

SpaceOps-2025, ID # 558

## FOCSE MMX ROVER GROUND SEGMENT

Marie Boutet<sup>(1)</sup>, Julien Baroukh<sup>(1)</sup>

1 : CNES, Centre National d'Etudes Spatiales, France

### Abstract

MMX (Martian Moons Exploration) is a Japanese space mission to the Mars system that will explore Phobos and Deimos, the Martian moons, and bring back to Earth a regolith sample from Phobos. Several scientific instruments are part of the MMX among which CNES provides MIRS an imaging spectrometer and Idefix, a French and German Rover. CNES also contributes to MMX through its flight dynamics expertise. MMX mission will be launched in autumn 2026, and Idefix landing on Phobos is planned for the very end of 2028.

JAXA manages the MMX mission operations during all the operational phases. CNES and DLR are both responsible for Idefix operation, in close coordination with JAXA. Two independent ground centers are set up in this regard. Operational data are synchronized between the two of them. Each center has its own implementation though they use the same commanding tool suite and share a planning tool. CNES Ground Segment also hosts Flight Dynamic System (FDS) and camera images processing low level chains.

Located at CNES, the French Rover Ground segment is part of the FOCSE (French Operation Center for Science and Exploration). It is based on CNES Initiative for Space Innovative Standards (ISIS) product line, that fulfills most of the Rover ground and flight operation's needs, completed by mission specific tooling.

In a first part, this paper will introduce MMX Idefix Rover mission and provide an overview of the operation and mission ground segment. Then, in a second part, the CNES Ground Segment for MMX Rover will be detailed, to present its requirements, its architecture and its high level development strategy.

**Keywords:** Martian Moons eXploration (MMX), Rover, Ground Segment, Idefix

## Acronyms/Abbreviations

JAXA	Japan Aerospace eXploration Agency,
CNES	Centre National d'Etudes Spatiales,
DLR	Deutsches Zentrum für Luft- und Raumfahrt,
MMX	Martian Moons eXploration ),
MiniRad	(miniaturized thermal mapper),
MUSC	Microgravity User Support Center
FCT	Flight Control Team
FOCSE	French Operation Center for Science and Exploration
GCT	Gournd Control Team
ISIS	Initiative for Space Innovative Standards
RAX	Raman spectrometer
SDB	System Data Base
SLUD	Separation, Landing, Uprightening and deployment
TC	TeleCommand
TM	TeleMetry
SSA	Sub-System Authorities

## 1. Idefix mission introduction

Idefix Rover is a French/German contribution to Martian Moons eXploration (MMX) mission, the JAXA space mission to reveal the origins of Phobos and Deimos, the two satellites of Mars. To reach its objectives, MMX will couple three complementary approaches, exemplary of the missions of the next decades: global characterization by remote observations, in situ analyses down to the microscopic scale from Idefix Rover that will land on its surface, collection and return to Earth of regolith samples from Phobos for laboratory analysis. The operations should last two Martian years, to be launched in 2026 and return of Phobos sample to the Earth around 2031.

Phobos is the largest (27\*21\*19km) and closest moon of Mars, it has a quasi-circular orbit around 5000km high with a period of almost 8hours, called a Phod, short name for Phobos day. Phobos has a very low gravity that is variable upon the localization on its surface, but also time of the day.

Idefix (see Figure 1 Idefix Rover) is a small rover (25kg) that will be deployed on Phobos surface by MMX probe. It is a scout, a demonstrator and an in-situ science investigator with technological and scientific purposes. As a scout, it will reduce risks of MMX probe landing by first experimenting the Phobos environment and provide data to minimize the hazards at first landing. It will demonstrate wheeled locomotion to extend the range of acceptable gravity levels for exploration Rovers, and self-driving capabilities. And, on the scientific side, it will perform multiple in-situ measurements at small scale over some areas to enrich the interpretation of the orbital survey and sample return analysis, in order to better understand the surface properties of Phobos and the regolith dynamics on small bodies [1].

To achieve its objectives, the Rover embarks 4 instruments with him: MiniRad an infrared radiometer, for characterizing the thermal properties of the regolith, NavCams two stereo RGB cameras dedicated to the navigation, soil and landscape observation, RAX a Raman spectrometer, to characterize the composition of the ground just below the Rover and WheelCams, two observation cameras of the wheels, to analyze the configuration and behavior of the regolith at small scale.

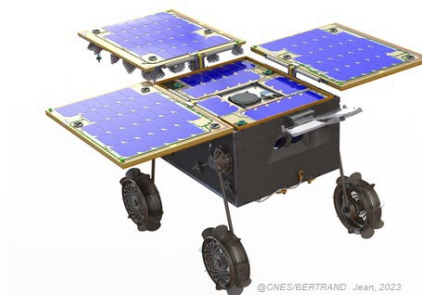


Figure 1 Idefix Rover

The Rover is equipped with a battery and solar arrays provide it with power, allowing to perform operations for about 16h (2 phods or Phobos days). Rover has to point the sun to recharge its battery every Earth day [2]. Rover communication relies on RF antenna, allowing to communicate with the spacecraft only.

Idefix mission is divided into 3 main phases [2]:

- Hitchhike (HH) phase: goes from the launch to the last switch ON/OFF of the Rover before its release of the spacecraft. This phase includes the cruise from Earth to Mars and early Phobos remote observations by MMX. In this phase, most of the time, the Rover is off; there are checkouts planned every 3 months, to ensure the Rover

is healthy and perform necessary maintenance and calibration operations. Phobos landing preparation will take place in parallel of the hitchhike activities.

- Separation Landing Up-righting and solar generator Deployment (SLUD) phase: begins when the Rover is switched ON before its release from MMX Spacecraft and ends when the Rover is up-right on its legs on Phobos surface, with solar array deployed, ready to perform its mission. Once started, this sequence is fully automatic as no interaction with the ground would be possible.
- The On Phobos phase is the exploration phase itself: it starts after solar arrays deployment, up until the end of the mission. This phase is supposed to last at least 100 effective days.

## 2. MMX and Idefix ground segment overview

Once on Phobos, Rover operation will have to deal with severe constraints and multiple goals. First goal is to guarantee the Rover survival despite its environmental constraints. At least, once a day, the Rover will perform a sun pointing to optimize the recharge of its battery.

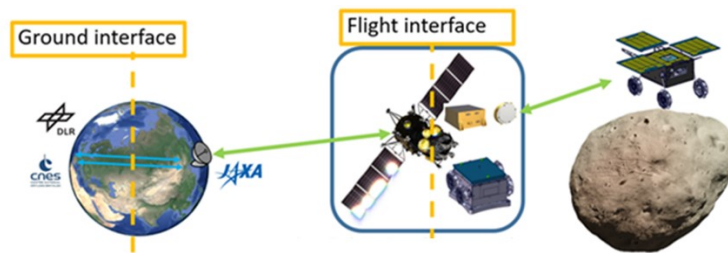


Figure 2: Schematic view of communication between Rover and its control center

Because of very low resources available in 25kg Rover, Idefix cannot communicate directly with the Earth, communications are relayed through the MMX spacecraft, which requires close coordination with the JAXA operation of MMX probe (see **Erreur ! Source du renvoi introuvable.**). MMX probe cannot communicate with Earth and Rover at the same time. As baseline, every 2 phods out of 3 (twice per Earth day), the MMX probe performs a maneuverer to point to the Idefix Rover and establishes spacecraft-rover communications. Rover telemetry is stored on board until next maneuver to point the Earth and download telemetry, among over instrument telemetry. Therefore, communication with rover takes time, usually up to 2 Earth days to send a command from JAXA to Rover and retrieve its acknowledgement in Rover Ground segment.

Once recharged and communication scheduled, Idefix Rover will perform other activities such as driving, or doing science measurements with the cameras, Minirad or Rax. Due to very low gravity, Idefix will drive at very low speed, around millimeters per seconds, to limit the risk of flipping over. The Rover also embeds 2 auto navigations system that will improve the drive capacity. In addition of their scientific goals, navigation and wheel cameras will be used all along the Rover mission to contribute to the operation.

From its Control Center in Sagamihara, JAXA leads all the operational activities of MMX mission. Two control centers are setup to manage the Idefix operations: the French Operation Center for Science and Exploration (FOCSE) at CNES, Toulouse and the German Rover Control Center (GRCC) in MUSC, Cologne for DLR. The French and German operation teams will operate in an alternating way from their respective control center.

To simplify the interactions with JAXA and the definition of the interfaces between the Rover and JAXA ground segments, a concept of Rover Control Center (RCC) has been introduced. Therefore, from JAXA point of view, there is only one interface, known as RCC, for the Idefix Rover Ground Segment (see Figure 3: Idefix Rover flight and ground segment overview).

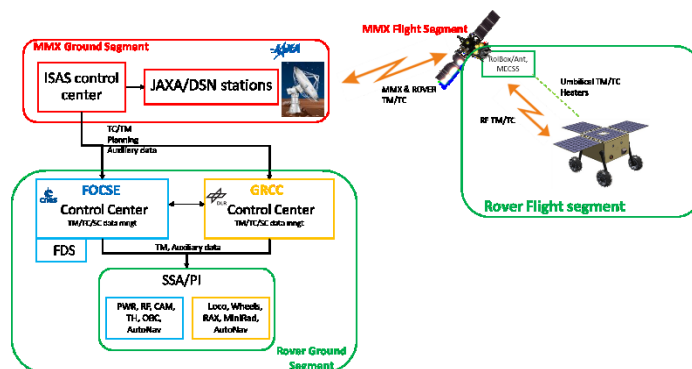


Figure 3: Idefix Rover flight and ground segment overview

MMX JAXA Ground Segment provides all the main interfaces needed to undertake Idefix operations and monitor their correct execution, in particular JAXA handles all the Earth from/to spacecraft data exchanges, through its Antennas and servers.

MMX JAXA servers allow to deliver all telemetry, mission and operational data to the Idefix Rover and other instruments teams. Rover ground segment is acting as a proxy to JAXA ground segment for Idefix Rover end users: it is responsible for retrieving telemetry and other operational products from JAXA servers, process them and make them available to on its own servers to the Idefix general community. On the other way around, RCC is responsible for provision of the Idefix rover commanding.

In addition to the Idefix Rover TM, during the Hitchhike phase, JAXA provides a subset of the spacecraft telemetry allowing the Rover team, to analyze the Rover flight environment while attached to the spacecraft.

During the On Phobos exploration phase, for the Rover team to plan the RF communications with the mothership, JAXA will also distribute the spacecraft orbits and attitudes prediction and afterwards determination.

In coordination with JAXA, CNES and DLR are both responsible for the Idefix operation. Rover subsystem authorities and scientific community will support them for rover operation preparation and execution, even though, most of the times, they will not be present in the Rover control rooms. This community gathers engineers and scientists, not exclusively from CNES and DLR, who will undertake the proposed investigations and provide scientific support to address the goals of the mission and engineers who will undertake the programming and monitoring of the Rover units.

As presented in Figure 3: Idefix Rover flight and ground segment overview, FOCSE and GRCC both operate the Rover. They are both responsible for commanding the Rover, exchanging products with JAXA servers, monitoring the Rover health state, store the TM, provide analysis, and distribute products to experts and science teams.

The operation sharing is called the “Ops cycle” principle, where the “prime” control center controls the Rover during this Ops cycle, whereas the “secondary” control center serves as a backup, and prepares the next Ops cycle, where it will become prime, while the prime becomes secondary [3]. Alternance should take place every week.

Operation and commanding products are synchronized between FOCSE and GRCC, relying on the Ops cycle principle, the prime control center delivers JAXA with the commanding products once generated, while the secondary prepares the next cycle, after synchronizing the operational data.

### 3. FOCSE MMX Rover Ground segment

Idefix Ground segment is part of French Operations Centre for Science and Exploration (FOCSE). In CNES, FOCSE groups all the Science Operations activities, including ground segment development, operations and data valorization for missions involved in Scientific exploration including Astrophysics & Fundamental Physics, Planets, Small bodies & Solar Physics and Human Spaceflight [4]. In this paper, FOCSE stands for FOCSE ground segment for Idefix Rover. In FOCSE, Idefix will be operated from a dedicated Operation Room, for all flight and ground activities, located close to other exploration missions. FOCSE operating room will also host Rover simulation means to facilitate test setting up and collaboration.

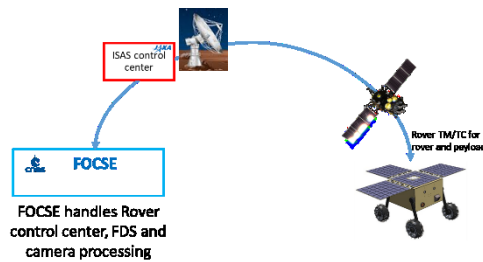


Figure 4: FOCSE scope

In addition to the tasks of the other mission centers installed at FOCSE, which operate payload instruments as part of a wider mission, Idefix Rover operations will require the management of a complete space system in all its aspects (thermal, power, communications, AOCS, Command and Data Handling, etc.) in a very constrained environment on Phobos. CNES has extensive experience in operating earth-orbiting spacecraft, but Idefix Rover will be the first complete system operated by CNES in deep space.

Operations will rely upon a Flight Control Team (FCT) in charge of programming and monitoring the Rover, a Ground Control Team (GCT) who will provide FCT with the infrastructure, means and tooling to operate the Rover and the community of sub-system authorities (SSA) and Scientifics (PIs), actively contributing to the Rover safety and the mission technological and scientific goals achievement.

Flight and ground control teams will operate from the operation room while SSA and PIs will just access the data distributed by the Ground segment and work from their own facilities.

To sum it up, FOCSE Idefix Rover stands for a control and mission center, that exchanges data with JAXA servers and stays synchronized with DLR ground segment. FOCSE also delivers Rover data to users involved in operation and science from outside the operation room.

FOCSE Idefix Rover ground segment has 3 main types of users contributing to operate the Rover (see Figure 5: FOCSE users and interfaces):

- Flight Control Team (FCT): CNES FCT are the users who directly operate Idefix Rover, plan for its activities, generate the commands, visualize and analyze the telemetry, coordinate with JAXA, DLR Flight Control teams and expert/scientific team. They operate from FOCSE control room.
- Ground Control Team (GCT): CNES GCT are users who check that the center is running fine, keep the infrastructure and applications in operational conditions, monitor the automated tasks, guarantees security of the center. GCT moreover handles development of new versions of the ground segment. GCT also work from the control room.
- FOCSE External users: all other users accessing only the center's data from outside the control room are considered in this category, mainly covering: Rover Sub-System Authorities (SSA) and PIs team, from CNES, DLR or labs, Landing Site Selection group, and also DLR flight and ground control teams accessing data generated only by FOCSE (from CNES simulation means or FDS).

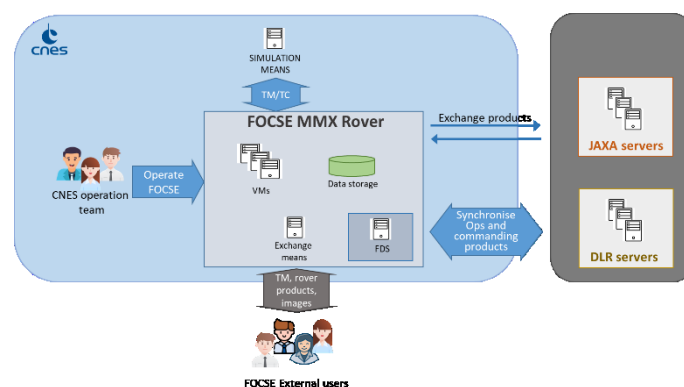


Figure 5: FOCSE users and interfaces

Interfaces are key elements in the Rover Ground segment to exchange with other systems, as direct communication with rover is not possible.

FOCSE MMX Rover is interfaced with the following systems (see Figure 5: FOCSE users and interfaces):

- Its users: Operation team through the center's GUI and consoles in the control room and its external users through an exchange server that can be accessed from inside or outside CNES

- JAXA who leads the operations. JAXA delivers telemetry, flight dynamics input products and all complementary products to operate and coordinate. On the other hand, Rover team provides JAXA with planning and commanding products. Rover ground segments are responsible for all the data transfers with JAXA.
- DLR for operation and data synchronization of all planning and commanding material.
- Flight Dynamic System (FDS): FDS is accessed from the control room although it is a separate system, exchanging data with Rover Ground segment,
- Simulation means, for testing purpose. Rover simulation means can be accessed directly (system to system) or exchanging files for telemetry and telecommands, thus simulating the interfaces with JAXA.

#### 4. FOCSE MMX Rover main functions

In CNES, FOCSE will allow to operate the Rover from the launch to the On Phobos Exploration phase. Its functions can be divided into different main categories related to the operation to control the Rover, to manage the center's configuration and to process the camera images (see Figure 6 : FOCSE main functions).

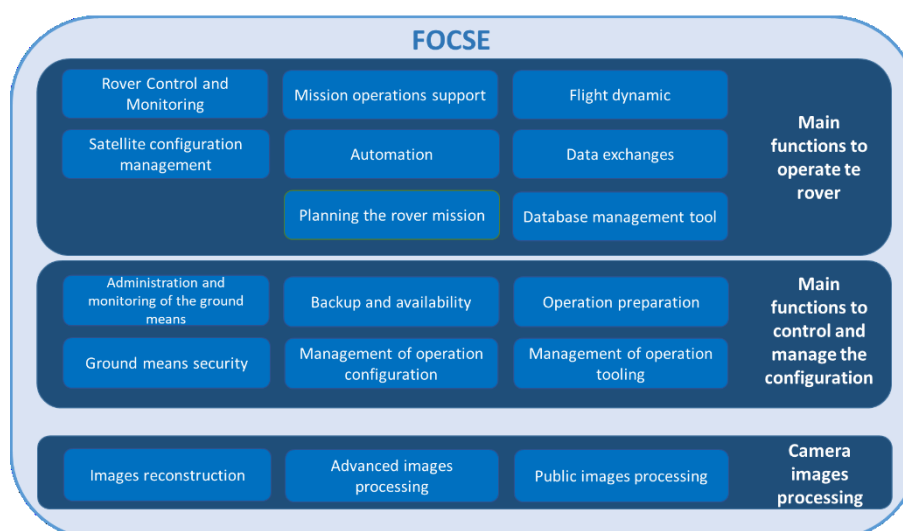


Figure 6 : FOCSE main functions

FOCSE MMX rover is a control center that does not manage the antennas. However, as usual Control Command Center, it operates the rover and allows to:

- Control and monitor the Rover: from mission activity sequences, FOCSE enables generation of Rover Telecommand profiles, embedded in a product complying with JAXA format. This commanding product also hosts specific spacecraft commands that need to be uploaded consistently with Rover commands. On the other way round, FOCSE allows to process and monitor Rover telemetry, store it in a database and raise automatic alarms when thresholds are overpassed. For specific parameters related to Rover environment, spacecraft telemetry also need to be monitored.
- Support mission operations with storage of all mission events, TM and operational products. FOCSE allows visualization of all telemetry in real and deferred time with mission configurable views and synoptics in order to produce reports.
- Compute orbit events for the Rover, thanks to FDS, mainly for identifying the communication passes between the Rover and the spacecraft, but also estimate the Rover position and attitude once on Phobos.
- Upgrade the flight software.
- Manage system database with tooling to handle its data model, ease its evolutions and distribution.
- Exchange products with JAXA, DLR, experts and PIs, relying on SFTP or HTTPS servers
- To automatize all repetitive center tasks, such as JAXA products retrieval,
- Plan the mission to ensure the Rover survival despite the multiple constraints and risks and perform as much driving and science as possible.

FOCSE provide functions and tooling for the center operational configuration management on ground, allowing to:

- Administrate and monitor the ground means: deals with authentication and access verification, traceability and imputation, and also monitoring the software and infrastructure all along the operations
- Ground means security: via administration and monitoring means so that the environment is kept up and running,
- Manage the operational configuration in close coordination with DLR control center, FOCSE shall version control the SDB and the qualified TC sequence catalog shared with DLR, so that operations are consistent in both centers

- Contribute to the operation preparation, by providing accessible operational documentation, means for flight control team to prepare and develop their own needs, provide management configuration tooling and strategies and means to perform tests apart from the operation
- Manage operational tooling: flight control team develops complementary tooling to ease verifications or test preparation; those tooling shall be version controlled, shared and easily deployable
- Backup all operational data and guarantee a reproducible deployment of the environment

Cameras will actively contribute to Phobos regolith science and also be essential to operations for driving and for autonomous navigation. To do so, FOCSE allows:

- To process automatically the telemetry once available to rebuilt and decompress the camera images downloaded into pieces for bandwidth optimization. Navigation and wheel images are needed for Rover driving and to better analyze the ground underneath the Rover while operating, therefore, after each pass. FOCSE will deliver all processed images that can be complete or partial, to help decision making while planning Rover activities.
- To correct the images geometrically and radiometrically, generate navigability map from navigation cameras and wheel movies, to deliver to auto navigation and science teams,
- To generate images for public outreach.

Even though controlling the rover is complex and risky, though interfaces with JAXA for operation are not entirely defined yet, most functions in FOCSE are standard ground segment functions and CNES on the shelves tooling will allow to build it up.

## 5. ISIS reuse strategy for FOCSE architecture

To rely on standards, benefits from various CNES missions experiences and inherits ISIS tailoring from Rover AIT, it has been decided to build up FOCSE MMX Rover upon ISIS product line.

ISIS project is an initiative to optimize the CNES space systems development through standardization of its mission interfaces and operational concepts. It provides technical standards allowing to rationalize space services in terms of operation and products for platform, command & control Ground Segment, simulator, system data base. The ISIS Product Line is the implementation of the command-control center, part of CNES' ISIS Project (Initiative for Space Innovative Standard)[5]. ISIS is based on standards for board-ground interface (PUS Packet Utilization Service, CCSDS) and ECSS. ISIS relies on international CCSDS TM/TC, PUS, XTCE, SLE, COP1 and ECSS, standards. ISIS product line gathers different subsystems to fulfill the usual functions for any type of satellite missions.

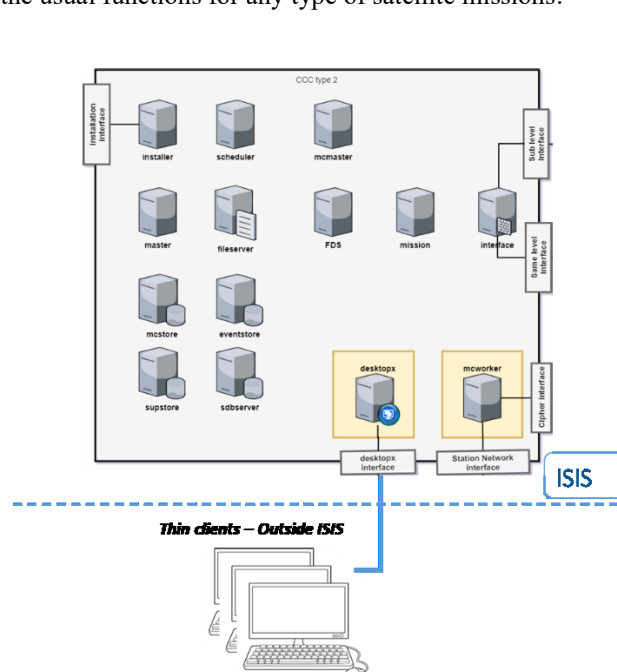


Figure 7: ISIS CCC target architecture [5]

In CNES, ISIS is provided to missions with a standardized assembly for Command Control Center, named CCC target. ISIS CCC target is presented in Figure 7: ISIS CCC target architecture [5], in which each of its server is thematic, dedicated to one role.

CNES ISIS product line a with a CCC target covers most of the functions needed for FOCSE. ISIS CCC target brings all the components **Erreur ! Source du renvoi introuvable.**, already assembled with a generic Earth Orbit satellite mission

configuration. Taylorisation of ISIS for the mission relies on different stack layers, allowing mission teams to inherit a shared assembly and focus on mission specific topics with more added value (see Figure 8: Stacking layers or how to focus on added value [5]).

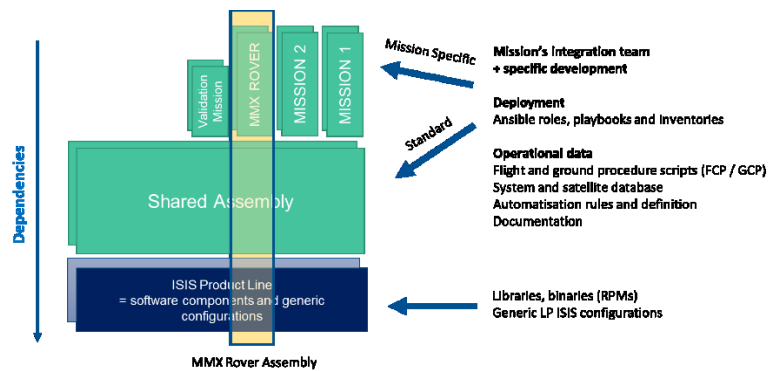


Figure 8: Stacking layers or how to focus on added value [5]

As a science mission, FOCSE Rover ground segment will be hosted on CNES Science Cluster, a shared mean already hosting multiple science missions both in operational, development or qualification phases. In addition of ISIS product line, the Science Cluster provides mission with computing resources, a set of common tools and a standardized approach for instantiation and operation of ISIS product line.

The Science Cluster platform is monitored and maintained by CNES platform manager who is independent of the missions. Idefix Rover project secured the availability of adequate Science Cluster's hardware resources by funding a server to scale up Science Cluster's capacity.

All the disks and virtual machines (infrastructure and applications) are backed-up on a regular basis to the backup cluster. Science cluster is deployed in an isolated operational network, where each mission control center can access through a firewall.

As common services on top of ISIS, Science Cluster offers a deployment and administration servers, Identity and access management facility, shared file server with quota per mission, in/out physical computer master to insert and extract files from the virtualized platform with an antivirus analysis and a shared and standardized supervision solution, based on Grafana. Last but not least, the Science Cluster security is validated by CNES security officers and comply with the requirements to host operational science space missions.

Reusability of ISIS product line with Science Cluster infrastructure and mean provide main functions for Idefix Rover ground segment, as presented in Figure 9: FOCSE main functions implementation strategy.

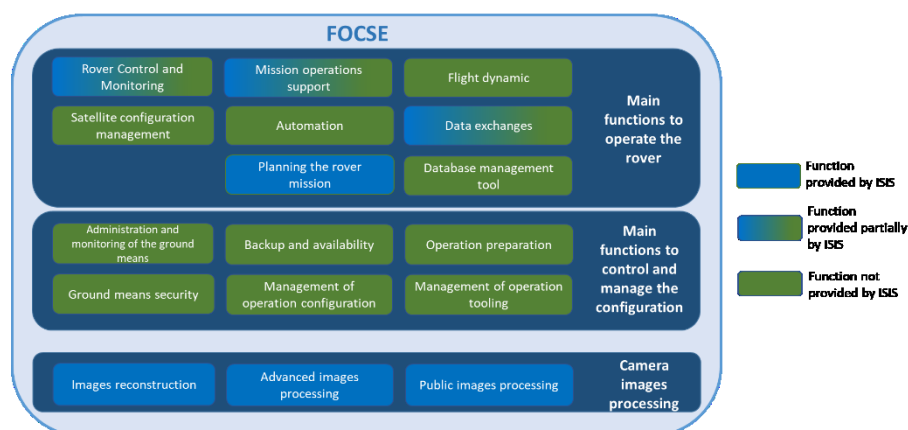


Figure 9: FOCSE main functions implementation strategy

Idefix Rover flight operation will mainly rely on ISIS components, though adaptations are needed to be sharable with DLR ground segment or to cope with specific part of JAXA servers.

Using Science cluster means and common services allows to fulfill all FOCSE Rover needs to control and manage the configuration of the center.

Camera image low level processing is specific to Idefix rover mission and will require specific development.

The large set of functions and standardized procedures provided by ISIS upon the Science Cluster infrastructure will cover major part of Idefix Rover ground segment requirements. Reusing ISIS PL is expected to be an accelerator to build up FOCSE complete control center so that development and integration time is saved for specific mission operation needs.

## 6. FOCSE MMX Rover specific components

Idefix is a French and German rover that will be operated by two control centers. To minimize risks of having two different implementations for critical functions and to reduce the development workload, Rover project decided to share components between the two ground segments. Two main topics have been decided to deal with critical and complex functions, that will be developed only once and shared with the other center:

- Commanding function is critical as two ground segments operate the Rover. The adopted key principle is that: from a given set of inputs, both ground segments generate the same output, as identical encoded TC profiles embedded in JAXA commanding format. OGEN, a unique commanding generation tool for Idefix Rover is defined that for. It is developed and maintained in CNES and shared with DLR.
- Mission planning tool helping Flight operation team to schedule the Rover activities, among the multiple energy, bandwidth, night/day or communication passes constraints is the other one. The planning tool is named Pinta (OnWeb). It is developed by DLR [7] and will be shared with CNES.

ISIS product lines offers a complete execution environment for Pycots, its encoding library. OGEN is the execution environment for ISIS Pycots TC encoding library outside ISIS. It can be executed in CNES or DLR, to generate Rover commanding independently of ISIS environment.

From a mission activity sequence, defined as a set of Flight Control Procedures (FCP), OGEN generates Rover binary profiles, embedded in a JAXA format product, that will be transferred to JAXA afterward.

OGEN complies with ISIS python FCP format as input, so that mission FCP can be executed either in ISIS for direct simulation or in OGEN for provision to JAXA.

OGEN is executed in command line and supports ISIS messages to ease readability of console or log messages. OGEN embeds comments, including TC name and parameters to help verification of the commanding.

Telemetry management is handled separately in CNES and DLR ground segments, which both retrieve it from JAXA servers. In FOCSE, Rover telemetry retrieval is not the ISIS standard TM flow from the station but a set of TM files provisioned by JAXA on SFTP servers (main and backup servers). Mission specific processing chains are responsible for automatically retrieving JAXA products, pre-process it before ISIS import for monitoring and deliver it to external FOCSE users.

Low level camera images processing is mission specific topic. Raw images captured by the camera are compressed on-board and downloaded on ground via PUS service 13, thus cut into pieces. In FOCSE, ISIS can automatically rebuild data from service 13 once complete. Idefix camera images are needed for the operation and may not be downloaded in one pass. Our concern is to rebuild the raw images, even though they are not complete on ground, relying on mission specific tooling. A specific processing chain is required to automatically rebuild and deliver the raw images to operation team, once the telemetry is available on ground. The raw images will be completed along the passes if additional telemetry is retrieved.

To generate images with first level corrections of the raw images, FOCSE will rely on CASPER Image Processing (CASPIP) [6]. Higher level images generation is handled by NAVCAM and WHEELCAM science team.

To cope with its different type of users from inside and outside CNES, FOCSE opened up mission Gitlab projects to DLR, sub-system authorities and scientific team. A SFTP server has been set up in a DMZ to deliver Rover telemetry and all data of interest to FOCSE users for operation. Last but not least, FOCSE relies on CNES Confluence for collaborative operational documentation and JIRA for ticketing.

## 7. Outline of the development strategy

FOCSE development plan is driven by the system development plan, thus with a two phases baseline and an iterative incremental strategy:

- First development phase dedicated to the preparation of the Rover mission hitchhiking phase for which operations will take place every 3 months; the center functional perimeter is simpler though main mission functions such as monitoring and control have to be mature. A year is given to implement the FOCSE before beginning of the system tests for hitchhike.
- Second development phase dedicated to the preparation of the mission SLUD and On Phobos phase, with a full functional center to perform a second period of system tests.

An iterative and incremental development strategy has been chosen in order to cope with development of new features in parallel of the system test preparation and execution. Monthly iterations and devOps strategy allowed to deliver new functions for system tests and to collect feedbacks from the center users, with quick and efficient loops.

System test for launch and hitchhiking phase started end of 2023 and took place for a year and could be executed successfully from FOCSE (for CNES part).

For the on Phobos phase, a new set of requirements has been defined that are to be developed for FOCSE v2.0. 2025 aims at defining the next system tests for the On Phobos phase. Development will take place in parallel, keeping an iterative and incremental development strategy. System test will start by the end of 2025.

## 8. First lessons learnt

As part of FOCSE it benefits from standardized ground operations process. As built upon ISIS, it takes advantage of a large set of standardized control center functions and procedures. Idefix Rover Ground segment is hosted close to other Martian rover mission centers in CNES to foster synergies between the missions, though Idefix rover Ground segment has different needs and relies on a completely different architecture. Distance with ISIS competent team was a slowing factor for Rover Ground segment building up, that need to be improved.

The risk of having different commanding generation in CNES and DLR Ground segments has been significantly lowered as both center generate commanding with OGEN. This successful externalization of ISIS function, will be extended to new features, for the On Phobos phase, for spacecraft commanding or parameter table upload preparation

Thanks to ISIS reproducible deployment feature, FOCSE deployment is fully automated and reproducible, with a DevOps approach, that allowed to complete the Ground segment all along the system tests for Rover Hitchhike phase.

Ground segment is deployed on a mutualized infrastructure and relies on common means for Identity management, backups and security.

ISIS TM core functions allow to store, decommute and visualize the telemetry, with Ops prepared views.

OGEN is integrated in FOCSE ISIS environment, allowing to follow up the rover TC upload on ground.

The automatic exchange functions with external servers comply with ISIS, though they do not rely on ISIS automation system and its monitoring capacities.

Due to ISIS CCC assembly for CNES Science Cluster, FOCSE ground segment could be setup quickly by a very small team.

Nevertheless, FOCSE development team encountered some technical and organizational difficulties.

On ground TC follow up (ISIS Ground model concept) is not possible as TC are generated in OGEN outside ISIS, for operation.

For reusing ISIS CCC and Rover AIT configurations, the impacts of using different ISIS targets in AIT and Rover CCC, different ISIS versions and planning constraints, as AIT was not over when Rover CCC started has been under evaluated, and stabilization of the first version took more time than planned.

As Rover operation is very challenging, we didn't expect to enter in routine and automation of activities in ground segment was not foreseen. Reality is different, JAXA provides us telemetry every ten minutes during the pass, and multiples processing are to be automatized. Simplified automation of processes have been deployed but needs to be reworked to ease monitoring and maintainability.

Rover project is a small project, with small team. Rover ground segment first version needed to be developed to start system test, while Rover On Phobos Operations are only foreseen 4 years later. Reality showed that the team was too small to address FOCSE development, documentation and system test preparation and execution.

In this context where not all needed functions are available yet in Rover Ground segment and ground documentation is incomplete for operations, FOCSE initial version was set up and the first phase of system test could be performed successfully.

Furthermore, for Rover AIT tests in Japan, FOCSE is used on a quasi-daily basis to retrieve automatically telemetry and products and deliver them to Rover team in Europe, thus evaluating and improving its robustness, resource monitoring and maintainability.

OGEN has been used successfully in CNES and DLR for all system tests, and also to prepare Rover commanding for AIT tests in Japan.

A lot has been learnt and for next phase, ISIS reusing strategy shall be enforced to complete Rover Ground Segment available functionalities with architecture supervision, automatic telemetry monitoring, improved automation of the processing chains and multiple other functions.

Proximity with other CCC in CNES using ISIS will be enhanced to share good practices and benefits from the lessons learnt by the other missions.

The team will be enlarged to deal with all those news objectives.

## 9. Conclusion

Idefix Rover is a small Rover, with risky and ambitious goals that require a solid ground segment. Rover Ground segment takes the entire responsibility of rover control in addition of the science and Idefix Rover will be the first complete system operated by CNES in deep space.

Built upon ISIS product line, though only used for Earth Orbit satellite missions (so far), Idefix Rover Ground Segment allowed to run the system tests for the hitchhiking phase of MMX Rover. Many lessons have been learnt making us confident it will also be able to run the On Phobos Operations. We have seen ISIS can offer much more for flight and ground operation, pushing us to reinforce the reusing strategy. Development teams will be brought closer to other ISIS development teams to foster synergies between the teams.

New ambitions are in front of us to perform system tests for the On Phobos phase, where the FOCSE Rover Ground segment intends to play its role and contribute more efficiently to Rover operations preparation.

### *List of references*

- [1] Murdoc et al, "REGOLITH SCIENCE WITH THE CAMERAS ON THE MMX ROVER", Asteroids, Comets, Meteors Conference 2023
- [2] C. Delmas, C.Krause et al, MMX-Rover: A small Rover for big firsts, 18th International Conference on Space Operations (SpaceOps 2025), 26.-30.052025, Montréal, Canada.
- [3] C.Krause, C. Delmas, et al, MMX Rover Operations – Concept and Current Planning, 18th International Conference on Space Operations (SpaceOps 2025), 26.-30.052025, Montréal, Canada.
- [4] Jocteur Monrozier et al, " FOCSE: CNES Exploration contributions for Operations and Innovation", 15th Europlanet Science Congress, 2021.
- [5] O. Churlaud, S. Becquet, " Tailoring of CNES' ISIS Product Line: Rationalization and efficiency for deployment and operations", SpaceOps-2020
- [6] N. Théret et al, "CASPEX Image Processing: a tool for space exploration", Europlanet Science Congress 2024
- [7] Nibler, R., Schöpf, A., Wiebigke, A., Wörle, M.T., Hartung, J., May, D., Muders, H., Krause, C., and Delmas, C., Pinta(OnWeb) setting sail for Martian moon Phobos – Establishing the Mission Planning System for the MMX Rover Idefix. 18th International Conference on Space Operations (SpaceOps 2025), 26.- 30.05.2025, Montréal, Canada