FIRST TRIPLE REXUS CAMPAIGN – FLYING SYSTEMS TWICE ON ONE ROCKET CAMPAIGN

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ABSTRACT

For the first time in 12 years of REXUS (Rocket Experiments for University Students) history, an on-range reconditioning of flown systems was performed. The Mobile Rocket Base (MORABA) has accomplished an on-range check to reuse two already flown modules during the same campaign. The trigger was the REXUS 24 non-nominal flight. Because of this issue, REXUS 23 was on hold and finally was accepted for launch during the REXUS 23/ 25/ 26 triple campaign. The campaign was executed with just two service and two recovery systems for three rockets. This means a reuse of systems on the same campaign was crucial for a successful three-launch campaign. Using a new procedure for checking the system condition, DLR MORABA could reduce the costs without affecting the quality of the additional flight, provided the flown systems were in proper shape after their first flight. The aim of this paper is to illustrate the campaign procedure as well as the procedure of on-range checking for the service and recovery module.

We analyse the REXUS triple campaign. We discuss the different technical procedures, the outputs of the campaign activities and the lessons learned of an on-range check. In conclusion, the on-range check makes the campaign more effective but it also holds unforeseen risks.

1. INTRODUCTION

On March 12, 2018 at 14:30 UTC, REXUS 24 was launched from ESRANGE Space Center and had a non-nominal flight. REXUS 24 was a part of the double campaign REXUS 23/ 24. The launch of REXUS 23 was put on hold by Range Safety awaiting information on the root cause of the failure of REXUS 24. After a failure investigation board had identified the root cause, REXUS 23 was accepted for launch during the REXUS 23/ 25/ 26 triple campaign.

During this time, a new procedure was performed. As projects move towards leaner, more agile processes and practices, the operational team must demonstrate an aptitude for open minded discussion. The campaign was executed with two service and two recovery systems for three rockets. Mobile Rocket Base accomplished an on-range check to reuse two already flown modules. Usually, a full refurbishment of these systems is not done during a campaign. Using a new procedure for checking the systems condition, DLR MORABA was able to show that it is possible to launch two REXUS rockets with one service and one recovery system within one week.

This paper gives an overview on the planning of the triple campaign, the campaign activities, the on-range check procedures and brief lessons learned of this new technique.

2. REXUS/ BEXUS PROGRAM

The REXUS/ BEXUS (Rocket and Balloon Experiments for University Students) programme is realised under a bilateral Agency Agreement between the German Aerospace Center (DLR) and the Swedish National Space Agency (SNSA). The Swedish share of the payload has been made available to students from other European countries through collaboration with the European Space Agency (ESA). On behalf of DLR Space Administration, the Center of Applied Space Technology and Microgravity (ZARM) carries out the German share of the programme. The experiment campaigns and the student support are conducted in close cooperation between DLR Mobile Rocket Base, SSC, ESA and ZARM. The programme offers students the opportunity to fly a self-developed experiment on a sounding rocket or on a stratospheric balloon. While the student teams conceive, design and build their experiment for several months, they receive training and support from DLR, SSC, ZARM and ESA experts. Two sounding rockets and two stratospheric balloons are launched each year from ESRANGE Space Centre carrying up to 20 Students Experiments. Figure 1 shows the REXUS/ BEXUS logo.

Figure 1. REXUS/ BEXUS logo

3. PLANNING [1]; [2], [3]

The triple campaign was scheduled from the February 25 until March 16, 2019. The planning of the campaign had several challenges.

REXUS 23, REXUS 25 and REXUS 26 accommodated five experiments each. In total, there were 15 experiments, which means it was necessary to take care of 15 experiments teams. Altogether 122 participants were registered for the campaign (without SSC ESRANGE staff). A usual REXUS campaign has around 80 participants. The huge campaign size could result in accommodation issues (the rocket launch facility is limited to 100 beds), support/ mentoring problems, etc. An overlap campaign planning was an alternative solution for these issues.

Another requirement was that the rocket campaign schedule of REXUS 25 and 26 should be similar to previous REXUS launch campaigns. The teams should enjoy the same spirit as all the previous teams.

The campaign was executed with two service and two recovery systems for three rockets. This requirement leads to the reuse of one flown system.

Last but not least, spin and balance of REXUS 23 was planned during the campaign. Normally, spin and balance testing is done before the start of a campaign.

Before the official campaign start, spin and balance testing of REXUS 25 and 26 was scheduled at ESRANGE. After that, the REXUS 23 campaign was planned to start on February 26, 2019. One week of REXUS 23 campaign incl. spin and balance testing at ESRANGE was intended.

The on-range check to reuse the REXUS 23 flown recovery and service module was scheduled right after the launch. The REXUS 23 launch day was planned to be the beginning of the REXUS 25/ 26 launch campaign. Parallel to the on-range check, the REXUS 25 and REXUS 26 campaign preparations and launch of first REXUS 25 and second REXUS 26 was intended. The planning is illustrated in figure 2.

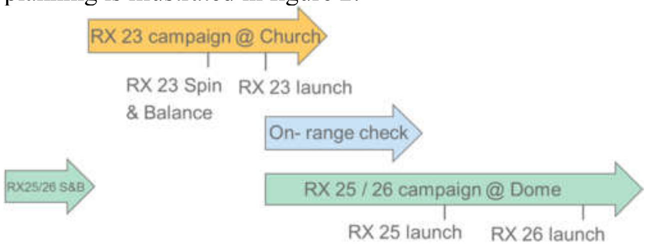

Figure 2. Planning of the triple campaign

4. CAMPAIGN

4.1. REXUS 23 launch

The proposed schedule was adhered to until the REXUS 23 launch.

REXUS 23 was launched on March 04, 2019. During the parachute sequence, an incident occurred concerning the main parachute's deployment. Instead of a nominal filling process right after the complete extraction as well as stretching of the suspension lines and the canopy, the main parachute did not fill correctly and remained in an unfilled condition with the canopy only acting as a streamer body. Until touchdown, 41seconds after the main parachute's activation, this condition remained unchanged, resulting in a hard payload landing with an impact velocity of approximately 55-60m/s. (see Figure 3) [4]

An investigation was immediately launched and completed on-range. The cause was identified. For the fixation of main parachute suspension lines on the designated nylon patch of the main parachute packing bag, a special breaking thread is used. During nominal parachute extraction, the stretched suspension lines rip the breaking thread fixations instead of being torn off the nylon patch and still enclosing the suspension lines. During the main parachute inspection one single loop of the respective breaking thread has been found around all suspension lines, approximately 90cm below the canopy base. After this analysis the following root cause conclusion can be drawn: Instead of ripping, the second or third (counted from the canopy base) fixation/breaking thread has been torn off the nylon patch and stayed undamaged around the suspension lines approximately 90cm from the canopy base and thus preventing the filling of the canopy. Without the correct canopy filling, the transverse opening forces are very small in comparison to the thread's breaking strength, thus keeping the loop and all fixation/breaking threads at the canopy and reefing line attached. [4]

The decision was taken to continue the campaign because it was not likely that the error would occur again.

Figure 3. Indications of hard payload landing with fully stretched but closed canopy

4.2. New REXUS 25 and 26 campaign schedule
A re-planning of the campaign was necessary because the REXUS 23 service as well as recovery system was not in a reusable status. The re-planning of the campaign again had a few challenges. The on-range check to reuse the REXUS 25 flown recovery and service module for REXUS 26 was the final solution.

A reconfiguration of the REXUS 26 rocket was necessary. The reason for the reconfiguration is that the service and recovery system of REXUS 25 and REXUS 23 are not identical in construction. The previous planned service system had two instead of one TV channels and is longer. The now used recovery system is longer and heavier. It had two camera modules, an interchangeable Manacle-Flange, double surface treatment (Surtec/ Eloxal), fixed guillotine assembly and a combined baro/ delay box. The different systems lead to different on-range check procedures, different spare parts etc. Moreover, the other systems lead to a new REXUS 26 spin and balance during the campaign.

The planning is shown in figure 4. The sequence was as follows: launch of REXUS 25, start with the on-range check, analyse the REXUS 25 data at DLR MORABA, set up the new Spin and Balance of REXUS 26 and finally launch of REXUS 26.

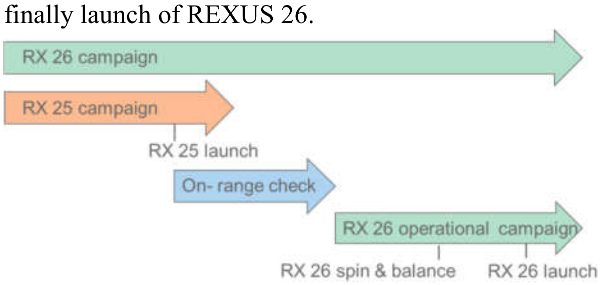

Figure 4. New REXUS 25 and 26 campaign schedule

4.3. REXUS 25 launch

REXUS 25 countdown started on March 11, 2019. The flight and the recovery were nominal. The recovery and service module were in a reusable status.

5. ON-RANGE CHECK

This chapter gives an overview on the on range check of the recovery and service module. The on-range check started on March 11, 2019 and ended on March 18, 2019. The individual operation was done by a highly experienced team of DLR MORABA at ESRANGE.

5.1. On-range check of recovery system
To realize the third launch of the REXUS 23/ 25/ 26 campaign it was necessary to perform an on-range check of the flown recovery system of REXUS 23. Therefore various procedures were established in advance and also a parachute system was packed before to ensure a smooth work flow. Following steps had been planned after the recovery of REXUS 23 for the amount of three days:

- Drying of the module for 24 hours
- Disintegration of the parachute system
- Disassembly of electronic hardware for inspection (e.g. PCB's, mechanical Raymond-Timer)
- Visual inspection of wiring harness, connectors and mechanical hardware
- Verification of all RF-components (Beacon and Iridium) and RF test on bench
- Charging and discharging cycles of all batteries
- Electrical tests (e.g. Resistances, short-circuits)
- Adjustment of mechanical Raymond-Timers according to events and trajectory of REXUS 26
- Verification of the camera system
- Functional timing tests
- Integration of parachute system
- Communication tests with service system

Due to the hard landing of REXUS 23, the on-range check was performed with REXUS 25 recovery system after its launch. The challenge was to establish new refurbishment procedures as this recovery system was a new development and had his maiden flight on REXUS 25. Also the parachute system which was prepared in advance could not be used. These issues were solved by shipping additional equipment from MORABA headquarters to ESRANGE Space Center. This shipment included a suitable parachute system which was already packed and also electronic test-equipment. Meanwhile new procedures were established which included the following steps:

- Drying of the module for 24 hours
- Iridium failure analysis (Malfunction on REXUS 25 flight)
- Iridium tracking test
- Disassembly of electronic hardware for inspection (e.g. RF-System, Ignition Unit, Cameras)
- Visual inspection of wiring harness, connectors and mechanical hardware
- Disassembly of mechanical hardware for

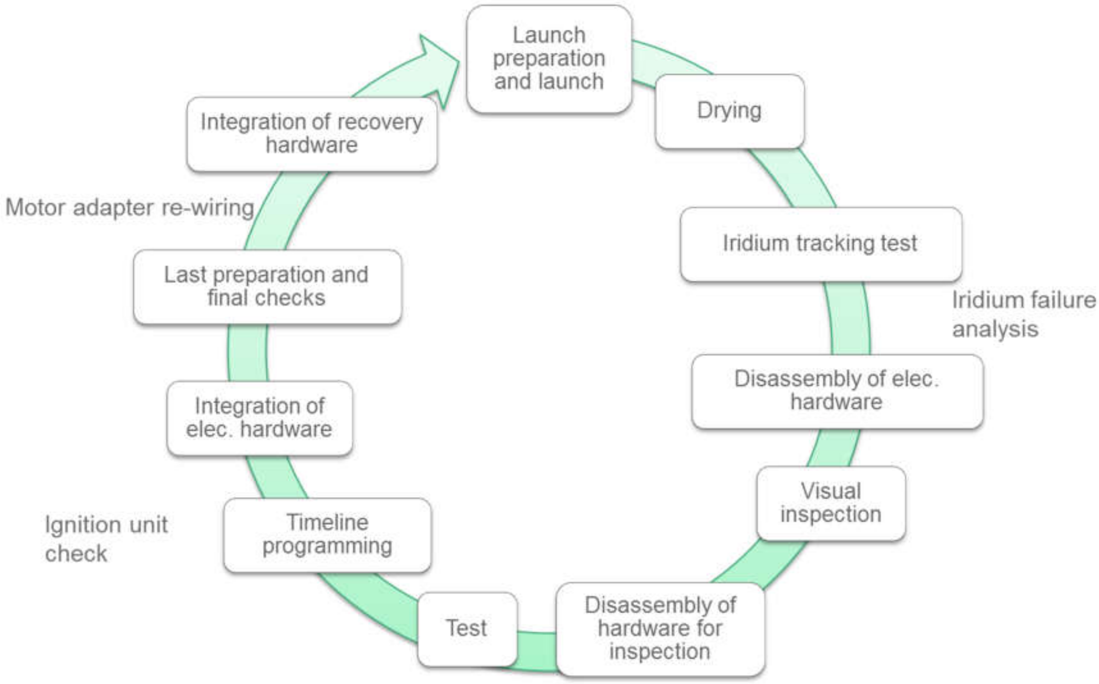

Figure 5. On-range check recovery system

inspection

- Verification of all RF-components (Iridium) and RF test on bench
- Charging and discharging cycles of all batteries
- Electrical tests (e.g. Resistances, short-circuits)
- Checkout of Ignition Unit and reprogramming to trajectory of REXUS 26
- Integration of electronic and mechanical hardware
- Re-wiring of the Motor Adaptor
- Functional timing tests and verification of Camera and Iridium Systems
- Integration of parachute system
- Communication tests with Service System

Figure 5 shows the on-range check of the recovery system. The on-range check was executed within three days. This reduced procedure did not include, unlike to refurbishment at DLR MORABA, verification of structural dimensions. In essence this was a reduced "on-range refurbishment" of the recovery module as an on-range check.

5.2. On-range check of service system

The on-range checked REXUS service module is foreseen to be used once within the same campaign. These checks can never replace a full refurbishment and therefore the risk of failure on the second flight is much higher than on the first one. The following points are not included in the on-range check procedure:

- Opening and disassembling side panels, inspecting threads, checking for loose parts and chips
- Battery cycling and verifying sufficient capacity
- Etc.

The duration of the service system check was 3.5 days. The checks are performed in four phases:

- A post-flight analysis based on the telemetry data immediately after the flight to identify anomalies within the various system components, the flight dynamics, etc. This step identifies extra checks and actions within the subsequent steps.
- A visual inspection of the recovered components to find damages and components exposed to loads above the nominal limits.
- Parts of the system will be disassembled and cleaned for more detailed analysis of electrical components, harness, etc., to find potential damages on these components.
- The last test of the reintegrated system concentrates on the implemented functions of data handling, power management and the implemented sensors with the system running. This is basically a function test.

A detailed overview of the service system on-range check is illustrated in figure 6. The inner cycle illustrates the planned actions and the outer description explains the unexpected events during the check.

6. LESSONS LEARNED

The term "Lessons learned" describes the knowledge gained from the process of performing the on-range check. These lessons can be used to improve future projects and future stages of current projects on behalf of an on-range check

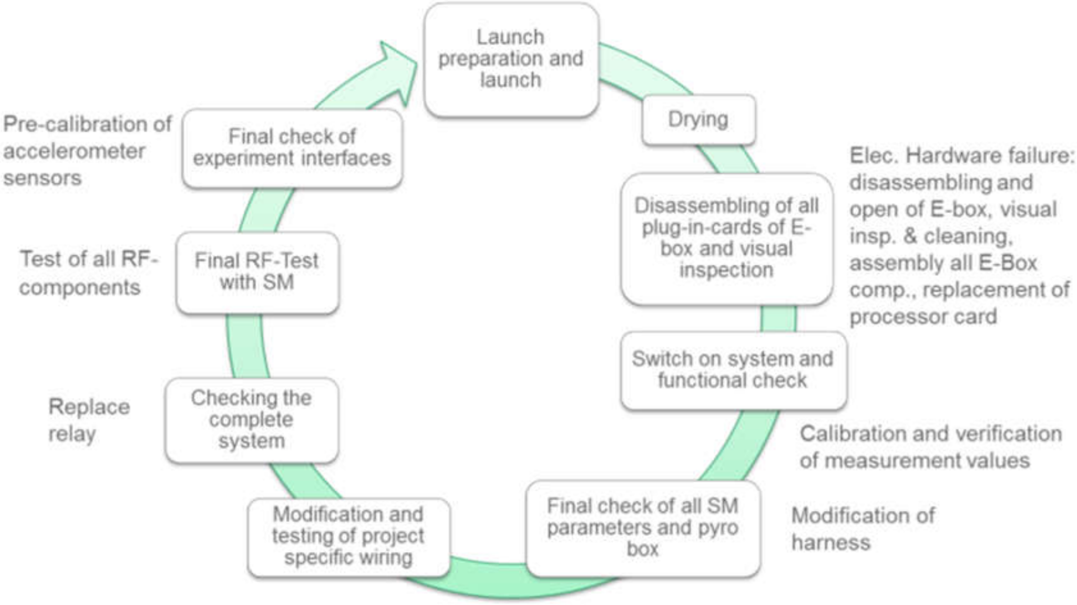

Figure 6. On-range check service system

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Below, a list of DLR MORABA´s lessons learned is given.

- When planning a campaign with two service and two recovery systems for three rockets, it is advisable to use two identical systems
- Definition and realization of the on-range check limits are very difficult. It depends on the project requirements
- Spatial separation of the refurbishment and experiment team was good
- Failure analysis on campaign is challenging (time, material, experts)
- Risk assessment and its fundamentals need to be clarified
- Etc.

7. CONCLUSION

It is possible to launch two REXUS rockets with one service and recovery system within one week. In conclusion, the on-range check makes the campaign more effective but it also holds unforeseen risks for the second rocket. A highly experienced team is a mandatory requirement for an on-range check attempt. Moreover, it was seen that there was a higher emotional pressure as well as a larger burden of work. Within this paper, we did not analyse the financial aspects in addition to the social aspects of the campaign.

Finally it can be said that flexibility of the campaign management is necessary for the sounding rocket market. Streamlined workforces, shifts in technology and a changing market are just a few reasons why flexibility is the new norm for many sounding rocket projects.

8. REFERENCES

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