T-MINUS ENGINEERING: A COMPANY IN ROCKETRY

The start of a company in automated aerial and space vehicles

The idea started when a group of students from Delft Aerospace Rocket Engineering were sitting at the breakfast table of the Esrange launch base canteen, in the far north of Sweden. It was the day after the successful launch of the self-built Stratos rocket, that broke the European altitude record for amateur rockets. "This is what we love to do, and apparently we are good at it. Let's try and make a living building rockets".

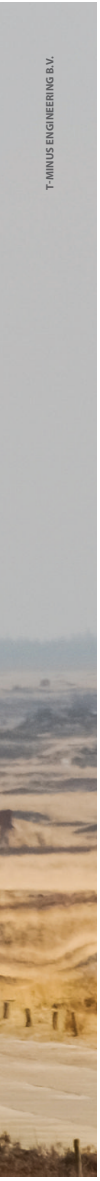
TEXT **Hein Olthof and Mark Uitendaal, Co-founders of T-Minus Engineering B.V.**

The idea to found a real rocket company was thus born that day in Sweden. The idea, however, was still very new, and the group broke up before it could really materialize. Mark Uitendaal graduated soon and went to work for the Swedish launch base. Eric Smit finished his study soon after that, and started working on the Delfi N3Xt satellite. Roel Eerkens and Hein Olthof were still following courses for their master's degree. However, the idea remained, and in 2011 the company T-Minus Engineering was finally founded. Given the background of the founders, who all graduated at TU Delft (aerospace engineering and electrical engineering) and have extensive experience in the design and operation of rocket systems, the perfect mix of skills and expertise was obtained to build high-quality rocket products on a professional basis.

Only five hours after signing in at the chamber of commerce, and celebrating the founding of T-Minus with a nice dinner, two of the founders already flew to Glasgow, Scotland for the first mission: giving a workshop for the Scottish CanSat competition.

The CanSat competition is expanding rapidly in Europe. This project is set up in order to promote science and technology among high-school students, under ESA's programme to promote STEM (science, technology, engineering and math) subjects. Several groups of four to ten students design and build a CanSat, a satellite the size of a soda can that is launched on a rocket to 1000m altitude, after which it descends through the atmosphere on a parachute and carries out its mission. Measuring temperature and pressure and transmitting these data in real time to a ground station is always the primary mission. But the secondary missions may be chosen by the teams themselves and therefore vary greatly. There are teams that just measure additional atmospheric properties, such as humidity or CO_2 levels. Others design a quadcopter to perform an autonomous descent.

T-Minus Engineering was involved in the European CanSat competition in a very early stage. At first, this involvement was only in the form of aiding in the organization of workshops and providing members for the CanSat jury. In 2012, two major contracts were signed with ESA: developing the CanSat starter kit and



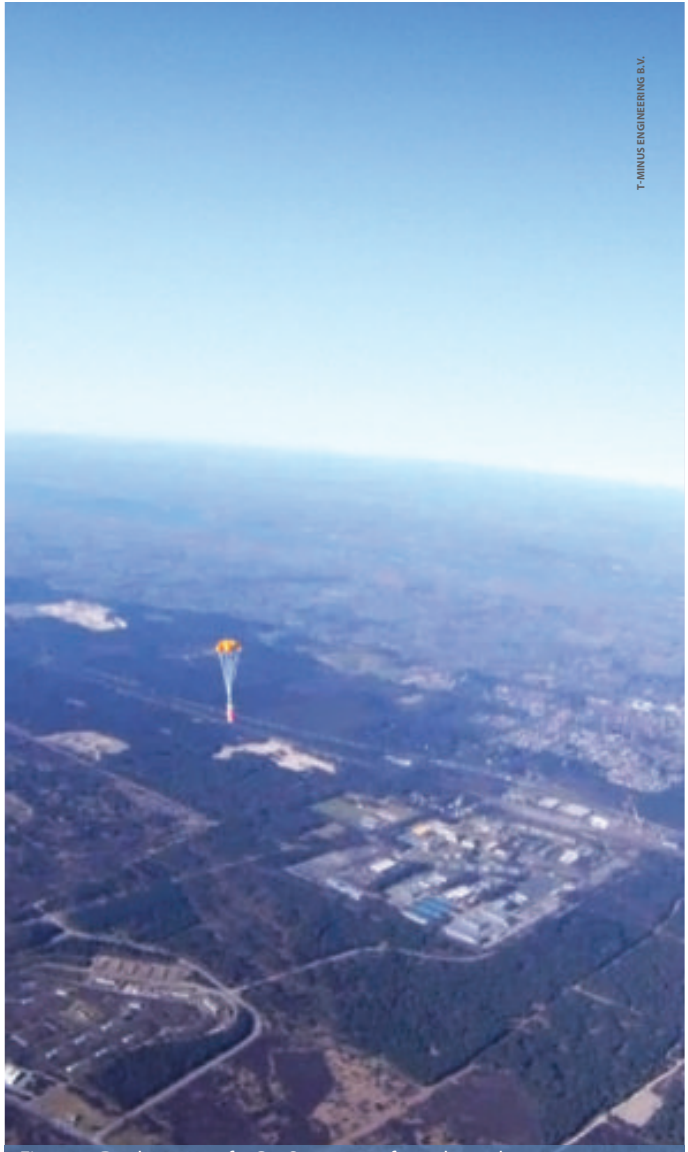


Figure 1. Deployment of a CanSat as seen from the rocket

Figure 2. CanSat launcher in tower

organizing the 2013 European CanSat launch campaign. This led to the development of the first two T-Minus products: the T-Minus CanSat kit and the T-Minus CanSat launcher.

THE T-MINUS CANSAT KIT

The T-Minus CanSat kit is designed to give the participating high-school students a quick start on building their CanSat. The heart of every satellite is its Master Control Unit (MCU). This is the part that collects all sensor data and distributes them to transmitters and storage units. Therefore, the core part of the kit is an in-house developed electronic circuit board that houses a powerful microcontroller, a power subsystem and all the necessary means to quickly connect sensors, storage devices and other necessary equipment. The board is electronically compatible with the popular Arduino experiment board, but the form factor is chosen such that it perfectly fits inside a soda can. Next to that, it also allows direct programming of the microcontroller, which greatly increases its flexibility. The board can not only be used for building a CanSat; it is much more versatile. For this reason, TU Delft already showed great interest in it, and even facilitated its development.

Next to the MCU board, the kit contains an experiment board that is easily connected to the MCU. As the name suggests, it can be used for experimenting: soldering sensors, data storage devices, etcetera. Also two transceivers are included, so that a radio link from the CanSat to the ground station can easily be established. To house all electronic components properly, the kit contains a simple structure on which the circuit boards can be mounted. Finally, extensive documentation and lecture material on sensor usage, data processing and parachute design is included.

THE T-MINUS CANSAT LAUNCHER

Of course, the most important and spectacular part of the CanSat project is the launch of the CanSats. For this, T-Minus Engineering designed a dedicated rocket: the T-Minus CanSat launcher. The key design elements for this vehicle are safety, operability and functionality.

The rocket is designed to deploy six CanSats simultaneously at an altitude of 1000m. It has a wide operation envelope, which means that it can be launched under a wide range of conditions. Wind speeds of 6m/s are no problem. It is passively stabilized by means of a fin set. The vehicle itself is 3.2m tall, with a diameter of 0.2m, and weighs 23kg when it is completely loaded. An in-house developed solid rocket motor delivers 1000N of thrust over a period of 4.2s, after which the rocket coasts to its apogee altitude. Here, the CanSats are deployed after which the rocket is recovered under a parachute. In this way, the rocket can be reused with minimal refurbishment effort.

The vehicle is divided into two parts: a motor module and a payload module. In order to minimize the safety risks during payload integration and the deployment shock on the payload themselves, the CanSat module does not contain pyrotechnic systems. Instead, it uses the T-Minus melter system for the payload deployment mechanism. This consists of a wire that supports the payload covers and a specially designed thermal knife. When the knife is activated, it melts through the wire and thus releases the payload covers, so that the payloads are deployed (Figure 5).

The maiden flight of the T-Minus CanSat launcher took place on March 4. Four liq-

Figure 3. Schematic representation of the DART vehicle

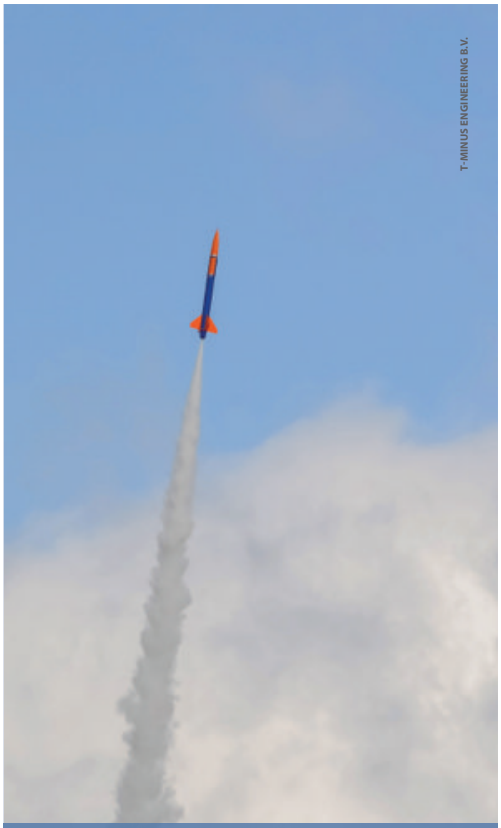


Figure 4. CanSat launcher in flight

uid filled soda cans were installed in the payload bay as dummy CanSats, together with one real CanSat, made by T-Minus from one of the CanSat kits, and a video camera. After mounting the rocket on the launch tower, adjusting the azimuth and elevation, the countdown started: "T-Minus 10, 9, 8 … 3, 2, 1, Launch!" The rocket rapidly left the tower with a loud roar and in a thick cloud of smoke. According to the telemetry, all flight parameters were nominal. Twelve seconds into the flight, a critical event should occur: the opening of the hatches and deployment of the payloads. The telemetry stream from the rocket showed that the thermal knife was activated. Shortly after that, the payload deployment was visually verified, perfectly at apogee. Two seconds later, the parachute unfolded and the rocket descended gently down to the ground. This seemed to be a mission success. The rocket was quickly retrieved by military personnel and inspected by T-Minus engineers. The parachute showed some degradation, due to the high deployment stresses caused by high dynamic pressure. The CanSat, however, could not be found immediately. This was already expected, as the impact terrain is quite rough. For this reason, the CanSat was equipped with a GPS tracker. Its exact location could therefore be pinpointed. Unfortunately, the military facility closed before it could be retrieved. A few days later, a phone call was received from the military: they had found the CanSat only one meter from its last transmitted GPS location. An inspection after the pickup showed that the CanSat was still in perfect condition. A quick replacement of the battery and it immediately started to send its pressure and temperature measurements!

EUROPEAN CANSAT COMPETITION LAUNCH DAY

Recently, the T-Minus CanSat launcher leapt into action on the launch event of the European CanSat competition. Fifteen CanSat teams participated and waited anxiously for their CanSat to take flight. After their arrival in Holland, they had one full day to unpack their CanSat and perform some last-minute checkouts and updates at the facilities of TU Delft, under the watchful eye of the T-Minus experts. Compliance of each CanSat with the competition rules was checked. For some teams, this meant that their parachute had to be adapted in order to meet the required descent speed. Other teams had to actually shorten their CanSat, in order for it to fit inside the rocket. Finally, all teams were ready for the flight and went to Artillerie Schietkamp 't Harde by bus, early in the morning. Upon arrival at the military base, the CanSats were unpacked and per six, they were installed in their respective payload bays. The ground stations were set up and the radio links were checked. Then, the payload bays were taken to the launch ramp, fitted with the motor modules and installed in the launch tower. Four launches later, every CanSat had flown and performed its mission. Some of them even had the chance to fly two times. Exhausted but happy, the students went back to Delft to analyze their results and prepare the final presentations that they had to give the next day. From these presentations, it appeared that the results of the teams varied greatly. Some missions were completely successful, while other teams had not managed to retrieve any data via their telemetry system. After an extensive discussion by the jury, in which a representative of T-Minus took part, the winners were chosen. They received a great applause and an impressive gift from ESA: a large telescope for use at their school. Surely, this event has motivated a lot of students to pursue a carrier in science and technology!

FUTURE CANSAT ACTIVITIES

Interest in the CanSat competition is growing within the European countries. After the Netherlands and Norway, similar initiatives can be found in Italy, Spain, Belgium and Great Britain. T-Minus Engineering, being a partner in organizing the European competition, is planning to take part in all of these projects, either by providing the CanSat kit, technical support or arranging the launch event.

T-MINUS DART

Although the CanSat project provides a great opportunity to operate launchers, the aim of T-Minus is always to go higher and faster. For this reason, the DART project is initiated. The concept of this system is simple. The layer of the atmosphere

between 50 and 120km is sometimes jokingly referred to as the 'ignorosphere', because no real means exist to perform in-situ measurements of this layer in a cheap and easy way. Stratospheric balloons only reach altitudes up to 50km, and satellites can perform missions only above an altitude of about 200km because of orbit degradation due to drag. Sounding rockets can be used, but a sounding rocket launch is usually too expensive for performing frequent and relatively simple measurements. The DART system will provide the means to perform a quick flight to the ignorosphere with a small payload, at a cost substantially lower than the launch of a sounding rocket.

The DART consists of a powerful, short burning booster motor and a thin payload dart (Figure 3). The booster is powered by a high-performance solid rocket propellant; similar to the one used in the space shuttle boosters. The design is optimized for high propellant mass and volume fraction, which means that as much propellant as possible is fitted into a small combustion chamber that is as light as possible. For this reason, the combustion chamber wall is made of composite material. The booster propels the rocket in approximately three seconds to several kilometers altitude, where it reaches Mach 5. After booster burnout, the rocket separates under the influence of drag and the dart coasts upwards its apogee.

The dart diameter is very small, approximately 30mm, in order to minimize the influence of atmospheric drag during this coasting flight. This might be a possible drawback of the system, since it limits the available payload volume. However, with the current trend of miniaturization of electronic systems and the use of Micro Electro-Mechanical Systems (MEMS), many missions can be carried out within this small volume. Small sensor packages, such as a GPS receiver, pressure-, temperature-, humidity (PTU) sensors or acceleration sensors are a few examples. Also, radio transceivers are sufficiently small these days to be fitted inside the dart.

A possible use of the DART system is performing frequent measurements of gas concentrations (ozone, CO_2, volatile organic compounds) in the higher atmosphere. If desired, multiple DARTs can be launched per day. This may provide valuable data for climate studies or pollution research. Another possibility is to use the DART for atmosphere probing prior to a large rocket launch. This can be a sounding rocket or, for example, a suborbital manned flight with space tourists. With the DART, wind speeds and directions at high altitudes can be mapped, so that the flight of the larger rocket can be predicted and planned more accurately. Several launch providers have already shown interest in using the DART vehicle for this type of mission.

OTHER ACTIVITIES

Although the CanSat and DART consume much of the time of the company, some other activities are undertaken as well. Firstly, T-Minus cooperated in the development of the Delfi N3Xt satellite, developing and supporting the electronics for some of the subsystems. Next to that, DLR Bremen contacted T-Minus with the request to design and produce a special payload hatch for use on the REXUS sounding rocket. This task was completed in less than two weeks and the hatch performed well during the flight.

INCUBATION AT YES!DELFT

Since the primary skills of the founders of T-Minus Engineering lie mainly in the field of science and technology, it was decided to find an institution that could provide assistance and advice on the other facets of running a company, for instance planning a strategy and product marketing. As for most technostarters in Delft, the incubation center YES!Delft is the place to go. After updating the businessplan and presenting it before a jury of experts, T-Minus was accepted in the YES!Delft program. This is a great chance for us to develop our company and make our dreams and ambitions come true.

FUTURE PLANS

In the future, T-Minus is planning to develop more and more advanced (sub-)systems for sounding rockets, establishing its name as producer of high quality aerospace products. The ultimate goal is to have a completely in-house developed sounding rocket system within ten years.

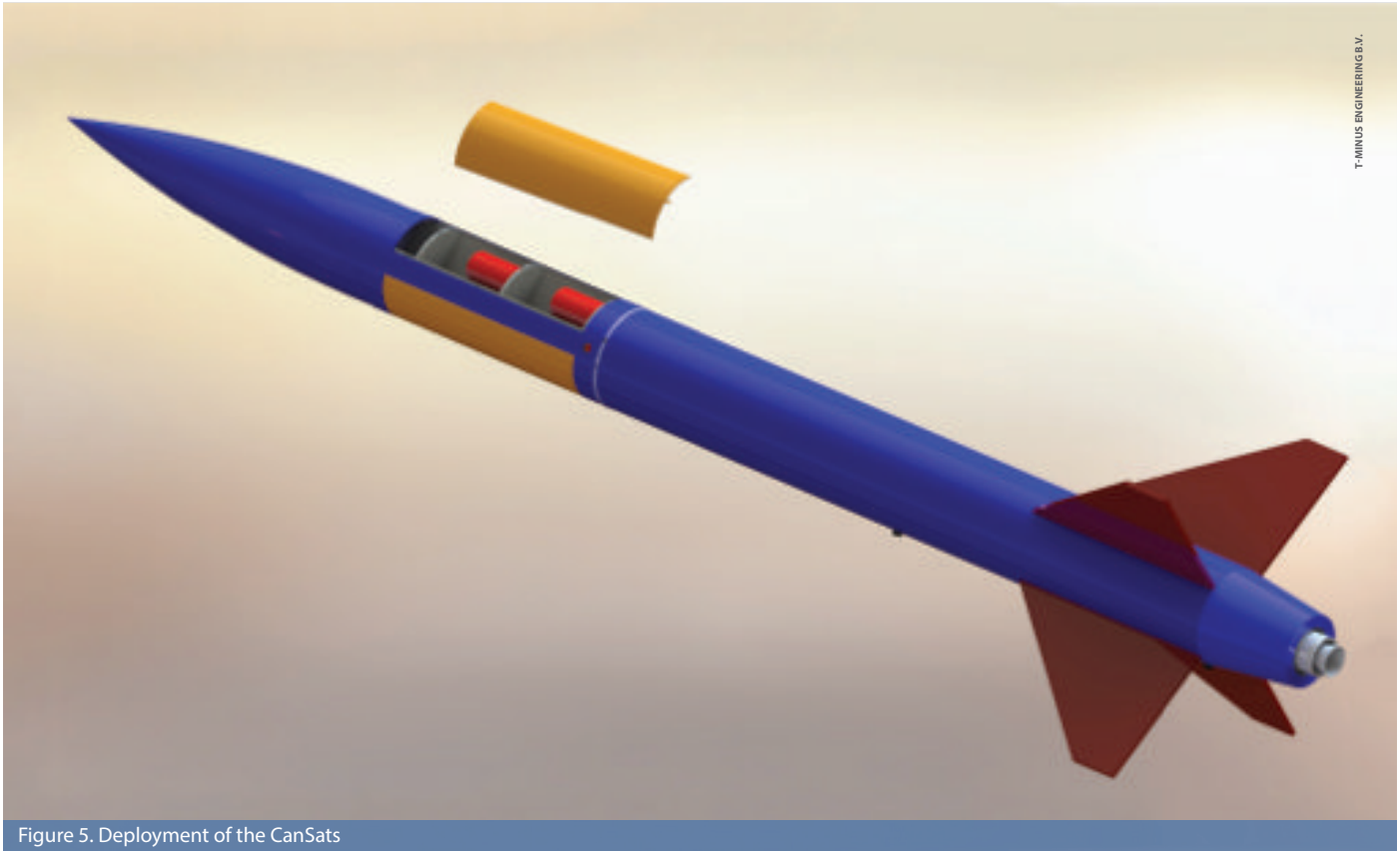


Figure 5. Deployment of the CanSats