µHoubolt EuRoC 2022 Flight Report

µHoubolt was successfully flown at EuRoC 2022. This report documents the launch preparation, launch and recovery.

13.10 Flight Readiness Review

In the afternoon, the flight readiness review was conducted. While the jury was satisfied with the vehicle and GSE, the documentation and checklists were lacking.
The rest of the day was spent thoroughly improving the documents, with some aspects getting signed off on the same day.

14.10 FRR Part 2 & Preparation

The rest of the documents required for FRR were completed and signed off by the jury, passing the FRR.

The launch pad with GSE was packed up and transported to the launch site, but assembly was not possible due to time constraints.

Final testing of the avionics and radio connection revealed a problem with the GNSS reception that was not present in prior tests. Despite it being unable to get a fix, it was decided to go ahead, as the redundant tracking system required for the competition worked as intended.

The rocket was assembled and packed up.

15.10 Scrubbed Launch Day

Starting early in the morning, part of the crew started setting up the launch infrastructure while the rest prepared the rocket at the launch site, hoping for an early launch readiness review (LRR) and launch.
Preparing the vehicle for the LRR took longer than expected and this, together with GSE troubles led to the decision to postpone the LRR. It was then held shortly after noon and passed.

Meanwhile, the server got set up next to the launch pad but refused to boot at first. This was probably due to the low temperatures and/or humidity in the morning, as the problem resolved itself after lots of troubleshooting.

After finishing rocket preparation and checking the launch pad, the vehicle was mounted on the rail to start integrated checkouts and launch preparations.
Testing the electronics and software revealed a problem with the electrical connection between the rocket and ground systems, making communication with the vehicle impossible. Troubleshooting was interrupted by the launch window opening, forcing the pad crew to retreat from the launch rails.

After the other launches were done, the crew rushed to fix the issues in time for launching during the still open window.
While this optimistic time plan did not work out, the issue was later resolved, by disabling the vehicle battery charging via umbilical, as it somehow interfered with communications.

Continuing with launch preparation, another issue popped up: the safety valve on the oxidizer fill system was defective and leaked at pressures well below its intended opening pressure.
Running out of time, the launch preparations were scrubbed, the vehicle taken off the rail, and the launch infrastructure secured for the night.
A risk assessment was performed and showed that replacing the malfunctioning safety valve (no spare available) with a plug was acceptable.

16.10 Launch Day

Again starting early, the safety valve was replaced with a plug, after which the fill system passed its pressure tests.

While the rest of the launch pad preparation went well this time, the rocket prep didn't.
During the final vehicle testing in the preparation tent, the ignition system suddenly activated. While this could be catastrophic with solid rockets, in this unfueled liquid rocket only the igniters burned for a few seconds and didn't cause any damage or injury (but lots of stress and unhappy EuRoC officials).
Troubleshooting revealed that activating the onboard cameras causes a sag in the main supply voltage, as the cameras initially draw more current than the over current protection in the PMU permits. This resets the ECU, which, with the pyro voltage applied (a scenario that was not considered during design or tested for) activates the igniters.
Running out of time to be ready in time for the planned launch window, the cameras were simply unplugged as a quick (but unfortunate, as no on-board video was recorded as a result) fix.

After installing the rocket on the rail without further hiccups and going through checkouts and preparations in time, the launch window was canceled due to weather conditions. The rocket was powered down to preserve battery life (as the charging system was deactivated) and the time was used for additional GSE testing.

With the next launch window approaching and the weather looking acceptable, the vehicle was powered back up and preparations were resumed. After the crew retreated from the launch pad, the oxidizer filling was started ahead of the launch window opening. As the launch was delayed by other teams preparing and launching their rockets, the oxidizer tank was repeatedly topped up to compensate for boil off.

At around this time the GNSS system suddenly got a fix for the first time, why it worked then and not before is unknown.

When venting the fill system in preparation for disconnecting the umbilical connections ahead of the launch, it was discovered visually and by pressure readings that the system

also purged oxidizer out of the vehicle tank, leading to the conclusion that the oxidizer fill check valve was leaking. The venting was interrupted.
With the launch options on the next and last day not looking good due to weather conditions, the team quickly decided to go ahead with the launch. The launch procedures were adapted on the fly to move fill system venting and umbilical disconnection as far back towards liftoff as possible, to lose a minimal amount of oxidizer.

The rest of the steps were executed quickly, with the rocket finally lifting off at 14:11.

A plume could be seen venting from the side of the vehicle near the oxidizer fill port, confirming the conclusion of the leaking fill valve. Apart from that and the vehicle visibly turning into the wind due to its rather low off-rail velocity, the flight went nominally. Except for a short period of time where it was in clouds (and deployed its drogue parachute by separating the nose cone), it could be visually tracked all the way through ascent, descent and main parachute deployment until disappearing behind trees.

The telemetry radio connection to both the SRAD avionics and the official tracker was good during the whole flight and both systems delivered similar data and landing coordinates. Recovery was further simplified by local firefighters spotting the descending rocket and leading the recovery crew directly to it. The vehicle was recovered 1.6km from the launch site without any visible damage.

During the debrief with EuRoC officials, no significant damage was found, making the recovery count as fully successful, a first for European student-built liquid fueled rockets. With only replacing a few single use components, the vehicle could have been flown again the next day.

17.10 Post-Flight Review

The post-flight review revealed that the avionics system worked well and recorded high quality position and system status data for the duration of the whole flight. Due to the loss of some oxidizer, the burn time was reduced from the planned 8s to around 6s, leading to a lower than planned altitude of around 2200m.

It was also discovered that one of the igniters was activated but stopped burning shortly after, leaving the second one to successfully ignite the engine. The cause of the failure is unknown.

The leak in the fill valve could be traced to an o-ring that was found in crumbles upon disassembly of the valve. While the FKM material it is made of is generally compatible with the oxidizer Nitrous Oxide (N_2O), it is known that N_2O can diffuse into the material over time, making it swell and become brittle. It is suspected that the repeated top-off of the oxidizer tank while waiting for the launch clearance was the cause, with the o-ring being exposed to the oxidizer and mechanically stressed for far longer than in previous tests.