STERN - A ROCKET PROGRAMME FOR GERMAN STUDENTS

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ABSTRACT

In April 2012 the German Aerospace Center DLR, launched a support programme for students to develop, build and launch their own rockets. The programme goes by the acronym STERN (STudentische Experimental-RaketeN) which is also the German word for star. Supported by funds from the Federal Ministry of Economics and Technology (BMWi) and conducted by the DLR Space Administration of the German Aerospace Center DLR, the STERN programme provides aerospace engineering faculties at universities with opportunities to introduce students realistically to subjects related to space transport. During the project duration of three years the soon-to-be engineers will develop their own rockets. There are no limits regarding peak altitude or the propulsion system used (solid fuel, liquid fuel, steam or hybrid). The rockets should have a small telemetry system to transmit key trajectory and housekeeping data back to Earth during flight and provide information to the students including the rocket altitude. In order to teach students engineering and science and to put their technical knowledge to the test as early as possible in their studies, there are no altitude restrictions except the normal range restrictions.

The students will be integrated into courses which already deal with various aspects of rocket technology. In addition to the design of the engine, project activities will focus primarily on the rocket system as a whole, which, because of its complexity, demands interdisciplinary thinking and teamwork. As in a large aerospace technology project, or the development of a new launch system, future graduates will have to meet milestones that specify both timing and technical progress. It is also necessary that they have to attend various reviews to present and explain their design to an expert audience which carefully reviews their proposals and work. The students will be invited to test the engines they have built at the DLR test centre in Lampoldshausen, Germany. At the end of the project, the result should be a flight capable rocket. Some of the rockets will be launched from the Esrange Space Center at Kiruna, in Sweden, where the European altitude record of 12.6 kilometres for an amateur rocket was set. To break this record and fly even higher could be a long-term objective of the DLR programme during its planned three-year duration – offering universities a long-term prospect for training a new generation of researchers, particularly in the area of astronautics.

DLR MORABA (Mobile Rocket Base), the DLR Space Propulsion Institute, and the DLR Space Administration are a major part of the Review-Board until flight. With a large number of sounding rocket launches, DLR's MORABA has acquired total system competence when it comes to assessing the structural integrity, flight behaviour, or flight performance of a rocket and makes access to Esrange possible. The DLR Space Propulsion Institute at Lampoldshausen has decades of experience in research and testing of rocket engines, especially those belonging to the European Ariane programme that was launched in the 1970s. The centre conducts both applied and fundamental research in the field of rocket propulsion systems.

This paper will give an overview on the activities of DLR in supporting the student teams to succeed in their aim of a successful flight of their own rocket. It will give an outlook on the ideas of the already selected teams and will also explain the differences to other student projects such as REXUS/BEXUS.

1. INTRODUCTION

The last decades have shown the economical and strategic importance for Germany as well as for Europe to have the capability of launching satellites and to have the own access to space. Since the Ariane programme was established in 1979 Europe has a launcher system that is independent from other nations. It guarantees the unrestricted access to space with its launcher in the fifth generation. Also Ariane has become a brand that dominates the commercial market. To ensure Europe's autonomous and cost-effective access to space for the future an ongoing development of the Ariane 5 and its successor is necessary. The main requirements for this development are well-educated skilled employees. Responses from the economy, the universities and analysis of the DLR Space Administration have shown a considerable decrease of young scientific and technical professionals in the field of space transportation. This leads in the long-run to a lack of competence of Europe in developing new launcher systems and is a danger for the important role that Germany has in the Ariane programme.

To stop this process the DLR Space Administration has initiated the programme STERN in April 2012. The aim is to establish the subject space transportation in German universities to enthuse future generations of engineers in this research field.

The programme will run for minimum three years and will be extended, depending on the university and the scope of the project. The students will be integrated into courses which already deal with various aspects of rocket technology. In addition to the design of the engine, project activities will focus primarily on the rocket system as a whole, which, because of its complexity, demands interdisciplinary thinking and teamwork. As in a large aerospace technology project, future graduates will have to meet milestones that specify both timing and technical progress. They will also be required to attend various reviews to present and explain their design to an expert audience.

2. PROGRAMMATIC AIMS

The Space Administration of the German Aerospace Center DLR in Bonn is responsible for the planning and execution of the German Space Programme for the German ministry of economics and technology (BMWi). One element of this programme is the support of the young scientific researchers and engineers. This is necessary since Germany has to compete in an international market and to ensure its competences in key technologies.

Therefore it is the aim of the STERN programme to enthuse students on the subject space transportation by hand-on activities, to motivate universities with the help of funding and to increase the lecture activities in the field of launcher systems.

The DLR Mobile Rocket Base and the DLR Institute of Space Propulsion will take a reviewer and support role in the STERN programme. The student support programme will give the two DLR institutes in an early phase of education a good possibility to recruit its own young engineers. Gaps in recruiting of young professionals have been identified.

In the long-term view DLR has the hope that as a result of this programme the research at the universities end up in a small sounding rocket that can be used for meteorological experiments. This could be a rocket like the Viper-Dart that did eject a small balloon in 90 km altitude to measure atmosphere data like pressure, density, temperature and wind velocities. Even the need for this type of rocket has been identified the rocket is not produced anymore nowadays after an accident during production. The specification of this rocket is reachable for the student programme STERN.

Figure 1. STERN Logo

3. SCIENTIFIC & TECHNICAL AIMS

The programme STERN is open for all German universities that offer aerospace engineering lectures and that offer students the possibility to develop, build, test and fly own rockets in university teams.

The focus is on the development of the complete rocket system. The primary aim is to implement a telemetry payload that transmits the flight data (acceleration, velocity and position) and if possible the house keeping (pressure, temperature of tank and motor, etc.) back to Earth.

There is no limit on the flight altitude or the chosen propulsion concept. Commercially available solid propulsion motors can be used as well as own developments in liquid-, hybrid- or hot water propulsion. The student's tasks will include pressure vessels such as tanks and motor casings, the nozzle geometry and strength calculations for the rocket components.

DLR expects at beginning of the programme flight altitudes between 3 and 15 km. The actual altitude record for an amateur rocket is 12.55 km. In a later phase of the programme flight altitudes of up to 100 km are possible. Because of the expected flight altitudes and the constraints of the air space not every launch of the STERN rockets will be possible in Germany. Up to 5 km altitude it is planed to use test fields of the German Armed Forces. Some universities do cooperate already now with the German Armed Forces to use these test fields. It is planned to launch rockets that fly higher than the 5 km at Esrange near Kiruna, Sweden where the REXUS, TEXUS, MAXUS and MAPHEUS campaigns take place. The DLR Mobile Rocket Base and SSC Esrange do have a long history of cooperation.

The aim of STERN is support the competence in developing future launcher systems in Germany. This is done by a financial funding but also by the attractive possibility of a rocket launch at Esrange for the involved professors and students.

Beside the lectures the students have to do several activities until the launch of the rocket. The students have to design the rocket motor and flight hardware, perform motor tests including health monitoring which can for example be done at the DLR Institute of Space Propulsion at Lampoldshausen, do wind channel tests and compare these results with modern numerical calculation methods and analyse the performance of the complete rocket system.

The work is part of seminar papers and studies. Because of the scope of work the projects can only be conducted in team work. For this reason the team members are coordinated by a supervisor pays attention on time schedules, milestones and reviews. In this way, students gain skills in project management and the all-important social skill that are necessary in the professional life.

4. ROCKET DESIGN

The student teams follow a wide range of concepts:

- DECAN (TU Berlin): Two-staged rocket with a lift-off mass of 150 kg. 1st stage hot water propellant, 2nd stage solid propellant.
- ZEpHYR (University Bremen/ZARM): Hybrid motor using paraffin / LOX
- ERIG (TU Braunschweig): Hybrid motor using HTPB / N2O
- SMART (TU Dresden): Single stage, liquid propellant (Ethanol / LOX)
- HyEnd (University Stuttgart): Single stage rocket with a lift-off mass of 120 kg, hybrid motor using paraffin / N2O
- HyComet (FH Augsburg): single stage rocket, lift-off mass 25 kg, hybrid motor, flight altitude 3-5 km
- Aquasonic (HS Bremen): Two staged rocket, lift-off mass 60 kg, 1st stage hot water, 2nd stage hybrid motor, flight apogee 10 km
- Hyper (TU München): Single staged rocket, hybrid motor (HTPB / LOX), flight apogee 15 km

5. TECHNICAL SUPPORT BY DLR

DLR's Mobile Rocket Base (MORABA) has decades of experience in preparation and performing sounding rocket campaigns. The TEXUS, MAXUS, MASER and MAPHEUS are scientific missions which are performed with participation of DLR. The focus of the REXUS campaigns is on education. The REXUS programme offers flight opportunities to European student experiments on rockets with reduced gravitation (milligravity). These launches are conducted by Eurolaunch, a joint venture of SSC Esrange and DLR MORABA, at the Esrange Space Center in Kiruna, Sweden.

The DLR Space Propulsion Institute at Lampoldshausen has decades of experience in research and testing of rocket engines, especially those belonging to the European Ariane programme.

From the beginning of the Project till the launch of the rocket, the students have to conduct several reviews in which they will have to present their actual design of the rocket. This will increase the chance of succeeding the mission goal of the student team and decrease safety risks the launch of the rocket. With decades of experience DLR experts from MORABA and the DLR Institute of Space Propulsion have the necessary expertise required for such reviews.

The DLR Institute of Space Propulsion has built a test field at which student rocket engines can be tested. Additionally the DLR MORABA will use their campaign proven software to calculate the static and dynamic stability of the student rockets, the flight trajectory and the impact area.

The following subchapters will give an overview of work packages that will be handled by DLR. These services are primarily queried through subcontracts by individual universities to DLR

5.1. ESRANGE

The DLR MORABA is the interface to SSC that is responsible for all launches performed at Esrange at Kiruna and that runs the ground facilities. Since each university is in a different developing phase of the rocket and different durations for each project has to be assumed it is planned to launch the STERN rockets after the completion of another launch campaign. It will be also tried to bundle several STERN rocket launches in one single campaign to reduce organizational effort and costs. The support of the universities includes:

- Assistance in booking the campaigns at Esrange
- Assistance in booking flight tickets and hotel booking for the student teams
- Assistance in organization of the transport of rocket hardware to Esrange
- Assistance in writing the Flight Requirements document
- Flight Trajectory and Impact zone calculation
- Use of Esrange infrastructure

5.2. REVIEWS

The universities will have to present the rocket design to DLR Space Administration and other reviewers during the development phase and before the launch of the rocket. The DLR Institute of Space Propulsion and the DLR Mobile Rocket Base will join every obligatory review with at least two staff members. One aim of the review process is to make the student teams familiar with reviews as they are common in space related projects. The reviews will also increase the success chance of the universities in reaching the mission aim and uncover potential safety risks. It is obligatory for the university to call a review board of minimum four persons that not directly involved in the university project.

Figure 2. Review Panel at the DLR Oberpfaffenhofen

Following reviews that cover the complete system rocket are mandatory for the universities:

- Preliminary Design Review (PDR) at the DLR in Oberpfaffenhofen
- Critical Design Review (CDR) at the DLR in Lampoldshausen
- Integration Progress Review (IPR) at the university
- Rocket Acceptance Review (RAR) at the University
- Flight Readiness Review (FRR) at the launch range

It is up to the university to call more reviews that focus on the sub-systems (rocket motor, launcher, etc.). The DLR will join these reviews only if the rocket systems complexity (e.g. liquid propulsion systems) makes it necessary.

5.3. SPACE PROPULSION WORKSHOP

The DLR Institute of Space Propulsion organizes every year within the STERN program a workshop 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 first workshop conducted in April 2013 supported the students in their preparation and conduction of rocket engine tests. Themes of exercises were e.g. conduction of experiments, use of measuring techniques and sensors, use of numerical tools for FEM structure analysis and conduction of work with a small test facility. In order to conduct experiments safely the students have also been trained in the conduction of risk analyses, which they also have to conduct prior to running tests.

5.4. WORKSHOP "STERNSTUNDEN"

The workshop STERNStunden will be organized every two years, conducted in Oberpfaffenhofen. The workshop will focus on the system rocket and all subsystems except the motor.

6. RESEARCH AND STUDENT TEST FIELD M11.5

At DLR site Lampoldshausen the M11.5 test field was erected and came into service in June 2013, at which beside rocket relevant research activities also the STERN student groups can come with their developed rocket combustors and engines to test them. These tests are conducted under the auspices of experienced researcher and engineers from the institute. This process of teaching, supervision and exercises shall help the students to get a deeper understanding how a development and test process runs and how to react on occurring difficulties.

The test field is equipped with an oxidizer tank for actually nitrous oxide and a separate control room from which the experiments are conducted. In order to have an effective stay at Lampoldshausen test site the students are encouraged to prepare their experiments in containers yet at their universities. After checks of flow and measurement systems these containers will be brought to Lampoldshausen. This procedure reduces start-up times so that more time is available for learning and common testing.

Two containers or experimental setups can be positioned on the concrete plate of M11.5. Hybrid engines with thrust levels up to 10 kN can be tested. Hybrid engines are favoured because of their inherent security advantages. Because of the security point of view cryogenic or poisonous propellants cannot be used.

Figure 3. Research and Student Test Field M11.5

7. SUMMARY & OUTLOOK

The STERN programme differs significant from other student programmes. Each project has a long duration at the university. A permanent supervisor at the university is very important. The programme is a great opportunity for universities and aerospace students to gain experience in building rockets and rocket engines.

8. REFERENCES

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