project enterprise

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T.I.M. report das Magazin

TALIS Institut

Development of an economically and enviromentally friendly launch vehicle for small civilian scientific and commercial satellites

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"As a child I often dreamt of travelling into space. As an adult I realised that this dream would only come true if private businesses and people with a vision committed themselves to making it a reality.“

Anousheh Ansari, X-Prize-Sponsor

Introduction

Project Enterprise, which was initiated by the TALIS Institute for Technology and Science, will develop and operate a civilian Microsat Launch Systems (MLS); a launch vehicle for scientific and private commercial payloads with a mass of between 100 - 200 kg, also known as micro satellites.

Micro satellites are usually designed, manufactured and used by colleges, universities or private companies. They are mainly used for scientific research in microgravity, observations of the earth, astronomical observations or as a means of communication.

With the ever-growing miniaturisation of technology, micro satellites are gaining in importance. Today, there are already more than 180 such micro satellites flying in low earth orbit (LEO) that carry out diverse tasks and provide an essential contribution to scientific research.

Example: experiments in material physics in microgravity for the further development of solar cell technology

One aim of micro gravity research is to gain new knowledge of material processes that can be used to develop environmentally friendly solar technologies. The solar panels used today can only convert a tiny amount of the light into electric energy so, if we want to use the sunlight we have at our latitude to make a significant contribution to our energy needs, we will need some considerable technological breakthroughs.


One of the essential requirements is to understand exactly how the atoms in solar cells are arranged. Experiments on earth aimed at studying the deposition of atoms have always been a problem for the industry because it was never possible to determine how the atoms reacted on their own and what part gravity played in their behaviour.

Experiments in microgravity using plasma deposition to grow crystals opened up entriely new perspectives as these interesting three dimensional structures do not form under normal gravity.

Since the discovery of the structures in so-called plasma crystals in 1994, the extent of research in this area has risen considerably throughout the world.
German scientists are world leaders in this field of research and are the only ones as yet to have gained experience in performing these types of experiments using zero gravity.

Numerous long-term experiments using automated laboratories in micro satellites could increase the knowledge already gained from past and future tests on the International Space Station (ISS). This would be an important contribution to the further development of environmentally friendly solar technology.

Unfortunately to date there is no suitable launch system for micro satellites that can meet the cost and availability requirements of the scientific and commercial satellite operator on an individual basis.

For this reason today micro satellites are generally transported into orbit via the “piggyback” method in conjunction with larger satellites.

Many micro satellites require a certain orbit which makes it difficult to transport them together with larger satellites. When a possibility to combine the two satellites finally arises, which can take years, it is usually made difficult due to the extremely expensive quality standards and safety measures required for the micro satellite. After all the “passenger” cannot endanger the main project. Further more it is quite common that the launch date is postponed for weeks, months or even years, due to reasons involving the larger satellites.

Due to these launcher related constraints, it is sometimes impossible to keep a micro satellite programm alive.
Robert Sackheim, acting director of Marshall Space Flight Center, goes so far as to say, ironically of course, that one should be happy to live long enough to see the piggy back load finally launch. As a rule the same specific launch costs apply for the micro satellite as for the larger satellite. These days normal prices are 7000 – 10000€/kg for the Russian systems and up to 10000 – 15000€/kg for the Ariane or American larger rockets. These prices do not apply for the Space Shuttle, which has a specific cost of over 20000€/kg. The Space Shuttle is usually not available anyway. Other available launch systems that have been specially tailored to the requirements of micro satellites are usually so much more expensive than the systems already mentioned that they are unaffordable for university or commercially funded projects and so only the military uses them. These will be explained in full shortly.

For example; the launch of the light micro satellite “BIRD” from the German Center for Air and Space Travel (DLR) which was developed as a warning system for forest fires cost, using the piggy back method, one million euros. That is approximately 10000€/kg

An investigation into the space market by NASA 2003 named ASCENT determined that the market for smaller cargoes was affected far more by the launch costs than the market for the large satellites. This research found out that most of the satellites funded by universities were micro satellites and that if the launch costs were reduced by 75% the number of launches for these systems would rise by 200%.

Many scientific plans in universities fall through nowadays due to the high launch costs of the protracted launch dates. This was what happended to CATSAT, a satellite from the university of New Hampshire, as well as SUNSHINE II, which was built by students. A lot of commercial micro satellites have also been either postponed or scrapped entirely because the cost of the available launch systems was too high.

The search for suitable transport systems for micro satellites

The small satellite community has been making an effort for decades now to find a reasonably priced and reliable launch system for micro satellites, the so-called Microsat Launch Systems (MLS). In the 90’s there were many failures in the quest to find a perfect transport system for micro satellites. Due to the high demand for MLS, state funded agencies in the USA and private companies worldwide are trying to develop a reliable and reasonably priced MLS, taking into consideration of course the mistakes which were made in the 90’s.

The American rocket Scout was for example a relatively low priced and reliable MLS that was designed by NASA four decades ago. However, the technology and knowledge has come a long way since then.

Although they would not meet the requirements of an MLS today, all of the first rockets developed by the USA were launch systems for micro satellites. Vanguard and Jupiter could only carry up to 30kg of payload into the LEO and had a failure rate of approximately 50%.

The rockets that were developed using the rules and criterion for aeronautics were very expensive because they had to be as light as possible and carry as much weight as possible.

(SCOUT(left), Vanguard, Jupiter)

Between 1963 and 1964, NASA flew the solid fuelled Scout rocket and in its final version, the Scout G, it managed to carry 210kg into LEO for a price tag of $13.3 million. That is more than $63000/kg

In the 80's came the Pegasus, which was a reliable system launched from an aeroplane. This rocket, which was built by Orbital Sciences Corporation, had an optimistic start with planned launch costs of $8 – $10 million. The actual Pegasus XL costs $25 million and more for bringing 280 kg cargo into LEO. $90000/kg is not only too expensive for civil research oragnisations but also for government projects.

Pegasus

The exorbitant cost of domestic systems together with the strict exports laws and the subsidies for payloads that come hand in hand with the American launch systems are leading to considerable delays of the further development of micro satellites.

Operators of micro satellites outside of the USA use numerous methods for launching and also fall back on methods used by the former Soviet Union. Unfortunately the high costs of launching also impede the usage of micro satellites.

Exactly how big the demand for MLS is is impossible to say as it is unknown how many satellites are not built due to the high launch costs and other difficulties. However, when we look back at the research in the study from the NASA we can see what the outcome could be if the costs were drastically reduced and what an enormous scientific and economical advantage it would be if we had reliable and affordable MLS.

Lessons from the past

In the last 20 years there have been various attempts to develop and build smaller and more affordable launch vehicles, especially in the USA. The reason for their failure was both politics (influence in who gets the contract from the government, lack of funding) and also technological problems (propulsion technology, overall concept). To have success with future projects and also with Project Enterprise, we will use the knowledge accumulated in these efforts.

Here a list of a few prevoius endeavours.

In 1981 the newly founded Space Service Inc (SSI) was working on a system called Percheron, which was a liquid fuelled rocket 12m high and 1.3m in diameter. The prototype exploded during a static ignition test, on the ground. A second rocket was never built.

Percheron

SSI changed their concept and used solid fuel. In 1982 they successfully tested a single stage rocket in a sub orbital flight. In 1990 SSI was bought out by EER systems. They then used commercial solid fuel motors. During the first launch into LEO with a cargo capacity of 880kg the vehicle lost control and was destroyed. EER planned a second test but never raised the capital required to finance it.

In 1982 the company Pacific Launch Systems was founded by Gary Hudson and developed the Liberty rocket family. The Liberty I was a two stage launch vehicle driven by liquid fuel with one engine per stage. In the first stage they used liquid oxygen (LOX) and kerosene, in the second stage they used the poisonous components N2O4 and MMH. The rocket should have costed $2.5 million to take a payload of up to 220kg into polar LEO. Whilst the first engine was still in the test phase the investors pulled out of the project because the Defense Advanced Research Projects Agency (DARPA) decided to buy Pegasus and, as a result, it was expected that Pegasus would now take over the entire micro satellite market. More than $2 million were invested in Pacific Launch Systems until the firm had to give up.

In 1989 MicroSat Launch Systems appeared and formed a partnership with Canadas Bristol Aerospace which was called Orbital Express. They wanted to use the solid fuel motors from the leading rocket producers Bristol. In 1990 they developed a launch vehicle which would cost $3.5 million and could carry a payload of 140kg. The construction was quite often redesigned to fulfill the needs of potential customers. In 1993 the only ever signed launch contract was cancelled.

The rocket PA-X, a two stage launcher using liquid propellants and designed by AeroAstro, lost in competition against the government supported Pegasus. Project PA-X ended 1995.

The year 2000 brought 2 successful launches for the Minotaur which was a modified Minuteman 1, whose third stage was replaced by the second and third stage of the Pegasus XL. The Minotaur was able to launch over 400kg into the LEO for $19 million.

Minotaur

In 1997, NASA assigned the task of researching and developing a new MLS called Bantam, which was intended to launch a cargo of 150kg into a 370km polar LEO for less than $1.5 million. NASA financed the research for 4 companies. Unfortunately the results showed that the launch cost of this kind of system would barely be below $3 million.

This would have been an enormous improvement but NASA decided to scrap the programme. Alledgedly the reason for this decision was that this kind of system would not have been commercially lucrative.

Current activities

As well as the European (Germany, Switzerland, Austria) initiative of the Talis-Institute, Project Enterprise, there are various activities taking place in the USA that can not be classes as purely civilian projects.

A company called Microcosm is currently developing an MLS called Sprite which should be capable of transporting a cargo of 220kg into the LEO for $2.5 million, which is $11360/kg. What is special about this project is that the liquid propellants, LOX and kerosene, will be contained within tanks made of fiber composites that will have to withstand the pressures needed to inject the propellants directly into the engine's combustion chamber.Whilst such a pressurised propellant system allows Microcosm to abandon expensive and complex turbo pumps for cryogenic fuels, a lot of rocket experts see bigger problems in this approach. Such concerns relate to the complications in the cryogenic tanks that were experienced during the NASA X-33 programme and the failure of various other rocket projects that have used pressurised gas propellant system. However, if Microcosm however are able to perfect this technology, the Sprite will be the biggest ever pressurised gas driven rocket. Two suborbital flights have already been successfully performed using a smaller version of the rocket. To mature the technology, 4 further flights have been planned. The first orbital flight is planned for 2006.

SpaceDev, a manufacturer of small satellites, has proposed a launch vehicle called Streaker, which can transport 315kg into polarLEO. The entire cost of the launch should be less than $10 million. SpaceDev plan to use a hybrid engine that uses a solid fuel combined with a liquid oxidizer. SpaceDev have improved an engine developed by AMROC and changed it to meet its own requirements. SpaceDev also built the hybrid motor for SpaceShipOne that recently won the ANSARI X-PRICE.

A firm called Space Exploration Technologies (SpaceX) is taking a different approach to developing the Falcon 1. The firm is being self financed by its 31 year old CEO Elon Musk who is using his private fortune to fund the project after he sold his electronic payment system, PayPal, to eBay in October 2002 for $1.5 billion. His previous company, ZIP2, has been sold to Compaq for $307 million. Space-X use and partially modify already existing technology and use subcontractors to develop new components.By adopting this approach, they have managed to do without a lot of advanced technologies. The Falcon 1 is a two stage rocket driven by kerosene and LOX that is capable of transporting 350kg into polar LEO for a fixed sum of $6 million.

After burn out, the first stage can be retrieved via a parachute, which is unique to liquid propellant rockets of this size.
There have already signed launch contracts from 3 customers and they even have a launch customer for the first Falcon 5, which is a further development of the Falcon 1. Musk hopes to be able to sell 4 or 5 launches per year to the American Department of Defense if the government is interested in the low cost rockets. The first test flight of Falcon 1 should take place in Vandenberg in early 2005.
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Falcon 1

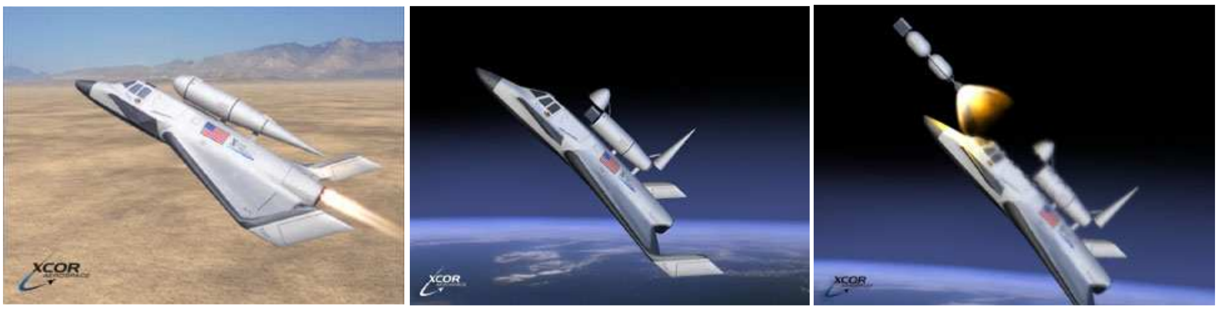
The Rocket Propulsion Engineering Company (RPE) also have something in mind. The LV-1 should be capable of transporting a 200kg cargo into the LEO. The fuel will be pumped and will use H2O2 as an oxidiser. Launch costs should be somewhere in the region of $2.3 million.

Further more, DARPA is developing a hypersonic aircraft that utilises “air-breathing” engines and will be used as a launch system which will be able to transport 110kg into the LEO for a price tag of approximately $10000/kg. The Space Launch Corporation, a small californian company that received the development contract, is also planning their own project called SLC-1, which will be capable of transporting 50kg of cargo into the LEO for a total price of $1.5 million.

The American company XCOR Aerospace, at which the German aerospace engineer who is now part of the Poject Enterprise team was working, would like to start sub orbital tourist flights using their own developed rocket aircraft called the Xerus which can be compared to the SpaceShipOne. According to their own statements they can then also launch the smallest of satellites. It is estimated that it will be possible to launch 10kg satellites into LEO with a minimal inclination (minimal angle to the equator) for approximately $500000. The EZ-Rocket is a test aircraft used for testing the XCOR rocket engines. The results from these test flights will be used in the development of the Xerus.

Dick Rutan is the EZ-Rocket test pilot, who along with Jeana Yaeger, successfully circled the earth without refuelling in 1984 in the Voyager which had been built and developed by his brother Burt Rutan.

Burt Rutan is the President and CEO of Scaled Composites, the company which built and designed SpaceShipOne.



Xerus

EZ-Rocket

The Project Enterprise

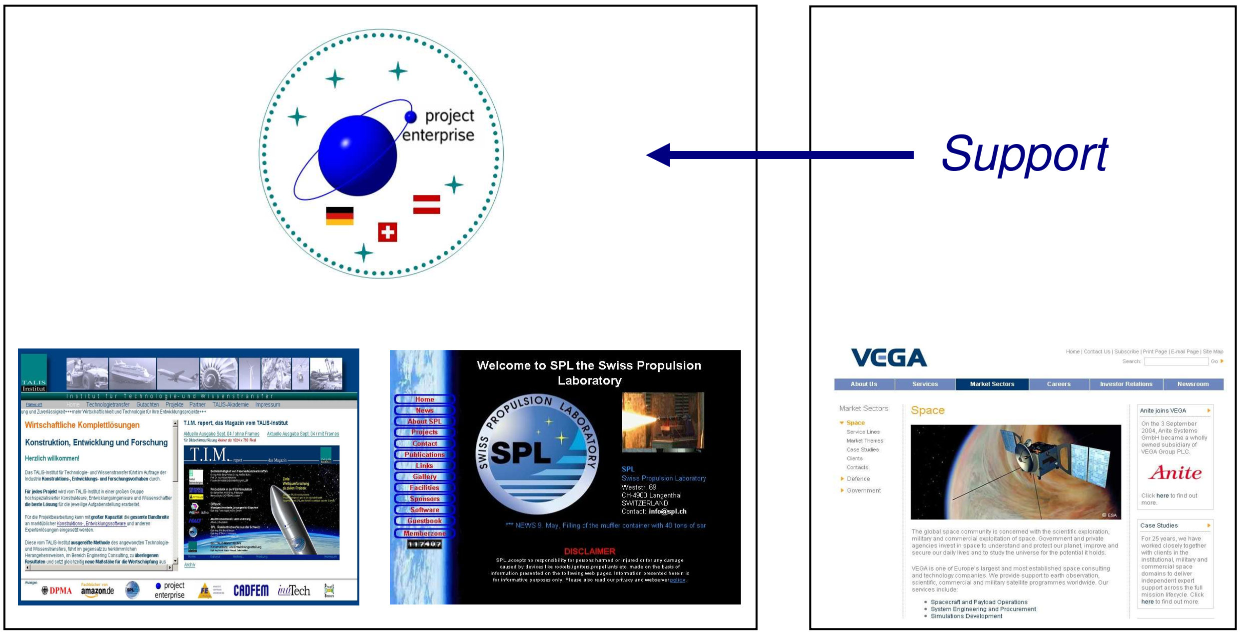
In contrast to most past or present projects, Project Enterprise is solely a civilian project that is privately financed with absolutely no state or military funding and will continue to be so thoroughout all aspects of the project. This will allowed an unprecedented freedom for planning and utilisation of an MLS for scientific space research and a reasonable price for commercial satellite operators.

The quality and amount of aerospace capabilities is far above average in Europe. This knowledge is a product of experience through countless international space missions and research in this field over decades. This alone qualifies the participating companies and institutes enough to allow them to realize the Project Enterprise. The Talis-Institute combines and coordinates this knowledge, using the best and most economical technologies to make Project Enterprise reality. Another great advantage is that we avoid large administration hierarchies, which is not the case with other similar companies or agencies.

The Enterprise will fill a huge hole in the research fields in which zero gravity (microgravity) plays a very big role. On one side we can continue to use drop towers, altitude research rockets or parabolic flights and on the other side we can fall back on larger rockets for example the Ariane, Soyus or similar systems. In more seldom cases, depending on necessity, we could partly have manual or automated experiments carried out on the space station ISS (but a lot of the automated experiments could be carried out in micro satellites that are capable of returning to earth on their own). The relatively large gap between these possibilites can today and in the future only be made smaller through the systems described here. The disadvantage of these systems lies on the one hand in the exorbitantly high launch costs (Pegasus, Minotaur) and on the other hand in state or military connections (like hidden subsidies through allocation of contracts) which can be a big disadvantage for scientific space research and for smaller commercial satellite operators. These are the target groups for which the Enterprise was conceived and it will play an important part for the future of science and the economy.

What differentiates the Enterprise from conventional systems? Engineers and scientists have a responsibility in deploying environmentally friendly technologies and in trying to remove or at least minimise the risks for the environment. For launch at sea we could use alcohol as fuel which would disolve with no problem in the sea should the launch be unsuccessful. Liquid oxygen will be used as an oxidiser which is also harmless to the environment.

The launch vehicle Enterprise will be designed, tested, built and operated by an alliance between the “Talis Institute for Technology- and Knowledgetransfer” and the “Swiss Propulsion Laboratory SPL”. This alliance is supported by VEGA which is one of the largest and most established consultant and technology companies in the field of astronautics in Europe. VEGA's 26 years of Spacecraft Operations experience throughout almost all European Space Agency missions will be utilised in a consultancy role to support the success of the mission and the further technological developments.



The Talis-Instut is comprised of a partnership of more than 50 renowned institutes and companies all in the field of advanced technology. Among these are the "Frauenhofer Institut für Bestriebsfestigkeit LBF" (please see the article in the Talis-Institutes magazine T.I.M report, issue Sept. 04) or companies like CADFEM which has a leading position in the area of engineering, inlcluding astronautics.

The field of expertise of the Talis Instute is advising industrial companies who work in the fields of machine and automobile construction as well as aero- and astronautics. The purpose of our consulting is to help the customer utilise the transfer of technology and knowledge to gain an advantage in the realization of his project and to help him on the way to thus far unreachable results.

The Talis-Institut uses this know how in the relization of its own project, Project Enterprise.

Project coordinator is the institutes director Dipl.-Ing. Frank Marco Günzel

Frank Marco Günzel (36) is a mechanical engineer and his field of speciality is energy technology and structural mechanics. He previously worked for 8 years as managing director and was on the board of directors at the LTM AG in the area of finite-element-simulations. Most of his know how was used for the development of large wind turbines, for example for the development of the worlds largest wind turbine the 5MW from Repower. Further customers came out of the area machine-, ship- and automobile-construction as well as the areas aero and astronautics. His area of speciality is calculating the life expectancy of building components when under complex dynamic mechanical strain. In the Talis-Institut Frank Marko Günzel is employed as a technology advisor and conducts seminars and workshops for various companies. Apart from this he has been conducting courses at the College of Flensburg for some semesters.
The motivations for this project are his connections in the technology landscape as well as his specialised knowledge and his passion for space travel technology. The Project Enterprise will benefit especially from Frank Marco Günzels year long engagement in environmentally friendly technologies in the field of wind turbines.

The Swiss Propulsion Laboratory SPL (see the article in the magazine from Talis Institue T.I.M. report issue Sept. 04) is the most important privatley financed foundation in Europe that develops "small" rocket engines with a maximum thrust of 10 tonnes, rocket test apparatus and other accessories. They are also following an own project to build a height research rocket, the X-Bow. SPL keeps close contact to diverse worldwide noteworthy rocket design programmes (see above) and is also responsible for the tank pressure system used in the Australian altitude research rocket AUSROC. The SPL has access to the most extensive database of constructions plans and constructions data from rockets and engines. This includes all freely available, but very difficult to find, construction documents from NASA.

The knowledge which was collected over the years and the successful tests of various different thruster variations make up the technological basis for the thruster and tank systems of the Enterprise.

Project director at SPL is SPL initiator and founding member Dipl.-Ing. (ETH) Hans-Ulrich Ammann. He is the managing director in the Swiss company ARO Technologies which builds filtering machines for environmental purposes. ARO Technologies was the first and most important sponsor for SPL. As does Frank Marko Günzel, Hans-Ulrich Ammann also commits himself to environmental technology. His competence is shown in his solar vehicle which he developed a few years ago under sponsoring from MÄRKLIN.

Dipl.-Ing. (ETH) Hans-Ulrich Ammann

Project engineer at VEGA is the German aerospace engineer Dipl.-Ing. Jens Lerch who studied aerospace engineering at the University of Stuttgart. His fields of spezialization are space systems, flight mechanics and optimization. He works in Darmstadt for VEGA, at ESA's European Space Operations Centre, as a Spacecraft Operations Enigineer on the European observations satellite ERS-2 launched in 1995, the predecessor of Envisat. The tasks of ERS-2 are: surface temperature, ozone and other trace gasses, radar pictures in medium resolution to detect vegetation, flooding, sinking of the ground and oil spills, wave height, wind speed over the sea, thickness of sea ice and glaciers, measuring the gravitational field of the earth. At present they are looking at the effects of a volcano outbreak on Iceland.
Previously, Jens Lerch worked at XCOR Aerospace, Mojave, USA and EADS Space Transportation, Bremen on the development of rocket engines and launch systems.

Dipl.-Ing. Jens Lerch

The concept for Project Enterprise utilizes simple technology where it is sufficient and advanced technology where it is necessary. The essential components and parts for the thruster, tanks and the fuel systems and the supporting struture will be new designs. We will rely on already known technologies for certain parts, after all we dont rely need to reinvent the wheel!

This method combines two advantages:

a.) using already known, successful technology saves development time and costs.

b.) Developing new single components or modifying already known technology is part of the usual optimising routines and creates alternative solutions that also save development time and cost and results in more safety.

Rocket engines on the test stand, SPL

The Enterprise will be a two stage rocket. Both stages will be fueled by LOX and kerosene or a similar environmentally friendy combination. The first stage will be use turbo pumps to inject the propellant into the rocket engine. A pressure-fed system will be used in the second stage. Mostly we will be using catalogue parts for the electronic circuit boards and mechatronic parts inside the vehicle. We will avoid using expensive materials in the vehicle. It is important to us that the materials we use for the thrusters, tanks and structures are easily procurable and easy to work with. In doing this we can make large cost savings with a marginal technological disadvantage (degree of efficiency of the thrusters, launch weight, redcution of cargo capacity, etc.)

Microsat class payloads need, depending on function, either polar LEOs or LEOs (low earth orbits) with a minimal inclination (minimal angle to the equator) The launch area will be chosen as to favour the payload capacity. The concepts that are being considered include retired oil platforms. This has been successful in other projects for example by SeaLaunch. (please see our computer simulation from the TALIS institute by Peer Gehrmann)

For our purposes it would also be possible to erect a special pylon in the sea with a launching pad attched to the side. Alternatively we could use our contacts in Woomera Australia to build a launch pad there. The first ever European rocket was launched from Woomera, which is already a certified launch site. The Australian state supports the reactivation of the site and SPL has received the assurance from ASRI that they would support us at no cost in getting the launch permission. From Woomera it is possible to launch in a NNE direction into a polar orbit.

Possible launch site for the Enterprise in Woomera (Australia)

Both options could also be used simultaneously. Already existing infrastructure, accessibility and legal aspects with the appropriate authorities will be decisive in choosing the location for the launch.

How much money will be needed for the project?

Approximately €5 million will be needed for the first phase of the project. The financing will be done with a partial funding through sponsors. Part of the funds will be used to help obtain the rest of the necessary amount, the other part will be used simultaneously to develop the liquid rocket engines at the Swiss Propulsion Laboratories SPL.

We will need to enlargen the existing test bays or build new ones. Further more, we will develop and construct the entire supporting structure of the rocket. Part of this is the aerodynamic. This will be optimised using CFD analysis and wind tunnel tests for sub and supersonic speeds. In this stage we will also develop the entire mechatronics and telemetry.

In the second phase we will test the rockets on various testing grounds throughout Europe and Australia. The launch pads will be developed and built and the logistics organised and tried. We will also need funding for this.

The entire cost of the project will be approximately €18 million. This sum is well under the development costs of certain other transport rockets. A comparison: Alone the new upper stage of Ariane 5 from the EADS Space Transportation in Bremen cost €200 million. The development of the Ariane 1 cost €900 million and for the Ariane 5 around €5 - €6 billion!

Obviously this is because they are much larger systems that are not really designed for the needs of micro satellites. Another factor are the afore mentioned extremely high personnel costs coupled with complex administration and decision system. After all the following needed to be coordinated by Arianespace: 41 participating companies in 12 European countries, 11 banks and various space agencies with their complete infrastructure.

All of the companies have to make a profit of course, which can of course, in combination with a minimal launch rate, lead to high launch costs and the other afore mentioned disadvantages for research institutions and commercial micro satellite operators.

The first launching of the Enterprise is planned in autumn 2007 or spring 2008.

The new transporter for micro satellites is predestined to be an MLS. The weight of a micro satellite lies in the region of 10 and 200 kg. The cargo capacity of the Enterprise is, depending on the orbit altitude (300-400km), equatorial approximately 200-250kg and polar approximately 100-150kg.

The launch costs are considerably lower than any previous or planned systems. The biggest advantage will be the availability of the system. This is makes possible the consequent realization of planned missions in the areas of material science, biotechnology and pharmacy and also promotes the economical development of low Earth orbit by micro satellites.

Due to its good economy and the growing market for micro satellites, a market with high growth potential is open to our launch vehicle.

Conclusions and a request for sponsorship

Project Enterprise is a meaningful and wholely civilian space project, driving the scientific progress for the good of mankind and environment and opens new opportunities for universities, companies and many other organistations which they would not otherwise have.

The project will be carried out in the highest technical and scientific standards and is dependant on sponsors who, with their contribution, want to promote new environmentally friendly technology in astronautics and promote the progress in the scientific astronautic research through meaningful employment of economically viable technology.

Thank you very much

Frank Marco Günzel, TALIS-Institut

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