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Sheffield students win US rocket competition

Viktor Fedun reports on success for SunrIde, a team of students from the University of Sheffield who designed and built a rocket.

Sheffield University Nova Rocket Innovation Design Engineering (SunrIde) is a student-led engineering group focused on rocketry. In 2018, the University of Sheffield team was the first from the UK to take part in the Spaceport America Cup (SA Cup), the world's largest annual student rocket competition. SunrIde launched and recovered a self-designed, payload-carrying rocket called Amy, which reached a measured altitude of 10 017 ft (~3053 m), winning the James Barrowman Award for Flight Dynamics for the most accurate altitude prediction, at 99.83%. SunrIde plans to return to the SA Cup in 2019, competing with their newer generation rocket, Helen, in the 30 000 ft category. SunrIde's achievement in 2018 boosts the UK's presence on the international high-power rocketry scene. It also sets an important precedent for UK students in STEM fields, encouraging them to develop their practical engineering skills beyond the academic framework.

Project SunrIde began in October 2017, as part of the university's Sheffield Space Initiative. A group of students from several departments – mostly MSc students from the Department of Automatic Control and Systems Engineering (ACSE) – with the support of Viktor Fedun, senior lecturer in ACSE, started a collaboration with Charles Simpson from the UK Rocketry Association (UKRA). UKRA's Team Project Support (TPS) scheme offers essential practical advice on projects that fall outside the traditional scope of the UKRA level 1–3 certification training process.

Ambition

The SunrIde team wanted to research, design and build a payload-capable high-power reusable rocket that could compete in the SA Cup 2018 in the category "10 000 ft above ground level (AGL) apogee with commercial-off-the-shelf (COTS) solid propulsion system". According to the rules, the rocket had to reach the 10 000 ft (~3048 m) mark within the smallest margin possible, while carrying a 4 kg payload – either scientific or non-functional.

1 Amy taking flight. (V Fedun)

None of us had any rocketry experience to match the project specification, so the prospect of building a high-power rocket from scratch proved daunting from a managerial and technical perspective. Nevertheless, within the academic year 2017–18, we undertook the relevant research into rocketry, secured funding, identified primary parts and materials suppliers, established an efficient iterative design cycle adapted to the university's manufacturing facilities and – eventually – overcame most of the unknowns that are an innate part of such a novel large-scale project.

The team faced an additional set of legal constraints in order to test some of the rocket-specific subsystems; the conventional certification route in the UK for a vehicle of the proposed power turned out to be incompatible with the demands of the competition. On top of this, the availability of high-altitude launch sites was limited. However, the TPS scheme offered a viable and lawful solution: through UKRA we got access to sample motors and pyrotechnics for the recovery system, allowing some supervised tests.

Building Amy

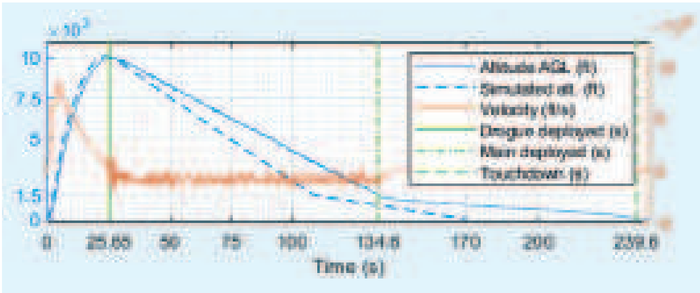
SunrIde named its rocket after Amy Johnson, the British aviator and University of Sheffield alumna. Once complete, Amy (figures 1 and 2) was about 2.7 m high and weighed roughly 28 kg – including a 3.8 kg, three-unit CubeSat payload mostly made of concrete. The airframe consisted of pre-glassed phenolic tubing with an outside diameter of 158 mm, which accommodated a solid-propelled, reloadable Cesaroni P98-4G M3400-WT motor providing a total impulse of ~10 Ns. The nose cone was made of fibreglass in an ogive shape. We shaped the four clipped delta rear fins into a circular arc aerofoil and strengthened them by laminating a fibreglass cloth layer between 3 mm thick plywood sheets cut by laser. They were mounted them on a removable fin can. But because we expected the rocket to reach the transonic flight regime (Mach ~ 0.96), we laminated an additional tip-to-tip fibreglass reinforcement layer over the fins to eliminate the risk of fin flutter.

The rocket had three sections. The lowest contained the motor and drogue parachute, with the main parachute in the upper section. The middle section held the payload and avionics. The parachutes were designed to allow them to fall without tangling and avoid damage to the airframe. The internal structure of the rocket was held in place by 1.8 cm thick, laser-cut plywood bulkheads, centring rings around the motor mount tube, and a custom-designed, CNC-machined aluminium motor retainer, all epoxied to the airframe.

We used two single redundant PerfectFlite StratologgerCF altimeter boards for the dual-event parachute deployment and altitude logging. Once a deployment condition is met, the altimeter detonates a charge of 3–5 g of black powder, separating the adjacent rocket sections. This lets the parachute spread out of the airframe and inflate. To prevent premature ejections mid-flight, both separation joints were also secured with four M3 nylon screws, which acted as shear pins during intentional deployment.

We intended to use an Eggtimer TRS – a more advanced primary flight computer with GPS/RF assisted recovery support – but it failed unexpectedly during the final testing stages of the competition. We replaced it with a spare StratoLoggerCF unit, and adapted the configuration to fit. Our final avionics circuitry was awarded an "On The Spot Recognition" token by the SA Cup judging panel for its robust layout.

2 The SunrIde team before lift-off. (Left to right): Viktor Fedun, Jae Hyun Lim, Andrea Schiona, Georgios Rontogiannis, Ankita Kalra, Iulius Seniuc, Vishan Nair, Gopika Narayanankutty. (V Fedun)



3 Amy's flight data, as logged by one of its on-board altimeters (22 June 2018, NM, operating temperature between 41.1° and 42.9°C).

Flight performance

The rocket was launched on 22 June 2018 at 20:13:07 UTC from a dedicated vertical launch site near Spaceport America (32°56′34.0″N 106°54′54.0″W), at an air temperature of ~40 °C, relative humidity of ~6% and a gentle breeze. Safety reports from previous SA Cup launches had noted that some StratologgerCF boards had failed to initialize properly in hot weather; in order to lower the risk of the altimeter overheating and falsely triggering parachute release, we sprayed the airframe with reflective white primer and transported it to the launch area under white cotton towels.

The vehicle performed a nominal flight, with the motor ignition and the recovery system both working as expected, an impressive achievement considering we had not been able to conduct either a test flight or extensive ejection tests. Shortly after reaching ~3053 m (10 017 ft) AGL at apogee, the drogue parachute deployed, stabilizing the descent rate at 24.5 m s^{-1}. Down at 457 m (1500 ft), the main parachute opened, allowing the rocket to touch down at a prudent 5.9 m s^{-1}. It is worth noting that the nominal flight success rate among all 99 finalist teams at SA Cup 2018 was only around 50%. While this demonstrates the inherent, frequent and dangerous system failures attached to high-power rocketry, it also highlights SunRIde's robust approach.

"We plan to reach 30 000 ft with our ambitious new rocket Helen at SA Cup 2019"

Our extensive flight simulations showed that, at an estimated static stability margin of 2.2 calibres, the final design of Amy was slightly "over-stable", as per the SA Cup 2018 design guidelines. This made it susceptible to weathercocking – a tendency to turn into the wind – during ascent. We had relatively favourable flight conditions, and our vehicle landed only 1.56 km away from the launch pad. We located it the next day and recovered it safely. Close inspection by competition officials found that the vehicle had not sustained any critical damage and was ready to fly again.

Amy overshot the 10 000 ft (3048 m) apogee target by just 17 ft (~5.18 m), representing 99.83% accuracy. This was the best result at the SA Cup 2018 for altitude prediction and won a technical achievement award: The James Barrowman Award for Flight Dynamics. The SunrIde team is also proud to have made contact with competition sponsors such as SpaceX, Blue Origin, Northrop Grumman, Virgin Galactic and more. This puts the University of Sheffield – and the UK – on the world map of student-driven high-power rocket engineering. We hope that our success will inspire more UK university teams to follow.

Future plans

In October 2018, SunrIde welcomed a new generation of talented students to build on our competition experience, increased media exposure and new funding. We are developing a rocket for the 30 000 ft COTS category of SA Cup 2019, named after Helen Sharman, Sheffield University graduate and first UK astronaut.

Helen involves a major design overhaul and improved telemetry. Together with new industry partners, we are working on a taller, thinner, carbon-fibre airframe, a metal-tipped nose cone and metal fins to allow the rocket to handle the more powerful N-class engine. With Helen, SunrIde will also attempt to send its first science payload to the upper atmosphere. ●

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MORE INFORMATION
Spaceport America Cup https://www.spaceportamericacup.com
UK Rocketry Association http://www.ukra.org.uk