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Securing and improving SEIS and APSS instruments operations with internal dedicated tools

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Abstract

InSight is a NASA-JPL (Jet Propulsion Laboratory) mission that landed on Mars on Nov 26th, 2018. CNES, the French space agency, contributed to this mission by providing a highly sensitive seismometer, Seismic Experiment for Interior Structure (SEIS). CNES also developed a dedicated operation center, the SeIS on Mars Operation Center (SISMOC), to operate SEIS by sending commands and processing/distributing the data acquired to the scientific community.

From early rehearsals to ongoing operations, the SEIS operational team has always had to manage multiple sources of information, such as operational plans, telemetry, command sequences, orbiter passes, etc. Thus, operators had to progressively automate repetitive tasks, extract relevant data, improve the accuracy and reliability of information for global analysis and ensure the repeatability of the analysis process - independently of the operator's skills.

Obviously, the team initially relies on a set of dedicated procedures (mainly one for the downlink and one for the uplink), which also continue to evolve throughout the mission. However, encountering new activities, new identified risks, comparisons or automatable analyses - without added human value - leads to the permanent reinforcement of the operator's toolkit.

Not really part of the ground segment, this set of operational tools is designed, developed and maintained by instrument operators themselves. It guarantees a perfect adaptation to the needs of the team, with great reactivity, avoiding iterations with a subcontractor or a dedicated service. However, this approach must follow the usual product assurance process, meaning tracking all changes, fixes and deployments, risking otherwise to create more problems than it solves in terms of validation, maintainability and version management. This paper will describe successive needs and constraints discovered during rehearsals and actual operations, and how team members addressed these shortcomings with specific tools, leading to safe operations and allowing operators to focus on operations and risk analysis. It will also discuss the trade-off between creating dedicated tools versus evolving the ground segment, with pros and cons, considering the Mars Insight mission context and potential reuse.

Keywords: ground, tools, operations, development, devops

Acronyms/Abbreviations

VBB	Very Broad Band. Mechanical seismic sensor developed by IPGP and SODERN, extremely sensitive.
HK	House Keeping. Telemetry provided for the purposes of monitoring the health and functioning of the instrument.
ORT	Operational Readiness Test. Simulation involving operational teams, playing a specific phase of a mission, nominally or with contingency. Aims to train people and test procedures and tools.
SISMOC	SeIS on Mars Operational Center. The place and the ground means allowing to operate SEIS. Located in CNES premises, Toulouse, France.
SVN	SubVersioN. Tool used for maintaining current and historical versions of projects, and to manage/track changes to code and assets across projects.
FTP	File Transfert Protocol. Standard communication protocol used for the transfer of computer files from a server to a client on a computer network.
APID	Application Process Identifier. Identification of a Source Packet (CCSDS format).
WOBL	What's On Board File. A file located on the InSight lander, updated after each uplink, gathering all files stored on-board. Downlinked during each uplink.

ERP Event Request Proposal. In the frame of SEIS, request from a science team about a dedicated channel (or set of channels) in the past, were data are asked to be sent by the lander, in higher resolution than the continuously received one.

PUL Payload Uplink Lead. Operator in charge of the uplink, meaning contribute to elaborate the plan, prepare the sequences, check the Flight Rules, and send them to JPL for uplink to spacecraft.

PDL Payload Downlink Lead. Operator in charge of the downlink, meaning analyse telemetry from the instrument, commands execution by the lander, assess that an activity has been successfully performed or not.

APSS Auxiliary Payload SubSystem. Meteorological station, helping to understand seismic signal context. Operated by SEIS PDL/PUL.

SOL A solar day on Mars. Mission starts at sol 0.

1. Introduction

Insight mission had for ambition to know more about Mars core, seismic activity, heat flows, and many other scientific objectives, that led to build a lander equipped of several instruments. Indeed, the mission had an arm – with a scoop and a hook -, a meteorological station called APSS (measuring wind, pressure, temperature), two cameras, a heat-flow probe (HP3), a magnetometer, and as main instrument: a seismometer, called SEIS.

From launch to end of mission, CNES mission was to operate both SEIS and APSS instruments, from SISMOC.

Like the other instruments teams of the mission, the operational roles were shared between:

- the PDL, that led the downlink analysis activity (looking for data completeness, interpret HK data, assess success or failure of an operational activity etc.)
- the PUL, that led the planning and commanding parts, ensuring that activities requested by the science team were correctly planned and modeled by JPL, wrote and checked on-board sequences (files containing commands and algorithms to be executed on board), ensured that flight-rules were respected, and delivered the bundle of sequences to JPL, that uplinked it to the lander.

An operational loop started with a “look ahead” meeting, where all inputs from all teams were collected, all timing and sequentially constraints were captured, with estimated durations and data volumes.

Based on this “wish list”, JPL planning team worked hard to fulfill all the needs, and presented a preliminary plan. This plan was reviewed by all teams. Late modifications were still possible if considered as necessary, notably if PDL discovered an issue in the latest data received.

A final role-call validated definitely the plan, and PUL could start working on it (writing or instantiating sequences, checked flight-rules, ensured requested files were on-board or added them to the bundle etc.).

All PULs delivered their sequences to JPL, which checked them according to the plan. A new meeting presented the definitive plan, the sequences and files delivered by every PUL. Files content were checked, and a final role-call confirmed the Go for uplink.

Once files were uplinked on the lander, all sequences were executing on-board, based on time-tagged structures. PDL knowing relay satellites downlink time, could start analyzing and could assess if planned activities executed as expected.

PDL had to report a synthetic status of its instrument during the Downlink Status Meeting. Meeting frequency changed during the mission, from one per day during deployment, to one per week during science monitoring phase.

In parallel, a new look-ahead planning already occurred, preparing next uplink cycle.

It is also necessary to introduce a feature that has been implemented to decrease the continuous bandwidth. Over the HK and engineering data helping to follow instruments activities, low-resolution science data flow was also downlinked. Once processed by SISMOC, science team looked at these data, and could have assumptions about a potential seismic event. In such case, they created an “Event Request Proposal”, to formalize the wish to downlink higher resolution on-board data during a given timeframe, specifying channels of interest.

Out of this case, considering a part of the bandwidth was always dedicated to this high-definition downlink, there were usual requests about all sensors, providing more precise data whatever the sensor requested (magnetometer, wind sensor etc.).

As every scientific team would like to take advantage of available “events” bandwidth, a selection process has been set-up. All requests were entered on a web portal then centralized in a CNES tool called “ERP-tool”. A pre-rank was performed by ERP-Gurus, setting a first level of prioritization. Then, once a week, after the final plan has been delivered by JPL, and before PUL started writing sequences, the plan was ingested in the “ERP-tool” (mainly to retrieve the weekly allocations for events). Pre-ranking was presented, and if no new priority change was raised, the tool performed an automatic allocation, splitting the requests in the different slots of the plan in an optimized way to avoid losing allocated bandwidth. The tool then generated sequences (called Event Sequences) that were part of the bundle sent to JPL by the PUL.

This mechanism could also be used for engineering purpose by operational teams, with a higher priority.

Note that both PDL and PUL had to report their information, decision, assessment and go/no-go to a common tool called "NSYT Report". This was a web-tool, where for each Sol, all positions (SEIS PDL, SEIS PUL, etc.) could fill its own page, and navigate on others to get information. This was a central tool for teams involved in JPL operations, allowing centralizing all operators' information, for downlink as well as for uplink.

Now that main operational activities and chronology are described, let's consider the means and tools designed to perform these tasks.

2. Context of ground segment development

The SISMOC ground segment was involved as for downlink and uplink tasks.

It has been designed to receive several kinds of data coming from the lander via JPL/Lockheed Martin: CCSDS files, ASCII files, HTML or XML files etc.

The focus has been set on processing the telemetry and compute scientific data. This was a high-level requirement.

SISMOC parts dedicated to operations were:

- IMIS tool (visualization tool that handles HK data, scientific data and alarms, mainly based on CCSDS files)
- Sequences writing and delivery
- Cataloging all received and sent data

Some other SISMOC features, about time correlation, conversion, and other important topics are not described in this article.

Those main topics were developed and validated on time, ensuring SEIS operational team interacting with the instruments. However, some needs were either not yet identified, or considered as less of a priority than previously described features.

Major advances in operational tools were directly linked to ORTs opportunities. Having on-console simulation, in JPL premises, during few consecutive day, allowed the team to identify clearly flaws in processes. After each simulation, new ideas emerged, new improvement were proposed. It quickly appeared that integrating such modifications in the Ground-Segment development cycle was no suitable solution. This article will expose the reasons for such difficulties, and the reasons that led to decide to develop operational tools out of usual industrial process.

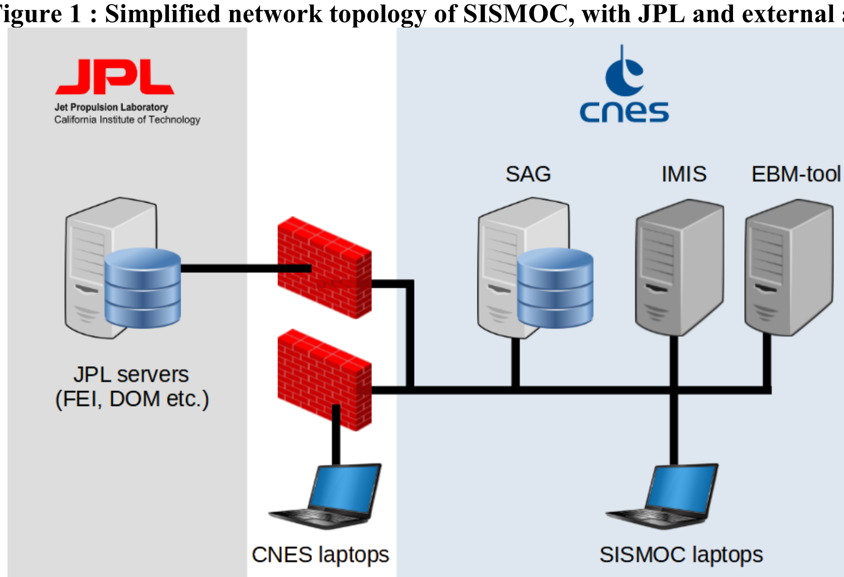
3. Work environment

SISMOC has been designed to support operations from CNES (Toulouse, France) and from JPL (Pasadena, California), which explains that operational workstations were imagined as laptops, allowing keeping the same environment from any of both places. Operating from JPL was a strong requirement. From landing on Mars to the end of commissioning - period that lasted about 4 months-, it has been agreed for CNES team to be present at JPL, in order to avoid time-shifting constraints, to ease communication between teams, and have all necessary people in the same building in case of failure.

So, SISMOC architecture considered this constraint and proposed a solution based on:

- Virtual machines located in CNES. Worked on Redhat, with python 2.7.
- Operational laptop workstations. Worked on Windows, with python 2.7. Can access files on the servers through SAMBA mounting points, ssh, tools GUI.
- Even if not considered as operational, CNES individual desktop computers (laptops too) could be used to perform off-line analysis and have some links with SISMOC servers. Worked on Windows, with mostly python 3. Interacted with virtual machines via a Webdav mount.

Figure 1 : Simplified network topology of SISMOC, with JPL and external access



It is important to know that SEIS GDS team was responsible of operational workstations configuration. It was possible to ask a specific client / software version, if validated.
Conversely, CNES servers and CNES desktop computers were very restrictive on software and libs installed, essentially for security reasons.

It is also important to consider that SISMOC is a software suite, maintained and delivered by a contractor. It means that a new version involved installing software impacted by an anomaly correction or an evolution. Exchanges with contractor were done through Anomaly Reports or Change Requests. After analysis, contractor answered with a Proposition (technical and financial). Once a set of proposition were accepted, a new version was proposed and installed on a Validation platform, for acceptance. If acceptance was successful, the new SISMOC version was installed on the operational platform.
It means that beside some specific customizations, most of software needs were assumed by an industrial contractor, and every modification had significant time and financial costs.

4. Dev constraints

Knowing this infrastructure landscape, operators had a good representation of constraints for tools development.

When first ideas of operational tools – meaning out of industrial part of SISMOC – appeared, experienced operators highlighted that even the most useful and powerful tool can become quickly unusable if maintenance and evolution became too difficult. Uncommented code, lack of traceability, out of control deployments and under-validation are pitfalls that can lead either to the abandonment of the tool, or to serious operational impacts. So even if operators are ideal people to answer an operational need, it became essential to know and adhere to good practice rules specific to software development.

Internal tools must follow the same rules, product assurance and validation demanding as for the whole software composing the SISMOC, meaning:

- developer operators must be familiar with the coding rules, the configuration management process, as well as validation principles and processes.
- tools must be considered as any other SISMOC product, in terms of product assurance, change request management, versioning and deployment

Even if it seems an additional constraint for operators, this is above all a way to optimize and secure significantly operations. The reactivity of on-site person, knowing perfectly the needs, being himself a final user, is the most efficient way to improve operations, if rules are respected.

5. Product assurance and processes

The benefits of internal tools developed by operators having been quickly perceived, it was important to be aware of the associated risks, and to anticipate them. Internal discussions led to list the following mistakes that could occur when a correction/evolution was requested:

Table 1 : Identified risks and impacts of internal development

Risk	Impact description	Impact on
Need partially identified,	Bad analysis. Need a new iteration. Costs time and resource.	Costs
Solution not convenient for the whole team	Bad analysis. Need a new iteration. Costs time and resource.	Costs
Unmaintainable code	Next evolution/correction takes more time than expected. Risk of regression.	Costs/Operations
Incomplete validation	Can encounter issue or blockage during real operations.	Operations
Regression	Can encounter issue or blockage during real operations.	Operations
Versioning issue in case of major regression	Difficulty to recover a nominal situation in case of issue.	Operations
Issue during deployment (rights, version etc.)	Can encounter issue or blockage during real operations.	Operations

To decrease the risks associated to these potential issues, CNES decided to integrate the tools management to its usual processes, with some flexibility. All along the process step,

Table 2 : Internal process set up facing identified risks

Process step	Description	Covers risk of	Output
Change Request, or Non-Conformance Report	Formal and detailed description of the expected change, or unexpected behavior with a proposed correction.	Need partially identified	An item with request description
Discussed weekly with the OPS team	For urgent/blocking issues, can be discussed out of weekly process	- Need partially identified - Solution not convenient for the whole team	A Go/NoGo for implementation
Implementation	Ops people develops and tests the evolution/correction.		
Validation	On validation platform, scripts are deployed and tested, with representative data.	Regression	Validation status
Configuration management	When validation is over, final source version are added in configuration management (SVN), and tagged with new revision number.	Versioning issue in case of major regression	Tool referenced and ready to be deployed
Deployment decision	Given the validation results, the System Engineer gives a Go/NoGo to deploy the tool on the operational platform.	- Incomplete validation - Regression	A Go/NoGo for deployment
Deployment	Ops people asks GDS to deploy the tool, giving the tag revision.		A deployment log from GDS team, detailing deployment actions and results
Verification	Ops people checks that deployment is correct, and that tool works fine on the operational platform.	Issue during deployment	
Demand closing	During weekly meeting, OPS team and System Engineer decides if evolution/correction is correctly performed and accessible. If yes, the demand is closed.		Initial demand is closed.

This process covers most of the risks identified here above, and removes most of them. Only the code quality was not checked systematically. For that, it has been decided that code analysis was run on-demand, and corrections were integrated to next release. This risk was also decreased by implicating ops-developer knowing CNES coding standards, about comments rate, functions size limits and other good-practices. This preventive action helped to maintain code readable and maintainable.

Now that process and means are described, let's describe the operational needs encountered during InSight operations.

6. Quick description of InSight operations timeframe

As for others Martian projects, operations were separated in two distinct themes: uplink and downlink.

SEIS operators were commanding the instruments by sending sequences to JPL, which gathers all instruments sequences for the upcoming plan.

Sequences are ASCII files containing list of commands to be executed on-board. Written by SEIS operators, sequences were the implementation of activities planned to be executed on-board. According to the mission phase, planning could be for 1 sol, 1 week or 2 weeks.

Once sequences were bundled and uplinked to the lander by JPL and Lockheed Martin, their execution on board was time-tagged. The lander started emitting telemetry to an orbiter that relayed the data to JPL via the Deep Space Network. Telemetry was broadcasted to agencies via a FTP server, allowing CNES to retrieve:

- CCSDS files, with APID matching the instruments (SEIS and APSS)
- Ancillary data
- Integrated reports
- EVRs

Such downlinks were programmed from 2 times a day – for deployment, commissioning, and science monitoring phases - to 1 every 3 sols – for end-of mission programming).

So, PDL received data very often until the end of mission phase, involving checking frequently completeness and activities success. Even if only one reporting by week was asked, PDL looked at data every day, to start early analysis in case of failure detected.

PUL also did not wait the last day to anticipate sequences writing. Anticipating incoming sequences allowed more time for checking and cross-checking.

7. Downlink tools

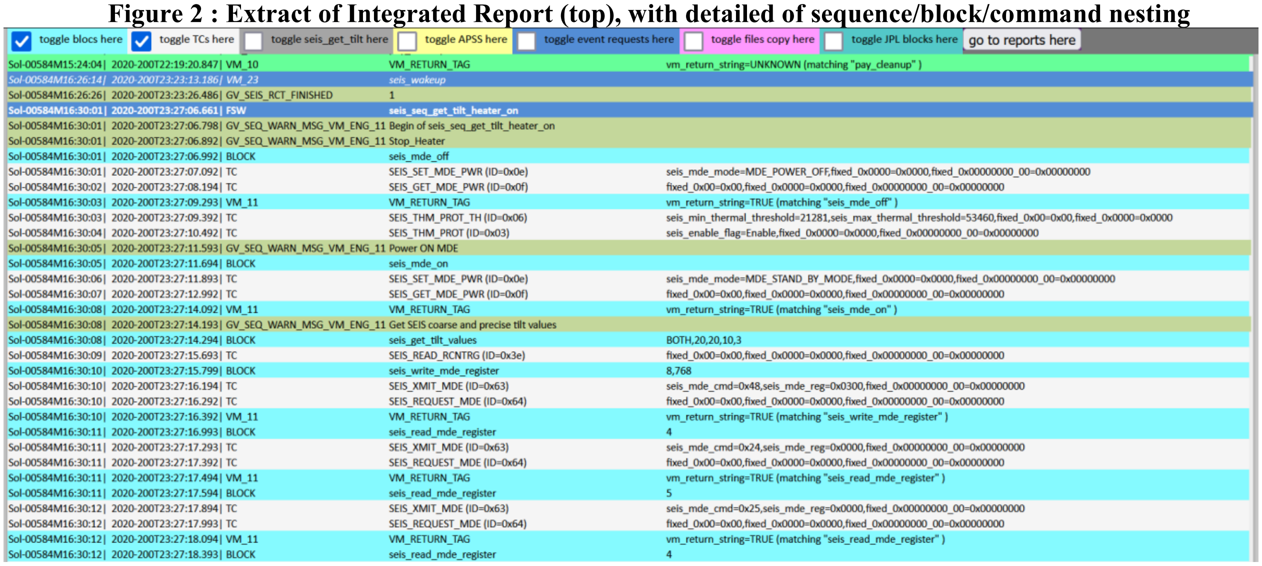
7.1. Gather on-board execution in a chronological way: Integrated Report

One of the first tools need identified by CNES was a script converting the verbose file "Integrated Report" to a human-readable HTML file, with colors, structure, and filtering feature.

The source was an ASCI tabbed file, where each line describes a low-level activity on-board (file copy, call to a sequence, call to a SEIS / APSS command etc.). Even if file was filtered by JPL/LM, it also contained some data about arm or HP3 activities, not useful for PDL analysis. A CNES filtering was necessary.

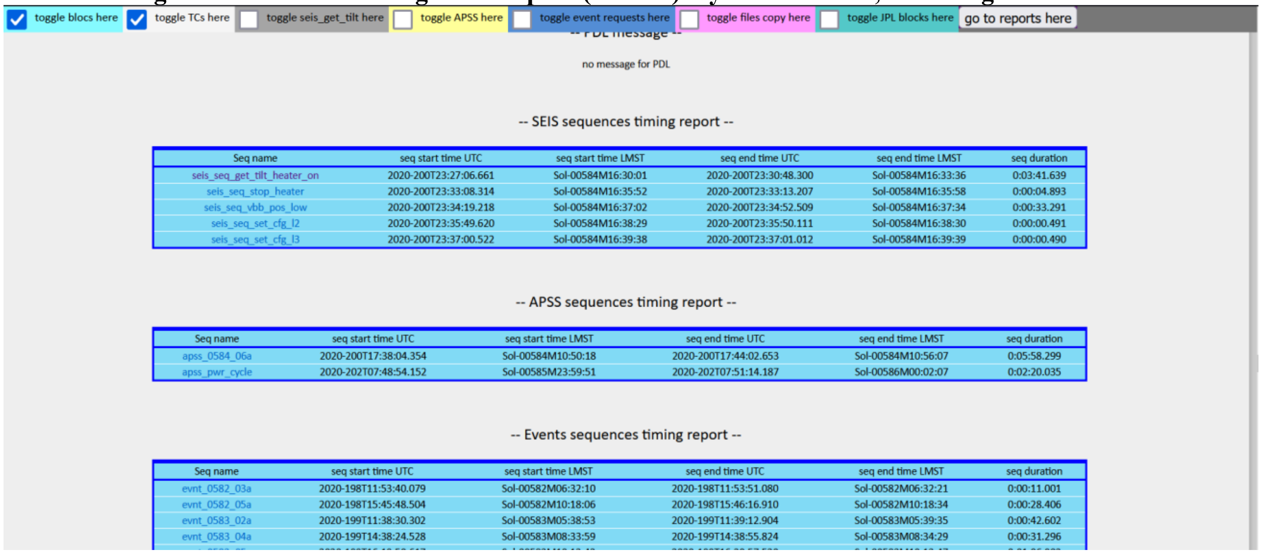
Even if such delimited file is easy to parse, the presentation needed by the operational team involved sophisticated algorithms to detect nested "functions" ("blocks") calls from a flat and linear file (see [1] for details about sequence/bloc/command structure).

Figure 2 : Extract of Integrated Report (top), with detailed of sequence/block/command nesting


toggle blocs here | toggle TCs here | toggle seis_get_tilt here | toggle APSS here | toggle event requests here | toggle files copy here | toggle JPL blocks here | go to reports here

Sol-00584M15:24:04	2020-200T22:19:20.847	VM_10	VM_RETURN_TAG	vm_return_string=UNKNOWN (matching "pay_cleanup")
Sol-00584M16:26:14	2020-200T23:23:13.186	VM_23	seis_wakeup	
Sol-00584M16:26:26	2020-200T23:23:26.486	GV_SEIS_RCT_FINISHED	1	
Sol-00584M16:30:01	2020-200T23:27:06.661	FSW	seis_seq_get_tilt_heater_on	
Sol-00584M16:30:01	2020-200T23:27:06.798	GV_SEQ_WARN_MSG_VM_ENG_11	Begin of seis_seq_get_tilt_heater_on	
Sol-00584M16:30:01	2020-200T23:27:06.892	GV_SEQ_WARN_MSG_VM_ENG_11	Stop_Heater	
Sol-00584M16:30:01	2020-200T23:27:06.992	BLOCK	seis_mde_off	
Sol-00584M16:30:01	2020-200T23:27:07.092	TC	SEIS_SET_MDE_PWR (ID=0x0e)	seis_mde_mode=MDE_POWER_OFF,fixed_0x0000=0x0000,fixed_0x00000000_00=0x00000000
Sol-00584M16:30:02	2020-200T23:27:08.194	TC	SEIS_GET_MDE_PWR (ID=0x0f)	fixed_0x00=0x00,fixed_0x0000=0x0000,fixed_0x00000000_00=0x00000000
Sol-00584M16:30:03	2020-200T23:27:09.293	VM_11	VM_RETURN_TAG	vm_return_string=TRUE (matching "seis_mde_off")
Sol-00584M16:30:03	2020-200T23:27:09.392	TC	SEIS_THM_PROT_TH (ID=0x06)	seis_min_thermal_threshold=21281,seis_max_thermal_threshold=53460,fixed_0x00=0x00,fixed_0x0000=0x0000
Sol-00584M16:30:04	2020-200T23:27:10.492	TC	SEIS_THM_PROT (ID=0x03)	seis_enable_flag=Enable,fixed_0x0000=0x0000,fixed_0x00000000_00=0x00000000
Sol-00584M16:30:05	2020-200T23:27:11.593	GV_SEQ_WARN_MSG_VM_ENG_11	Power ON MDE	
Sol-00584M16:30:05	2020-200T23:27:11.694	BLOCK	seis_mde_on	
Sol-00584M16:30:06	2020-200T23:27:11.893	TC	SEIS_SET_MDE_PWR (ID=0x0e)	seis_mde_mode=MDE_STAND_BY_MODE,fixed_0x0000=0x0000,fixed_0x00000000_00=0x00000000
Sol-00584M16:30:07	2020-200T23:27:12.992	TC	SEIS_GET_MDE_PWR (ID=0x0f)	fixed_0x00=0x00,fixed_0x0000=0x0000,fixed_0x00000000_00=0x00000000
Sol-00584M16:30:08	2020-200T23:27:14.092	VM_11	VM_RETURN_TAG	vm_return_string=TRUE (matching "seis_mde_on")
Sol-00584M16:30:08	2020-200T23:27:14.193	GV_SEQ_WARN_MSG_VM_ENG_11	Get SEIS coarse and precise tilt values	
Sol-00584M16:30:08	2020-200T23:27:14.294	BLOCK	seis_get_tilt_values	BOTH,20,20,10,3
Sol-00584M16:30:09	2020-200T23:27:15.693	TC	SEIS_READ_RCNTRG (ID=0x3e)	fixed_0x00=0x00,fixed_0x0000=0x0000,fixed_0x00000000_00=0x00000000
Sol-00584M16:30:10	2020-200T23:27:15.799	BLOCK	seis_write_mde_register	8,768
Sol-00584M16:30:10	2020-200T23:27:16.194	TC	SEIS_XMIT_MDE (ID=0x63)	seis_mde_cmd=0x48,seis_mde_reg=0x0300,fixed_0x00000000_00=0x00000000
Sol-00584M16:30:10	2020-200T23:27:16.292	TC	SEIS_REQUEST_MDE (ID=0x64)	fixed_0x00=0x00,fixed_0x0000=0x0000,fixed_0x00000000_00=0x00000000
Sol-00584M16:30:10	2020-200T23:27:16.392	VM_11	VM_RETURN_TAG	vm_return_string=TRUE (matching "seis_write_mde_register")
Sol-00584M16:30:11	2020-200T23:27:16.993	BLOCK	seis_read_mde_register	4
Sol-00584M16:30:11	2020-200T23:27:17.293	TC	SEIS_XMIT_MDE (ID=0x63)	seis_mde_cmd=0x24,seis_mde_reg=0x0000,fixed_0x00000000_00=0x00000000
Sol-00584M16:30:11	2020-200T23:27:17.392	TC	SEIS_REQUEST_MDE (ID=0x64)	fixed_0x00=0x00,fixed_0x0000=0x0000,fixed_0x00000000_00=0x00000000
Sol-00584M16:30:11	2020-200T23:27:17.494	VM_11	VM_RETURN_TAG	vm_return_string=TRUE (matching "seis_read_mde_register")
Sol-00584M16:30:11	2020-200T23:27:17.594	BLOCK	seis_read_mde_register	5
Sol-00584M16:30:12	2020-200T23:27:17.894	TC	SEIS_XMIT_MDE (ID=0x63)	seis_mde_cmd=0x25,seis_mde_reg=0x0000,fixed_0x00000000_00=0x00000000
Sol-00584M16:30:12	2020-200T23:27:17.993	TC	SEIS_REQUEST_MDE (ID=0x64)	fixed_0x00=0x00,fixed_0x0000=0x0000,fixed_0x00000000_00=0x00000000
Sol-00584M16:30:12	2020-200T23:27:18.094	VM_11	VM_RETURN_TAG	vm_return_string=TRUE (matching "seis_read_mde_register")
Sol-00584M16:30:12	2020-200T23:27:18.393	BLOCK	seis_read_mde_register	4

Figure 3 : Extract of Integrated Report (bottom). Synthesis tables, including real durations.



-- SEIS sequences timing report --

Seq name	seq start time UTC	seq start time LMST	seq end time UTC	seq end time LMST	seq duration
seis_seq_get_tilt_heater_on	2020-200T23:27:06.661	Sol-00584M16:30:01	2020-200T23:30:48.300	Sol-00584M16:33:36	0:03:41.639
seis_seq_stop_heater	2020-200T23:33:08.314	Sol-00584M16:35:52	2020-200T23:33:13.207	Sol-00584M16:35:58	0:00:04.893
seis_seq_vbb_pos_low	2020-200T23:34:19.218	Sol-00584M16:37:02	2020-200T23:34:52.509	Sol-00584M16:37:34	0:00:33.291
seis_seq_set_cfg_l2	2020-200T23:35:49.620	Sol-00584M16:38:29	2020-200T23:35:50.111	Sol-00584M16:38:30	0:00:00.491
seis_seq_set_cfg_l3	2020-200T23:37:00.522	Sol-00584M16:39:38	2020-200T23:37:01.012	Sol-00584M16:39:39	0:00:00.490

-- APSS sequences timing report --

Seq name	seq start time UTC	seq start time LMST	seq end time UTC	seq end time LMST	seq duration
apss_0584_06a	2020-200T17:38:04.354	Sol-00584M10:50:18	2020-200T17:44:02.653	Sol-00584M10:56:07	0:05:58.299
apss_pwr_cycle	2020-202T07:48:54.152	Sol-00585M23:59:51	2020-202T07:51:14.187	Sol-00586M00:02:07	0:02:20.035

-- Events sequences timing report --

Seq name	seq start time UTC	seq start time LMST	seq end time UTC	seq end time LMST	seq duration
evnt_0582_03a	2020-198T11:53:40.079	Sol-00582M06:32:10	2020-198T11:53:51.080	Sol-00582M06:32:21	0:00:11.001
evnt_0582_05a	2020-198T15:45:48.504	Sol-00582M10:18:06	2020-198T15:46:16.910	Sol-00582M10:18:34	0:00:28.406
evnt_0583_02a	2020-199T11:38:30.302	Sol-00583M05:38:53	2020-199T11:39:12.904	Sol-00583M05:39:35	0:00:42.602
evnt_0583_04a	2020-199T14:38:24.528	Sol-00583M08:33:59	2020-199T14:38:55.824	Sol-00583M08:34:29	0:00:31.296

7.1.1. Reports frequency and evolution of needs (last pass -> last 7 sols)

As briefly mentioned in the previous paragraph, the Integrated Reports were received around twice a day in nominal operations. Even if PDL was monitoring them every day, it was useful to have a weekly view, mainly in the frame of weekly meetings, like "downlink status report" or SWIM meeting (both every Monday). Thus, concatenation of Integrated Report became a necessity. However, experience shown that data were not always retransmitted chronologically, meaning that a gap in the first report can be filled by some lines of the next one.
Consequently, concatenation had to take into account real data chronology, and not just append files one after another. Higher-level script was necessary to manage data chronology, and ensure splitting all data by weeks, even if week change involves cutting a file in half.

As the first entry point for operations analysis, this script had to be reliable and miss no command or function call. And even in case of discrepancy (i.e due to file interruption), the script should go ahead, with a notification for the user that something was inconsistent. Generated HTML page included a toolbar with filtering and direct links to specific section. Finally, a summary of SEIS, APSS and Event sequences was presented, as three tables, with sequence name, start and stop times (in UTC and LMST) and duration. Events were also detailed with a flat representation, showing Event Id (unique identifier of a request), and for each channel (meaning a specific sensor at a specific rate), the file matching the request. If any channel returned a failure (could happen if requested channel at given time returned no data), it appeared in red, pointing exactly the issue, and allowing operational team to investigate the issue and inform the science community. A table represented details about data processing activity, with start time and if all remaining data were processed in the given timeout. If not, it appeared in red.

All the synthetized information extracted from raw reports helped operators having quickly a good overview of passed on-board activities, recent or olders.
Those scripts were created and maintained by an SEIS operator, and underwent 28 versions during the mission.

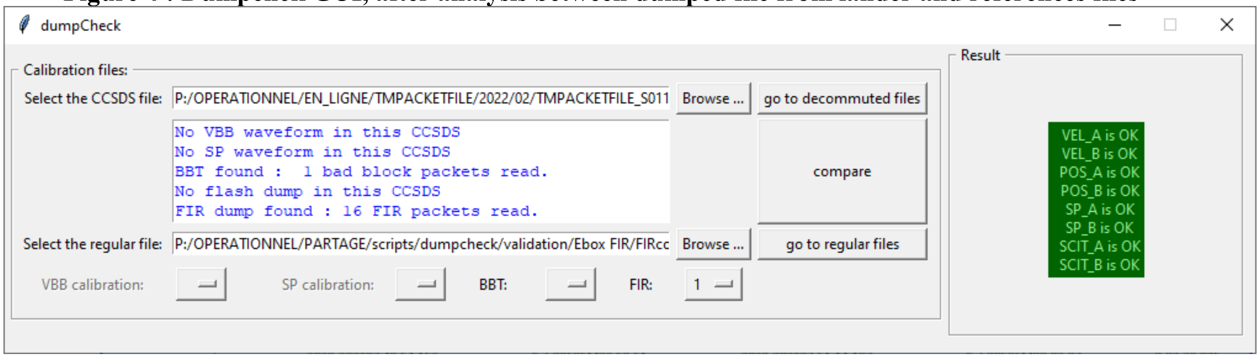
7.2. Confirm operational binary files really on-board : dumpcheck

One of the SEIS features was the ability to upload new binary files to customize some activities:

- Upload a new calibration curve for VBBs
- Upload a new calibration curve for SPs
- Upload a new bundle of E-Box FIR filters (8 stages)

These activities were prepared through dedicated sequences by the PUL, including the specific files to be used. Based on the last uplink report, PDL has the task to ensure that such activities were executed successfully.

Figure 4 : Dumpchek GUI, after analysis between dumped file from lander and references files



7.2.1. VBB and SP calibration curve update

E-Box was able to store one calibration curve per type of sensor, meaning one for the VBBs and one for the SPs. Both were very similar, with an ASCII file, listing couples of step/integer. The file was "compiled" as a binary file for uplink purpose. Once on-board, the file was stored in the Ebox, and its content was dumped and packetized in a CCSDS file. An operational task in case of file upload was to ensure on-board file was the same than sent file. Comparison of ASCII content was made possible by decommutating the CCSDS file, extracting the ASCII content, and check if any difference was detected with the original file.

7.2.2. FIR filters update

Ebox relied on FIR filters on-board for continuous data processing. Operators developed activities that allowed updating those FIR filters for specific operational cases. It was used in two situations:

- Re-enforce the current FIR filters on-board, given as an instruction to ensure good performances in data processing.
- Adapt the FIR filters to the planned activity, mainly when HP3 was hammering.

Even if uplink part was easy and logical (erase the 8 stages of FIR filters, then load the new ones), the strategy included a way to downlink the FIR filters content before and after uploading, providing operators precious information in case of failure or discrepancy. Meaning that from a set of space packets (CCSDS file) with a specific APID, operators were supposed to decommutate the binary files, that contain the 8 pages of dumped FIR filters (8 before the change, 8 after the change), and finally compare the pages (represented as ASCII files of 255 numbers) with the reference ones.
When performed manually, this operation was very long, with high risks of mistakes, as data were very similar between stages. The dumpcheck tool automatized that task.

7.2.3. Ensure on-board binary files are the expected ones

Even if calibration and FIR are distinguished use cases, the need of a dedicated tool quickly appeared for the following purposes:

- Analyse CCSDS file content (FIR ? VBB calibration curve ? or SP ?) by integrating decommutation feature.
- Propose to compare with a reference, via a GUI
- Proceed to comparison between reference and downlinked data
- Display a synthesis : match / don't match, and in such case, provide details about discrepancy

A solution integrating a user interface, allowing selecting references files easily, led to design the tool with a GUI, allowing easy file-browsing.
GUI via python involved the tool to be available on workstations, with the available graphical lib. TKinter has been chosen, fulfilling all the pre-requisites.
The tool also relied on a decommutation tool provided by ETH, that converted CCSDS to several ASCII files, being easily parsed.
Complexity was increased for FIR filters, as the bundle of 8 pages could be composed of 8 similar or different pages, meaning that meta-configurations should rely on existing FIR files, but specified in a given

order. User just had to select the use case (i.e: nominal, hammering), and associated sub-files were parsed, in the specified order.
Due to difference in python version between operational workstations and desktop laptops, the tool was initially intended only for the operational context. But when lockdown occurred in 2020, operators had to adapt the tool for working also on CNES individual office laptops, taking into account a different version of python, and a slightly modified version of TKinter lib. The definitive version was able to execute on both platforms, by detecting automatically its environment.
PDL tasks was thus eased, by opening the tool, choosing the CCSDS file matching the binary file activity, select the reference to compare with, and analyze the tool's results, saving time and exactness of the comparison.

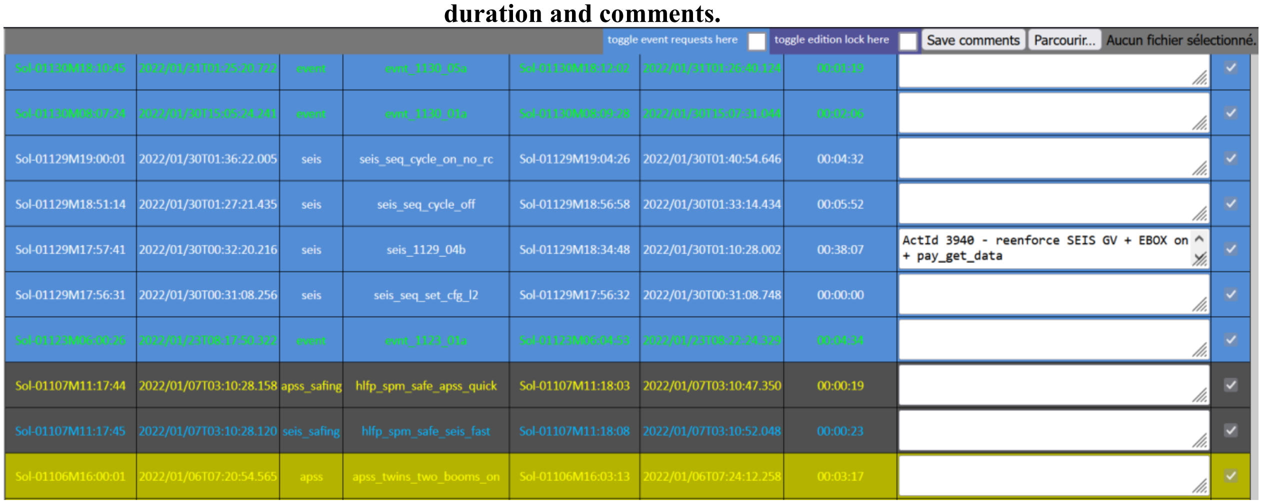
The tool was created and maintained by a SEIS operator, and underwent 12 versions during the mission.

7.3. *Keep track of executed sequences : Ultimate Integrated Report*

Close to first year of mission, operational team noticed the need to check in the past the previous occurrences of an activity, and to add context on its execution. Operational people have identified as missing a summary of what has been executed when, and for how long. In addition, it would be nice to add for each activity a contextual comment – as a free text from operators, helping to understand specific points in the future.

Such a report was fed by the reception of new integrated reports, containing real on-board execution products and timing. It involved that mission summary was enriched after integrated report reception, and must kept a link with comments entered by operators.

Figure 5 : Ultimate Integrated Report (top). Activities are listed chronologically, with start/end time, duration and comments.



toggle event requests here | toggle edition lock here | Save comments | Parcourir... | Aucun fichier sélectionné.

Sol-01130M18:10:45	2022/01/31T01:25:20.722	event	evnt_1130_05a	Sol-01130M18:12:02	2022/01/31T01:26:40.124	00:01:19	
Sol-01130M08:07:24	2022/01/30T15:05:24.241	event	evnt_1130_01a	Sol-01130M08:09:28	2022/01/30T15:07:31.044	00:02:06	
Sol-01129M19:00:01	2022/01/30T01:36:22.005	seis	seis_seq_cycle_on_no_rc	Sol-01129M19:04:26	2022/01/30T01:40:54.646	00:04:32	
Sol-01129M18:51:14	2022/01/30T01:27:21.435	seis	seis_seq_cycle_off	Sol-01129M18:56:58	2022/01/30T01:33:14.434	00:05:52	
Sol-01129M17:57:41	2022/01/30T00:32:20.216	seis	seis_1129_04b	Sol-01129M18:34:48	2022/01/30T01:10:28.002	00:38:07	ActId 3940 - reenforce SEIS GV + EBOX on + pay_get_data
Sol-01129M17:56:31	2022/01/30T00:31:08.256	seis	seis_seq_set_cfg_l2	Sol-01129M17:56:32	2022/01/30T00:31:08.748	00:00:00	
Sol-01123M06:00:26	2022/01/23T08:17:50.322	event	evnt_1123_01a	Sol-01123M06:04:53	2022/01/23T08:22:24.329	00:04:34	
Sol-01107M11:17:44	2022/01/07T03:10:28.158	apss_safing	hlfp_spm_safe_apss_quick	Sol-01107M11:18:03	2022/01/07T03:10:47.350	00:00:19	
Sol-01107M11:17:45	2022/01/07T03:10:28.120	seis_safing	hlfp_spm_safe_seis_fast	Sol-01107M11:18:08	2022/01/07T03:10:52.048	00:00:23	
Sol-01106M16:00:01	2022/01/06T07:20:54.565	apss	apss_twins_two_booms_on	Sol-01106M16:03:13	2022/01/06T07:24:12.258	00:03:17	

Strongly linked to Integrated Report format, the script was designed to run on SAG server (python 2.7), and triggered right after new integrated report reception. Knowing that integrated report could be received in non-chronological order, decision was made for this tool to re-process systematically all the previous integrated reports in order to sort all useful information chronologically. Although this approach was not optimal in terms of performance, it ensured to cover the whole mission in chronological order, even if gaps were filled later.

This summary file displayed SEIS, APSS and Event sequences, with start and end date, in UTC and LMST, and a free text associated. This helped operational team to check previous activities, confirm durations, check last occurrence of an operational activity.

The tool was created and maintained by a SEIS operator, and underwent 10 versions during the mission.

7.4. Fine analysis of recenterings: STAR

For reminder, SEIS operational team operated SEIS instrument that was composed of two seismic sensors: VBBs and SPs.
VBBs are pendulums, whose oscillations are detected by very sensitive sensors. The better the pendulum is centered, the better it can cover a detection range without any risk of saturation (meaning loosing data).
Thermal variations could lead to sensor drift, which involved operators to trigger a “re-centering” activity. Activating the recentering motor until reaching the given target was a sensitive operation, with a complex algorithm, where big-jumps and small steps were computed, trying to avoid any backlash in the mechanism.

Analyzing if a VBB recentering was as successful as expected was a major operational task, capital for science data quality.
However, there were several points to monitor before concluding: amount of big-jumps and small steps performed, initial and final position value (voltage), number of iterations etc.

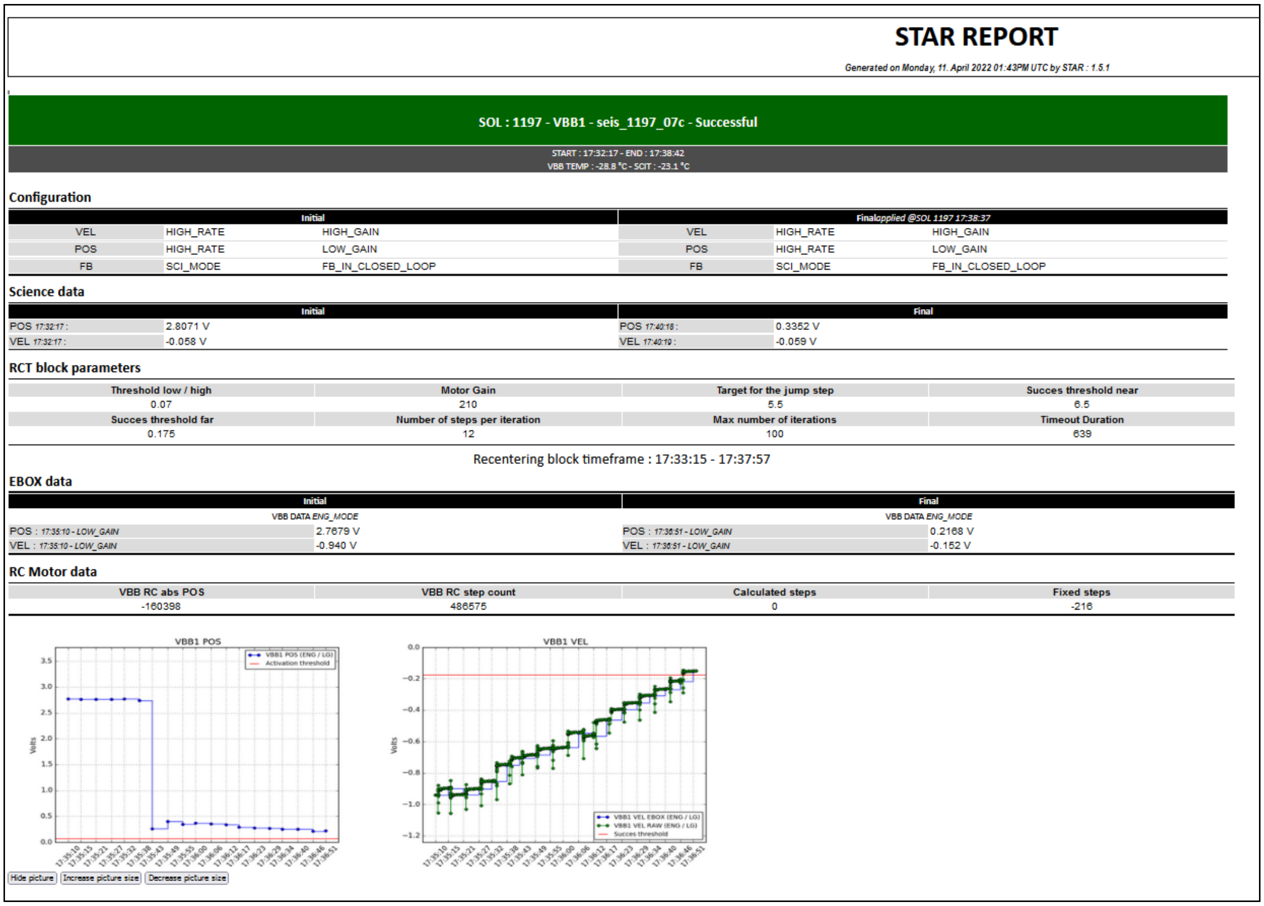
It was also interesting to study successive recenterings all along the mission, and understand the possible gap between what was commanded and what was observed. That is why, quickly appeared the need to have a tool dedicated to this study.

Based on this, the objectives of the STAR tool were:
- automatize VBB recentering analysis
- keep a history of recentering operations, allowing trend analysis and long-term follow-up.

To do so, STAR used as inputs:
- An integrated report (see §7.1) containing execution of recentering, with commanding and messages
- Telemetry from instrument (extracted from IMIS tool, thanks to a batch feature)
- Long-term follow-up file
- Contextual comment from user related to this recentering

The tool provided an HTML report and a PDF report, with graphics showing evolution of POS and VEL parameters. It detected if an issue has been encountered, or if recentering was finally not needed.

Figure 6 : STAR report. The tables summarize the configurations. The integrated curves show the evolution of the POS and VEL observables.



STAR REPORT

Generated on Monday, 11. April 2022 01:43PM UTC by STAR : 1.5.1

SOL : 1197 - VBB1 - seis_1197_07c - Successful

START : 17:32:17 - END : 17:38:42
VBB TEMP : -28.8 °C - SCIT : -23.1 °C

Configuration

Initial			Finalapplied @SOL 1197 17:38:37		
VEL	HIGH_RATE	HIGH_GAIN	VEL	HIGH_RATE	HIGH_GAIN
POS	HIGH_RATE	LOW_GAIN	POS	HIGH_RATE	LOW_GAIN
FB	SCI_MODE	FB_IN_CLOSED_LOOP	FB	SCI_MODE	FB_IN_CLOSED_LOOP

Science data

Initial		Final	
POS 17:32:17 :	2.8071 V	POS 17:40:18 :	0.3352 V
VEL 17:32:17 :	-0.058 V	VEL 17:40:19 :	-0.059 V

RCT block parameters

Threshold low / high	Motor Gain	Target for the jump step	Succes threshold near
0.07	210	5.5	6.5
Succes threshold far	**Number of steps per iteration**	**Max number of iterations**	**Timeout Duration**
0.175	12	100	639

Recentering block timeframe : 17:33:15 - 17:37:57

EBOX data

Initial		Final	
	VBB DATA ENG_MODE		VBB DATA ENG_MODE
POS : 17:35:10 - LOW_GAIN	2.7679 V	POS : 17:36:51 - LOW_GAIN	0.2168 V
VEL : 17:35:10 - LOW_GAIN	-0.940 V	VEL : 17:36:51 - LOW_GAIN	-0.152 V

RC Motor data

VBB RC abs POS	VBB RC step count	Calculated steps	Fixed steps
-160398	486575	0	-216

The tool was created and maintained by a SEIS operator, and underwent 6 versions during the mission.

7.5. *Fine analysis of missing data : GAFA*

GAFA need was identified early, but took time to clearly define and implement. The idea was when missing data were detected in final products (mseed files) to have a clear list of lost channels and time gaps, in order to check if this corresponded to global missing data, or if it was a problem at SISMOC level.

Indeed, during weekly coordination meetings with scientific teams exploiting SISMOC data, operational team had regularly questions about missing science data (i.e gaps in VBB position or velocity signals). Most were explainable, due to short-interruptions of acquisitions due to an engineering activity, or known missing data from the orbiters, sensors Off etc. But sometimes, after all those verifications, nothing explained the gaps. So, GDS team was asked to check any issue on SISMOC data management.
Having in advance the ability to self-check gaps in science products helped to anticipate the investigations.

Moreover, as described in §1, the whole System (including SISMOC, JPL, and InSight lander) had the feature to ask data in the past, via Event Request process. First designed to retrieve interesting set of channels in high resolution, this mechanism was also used to recover data gaps, when continuous data flow had been interrupted, or to get data between the last data processing and an unexpected safing (case where lander and/or instruments triggers their fault-protection after failure detection, turning-themselves off preventing any damage).
Science and engineering teams had access to an on-line tool, helping to create a request, mainly by specifying the time window and the channels. These requests were then prioritized, according to scientific interests,

available bandwidth, etc. Then requests were then sent on-board like others sequences, to be executed on programmed time.

The link with GAFA tool is that it was also designed to generate directly the Event Requests in a format adapted to the CNES ERP-Tool, based on the detected gaps in science data, preventing scientists to spend time on requests creations. Up to PUL to only keep the ones associated to real gaps, and not the ones matching an expected interruption.
However, this feature has been never used in operations, because it went too late during the mission and was hard to integrate into an already tight operation schedule.

Figure 7 : Example of GAFA output, detecting gaps, and generating ERPs.

```
========================================
======= GAP FAST ANALYSIS REPORT =======
========================================
Report generated by: sintegra on: 2022-04-04 14:59:57.273846
firstDayScan : 2022-03-12
lastDayERP   : 2022-03-27
lastDayScan  : 2022-04-02
========================================
==> 4 gaps for channel: HK LOW
  Start                        End                          Duration (s)                 ERP file
SOL1170T06:04:48.933784      SOL1170T06:09:56.412801      215.931999922                None
SOL1170T11:35:58.623153      SOL1170T11:41:45.121480      256.023999929                None
SOL1182T16:06:05.631444      SOL1182T16:10:54.721984      197.038000107                None
SOL1183T09:06:19.790588      SOL1183T09:09:18.910361      84.0440001488                None
==> 0 gaps for channel: VBB_1_VEL
==> 0 gaps for channel: VBB_2_VEL
==> 0 gaps for channel: VBB_3_VEL
==> 0 gaps for channel: VBB_1_POS
==> 0 gaps for channel: VBB_2_POS
==> 0 gaps for channel: VBB_3_POS
==> 0 gaps for channel: VBB_1_TEMP
==> 0 gaps for channel: VBB_2_TEMP
==> 0 gaps for channel: VBB_3_TEMP
==> 0 gaps for channel: SCIT
==> 0 gaps for channel: SP_1_VEL
==> 0 gaps for channel: SP_2_VEL
==> 0 gaps for channel: SP_3_VEL
==> 5 gaps for channel: PRESS
  Start                        End                          Duration (s)                 ERP file
SOL1171T13:49:30.514095      SOL1171T14:56:22.636820      4122.421                     ERP.SISMOC.20220404-000000.xml
SOL1171T22:00:40.663792      SOL1173T06:07:29.642266      118787.214                   ERP.SISMOC.20220404-000001.xml
SOL1173T15:56:17.606314      SOL1173T21:56:59.515151      22236.7720001                ERP.SISMOC.20220404-000002.xml
SOL1174T09:00:41.654690      SOL1185T19:56:59.364540      1016987.938                  None
SOL1186T05:59:08.160711      SOL1187T03:33:03.429009      79769.559                    None
```

The tool was created and maintained by a SEIS operator, and underwent only 1 version during the mission.

7.6. Aggregate significant downlink data to ease reporting : SIRENA

InSight operations went over some regular operational key points. One of them was the "downlink assessment meeting". Initially a daily meeting, it became a weekly meeting when Science Monitoring phase started.
The aim of this meeting was to provide a whole status of the spacecraft and instruments. The CNES PDL had to report SEIS and APSS statuses, and provide an assessment for period starting from last meeting, about general instruments status and executed activities.
Following its procedure, PDL had to verify HK data (temperatures, voltages, currents, etc.), alarms, executed sequences, specific activities analysis (like recentering, calibration etc.).
Even if the PDL had a range of tools (IMIS – at least for HK data and alarms, Integrated Report, dumpcheck), synthesizing and presenting the information remained a tedious task.

Beyond grouping the information, it was necessary to present it in a standardized way regardless of the operator, in order to have homogeneous reports every week.

Very quickly, the need to aggregate the usual information from different sources appeared, with the objective of relieving the operator of all tasks of authentication, research, copying, formatting etc.
This hard task is accomplished by SIRENA, that was reading:
- sequences execution (from integrated reports)
- HK values, like voltages, currents, (from a bash connection to IMIS tool)
- alarms raised by monitoring plan (same source)
- current instruments configuration (for both SEIS and APSS, also from IMIS)

This has been identified as a major need, due to amount of data to gather in limited time. Thanks to SIRENA, operator can focus on data analysis and interpretation, instead of spending time in connections, logins, requests, formatting, copy etc.

SIRENA also evolved to trigger automatically some of the previous tools described before:

- GAFA (on-request, if any data reception analysis was required).
- STAR, if a recentering was detected in the analyzed period.

Beyond its ability to interface with multiple tools, a special ergonomic effort has been made, through use as a web page. Instead of launching a script with several parameters (start/end date covering the report, and flags asking to generate or not specific reports about Heater, Recentering, GAFA (gaps in science data), and specific reports about SEIS, APSS or even SWIM), it has been agreed between operational and GDS teams that a web page integrated to SISMOC would be more convenient. A very big work of industrialization was carried out with a precious support of GDS team, in order to structure the tool. This joint work with GDS team improved modularity, portability and packaging. This webpage also displayed in real-time the requests from the tool, and finally provided link to web report. Other reports (SEIS, APSS and SWIM) were PDF files, available in a SIRENA directory.

Figure 8 : SIRENA GUI, with fields and options proposed to the user.

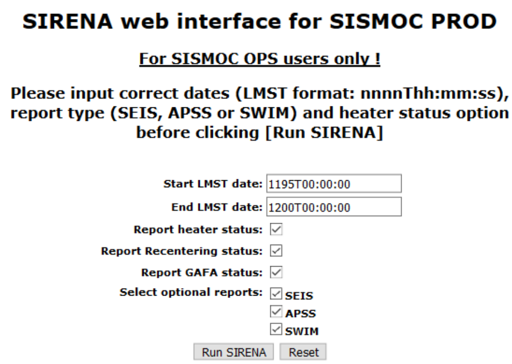
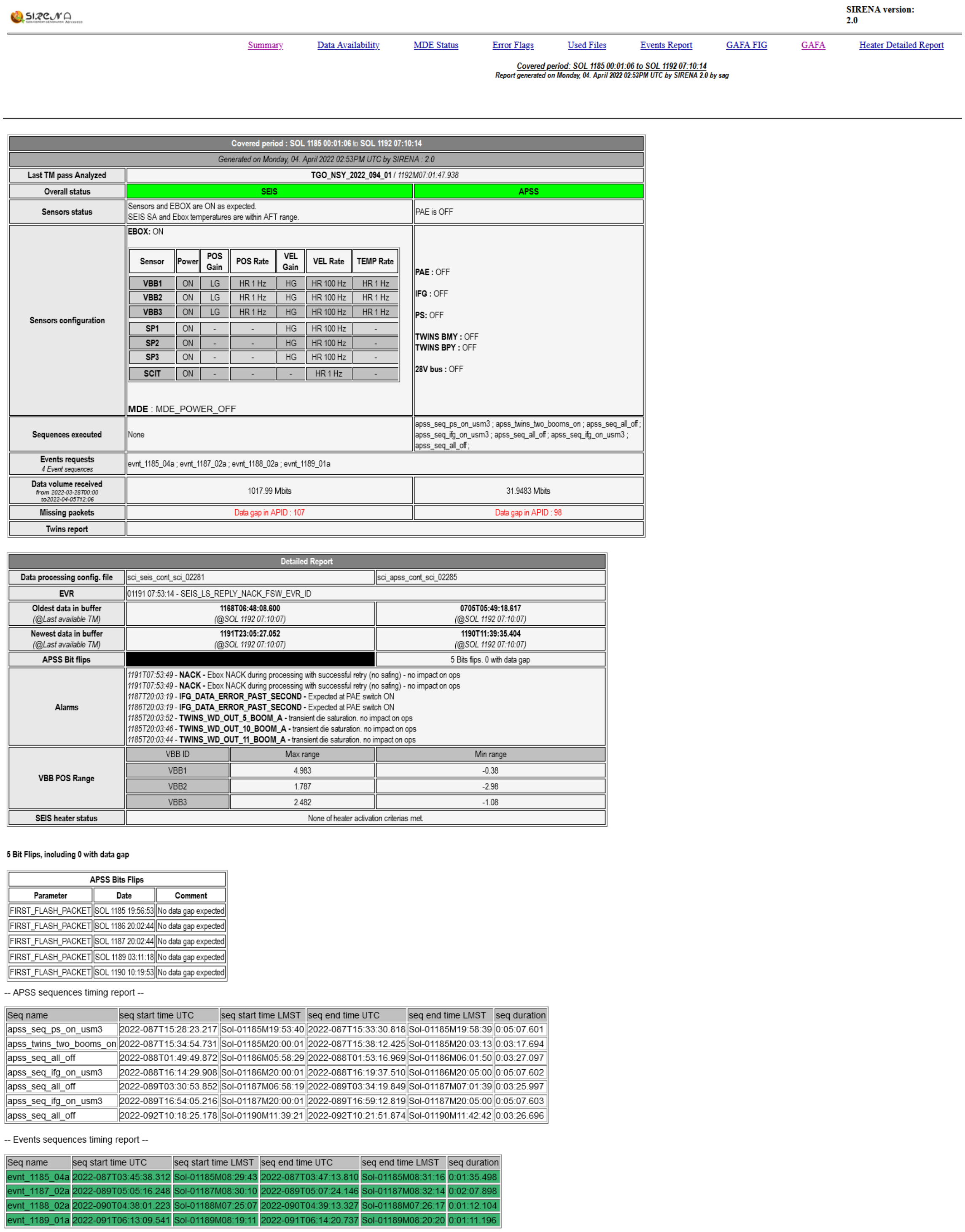


Figure 9 : main SIRENA output. Synthesis of instruments. Notice that many dedicated sub-pages are available thanks to the top toolbar.



SIRENA version: 2.0

Summary | Data Availability | MDE Status | Error Flags | Used Files | Events Report | GAFA FIG | GAFA | Heater Detailed Report

Covered period: SOL 1185 00:01:06 to SOL 1192 07:10:14
Report generated on Monday, 04. April 2022 02:53PM UTC by SIRENA 2.0 by sag

Covered period : SOL 1185 00:01:06 to SOL 1192 07:10:14		
Generated on Monday, 04. April 2022 02:53PM UTC by SIRENA : 2.0		
Last TM pass Analyzed	**TGO_NSY_2022_094_01** / 1192M07:01:47.938	
Overall status	**SEIS**	**APSS**
Sensors status	Sensors and EBOX are ON as expected. SEIS SA and Ebox temperatures are within AFT range.	PAE is OFF
Sensors configuration	**EBOX:** ON (see sensor table below) **MDE** : MDE_POWER_OFF	**PAE :** OFF **IFG :** OFF **PS:** OFF **TWINS BMY :** OFF **TWINS BPY :** OFF **28V bus :** OFF
Sequences executed	None	apss_seq_ps_on_usm3 ; apss_twins_two_booms_on ; apss_seq_all_off ; apss_seq_ifg_on_usm3 ; apss_seq_all_off ; apss_seq_ifg_on_usm3 ; apss_seq_all_off ;
Events requests *4 Event sequences*	evnt_1185_04a ; evnt_1187_02a ; evnt_1188_02a ; evnt_1189_01a	
Data volume received *from 2022-03-28T00:00 to2022-04-05T12:06*	1017.99 Mbits	31.9483 Mbits
Missing packets	Data gap in APID : 107	Data gap in APID : 98
Twins report		

Sensor	Power	POS Gain	POS Rate	VEL Gain	VEL Rate	TEMP Rate
VBB1	ON	LG	HR 1 Hz	HG	HR 100 Hz	HR 1 Hz
VBB2	ON	LG	HR 1 Hz	HG	HR 100 Hz	HR 1 Hz
VBB3	ON	LG	HR 1 Hz	HG	HR 100 Hz	HR 1 Hz
SP1	ON	-	-	HG	HR 100 Hz	-
SP2	ON	-	-	HG	HR 100 Hz	-
SP3	ON	-	-	HG	HR 100 Hz	-
SCIT	ON	-	-	-	HR 1 Hz	-

Detailed Report		
Data processing config. file	sci_seis_cont_sci_02281	sci_apss_cont_sci_02285
EVR	01191 07:53:14 - SEIS_LS_REPLY_NACK_FSW_EVR_ID	
Oldest data in buffer *(@Last available TM)*	**1168T06:48:08.600** *(@SOL 1192 07:10:07)*	**0705T05:49:18.617** *(@SOL 1192 07:10:07)*
Newest data in buffer *(@Last available TM)*	**1191T23:05:27.052** *(@SOL 1192 07:10:07)*	**1190T11:39:35.404** *(@SOL 1192 07:10:07)*
APSS Bit flips		5 Bits flips. 0 with data gap
Alarms	*1191T07:53:49* - **NACK -** Ebox NACK during processing with successful retry (no safing) - no impact on ops *1191T07:53:49* - **NACK -** Ebox NACK during processing with successful retry (no safing) - no impact on ops *1187T20:03:19* - **IFG_DATA_ERROR_PAST_SECOND -** Expected at PAE switch ON *1186T20:03:19* - **IFG_DATA_ERROR_PAST_SECOND -** Expected at PAE switch ON *1185T20:03:52* - **TWINS_WD_OUT_5_BOOM_A -** transient die saturation. no impact on ops *1185T20:03:46* - **TWINS_WD_OUT_10_BOOM_A -** transient die saturation. no impact on ops *1185T20:03:44* - **TWINS_WD_OUT_11_BOOM_A -** transient die saturation. no impact on ops	
SEIS heater status	None of heater activation criterias met.	

VBB POS Range: VBB ID	Max range	Min range
VBB1	4.983	-0.38
VBB2	1.787	-2.98
VBB3	2.482	-1.08

5 Bit Flips, including 0 with data gap

APSS Bits Flips		
Parameter	**Date**	**Comment**
FIRST_FLASH_PACKET	SOL 1185 19:56:53	No data gap expected
FIRST_FLASH_PACKET	SOL 1186 20:02:44	No data gap expected
FIRST_FLASH_PACKET	SOL 1187 20:02:44	No data gap expected
FIRST_FLASH_PACKET	SOL 1189 03:11:18	No data gap expected
FIRST_FLASH_PACKET	SOL 1190 10:19:53	No data gap expected

-- APSS sequences timing report --

Seq name	seq start time UTC	seq start time LMST	seq end time UTC	seq end time LMST	seq duration
apss_seq_ps_on_usm3	2022-087T15:28:23.217	Sol-01185M19:53:40	2022-087T15:33:30.818	Sol-01185M19:58:39	0:05:07.601
apss_twins_two_booms_on	2022-087T15:34:54.731	Sol-01185M20:00:01	2022-087T15:38:12.425	Sol-01185M20:03:13	0:03:17.694
apss_seq_all_off	2022-088T01:49:49.872	Sol-01186M05:58:29	2022-088T01:53:16.969	Sol-01186M06:01:50	0:03:27.097
apss_seq_ifg_on_usm3	2022-088T16:14:29.908	Sol-01186M20:00:01	2022-088T16:19:37.510	Sol-01186M20:05:00	0:05:07.602
apss_seq_all_off	2022-089T03:30:53.852	Sol-01187M06:58:19	2022-089T03:34:19.849	Sol-01187M07:01:39	0:03:25.997
apss_seq_ifg_on_usm3	2022-089T16:54:05.216	Sol-01187M20:00:01	2022-089T16:59:12.819	Sol-01187M20:05:00	0:05:07.603
apss_seq_all_off	2022-092T10:18:25.178	Sol-01190M11:39:21	2022-092T10:21:51.874	Sol-01190M11:42:42	0:03:26.696

-- Events sequences timing report --

Seq name	seq start time UTC	seq start time LMST	seq end time UTC	seq end time LMST	seq duration
evnt_1185_04a	2022-087T03:45:38.312	Sol-01185M08:29:43	2022-087T03:47:13.810	Sol-01185M08:31:16	0:01:35.498
evnt_1187_02a	2022-089T05:05:16.248	Sol-01187M08:30:10	2022-089T05:07:24.146	Sol-01187M08:32:14	0:02:07.898
evnt_1188_02a	2022-090T04:38:01.223	Sol-01188M07:25:07	2022-090T04:39:13.327	Sol-01188M07:26:17	0:01:12.104
evnt_1189_01a	2022-091T06:13:09.541	Sol-01189M08:19:11	2022-091T06:14:20.737	Sol-01189M08:20:20	0:01:11.196

The tool was created and maintained by a SEIS operator, and underwent 25 versions during the mission.

8. Uplink tools

8.1. Cross-check files delivery with the operational plan : PUL Report

The first weeks showed pitfalls which the operational staff could have fallen into without great vigilance. Remind that the four firsts months of operations were located in JPL premises, with an uplink per day. The operational cycle was:

- Morning briefing about what will be downlinked, and what will be uplinked.
- Data arrival, giving one hour to operators for their downlink assessment.
- Soon after, APAM (initial uplink briefing) propose a first draft of activities to uplink
- After a role-call asking a go/no-go on the plan, PUL operators have around 1 hour and a half to deliver their sequences to JPL. During this time, PUL has to implement sequences, validate them thanks to Command/Control team, check the flight rules, ensure they compile, build a Sequences Delivery List (a file that summarize the bundle content), deliver the files, and report the delivery reasons and content in a shared tool called "NSYT Report". A lot of work, involving again several tools, human interactions, multiple checks. There are many ways to make a mistake, and any help from a tool was welcome.

To secure this sensitive phase, a tool quickly appeared: PUL Report. The two main purposes were:

- Cross-check products to be delivered with tactical plan, ensuring nothing was missed or added.
- Help reporting for NSYT report tool.

The tool relied on two principal inputs:

- The tactical operational plan: an HTML with all details about incoming plan. The tool just parsed it and extracted some information.
- The Sequences Delivery List. If given to the tool, then a comparison was performed, in order to detect any missing or superfluous sequence. This verification was essential before sending list and files to JPL. If the file was not given, the tool only processed the plan, and presented a synthesis of what was expected on-board. This feature can help operators when building the SDL.

For more accurate information, it also took into account as input the WOBL (What's On Board List – a file where are dumped the names of all files present on-board). Knowing if the file must be uploaded or not helped JPL during operations.

The tool also detailed the event sequences content, keeping a trace of file, date, and ERPs listed inside.

Little by little, the tool was enhanced with other functionalities:

- When operations switched to 2-week plans, it has been decided by JPL that the first week delivery by PUL would contain all the operational sequences for the 2 weeks, but only the event-request for the first week. It was understandable as data continuing flooding during the first week, Science team could adjust events for the second week according to new interesting data. Thus, PUL operators had two kinds of uplinks: for week 1, a delivery covering the 2 weeks of operations, but the first week of events. And for week 2, only the events.

It involved a huge modification of the tool, adding a menu, with computed propositions about which week to process.

- As the mission progressed, and lander's power declined, the time spent by the lander to process the continuous data to send to Earth interested more and more operators. JPL added regular activities asking the lander to process a chunk of HK and science data, to fill the dedicated buffers, being ready to be sent for the next communication slot. This processing was usually called "data processing", and had as main parameter a timeout duration. This was the given time to the lander to process all the data from the last processing until now. Duration was computed by JPL from an approximate rule that matches most of the cases.

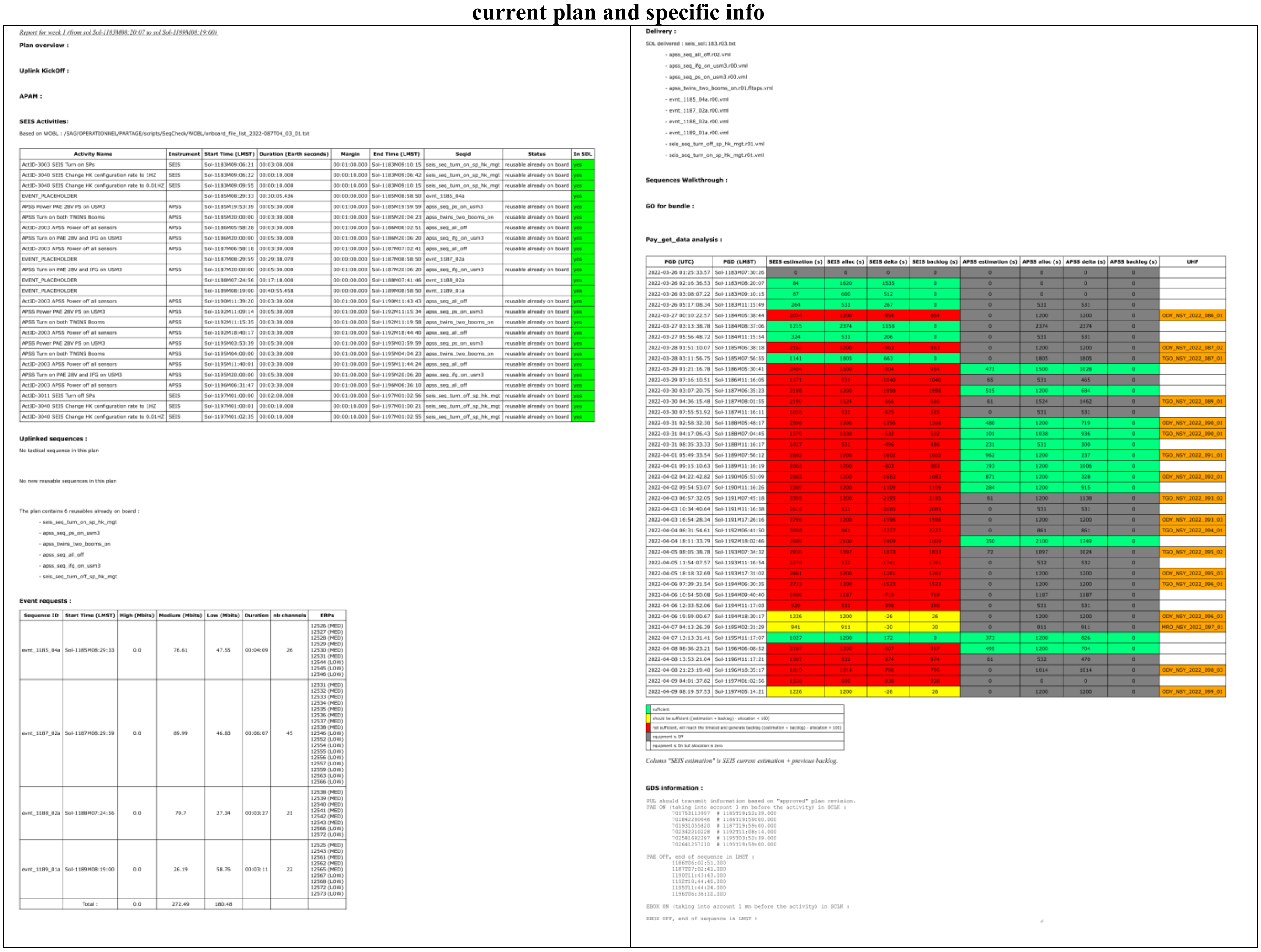
  But according the sensors status (on/off) and rate (low/high), the amount of data to be processed was very different.

In order to compute on CNES side a good estimation of required timeout, an analysis has been performed from lots of cases. It appeared that a linear approach, with coefficients matching configurations, provided a good estimate. From this manual check, it has been decided to include this feature of data volume estimation, taking also into account an estimation of remaining data after an incomplete data processing.

Over the objective to challenge the JPL estimation, the aim behind was to detect a cumulative deviation, which would not end up converging, with the risk of accumulating too much delay in data processing, and maybe a loss of data.

The tool's configuration file has been completed with coefficient sections, as well as a correspondence table between usual sequences and its effect (turn on/off a sensor, switch it to high/low rate). With this new information, a new functionality dedicated to data processing computation has been added, providing to PUL an estimation if the remaining unprocessed data is growing, remains stable or is null thanks to good coverage in JPL plan. It also provides key information for discussion with JPL, asking to increase some programmed durations, preventing issue later in the plan.

Figure 10 : PUL report output (page presented in 2 panels). The first section recalls the sequences used in the plan. Just after, the detail of the Events then of the SDL. Finally, a projection of data processing for the current plan and specific info



Report for week 1 (from sol Sol-1183M08:20:07 to sol Sol-1189M08:19:00)

Plan overview :

Uplink KickOff :

APAM :

SEIS Activities:

Based on WOBL : /SAG/OPERATIONNEL/PARTAGE/scripts/SeqCheck/WOBL/onboard_file_list_2022-087T04_03_01.txt

Activity Name	Instrument	Start Time (LMST)	Duration (Earth seconds)	Margin	End Time (LMST)	Seqid	Status	In SDL
ActID-3003 SEIS Turn on SPs	SEIS	Sol-1183M09:06:21	00:03:00.000	00:01:00.000	Sol-1183M09:10:15	seis_seq_turn_on_sp_hk_mgt	reusable already on board	yes
ActID-3040 SEIS Change HK configuration rate to 1HZ	SEIS	Sol-1183M09:06:22	00:00:10.000	00:00:10.000	Sol-1183M09:06:42	seis_seq_turn_on_sp_hk_mgt	reusable already on board	yes
ActID-3040 SEIS Change HK configuration rate to 0.01HZ	SEIS	Sol-1183M09:09:55	00:00:10.000	00:00:10.000	Sol-1183M09:10:15	seis_seq_turn_on_sp_hk_mgt	reusable already on board	yes
EVENT_PLACEHOLDER		Sol-1185M08:29:33	00:30:05.436	00:00:00.000	Sol-1185M08:58:50	evnt_1185_04a		yes
APSS Power PAE 28V PS on USM3	APSS	Sol-1185M19:53:39	00:05:30.000	00:01:00.000	Sol-1185M19:59:59	apss_seq_ps_on_usm3	reusable already on board	yes
APSS Turn on both TWINS Booms	APSS	Sol-1185M20:00:00	00:03:30.000	00:01:00.000	Sol-1185M20:04:23	apss_twins_two_booms_on	reusable already on board	yes
ActID-2003 APSS Power off all sensors	APSS	Sol-1186M05:58:28	00:03:30.000	00:01:00.000	Sol-1186M06:02:51	apss_seq_all_off	reusable already on board	yes
APSS Turn on PAE 28V and IFG on USM3	APSS	Sol-1186M20:00:00	00:05:30.000	00:01:00.000	Sol-1186M20:06:20	apss_seq_ifg_on_usm3	reusable already on board	yes
ActID-2003 APSS Power off all sensors	APSS	Sol-1187M06:58:18	00:03:30.000	00:01:00.000	Sol-1187M07:02:41	apss_seq_all_off	reusable already on board	yes
EVENT_PLACEHOLDER		Sol-1187M08:29:59	00:29:38.070	00:00:00.000	Sol-1187M08:58:50	evnt_1187_02a		yes
APSS Turn on PAE 28V and IFG on USM3	APSS	Sol-1187M20:00:00	00:05:30.000	00:01:00.000	Sol-1187M20:06:20	apss_seq_ifg_on_usm3	reusable already on board	yes
EVENT_PLACEHOLDER		Sol-1188M07:24:56	00:17:18.000	00:00:00.000	Sol-1188M07:41:46	evnt_1188_02a		yes
EVENT_PLACEHOLDER		Sol-1189M08:19:00	00:40:55.458	00:00:00.000	Sol-1189M08:58:50	evnt_1189_01a		yes
ActID-2003 APSS Power off all sensors	APSS	Sol-1190M11:39:20	00:03:30.000	00:01:00.000	Sol-1190M11:43:43	apss_seq_all_off	reusable already on board	yes
APSS Power PAE 28V PS on USM3	APSS	Sol-1192M11:09:14	00:05:30.000	00:01:00.000	Sol-1192M11:15:34	apss_seq_ps_on_usm3	reusable already on board	yes
APSS Turn on both TWINS Booms	APSS	Sol-1192M11:15:35	00:03:30.000	00:01:00.000	Sol-1192M11:19:58	apss_twins_two_booms_on	reusable already on board	yes
ActID-2003 APSS Power off all sensors	APSS	Sol-1192M18:40:17	00:03:30.000	00:01:00.000	Sol-1192M18:44:40	apss_seq_all_off	reusable already on board	yes
APSS Power PAE 28V PS on USM3	APSS	Sol-1195M03:53:39	00:05:30.000	00:01:00.000	Sol-1195M03:59:59	apss_seq_ps_on_usm3	reusable already on board	yes
APSS Turn on both TWINS Booms	APSS	Sol-1195M04:00:00	00:03:30.000	00:01:00.000	Sol-1195M04:04:23	apss_twins_two_booms_on	reusable already on board	yes
ActID-2003 APSS Power off all sensors	APSS	Sol-1195M11:40:01	00:03:30.000	00:01:00.000	Sol-1195M11:44:24	apss_seq_all_off	reusable already on board	yes
APSS Turn on PAE 28V and IFG on USM3	APSS	Sol-1195M20:00:00	00:05:30.000	00:01:00.000	Sol-1195M20:06:20	apss_seq_ifg_on_usm3	reusable already on board	yes
ActID-2003 APSS Power off all sensors	APSS	Sol-1196M06:31:47	00:03:30.000	00:01:00.000	Sol-1196M06:36:10	apss_seq_all_off	reusable already on board	yes
ActID-3011 SEIS Turn off SPs	SEIS	Sol-1197M01:00:00	00:02:00.000	00:01:00.000	Sol-1197M01:02:56	seis_seq_turn_off_sp_hk_mgt	reusable already on board	yes
ActID-3040 SEIS Change HK configuration rate to 1HZ	SEIS	Sol-1197M01:00:01	00:00:10.000	00:00:10.000	Sol-1197M01:00:21	seis_seq_turn_off_sp_hk_mgt	reusable already on board	yes
ActID-3040 SEIS Change HK configuration rate to 0.01HZ	SEIS	Sol-1197M01:02:35	00:00:10.000	00:00:10.000	Sol-1197M01:02:55	seis_seq_turn_off_sp_hk_mgt	reusable already on board	yes

Uplinked sequences :

No tactical sequence in this plan

No new reusable sequences in this plan

The plan contains 6 reusables already on board :

- seis_seq_turn_on_sp_hk_mgt
- apss_seq_ps_on_usm3
- apss_twins_two_booms_on
- apss_seq_all_off
- apss_seq_ifg_on_usm3
- seis_seq_turn_off_sp_hk_mgt

Event requests :

Sequence ID	Start Time (LMST)	High (Mbits)	Medium (Mbits)	Low (Mbits)	Duration	nb channels	ERPs
evnt_1185_04a	Sol-1185M08:29:33	0.0	76.61	47.55	00:04:09	26	12526 (MED) 12527 (MED) 12528 (MED) 12529 (MED) 12530 (MED) 12531 (MED) 12544 (LOW) 12545 (LOW) 12546 (LOW)
evnt_1187_02a	Sol-1187M08:29:59	0.0	89.99	46.83	00:06:07	45	12531 (MED) 12532 (MED) 12533 (MED) 12534 (MED) 12535 (MED) 12536 (MED) 12537 (MED) 12538 (MED) 12546 (LOW) 12552 (LOW) 12554 (LOW) 12555 (LOW) 12556 (LOW) 12557 (LOW) 12559 (LOW) 12563 (LOW) 12566 (LOW)
evnt_1188_02a	Sol-1188M07:24:56	0.0	79.7	27.34	00:03:27	21	12538 (MED) 12539 (MED) 12540 (MED) 12541 (MED) 12542 (MED) 12543 (MED) 12566 (LOW) 12572 (LOW)
evnt_1189_01a	Sol-1189M08:19:00	0.0	26.19	58.76	00:03:11	22	12525 (MED) 12543 (MED) 12561 (MED) 12562 (MED) 12565 (MED) 12567 (LOW) 12568 (LOW) 12572 (LOW) 12573 (LOW)
	Total :	0.0	272.49	180.48			

Delivery :

SDL delivered : seis_sol1183.r03.txt

- apss_seq_all_off.r02.vml
- apss_seq_ifg_on_usm3.r00.vml
- apss_seq_ps_on_usm3.r00.vml
- apss_twins_two_booms_on.r01.fltops.vml
- evnt_1185_04a.r00.vml
- evnt_1187_02a.r00.vml
- evnt_1188_02a.r00.vml
- evnt_1189_01a.r00.vml
- seis_seq_turn_off_sp_hk_mgt.r01.vml
- seis_seq_turn_on_sp_hk_mgt.r01.vml

Sequences Walkthrough :

GO for bundle :

Pay_get_data analysis :

PGD (UTC)	PGD (LMST)	SEIS estimation (s)	SEIS alloc (s)	SEIS delta (s)	SEIS backlog (s)	APSS estimation (s)	APSS alloc (s)	APSS delta (s)	APSS backlog (s)	UHF
2022-03-26 01:25:33.57	Sol-1183M07:30:26	0	0	0	0	0	0	0	0	
2022-03-26 02:16:36.53	Sol-1183M08:20:07	84	1620	1535	0	0	0	0	0	
2022-03-26 03:08:07.22	Sol-1183M09:10:15	87	600	512	0	0	0	0	0	
2022-03-26 05:17:08.34	Sol-1183M11:15:49	264	531	267	0	0	531	531	0	
2022-03-27 00:10:22.57	Sol-1184M05:38:44	2054	1200	-854	854	0	1200	1200	0	ODY_NSY_2022_086_01
2022-03-27 03:13:38.78	Sol-1184M08:37:06	1215	2374	1158	0	0	2374	2374	0	
2022-03-27 05:56:48.72	Sol-1184M11:15:54	324	531	206	0	0	531	531	0	
2022-03-28 01:51:10.07	Sol-1185M06:38:18	2163	1200	-963	963	0	1200	1200	0	ODY_NSY_2022_087_02
2022-03-28 03:11:56.75	Sol-1185M07:56:55	1141	1805	663	0	0	1805	1805	0	TGO_NSY_2022_087_01
2022-03-29 01:21:16.78	Sol-1186M05:30:41	2404	1500	-904	904	471	1500	1028	0	
2022-03-29 07:16:10.51	Sol-1186M11:16:05	1571	531	-1040	1040	65	531	465	0	
2022-03-30 03:07:20.75	Sol-1187M06:35:23	3198	1200	-1998	1998	515	1200	684	0	
2022-03-30 04:36:15.48	Sol-1187M08:01:55	2190	1524	-666	666	61	1524	1462	0	TGO_NSY_2022_089_01
2022-03-30 07:55:51.92	Sol-1187M11:16:11	1056	531	-525	525	0	531	531	0	
2022-03-31 02:58:32.30	Sol-1188M05:48:17	2596	1200	-1396	1396	480	1200	719	0	ODY_NSY_2022_090_01
2022-03-31 04:17:06.43	Sol-1188M07:04:45	1570	1038	-532	532	101	1038	936	0	TGO_NSY_2022_090_01
2022-03-31 08:35:33.33	Sol-1188M11:16:17	1027	531	-496	496	231	531	300	0	
2022-04-01 05:49:33.54	Sol-1189M07:56:12	2802	1200	-1602	1602	962	1200	237	0	TGO_NSY_2022_091_01
2022-04-01 09:15:10.63	Sol-1189M11:16:19	2003	1200	-803	803	193	1200	1006	0	
2022-04-02 04:22:42.82	Sol-1190M05:53:09	2883	1200	-1683	1683	871	1200	328	0	ODY_NSY_2022_092_01
2022-04-02 09:54:53.07	Sol-1190M11:16:26	2309	1200	-1109	1109	284	1200	915	0	
2022-04-03 06:57:32.05	Sol-1191M07:45:18	3395	1200	-2195	2195	61	1200	1138	0	TGO_NSY_2022_093_02
2022-04-03 10:34:40.64	Sol-1191M11:16:38	2616	531	-2085	2085	0	531	531	0	
2022-04-03 16:54:28.34	Sol-1191M17:26:16	2796	1200	-1596	1596	0	1200	1200	0	ODY_NSY_2022_093_03
2022-04-04 06:31:54.61	Sol-1192M06:41:50	3088	861	-2227	2227	0	861	861	0	TGO_NSY_2022_094_01
2022-04-04 18:11:33.79	Sol-1192M18:02:46	3509	2100	-1409	1409	350	2100	1749	0	
2022-04-05 08:05:38.78	Sol-1193M07:34:32	2930	1097	-1833	1833	72	1097	1024	0	TGO_NSY_2022_095_02
2022-04-05 11:54:07.57	Sol-1193M11:16:54	2274	532	-1741	1741	0	532	532	0	
2022-04-05 18:18:32.69	Sol-1193M17:31:02	2461	1200	-1261	1261	0	1200	1200	0	ODY_NSY_2022_095_03
2022-04-06 07:39:31.54	Sol-1194M06:30:35	2723	1200	-1523	1523	0	1200	1200	0	TGO_NSY_2022_096_01
2022-04-06 10:54:50.08	Sol-1194M09:40:40	1906	1187	-719	719	0	1187	1187	0	
2022-04-06 12:33:52.06	Sol-1194M11:17:03	929	531	-398	398	0	531	531	0	
2022-04-06 19:59:00.67	Sol-1194M18:30:17	1226	1200	-26	26	0	1200	1200	0	ODY_NSY_2022_096_03
2022-04-07 04:13:26.39	Sol-1195M02:31:29	941	911	-30	30	0	911	911	0	MRO_NSY_2022_097_01
2022-04-07 13:13:31.41	Sol-1195M11:17:07	1027	1200	172	0	373	1200	826	0	
2022-04-08 08:36:23.21	Sol-1196M06:08:52	2107	1200	-907	907	495	1200	704	0	
2022-04-08 13:53:21.04	Sol-1196M11:17:21	1507	532	-974	974	61	532	470	0	
2022-04-08 21:23:19.40	Sol-1196M18:35:17	1810	1014	-796	796	0	1014	1014	0	ODY_NSY_2022_098_03
2022-04-09 04:01:37.82	Sol-1197M01:02:56	1538	600	-938	938	0	0	0	0	
2022-04-09 08:19:57.53	Sol-1197M05:14:21	1226	1200	-26	26	0	1200	1200	0	ODY_NSY_2022_099_01

(green)	sufficient
(yellow)	should be sufficient ((estimation + backlog) - allocation < 100)
(red)	not sufficient, will reach the timeout and generate backlog ((estimation + backlog) - allocation > 100)
(grey)	equipment is Off
(white)	equipment is On but allocation is zero

Column "SEIS estimation" is SEIS current estimation + previous backlog.

GDS information :

```
PUL should transmit information based on "approved" plan revision.
PAE ON (taking into account 1 mn before the activity) in SCLK :
        701753113997  # 1185T19:52:39.000
        701842280646  # 1186T19:59:00.000
        701931055820  # 1187T19:59:00.000
        702342210228  # 1192T11:08:14.000
        702581682287  # 1195T03:52:39.000
        702641257210  # 1195T19:59:00.000

PAE OFF, end of sequence in LMST :
        1186T06:02:51.000
        1187T07:02:41.000
        1190T11:43:43.000
        1192T18:44:40.000
        1195T11:44:24.000
        1196T06:36:10.000

EBOX ON (taking into account 1 mn before the activity) in SCLK :

EBOX OFF, end of sequence in LMST :
```

The tool was created and maintained by a SEIS operator, and underwent 34 versions during the mission.

8.2. Check sequences content when written manually : SeqCheck

Sequences sent on-board could have been written by two ways:

- In advance, for generic cases (also called “reusable sequences”)
- In the day/week by the PUL, according a specific need (also called a “tactical” sequences).

Reusable sequences were anticipated products, validated on the simulator, cross-checked, compiled, meaning that the sequence is considered as ready when needed.

For tactical sequences, there was much less time. PUL started writing its sequence from a validated template, but had to change some fields. Templates had identified fields that must be updated, using the keyword FIXME. Showing this keyword meant to PUL to instantiate the corresponding value, according the plan. It could be a sensor number (VBBx becomes VBB1, VBB2 or VBB3), a number of steps, a file name etc. PUL also had to update the file header, containing also keyword like file name and data collection.

During local tests or joint simulation, ops team observed that such tactical modifications involved a high risk of mistake, that even human cross-review can miss – like naming conventions not respected or exceeding number of characters in specific strings.

To secure such operations, the team agreed to create a verification tool: seqCheck.

The main points checked by the tool were:

- Verify if filename respects naming convention
- Verify if any FIXME statement is present
- Ensure header is correctly filled
- Ensure that sequence name is correctly reported in specific statements
- Verify that sequences flags are present (autoexecute and autounload)
- Check that files called are present in the WOBL.
- Check consistency of FIR start/end blocks
- Check for forbidden characters in strings

Result is an HTML report file with warning and errors raised during file analysis.

Based on these checks, operator was confident with main issues, and could focus on sequence content.

Figure 11 : SeqGen output, in an error case where many mistakes are found.

seis_seq_cycle_on_flash.r00.vml

0 not default use(s), 2 warning(s), 0 error(s), and 0 violation(s) found in sequence.

WARNINGS

Line	Command	Comments
All		Sequence file name does not comply with naming convention
105	ISSUE	Use of FILE_DELETE while sequence name does not look like single-use. Is this intentional ???

SEIS_3450_Pwr_ON_and_Configure.vml

0 not default use(s), 9 warning(s), 2 error(s), and 0 violation(s) found in sequence.

WARNINGS

Line	Command	Comments
All		Sequence file name does not comply with naming convention
2	DATA_SET_ID	Data Set ID set to VML_SEQ_TEMPLATE_SEIS - Expected value: VIRTUAL_MACHINE_LANGUAGE_SEIS
93	RELATIVE_SEQUENCE	FIXME found
101	ISSUE	FIXME found
101	ISSUE	Use of FILE_DELETE while sequence name does not look like single-use. Is this intentional ???
102	ISSUE	FIXME found
116	ISSUE	FIXME found
117	CALL	FIXME found
203	ISSUE	FIXME found

ERRORS

Line	Command	Comments
93	RELATIVE_SEQUENCE	RELATIVE_SEQUENCE set to FIXME_3450 - Expected value: SEIS_3450_Pwr_ON_and_Configure
101	ISSUE	FILE_DELETE set to f2:/seq/FIXME_3450.mod - Expected value: f2:/seq/SEIS_3450_Pwr_ON_and_Configure.mod

Sequence Checking V1.2 (c)CNES Team 2021

The tool was created and maintained by a SEIS operator, and underwent 3 versions during the mission.

9. Discussions : pros and cons

Definitely, choices made in SEIS operations frame can be discussed. Some don't tolerate any out-of-industry tools, and can argue that such needs should have been identified earlier and taken into account in the whole system, totally integrated in the ground segment, and delivered within the defined process.
This is understandable, as operators are not developers. It has a cost to formalize, design, write, test, validate and deploy each version of each tool. Algorithms are probably less optimized than industrial ones.
On the other hand, in a given process, where the project manages such tools like all other tools, with confirmation of the needs, validation presentation, and go for deployment, the risk to lose control on such tools decreases significantly. While the time spent on those tools is acceptable (and not to the detriment of operations) and basic knowledge of coding rules, versioning and team consultation are granted, the risk of having a tool not perfectly answering the expectations is also decreased. New delivery or patch from contractor also have costs, like meetings to discuss if discrepancy comes from given requirements or implementation choices.
A major argument is also the lifespan of the mission. With a nominal basis of two years of operations, and having continued the operations two more years thanks to lander/instruments outstanding performance, this type of project is not long-term and prefers to capitalize through an internal process rather than incurring costs and delays for the implementation of functionalities that can be provided internally.

In the context of short projects, with already internal knowledge in software development, avoiding contractor process by internal resources, accepting sharing some time on an operational subject, with collegial needs definition and opinion about the solution, was considered as a good choice.

References

List of references

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