OTRAG Rocket

Introduction

In this article, it should also be reported on the most ambitious project in the aerospace industry: The German OTRAG rocket. End of the 70 years he made these headlines. The idea of OTRAG is from Lutz Kayser, who was soon able to attract investors for the loss of depreciation. The concept of OTRAG rocket was completely dedicated to a low starting price. There were neither sophisticated technology nor low start mass but only the starting price.

The article was by the search longer and so I have it divided into two parts:

- In the first part I give to a large extent the data of OTRAG again and what I found out through research. Here is a technical description of the modules, the rocket and a history of OTRAG as a company and the development of the rocket as it was communicated to me by Lutz Kayser.
- In the second part, I would like to discuss this. It's partly a question of whether the values of OTRAG are correct. Second, if you so all can build a large rocket. Last, there are always sources who claim that Kayser has worked for the Libyan military. This is also discussed.

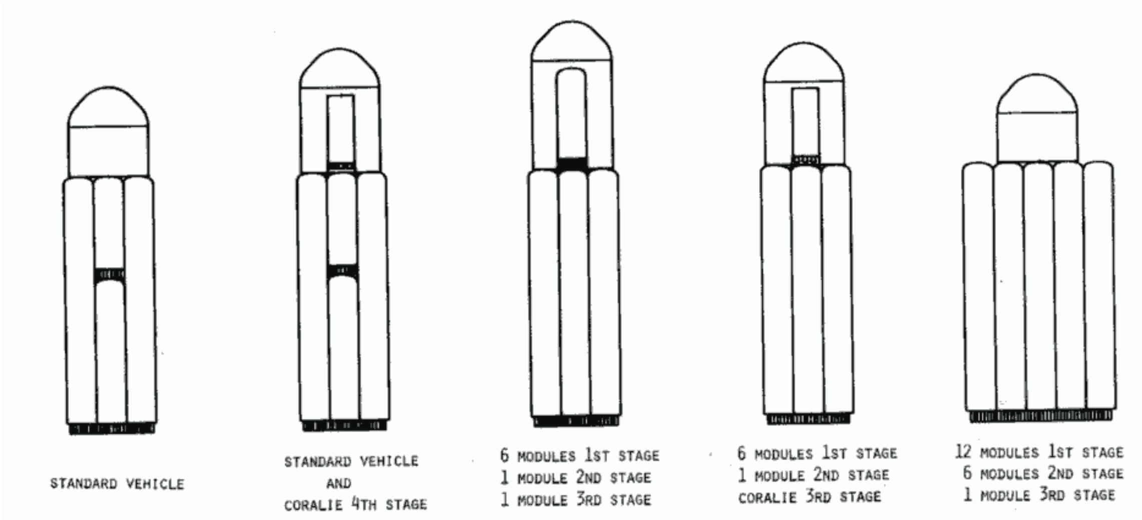
This part contains the sources for both articles

The emergence of OTRAG

Lutz Kayser (born 1939) was occupied as a teenager with rockets and studied under Eugene singer at the Stuttgart University of air and space technology since 1954 and was part of the Society for Space Research (GfW) as a member. The concept of the rocket he had his bundle of O. Lutz knew, Dadieu, Wolfgang Pilz taken, which in turn prepared by the J. Winkler, between 1928-1930 worked out concept. This saw the tying many identical units, each with 10 tonnes of thrust.

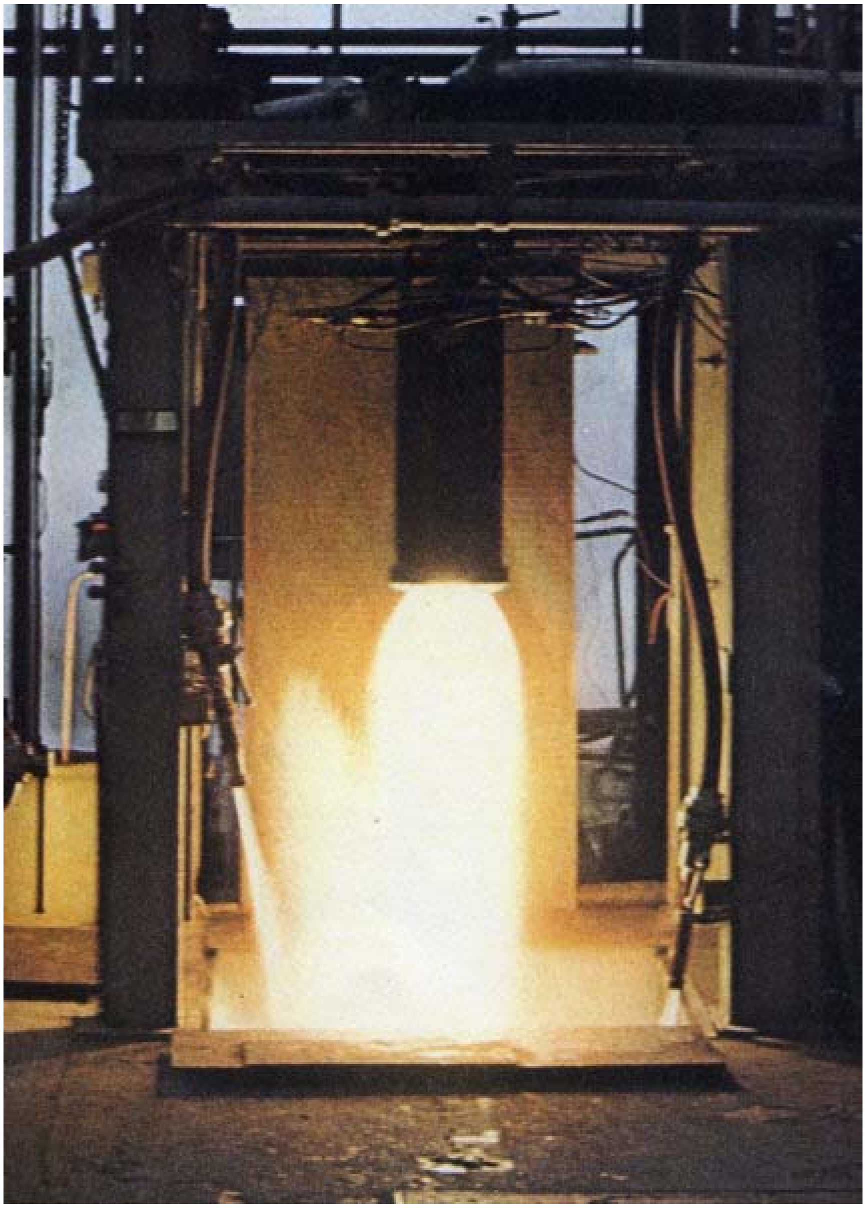
Lutz Kayser belonged to a student association of space enthusiasts, and developed on the farm of his father, who was director of the Südzucker rocket engines. It was there a 5-foot test stand for engines. The group was supervised by Irene Sänger-Bredt, wife of Eugen Sänger.

In the summer of 1971, awarded by the Federal Research Ministry of Germany four contracts to firms who (should lead to the later, the Ariane) an alternative plan for a low cost alternative to Europe III B rocket should work out. The new rocket would be cheaper than the use of the Euro II and the development costs of 2 billion DM for the European undercut III. Besides the two was already established companies ERNO, Dornier and MAN was a newcomer to this technology Research. This company Lutz Kayser founded in 1971. Each of the contracts was rewarded with 250,000 DM. The proposal by Dornier (Lutz Kayser's brother worked there) was, strangely, never mentioned publicly.



The concepts of ERNO and MAN provide for a savings of 10-20% of development costs and used extensively in parts of the Europe Program were developed. The proposal of the Technology Research contrast, represents a radical new concept: the rocket will consist of 6 modules in the first stage. Each module was equipped with 36 engines, which work with simple fuels such as heating oil and nitric acid. The second step then consisted of a module of 36 engines. The control in the pitch and yaw axis would settle down by the thrust of one of the outer engines happen.

The picture above shows some configurations, the time nor the Coralie stage of Europe I and II is used as the upper stage. This arrangement would, according to the Technology Research GmbH, the development costs not only reduced slightly from 2000 but reduced to 500 million DM. This was the first concept of Lutz Kayser, that he perfected later.



Lutz Kayser was in addition to the initial DM 250,000 for the study further funding from the Federal Ministry of Research, perfect 4 million DM to 1974, the concept and to develop an engine. Then, Germany participated in the development of Ariane and the approach to the research ministry has become uninteresting. During this time there were already initial testing of the engine.

1971 and 1974 Kayser published two articles that dealt with the concept. The concept of radial injection he had worked 1964th In 1973 Frank published Wukasch, the Vice-Kayser for his thesis which dealt with the numerical simulation of the multiple bundling.

Lutz Kayser tried to build the rocket, without state support and founded the OTRAG. Now completed the publications and not only on the OTRAG there was no information about the missiles. The acronym stood for OTRAG Orbital Transport and rocket-stock company with headquarters in Neu-Isenburg. It was founded in 17.10.1974 with a capital of 1 million DM. The concept for the company Kayser made rich with a bang: The results, which resulted from research funded by the BMFT Kayser sold for 150 million DM to the OTRAG (which he chaired) and read at once pay 20 million and the rest as credit, should be replaced if revenue gushed from the company. A Quick Change of a stroke made him rich. He needed now only people who were willing to pay 150 million for research by the federal government previously funded with a 40 position of the sum had. This was achieved with a curiosity of the German tax law: Because the company did so virtually from the beginning, only losses, investors won the deposit as a loss, the tax savings was due to the enormous debt the company is much higher than the deposit.

In June 1978, Lutz Thilo Kayser had a total of 95 million DM of not less than 1,150 shareholders, acquired mainly employees and officials. This was because there were tax law by the loss allocation of up to 275 percent. In other words, do not log the OTRAG rocket is successful, the investors could make a loss of 275 percent of the invested capital tax. Who had an income replacement storage of more than 37 percent, also made a profit if the OTRAG not rocket flew successfully. Many investors saw the OTRAG therefore society as a loss of depreciation and the allegation that it was actually not about to bring a satellite into orbit, Kayser pursued during the whole time OTRAG.

Static test of a RaketeVon universities Lutz Kayser took about 40 engineers fresh from university and gone as chairman after he won an 8-day closed meeting Kurt Debus, the former head of the Kennedy Space Center from 1962 to 1974. He stood in 1976 before the Supervisory Board of OTRAG. In late 1980 he retired from the OTRAG because they now start in Libya and prepared by its board of NASA would have been endangered. (Debus was a U.S. citizen and therefore should not be chairman of the board a company that does business with Libya). Debus gave the OTRAG credibility and thus they only came to Central. He entered but not outwardly apparent. In 1980, when Debus Lutz Kayser was retired Chairman of OTRAG and his deputy Frank Wukasch CEO. Although OTRAG was a public company, Lutz Kayser decided virtually everything personally.

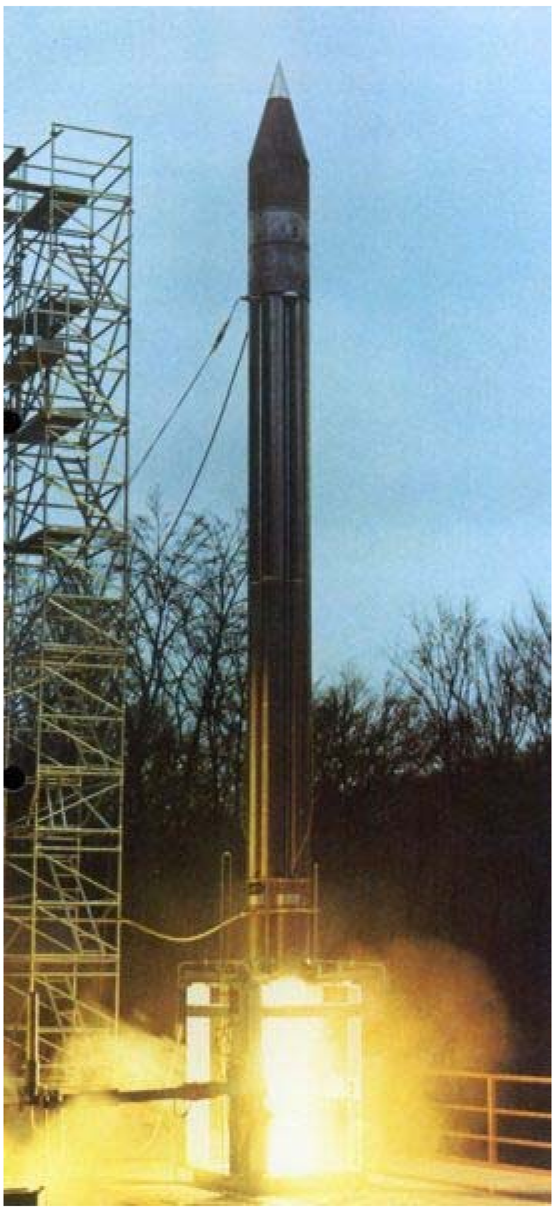
The OTRAG had as a small company, of course, does not have that large space corporations or States enjoy. For static tests of the engine or the module is reached, therefore, on the back for the European-built rocket test facility in Lampoldshausen. To start you had to look for a place outside of Germany.

The concept

Lutz Kayser believes that existing carriers are not optimized at the expense down. Lowering the related as "Billigstrakete" in the newspapers received rocket following principles about the cost, even if the takeoff weight is inevitably much higher than the imported sources:

- Reduce costs by using commercially available technologies: The tanks are made of steel tubes for pipelines, the engines are from the ignition valve Bosch and otherwise to carry windshield wipers.
- Lower development costs through the use of many smaller engines, instead of the expensive development of larger engines
- Reduction of production costs through a simple design and high quantity (series principle)
- Reduction of production costs through low-cost fuels

In the rocket stuck to Lutz Kayser's figures, 31 of his patented developments. In 2005, of which 20 should have to endure.



The modules
The basic principle was the massive bundles of single very simple engines. A minimal module consisted of 4 tanks and 4 power plant. Internally, of "1-Pack", "4-Pack " and so on ever spoken to engine number. Today, Lutz Kayser of the technology in the U.S. and speaks of "Common Rocket Propulsion Modules" abbreviated CPMR or "Common Rocket Propulsion Units (CRPU). Seems a German name for the modules to have it so never existed. The same applies to the rocket. At a shareholders meeting was "Wotan"proposal, but failed to happiness. In the press were mostly of the "OTRAG rocket" or "cheap rocket"is mentioned.

The tanks
The tanks consisted of modified pipeline pipes from the petroleum industry. They were manufactured in a special cold-rolling process for the relatively high empty weight required. The steel had ² a stress limit of 232,000 PSI [1600 N / mm^2]. The weld seam needed to be made with a spiral welding process. One important however to normal deep-drawn tubes. Each tube is 10.63 in [27 cm] thick and 9.84 ft [3 m] long. It consists of 0.020" – 0.040" [0.5-1 mm] thick, low-carbon steel. A machine could produce 10 tanks a day largely automatically. Thickness for the tank was in a 1979 report called a value of 0.040" [1.0 mm] and Lutz Kayser stateed in 2005 that it was 0.020" [0.5 mm]. Harry O. Ruppe writes of 0.015" [0.38 m], but at 435 PSI [30 bar] pressure. Thus one has tried tank thickness and pressure in order to optimize the best performance.

Because of the thin wall of the tanks were unstable in the transverse direction and the tank pressure was needed to stabilize it, as was done with the Atlas. The tank weight with a 0.020" [0.5 mm] wall thickness was about about 2.2 lbs per foot [3.3 kg per meter]. At each tank joint was an intermediate bulkhead of 4.4 lbs [2 kg] mass. A 9.8 ft [3 m] module came to a weight of about 26.5 lb [12 kg] for the M10 bolt connections.

Up to 8 of these tubes, together with a bayonet attached, form a tank of 10.6 in [27 cm] diameter and 80 ft [24 m] in length. There are also bundles of smaller lengths. (40 ft [12 m] and 60 ft [18 m] long modules were planned). Each tank has a tank bottom can be interrupted, so the tanks can be filled continuously. The fuel tanks are only partially filled, the rest is air at up to 580 PSI [40 bar] initial pressure, which takes over the fuel support. Due to the emptying of the tanks, the pressure then drops to 218 PSI [15 bar] at the end.

As the fuel cost combined nitric acid / diesel oil is used. This combination is far less expensive than the usual combination of hydrazine / nitrogen tetroxide. This is because the rocket on the one hand, cheaper than the competition must, on the other hand, weighs much more. Other combinations such as the use of liquid oxygen are eliminated because of the high evaporation rate in the thin tanks.

Nitric acid tank has a good weight advantage. A liter weighs 1:52 kg. The addition of nitrogen tetroxide is the composition that again a little closer. In American usage as HDA (High Density Acid) or "IRFNA IV" called liquid is a mixture of 50% nitric acid and 44-49% nitrogen tetroxide and small amounts of hydrogen fluoride and water. HDA is denser than nitric acid and added at 0 degrees Celsius has a density of 1.66 g / cm ³. It was favored because of slightly higher density for the orbital missions by Kayser. The tests were still held at normal 98% nitric acid.

This acid combination was both the U.S. and the USSR in the 50 years he tried to limit the first release of nitrogen tetroxide by the nitric acid, but one more soon to pure anhydrous nitrogen tetroxide as the oxidizer. A number of rocket engines, which are well known are the engines in the Russian Kosmos rocket, related this combination in the 50 years he as rocket fuel. The disadvantage of the acid - that the density is strongly temperature dependent - played in the partially filled tanks of the rocket OTRAG not matter. The nitric acid had to be at the OTRAG are up, while normally, in order to obtain a lower center of gravity, the heavier fuel fill down. By only partially filling the tank but this led to a better center of gravity than the reverse filling. The oxidizer was there 3 times longer than the fuel tank, which corresponds to a mass ratio of 1:5.56 (HDA) or 1:6.07 (nitric acid).

It has also other combinations such as red fuming (68%) nitric acid as oxidizer and other hydrocarbons (kerosene, JP-1) tested as a fuel. The injection head of the engine proved to be very robust to different oxidizers and combustion sources. The refueling process was unusual:

The refueling before the launch took place as follows:

1. Loading of compressed air to 40 bar internal pressure.
2. The opening of the fuel valve releases air pressure from the engines up to 15 bar from. This is the positive control function of the valves and freedom of the injection head of any blockages.
3. Pressure refueling with the same oxidant and fuel tank up to 40 bar pressure.

The whole procedure took place in at least 3 minutes and is done in parallel and automatically in all modules with separate fueling systems. The pressure decreases when operating at 15 bar (the pressure which the tanks were empty before). The valves in the tanks are adjusted so that the resistance of the combustion support is higher than for oxidizer, so that a uniform fuel flow and the volume ratio of oxidizer to fuel remains the same.

Since the engine is always difficult, takes the full / empty mass ratio to rise at length. Was considered to be optimal in length of 24 meters. In addition, the losses increase by gravity to the low thrust back sharply. The thrust would allow an extension of up to 40 meters.

The empty / full mass ratio given in 1980 for a 24-meter version 0.15, about twice as high as for conventional rockets. The data which I gave in 2005 Lutz Kayser are much better and be a 0.1 for a 24-meter version 0.15 for a 18 m version and 0.18 for a 12 m version. In the 24 m version a module containing HDA 1130 kg and 220 kg diesel oil, ie 1350 kg propellant at a launch mass of 1500 kg.

In the first 4 modules can he still turned to another technology and fully filled the oxidizer and the pressure generated by a pressure line from the fuel tank. Later they came back to the conventional solution, because the overhead the advantage of a slightly better weight balance (you could fill the tanks full of something) justified.

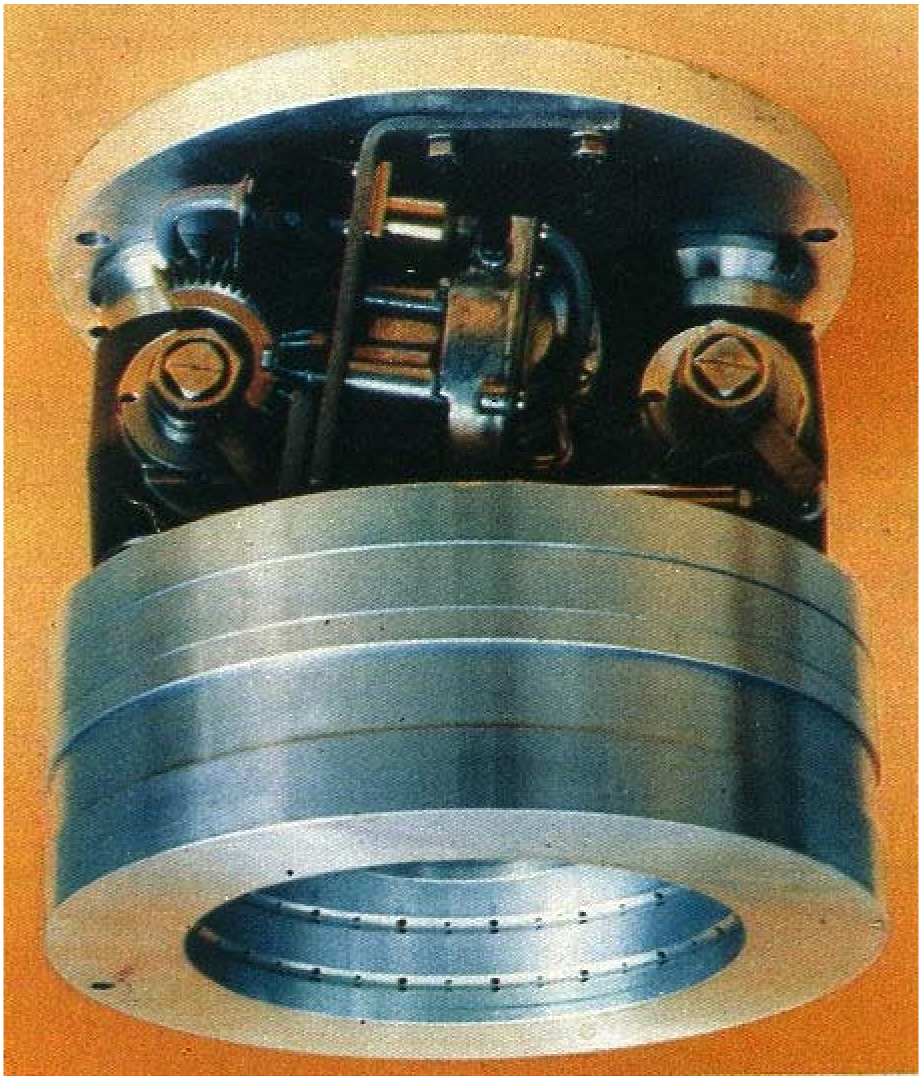
Characteristic	Standard	Metric
Segment length of a tank	9.8 ft	3 m
Diameter of a tank segment	10.63 in	0.27 m
Mass of tank segment	22 lbs	10 kg
Mass of a connector	4.4 lbs	2 kg
Tank volume	6 cuft	171 l
Nitric acid at 66% full load	384 lbs	174 kg
HDA load at 66% filling	414 lbs	188 kg
Load diesel at 66% fill	203 lbs	92 kg
Tank pressure (ignition)	580 PSI	40 Bar
Tank pressure (firing)	218 PSI	15 Bar

The engine

Each engine is like the tank 27 cm wide and 1 m long. Of this, 60 cm to the combustion chamber and nozzle, and the rest of valves and injection block. The engine is solid, does not swivel. It is not actively cooled, but used a ablative cooling resin and asbestos. The only moving parts are the valves which regulate the fuel flow. The ball valves are from Argus in the chemical industry and are driven by DC electric motors in the automotive industry. (First it was 50 watts Bosch motors for windshield wipers, but they were not powerful enough, so the third launch failed in a push system, so you went to 100-120 watt motors). Particularly difficult was the development of the radial injection of fuel. Each engine has an average thrust of 25 kN. However, this can be varied over a wide area, and decreases during the combustion.

The engine has one line for the oxidizer and one for the combustion support. It has now been fixed so that was one of the two lines of a tank connected to an engine. An engine that is related to the oxidizer from a tank and the fuel from another tank. This design allowed the engine with a screw to attach firmly. The mass of the engine was 65 kg for the start. A reduction in mass of 50 kg should be possible, according to Lutz Kayser.

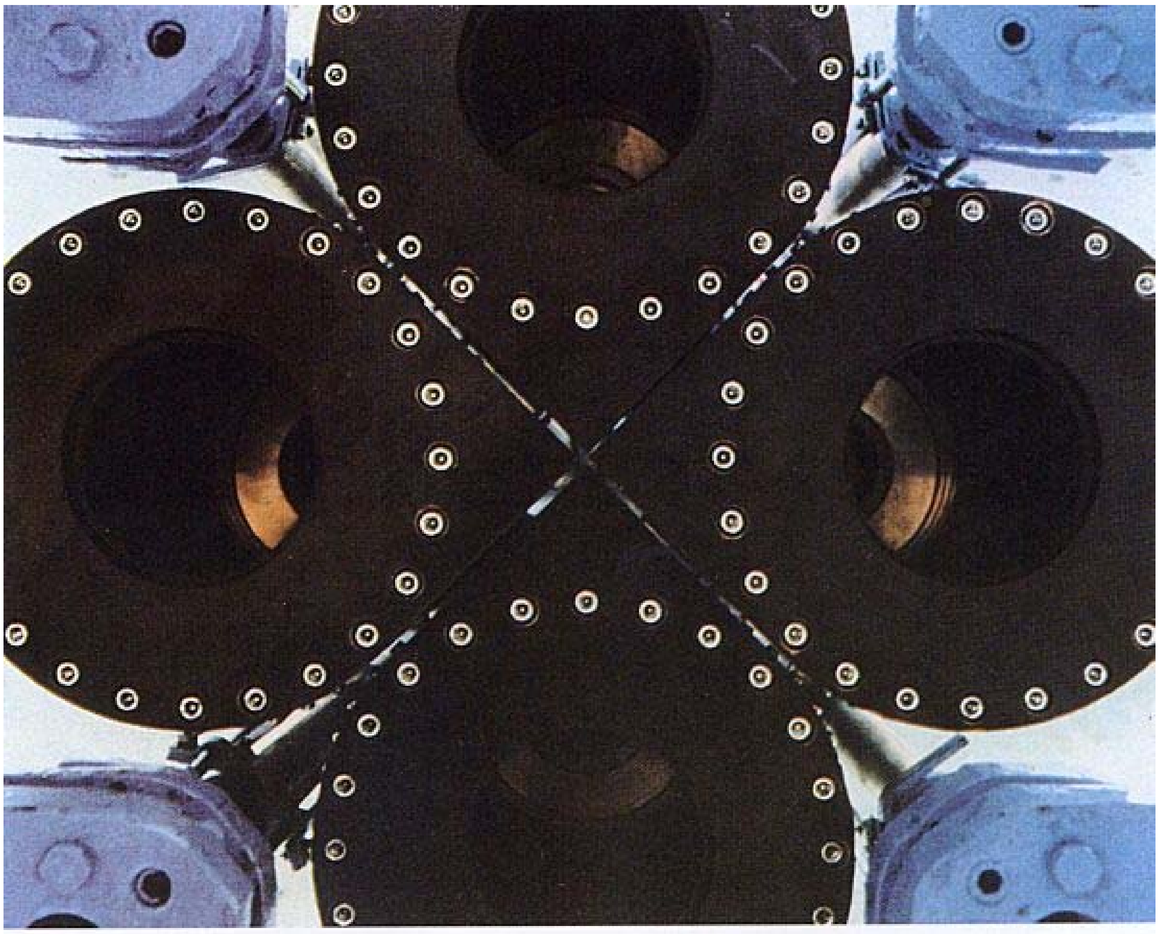
The engine has been tested yet with the DFVLR and tested. The concept and the rights to the developments were contractually required to Lutz Kayser, who they could bring to his new company OTRAG.



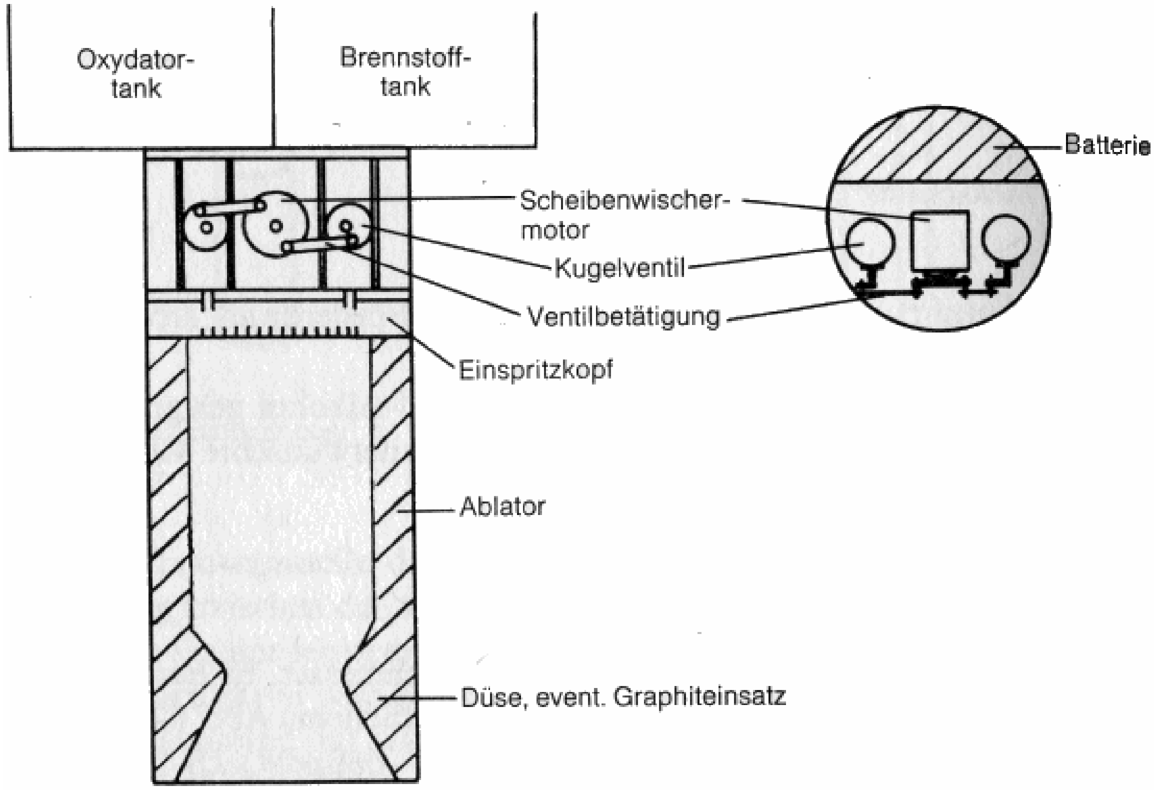
OTRAG injection head in the first phase of the project until 1972, there were already 200 firing tests with 3 failures. By the end of the support by the BMFT, in 1974 there were 2,000 tests and now it will be 6000, with an accumulated operating time of 1 million seconds. I have received from Lutz Kayser no slice of the engine, fearing that someone might steal his intellectual property. The pictures here show, therefore, only the schematic operation.

Each engine has an overhead line from the oxidizer and fuel tank. Unlike other engines, the fuel injection is not a head above the engine but is injected radially from the outside. Lutz Kayser points this out as one of 31 developments that worked only after long time and some setbacks. The injection is performed by 3 rings with 144 holes, which should allow a particularly good combination. The radial approach prevents the fuel reaches the combustion chamber wall, and thus cut off the reaction. The result is a very high combustion efficiency. The nozzle throat is a simple graphite ring. Due to its opening, the thrust will be regulated in a very wide range. The engine is so varied in a wide range of 5-50 kN. An aperture of 80 mm was used in the tests with 6 or 12 m long modules. This opening is a thrust of 25 kN, the linear in-flight decreases to 15 kN (by the decrease in the combustion chamber pressure of 30 to 10 bar). With the larger 24 m long modules for a space launcher, the opening has a diameter of 100 mm would have been. The thrust would then have 35 kN at the beginning, be decreasing to 15 kN.

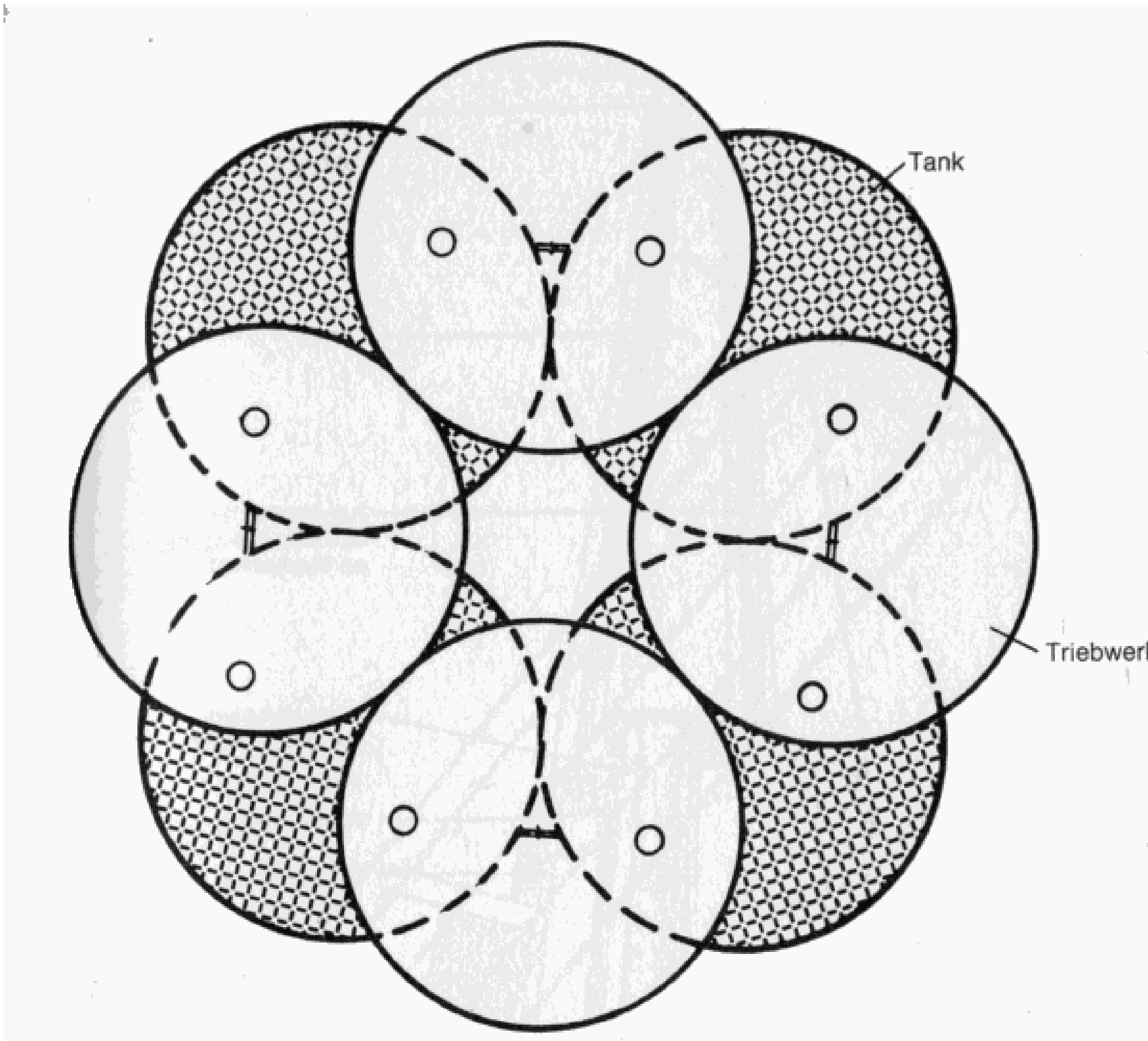
Since the tank pressure decreases by increasing emptying of the tanks, the combustion chamber pressure drops during operation from 30 to 10 bar.



The combustion chamber had a throat to nozzle expansion ratio of 15. There was no special adaptation for operation at high altitude for the second and third stages. The engine lost during the operation 15 kg mass, because the ablation evaporated. By burning this mass is the specific impulse by 1-2% have been increased.



The burn time was dependent on the degree of filling of the tanks and the thrust and was 20 to 150 seconds. Version 150 m for the 24 seconds were given for the 15 m version 120 seconds. The specific impulse for the 24 m version was given by Kayser with 2648 m / s at 1 bar external pressure and 2913 m / s in a vacuum. However, these are values that were not found experimentally because it requires a set of effect occurs after Kayser information only in larger bundles. In the tests on the ground, the engine had a specific impulse of only 1800 m / s corresponding to about 2000-2100 m / s in a vacuum.



The below average image that anticipates some of the simple design of the engine. First, there are no moving parts. No possibility to adjust the nozzle, no pumps or gas generators. Also accounted for a complex design of the combustion chamber. There is not walled chamber with regenerative cooling, as accounted for a complex construction of the nozzle. It is similar in the basic structure of any existing engine and can be compared as EHEST even with satellite engines that also operate in the "blowdown" process. Compared to these, there is another simpler (some say: primitive) designed.

DüseDie nozzle is simply a conical opening in the block of ablation. The whole engine is practically out of a block with the ablation of asbestos embedded in a matrix of phenolic resin (in its properties to the heat shields of Soyuz capsules as the equivalent), from which they had milled the contours of the combustion chamber and nozzle. The nozzle throat was because the highest stresses occur here, of graphite, which sublimes at 3825 degrees Celsius. The combustion temperature of HDA is a diesel but only about 3200 degrees Celsius. Due to the design of the rocket engine, a maximum of 27, only to be "wide, which means that the nozzle area is limited and you can only use a fraction of the energy in the fuel jet. Lutz Kayser keeps ratios of nozzle area: Düsenenghalsfläche of about 20 for uneconomic (This value is in modern Oberstufen 100-1000 utilize efficiently the fuel). He refers, however that the closely spaced engines produce a common collimated beam, which generates a dynamic pressure, which should offset this again to some extent.

In the built form of the nozzle end almost directly behind the nozzle throat, so that the fuel was not used very efficiently. The area ratio of nozzle throat to nozzle outlet is only 6

Ignition takes place through a liquid (50% furfuryl alcohol in 50% water) at the bottom of the diesel oil tanks, the first flows into the engine. The 0.3 kg furfuryl alcohol in aqueous solution miscible heavy as diesel oil, and not with this. The mixture is hypergolic with HDA, thus igniting on contact. The ignition takes place within 10 ms and the inflow of diesel oil maintains the burn. A re-ignition is not possible and an ignition under microgravity not (in this case would Furanol with the fuel mix).

Cross section through the engine is done via a control valve with a planetary gear that regulate the fuel flow in 3 positions. (Close, Half Flow, Full flow). The flow rate corresponded to half a thrust of 40% of the nominal value. The missile would likely be by lowering the flow on one side and so the thrust reduced. In the aerodynamic phase, tube fin in the simple first models (short pipes) rather than stabilize the rocket fins. This concept was tested in wind tunnels of DFVLR. Larger versions would be a system of thrust used to change the path.

In addition to controlling the thrust of the inflow, it was also possible to regulate the thrust through the supply pressure. This decreased, while the tanks empty, on its own from 40 to 15 bar. It would also have been possible to reduce the initial pressure. The minimum shear for stable operation was 40% of the nominal thrust, or about 10 kN.

Each engine contains a simple microcontroller, which can only determine whether an engine works. It was a simple ASIC from Motorola, which was cast with the nickel cadmium battery and two Darlington transistors in a polyurethane block. The Darlington transistors would allow the high current load for the motors to generate the supply voltages without the battery to charge.

In case of malfunction, the valve is closed and passed a message to the host computer to control the entire missile by radio. This switches the case of malfunction the corresponding opposite engine to thrust is symmetrical. This control has been tested by computer simulations.

Kayser is the reliability of the engines as the "6 Sigma". But it is a size from the production technology, the estimated production for a committee of 3.4 parts of 1 million units produced. There is no reliable value for rocket engines. Similarly designed engines for satellites without cooling and discharge are estimated with a reliability of 99.55%. This value appears likely in view of the false starts of at least two OTRAG missiles.

RohrfinnenDas engine is distinguished by the fact that several parameters change during the flight. The combustion chamber pressure drops during operation, the combustion chamber volume is increased by removal of the insulation material. In all, more than 20 years have flown over 50 million DM in the optimization of the engine.

Characteristic	Standard	Metric
Mass (at ignition)		65 kg
Mass (after firing)		52 kg
Length		1 m
Diameter		0:27 m
Combustion chamber and nozzle length		0.6 m
Combustion chamber pressure (ignition)		30 Bar
Combustion chamber pressure (firing)		10 Bar
Characteristic length on ignition		2.0 m
Characteristic length at the end of firing		1.5 m
Thrust range of		5-50 kN
Thrust in the tests (soil)		30 kN
Thrust during test (vacuum, theoretical value)		36.2 kN
max. Shear at 100 mm nozzle throat diameter of		35 kN
max. Shear at 80 mm nozzle throat diameter		25 kN
Minimum thrust in% of the starting spurt		40%
Minimum Burn Time		20 seconds
Maximum Burn time		150 seconds

Stages
A tank and an engine form a basic unit. Lutz Kayser now called the technology "Common Rocket Propulsion Units", abbreviated CRPU.

The length of the missile can be varied by the number of 3 m tank modules. The tests were carried out with modules from 6 to 12 m in length. Possibilities to about 30 m long modules have been. Are ideal because of the volume ratio of oxidant: fuel of 3:1, the rockets from 12 to 24 m in length, because then there is the diesel tank of a 3 m or two segments. For intermediate sizes, it is not possible to exploit the full capacity of a tank.

The simplest OTRAG rocket is now composed of concentrically nested cubes with the following steps:

Level 3: 4 CPMR (2x2 cube)
Level 2: 12 x CPMR (+4 = 16 CPMR CPMR = 4x4 cube)
Level 1: 48 x CPMR (+12 = 64 CPMR CPMR = 8x8 cube)

This rocket with a launch mass of about 100 t possess a payload of 1 ton and would be high without payload 25 m and 2.4 m wide. The amount is only the width is in the following models are larger.

Similarly, a rectangular configuration. This shows the next larger model:

Level 3: 8 x CPMR (2x4 square)
Level 2: 24 x CPMR (+8 = 32 CPMR CPMR = 4x8 rectangle)
Level 1: 96 x CPMR (+24 CPMR CPMR = 128 = 8x16 rectangle)

This missile would be 4.8x2.4 m wide at a height of 24 m. It has also been considered to extend the outer ring by 3 m in order to form the payload space. These engines would then burn 15 seconds longer. In later approaches you have rejected this idea again.

The rapidly increasing width of the rocket and the bundling of many engines should provide an additional ideas to Lutz Kayser back fabric. As described, the nozzle end shortly after the combustion chamber, so that the gases at the nozzle exit, very little energy has been transferred to the rocket. Up of many engines connecting gas flows and accumulate it comes to a further rebound in order to increase the specific impulse for Kayser detail by 10-12%.

The following standard versions were being considered (payload for a 200 km high orbit LEO)
Total number of CPMR payload launch mass Level 1 Level 2 Level 3
64 1 t 100 t 48 12 4
T 200 t 128 2 96 24 8
256 4 t 400 t 192 48 16
512 8 t 800 t 384 96 32
1024 16 t 1600 t 768 192 64

The payload data refer to a low Earth orbit. The payload for the GTO orbit betrugNo text about 40% of it and the payload for the GSO orbit about 20% of them (this would be roughly the payload to Venus or Mars). A 200-ton rocket with 128 modules, so the payload would have had a Delta 3914, the standard model of the time, and a version with 256 modules would be something worse than an Atlas-Centaur or Ariane 1 was.

Mr. Kayser I first gave values of 24 m module, and when I complained inconsistencies, new data, which differed in the thrust and burn time of the first substantially. I have therefore both separately identified by a "/". Here, the data of a 24 m long module consists of a tank and an engine. This length would have been provided for an orbital version.
Length 25 m
Diameter 0:27 m
Tank mass of 100 kg
Engine 65 kg
at the end of firing 50 kg
Push the start 35 kN / 25 kN
Thrust at the end of firing 15 kN / 15 kN
Burn time 150 sec / 120 sec
Oxidizer HDA 1130 kg
Filling 66%
Oxidizer length 18 m

Diesel oil combustion support 220 kg
Filling 78.1%
Length fuel tank 6 m
Takeoff weight 1515 kg (1978: 1361 kg)
Empty weight 165 kg (1978: 172 kg)
specific impulse (bottom) 1778/2648 m / s
Specific impulse (vacuum) 2276/2913 m / s

The divergent values, I will discuss further below.

These are just some of the possible launch vehicles. It is always possible to add modules to increase or to have gone. With the larger missiles, it is also possible to introduce a fourth or fifth level, by using, for example, the 256 version the central 16 CPMR CPMR CPMR in 12 (third stage) and 4 CPMR (fourth stage) splits. This would have been necessary for a shipment in the geostationary orbit or on planetary missions. This flexibility is certainly one of the advantages of the OTRAG concept. Such a unit with 4 fuel bundles and 4 engines would cost 33200 USD.

No TextDer build the rocket turned out to be relatively simple. It took only a working platform with fixed access points in each 3 m distance around each of the rocket to increase by a module. Much more complex than a scaffold, therefore, the starting system is not. The refueling stage was first with compressed air and then leak test the fuel. This was relatively easy for the 1-4 modules that have been started at the test launch, though this was as simple modules have been at 500, is doubtful.

The launch took place as follows:

Each engine controller of each module receives the following commands from the host computer (in the 3rd stage) and converts it in to power to the DC motors valve actuation:

1. Valve opening to 40% thrust
2. Message from the controller when the chamber pressure of 40% is reached at the central computer.
3. If the central computer has received the 40% feedback on all engines, it waits 0.2 seconds and then gives the command "100% thrust" to all engines.
4. Valve opening to 100% (within 0.5 seconds, the rocket takes off, without it having to be held on the ground)
5. If out of pitch and yaw movement of the nominal value of the corresponding engine controller obtained from the central computer the command to push throttle / thrust increase.
6. Upon reaching the final speed command to throttle the engines to zero.

Within 1.2 seconds the rocket lifts off also. This is very fast and compared with other missiles in which the thrust to be developed must (by starting the gas generator and turbine), a record high (The Ariane 5 and the Space Shuttle does it take for example 7 seconds from Zündkommando to take off).

A controller in the pitch and yaw axis was targeted by throttling individual thrust engines. An engine failure is met by the shut down by the focal point symmetry located engine. A disadvantage of this approach is that retained by the reactors and switching off of engines larger quantities of fuel in the tanks, which of the other engines can not be used. They thus increase the empty weight considerably. The roll control is considered first, the engines of the outermost ring at 10 degrees to the thrust axis to install. A reduction of the thrust of one engine then causes a rolling of the whole rocket. Later we took an additional cold-gas system in the eye.

No text to roll the tanks allow a staging by the next stage of rolling out the scaffolding surrounding the stage out. , the respective upper stage by 5 runs per CPMR (module) to the respective lower level based, so they "slip" is not down but up at ignition start out. The separation takes about 2 seconds.

There is no Vorbeschleunigungstriebwerke, which earn a start in zero gravity, the fuel on the ground. Since the first furfuryl alcohol in the combustion chamber must flow, the stage will be ignited hot, ie The upper stage will be ignited, while the lower one is still in operation. The staging was therefore not when the fuel is exhausted, but the rocket had reached a predetermined speed.

Over the last step is a central computer that has like other missiles on the object to control the rocket. He should have a gyroscopic system to detect the accelerations. This was used to calculate the speed and location of the rocket. The control was carried out by a conventional program, which directs the rocket to a predetermined target trajectory. The engine controls were driven by a 600 channel radio transmitter / receiver. Today Kayser would use in their own words for this WLAN. The first and second stage should be operated until the fuel is exhausted. This should be possible accurately to 0.1%, according to Kayser. The third stage is switched off when the desired final speed. This should be possible with an accuracy of 0.01 seconds.

Test flights of the smaller versions have been controlled by the program and were stabilized aerodynamically. Interference torques about the roll axis are considered because of the high Kayser Bausymmetrie the bundled modules to be very low. They should be compensated for by a tangential thrust cold-gas system in each stage

For the development of a missile with 2 t GTO payload would have OTRAG used about 500 million marks, or about a quarter of the Ariane development costs. Such a support should be developed within 10 years. Later, the OTRAG employ up to 2,000 people directly and save 40,000 jobs in supplier companies. If the rocket OTRAG become truly successful, it would have been certainly the most scalable and most cost carrier.

Variants of the OTRAG Launch Vehicle

As already explained, it would be possible to launch any payload through an appropriate combination of modules. Kayser has submitted the following standard sizes. They differ from each other by their diameter increases always 8 module widths (2.4 m). For larger missiles hexagonal arrangements rather than square or rectangular would be cheaper. The orbital versions should consist of 24 m modules. Shorter modules were used to study the technology.

types would have allowed a fourth or fifth level I've set the data for a fourth stage in parentheses () and the fifth for a stage in square brackets []. Besides the list of Kayser I recorded some in blue type have been reported in contemporary publications. The OTRAG was a payload of the Delta Class (2.5 tonne weight) for 7 million, an Atlas of the class (5t weight) for 12 million and a start of the Titan Class (10 tons) for $ 15 million.
Type Dimensions Level 1 Level 2 Module Module Module Level 3 Level 4 Level 5 modules modules payload launch mass
Pak-64 2.4 x 2.4 mx 25 m 48 12 4 - - 1 t 97 t
Pak-128 2.4 x 4.8 mx 25 m 96 24 8 - - 2 194 t t
Pak-256 4.8 x 4.8 mx 25 m 192 48 16 (12) (4) - 4 388 t t
Pak-512 8.4 x 9.6 mx 25 m 384 96 32 (24) (8) [6] [2] 8 t 784 t
Pak-1024 9.6 x 9.6 mx 25 m 768 192 64 (48) (16) [12] [4] 16 t 1578 t
Pak-676 8.0 x 8.0 x 25 m 508 131 36 (27) (9) [6] [3] 10 t 1031 t
Pak-289 5.0 x 5.0 mx 25 m 225 48 16 (12) (4) - 5 388 t t
Pak-169 4.0 x 4.0 x 25 m 121 36 12 (10) (2) - 2.5 t 255 t
Pak-100 3.0 x 3.0 x 25 m 75 21 4 - - 1.5 t 151 t
Pak-36 1.8 x 1.8 x 25 m 27 8 1 - - t 0.5 54.3 t
Pak-25 1.5 x 1.5 x 13 m 16 4 2 - - 0.2 t 2.20 t

The evolution of the concept

We already explained the basic concept was developed in 1971 and 1974 and developed with 4 million DM from the research budget of the BMFT the engine. The then published engine parts also correspond to those that appeared in 1980 in the scientific literature. However, there was a change in the type of bundling.

The first proposals, in 1974, yet the technology developed by Research saw, even before a massive engine bundling, however a common tank.

Engines of 36 should sit in a common tank of 2.54 m in diameter. The thrust of one engine should be depending on tank length up to 75.2 kN. The thrust would have been dependent on the length, which means that the pressure for longer fuel tanks would have been higher.

The first stage would be after these plans have been about 24 meters long and would have essentially consisted of 6 modules, each with 36 engines. The second stage would be about 16 m long and should have been made also 36 engines. It would have been surrounded by the 6 modules of the first stage. The third stage should be different from the later concept of OTRAG be positioned on the second stage and only 8 m long, with also 36 engines. Here, the author of a magazine data reconstructed rocket. She would have had a payload of 10 tons in a 200 km high circular orbit. The takeoff weight would be 978 tons.

Assembly of a module
Level 1 Level 2 Level 3
Engines 6 * 36 = 216 36 36
16 245 kN thrust 2008 kN 1035 kN
Length 22 m 13.9 m 8.1 M
Diameter 2.54 m 2.54 m 2.54 m
Take Off Weight (estimated) 831500 kg 94900 kg 51 100
Empty weight (estimated) 76800 kg 11900 kg 9700 kg
Burn time 113 seconds 112 seconds 112 seconds
specific impulse (estimated) 2433 m / s 2709 m / s 2800 m / s

Later Lutz Kayser is the concept of a large tank and come off as well as the use of individual tubes tanks. The reason is mainly the flexibility, because you can combine virtually any number of units and can adapt the missile payload. Technically, of course, a large tank is much easier because the surface is smaller, but went to the OTRAG rocket it is not the best technically but commercially best solution. When OTRAG plays, of course, another point important: How much does the installation for the production? A plant which produces large tank is also big and expensive and thus increase the development costs, though perhaps later, the production costs are lower.

Many innovative concepts were pursued initially Kayser phased out. So should the tanks are manufactured in the spiral welding process. It then went on to "normal" deep drawn steel tubes. Also, different size modules, different engine types and a start of a 20,000 tons ship was not pursued. (Considered as an alternative, after being expelled from Zaire). Over time the module is simpler and more uniform.

On with the engines, there was an evolution. It was essentially in the early foregone blend Diesel / nitric acid (which can vary in test launch has by something other hydrocarbons (kerosene, JP-1) or nitrogen oxides (nitric acid is nothing more than an aqueous nitrous oxide solution) tested. Was at the performance however, it is permanently downhill towards lower drawers. Of the 75 kN which one 1974 approach instead, out of 25 kN in the 80 s. Again, the development and production costs involved. The higher the boost the more difficult the use of ablation for the cooling of combustion chamber and nozzle.

The first rocket was launched in Zaire, still had conventional aerodynamic fins. 1979, has tubular fins used for stabilization. There was no further change it in the length of the modules. In the plans in the 70 years for smaller payloads still versions of 12 m and 18 m long tanks were provided. Subsequent plans continued due to the lower full / empty mass ratio to a uniform height of 24 m for the tanks.
Leased premises of the policy OTRAGDie

Pretty soon got the OTRAG together the money for the development and could go even 2 years after the founding of the planning of a start. The most important person in the

OTRAG were to Lutz Kayser (CEO) Frank Wukasch (Chief assistant and successor, the Board), Bayer (manufacturing), Mok (Flight Mechanics), Bierman (telemetry), Niviadomski (electronics), Statezny (engine development and launch facilities), Ziegler (starting line). Kurt Debus was the representative, but less influential post of chairman held. Legally, the OTRAG been a public company, but other than shares, but in the hands of about 1000-2000 silent partners. Kayser was entitled to 3-5% of net profits. From 1974-1976, they developed the engines and modules. At the same time you looked for a suitable launch site. Already at that time there was resistance from the established groups and scientists oppose the concept. MBB then sent one of their best people, Dieter Koelle, on lecture tour by ranting against the concept. Others considered, even if the rocket would fly successfully, it is not economical in view of the space shuttle was to revolutionize space transportation since 1980.

A launch of the rocket OTRAG different in Europe because of population density from the start. Kayser came in 1975 in negotiations for a starting place with several equatorial situated States. (Zaire, Brazil, Uganda, Singapore, Nauru). Also we tried to Debus a start from the U.S. to reach out, but without success. Ideal would be a start for Kayser ideas in Indonesia have been, as it is an equatorial area of many islands, where the rocket stages would fall into the water. An equatorial launch site has the advantage that it can carry much larger payloads into geostationary orbit. Therefore start from the Ariane rocket from French overseas department of French Guiana. Spoke against Indonesia in particular the great distance of 14,000 km to the production of the rocket in Baden Wuerttemberg.

Kayser got after just 10 days a commitment by the dictator Mobutu, head of state in Zaire. (Now the Democratic Republic of Congo). A contract was concluded on 09.12.1975 and on 03.24.1976 published. 1976 he leased a 100,000 km ² launch site in the province of Shaba until 2000. (100,000 km is almost the size of the former GDR). The size was by Kayser information necessary to ensure that the burned-out stages at the equatorial launch as polar fell in uninhabited country. In return 5% of net profits to Mobutu had to pay and launch a reconnaissance satellite for Zaire in vain. This should allow a telescope to detect any point in Zaire with 1 m resolution in real time. It is open whether it would ever come about, even if the rocket OTRAG been operational. Finally, there was only time reconnaissance satellites in the U.S. and the USSR. But they had determined not built for Zaire. Some sources also speak of it, that the following intervention by the Soviets because of that satellite reconnaissance was carried out, as the monopoly of the superpowers would have been broken and, in particular Zaire, Angola was ruled neighboring socialist.

Other sources also speak of a fixed annual rental of $ 50 million when the company made with the satellite transport profits. Those reports contradicted the OTRAG. The lease was irredeemable and included rights that go far beyond the police force went out, as the opportunity to relocate residents or exploit any natural resources.

Test Site in ZaireZaire offered ideal conditions for the start in geostationary orbit, as it lies on the equator. Launch site was a 1300 m high plateau at Luvua river. The launch platform was located on the edge of sloping cliffs several hundred meters. But first the land had to be developed. The first thing we built, so it was a landing strip for airplanes.

Since late 1976 there was a 2100 m long and up to 40 m wide runway, and it stayed around 10-20 OTRAG technicians permanently in Shaba. They lived largely in primitive conditions in tents. Most were not rocket specialists, but masons and carpenters who first built the launch facilities required. The OTRAG became the major employer for the sparsely populated area with about 100,000 residents in the 100,000-acre lease area and employed up to 450 natives. two decommissioned aircraft Argosy material transported to Zaire. For this purpose they founded a separate subsidiary company called OTRAS (OTRAG Range Air Service).

In the West, two were criticized on the deal. To be the one with the dictator Mobutu Kayser took in rather than look for a launch site in a democratically governed country. Second, there were complaints that the rights had OTRAG in the field, which actually fell to the only other state such as Residents to relocate. There was talk of "modern colonialism." What was really behind it was the right Bushmen who approached before the start of the launch site to take up, and bring them to safety. As the OTRAG should manage 40 employees an area of 100,000 km ² "colonialist", as some newspapers speculated, was not answered, however. But in the surrounding states saw it differently and it began to ferment slowly.

The first launch of a module took place on 5/17/1977. This first rocket had 4 modules of 6 m length. There were massive political pressure on South Africa, East Germany and the USSR. Pravda and TASS headlines in the autumn of 1977 several times with agitation against the OTRAG. This would be on behalf of Germany there launchers develop nuclear weapons and there in the OTRAG Debus worked, who had worked at the A-4 in Peenemünde, of course, remained the Nazi charge that was used more like the USSR is not sufficient . Unconfirmed reports that the Soviets are even specially observation satellite Cosmos 922 and 932 have started to photograph the OTRAG launch site. The orbits of both satellites led to the best viewing conditions, at least over Zaire. The author believes it would be much more easily have been operated by the communist-ruled Angola Nachbartsaat using aircraft reconnaissance and Kayser reported by MIG-23, flying at low altitude over the launch site.

kayser runway while always stressed that the OTRAG would be inappropriate as a ballistic missile, because they have insufficient accuracy, would have believed him, this has none. Also required a OTRAG missile launch preparations extending over several hours. On a request of the Bundestag Norbert Gansel, the then Federal Government responded in 1978: "After we realized that the rocket is capable by their design features not for military purposes.".

In an interview with the magazine "Transatlantic" Kayser revised 1980 this ruling and stated that the rocket would not immediately ready to start, but much more targeted than a solid rocket, because they would be taxable.

On the other hand, the OTRAG for Mobutu was so important that arrived on the third start Mobutu himself. Like most of these demonstrations went wrong at the start 6/5/1978. The rocket began shortly after starting to turn to the side and struck soon back on the floor. Kayser has a different opinion and talk of a test of the thrust control that led to the tilt of the rocket and evaluates it as a partial success (50%). The cause was a valve that is stuck in the 40% setting that led to a thrust asymmetry. The deviation of the rocket to the left is clearly visible in the figure below.

The OTRAG was just a pawn in the chess game of the Cold War. Zaire was then one of the few Western-oriented countries in Africa and with the OTRAG and the alleged threat to neighboring countries by missiles would be propaganda against the West. The Russian propaganda, resulting effects. On 05/04/1978, the socialist government of Angola had an influence in the UN because of a new wave "Zairean attacks" and published in the same month Nigeria's largest daily newspaper "Daily Times" an article which was directed against the threat from neighboring Zaire by rockets. On 1 June 1978 said the Prime Minister of Angola by a threat to his country by the "West German rocket testing station. When Helmut Schmidt was touring through Africa in June 1978, he heard all the complaints about OTRAG. In August 1978, the Mirror quoted Chancellor Helmut Schmidt as saying: "I could turn around the guy's neck." In the fall of 1978, Brezhnev himself was under Helmut Schmidt made representations.

Launch preparations in ZaireKayser believes that Chancellor Schmidt had personally forced Mobutu to solve the lease. Mobutu was to receive extensive compensation in the form of development assistance. Other rumors speak of political pressure from France, which feared for the German participation in the Ariane and concerns had to because of the competition Ariane. No matter what triggered (1977/78 there was also the Katanga rebellion coming from Angola, was in the area in which the OTRAG their starting base). Mobutu announced the really non-cancelable contract on 15/04/1979. You had to leave Zaire. But it was not thrown out, but you could fly out the entire technical equipment.

7 OTRAG employees came in the summer of 1979 at a company outing, Frank Wukasch called "spin" on your own, on the river Luvua killed. Although they explored the river from the air, but lost ground on the orientation. They died when they were sailing without life jackets and other safety measures in a boat in the river and a wrong turn on a 30 m deep rushed down a waterfall and drowned it. At least some survivors told the author doubts about the official version.

The optimistic plans: for 1979 a start of a two-stage rocket and 1980/81 for an orbital test were to hold no more. Frank Wukasch was again in talks with Brazil and was looking for an island in the Pacific that could serve as a starting base. At times even the launch was a 20,000 tons ship (a precursor of Sealaunch) considered but abandoned as too expensive. In an interview he stated that they had lost at least 6-12 months by the loss of starting place.

They found a new launch site at Tawiwa, 600 km south of Tripoli. Libya was elected, according to Kayser, because it is independent from its oil fields was. But the call of Kayser and OTRAG it was even less conducive than Zaire. Finally, ruled at that time pursued Gaddafi and an anti-Western course. There was already in August 1981 meetings between Libyan and U.S. Navy fighter pilots. The neighbors felt threatened by Libya and reconnaissance aircraft shot down over Libya from its territory. With the move to Libya, the OTRAG disappeared from the public. It was released no more details about the test flights.

In August 1980 was agreed upon production in Stuttgart-Vaihingen and the administration in Neu-Isenburg in a new plant in Garching near Munich. Press reports from that time spoke of a too large area for a company that only had about 40 employees. Unofficial reason of the move was the outstanding property and business taxes in the millions owed to the city of Stuttgart. Each employee received DM 10,000 for the move. OTRAG OTRAS also had in addition to subsidiaries in France (OTRAG France), a time in Zaire (Zaire OTRAG) and was also a planned U.S. subsidiary. Critics called it a mania of Kayser, because before we had even launched a rocket that made these offices no sense. In the course of 1980, took over the function of Wukasch Kayser as chairman of the company. Wukasch led 31st IAA Congress in September 1980 a 25-minute film about the OTRAG before and seeking new capital, after the development had been swallowed up 145 million DM and it was estimated that 660 million needed to start to an orbital version. 10-12 orbital launch, there should be from 1984 to 1990. 1981 there should be a test with a two-stage version in 1982 starting with 48 modules and 1984, the largest with 10 tonne payload version should be available.

The reason for his involvement in Libya, according to Kayser was the ability for small sums insured against liability for personal injury, that the Sahara as the preferred starting point. The Outer Space Treaty imposes a civil liability insurance of $ 200,000 per person and the Sahara is one of the least populated areas on earth. This insurance is also a reason that most of the space stations are at sea. Also hoped to escape so the reconnaissance satellites of the Soviets.

Other sources however say that he at least hoped for a deal with the Libyan military to make. At least for the first time on 03.03.1981 Libyan generals were present. Kayser acknowledges that there was interest on the part of the Libyan military and also attempts to influence the experiments. Whether the election of Libya was a folly, or appropriations by Kayser Libya promised, will probably not be resolved. In any case, he increased the difficulties of OTRAG domestically. In an interview he gave in a television movie, he readily admits that he thought that it could not prevent the proliferation of high technology to developing countries and he would have no problem to transfer the technology to developing countries. In hindsight, he acknowledges that the Pacific might have been better. The launch site was located in an oasis in the Sahara, 600 km south of Tripoli, and was called "Camp Tawiwa. It was located at 27 ° 02 '00 "North and 14 ° 26' 00" East.

Startin Libya took place in Zaire only start from smaller modules. They went from 7.ten start (the fourth in Libya) even 4 engines back on one. By increasing the concentration to 16 and 32 engines, start a small orbital version was not more talk. According to Kayser reduce to the influence exerted by Libyan military. It went to Lutz Kayser now is to optimize the parameters of a module and to reduce costs, business is only one engine per attempt.

The first launch from Libya took place on 03/03/1981. There are different reports about him. Kayser even described him as a great success. (However, Kayser also called the false start earlier than 50% success). The then OTRAG engineer Christoph direct reports, however, that the rocket after 21 seconds was set aside because the cylinder-shaped payload was probably too heavy. Announced after the start that the tested version 4 module a payload of 400 kg in 80 km altitude and can take 100 kg in 230 km altitude. At least with this starting Libyan military was present. Kayser is a total of 14 launches were made at the time he was still in the OTRAG. But these are not verifiable, because now the public was excluded.

In the spring of 1981, there were reports in Moroccan newspapers and The New York Times that Libya and the OTRAG had signed a contract for the supply of medium-range missiles. The OTRAG denied the existence of such a contract. The Space Digest (forerunner of today's RSS feeds) reported on 29/12/1981 that the OTRAG has halted its activities in Libya for 2 months because there were internal conflicts.

When Kayser refused by his own admission, to develop a two-stage version, the entire production confiscated end of 1982. Kayser had to vacate his seat as chairman and Frank Wukasch took over the business of the OTRAG. After the confiscation in Libya, about 20 engineers and technicians for several years continued to be employed and paid by the Libyans. The OTRAG left the country with Kayser.

In Libya, were again held startup. These were carried out by the Libyan military. The author is aware of launches have taken place yet 1984th However, the rate increased sharply after 1984 and the last starting in 1987 will be made. As Kayser left Libya OTRAG had been there for 400 tubes, the tank then fired probably gradually. 10 years Kayser litigated against the Libyan government to get compensation. This work starts with even higher fuel pressures to increase the specific impulse. Obliquely launched at an angle of 71 degrees achieved partly loaded (50% fuel instead of 66%) OTRAG missile has a range of 50-70 km. Here are the dates of 12.ten under Libyan Director launched the module:
Flight Results 12 20 May 1984 Unit
Empty weight 185.00 kg
Pack weight 240.00 kg
Oxidizer length 4.34 m
Length 1.65 m Fuel tank
Oxidizer pressure 37.00 bar
Fuel tank pressure 40.00 bar
Oxidizer filling 52,00%
Fuel tank 53,00%
Vertical launch angle 70.50 °
Start azimuth angle 216.00 °
Flight results

Thrust during lifting 3.00 tonnes
Burn after 32.00 sec
Burn out at 3.00 mach
Total flight time 3.00 min
Impact after 50 - 70 km

After an internal dispute Lutz Kayser left OTRAG 1982. On 10/04/1982 reported Aviation Week & technology that is now trying OTRAG under the sole direction of Frank Wukasch her troubled relationship with the German government to clean up and is now focused on the development of sounding rockets as an intermediate for the orbital version. A single module can bring in 50 200 kg or 30 kg km altitude in 90 km altitude. A two-stage version with 6 modules and a first module, the second stage is 500 kg in 280 km height or 50 kg bring in 655 km altitude. Wukasch acted smarter than Kayser. As mentioned, the Soviet propaganda made against the company and even some U.S. media participated in it (In March 1978, Ted Szulc-shifting in the men's magazine "Penthouse", which was developing a OTRAG "V3" from other African countries). Of course this led to reactions from the German government. Kayser reported each wanted to know (or not) as he was being followed by the German government, rather than the posts directly to write to find a solution beyond the public). Frank Wukasch knew that a confrontation was futile for such a small company and changed the company policy - First of all cooperation with Germany by the OTRAG offered as a sounding rocket - so do not compete with Ariane. The following options were provided:
1-6-P 3-9-9-P 4-P 3-6-P 2 4-6-6-9-P2 P2
Module level 1 1 3 4 3 4 6
Module Level 2 - - - 1 1 1
Total length 9.4 m 14.1 m 14.1 m 4.4 m 15.1 m 14.4 M
Diameter 0:27 m 0.58 m 0.64 m 00:58 / 0.27 m 0.64 / 0.27 0.98 m / 0.27 m
Payload length 1.4 m 3.1 m 3.1 m 1.4 m 1.4 m 4.0 m
like cylindrical 0.5 m 1.1 m 1.1 m 0.5 m 0.5 m 1.5 m
this peak 0.9 m 2.0 m 2.0 m 0.9 m 0.9 m 0.9 m
Diameter 0.64 m 0.64 m Payload 00:27 m 00:27 m 12:27 m 0.98 m
Maximum payload weight: 200 kg 250 kg 300 kg 250 kg 350 kg 500 kg

No text but it was too late for a turnaround. The program then trickled out slowly, mainly because there were problems within Germany. The tax authorities and the Federal Financial Court said the OTRAG from the profit. Thus, the OTRAG had become less attractive for investors, for now fell off the write-offs, had alienated If the move to Libya to investors not previously, the OTRAG was now in any case not more new money. The technical development was halted.

There was still a start, led by Frank Wukasch at ESA in Kiruna (Norway) in 1983. This was successful, and started experiments and the RWTH University of Munich. However, the parachute opened and so was not the instrument capsule lost. Kayser's company was liquidated in 1986 by the shareholders.

Until then, the carrier rocket development swallowed up 150 million marks, of which

25% each for the activities in Zaire and Libya. Lutz Kayser expected that the development of a rocket would have required at least 500 million DM. These funds were compared to 18 launches of missiles from 2.5 to 10 tonnes thrust. Thus, the development was a lot OTRAG ineffective as the development of the Ariane. The cash flow is extremely high for a company with no more than 40 employees. But Lutz Kayser had a private jet with pilots, a villa on the Costa Esmeralda and a motorboat. Even if everything was just rented, you can see from Articles of the 70s that Mr Kayser was living the high life.

The authorities in Switzerland and Australia imposed a travel ban in 1997 to Lutz Kayser. They referred it to a written agreement between Libyan authorities and Kayser, who had them leaked to the CIA. It appears that Kayser reportedly still working with Gaddafi on missile program. Officially worked Lutz Kayser, who lived for 10 years after its expropriation in Tripoli, in the development of solar chimney power plants. He had the rank of professor in 2002 and was a Director of Technical Education at the Libyan Academy of Sciences.

was sentenced in 2001 to OTRAG came again indirectly into the headlines when a former employee of OTRAG for illegal shipments of missile parts in the years 1991 to 1996. However, they are not related to OTRAG and found only after the end of the trials held in Libya.

Kayser then pursued further theoretical work on the carrier system with basic research in physics (calculation of atomic and nano-structures and their dynamics), solar seawater desalination and atmospheric solar chimney power plants. Lutz Thilo Kayser now lives in San Mateo, Florida. He is CEO and president of the company, "von Braun Debus Kayser Rocket Science LLC, based in Wilmington, Delaware, USA. He tried the technology of today OTRAG to market in the U.S.. According to Kayser was to bring von Braun and Kurt Debus target the technology in the United States and therefore he has used this name for the company.

The Corporate Law (Corporate Law) in the State of Delaware is for entrepreneurs and operators of the cheapest in the United States. Delaware therefore has registered 700,000 people in 200 000 companies. An LLC (Limited Liability Company) is a particularly convenient form of a "single-member", in which are primarily the registration fees very low. Von Braun Debus Kayser is the Rocket Science LLC for Kayser information therefore gives only a cloak to transfer the license rights to the U.S. for the possible future introduction of CRPU mass production and their use in commercial space launch vehicles. Kayser has not been the OTRAG paid for his inventions to be and still own the rights to them. Frank Wukasch, successor of the board of the Kayser OTRAG remained of the view that the rights in the developments in OTRAG still lie with the shareholders of OTRAG. Since there is no longer the OTRAG, this question is only of academic interest.

In June 2005, the small company, Armadillo Aerospace, which works known to LOX / ethanol-driven systems for suborbital manned flights that Lutz Kayser has left them a injector for the engine and you are excited about the concept. However, you want to try it with hydrogen peroxide / kerosene, a fuel combination that is not much better than nitric acid / kerosene is for a low density, so more of a step backwards as progress.

Test of InterpribtalIm 2008, the company announced interorbital that Kayser she advises on the drive technology. Your new class of "Neptune" missile uses the OTRAG engines and the module concept, where the published data can recognize this. There are only minor changes. So now is the shape of the rocket cloverleaf-shaped and the first stage is discarded in the form of external beams. The second and third stages now seem to exhibit real jets. The thrust lies in the region where one was already in the OTRAG: 6000 pounds, about 27 kN. Videos show test runs (though only about 9 seconds burn time) and a start of a CRM configuration 8offensichtlich in 6 m), with this tendency, but from the start itself. Whether this is intentional or not is hard to say. Again, the module was burning only a few seconds.

It seems to have been considerably increased the payload - A 33 CPMR carrier "Neptune 1000" added a payload of 1,000 kg into a polar orbit - was needed to OTRAG times to even 64 modules. There is now four stages (first stage of 24 modules, six second. Two as a third and a module as the fourth stage. Thus the company hopes to win the Google Lunar X-Price. A larger model "Neptune 4000" will be tourists for 5 bring millions of dollars for a week in space. If you are fast can secure a ticket for the spot price of $ 250,000!

What failed the OTRAG?

The OTRAG was a pioneer of private rocket construction and also shows how to do it. On the technical concept

On that opinions are divided. Some think it's awesome, others believe that not enough power to carry a payload into orbit.

Advantages of the concept

The massive concentration leads to a high production rate and thus lower manufacturing cost per piece - According to the law of series production. Since the whole construction is very simple, it can also be produced efficiently. Partly as technologies from other areas were included, so that one could build on already inexpensive mass-produced parts.

In the tanks the OTRAG said, for example by a reduction in production costs by 95% for the staff cost shares of 20% instead of the usual rocket 80%

In addition, one needs only one engine for a rocket to a very wide load range covers. If the rocket ever fly so it would certainly be the cheapest and most scalable carrier ever built.

Another advantage relates to the available space for the payload. A disadvantage of the current carriers were developed as the OTRAG was, was that these were more powerful booster by, but the last stage that the diameter of the payload envelope is not dictated by growth. A very important factor in the development of the Ariane and the Space Shuttle, it was so much space for the payload to provide. The Ariane 5, this is even more striking.

When OTRAG rocket payload fairing will automatically wider if you use more modules, since the rocket is always high, but increases the diameter of the rocket. However, it is likely that this is not adapted to any adjustment of the diameter of new modules, but is likely to offer a range of standard types.

A disadvantage of the air resistance at this rocket is larger than other types. This is one reason why the initial acceleration of OTRAG was so high that it happened as quickly as possible the dense layers of the lower atmosphere.
The disadvantages of the concept

Even if there were, according to the OTRAG over 6000 tests of the engines on the bench

but it is quite another to launch a rocket, especially if one has so far been tested only single engines, and now 500 are fired at once. On the concept already existed in the 70's strong criticism. The DFVLR examined it and came to the conclusion that the financial success is questionable. With the technical approach is employed Prof. Ruppe. He came to the conclusion that to be too optimistic on the one hand the details of OTRAG and it is questionable whether it is technically feasible. Other experts complained numerous "white spots" in the concept, that is completely unresolved aspects of the support. Here are some personal considerations which must be assessed critically in this rocket.
POGO effects

Start No. 15 Photo 1The construction is very susceptible to POGO oscillations. POGO oscillations in rocket technology feared because they can not be simulated on the ground. Several rockets were suffering from the first flights under POGO oscillations, the Titan, Saturn V and the Ariane. Is caused by engine vibrations which are transferred to the tanks and bring the liquid to spill. This then amplifies the vibrations again so that it may in extreme cases to a fraction of the structure, as it happened in the second flight of the Ariane first

This affects almost only first steps because they have very long tanks. In addition, the phenomenon usually occurs only after some time when the tanks are no longer full. Looking at the OTRAG rocket, so the tanks have a length of up to 24 m and a width of only 0.27 m. Representing a ratio of 80:1 means of length to width. In contrast, rocket stages, it is from 4:1 to 8:1. Furthermore, the tanks are already at the start only partially filled with fuel. Speaks against a vulnerable print promotion. There is no turbo pumps and portable engines, which come as sources of vibration in question.

All tests which has made the OTRAG were relatively short modules (6 or 12 m length) instead. The shorter due to their length do not react quite as sensitive. It should also take into account that the tanks are very thin and, therefore, a break is easier. Kayser himself admits that the construction of long steps (18, 24 m) is only possible by pooling of many engines. Even without POGO oscillations otherwise the construction is not stiff enough.

On the other hand, the rocket built entirely differently than other types and is constantly expanding the more modules are available. This can have an impact. It will probably be in the OTRAG rocket as with other missiles: for the first show for how the rocket behaves.

The N-1 effect

Start No. 15 2It image is a mistake to believe an engine, which we have extensively tested on the ground would be flight-qualified so automatically. The European space exploration has bitterly during initial launch of the Ariane 5 ECA experienced, not as the Vulcain 2 engine in flight withstand the pressures, although it was extensively tested on the ground before.

Another improvement is the bundling of engines. Each engine also indirectly affects the other. It transmits vibrations it gives off heat, it loads the structure. The best known example of the consequences is the Russian moon rocket N-1. Their engines have been tested extensively on the ground and were considered flight qualified. The block A, the first stage with 30 engines, but has no one tested as a whole, because it was the cost of a test stand of the enormous thrust force of 46000 kN has wanted to save. This took revenge. All four launches of the N-1 failed because of problems with the block A.

OTRAG The rocket is the same problem: only here it is up to 500 engines are ignited at once. Unlike other missiles, it is not possible to test the engines before the start: After a test run, the ablation layer melted away and the engine scrap. A single test run on the ground of a 500 engine beam is thus quite expensive. Probably could not afford OTRAG also be capable of this test stand. (500 engines a takeoff thrust would result in up to 17 500 kN, 15 times more than have a test stand for the Vulcain engine of Ariane 5 start to load).
Engine failure

Start No. 15 Image 3Ein Another point concerns the effects of engine failure. In the experiments until 1974, there were 3 failures in 200 trials. Later, it was only known that there should have been more than 2,000 tests, but no success rate. 3 failures in 200 trials is a standard in rocketry size that I want to talk to include in the considerations.

At first it seems a Triebwerksaufall a rocket with so many engines is critical. If only the loss of thrust, this is also unrestricted. What one should not forget: Since each 2 engines are attached to a common tank, remains on premature shutdown still a lot of fuel that is not used and then changed the full / empty mass ratio.

In other missiles with multiple engines, you can catch the engine failure by the other can burn longer. This happened, for example, the mission of Apollo 13 when one of the engines turned out the second stage. This possibility OTRAG the rocket did not.

For the 4 ton version with 256 engines, I have times the probability and consequences of an engine failure for a confidence just 99%. (A loss in 100 firings) The amendment to the empty weight is for the "worst case" scenario, that the engine failure immediately after the ignition:
Level number engine failure probability of a change in idle speed changing mass loss of payload
1192 85.5% 4.7% -27 m / s -75 kg
2 48 38.3% 18.8% -97 m / s -260 kg
3 16 14.8% 56.3% -497 m / s -1350 kg

Start No. 15 4Es image reveals the following: Although the failure of one engine in the first stage is relatively likely and should occur in virtually every mission, the impact is yet to begin. A cushion of 100 m / s, however, is today the exception rather rockets and a cushion of nearly 500 m / s corresponds to a reduction of the payload by a third.

This means that the rocket OTRAG start with either a very large safety cushion needs, or any 6.te start going wrong statistically. In a reliability of 99% you would have at least the first two stages also examine the probability of two engine failures.

This bill is not even considered that it will turn off when engine failure, the opposite in order to maintain the boost symmetry. Makes you double it, then the impact.

Kayser gives true that the engines were qualified "6 Sigma". But these are only a criterion from the production, that indicates that you have during the preparation of a committee of about 3.4 parts per million. This does not mean that fail during the flight so few engines. Finally, there was at 18 OTRAG launches two false starts at only 4 or one engine per start. As the sum can be simplified to say that the OTRAG rocket engines with 100 times more than conventional construction also provides 100 times greater demands on the reliability of the engine. Lutz Kayser is sure that the engine is so reliable.

Already formed in the control fuel residues are immense. Each rocket must be after the start of the horizontal plane be diverted to the vertical. When do you OTRAG this by shutting down the engines on one side to 40% thrust. Here, too, remain fuel residues. These are relatively large: Assuming that the same top speed as OTRAG rocket Ariane has to reach, so expect it back, that the first stage would still have about 5,000 kg residual fuel in the stage separation.
OTRAG was tested systems engineering

What was the OTRAG never reached the full test of a carrier. De facto, all tests are only tests of individual engines under flight conditions. In principle, we have developed a rocket height of the lower power class - but no launcher.

The thrust vector control of, the shutdown of engines in case of failure, the whole scheme of hundreds of engines, the stage separation and the entire control. All this was never tested. Not for nothing was Lutz Kayser, the financial cost of developing a launch vehicle with 500 million DM. It is expected that there would be still some setbacks.

In other rockets there is a big step from one engine to a reliable missile. There are, in this age of computer simulations, and even companies with decades of experience setbacks, for example, was at the Delta III, the set after 2 miscarriages and a partially successful demonstration launch.

In a completely new concept to me unproven technologies, the risks are very high. Today the trend is to use less engines. Ariane 5 has only 4 engines instead of up to 10 4 in the Ariane The Delta 4 is a maximum of 6 engines instead of up to 12 2 in the Delta This is to reduce the reason the possibility of error.
Control

The control of the rocket as OTRAG was written by throttling an engine. It is therefore not possible to regulate the thrust arbitrarily fine but only in fixed steps. Conventional engines swing the other hand, their engines and can thus influence the direction of thrust fine.

The whole thing is like comparing analog and digital: If you have a lot of engines in order to vary the push is really matter because you can dispense with the many fine engines, the thrust. If it is turned down by a rocket, an engine 128 modules at 40%, so this affects the thrust in the first stage by less than 1%. The smaller the steps, however, be greater the effect. 4 modules for this already makes up 15% of total thrust. When hanging the third Test in Zaire, a valve in the 40% position, the rocket was shot from the start, immediately to the side as you see in the photo sequence.

This approach is useful so only for large missiles. But even upper stages have their course can change. It appears therefore not practical for upper or smaller missiles. This problem have been underestimated in the development well. There is a second problem: The long partially filled pipes is the focus of the rocket is very unfavorable. When you first start in Libya was part of the payload and the rocket tilted too heavy after 20 seconds as part of the fuel was consumed, to the side and pitched on the floor. This problem may also occur in the upper stages, the need to transport a heavy payload. The cold gas system which would take over the control about the roll axis was never tested.

Professor Ruppe in an investigation showed that the engines are very slow because of the high pressure. He held the rocket because of this feature for non-controllable, because you could not react fast enough. Lutz Kayser explained that the false start on 05.06.1978 and the engine was too weak (100 W) and is at least a 150 W motor needed. All subsequent starts took advantage of the possibility of the thrust vector control to no use. This control has never been successfully tested.
Notes on the data
Full and empty mass

The author has built no technical descriptions of the OTRAG from the time than they do. Newspaper clippings from this period appeared mainly in popular magazines and contain very few technical details. In August 2005, I Lutz Kayser has contacted personally and send me information by e-mail. This could see much better than they expected for such a massive construction. There are also some inconsistencies which I will explain below.

No text at first I got a 16 meter module, the following data:

* Pack weight: 1500 kg
* Empty weight: 150 kg
* Thrust (Central) 20 kN
* Burn time: 120 seconds
* Specific Impulse 2648 soil
* Specific Impulse Vacuum 2913

Kayser writes, as I did on older data instructions which is 15% empty weight of the speech (a plausible value) that this refers to the 18 M based version, the 12 m version would be set at 18% and the data that I would get would be for the 24 m module. But even these data are not coherent:

Length 24 m 18 m 12 m
Fuel 1350 kg 1012.5 kg 675 kg
93.2 kg 69.4 kg tank 45.6 kg
Engine 65 kg 65 kg 65 kg
Takeoff weight 1508 kg 1147 kg 790.6 kg
Empty weight 158 kg 134.4 kg 110.6 kg
Empty weight% 10.5% 11.7% 14%

I have something to play with the numbers. Although one can increase the weight of the engine to get to the specified Kayser values (with a mass of 105 kg is achieved, for example, the specified 15% empty weight at 18 m and 18% no mass at 12 m length), but then right again the values are not for the 24 m version.

Considering that the tanks an extremely unfavorable volume / surface ratio, and have also been filled only partially, the structure masses are very optimistic. Here again for comparison, the data of the European Colleges Astris, which is in approximately the same mass and thrust range:
Parameter module OTRAG Astris
Pack weight 1508 kg 3370 kg
Empty mass 158 kg 600 kg
Thrust (Central) 25 kN / 20 kN 22.96 kN
Empty weight% 10.5% 17.8%

Preparations for start 2Ein similar to full-empty weight ratio also have other levels of this magnitude. A value of 10 usually reach only levels of about 30 tons of mass. In an orbital version would have to bear the additional load modules surrounding the inside steps, this is an additional burden to the still affects one side, one on the inside of each module. Is increased but the tank thickness of 1 mm, as it was in a 1979 report, the empty weight of a 24 m modules to increase from 158 kg to 251 kg and the result is the empty weight specified in earlier publications share of 15%. A checked in Libya module with only 6 m in length had been an empty mass of 185 kg on, unfortunately, is not known how much of it was spent on the payload.

Published in 1979, Harry O. Ruppe in his book "The boundless dimension" Volume 1 all other data: A 4-chamber unit of 24 m length should have the following data:
Size OTRAG Ruppe
Fuel 1350 kg 1176 kg
Gas pressure 28 kg
Residual fuel in 11 kg
Takeoff weight 1508 kg 1361 kg
Empty weight 158 kg 197 kg
Specific Impulse 2648 m / s 2276 m / s

The OTRAG leaves fuel residues and compressed natural gas under the carpet. In fact, the Air weighs in a 24 m module (with a 2 / 3 filling) kg at a pressure of about 40 Bar 22nd Fuel residues that can not be used there in an order of magnitude of 1% on each rocket. They must be considered in the mass and this one does in other missiles.

While blowing the gas pressure in the fuel, creating a low shear (270 N initially, in 13 seconds to 135 N to low). But this is usable? The missile has no OTRAG adaptation to zero gravity decreases Once the thrust begins Furanol with the kerosene mix and the next stage can not be ignited. A staging must be done so long as the push still does not drop, just before the end of firing of the outer levels.
The specific impulse

Kayser is a specific impulse of 2648 m / s on the ground and 2913 m / s in vacuum on. These values would be for this combination of fuel a record. I have to compare the performance once the engine RD-214 indicated the Kosmos booster rocket, which works with the same mixture:
Parameter OTRAG engine RD-214
KN 730 kN thrust 50-50
Chamber pressure of 10-30 bar 43.6 bar
Final pressure 0.7-2 bar 0889
Combustion chamber / Final pressure 15 52.3
Specific impulse ground 2648 2255
vacuum specific impulse 2913 2590
CEA: theoretical pulse vacuum 2474 2739
CEA: theoretical ground pulse 2135 2541

Although the pressure drop and the RD-214 is much larger (52.3 to 1) instead of (15 to 1) and the engine always operates at the optimum pressure, has the engine from the OTRAG a higher specific impulse, so a higher quantity of energy burned kilos of fuel on . This is the data for the mixture HDA / kerosene. The mixture of nitric acid / kerosene is a little worse, but not much (about 30 m / s).

I have published by the NASA CEA program that allows you to calculate, among other things, the theoretical performance of a rocket engine under given boundary conditions, fed with data from the OTRAG and RD 213th As used in this program an idealized rocket engine in which it eg There is no need for cooling, a real engine always worse than these theoretical values. You can see that the RD213. It is a slightly better specific impulse (difference 150 m / s) obtained in the simulation.

Start 2 nachtsWie is different here OTRAG the engine! It operates with a lower chamber pressure and a higher nozzle opening pressure, and yet it has a higher specific impulse! Yes, the specific impulse is even higher than for any engine that was ever built with this fuel combination. Even upper level with a much higher expansion ratio have less value. But these values are not verifiable with CEA.

They are also verifiable from the data of the engines. If a module such as a fuel mass of 1350 kg and kn given a boost of 25 knots, decreasing linearly to 15 has at a burn time of 120 seconds, then gives a specific impulse of almost exactly 1778 m / s. At the same values you get when the published data on heights and payloads OTRAG test shots back rate.

Two former employees OTRAG me consistently confirmed that the calculated value of me was incorrect and the flights at a specific impulse of 1800 m / s was measured on the ground.

When I pointed this discrepancy Lutz Kayser, there were suddenly new values. Now the thrust should be on average 25 kN and the burning time of 150 seconds. Thus the specific impulse of 2740 m / s would be even higher than previously indicated. Only you need according to my calculations, a combustion pressure to mouth pressure ratio of 100:1 to these specific impulse to achieve. As the engine but operate at 1 bar ambient pressure must be no higher than 30:1 ratio possible.

Lutz Kayser makes assumptions that there would be an aerodynamic dynamic pressure of the gases through the combination of so many engines and through the annular combustion even a nozzle effect. This would increase the specific impulse by 10%. Since the OTRAG never came into the stage of massive bundling is not verifiable. The same applies to the burning time and the thrust of a 24 m version, since such a variation have never been tested.

Also, Harry O. Ruppe wrote in his book "The boundless dimension" of a relatively low expansion ratio of 6 and a specific impulse of 2286 m / s. He also writes that the OTRAG information was 12% higher, because "Mr Kayser said many Paralellstrahlen create a nozzle effect. This seems to apply only very limited". It concerns with the specific impulses of Mr. Kayser so pure desire values he predicts great future versions.

Why the author used so much time on discussing this issue? Now, the specific impulse is a measure of how much energy can be extracted from a fuel. The smaller it is the smaller the payload and below a specific value creates the OTRAG not even empty their zutransportieren mass into orbit.

No text here is the buck is not so much the fuel mixture. It is somewhat inferior to the combination of hydrazine / nitrogen tetroxide. But she is still in the area and the solid propellants reach and out of these missiles are built well. (Pegasus, Scout, Start, Taurus). In addition, did not say that the OTRAG to stay with this fuel combination. There were speaking technically not mind switching to hydrazine and nitrogen tetroxide. The employee who had chosen the combination was due to the high price of these fuels. In the past 20 years, prices remained fairly constant while rockets were expensive. The price advantage would therefore no longer exists on this scale.

The problem is the nozzle that can be said because of the construction never wider than the engine or more specifically the combustion chamber. The expansion ratio is low, which means that the gases leave the engine even with a relatively high pressure and thus wasted a lot of energy.

There is little data on the engine to say whether this situation can be remedied. Since the nozzle throat diameter is variable, it is at least possible that for the upper stages to reduce and to increase the specific impulse at the expense of thrust. Two former employees of OTRAG confirmed my suspicion. In test flights, according to Kayser's successor, Frank Wukasch of a specific impulse of 1800 m / s was measured. Taking this for the first and 2100-2200 for the upper levels, then the payload is reduced considerable. The three-stage design is not possible and a four-stage version is necessary. Even this would be only about one-fifth of the details of Lutz Kayser. Module for the 256 version I calculate a maximum payload of 800 kg instead of 4000th Harry O. Ruppe has also calculated the OTRAG rocket with realistic detail and comes to 2900 kg instead of 10000 kg for the large version. Harry O. Ruppe is no stranger: He was involved at the start of the lunar probe Pioneer 4, in the implementation of the Apollo project and Director of the Planning Office for Skylab. From 1966 he established the Department of Aerospace Engineering at the TUM and was long-time professor and Director of the TUM. This shows that even professionals get the same results. Harry Ruppe also assumes a maximum specific impulse of 2286 m / s.

Ruppe sees two other weaknesses in the concept: First, the type of control. The high pressure of the fuel, the engines react slow, for a large rocket which requires much more sensitive towards disturbing forces is likely to slow. Ruppe said only after 1 second would occur if a large rocket a tax effect. In fact, so was the only test in which they wanted to test this control, a failure because they rocket tipped off and the controller could not compensate for this.

The second criticism is as claimed by the Corps as the modular concept is not really scalable. There are geometric constraints complied with in practice will lead to that individual missiles have always twice the payload of the previous version. If we extend a rocket to left or right modules, so this only increases the ratio of the mass of the first stage to second stage. However, this is not the payload is so important. The price of the rocket increases, but hardly the payload. Intermediate sizes are possible only by partial filling, corresponding to a specific deterioration of the rocket. The price for the modules RECOURSE same, only the decrease in fuel costs.

Way, there are still a weakness in OTRAG Concept: The size of the graphite ring to the thrust can be controlled. One thing is clear: Larger nozzle throat area - more thrust. But: The capacity is always the same and the delivery pressure as well. Thus, the jet velocity decreases in the same way. The 24 m module but must have more thrust than a 12 m module. This further worsened the specific impulse. This is most clearly seen in the thrust coefficient: This is a 10 cm ring at 1.27, worse than any other rocket (typical values 1.4 - 1.9) and already close to that of a firework rocket (1.0 = no nozzle).

Libya

The history of OTRAG in Libya is still a puzzling chapter. The official version I've played. Here again are the short form:

According to Mr Kayser he chose because Libya, the Libyan government is not unlike many others is blackmail. This conclusion, he moved to the expulsion from Zaire.

Another argument should be relatively cheap insurance against civil liability for personal injury. In Libya, he was then confronted, that the military was interested in his rockets. As a result, were then made only starts with a module. When Kayser refused to go on a two-stage version, he was dispossessed. As far as the description Kayser.

Researched it on the internet it is considered by most sources as a foregone conclusion that it has developed rockets for the military in Libya. I would like to once again face the facts and possible explanations. The basic problem is that there are contradictions that can be interpreted either way.

* The activities of a military missile program, says that even admits himself that from the beginning Kayser stated in Libya desires of the military. One wonders why he has not time to leave the country again. However, confirmed a report by the magazine "Transatlantic" from August 1980, when a journalist long time Kayser, accompanied him a "remarkable political naivety".
* For a participation in a military program, the fact that Kayser was expropriated. However, employees were working then and only Kayser and part of the team left Libya. The employees resigned from the OTRAG and were paid by Libya.
* The expropriation is probably the most puzzling in all of history. As a company expropriated and then terminate employees at this and continue working for the Libyan military. Kayser, who was dispossessed, but has another 10 years resident in Libya. In 2002 he was speaker of the Libyan Academy of Sciences.
* For most suspicious that the move to Libya, ending the public. Most independent sources of lead only the first start in Libya on 03/03/1981. After that there is no more information. This is for a company that relies on funds from shareholders, not conducive.
* 4 module untenBei the starts they made a step back from 4 to 1 module. Even here there are two explanations. First, Kayser says, that they wanted to test different parameters and this was just as good with a module. In a two-stage version would be in conflict with the MTCR (prohibition of exports of missiles over ranges of 300 km in developing countries). come. For a missile of strategic importance but a module would have been better, because it is easier to handle.
* It can be found in Kayser's list some odd starts as of the start in the 60 degree angle. Thus, most started artillery rockets. Kayser said the program can save by a pitch to the missile and thus would not fall on the grid. There are even Japanese rockets Sun started, but these are pure solid fuel rockets with limited possibilities for control. The rocket should OTRAG but use a different concept of control. Subsequent tests of Libya, that shows a log made available to me were only 1 module tests in oblique angles. At 50% filling degree and 70 degree inclination ereichte to distances of 50-70 km. If one were transferred to this ideal. (45 degree firing, full tanks), a module would achieve the same payload with a range of 170 km. That range would be larger than that of any Artelleriegeschosses.

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