STERN

A Rocket Programme for German Students

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Abstract
The STERN programme was initiated by DLR Space Administration to promote young professionals for launcher-systems. In order to reach this objective student groups have the task to design, build and fly a rocket which reaches subsonic speed and an altitude of at least 3 km. This paper gives a deeper background of STERN how it is funded and which universities are addressed. It describes the modalities allowing for participation in the STERN programme and the tasks to be performed by the students. Furthermore the necessity of DLR institutes involvement and the distinctions to the DLR Space Administration is explained. In the end of the paper all STERN participants are listed with a brief description of each project. More project details are given by the issued papers of each STERN university at EUCASS. Therefore consider this paper only as programme description.

1. Promoting students for launcher-systems

Europe's independent access to space is both strategically as well as economically very important for Europe. Therefore it is an essential component of the German space policy. One successful case in point is the Ariane programme, for which Germany supplies important components and/or sub-systems such as thrust chambers for liquid-fuel engines, tankage structures, and the upper stage of Ariane 5. Further contributions come from DLR's test beds for rocket engines at Lampoldshausen and the many research facilities that have made Germany an indispensable partner in the Ariane programme.

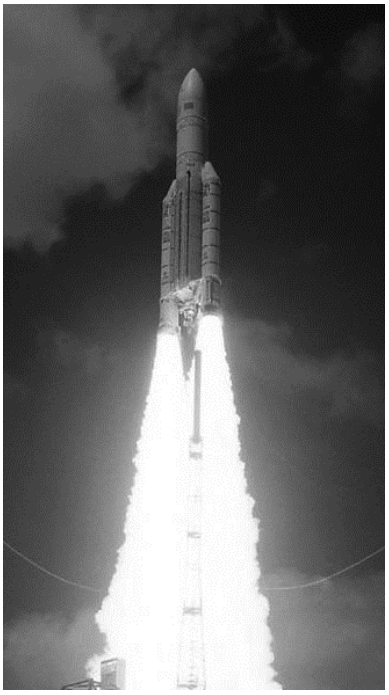

Figure 1: Ariane 5 launcher

To ensure that Germany will go on playing a crucial part in the development, production and exploitation of Ariane 5 and new launcher systems in the long run highly educated professionals are needed. At this point DLR Space Administration comes into play. In order to prevent any loss of key development competences and skills due to a lack of young talents in the field of launchers the national programme STERN was initiated.

Figure 2: STERN-Programme

The acronym STERN (German word for STAR) stands for “Experimental Rocket Programme for German Students”. In context of STERN every German aerospace university focussing on launcher aspects has the possibility to request funding from DLR Space Administration for a period of three years. With STERN additional incentives shall be created to inspire students for launcher subjects. Besides technical competence, practical work on the project, teamwork and interdisciplinary thinking are the main drivers to successfully master the development of a launcher. But above mentioned skills get more and more lost due to increasing specialisation on technical subjects. Therefore the main objective of STERN is to build up system awareness as well as to foster teamwork of the participating students.

1.2 Designing, building and launching a student rocket

In order to attain this objective the universities have the task to design, build and fly a rocket. This shall be aligned with the teaching content. For the propulsion system in-house developments (like liquid fuel, hybrid or hot water) as well as purchasable solid rocket motors for mid and high power model rocketry (class O until 40.000 Ns) may be used. Regarding the peak altitude there are no limits but as a minimum, rockets shall reach an altitude of three kilometres and the speed of sound. Further mandatory requirements include a telemetry unit to transmit the most important trajectory data, such as acceleration, velocity, and altitude back to Earth, and a parachute or similar equipment to ensure that the rocket can be recovered safely.

At present, rockets are expected to reach altitudes between 5 to 20 kilometres, and will normally be launched from the Esrange site near Kiruna in the north of Sweden. From this side DLR-MORABA (Mobile Rocket Base) is already launching, amongst others, rockets and balloon experiments (REXUS / BEXUS) in the framework of other educational programmes. The prospect of a launch campaign at Kiruna will be an additional incentive for the students and enhance the attractiveness of the STERN programme.

Because rocket projects are very complex, students will have to work in groups and share among themselves all special tasks such as trajectory calculation, flight stability, structure, propulsion system, tests, telemetry, ground segment, et cetera. There are many possibilities for the universities to integrate these topics in the regular lectures. Thus, for example, flight stability may be determined with the aid of modern computational fluid dynamics (CFD) and subsequently verified in windtunnel tests. Similar options are available when designing pressure vessels (tanks, engine casings) and nozzles or calculating the strength of individual rocket elements (finite element method). Further items to be taken into consideration include fuelling, pressurising, engine ignition, stage separation, initiation of the recovery system, the reception of telemetry data and considerations on redundancy (installing two systems in case one fails). Where pressurized parts are concerned (e.g. tanks, combustion chambers) it is planned to have student work assisted and monitored by the TÜV (German Technical Surveillance Association). Lastly, students will have to develop procedure specifications in the form of checklists so that all steps in preparing engine tests or the launch of a rocket are followed in their exact sequence. This is absolutely mandatory to avoid errors that might threaten their safety or the success of the mission.

1.3 Reviews as in real development programmes

As in any 'real' development programme, students have to pass several reviews (PDR, CDR, IPR, RAR, FAR) at various stages of the project. The review board consists of non-partisan experts from the university and one representative each of DLR MORABA, the DLR Space Propulsion Institute, and the DLR Space Administration. Additional experts from the industry may be consulted.

Students have to present and defend their rocket design before the review board, whose recommendations will serve to enhance the safety of the mission as well as the probability of its success. A last review (FRR) covering the current configuration of the rocket, the launch infrastructure needed, all tests previously completed, and the flight performance expected will take place at the launch site itself. The go-ahead for launch will only be given after this final review has been successfully completed.

2 DLR involved in STERN

2.1 DLR Space Administration in Bonn

In contrary to the DLR-institutes with its extensive research and development work in Aeronautics, Space, Energy, Transport, and Security as well as the project-management agency the DLR Space Administration has another task.

The latter has been given responsibility for the forward planning and the implementation of the German space programme by the German federal government as well as for the international representation of German interests. In this context it works on behalf of the Federal Ministry of Economics and Technology (BMWi) and is focussing on ESA activities. Germany’s financial contribution to ESA like earth observation, navigation, space station, launcher et cetera is reflected in the different departments in Bonn, which perform in consultation with the BMWi the programme implementation. Following the principle of “Geo return” money which was given by the ESA member states for each programme has been given back to domestic industry in the same ratio. Along with the programmatic implementation controlling of the “Geo return” is another important task of the Agency.

Also funded by the BMWi is the National Space Programme which allows supporting identified areas of research and development activities. The assessment of such a necessity and the allocation of funds (for industry, et cetera) is another important task of the Space Administration and has to be in accordance with the funding guidelines which also respecting EU-policy.

Figure 3: DLR-Bonn

2.2 The DLR-institutes in Lampoldshausen and Oberpfaffenhofen

Due to the complexity of the project proficient support is necessary. This is why DLR Lampoldshausen and DLR-MORABA actively support the participating universities.

The DLR test centre Lampoldshausen has decades of experience in testing rocket engines, especially those belonging to the European Ariane programme that was launched in the 1970s. In addition, the centre conducts both applied and fundamental research in the field of rocket propulsion systems. Based on this experience the universities have a strong partner for assessing their propulsion system. If requested the universities can take the option for testing their rocket engines on a dedicated test field under supervision of experts.

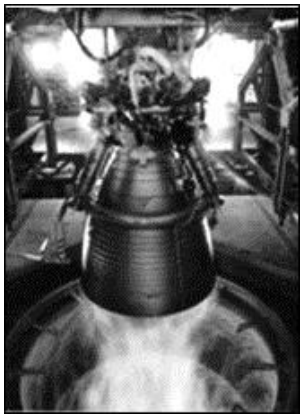

Figure 4: Vulcain 2-test for Ariane 5 in Lampoldshausen

Having launched a large number of high-altitude research rockets, DLR's MORABA has acquired competences to assessing the structural integrity, flight behaviour or flight performance of a rocket like static and dynamic stability for sub- and supersonic conditions, the trajectory, the flight corridor and the landing area. Functional aspects like stage separation, recovery system, data transmission, et cetera could also be under consideration. Furthermore the long year collaboration with the Esrange staff offers universities the option to launch their rockets in Kiruna.

Figure 5: Launch of a sounding rocket at ESRANGE Kiruna by MORABA

3. Additional activities in the STERN-programme for students

Within the framework of STERN different activities are provided by DLR-MORABA and DLR-Lampoldshausen for the students. MORABA hosting a three-day event “STERN-Stunden” (German word for STAR-hours) with subjects like flight dynamics, telemetry, technical surveillance et cetera.

Also a three day event is the “Workshop space-propulsion” where students are given a chance to do some hands-on, system-relevant work on engines and at test stands. The students works in groups of two and have to treat topics like FEM-analysis, test execution, introduction in measurement, application of sensors and risk analysis on a hybrid engine.

The first workshop was held in April, “STERN-Stunden” will follow later this year. “STERN-Stunden” are offered every two years whereas the workshop takes place every year.

4. Short overview of the participants

Since beginning of STERN eight German universities are participating. These are TU-Berlin (04/12), ZARM-University Bremen (04/12), TU-Brunswick (07/12), TU-Dresden (08/12), U-Stuttgart (09/12), HS-Augsburg (11/12), HS-Bremen (01/13), TU-Munich (03/13) (Number in brackets indicate the starting time of the project) and the RWTH-Aachen with a different project but not directly linked to STERN. The duration of each STERN-project is planned for three years.

Hereinafter a brief technical overview for each University is given. Keep in mind that changes during the project duration are possible. A more detailed description is available from the individual STERN-papers of each university at the EUCASS-conference.

TU-Berlin:
Two-stage Rocket with hot-water for the first and a purchasable solid rocket motor for the second stage. The lift-off mass will be approximately 150 kg with a maximum altitude of 8 km. A 0.35 kg CanSat payload is foreseen. Long-year experience for a hot-water propulsion system is available through the AQUARIUS-student group.

ZARM-University Bremen:
Inspired by the ARCAS-sounding rocket the ZARM-institute has set itself the objective to reach an altitude of 20 km with a hybrid engine consisting of paraffin and LOX as fuel. It is planned to have a lift-off mass of 43 kg and a 1 kg payload. Experience in hybrid engines was build up during research activities for fire safety in space because of comparable burning characteristics. Firering tests were performed with GOX/PMMA as well as GOX/paraffin.

HS-Bremen:
Two-stage Rocket with hot-water for the first and a hybrid rocket or hydrogen peroxide/gasoline motor for the second stage. The decision for the second stage will be part of a trade-off performed later. An altitude of 10 km is envisaged with a small payload weighting 2 – 5 kg. The hydrogen peroxide/gasoline motor based on “Systeme Solaire” a rocket assembly kit which can be bought in the US/Canada. In the past students groups of HS Bremen have flown this kit with modifications.

TU-Brunswick:
Single stage rocket weighting 30 -50 kg with hybrid engine (HTPB/N2O) expected to reach an altitude of 11 km.
Long year experience was gathered with the student group ERIG e. V. (registered association) which is integrated in the university activities. Many tests were successfully performed by ERIG with PMMA/GOX as well as PE/GOX.

U-Stuttgart:
Single stage rocket weighting 120 kg with hybrid engine (paraffin/N2O) expected to reach an altitude of 20 km and a payload of 1 - 2 kg. Many tests with hybrid engines were also successfully performed in the past.

HS-Augsburg:
Single stage rocket weighting 25 kg with hybrid engine (HTPB/N2O is foreseen) and an envisaged altitude of 3 – 5 km. During the project the students will focus on light materials like carbon for the tanks as well as thrust chamber and ceramic for the nozzle.

TU-Munich:
Single stage rocket with hybrid engine (HTPB/LOX is foreseen) expected to reach an altitude of 15 km. The TU-Munich is very strong represented in all space related activities by the WARR student group which has a long tradition since 1962. The first German hybrid rocket Barbarella was successfully launched in 1974 by WARR members. Since 2005 the activities for hybrid rockets were forced again. Engine tests were performed with HTPB/GOX and PE/N2O.

TU-Dresden:
This very challenging project is a replica of the “MIRAK” flown in the 1930. The rocket has a lift of mass of 20 kg and a liquid propulsion system burning ethanol and LOX which shall be able to develop a thrust of 500 N. The development of a small test stand for the rocket engines is nearly completed. An altitude of 3 km is envisaged.

Except the rocket of TU-Dresden all other universities will launch in Kiruna/Sweden. For the two stage rockets in case of TU-Berlin and HS-Bremen each stage will fly on its own on a qualification flight in Germany.