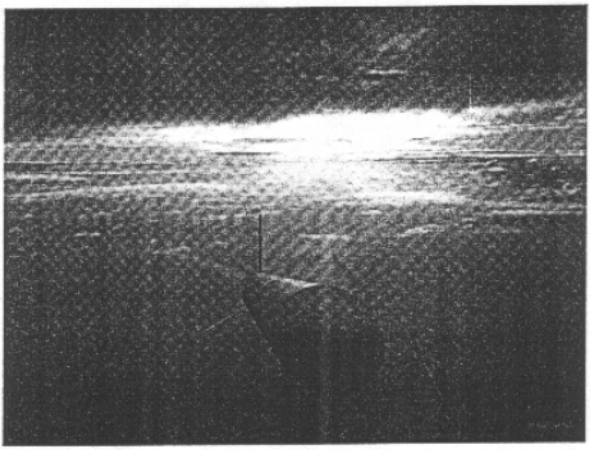
# The Experimental Two Staged Steam Rocket Project X-PRO

*Berkant Goeksel, Berlin*

** Designed and Built by Students of an Exercise Group in Astronautics.*



The X-PRO flying in twilight.

**This project was really an experiment. It was the first time that students in an exercise group during lectures in astronautics at the Technical University Berlin could design and build a steam rocket. Prof. Dr. Roger Lo has made it possible and was responsible for the experimental project. The time, personal and material resources were limited. Only the term of one winter period was available.**

The experimental two staged steam rocket X-PRO has been completed in February '96. After the first launch in April '96 the rocket was presented by the exercise group to the International Aerospace Exhibition (ILA, Hall E) in Berlin-Brandenburg on the south grounds of the Berlin-Schoenefeld airport from 13th to 19th May 1996.

## The X-PRO Project Description

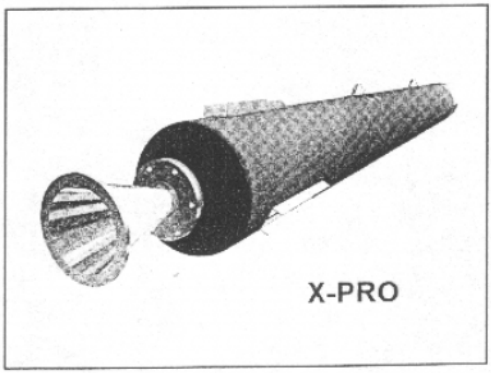
The steam rocket project concerning design and build stage was launched at the beginning of December 1995. Two month before the exercises began in the theoretical fundamentals of a water steam rocket.

The calculation of the thermodynamic data was the basement for the following design and manufacturing stage. The thirteen students of the exercise group chose between two possible steam rockets. Available were two different pressure tanks: one with 70 mm and the other 140 mm in diameter. So they could design and build a single staged or a two staged rocket vehicle.
The motivated exercise group decided to build a two staged steam rocket. At first, their decision seemed very optimistic. You could say it was impossible. There were only between two and three month for designing and manufacturing the whole rocket vehicle with two independent full functional recovery units. So the students divided the whole team in two working groups.

Each group was responsible for one rocket stage and held also several students responsible for the important separating section between both stages.

Furthermore, two project managers were selected for good communication and presentation efforts. A third student managed the design characteristics of X-PRO. This fact accelerated the manufacturing stage enormous.

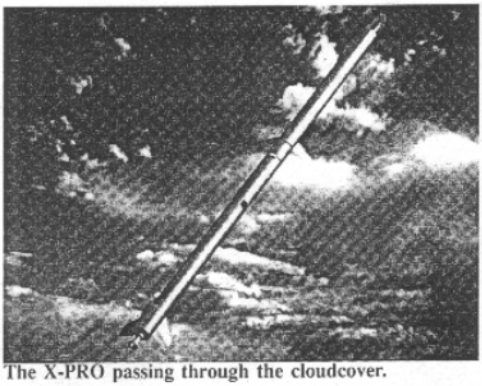
The separation tests of the first and second stages and the tests of both recovery units with parachutes were successfully conducted in February '96.




The second section of the X-PRO.

## The Basic Design Characteristics

The overall length of X-PRO is about 4 m. The length of the second stage is 1.77 m. Diameters of both stages are 0.14 m. Only the second stage has thermal insulation.
The X-PRO is a module construction and a combination of two independent single stage steam rockets. Instead of the separating section, the nose section of the second stage can be assembled to the recovery unit of the first stage. You only need new fins for successful launch.



**The X-PRO passing through the cloudcover.**

During the exercise one responsible student made a detailed solid model of X-PRO with computer aid.

In further developments this solid model could be used for computer aided aerodynamical or structural analysis, for design optimization and automatic manufacturing. By the way there are new possibilities of generating pictures and animation for technical and presentation efforts.

## The Basic Performance Characteristics:

the maximum take off weight is 58.5 kgf;
the rocket shall reach an altitude of 680 m;
it has a range of about 600 m;*
the rocket is available to reach more than 2000 meters;
the first stage delivers 1.60 kN thrust at sea level;
the tank pressure is nearly 38 bar at the beginning;
the second stage weighs only 9 kgf and delivers 0.40 kN thrust at launch in about 200 m;
the maximum tank pressure is 50 bar.

** The two nozzles were optimized for this short range. So the students can pursue the track, observe the separation and localize the landing places.*

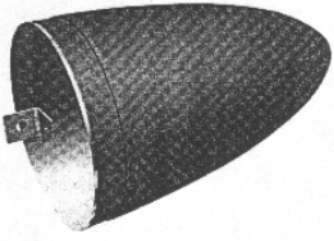
## The First Launch

The first launch was conducted in April '96 at the training grounds of the German Federal Armed Forces. The two staged steam rocket started successfully and reached about 200 m in stable flight. So the fin calculations of the first stage were confirmed.

In nearly 200 m the rocket began to fold in the separating section, that could not support the second stage anymore. The video tapes showed this happening. The result was a breakage of both joints in the separating section. The strength of the joints was probably not sufficient.

So the second stage started to fly without control before reaching the separating altitude and began to rotate. The break and following early separating destroyed some important cables and the start mechanism of the recovery unit of the first stage.

The rotation of the second stage resulted in loosing the nose section, which is connected to the parachutes. The lines tear away. The whole rocket flew down in pieces and crashed. But as a matter of fact the students could repair most outer parts and presented the two staged steam rocket in full length on the ILA '96.



**The nose section that got lost during the first flight.**

## The Future of X-PRO

Today, X-PRO is in use by the external student working group AQUARIUS. This group has developed preliminary single staged steam rockets for five years. Several members have specially experiences in theoretical thermodynamic and performance calculations and get the chance to teach fundamentals during the beginning exercises.

The former X-PRO probably will be an important technical basement for new two staged developments by AQUARIUS or by other student working groups. But there is a need for modifications especially in the separating section.

The want for structural tests in different angle positions to prove the strength of the new stronger separating section (with respect to the start angle of 85 degree), also exists. This group will also do further thermodynamical ground tests before the next launch.

In summer lectures in astronautics the same exercise students are supporting the AQUARIUS in optimizing the rocket for the next launch and preparing it for the ground tests. Today these students are also working on a study to use steam rockets for position regulation in different satellites. The study shall compare this technology with all available propulsion technologies used in satellites.

The X-PRO.

On the other hand all interested students of the institute are waiting for the first successful launch, which shall take place during the next months. For AQUARIUS it could mean a break even point and a chance to proof their efforts to start a full functional steam rocket for five years.

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# Variable Geometry Vs Delta Concept

*Andrea Merticaru & Adrian Florea, Bucharest*

**The Motto: " The attack on the sound speed boundary asked for a change in the airfoil and wing shape. The rectangular aspect of mainplane was surpassed by the swept wing featuring reduced drag and thus able to reach higher speeds."**

When the well-known pilot Chuck Yeager jumped in his Bell X-1 to speed faster then sound, aircraft designers were still having difficulties in handling the complex problems specific to the critical and supercritical flow regime. Leaving behind the difficulties aerodynamic researchers probably felt some disappointment as they observed that the "arrow" wing* showed a low lift performance.

The angle of sweepback, usually measured between a line normal to the axis of the body and the leading edge, reduces, compared to the rectangular wing, the lift and drag coefficients. The main advantage is that $C_D$ knows a larger decrease than $C_L$, as $C_D$ is multiplied by the cosine of the angle of sweepback raised to an exponent of three. On the other hand, $C_L$ is multiplied by the same cosine but raised to an exponent of two ( see formulas ). Note the cosine is inferior to one:

$$C_D = C_{D\,\text{rectangular}} \cdot (\cos(\text{hi}))^3$$

$$C_L = C_{L\,\text{rectangular}} \cdot (\cos(\text{hi}))^2$$

hi = sweepback angle

While the decrease of drag is desired, the decrease of lift generates an unsatisfying performance of aircraft at low speed flight. A compromise was achieved by the variable geometry and delta wings.
The variable geometry concept holds together the advantages of rectangular and arrow-shape wing by use of the angle of sweepback variation device.

## The Stability of the Airplane

One particular problem that has occured, is connected to the degree of stability of the airplane; once the aircraft approaches Mach 1, the aerodynamic pressure centre moves towards the trailing edge of the wing. Though the sweepback is not the only shape of the mainline touched by the inconvenience, this particular shape features a significant value of the displacement and lead to the existence of a moment rotating the aircraft vertically around the mass centre.

The pitch moment is responsible for a number of accidents in the early age of supersonic aviation because pilots did