MELiSSA

MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

CREATING A CIRCULAR FUTURE

Lessons learned from life support systems payloads operations

Blandine Gorce – ESA

I- Intro

I- Complexity of operations

Limited resources

Microgravity

Space Environment

Communication with control centre

Confinement

Radiations

Communication

Complexity due to Space conditions and the complexity of communication with ground.

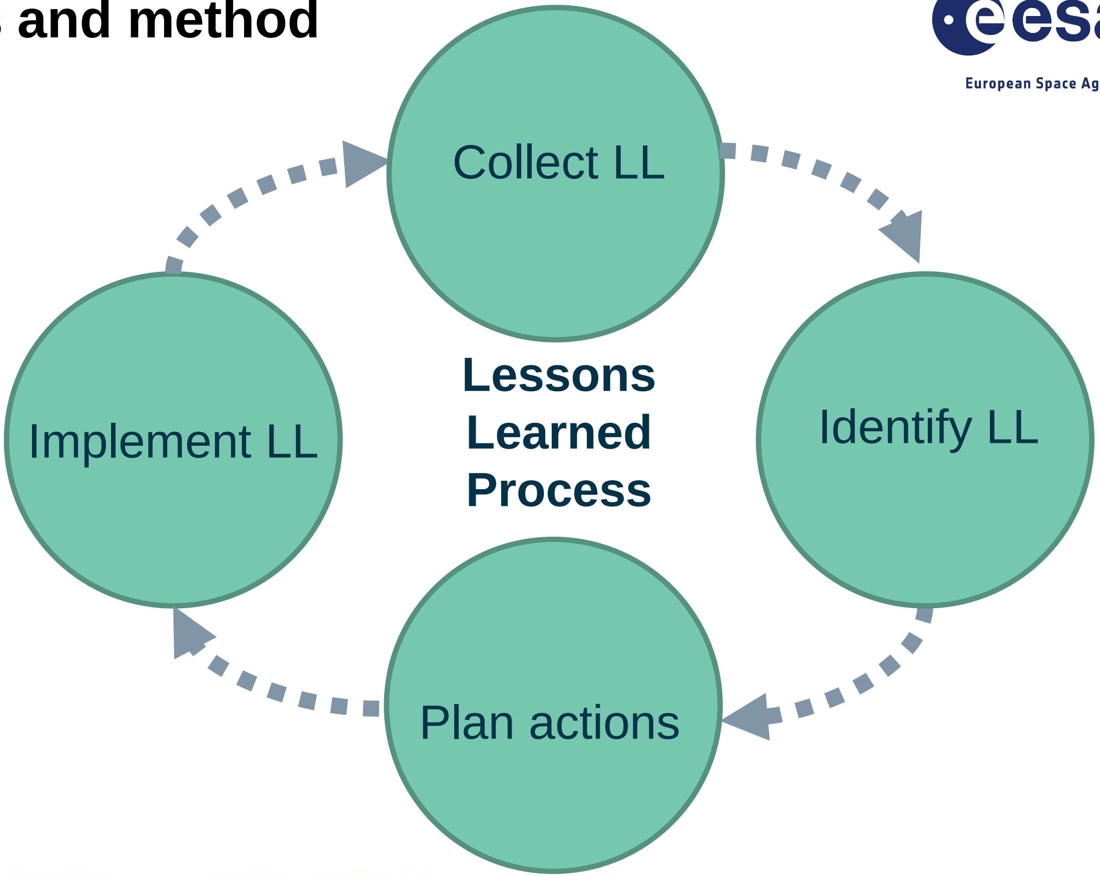
→ ISS = A lab like nowhere else.

II- Method

II- Objectives and method

Objective:

- take advantages of ESA’s 30 years of experience in operation in the Columbus module for the development of the next payloads.
- Provide a ready to use document for the development of current LSS payloads.



II- Collect lessons learned

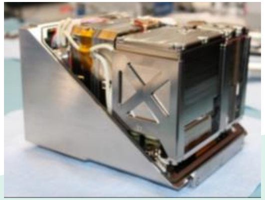
Method used: **expert interviews** on voluntary bases of 1h to 1h30, that I prepared in advance through bibliography.

Scope of the interviews:

- ❑ **4 payloads** were targeted in the LSS experiments of the past decade.
- ❑ Every role in operation targeted: from increment manager to payload developer.
- ❑ Focused on operation trouble shooting

Analyzer Interferometer for Ambient Air (ANITA)

Life Support Rack (LSR)



Arthrospira-B

Photobioreactor at Life Support Rack (PBR@LSR)

II- Identify lessons learned

Key Figures

6
Persons interviewed

32
Total lessons learned collected

70
Actions derived from the lessons

5
Main topics identified

Main topics

- Communication between stakeholders
- Constraint on the payload design
- Test campaign
- Detailed hardware troubleshooting
- Planning and schedule

Title	Must be short, clear and to the point.
Context	Context (which payload, explanation of operation context).
Description	Detailed actions and issues that arose. Description of the impact on the payload operations.
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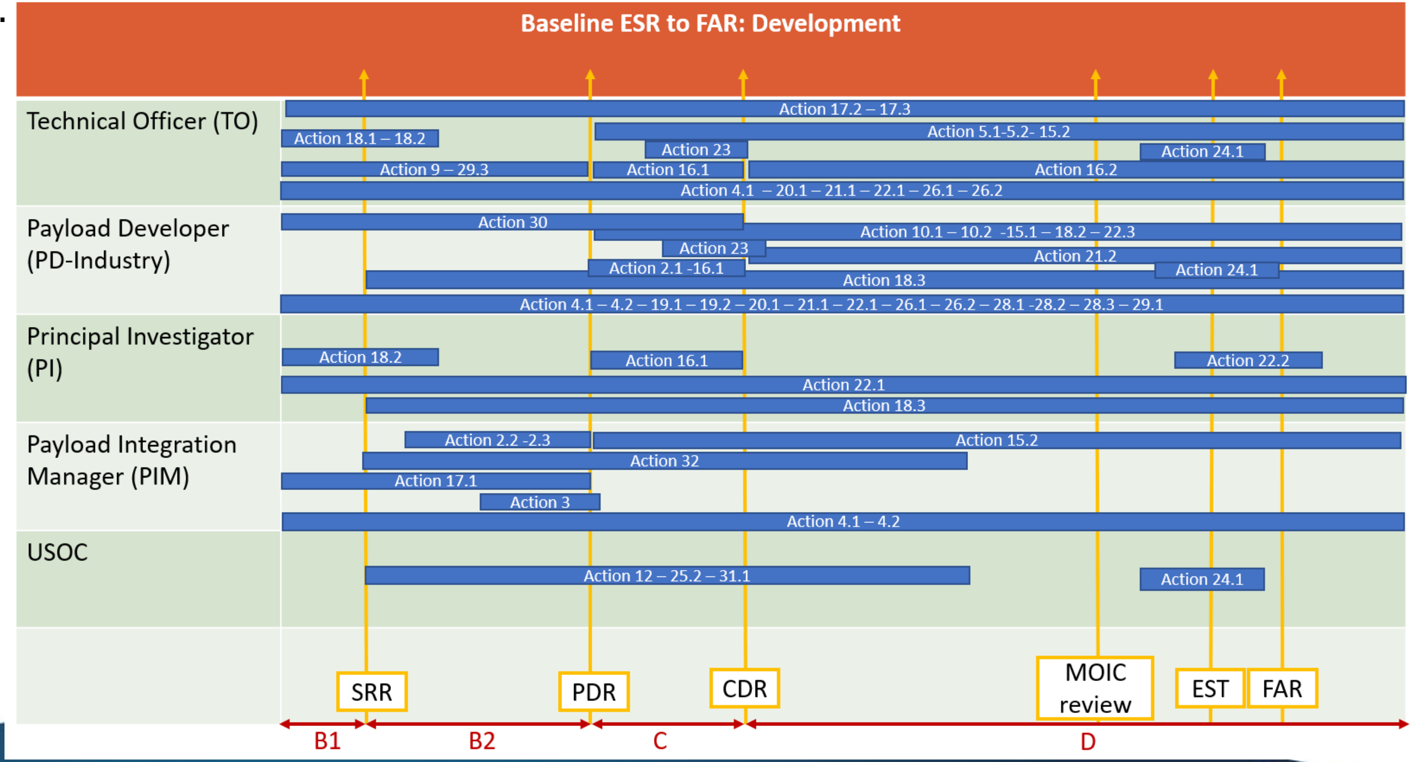
II- Communicate and plan actions

Timeline of actions distributed over the different phases of development and role → should be used as a reference document.



III- Content

III- Overview of the content

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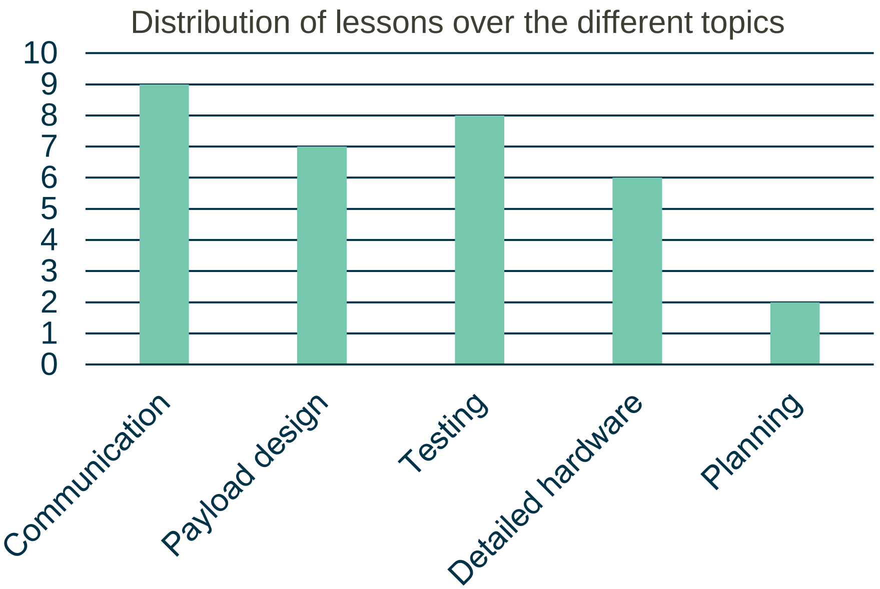
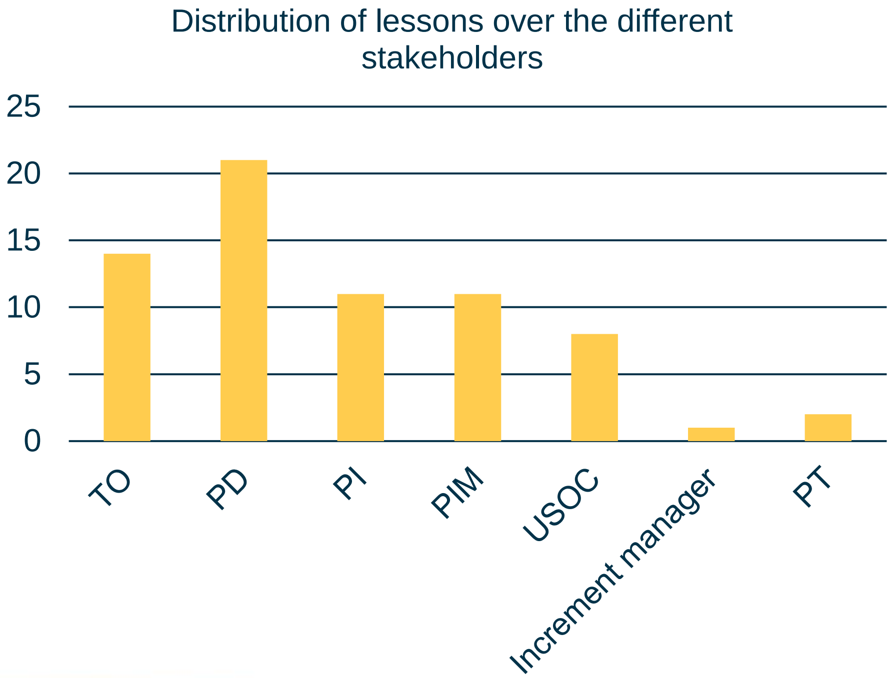
The lessons learned in graphs





III- Communication between different stakeholders

Highlights:

1. Detailed and frequent communication between all operation teams can save the science of a payload.

2. When a payload requires complex integration to ISS resources, involve NASA before PDR.

3. USOC can bring useful remarks before the PDR, when the payload design is not yet completed.

4. Encourage communication between payload developer and rack ground facilities teams.

5. It is worth for ESA to go and meet the prime during the test campaign to solve problems faster.

6. Anticipate the PD availability to support the payload’s operations when needed.

7. Avoid Biolab for biological experiments. If not possible, prepare a set of commands.

8. It is important to keep track of payload overall status when troubleshooting.

9. Ask NASA for the most recent data on resources before establishing requirements.

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Example: Encourage communication between payload developer and rack ground facilities teams.

The Biolab Rack ground replicate was designed by Airbus many years ago, and the payload Arthrospira-B was developed by QinetiQ. The rack interface compatibility between the payload and the Biolab ground testing facility was complex.

→ **To create a list of all the available documentation on the rack and verify which are up to date.**

→ **To rapidly contact the industrial responsible of the rack in case of questions or lack of information.**

III- Constraints on the payload design

Highlights:

10. Take into account, in the payload design, the easy maintenance activities.

11. Planning and integration are easier when onboard and return nominal/cold stowage are minimized.

12. Designing, when possible, a payload with already the required level of containment, allows to avoid the use of the Biolab glovebox.

13. Make sure the PI has real time access to the data of the experiment, when possible.

14. Take into account astronaut's feedbacks during crew check-up of the payload.

15. During operation of long-term payloads, software security updates can cause interfaces incompatibilities.

16. Good enough is good enough in a technology demonstrator's requirements and design.

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Example: Good enough is good enough in a technology demonstrator's requirements and design.

ANITA 1 & 2 were payloads that worked very well because the objectives were well defined and clear, and focused on one objective only: the detection of gaseous compounds. When trying to do more than what is requested in the requirements, the resulting system will be closer to a final product than a technology demonstrator, therefore more complicated. It can then lengthen considerably the development process and the phase B timeline.

→ To define and write clearly the scope of the science under investigation.

III- Test campaign

<u>Highlights</u>:

17. Tests on ground have to validate all the limits specified in the requirements.

18. Some processes can induce biotoxicity from hardware materials for the photobioreactor cells.

19. A lifetime test for all hardware that has never been used as long as the payload duration can help prevent the emergence of unwanted behavior.

20. The longer the experiment duration is, the less flexible testing will be.

21. Hardware behavior during high probability off nominal situation shall be anticipated and tested.

22. Testing wide range around parameters nominal values and hardware physical limitations will facilitate troubleshooting during operations.

23. It is recommended for the PD not to go further when something is not working at the Critical Design Review (CDR).

24. The difference between ground test facility and on-board rack is a crucial information.

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III- Test campaign

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Example: Some processes can induce biotoxicity from hardware materials for the photobioreactor cells.

In the case of Arthrospira-B, the compatibility of the material of the culture chamber had been evaluated. However, when the hardware tests started, the culture chamber had to be stored for 4 weeks at -20° C and then heated to 33° C according to the protocol of the experiment. Due to the changes in temperatures and long storage in the freezer, the plastic started to excrete some particles that was not generated before. The cells completely died in the hardware because the material was toxic for them.

→To anticipate the change of biotoxicity of certain materials during heating and cooling.

III- Detailed hardware troubleshooting

<u>Highlights</u>:

25. In case of unexpected leakage, it is key for PD, USOC and safety teams to be able to identify the type of leakage fast enough to prevent unnecessary termination of the experiment.

26. Valves are critical hardware in a payload.

27. Launching extra spud sponge allows to have enough maintenance supplies in case of breakage.

28. The broader picture shall be kept in mind when solving an issue during payload development.

29. Interfaces between the payload and the ISS rack are a key aspect of the payload because it is often where technical issues arise.

30. Sliding interferometers are less robust in space environment than pendulum interferometers.

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Example: Valves are critical hardware in a payload.

A venting valve, that had been working during testing was clogged due to long term permeability of the Zarrouk medium through the gas permeable membrane. The USOC was finally able to unclog it by opening and closing the valve. This problem was solved in Arthrospira-C by installing a filter between the valve and the membrane to protect the valve and make sure no Zarrouk droplets will arrive to the valve.

- → **To test in different conditions, not only the nominal conditions specified for this payload.**
- → **To anticipate on the design to prepare contingency actions in case of valve blockage.**

Communication between different stakeholders | Constraints on the payload design | and schedule

III- Planning and Schedule

<u>Highlights</u>:

31. Flexibility is key when writing the operational timeline of biological experiments.

32. Crew schedule gives boundaries when writing the planning request.

III- Planning and Schedule

Highlights:

31. Flexibility is key when writing the operation

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Example: Flexibility is key when writing the operational timeline of biological experiments.

The planning of the Arthropira-B payload had to be modified in real-time because the biology was growing too slow. It often happens that due to different conditions in space, the metabolism reactions dynamics are changed. In that case, it was a lot slower than expected.

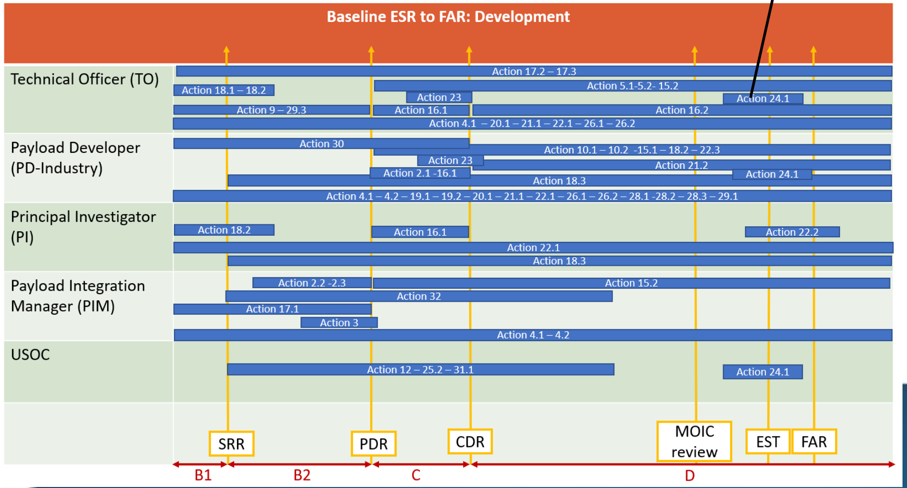
- → **To keep in mind the need of flexibility when writing the MOIC and simplify as much as possible the concept of the experiment.**
- → **To consider as many telemetry parameters as possible to fine tune the speed of the experiment.**

How to use the report ?

The lessons learned report is classified along several markers:

- Per role
- Per key-words
- Summary of actions
- Timeline

Actions 24.1	USOC, PD-Industry, TO	To ask for documentation on differences between flight model and ground model.	EST



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