STRATOS II: HALFWAY TO SPACE

The next step in reaching space by a student-built rocket

The dream to launch a student-made rocket into space came alive after the successful launch of the Stratos I rocket in March 2009. The rocket attained an altitude of 12.5km above the launch pad, breaking the European altitude record for amateur rocketry. The excitement of “what’s next?” filled the minds of DARE members who had worked on the project. A preliminary calculation showed that with a higher specific impulse and a larger and better-performing propulsion system, it was possible to build a rocket that would reach the Karman line—the boundary of space, at 100km altitude. Before that can be achieved though, a milestone altitude between the attained altitude of 12.5km and the boundary of space first needs to be reached.

This is how the Stratos II rocket project was born.

The goal of the Stratos II is to fly a scientific payload to an altitude of 50km and return it safely to Earth, with a rocket entirely designed and built by students. The two-stage rocket will be approximately 7m tall and 20cm in diameter, and will achieve its top speed of Mach 5 after the second-stage burnout. The planned trajectory is shown in figure 1. After ignition, once the first stage is spent, it will be jettisoned, leaving the rocket to coast to 8km. At this point the second stage will ignite, giving the rocket a sufficient change in velocity to coast to the target altitude of 50km. The rocket will follow a parabolic trajectory down until the second stage is jettisoned at 8km. In the lower layers of the atmosphere, the parachute will be deployed and the nosecone will safely land. Throughout the flight, the scientific payloads in twelve slots in the nosecone
(figure 2) will conduct their experiments. Any data recordings will be downcast to a telemetry station at the launch site. Due to the goal altitude and the restrictive launching regulations of the Netherlands, the rocket will have to be launched abroad, on a professional rocket range.

The high-performance propulsion system necessary for Stratos II requires a new technological level, never previously achieved by DARE. To guarantee the best performance, two propulsion teams—hybrid and solid—are competing with each other for the right to manufacture the rocket engine that will bring Stratos II to its goal apogee. Besides the two propulsion teams, the major technical teams include a capsule & payload group, an electronics group and an operations & logistics group. In total about thirty students will be working on the project.

SOLID PROPULSION
The solid propulsion system will consist of two identical motors, each delivering 1500kg of thrust for ten seconds. This gives a total impulse of 150kNs per motor. Some very innovative features are incorporated in the design.

Firstly, a completely new propellant is designed. This propellant uses ammonium nitrate as oxidizer and aluminum powder as fuel. This combination produces a high temperature when ignited, which leads to a high motor performance. Unlike the solid propellants that are in use now, this propellant does not produce the very harmful and dangerous hydrochloric acid when it is burned. This means that a motor using this propellant is much less polluting and causes less wear on launch equipment than standard rocket motors. Each motor will contain 75kg of this high-performance propellant.

Next to that, the combustion chamber will be made of composite material (carbon reinforced plastic), keeping the total mass of the motor low while still retaining the necessary stiffness and strength. The combustion chamber also acts as the fuselage of the rocket; this is a so-called monocoque design, which additionally reduces the mass of the rocket. The mechanical loads on the motor casing are very high during flight: the pressure inside the motor is 70bar, the rocket accelerates at more than 10G’s during launch and heavy vibrations are induced during its Mach-5 flight through the atmosphere. Additionally, the heat load on the casing is very high: the propellant burns at 2500K for ten seconds. This combination makes the design of the motor a real engineering challenge.

Finally, the use of a new, heat-resistant polymer for the nozzle of the motor is investigated. Currently, a research project is being performed at the Faculty of Aerospace Engineering, aimed at investigating the properties of this material. If it is found suitable for use in the rocket nozzle, it will yield a very lightweight, easy-to-fabricate and relatively inexpensive product.

HYBRID PROPULSION
Next to the solid propulsion system, a team within the Stratos II project is developing DARE’s first fully-functioning hybrid rocket engine. This project is called Dawn.

The Dawn hybrid engine makes use of a solid fuel and a liquid oxidizer. Traditional DARE motors have both fuel and oxidizer combined into a single solid grain, which makes them relatively simple but also less efficient in the amount of thrust they produce for every unit of propellant. Liquid rocket engines, using liquid fuel and liquid oxidizer, are far more complex but also offer better performance than a solid motors. A hybrid engine combines properties of both solid and liquid engines. It is more effective than a solid engine but less complex than a fully liquid one.

The Dawn engine is comprised of several subsystems, each fulfilling a particular role in the engine. Figure 3 is a schematic
representation of the engine. The numbers represent the different subsystems. The largest volume in the engine is used for the oxidizer tank (1). This will be a composite tank in which N₂O will be stored under pressure. N₂O is also known as nitrous oxide or laughing gas.

Below the tank is the feed system (2), which connects the tank with the engine. It contains a special valve that is activated using a pyrogen charge. When the valve is opened, the oxidizer will start to flow through the pipes of the feed system towards the combustion chamber.

The N₂O first passes from the feed system to the injector (3). The injector is placed in the combustion chamber (5) where it vaporizes the incoming nitrous oxide. This will make the N₂O react more easily.

A small solid propellant grain is placed near the injector. This is the igniter (4) which, as its name suggests, ignites the engine. An electrical current sets off a blackpowder charge, which in turn lights the igniter grain. The igniter grain then heats up the combustion chamber and the fuel inside it. When the nitrous oxide vapor enters the combustion chamber through the injector, it will become hot enough to start reacting with the fuel.

The fuel and oxidizer will then start to burn, forming gasses and building up pressure in the combustion chamber. These gases will travel further down the engine, through the nozzle (6). Due to the shape of the nozzle, the gases will accelerate greatly and thus propel the rocket.

The Dawn project team has worked out its concept for the engine and is now testing the different subsystems. A test with the igniter has already been successfully conducted. Further tests with the injector and burn tests to select the final components for the fuel, are scheduled in the near future.

**PAYLOAD AND CAPSULE**

Imagine: first you put your expensive smart phone into a freezer for an hour. Next, you accelerate it with 15 G flying through the arctic atmosphere at -100°C while at the same time the top of your phone heats up to 1000°C due to the supersonic flow around it. You might want to add some protection. This is one of the challenges the capsule of the Stratos II rocket has to solve.

The capsule is the top segment of the rocket and is the only section which will be recovered. It harbours the flight computer, third parties' payloads and the recovery system. Protecting these delicate systems against the elements and lowering and coping with the aerodynamic forces are the functions of the outer shell. Stratos II will be the first DARE rocket which needs a special thermal protection system at the top of the nosecone, because otherwise it will melt.

The high altitude and speeds result in new requirements for the recovery system. The connection between the nosecone and the rest of the rocket needs to be stiff but easily separated. Very often designs with explosive charges are used to fulfil this function. Unfortunately, the explosives students are allowed to work with, do not work at high altitudes due to the low atmospheric pressure. DARE uses a lot of servo activated systems in their rockets, but again these are not the best option for Stratos because of the heavy vibrations due to the high speeds. In the end, a new idea based on melting Dyneema wires was developed. A rocket testing this system in a prototype capsule will be launched this Spring to an altitude of 1km at a DARE launch day in ’t Harde, the Netherlands.

Figures 4 and 5 show an overview of the separation system. The upper part of the propulsion segment and the bottom of the capsule each have a ring that connects to a clamp-band, which secures the two segments with respect to each other. Due to the geometry of the rings and the clamp-band, the system is automatically aligned and will become stiffer if the radius of the clamp-band is reduced. This reduction is achieved by pulling the Dyneema wire inside a pre-tensioning system. When the nosecone needs to be separated, this Dyneema wire is melted by heating a resistor. The Dyneema wires breaks and the clamp-band is released.

The nosecone will begin to tumble upon second stage separation because it is aerodynamically unstable. With a maximum speed of 80m/s it will fall back to Earth. At a predetermined altitude a second Dyneema wire will be melted, resulting in the deployment of the main parachute, reducing the speed of capsule to a safe landing velocity.
ELECTRONICS

The electronics segment consists of a flight computer and a ground station. The flight computer layout for Stratos II is built on the experience gained from developing the flight computer of the Stratos I rocket. Its task is twofold: to execute the rocket flight plan and to provide power and communications for the payloads. The flight computer consists of a master control unit (MCU), a data controller, a measurement board, a storage board, a transmitter, a power board, a pyroboard, and the backbone. The MCU controls the overall state of the rocket, mostly based on the measurements provided by the measurement board. The data controller routes the data received from the measurement board and payloads to the storage board, the transmitter, or both.

The choice of using a separate data controller for flight data routing instead of letting this be handled by the storage board or MCU (as is the case in more conventional designs) was mostly driven by the need to provide data routing for the payloads.

The storage board collects the data onto a solid state storage device. Important rocket data, like state information and altitude measurements, are also transmitted back to a ground station via the transmitter. The transmitter will also send down data from the payloads if requested. This will decrease the loss of useful data in case the solid state storage devices cannot be recovered, as was the case for Stratos I.

The power board provides a stable power supply to the boards and payloads. Additionally it can charge the batteries while connected to an external supply.

The pyro board will provide all interaction with the engines and mechanisms. In case hybrid engines are used, the pyro system will most likely include its own batteries for ignition.

By far, the largest change compared with previous designs is the backbone. The backbone will handle the physical routing of the data and power lines. Previous flight computers developed by DARE used a wire harness for connecting panels to the power supply and each other. Due to the increasing complexity of the flight computers, it became hard to perform the integration with the capsule structure. Especially Stratos I was a tight fit and the high density of power lines close to the antenna was the main cause for the decreased performance of the transmitters. The backbone eliminates such problems. The ground station will provide launch command and receive the transmitted signal, once the rocket is in flight. It will also distribute the received data to its intended recipients. For this distribution, a network separated in three zones—the command zone, the team zone, and the client zone—is created. The command zone is able to directly change the state of the rocket and is the only zone that can give the launch order. The command zone is also responsible for routing to and from the other zones. The team zone can change software on the rocket while it is in maintenance mode and get the state of the rocket. It receives and handles only flight data from the flight computer during the flight. The client zone can upload software and data to the payload when specifically enabled to do so. During flight it receives, in addition to state information, only those data packets its respective payload has sent on the transmitter.

LOOKING AHEAD

The Stratos II project officially began in February 2010, and since that day, many technological challenges have been solved by the enthusiastic and hard-working DARE rocketeers. The first subsystem test results have been presented at the International Astronautical Congress in October 2010, and the project has been very well received by the European and Dutch space communities.

However, many more milestones, such as propellant formulation, rocket engine design, electronics and payload integration, have to be achieved before the planned launch in mid-2012. DARE is hopeful that the success of the Stratos II rocket will bring us one step closer to attain our dream of reaching space by a student-built rocket.

For more information on joining the Stratos II team, sponsorship opportunities, as well as news or updates about the project, please visit projectstratos.nl or send an email to info@projectstratos.nl.

References

Projectstratos.nl