

A Case Study on how Space Agencies are Capitalizing on Space Projects: Lessons Learned Through Capture Events

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Abstract: The issue of effectively learning from experience through Lessons Learned (LL) is a long-standing one. Its deployment in the space sector, although more recent, is a well-established issue in the space business. Both the European Space Agency (ESA) and the French Space Agency (CNES) include Lessons Learned capitalization in their processes regarding development of orbital systems. One of the goal of these activities is to improve the risk assessment managed by the project teams, by providing them with lessons learned coming from previous projects. Management procedures, technical standards and handbooks used by the projects can also be improved as a result of the lessons capitalization. There are several steps in the capitalization process. Lessons Learned proposals need to be collected, then analyzed by experts, shared and agreed before being turned into understandable and usable lessons. Finally, these lessons need to be made available to the potential users. The first step in the capitalization is to collect the lessons, which is time consuming. People working in space projects do not usually produce lessons on their own. In order to help them, both agencies have organized Lessons Learned capture events, gathering people working on a project, and inviting them to elaborate collectively the Lessons Learned from their project experience. Attendees can come not only from the agencies, but also from their partners (for example other agencies, industrial companies). The paper deals with how ESA and CNES apply their LL processes. It especially describes the case study of capture events (preparation, typical description of an event, outcomes). The emphasis is put on the methods used both to have participants committed to the approach and to produce useful lessons. Events typical examples are given. Finally, the paper compares ESA and CNES approaches and insists on the benefits capture events can bring to Organizations.

Keywords: Space Sector, Lessons Learned, Knowledge Sharing, Cooperation, Event

1. Introduction

The issue of lessons capitalization - effectively learning from experience through Lessons Learned - is a long-standing one. Both the European Space Agency (ESA) and the French Space Agency (CNES) include Lessons Learned capitalization in their processes regarding development of orbital systems

The first step in the capitalization is to collect the lessons coming from the projects. There are several ways to do that. For example, we can analyze reports written by the projects teams, reports written by investigation committees on anomalies, anomaly sheets. But this is not enough. That is why a more collaborative approach such as capture events to collect the lessons has been put in place both at ESA and CNES.

After a brief description of the Lessons Learned processes in both agencies, the paper will focus on a case study of how ESA and CNES organize these capture events. The aim is to show what kind of methods can be applied to collect lessons, and what their respective advantages and drawbacks are.

2. Lessons Learned Processes

2.1 At ESA

The Lessons Learned (LL) process is an ESA level (corporate) implementation of the principles set out in the ESA Lessons Learned Policy.

The objectives of the Lessons Learned are to:

- Continually improve the quality and value of all the Agency's activities through improving standards, processes, tools and training;
- Identify changes needed as a result of experience in the execution of the Agency's activities, through deployment of appropriate processes and associated tools;
- Create an environment within which continuous improvement occurs.

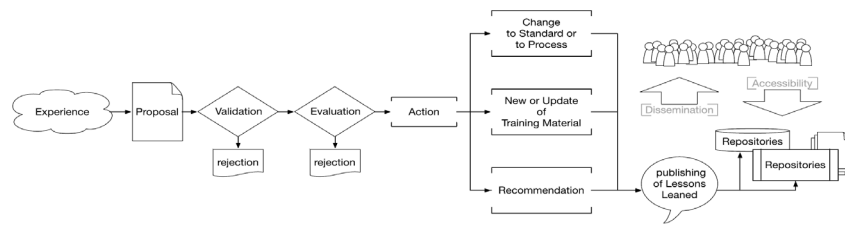


Figure 1 : Overview of ESA Lessons Learned process

The Lessons Learned process allows captured experiences, both positive and negative, to be transformed into knowledge shared for current and future use, as part of everyday practice throughout the Agency. The ESA Lessons Learned process is based on the following principles:

1. The Agency ensures effective communications and knowledge sharing throughout the organisation, including across organisational boundaries;
2. The Agency ensures that staff has access to relevant organisational experience and information;
3. No one in the Agency is excluded from proposing valuable lessons to be learned;
4. The Lessons Learned process is based on all experiences, positive and negative ones;
5. All Lessons Learned proposals are systematically screened (i.e., validated by the activity / project manager, evaluated by the ESA or Directorate level Board);
6. The Lessons Learned process is supported by appropriate tools (ESA Lessons Learned Portal**), training and resources;
7. Respective Directorate processes are aligned and comply to this Agency Lessons Learned process;
8. Actions are to be taken, following positive evaluation of a proposal, to implement proposed changes and thereby learn the lessons (i.e., Learning actions assigned to process owners to assess experience and adoption in the relevant process, its related documentation and training);
9. Originators of Lessons Learned receive feedback on their proposals;
10. The Agency ensures that approved Lessons Learned are appropriately disseminated within the organisation and that Lesson Learned records are retained and archived (ESA Lessons Learned Portal**);
11. The Agency actively promotes and supports the Lessons Learned process;
12. Confidentiality is respected where necessary, although the focus is on organisational learning.

As a lesson is not learned through its identification only, the Lessons Learned process is to be understood to involve the identification and learning of lessons as two discrete but interfacing processes:

- identification of potential lessons and their validation; and subsequently
- organisational learning of the lessons through implemented action.

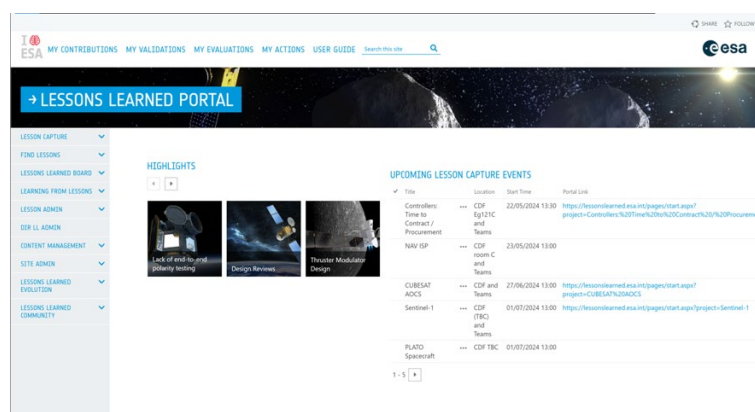


Figure 2 : Homepage of the ESA Lessons Learned portal **

Lesson identification is a process that identifies topics where experience and/or expertise need to be transferred within the Agency. Lesson identification is relevant for every aspect of the Agency's activities, but the nature of experience gained and the manner in which they are assessed, validated and disseminated may vary considerably according to organisational area and/or domain. Proposed and dispositioned lessons are captured in an ESA central repository, the ESA Lessons Learned Portal**, which contains the history of validations, evaluations and the learning action closure of all proposed lessons, specifically:

- the context in which and a description of the experience gained;
- a proposed learning /improvement derived from the experience,
- if rejected, the justification for rejection, and if approved, the action needed for systematic learning

2.2 At CNES

The organization of the CNES Orbital Systems Lessons Learned (LL) is described in the CNES Management System, certified by ISO 9001 and ISO 14001.

The first issue of this process was written in 1996. Prior to that date, the various CNES departments operated independently regarding LL. Then, as a lesson learned, the need for centralization became obvious.

LL deals with the following topics:

- The technical outcomes of an orbital system project (for example engineering and quality),
- The operational issues at system or subsystem levels,
- The project management.

The organization is based on a LL Bureau, in charge of the technical coordination and of the LL tool management. The Bureau supports the secretariat and animation of the Comity of Return of Experience (COREX), which is a board of 20 senior experts, deciding the validation and publication of Lessons Learned. Members of the board come from the different CNES directorates, and the board covers the different kinds of orbital systems projects, and all associated technical skills. They are the LL points of contact for their respective directorates.

LL proposals are collected from different sources:

- The COREX members,
- The projects managers and their teams: the inputs coming from projects can be Anomalies, Non Conformances, quality alerts, technical Working Group and Review reports, but also End of Projects evaluations, which include LL proposals.
- Each CNES employee, who can propose LL directly through our database (Figure 3).

From these proposals, the Bureau and the COREX prepare LL sheets, completed by generic RIDs (Review Item Discrepancy), to be used by the other projects teams and reviewers, to help them better managing the risks. The goal of the LL process is also to capitalize by improving the CNES Normative System. The LL can generate change request proposals to update both the CNES Internal Standards and the applicable ECSS (European Cooperation for Space Standardization) standards.

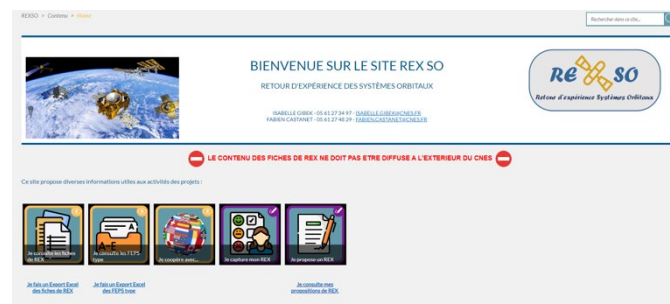


Figure 3 : Homepage of the CNES LL database, called REXSO

The LL are published in a cooperative tool: the REXSO database. Each LL sheet contains lessons and recommendations, and is pointed towards one or several generic RIDs. These generic RIDs suggest adequate questions, built from the LL sheets recommendations, to help reviewers as reminders during the project reviews. They are written both in French and English, and they depend on the project phases.

We have decided to keep a total of less than one hundred (100) active LL sheets inside the database, so that the analysis remains feasible for the projects team members, in compliance with their workload. LL sheets are regularly evaluated and archived in a backup folder, for example each time a related topic is included either in the standards or in our internal training material. The database is also used to preserve these archived LL sheets.

The projects teams only use the active LL sheets. The Bureau holds a LL kick-off meeting with the Project team at the very beginning of a project. The project team, with the help of the Product Assurance people, analyses

the potential applicability from the list of active LL sheets and selects the valuable ones. To manage the verification of conformity with these project useful selected sheets, experts are identified and tasked to take into account the associated LL. Then the conformity status is presented during the main reviews all along the project development.

CNES existing LL process has remained at internal level in the collection of lessons since many years. This is changing with a common plan to also capture and share lessons with ESA LL process, from projects developed in cooperation with integrated teams (Herd et al, 2022).

3. Capture Event

3.1 In General

There are in general, three capture techniques that could be employed by any organization to capture learning from experience. The techniques each have their strengths and weaknesses, and require different levels of investment to prepare for carry out and complete the experience capture process.

3.1.1 Interview Technique (Teams)

Team member interviews (carried out at the individual level) are a resource-intensive approach to lesson capture, but one which overcomes reluctance for team members to “speak up” during collective or group meetings, and ensures all voices are heard. This approach is a combination of an After Activity review questioning and the “Learning History” approach used at the Massachusetts Institute of Technology (MIT). The technique affords both Individual and (project) team based involvement with validation by the authorized individual. The outcome of this technique is the publication of individual lessons to be learnt and may include lesson prioritization. This technique’s capture event typically has a duration spanning weeks to months and may be performed at any point within or at the end of a project.

Involvement - Individual or (project) team based collection

Validation - Individual validation

Outcome - Publication as individual lessons to be learnt

Lesson prioritization - on Team-based highest ranked learning taken from:

project objectives and outcomes, and

ranking of the key learning points (impact to the project) and,

their transferability to other projects

When to capture - no predetermined time

Capture event duration - weeks to months

Applicable time-span of lesson capture - At any point within or at the end of a project

3.1.2 After Activity Review

This technique is a short and focused meeting conducted by project teams, lasting for around 30 min. It is intended for immediate and in-the-moment learning. The After Activity Review allows for the capture of useful operational knowledge that can be discretely implemented for immediate repetition, allowing for improving performance by:

- Initiating course corrections during activities based on what is being learnt
- Addressing and optimizing a team’s way of working
- Building collective operational knowledge resources

Involvement - (project) team-based lesson collection

Validation - immediate / in the moment

Outcome - immediate learning within the team

Lesson prioritization - no selection - all lessons where there was a deviation in outcome from expectation

When to capture - Immediately after each "activity" - single time-slot based on event or pre-specified time duration

Capture event duration - 30 minutes

Applicable time-span of lesson capture - Focus on a daily or limited period of time (discrete action, and proposed immediate repetition of that discrete action) - may also be since last After Activity Review

3.1.3 *Retrospective View*

The Retrospect is one of the most effective processes with a duration ranging from ½ to several days, for capturing Lessons from a project team, at key milestones/deliverables, or at project end. A Retrospect can bring out the key knowledge and experience developed by a project team, and capture it for future reuse and for the benefit of future projects. By facilitating a dialogue within the whole team, knowledge can be identified that comes from the whole team experience - knowledge that any one individual may be unaware of, but which the team as a whole knows. Good facilitation ensures high quality lessons which can be understood by people outside the project team.

Involvement - Team-based collection of lessons at the end of a project

Validation - by team during dialogue

Outcome - learning is captured in the form of a lesson by facilitator

Lesson selection - on Team-based highest ranked learning taken from:

project objectives and outcomes, and

ranking of the key learning points (impact to the project) and,

their transferability to other projects

When to capture - at the end of the project

Capture event duration - 4hrs to 4 days

Applicable time-span of lesson capture - entire project - however known limitations with memory of individuals based on the following

i) the limited recall

ii) preference on recently (better remembered events) than those of by-gone years

3.2 **At ESA**

At the corporate level, ESA has adopted an adaptation of the retrospective approach – improving it to fit within project lifecycle and the dynamics of the space sector in the definition, design manufacture and test and finally commissioning operations and de-commissioning of a space mission.

3.2.1 *Event-Based Lesson Capture (and Validation)*

The event-based focuses on collaborative team lesson collection and validation, facilitated in 3 modes – physical meeting, on-line videoconference (called e-capture) or a mixture of the two (called hybrid capture). Initially (from 2019) carried out as only a physical meeting, using the Concurrent Design Facility (at the largest ESA site, both in terms of workforce and footprint – ESTEC, The Netherlands), ESA created an immersive and safe environment to share experience from projects (both positive and negative). This meeting enabled the experience and associated proposed learning to be captured effectively on the basis of team discussion and agreement by the activity / project management. Discussion was supported through the use of ESA Lessons Learned Portal (based on Sharepoint) using a dedicated project-specific webpage, which could be shared by the portal administrator to all those in the meeting. During COVID (2020 / 2021) the capture events were adapted to on-line only, and the format reduced to 1/2day.

13:00	Introduction
	I) Overview of Project / Activity (Activity / Project Manager)
	II) Lesson Capture Process (ESA LL Secretariat)
13:30	Lesson Capture
	Collection of Lessons
14:30	Break
14:45	Validation
	Group discussion on each lesson
	Validation of lessons by Activity/Project Manager
17:15	Event Feedback and e-questionnaire
17:30	Meeting Ending

Figure 4 : Typical agenda of an ESA (corporate) Lesson Capture Event

It was found still effective using this technique with the added benefit of efficiency regarding reduced time of the event and removing the need to travel. As such it was found that participation of experts in the e-event increased significantly over the COVID period. Now out of COVID constraints, the ½ day format remains, with the event being both physical and on-line – creating the so-called “hybrid” event.



Figure 5 : ESA Project (AEOLUS) capture event using the Concurrent Design Facility (CDF) in 2019

It is typically a space mission project focused technique which is initiated at discrete significant milestones in the project (at least 3 times, relating to key project phases). It involves project and technical teams who have been directly, indirectly or partially and temporarily involved in the project, and includes validation authority (typically the activity or project manager) and can also involve evaluation entities. The validation of captured lessons happens by the project manager during the event through sharing of the captured lesson and dialogue that is initiated with the team present in discussing their content. Once lessons are validated, they are immediately visible to all ESA colleagues, as well as being forwarded to the Lessons Learned board for evaluation. This technique is applied equally to projects as it is to technical and non-technical topics.

Focus over a period of time (typically years)

Involvement - project and technical teams

Validation - by project manager during event dialogue

Outcome - proposed and validated lessons (ready for LL Board evaluation)

Lesson selection - none - all considered equal (if validated - pending evaluation)

When to capture - at discrete significant milestone in the project

Capture event duration - 1/2 to 1 day

Applicable time-span of lesson capture - from previous lesson capture event (i.e. part of a project)

3.3 At CNES

Two years ago, CNES decided to improve the collection process of LL from projects, because there were less and less written end of project reports. Moreover, projects can last several years, and these reports, often available

only at the end of a project, did not present the LL learned from people that have moved away during the project time frame.

We studied ISO 16192, which outlines LL principles and guidelines that are applicable in all space project activities. It is a good basis which can help to define an in-house process. But each step of the LL process is not precisely defined, especially, the collection of relevant information.

NASA White Paper (2004-2006) describes a Pause and Learn (PaL) session, which is a structured discussion that focuses on recent project developments, challenges, and critical milestones. Consequently, the PaL process is a critical project management tool for learning during the project life cycle. PaL sessions enable project team members to collectively reflect on their experiences and articulate their LL and insights.

That is why we proposed accordingly to put in place capture events and the organization of a moderation process consistent with the objectives of efficiently capturing feedback.

3.3.1 Some observations from a knowledge engineering viewpoint

A particular feature of the proposed approach, as will be detailed shortly, is that it involves two colleges in the selection process: a first college made up of project members, and a second college made up of COREX members.

From a cognitive point of view, this corresponds to two significantly different objectives.

The first panel is tasked with identifying - unanticipated - circumstances that have prevented the production of knowledge that would have been necessary at a given time, or those that have, on the contrary, enabled the production of knowledge that has proved to be particularly useful in solving a problem. This collective awareness of unfavorable and favorable circumstances corresponds to the production of one or more pieces of knowledge. As we shall see, this stage is followed by a selection process based on their representativeness in relation to the project.

The second group will select this knowledge as *data* that is sufficiently new to be included in the REXSO database and to complement existing processes, standards and norms for orbital systems, on condition that it constitutes a corpus that can be processed by humans.

3.3.1 Event Preparation

A capture event consists of a dedicated meeting, attended by the project manager, the project team and as far as possible the main project stakeholders. The project manager is the technical facilitator. He or she is accompanied by the LL Bureau and organizational facilitators. Facilitators manage the brainstorming process during the session, highlight the key messages and control time. The project manager is asked to prepare before the collocation meeting the list of participants among the project team members, which number is on purpose restricted to about 15 people to ease the discussions, even if the project team is often much bigger. Most of the events have yet been organized with CNES people only, but it is encouraged to invite, when appropriate, people from participating research laboratories and from industry.

The meeting date must be fixed long time in advance, so that people can get available. The meeting takes place in person only. It is held in a big open room called "Creallab", where we can move from one zone to another one according to the different steps of the meeting. A timeline tracing the main stages of the project is displayed, with the aim of encouraging participants to think back to the history of the project. It is mandatory and of high value to get LL proposals not only from the most recent project events.

Prior to the event, a questionnaire is established in order to:

- Inform the participants of the process and give them the opportunity to go back over the project before the capture session,
- Make a preliminary collection of event records likely to be the material for a LL proposal.

This questionnaire is in the form of an Excel file to be sent to participants. It contains LL proposal forms to be completed, as much as possible, by the participants. Participants are asked to send it back several days before the event.

Questionnaires to be completed during the session are also prepared.

3.3.2 Event Sequence

Table 1 shows a typical agenda. Flexibility should be maintained in the event program so that it can be adjusted according to the number of proposals. The duration is a compromise between:

- Not too short to obtain usable results,
- Not too long and dissuasive for participants' availability.

At the beginning of the meeting, we take time for participants to get and share together. It is important to create a good productive atmosphere.

There are three workshops steps during the event:

- The first workshop step, entitled "Vide-greniers", is divided into two phases: an initial presentation of their proposals by each contributor, followed by a second phase during which participants who had not completed the questionnaires beforehand, but who have nonetheless feedback proposals, can express their views.
- A second workshop step is called "The Stations". Participants are divided into sub groups and asked to think about events that could be the subject of feedback based on evocation of three "emotions" (joy, disappointment, pride). A discussion is then led on a priori anecdotal situations occurred during the project, in order to bring into light events likely to be material for new LL proposals.
- A third "sharing" workshop step is held to review and complete the proposals to be submitted to the COREX for decision to include them or not in the LL database.

During this last workshop step, people receive flags for voting. Only proposals considered as lessons sufficiently representative of the project and agreed by the majority of participants are completed. Some proposals can also be gathered according to their similarities and their complementarity.

Enough time must be kept at the end of the event, because clear and elaborated proposals are needed, so that the COREX can analyze them properly.

Table 1 : Typical agenda of a capture event

Phase	Duration
Welcoming participants	30 minutes
General presentation	15 minutes
« Vide-greniers » workshop	2h00
Break	15 minutes
« Les Stations » workshop	45 minutes
Lunch	1h15
« Sharing » workshop	45 minutes
Drafting of the final version of selected LL proposals	1h30
Conclusion	15 minutes

3.3.3 Event Outcomes

Table 2 shows the number of LL proposals obtained at the end of a capture event, and the number of corresponding LL sheets validated by the COREX.

We can see that the number of LL proposals at the end of the collecting event is of the order of a few dozens. After analysis and selection by the COREX, the number of new LL sheets is limited to a few of them. That is to say that only one tenth of the proposals are considered as new lessons to be added to the Orbital Systems LL database.

This drastic selection can be explained in different ways:

- The proposal can be used to update or complete an existing LL sheet, without creating a new one.
- The proposal is not retained as LL sheet, but will be used to update internal trainings, especially the trainings dedicated to people working on projects.
- The recommendations written in the proposal are not mature, and it is necessary to put in place a Working Group on the subject to produce the relevant recommendations. This can later lead to a new LL sheet.
- The proposal is covered by existing processes, standards and norms.
- The proposal corresponds to normal work, the lessons are well-known (It may have been difficult for the project to apply them, for various reasons (human resources, budget, planning, etc.)).
- The proposal needs to be shared with ESA, when it comes from a project in cooperation between ESA and CNES. This can later lead to a new LL sheet.
- The proposal is limited to a specific technical skill, it is not published at system level, but is managed at experts' level.
- The proposal is not generic enough, too specific to a project and its background, and cannot be easily reused.

Table 2 : Number of lessons

LL Capture event	Total number of proposals	Number of proposals after project team vote and gathering	Number of new validated LL sheets	Number of participants in the event	Analyzed project duration (years)
Project A	33	33	3	12	8
Project B	51	31	6	21	3
Project C	62	45	4	18	12

4. Comparison Between ESA and CNES Approaches as Concerns Capture Events

Table 3 shows some differences between the ESA and CNES approaches for capture events.

Table 3: Comparison between ESA and CNES LL events

Category	ESA	CNES	Advantages / Drawbacks
Is capture mandatory as part of normal project process?	Stated as policy, and locally in Directorates implementation varies between best practice and mandatory	Proposed	Mandatory : LL not missing Proposed : People want to come
Language of capture	English	French	English : multi-national organization French : clearer in native language, both for preparation and use of the LL
Is event physical meeting or held on-line (remotely)?	In-person, remote or hybrid techniques	In person only	Remote : easier for participants In person : better discussion and team event
How many lessons are generated (per event)?	No limit placed on lesson capture numbers (averaging around 30 lessons per event, with approx. 10 events per year)	No limit	Most often, people have a lot of things to say

Category	ESA	CNES	Advantages / Drawbacks
How many lessons are held in the database overall?	1600 hundred lessons currently – increasing at around 300 per year	100 active lessons maximum Continuous “cleaning” required	The way projects use the LL contained in the respective databases must be different (see below)
Means to learn from the lessons (portal only, dedicated lessons summaries or lessons embedded in processes document and training)	About 70% lessons are incorporated in our processes and related documents. The remaining 30% is uniquely accessed in the Portal. Function specific views allow for users to easily retrieve their learning.	LL sheets inside the database New versions of processes and standards Internal trainings	Same principles
Is the Agency applying new techniques or technology to ease access to lessons / learning ?	AI techniques are being applied and will be released this year (2024) – knowledge graph and ChatBot techniques assist the user in the ease and quality of both lesson capture and retrieval	AI techniques not required up to now On-line help for the principal operating modes of the database (Confluence pages)	Techniques depend on the amount of data

Thanks to capture events, new lessons are available on a regular basis. The last three lines of the table show the consequences for the overall functioning of the LL process.

5. Conclusion

Both ESA and CNES agencies have organized Lessons Learned capture events, gathering people working on a project, and inviting them to elaborate collectively the Lessons Learned from their project experience. These events are effective, as a great amount of LL material is produced. Projects teams really enjoy the opportunity, when the process is completed, even if some of them are reluctant at the beginning.

These events require a dedicated organization. The organization principles are the same in both agencies, and common capture events could be envisaged. It must be noted that ESA already invite partners to this kind of events.

The lessons coming from capture events are either incorporated in processes and standards, or used to prepare dedicated LL sheets, available in a database. Up to now, ESA and CNES have a different approach as regards the number of applicable lessons in their respective databases. But this does not prevent from organizing common capture events. The common lessons coming from these events can be processed by each agency, according to its own methods.

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