STERN – EDUCATIONAL BENEFIT FOR THE SPACE INDUSTRY

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ABSTRACT

STERN, the German word for star, is also an acronym for **ST**udentische **E**xperimental-**R**aketeN**.** It is a program to provide students with "hands-on" experience in space systems and research. This name was chosen for two reasons. The first reason was to emphasize the idealistic goals of spaceflight providing students with the opportunity to "reach for the stars". The second and most important one was that the program offers engineering students a practical chance to experience the scope of aerospace and should motivate them to become a new star in this field. Currently eight German universities are participating in the STERN-program. STERN was initiated in April 2012, by the DLR Space Administration in Bonn and is supported by funds from the German Federal Ministry of Economics and Technology (BMWi). During the project runtime of three years the students should develop and launch their own rocket.

There are no limits regarding trajectory, altitude or the propulsion system used (solid fuel, liquid fuel, steam or hybrid). The reason for the "no limits" strategy is to create a new perspective of a problem and encourage new technological ideas. The students shall not be limited in their creativity. Nevertheless the spacecraft should have a telemetry system to transmit key trajectory and housekeeping data back to earth during flight and provide information to the students including the rocket altitude. Moreover the rocket shall reach a velocity of at least Mach 1. The project requirements are set to show the real world of work to the students. To reach the project goal, the students have to work project-oriented and in teams. In order to teach students engineering and science, as well as to put their technical knowledge to the test as early as possible in their studies, they are integrated into courses at their universities, which already deal with various aspects of rocket technology and space research.

As in any development program, the students have to pass several reviews in which they have to present and defend their rocket design in front of experts. This practically oriented study should prepare the students for life in industry. The DLR Mobile Rocket Base (MORABA) and the DLR Institute of Space Propulsion as well as the DLR Space Administration, accompany the students during the reviews and until launch. MORABA has five decades of experience in launching sounding rockets and the Space Propulsion Institute in testing of and research in rocket engines. The reviews as well as special workshops (organized by DLR MORABA and the DLR Institute of Space Propulsion), offer a platform for exchange of technical information. The STERN project provides an opportunity to train the next generation of aerospace engineers.

STERN PROGRAM IN GENERAL

In April 2012, the German Aerospace Center DLR launched the STERN program, which is supported by funds from the Federal Ministry of Economics and Technology (BMWi) and conducted by the DLR Space Administration.

Figure 1. Logo of STERN

The aim of the STERN program is to enthuse students on the space transportation subject by hands-on

activities, to motivate universities to supervise and support the student projects with the help of financial support and to increase the lecture activities in the field of launcher and propulsion systems. [1]

The program is open for all German universities which offer aerospace engineering lectures and offer students the possibility to develop, build, test and fly their own rockets in university teams. The focus is on the development of the complete rocket system within three years. The minimum requirement is to implement a telemetry payload which transmits the flight data (acceleration, velocity and position) and if possible the house keeping (pressure, temperature of tank and motor, etc.) back to the ground station.

The students will be able to develop their knowledge in the following disciplines:

- Rocket propulsion and space thrust systems
- Aerodynamics, mechanics and lightweight structures
- Performance calculation, trajectory optimization, mass and center of gravity calculations
- Application of professional tools (for example CAD, CFD, FEM)
- Wind tunnel investigations
- Manufacturing and integration of parts
- Testing of the rocket and its subsystems
- Launch of a sounding rocket

From the beginning of the project until the launch of the rocket, the students have to conduct several reviews in which they will have to present their current work to a review team consisting of DLR Space Administration, DLR experts from MORABA and the DLR Institute of Space Propulsion, but also further experts if required. This will increase the chance of achieving the mission goal of the student teams and decrease safety risks during development and launch of the rocket [1]

The requirements for participation in the STERN program are

1. *formal requirements*
   - German universities focusing on aerospace, particularly on launcher aspects. Teaching content at university must be linked to the project.
   - Conduct of reviews including the participation of one reviewer from DLR MORABA, DLR Institute of Space Propulsion and the DLR Space Administration, respectively

2. *technical requirements*
   - Minimum apogee of 3 km and velocity of sound at minimum
   - Recovery system for the rocket
   - Telemetry unit to transmit the most important trajectory data (acceleration, velocity, altitude and GPS-position) during flight to ground

Figure 2. Representatives of each STERN Team and DLR Space Administration as well as some of the reviewers

Overview of the student projects within the STERN program

Three of the teams are planning to launch in October 2015. Due to the expected high flight altitude, the launches will take place at the SSC ESRANGE Space Center in Kiruna, Sweden. An overview of the three candidates is given in the following:

DECAN:

“DECAN – Deutsche CanSat-Höhenrakete” is the designation of the two-stage sounding rocket project of the Technical University of Berlin. The project is performed under professional supervision, is based on ECSS standards and is supported by the Aerospace Institute and quality assurance experts from the German Certification Institution (TÜV). It will have a launch mass of 150 kg and shall transport a small CanSat payload to an altitude of over 10 km. The DECAN sounding rocket consists of a lower and an upper stage. The upper stage is powered by a solid rocket motor. Only this stage will be launched in October 2015 in Kiruna. The lower stage is powered by an environmental friendly hot-water rocket motor. Each stage requires an individual recovery system to allow permit a safe return to ground. A telemetry unit records and transmits important trajectory data. The project offers Master Students within the course “Project Space Systems”, the opportunity to improve their knowledge in the field of space transportation systems on a practical mission. The complete two stage rocket shall be launched during the project term of STERN II. [2]

HyEnD:

The STERN program enables the HyEnD student group (Hybrid Engine Development) at the University of

Stuttgart to expand its field of work and to broaden their experience of engine development by building a sounding rocket. Since the start of the project, several hybrid rocket engines were designed, built and ground tested. The goal of HyEnD's sounding rocket is to reach about 20 km maximum altitude with a top speed greater than Mach 2.5, whereas a hybrid rocket engine of 10.000 Newton thrust shall be realized. The rocket will be approximately 7 meters long and it has a diameter of 22 cm. The hybrid rocket engines are operated with nitrous oxide and paraffin as propellants. [3]

ERIG:

The ERIG is an association at the Technische Universität Braunschweig (Institute of Aerospace Systems ILR). As participant, the ERIG is developing a research hybrid rocket and a new hybrid rocket engine within the Leonis project. The engine consists of a solid HTPB (hydroxyl-terminated polybutadiene) grain in combination with a liquid oxidizer (nitrous oxide). It is planned to deliver about 1 kN of thrust, which should allow the rocket to reach altitudes of the order of 5 km. Furthermore, ERIG is designing a telemetry platform with the help of an inertial measurement unit (IMU) and navigation data via GPS, as well as a new flight simulation called ExRaS (ExperimentalRaumfahrt-Simulation), which allows for individual simulation runs with different configurations and the estimation of key parameters such as the maximum altitude and velocity. By including online weather data, it is possible to perform a complete flight simulation and thus to predict where the rocket will touch down. [4]

The other student teams are described shortly below:

- ZEpHYR (University Bremen / ZARM): Hybrid motor using paraffin as fuel / liquid oxygen (LOX) as oxidiser, planned launch: begining of 2016
- SMART (TU Dresden): Single stage, liquid propellant using ethanol and liquid oxygen (LOX), fed by pressurized nitrogen (N_2)
- HyComet (FH Augsburg): single stage rocket, lift-off mass 25 kg, hybrid motor (polyethylene (PE) or hydroxyl- terminated- polybutadiene (HTPB) + liquid oxidizer (nitrous oxide (N_2O), flight altitude 3-5 km, planned launch: 2016
- Aquasonic (HS Bremen): single stage, hybrid rocket motor using polyethylene (PE) as a fuel and nitrous oxide (N_2O) as oxidizer, flight apogee 4 km, planned launch: 2016
- Hyper (TU München): Single staged rocket, hybrid: cryogenic propellant using liquid oxygen (LOX) and hydroxyl-terminated polybutadiene (HTPB), flight apogee 15km

BENEFIT

The STERN program was originally initiated by DLR Space Administration to help to secure Europe's access to space through launchers. Moreover how can the involved parties benefit out of this project?

After the participation in such a program, the students should have a better knowledge about the space industry. The project requirements are set to give a hint to the real world of work to the students. For example the following reviews are mandatory to pass for the universities:

1. Preliminary Design Review (PDR) at the DLR Institute of Space Propulsion in Lampoldshausen
2. Critical Design Review (CDR) at the DLR MORABA in Oberpfaffenhofen
3. Integration Progress Review (IPR) at the university
4. Rocket Acceptance Review (RAR) at the university
5. Flight Readiness Review (FRR) at the launch range

The procedures should show the real work of a space engineer. The students should understand that the space branch has a lot to do with (necessary) paper work and quality assurance. It is more than just building a rocket.

In conclusion, the students are also trained in social skills in addition to the technical work. To build a rocket in such a short time besides their university life, the students have to work project-oriented and in teams. Additionally they gain experience in project management as well as learn interdisciplinary thinking.

Benefit for rocket launch ranges

The in several teams used hybrid rockets bring new technology and launch processes to rocket launch ranges like SSC ESRANGE Space Center. ESRANGE was not mainly working with hybrid rockets until the STERN program. Radio controlled fueling and pressurization of the launch vehicles are very different from handling with solid propellant, which are used commonly in sounding rockets. Special care must also be taken when handling liquid oxygen (LOX). Due to this, launch preparation associated processes have to be adapted. This new experience enables ESRANGE to gain knowledge for commercial payload experiments in the near future.

Within the STERN program, it was decided to launch these rockets at ESRANGE near Kiruna, Sweden. Since each university is in a different development phase of their rocket and different durations for each project have to be assumed, it is planned to launch the STERN rockets after the completion of other launch campaigns, which are conducted by MORABA. It will be attempted to bundle several STERN rocket launches in one single campaign to reduce organizational effort and costs. A final go / no go decision of launching the rocket is in the responsibility of the test range.

Benefit for European space industry

The main benefit to the European commercial space industry is to provide well-educated, skilled employees, because the students gain experience in building rockets and rocket engines. This is necessary since Germany has to compete in an international market as a strong partner in launcher programs like Ariane and to ensure its competences in key technologies.

Beside the main point, the commercial space industry can use the student rockets for the transportation of their own payloads or test equipment if required. The rockets provide a cheap way to fly payloads and lead to new investigation and space improvements.

For example in Cooperation with Airbus Safran Launchers GmbH, thermoelectric generators are part of the payload of two projects. The first is the AQUASONIC project of the Hochschule Bremen and the second is the ZARM Experimental Hybrid Rocket (ZEpHyR) project from the centre for Applied Space Technology and Microgravitation (ZARM) of the University of Bremen. Airbus Safran Launchers GmbH is investigating the deployment of thermoelectric generators (TEGs) in high temperature area. The purpose is that the heat loss from the hybrid rocket engine is used to generate electrical power with the thermoelectric generator. The hardware concept for the payload plans with the TEG near the Propulsion System. The TEG shall provide a wireless transmitter with energy. The transmitter sends the measured electrical current to a receiver which is connected to the on-board computer which sends it afterwards to the Ground Station.

Benefit for research organizations, universities and associations

The non-profit research organizations and associations, which are involved in the STERN program, can obtain different kinds of benefits from the participation in this program.

The DLR Mobile Rocket Base and the DLR Institute of Space Propulsion will take a reviewer and support role in the STERN program. The student support program will give a good possibility to recruit its own young engineers to the two DLR institutes in an early phase of education. The participating universities have also the possibility to identify candidates for PhD student projects.

Likewise, the reviews as well as special workshops offer a platform for the exchange of technical information. In the project there are two kinds of workshops. The first one called STERNStunden, which is organized every two years, is conducted in Oberpfaffenhofen. The workshop will focus on the system rocket and all subsystems except the engine. The DLR Institute of Space Propulsion organizes every year the second kind of workshop, which is dedicated to propulsion relevant topics. Beside lectures, the major part consists of exercises, where the students have the opportunity to strengthen their practical capabilities.

The students associations, like ERIG on behalf of TU Braunschweig (Brunswick) and HyEnD from the University of Stuttgart, get the chance to do scientific studies about rocket engines, design, structures and electronics. It could be noticed that the members of the space students associations increased due to such a project. Solving practical problems and seeing how it works in practice is a great experience contrary to the theoretical work at universities. STERN allows a lot of creativity during the complete design and testing of rocket parts and the rocket itself.

Benefit for DLR Space Administration on behalf of the German ministry of economics and technology

The Space Administration of the German Aerospace Center DLR located in Bonn is responsible for the planning and execution of the German Space Program on behalf of the German ministry of economics and technology (BMWi). In the following, the reason to initiate such a program is presented.

It is strategically as well as economically important for Europe to secure its access to space through launch vehicles of its own. One successful case in this point is the Ariane program, for which Germany supplies important components and sub-systems such as thrust chambers for liquid-fuel engines, tank structures, and the upper stage of Ariane 5. Further contributions come from DLR's test center for rocket engines at Lampoldshausen and the large number of research and technology development facilities that have made Germany an indispensable partner in the Ariane program. To make sure that Germany will continue playing a crucial part in the development of new launcher systems like Ariane 6, and to prevent any loss of development competence, students and young professionals have to be trained and educated.

Until March 2015, 297 students (not included volunteers) participated in the STERN program. The number of contributors (diploma, master, bachelor etc.) is 157. The project status of the different teams was presented at several conferences and congresses. Some of the projects were also mentioned in numerous press articles and short television and radio broadcasts also. All this will give (especially in Germany), public attention to Europe’s Launcher Program, its importance to the guaranteed access to space and Germany´s strong contribution to launcher programs like Ariane.

CONCLUSION AND OUTLOOK

The exciting thing about this project is that it requires knowledge of a large variety of engineering topics which have to be learned over the course of studies in aerospace engineering such as thermodynamics, fluid and aerodynamics, mechanical, structural and electrical engineering. This whole range of different topics makes the STERN program very interesting and demands and enhances various skills of the participating students. However, the profit from such a project is not limited to the students. Also the space industry will derive benefits. It has to be agreed how to collaborate with and support the STERN student teams to be beneficial for all, e.g. by inclusion of experiments, etc. during flights.

The launch of the first three rockets is scheduled for October 2015. After formally closing the project, the universities have the opportunity to apply for a follow up during STERN II. The STERN II program could be started in 2016! The STERN program differs significantly from other student programs and in summary it is a great opportunity for students to enhance their skills.

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