Testing campaign for ECRIDA: the UV resin 3D printer flying on REXUS

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Abstract

ECRIDA is a student project participating in the REXUS/BEXUS campaign that develops a UV resin 3D printer device capable of working in the low-gravity environment offered by the REXUS rocket flight. Our main objective is to describe the impact of low gravity on the UV resin 3D printing process by comparing samples printed on Earth with samples printed in space. Due to the requirements of the host vehicle and driven by the novel design of our device, a thorough testing campaign must be planned and completed to qualify the device for flight and maximise the success of the scientific objectives. This paper describes the requirements that the device must fulfil and goes into the design of our test plan describing the procedures and the results. Vacuum, vibration, pressure, and functional tests were performed and described together with our learned lessons and conclusions in our will to help student teams with their testing activities.

Keywords

3D printing, REXUS/BEXUS, milligravity, testing

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Acronyms/Abbreviations

REQ	*Requirement*
ESA	*European Space Agency*
REXUS	*Rocket Experiments for University Students*
BEXUS	*Balloon Experiments for University Students*
SNSA	*Swedish National Space Agency*
DLR	*Deutsches Zentrum für Luft und Raumfahrt*

1. Introduction

It is known that additive manufacturing is a key technology when it comes to human space flight [1] as it gives the possibility of manufacturing desired parts right in orbit while relying less on the supply missions from ground that involve big costs and risks.

3D printers based on resin UV polymerization might be a great candidate for space applications due to their mechanical simplicity and better resolution compared to the already widely used Fused Deposition Modeling technology [2]**.** Together with the promises of the technology, a few challenges arrive when one could think to implement this manufacturing process in a low gravity environment.

Project ECRIDA proposes a proof-of-concept UV resin 3D printer based on the Digital Light Processing (DLP) technology to be tested on board the REXUS 29 rocket. The main objective of our project is to prove that the DLP technology can be used for additive manufacturing applications in low gravity by printing some traction samples during the REXUS flight. We also plan to compare them with samples printed on Earth to assess the impact of gravity on the UV polymerization process [3].

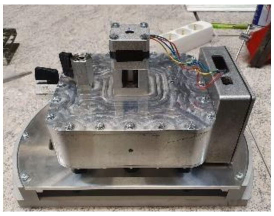

Figure 1. The ECRIDA 3D Printer

The flight model of our experiment is shown in Figure 1 and it was built by a team of 8 students participating in the REXUS/BEXUS campaign. REXUS/BEXUS is a campaign organized by SNSA, DLR, and ESA that gives the possibility to students to propose and implement a project that will be operated inside a sounding rocket or a high-altitude balloon. The whole campaign replicates the process of designing, integrating, testing, and launching a real space project while educating the participants on all these aspects.

To deliver the experiment for launch, the student teams must prove that they fulfill all the requirements that were agreed with the campaign organizers. The most important requirements like the main functionalities of the experiment or the safety ones must be proven by actual tests. The purpose of this paper is to give a high-level description of the test campaign that the ECRIDA project designed and performed to prove the main requirements of the project.

2. Testing Campaign

The testing campaign started in September 2021 and lasted 3 full months with a tight schedule. The main two locations where the tests were performed are the CAMPUS Research Center from University Politehnica of Bucharest and the Romanian Institute of Space Sciences.

The equipment used for each test was made available by the hosting facilities or it was acquired by our team via sponsorship agreements.

Each test is described in what follows by mentioning the main requirements (REQ) that need to be verified, a brief description of the proposed procedure, and the success criteria. Two types of tests were performed: functional and environmental. The authors considered to give only a brief mention about the functional tests and to focus more on the environmental ones as they consider them to be more relevant for the reader since most student experiments hosted by a launch vehicle usually must undergo the same procedures, whereas the functional ones are more experiment specific.

2.1. Constraints

The testing campaign needed to end before the Experiment Acceptance Review (EAR) that took place in mid-November. The EAR marks the end of the integration and testing periods performed by the REXUS teams and its completion proves that the experiment is ready to be delivered for the final pre-launch tests.

Manpower constraints were also considered as the campaign took place during university time and the COVID-19 crisis added many restrictions over the normal usage of the testing equipment. Constraints like the limited number of allowed team members inside a lab or the lack of trained personnel available to help us with the equipment affected the nominal execution of the campaign. The team reacted confident and faced these challenges with success without delaying the initial schedule of the campaign by more than a few days.

2.2. Functional Tests

All the functional requirements of the experiment were tested by a comprehensive printing test that consisted of running 3 times the complete timeline of our experiment from power on to power off.

The procedure consisted in running the launch timeline while tracking all the sub-systems activity (power, communication, data collection, data storage, motor, LEDs) and measuring the dimensions of the printed samples (as in *Figure 2*) to prove that the printing function achieves its purpose and that the samples are printed in the tolerances needed to perform the post-launch analysis campaign.

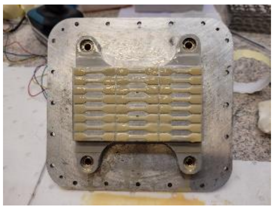

Figure 2. Samples after printing

2.3. Safety Pressure

REQ: *The pressure inside the resin container shall be the atmospheric pressure when closed at the ground during pre-flight and experiment operation.*

The containment of the resin is done inside a pressurized chamber that is sealed on the ground during the assembly. The experiment will be exposed to vacuum conditions during the flight and proving that the chamber can hold the resin at a pressure of 3 bar (x2 safety factor) is the main driver of our proposed procedure.

It was decided that a pressurized air test would be more accessible and proving that the chamber is airtight is sufficient to tick the requirement.

The experiment has by design two valves, one input valve and one output valve. A manometer was connected to the output valve and pressurized air was introduced via the input valve using a household compressor. As soon as the chamber established an inside pressure of 3 bar, the input valve was closed. The experiment was also submerged into a transparent container filled with water and its sides were recorded with cameras to observe any potential leaks (as shown in Figure 2).

The success criteria summed to observing a decrease of less than 0.2 bars of pressure over a period of 1 hour.

Figure 3. Safety Pressure Test

2.4. Absorbent Material

REQ: *The absorbent material shall be capable of absorbing 20 times the quantity of the used resin.*

To comply with some functional requirements of the experiment, a special type of UV resin is used for the printing process. Utilizing 4 liters of it for the test would have had quite an impact on our budget and for this reason we agreed with the organizers to perform this test with a cheaper liquid with almost identical properties (engine oil).

The procedure was quite straightforward, the exact volume of absorbent material used in the flight model was placed on a table and 4 liters of engine oil were spilled over it while trying to cover its surface as much as possible with the same pouring rate (as shown in Figure 4).

The success criteria of the test consisted in proving that after a time of 1 hour, all the oil is absorbed, and no oil traces are found on the other side of the absorbent pad.

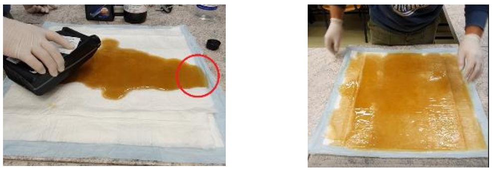

Figure 4. Absorbent Pads Test

2.5. Thermal

REQ*: The experiment shall have nominal performance at temperatures of up to 45 °C.*
REQ: *The experiment shall maintain functionality with nominal performance after being exposed to a temperature of almost -30°C before the flight.*

Extreme temperatures must be considered before the operation of the experiment. The launch will take place from the ESRANGE launch site inside the Arctic Circle. so, the experiment could be exposed for a long period of time to very low temperatures before the launch. Also, the heat coming generated during the flight can drastically rise the temperature inside our experiment module before the milligravity period.

The procedure consisted in artificially exposing the experiment to low (using a household freezer) and high (using a lab oven) temperatures and running the full printing sequence immediately after (see Figure 5). This test is quite conservative as in reality, thermal insulation is used inside the rocket module and the organizers can heat the rocket to a desired temperature before the flight.

The success criteria was represented by the successful completion of the printing procedure after the cold/heat exposure.

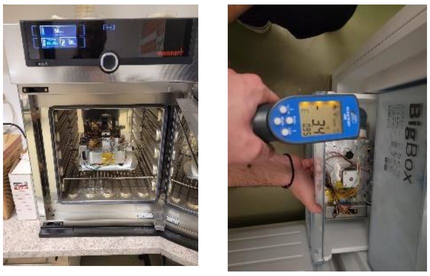

Figure 5. High(left) and Low(right) temp. tests

2.6. Vibration

REQ: *The experiment shall withstand the vibration loads during the launch of REXUS rocket.*

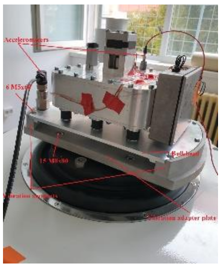

Figure 6. Vibration Test Set-Up

The vibration test was the most conventional test performed by our team compared with all the others.

The procedure was entirely specified by the REXUS User Manual [4] and by the REXUS/BEXUS organisers. The experiment was mounted on a shaker and different vibration input profiles were used while observing and recording data from the accelerometers placed on different spots on the experiment's body.

One of the challenges of performing the test was the design and manufacturing of the interface board to the shaker that was needed to match the shaker mechanical interfaces with our experiment.

The success criteria was to have a functional experiment after exposed to vibrations.

2.7. Vacuum

REQ: *The experiment shall have nominal performance in vacuum conditions (pressure below 0.5 mbar).*

Most of the electronics used are off-the-shelf components that will be exposed to vacuum for a short time during operation in milligravity. For this reason, all the electronics parts were tested while in operation inside a vacuum chamber at a pressure of less than 0.5 mbar.

The procedure consisted in running the electronics with the printing software inside the vacuum chamber while measuring and recording temperature data via the sensors placed on the most critical parts of the assembly (the stepper-motor and the most power consuming chips of the PCB). To command the electronics while inside the chamber, we implemented a Bluetooth communication that allowed us to control the process.

The success criteria consisted of confirming full functionality of the electronics while inside the vacuum chamber and to prove that the hotspots' temperatures of the assembly were in line with the requirements.

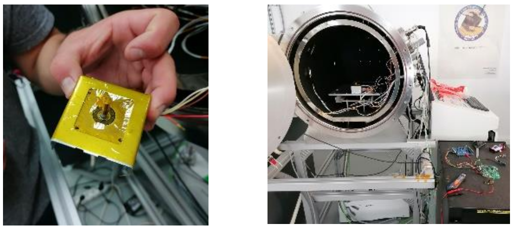

Figure 7. Electronics Vacuum Test

3. Results

All the test procedures presented in Section 2 were successfully carried out by the team in the given timeframe. The Thermal Test was performed with some delay as the initial plan was to access a thermal chamber but given the high number of COVID infections at that time, we continued with the freezer/oven procedure.

All the success criteria were achieved, and extensive test reports were delivered to the campaign panel. The test activities ended with a successful Experiment Acceptance Review and with the delivery of the experiment to the REXUS/BEXUS organisers for the launch campaign pending to take place in 2023.

4. Conclusions

The test campaign executed by the ECRIDA team participating in the REXUS/BEXUS framework is presented. Our method of designing the campaign, the constraints we faced, and a high-level description of every test performed are described with focus on the more general aspects and without digging into the specifics of our experiment. The purpose of the authors is to make all the information valuable to any student project that will be hosted by a launch vehicle and that must undergo test procedures.

Given the circumstances of the COVID pandemic, our team faced various challenges while performing the test plan but eluded them with confidence resulting in a successful test campaign. The experiment was delivered to the REXUS/BEXUS organizers and now final preparations for the launch are performed.

Acknowledgements

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