Introduction

As the new-space industry grows and operations-as-a-service becomes more of a standard product offering, the need for enhanced automation at all stages becomes critical to ensure an efficient and reliable service. Efficiency and reliability shape the derived requirements of the mission and supporting system. They create a focus on building an infrastructure that employs a high level of automation both on the ground and in orbit, as well as tools that allow for proper capture and tracking of performance metrics.

In-Space Missions (ISM) has developed a suite of automation tools, with plans for further development and optimisation, to allow for streamlined operations and flexibility for customers. These tools can be used for missions designed and developed both internally and externally as a result of implementing a standardized architecture. Tools that can be accessed and integrated seamlessly with external user systems create versatile options for operations.

Currently, many LEO CubeSat missions are being developed to be as cost effective as possible, leading to easier access to space, as well as access to data from the on-board payloads. One way to reduce costs is to rely on external services that can be used to enable the mission, without the need for internal development or maintenance. Many companies offer a full ground systems or operations architecture as a service; however, this can be a costly addition to the mission budget. Smaller service elements such as Ground segment and Operations capability, often accessed through cloud-based interfaces can also be found. These often utilise a large degree of automation, and extending these external services with internally developed tools can enhance missions' capabilities whilst saving cost.

2. Initial Software Requirements

Defining the initial requirements for the software needed to manage and operate a satellite can be challenging, especially when designing the Ground Segment & Operations architecture for a first mission. ISM's main objective was to have a system that is robust and flexible allowing for operator intervention. The advantage of mission agnostic tools was also evident as it would facilitate portability onto future missions.

Due to limited resources at the beginning of ISM's development, the Space and Ground software for running the spacecraft was outsourced. This is often a choice made by smaller companies, as it allows access to a team of experienced developers and tools that already have heritage on other missions. However, to maximise the usability and reliability of the software components, an additional set of tools was needed to optimise the whole Operations chain. These tools link into the outsourced code, in order to automate the system according to mission requirements. Although outsourcing software development can accelerate progress, it is still necessary to have an in-depth knowledge of the underlying logic in order to make best use of the code.

The requirements were derived from ISMs internal development plan which described how the ground/space chain was to function. The key areas were:

- Platform accessibility for payloads
- Ground segment accessibility
- Data availability (both Platform, Payload and Ground Segment)
- Spacecraft safety

3. Automation Tools

Based on the requirements, a set of automated tools has been developed in addition to the existing Mission Management software.

- Ground Segment Monitoring Tool

Responsible for monitoring of the Operations and Ground Segment system, this tool collects the telemetry from both the In-Orbit and Ground systems to notify operators of any anomalies or system outages. Alerts are raised based on thresholds set within the tool so that operators can respond promptly to safety critical messages.

- Client Data Portal (CDP)

The main interface between the Customer and their payload, and the platform. All payload tasking requests are submitted through this tool. These are time-based and the customer can request changes in any parameters as necessary. Following execution of any payload activities, the data is then automatically pushed to the CDP to be collected by the customer.

- Service Management Tool (SMT)

This tool holds all the Service Delivery goals of the mission, tracking requests and information through a ticket-based system. The service can be monitored against key performance indicators (KPIs) and workflows to ensure consistency and structure. The SMT facilitates tracking and reporting against targets. In addition, it is responsible for assigning a Point of Contact between the customer and the project team and keeping log of all communications and issues raised. Whilst this tool operates mostly based on automated workflows, it also allows for intervention at each point. This is essential during critical phases of the missions such as Launch and Early Operations Phase (LEOP).

- Contact Schedule Planning System (CSPS)

The CSPS handles the interface between the ISM ground system and the Ground Segment provider, as well as the generation of the on-board schedule responsible for executing any on-board activities. This whole process, if handled manually, can be time-consuming and is the main area where human error is likely to occur.

- Automation Scripts

Various scripts have been developed to overlay and join up many of the tools to decrease the need for operator intervention. The scripts are configurable and (where possible) mission agnostic. The benefit of using scripts in this way is that they can be tested on a simulator environment, and during the build and test phase of the mission.

Fig. 1 shows how the different tools work together to facilitate the payload tasking workflow.

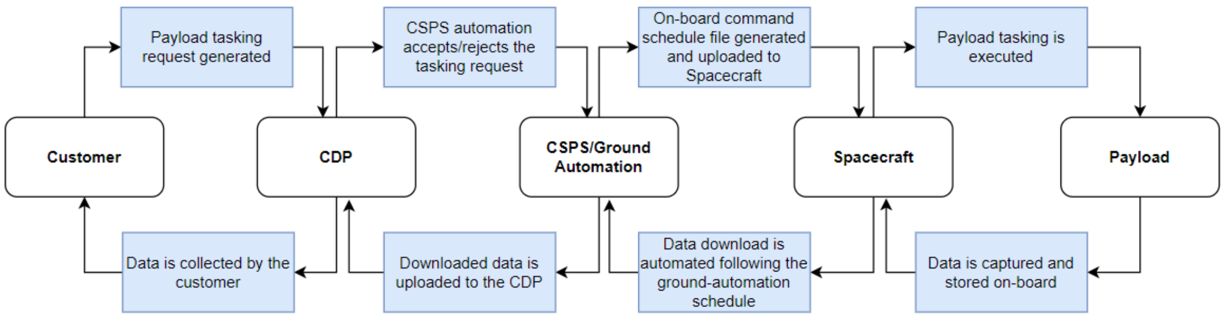

Fig. 1. Payload tasking workflow.

4. Impact on S/C Operations

The tools described in Section 3 have allowed ISM Operators to better monitor overall mission status, but also provide a key interface between all the existing external tools, such as the Ground Segment Service. At each interface point, a RestAPI architecture has been utilised to allow for scaling and additional input if needed.

In particular, the Ground Segment Monitoring Tool not only ensures quick intervention for highly critical issues but also better awareness of the overall spacecraft status. It performs checks consistently on a large pool of parameters obtained from the spacecraft which an operator may not immediately notice during the limited time of a live ground contact. It also provides a data visualization tool facilitating trend analysis performed by the mission's systems engineers. Fig. 2 outlines the interaction of the Ground Segment Monitoring with the SMT to notify operators of any incidents.

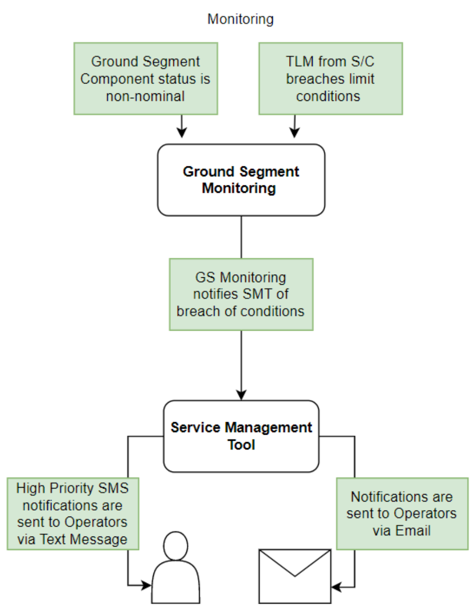

Fig. 2. Ground segment monitoring workflow.

The use of the CDP and SMT has significantly aided tracking the different Service Level Agreements with customers and ensuring that they are met. These include the time to respond to information requests or resolving an incident with the spacecraft. Dealing with multiple missions or payloads increases the need for automated tools that can handle customer tasking requests in an efficient way by streamlining acknowledgment responses, schedule generation and conflict resolution. For this chain to work, however, there need to be clear checkpoints at which an operator can intervene if required with alert messages being raised to notify of any issues.

Finally, the automation scripts as well as the CSPS are used daily to manage the ground contacts with the spacecraft and perform the planned operations. As a result, the resources required to monitor and operate the ground contacts on a regular basis have decreased. The scripts that have had the greatest effect on day-to-day operator workload focused on the following activities:

- Data Downloads (Platform and Payload)
- Data Processing and Archiving
- Schedule Generation and Upload for tasking payload activities
- GS Set-up at the start of the contact
- Key Telemetry collection and transfer to GS Monitoring tool

5. Further Development

Having a consistent development plan is key to ensuring that ISM is continuing to offer the best solutions both for customer operations and for internal improvement. At the beginning of the development, a plan was formulated for how the Operations and Ground Segment architecture would best fit the needs of the initial missions. Whilst this overview was important to allow for the first stages of the development, many modifications and scope changes have been needed to meet the challenges and idiosyncrasies of each mission.

Interfacing with external software became the focal point for automation of standard operations, such as data storage, download and processing, housekeeping activities and spacecraft safety. These were the target areas for improving automation, and in doing so has provided the opportunity for reduced operator interaction.

Now that these standard automation tools have been defined and implemented in operations, it has been possible to step back, revisit the longer-term development plan, and begin to address any tech debt that has accrued. The targets for future automation are for improvement of the overall service, including optimisation of the mission (orbit maintenance), contextualisation of safety notifications, data legacy and storage, customer interaction and refinement of the customer journey during operations.

Focusing on flexibility and portability has been an important lesson-learnt during this development. Implementing strict rules and objectives is important to ensure a coherent and consistent approach but can be limiting when starting the development or utilising a tool that has been developed by a third party. Furthermore, strict timescales meant that a large amount of tool development work, such as the Service Management Tool, Client Data Portal and Automation Scripts had to be done before tangible customer interaction took place. Furthermore, targets were set, and requirements confirmed before it was possible to understand how the spacecraft itself would operate in orbit. This meant that when these tools were initially rolled out, there was an adjustment period where certain scenarios no longer fit the functionality of the tool due to changes to the mission. This iterative approach has been beneficial in allowing ISM to improve its systems to better fit the needs of current and future missions, leading to better requirement capture and ConOps development. Understanding how different external tools inter-operate and complement each other has given ISM the opportunity to better define its development plan; including working with customers to obtain feedback and, in some cases, re-define methods and use-cases.

6. Conclusion

Gaining a thorough understanding and building on requirements set in the initial stages of ISM’s development, and before any missions were in operations has proved to be challenging at times; but overall, the underlying software components have remained the same. Allowing for portability across multiple systems, and interfaces, despite sometimes conflicting use-cases has been necessary to create a functional and coherent system. Whilst the ambition of full automation has not yet been fully realised, the work conducted so far has aided our design and highlighted important additions to the automation development.