History of Rocketry and Astronautics

Proceedings of the Seventh and Eighth History Symposia
of The International Academy of Astronautics

Baku, U.S.S.R., 1973

Amsterdam, The Netherlands, 1974

Kristan R. Lattu, Volume Editor

R. Cargill Hall, Series Editor

AAS History Series, Volume 8

A Supplement to Advances in the Astronautical Sciences

IAA History Symposia, Volume 3

AAS Publications Office
P.O. Box 28130
San Diego, California 92128

Affiliated with the American Association for the Advancement of Science
Member of the International Astronautical Federation

First Printing 1989

ISSN 0730-3564

ISBN 0-87703-307-2 (Hard Cover)
ISBN 0-87703-308-0 (Soft Cover)

Published for the American Astronautical Society
by Univelt, Inc., P.O. Box 28130, San Diego, California 92128

Printed and Bound in the U.S.A.

Chapter 11

A HISTORY OF THE FRENCH SOUNDING ROCKET VERONIQUE*

Jean Corbeau†

The history of the sounding rocket Veronique is a long one. It began in 1949; since then 83 rockets of this type have been launched, the last one in April 1973, and 4 rockets are due to be launched in 1975. For several years these rockets were the only French vehicles available for research of the upper atmosphere; experience gained in this project has been directly utilized for other achievements of a larger scope, such as the sounding rocket Vesta, which is the first stage of the satellite launcher Diamant. Diamant made France the third country among the space powers in 1965. We should also mention the second stage of the launch vehicle Europa, and finally the first and second stages of the launch vehicle Ariane presently under development, which should place 750 kg in geostationary orbit in 1979.

After the second world war, at Vernon, in Eure, in France, at the Laboratory for Ballistic and Aerodynamic Research (LRBA), there was a small group of German engineers who worked in the field of rocketry. Among them was a team of specialists in rocket-engine propulsion whose leaders were Mr. Wolfgang Pilz and Mr. Zangl. This team worked essentially on two subjects: liquid-fueled ballistic missiles derived from the V-2, and a nitric acid and kerosene rocket-engine with a thrust of 4 tons. This thrust seemed reasonable to perform representative experiments that could be scaled-up later to larger thrusts. It is this team, gradually reinforced by French personnel, that I had the honor and the pleasure to lead from 1949 to 1963.

The decision to build the sounding rocket Veronique was made in March 1949 by the Directorate for Armament Studies and Fabrication, an organization to which the LRBA was subordinated. This rocket was designed to meet two objectives: the study of the in-flight performance of rocket-engines, and, later on, to make possible atmospheric soundings up to an altitude of 65 km. The weight of the scientific instruments making up the payload had been fixed at 60 kg. The decision for development gave the following characteristics for the experimental missile 4213, soon afterwards called Veronique:

* Presented at the Eighth History of Astronautics Symposium of the International Academy of Astronautics, Amsterdam, 1974.

† Technical Directorate of Missiles, Laboratory for Ballistic and Aerodynamic Research.

- caliber . . . . 60 cm
- length . . . . 6 meters
- initial mass . . . . 1 ton
- mass at the end of combustion . . . . 300 kg
- payload . . . . 100 kg
- oxydizer: nitric acid
- fuel: petroleum ANF 58
- fueling: the reservoirs are brought under pressure with the help of:
  - either a pyrotechnic generator,
  - or a generator with auxilliary furnace,
  - or a chemical generator;
- stabilization: by fixed aerodynamical empennage,
- guidance: none
- launching: on a ramp with 14 meters of useful length, with auxilliary propellers delivering a total of 6 tons during 1/2 second; jettisoning taking place before the missile leaves the ramp.

VERONIQUE N

Under these general directives, and a concern for building sounding rockets as simple as possible, the design work started at LRBA in 1949. The concern for simplicity led, in particular, to the adoption of fueling by tank pressurization, over fueling by turbo-pumps. Indeed, for missiles of the size of Veronique, this technique appeared the most reasonable because of its simplicity, its reliability of operation, the rapidity of its adjustment, its cost, without the empty weight of the rocket being excessive.

The missile thus conceived, called Veronique N, was essentially a flying engine, and like all the later types of Veronique, was made up of the following main assemblies: in the center, the most bulky and the heaviest part, a two-compartment reservoir constituted the external framing of the rocket and contained the oxydizer and the fuel; to this reservoir were fastened, in the front, the gas generator, and, in the rear, the engine; to complete the assembly one found at the extreme front, a nose destined to receive the payload, and in the rear, a four-fin empennage destined to insure the aerodynamic stability of the rocket during the flight. The command to ignite started the operation of the generator, which generated pressured gases. The gases pressurized the rocket reservoirs and drove the oxydizer and the fuel toward the engine. (Figure 1).

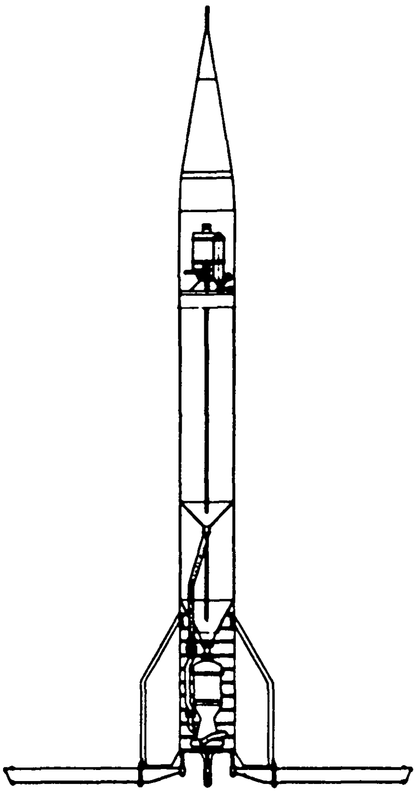

Figure 1 Inboard profile.

Description

The nose. The nose consisted of a conical part of a 10° half-angle at the apex, followed by a part in the shape of a truncated cone which was fitted to the cylindrical body of the rocket. It accommodated a payload with a volume of 130 liters. The data of the scientific experiments were either recorded on-board and recovered with the nose cone on a parachute, or transmitted via telemetry.

The nose separated from the body of the missile, after the completion of the propulsion phase, by three exploding bolts controlled by a timer. The parachute system guaranteed a payload recovery at a speed of impact on the ground of the order of 8 m/sec for a nose mass of 100 kg.

The gas generator. The gas generator was composed of two bottles of compressed gas, a remotely controlled pyrotechnic valve, and three concentric ring-shaped reservoirs in a block containing nitric acid, a solution of ammonium nitrate, and some furfurylic alcohol. A small combustion chamber surrounded by a cooling jacket completed the gas generator. An injector at the entrance of this chamber injected nitric acid and the furfurylic alcohol; at the exit of the chamber a jet injected the ammonium nitrate into the combustion gases. The gases were generated at a temperature of about 400°C, a temperature high enough to increase their pressurizing power and low enough not to reduce appreciably the mechanical resistance of the reservoirs; in addition, the gases had to be as chemically neutral as possible to avoid any reaction with the oxydizer or the fuel.

The reservoirs. The two reservoirs for the oxydizer and the fuel form a block and at the same time constitute the outer shell of the rocket. They were fitted for the attachment of the gas generator in front, and the fin empennage and the engine in the rear. The conical bottoms guarantee a good flow of the liquids. The reservoirs were pressurized at 40 bars during their operation, and were made of rolled and welded high- resistance steel sheet. (Figure 2).

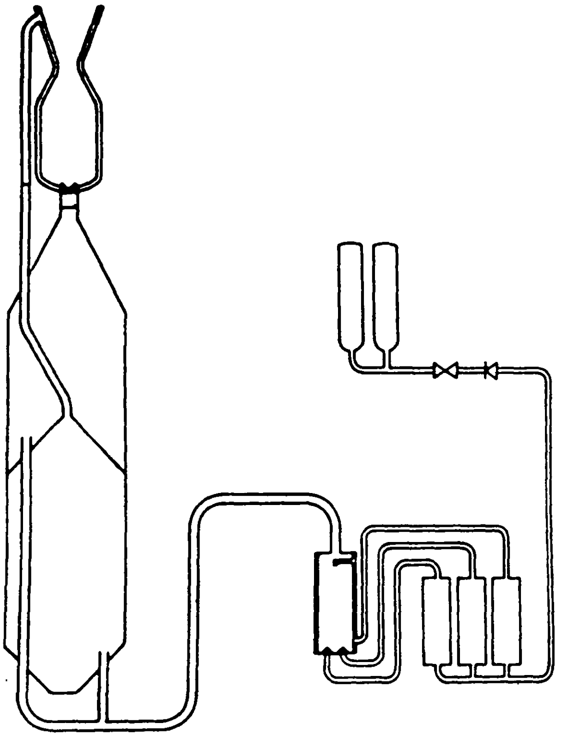

Figure 2 Propulsion scheme.

The engine. the engine was composed of an injector, the combustion chamber, and the convergent-divergent nozzle. Two types of injectors have been used: a plane injector made of a light alloy, with injection parallel to the axis of the engine, and an injector made of steel with injection perpendicular to that axis. It constituted the top wall of the combustion chamber, with its spraying holes disposed in such a way that, alternatively, a jet of acid impinged against a jet of acid and a jet of fuel impinged against a jet of fuel. In addition, the injector had a series of spraying holes along its circumference, through which part of the fuel was injected along the wall of the combustion chamber, thereby forming a cooling film. Indeed, for this small engine the ratio between the flow rate of the cooling acid and the area of the wall to be cooled was unfavorable; it required an exactness and a regularity of fabrication difficult to realize with rolled and welded steel sheets, a technique which one wanted to retain for reason of economy; under these conditions, additional film cooling was necessary.

The combustion chamber, made of steel, had a double wall forming a jacket cooled by the nitric acid. The convergent part, the throat, and the divergent part, the nozzle, which form the extension of the combustion chamber, were cooled in the same way. The chamber between the reservoirs and the injector were closed by membranes that burst at the time of pressurization of the reservoirs. The delayed arrival and the progressive flow rate of the acid in the combustion chamber of the engine during the starting phase was achieved by installing a gate with progressive opening in the acid mains. The fuel used was kerosene.

The fin empennage. The four-fin empennage was constructed of light alloy sheets. It supported the rocket on the launching pad and was fitted to the latter by exploding bolts. In addition, it made possible the attachment of the guidance arms, about which we will talk later; this attachment was also made using exploding bolts. Finally, it carried a control box for jettisoning the guidance arms. On the trailing edge of two fins of the empennage, two radomes made of a glass-resin protected the telemetry antennas and the radar-transponder. (Figure 3 and Figure 4).

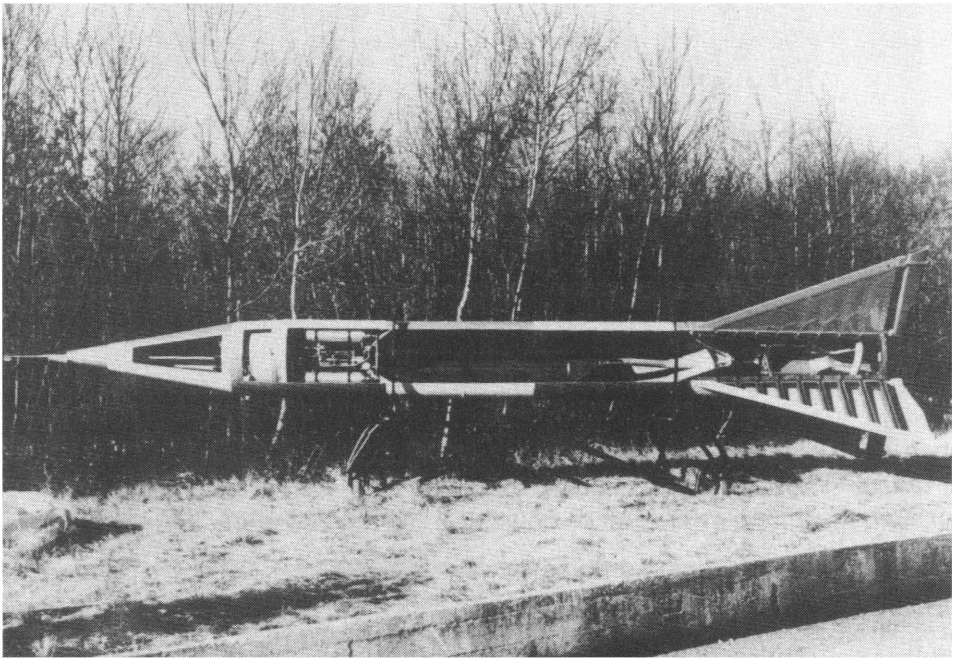

Figure 3 Veronique N with panels removed.

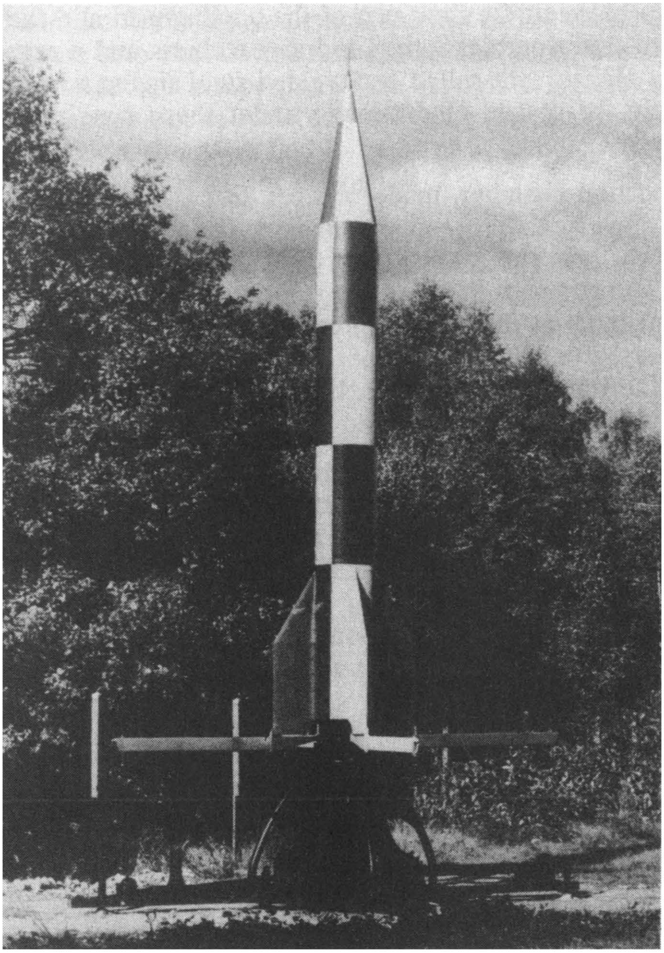

Figure 4 Veronique N on launch stand.

Operation

The engine was started by remotely controlled opening of the pyrotechnic gate of the gas generator. The compressed gases from the high-pressure bottles go through the pressure-reducer. Regulated by the latter at a pressure of about 33 bars, the gases forced out the liquids contained in the three reservoirs for the generator and sent them toward the combustion chamber of the generator.

The furfurylic alcohol and the nitric acid injected by the injector situated at the top of the combustion chamber ignited spontaneously because of their hypergolic nature. The combustion gases generated are cooled and their quantity is increased by injecting a counter-current of solution of ammonium nitrate which first passed through the cooling jacket of the chamber.

The gases thus generated, pressurized the main reservoirs at about 30 bars. The rise of pressure in the reservoirs burst the membranes. The membranes were located in the lines which bring the oxydizer and the fuel to the reservoirs of the engine. The furfurylic alcohol, a hypergolic igniter, denser than the fuel and non-miscible with the latter, first flowed at full rate through the injector into the combustion chamber of the engine; the incoming nitric acid was slowed and controlled by a gate which opened progressively; this delay and the progressive opening of the gate guaranteed a gentle start of the engine. After a few seconds of operation, the furfurylic alcohol was exhausted and the fueling of the chamber continued with kerosene. (Figure 5).

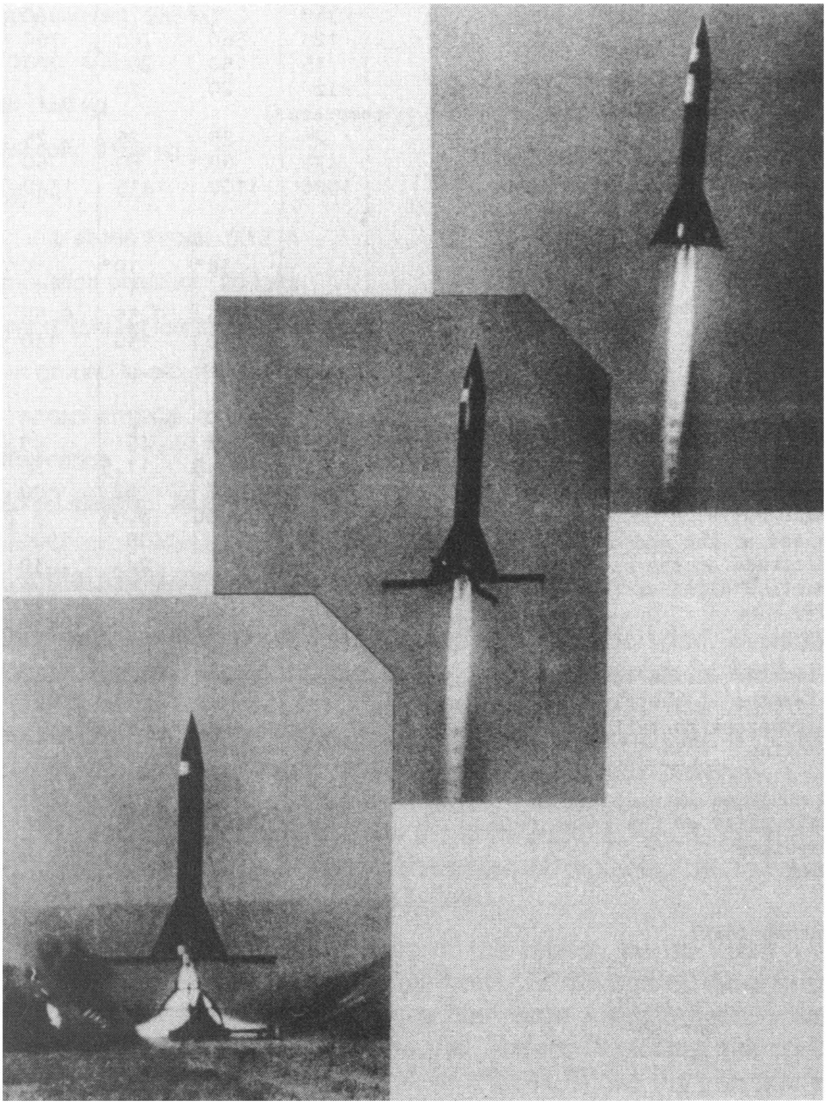

Figure 5 Veronique N launch sequence.

Table 1

COMPARATIVE CHARACTERISTICS OF THE VARIOUS TYPES OF VERONIQUES

Characteristics	TYPE R	TYPE N	TYPE NA	TYPE AGI	TYPE 61
DIMENSIONS (m)					
Length	5,80	6,50	7,30	7,30	9,50
Diameter	0,55	0,55	0,55	0,55	0,55
Span	1,35	1,35	1,35	1,35	1,35
WEIGHT (kg)					
Empty rocket	360	285	370	280	321
Oxydizer	125	560	760	760	1213
Fuel	35	150	200	200	367
Propergols for the gas generator	air compressed	20	20	17	31
Guiding arm	25	25	25	25	
Payload	475	60	60	60	
Total at launch	1020	1100	1435	1342	1932
PAYLOAD					
Angle of the cone		10°	10°	10°	10°
Length (m)		1	1	1	variable
Maximum diameter (m)		0,55	0,55	0,55	0,55
Volume (l)		130	130	130	variable
PERFORMANCES					
Thrust at ground level (kg)	4000	4000	4000	4000	6000
Duration of propulsion (sec)	6,5	32	45	49	54
Initial acceleration (m/sec^2)	27	26,5	17,5	20	17,5
Maximum acceleration (m/sec^2)		92	82	100	115
Mass ratio		2,80	3,33	3,7	4,8
Speed at the end of propulsion (m/sec)	200		1400	1900	2400
Altitude at the end of propulsion (km)			24	30	44
Maximum altitude (km) for a 60 kg payload	2	70	135	220	315
ENGINE					
Diameter of the combustion chamber (m)		0,26	0,26	0,26	
Diameter at the throat (m)		0,13	0,13	0,13	0,16
Decompression ratio		22	22	22	30,9
Cooling		double wall	double wall	film	film
Combustion pressure (bar)		20	20	20	20,6
Exit speed of the gases (m/sec)		1850	1850	2050	2055
Oxydizer		NO_3H	NO_3H	NO_3H	NO_3H
Fuel		gas-oil	gas-oil	turpentine	turpentine
Thrust (daN)	4000	4000	4000	4000	6000

Characteristics

The principal characteristics of Veronique N appear below. All comparative characteristics appear in Table 1.

a. Dimensions

length: 6.50 m

diameter: 0.55 m

span: 1.35 m

b. Weight

empty vehicle: 285 kg

oxidizer: 560 kg

fuel: 150 kg

at takeoff: 1100 kg

c. Engine

diameter at the throat: 0.13 m

combustion pressure: 20 bars

thrust at ground level: 4 tons

I_{sp} at ground level: 189 sec

duration of propulsion: 32 sec

d. Performance

maximal altitude: 70 km for a 60 kg payload.

Device for Initial Guidance

Unguided rockets are sensitive to the influence of the wind, even more so when their speed is low. Therefore, one has to guide these rockets until a certain speed is reached when the wind influence becomes small. In the case of liquid-propelled rockets, the initial accelerations are small and a long path is necessary to reach a speed at which the influence of the wind is sufficiently reduced. A classical guidance system would have required a high tower. To limit the tower to 14 meters, a decision in 1949 added auxilliary rockets for acceleration. Again, for the sake of simplicity, Mr. Wolfgang Pilz had the ingenious idea of replacing the tower and the auxilliary rockets with the device described below.

Under the four fins of the empennage of the rocket, we mounted four two-meter arms connected by means of exploding bolts. At the end of these arms were four cables which, through rewind pulleys, wound onto a single spool whose axis was vertical and which was mounted on the pad. Before launching, the rocket was fastened to the pad by another series of exploding bolts. When the pressure exerted by the injected gases upon a small paddle reached a certain threshold, the paddle dropped and thereby closed a circuit that controlled the functioning of the exploding bolts used to hold the rocket down on the pad. The rocket then took off and pulled the cables, which all unwound with the same length so that the axis of the rocket stayed parallel. The inertia of the spool was calculated so that the four cables always stayed taut. When the 55-meter long cables left the spool, a timer started at takeoff, ignited the exploding bolts that held the arms to the empennage. The rocket was then in free flight. (See Figure 5)

Veronique is an aerodynamically stable rocket; it therefore has the tendency to place itself in a direction relative to the wind; that is, a rocket launched vertically moves in the direction from which the wind is coming. Therefore, if one wanted to make it go in a certain direction, you inclined or tilted the pad in order to correct the trajectory; this operation was done manually about half an hour before launching, according to the direction and the speed of the wind at ground level.

First Launchings of the Reduced Version

Veronique P2. This preliminary machine was propelled by four solid-propellant powder rockets, immediately available at that time, which together gave a thrust of 2 tons for 2 seconds. It was destined to test the functioning of the device for initial guidance previously described. It had the outer contour of the rocket Veronique N, but weighed only 500 kg at the start in order to conserve the initial acceleration of this machine. The length of the guiding cables was reduced to 45 m which corresponded to the altitude at the end of the propulsion. The launching took place at the LRBA in April 1951, and the initial guidance device worked perfectly.

Veronique P6. To test the guiding device by cables over the whole length of the cables, an experimental powder rocket, called Veronique P6, was conceived. It also had the outer contour of the rocket Veronique N, also weighed only 500 kg at the start, and was propelled by a single powder-propulsion unit delivering a 2-ton thrust over 6 seconds.

Two Veronique P6 rockets were launched successfully in January 1952 at the Cardonnet Proving Grounds in southern France. They confirmed the proper functioning of the device for initial guidance.

Veronique R. After the Veronique P's, an intermediate step was taken to again test the initial guidance device under conditions closer to those of the rocket Veronique N. It was indeed necessary to ensure that the cable guiding device functioned correctly according to the law of actual thrust of the liquid-powered propulsion unit of Veronique, and it was also necessary to test the starting operation itself. The dispersion of the point of landing, proportional to the maximum altitude reached, called for testing of a more advanced Veronique N at the Inter-armies Center for Testing Special Weapons, at Hamaguir in the Sahara. Therefore, since we desired to make the first tests in France, the rocket Veronique R (reduced) was conceived, which was practically identical to Veronique N, except that the duration of propulsion was reduced to 6.5 seconds. To this end, the reservoirs of oxydizer and fuel were reduced, and the reservoir assembly included a third reservoir that contained water used as a ballast.

The principal characteristics of Veronique R appear below. Comparative characteristics appear in Table 1.

a. Dimensions:

   Length: 5.80 meters

   Diameter: 0.55 meters

   Span: 1.35 meters

b. Weight:

   Empty rocket with ballast: 835 kg

   oxidizer: 125 kg

   fuel: 35 kg

   at takeoff: 1020 kg

c. Engine:

   diameter at the throat: 0.13 m

   combustion pressure: 20 bars

   thrust at ground level: 4 tons

   I_{sp} at ground level: 189 seconds

   duration of propulsion: 6.5 seconds

d. Performance:

   maximum altitude: 2 km

In all, eight Veronique R rockets were launched: two in July 1950 at the Suippes Training Camp in eastern France, three in October 1951 at the same location, and, finally, three at Cardonnet in January 1952. The results were very satisfactory as a whole. They showed that the rocket started correctly and that the cable guiding device functioned in a satisfactory manner. We tried to make two of the cables unroll more slowly than the others using spools with a curved meridian section. This system proved satisfactory, but finally cylindrical spools, and the tipping of the launch pad and rocket, offered more flexibility.

In-Flight Tests of Veronique N

Eleven Veronique N rockets were launched from Hamaguir Base, Algeria, between May 1952 and April 1953, in three series of tests.

Test series of May 1952. The rockets N1, N2, and N3 were launched, but only N3 reached the nominal altitude of 70 km and confirmed the good conception of the machine. The N1 failed due to the breaking of the fin empennage, and the N2 failed due to improper engine burning. The empennage was then reinforced. The improper burning of the engine was attributed to a defect in fabrication.

Test series of November 1952. Six rockets N4, N5, N6, N7, N8 and N9 were launched, and proved a catastrophe, exhibiting a little known phenomenon, at least in France at that time--combustion instability at low frequency. Five of the rockets were affected by combustion instability and destroyed the engines after various times, but times distinctly shorter than the nominal duration of combustion. The maximum altitude reached was 10 km; the sixth machine exploded at the end of combustion.

It appeared that the engine tests had been done on the bench with long fueling lines that stabilized the functioning of the system, and that subsequent tests of the whole rockets were done with a fastening method that prevented the phenomenon from take place. We then decided to change the injector and to go from a plane injector made of light alloy to a radial injector made of steel.

Test Series of April 1953. Two rockets were launched, the N10 and the N11. The N10 functioned nearly correctly and reached an altitude of 45 km; the N11 showed the same phenomena of combustion instability as those of the preceding test series.

In conclusion, one can say that the tests done with the types P, R and N made it possible to confirm proper functioning of the cable guidance device, good ignition of the engine, and that the rocket would be able to reach the altitude for which it had been designed. One arduous problem remained to be solved: that of the stability of combustion.

VERONIQUE N A

We realized rapidly that the maximum altitude of 70 km was not sufficient to make interesting soundings beyond the ionized layers of the atmosphere. This is why, for the rockets Veronique following the rocket N11, Veronique NA; in addition to lengthening the reservoirs by about one meter, a modification was made to the injector of the engine to obtain better stability.

The principal characteristics of Veronique NA are given below. Comparative characteristics appear in Table 1:

a. Dimensions:

Length: 7.30 m

Diameter: 0.55 m

Span: 1.35 m

b. Weight:

Empty rocket: 370 kg

oxidizer: 760 kg

fuel: 200 kg

at takeoff: 1435 kg

c. Engine:

Identical to that of Veronique N except the injector.

d. Performance:

Maximum altitude for a 60 kg payload: 135 km

Four Veronique NA rockets were launched from the base at Hamaguir, Algeria, in 1954 in two series of tests.

Test series of February 1954. The rocket NA 14 functioned normally and reached the maximum nominal altitude of 135 km. But the rocket NA 15 reached only 29 km; this failure was attributed to the defective functioning of the gas generator.

Test series of October 1954. The rocket NA 12 functioned normally; but again, however, the rocket NA 13 reached only 39 km. This failure was attributed to a leak in the acid mains due to the necessity of filling the jacket of the engine with acid long before launching.

These test series showed that the contemplated altitude could be reached, that the instabilities of combustion were probably surmounted, but that more new improvements were necessary.

VERONIQUE AGI

The scientists were interested in the encouraging results obtained and were considering, in connection with the International Geophysical Year (IGY), the launch of some payloads at an altitude of the order of 200 km. A new version of Veronique called Veronique AGI was therefore conceived for that purpose in 1955-1956, through the incorporation of a certain number of improvements.

First, the reservoirs were made of a new and more resistant steel, which thus allowed a reduction in the thickness of the walls, and therefore provided weight savings and performance increase.

Second, the engine was considerably modified, although its thrust remained the same. The injector with radial injection was made of lighter alloy. The combustion chamber, slightly conical in shape toward the nozzle, was of stainless steel sheet with a single wall; it was cooled only by the internal injection of a fuel film. The throat of the nozzle, that is, the convergent part and some of the divergent part, was machined out of electrode graphite and was held by refractory cement which allowed a progressive fueling of acid into the combustion chamber for the starting phase.

Finally, kerosene fuel was replaced by turpentine. This had two favorable effects: a smaller sensitivity to combustion instability and an increase of 5% in the specific impulse.

The principal characteristics of Veronique AGI are given below. See Table 1 for comparative characteristics.

a. Dimensions:

Length: 7.30 m

Diameter: 0.55 m

Span: 1.35 m

b. Weight:

Empty rocket: 280 kg

Oxidizer: 760 kg

Fuel: 200 kg

At takeoff: 1342 kg

c. Engine:

Diameter at the throat: 0.13 m

Combustion pressure: 20 bars

Thrust at ground level: 4 tons

I_{sp} at ground level: 201 seconds

Duration of propulsion: 49 seconds

d. Performance:

Maximum altitude for a 60 kg payload: 210 km

Forty-eight Veronique AGI rockets were launched from bases at Hamaguir in Algeria and Kourou in Guiana between 1959 and 1969. Table 2 gives the launch dates, the experiment they used, and the functioning of the rocket. Figure 6 gives the cumulative percentage of the successful launchings as a function of the number of launchings; the final percentage of success was 81.5%

VERONIQUE 61

The fabrication of the Veronique AGI's continued until 1963, but as early as 1961, upon the request of scientists who wanted to send heavier payloads to higher altitudes, a program of development began for the purpose of increasing by 50% the performance of this model. In the new version, called Veronique 61, the principle of driving the propellants by pressurization was retained, and the capacity of the reservoirs and that of the gas generator was increased, as well as the thrust of the engine, which improved from 4 tons to 6 tons.

The steel of the reservoir was changed to make it lighter, the shape of the bottom was modified, and a thrusting frame was added. The generator and the engine were variations of those of Veronique AGI. The fin empennage was slightly modified on the version Veronique 61M. Besides, a new launching pad was built that permitted remote-control of the inclination.

The principal characteristics of Veronique 61 appear below. See Table 1 for comparative characteristics.

a. Dimensions:

Length: 9.50 m

Diameter: 0.55 m

Span: 1.35 m

b. Weight:

Empty machine: 321 kg

Oxidizer: 1213 kg

Fuel: 367 kg

At takeoff: 1932 kg

c. Engine:

Diameter at the throat: 0.16 cm

Combustion pressure: 20.6 bars

Thrust at ground level: 6 tons

I_{sp} at ground level: 201.5 seconds

Duration of propulsion: 54 seconds

d. Performance

Maximum altitude for a 60 kg payload: 315 km

Twenty Veronique 61 rockets were launched from the bases of Hamaguir in Algeria and Kourou in Guiana between 1964 and 1973, and four more launchings are scheduled in 1975; Table 2 gives the launch dates, the experiment they carried and the performance of the rocket. Figure 7 gives the cumulative percentage of successful launchings as a function of the number of launchings. The final percentage of successes was 90%; all of the last 15 launchings have been successes.

CONCLUSION

As you can see, the history of the French sounding rocket Veronique is a long one, beginning in 1949, and it continues today, twenty-five years later. In fact, it embraces a succession of rocket models of the same concept, whose performance evolved over the course of the years, as is indicated in Figure 9.

These rockets have been used to launch payloads diverse in nature and in weight. The weights have varied from 65 to 295 kg. Figures 9 and 10 give the altitude reached as a function of the payloads for the models Veronique AGI and Veronique 61.

What made the Veronique story continue for so long a time? First, it so happened that Veronique was the only rocket probe available in France at the time when scientific research in the upper atmosphere started. The encouraging results obtained in 1955 made it possible to decide upon the fabrication of 15 Veronique AGI. Later, other successive orders for Veronique AGI's appeared. Similarly, the construction of the Veronique 61 was pursued because the scientific users of Veronique AGI were attracted by its improved performance while still having a sounding rocket that retained the generic characters of the first model. The market availability is therefore an important element of the success.

Table 2
LIST OF THE LAUNCHES OF VERONIQUE ROCKETS

Launch No.	Rocket No.	Date	Location	Experimentation	Observations
1	N-1	20.5.52	Hamaguir	technology	Failure: rupture of empennage
2	N-2	21.5.52	"	"	Failure: burning of engine
3	N-3	22.5.52	"	"	good functioning
4	N-4	8.11.52	"	"	Failure: combustion instability
5	N-5	9.11.52	"	"	" "
6	N-7	13.11.52	"	"	" "
7	N-6	16.11.52	"	"	" "
8	N-9	17.11.52	"	"	" "
9	N-8	18.11.52	"	"	Failure: explosion at end of combustion
10	N-11	18.4.53	"	"	Failure: combustion instability
11	N-10	21.4.53	"	"	good functioning
12	NA-15	20.2.54	"	"	Failure: defect in generator
13	NA-14	21.2.54	"	"	good functioning
14	NA-13	17.10.54	"	"	Failure: leak acid circuit
15	NA-12	29.10.54	"	"	good functioning
16	AGI 18	7.3.59	"	Na emission	Failure: (calamine reservoir)
17	AGI 17	10.3.59	"	"	good
18	AGI 16	12.3.59	"	"	good
19	AGI 23	23.2.60	"	Scientific measurements	Failure (misfire of exploding bolts)
20	AGI 22	2.3.60	"	Na emission	good
21	AGI 21	5.3.60	"	"	good
22	AGI 20	13.6.60	"	"	good
23	AGI 19	16.6.60	"	"	good
24	AGI 25	18.6.60	"	Explosives	good
25	AGI 26	22.6.60	"	"	good
26	AGI 27	11.2.61	"	Scientific measurements	good
27	AGI 28	13.2.61	"	"	Failure (unsuccessful ignition)
28	AGI 29	15.2.61	"	"	good
29	AGI 30	18.2.61	"	"	Failure (degenerate fuel)
30	AGI 24	22.2.61	"	animal behavior	good
31	AGI 31	10.6.61	"	double charge explosive explosive	good
32	AGI 39	24.5.62	"	explosive	good
33	AGI 38	31.5.62	"	"	good
34	AGI 41	1.6.62	"	double explosive	good
35	AGI 42	4.6.62	"	"	Failure (cable guidance incident)
36	AGI 43	6.6.62	"	explosive	good
37	AGI 37	15.10.62	"	animal behavior	good
38	AGI 36	18.10.62	"	animal behavior	good
39	AGI 44	19.10.62	Hamaguir	technology	good
40	AGI 46	22.10.62	"	"	good
41	AGI 32	23.10.62	"	photometry	good
42	AGI 34	29.10.62	"	"	good
43	AGI 35	20.4.63	"	ionospheric measurements	good

Table 2 (Continued)

Launch-ing No.	Rocket No.	Date	Location	Experiment	Observations
44	AGI 49	23. 4.63	HAMAGUIR	Ionospheric mea-	Good
45	AGI 45	1. 5.63	"	surements	
46	AGI 48	10. 5.63	"	Magnetometry	Good
47	AGI 33	18. 6.63	"	Coronography	Good
48	AGI 40	19. 6.63	"	Lyman Alpha	Good
49	AGI 47	18.10.63	"	"	Destruction for safety at 27 sec.
50	AGI 50	24.10.63	"	Animal behavior	Failure (separation pad-rocket)
51	AGI 51	14. 4.64	"	Lyman alpha	Good
52	61/75	8. 6.64	"	Technological	Good
53	61/76	13. 6.64	"	"	Good
54	AGI/53	4.11.64	"	Lyman Alpha	Good
55	AGI/52	8.11.64	"	Colorado pointer	Failure (timer guiding
56	AGI/56	12. 2.65	"		arms)
57	61/79	27. 5.65	"	LCA pointer	Good
58	AGI/54	22.10.65	"	Lyman alpha	Failure (defective pro-pulsion)
59	AGI/55	28.10.65		Electronic density	Good
60	61M/80	24. 3.66	"	"	Good
61	61M/78	4. 4.66	"	Technological	Good
62	AGI 57	6. 4.66	"	Lyman alpha	Failure (arms not jetti-
63	AGI 60	27. 6.66	"		soned)
64	61M/77	3.10.66	"	Pointer	Good
65	61M/82	24.11.66	"	Technological	Good
66	AGI 59	9.12.66	"	Lyman alpha	Good
67	AGI 63	13. 1.67	"	Technological	Good
68	61M/84	11. 1.67	"	Spectrometer	Good
69	61M/85	17. 1.67	"	Solar spectrum	Good
70	61M/81	24. 2.67	"	Night cameras	Good
71	AGI 64	17. 3.67	"	Astronomy	Good
72	61M/86	24. 3.67	"	Technology	Good
73	61M/87	29. 3.67	"	Coronography	Failure (functioning
74	61M/88	4. 4.67	"		safety)
75	AGI 62	9. 4.68	KOUROU	Lyman alpha	Good
				"	Good
76	61M/89	25. 7.68	"	Night camera	Good
77	61M/83	18.12.68	"	Recovery at sea	Good
78	61M/90	22.12.68	"	"	Good
79	AGI 61	20. 2.69	"	Astronomy	Good
80	61M/93	8. 6.71	"	"	Good
81	61M/94	12. 6.71	"	Mass spectrometer	Good
82	61M/92	16.12.71	"	Solar pointer	Good
				Ionospheric mea-	
83	61M/95	4.73	"	surements	Good
				Solar UV spectrum	Good

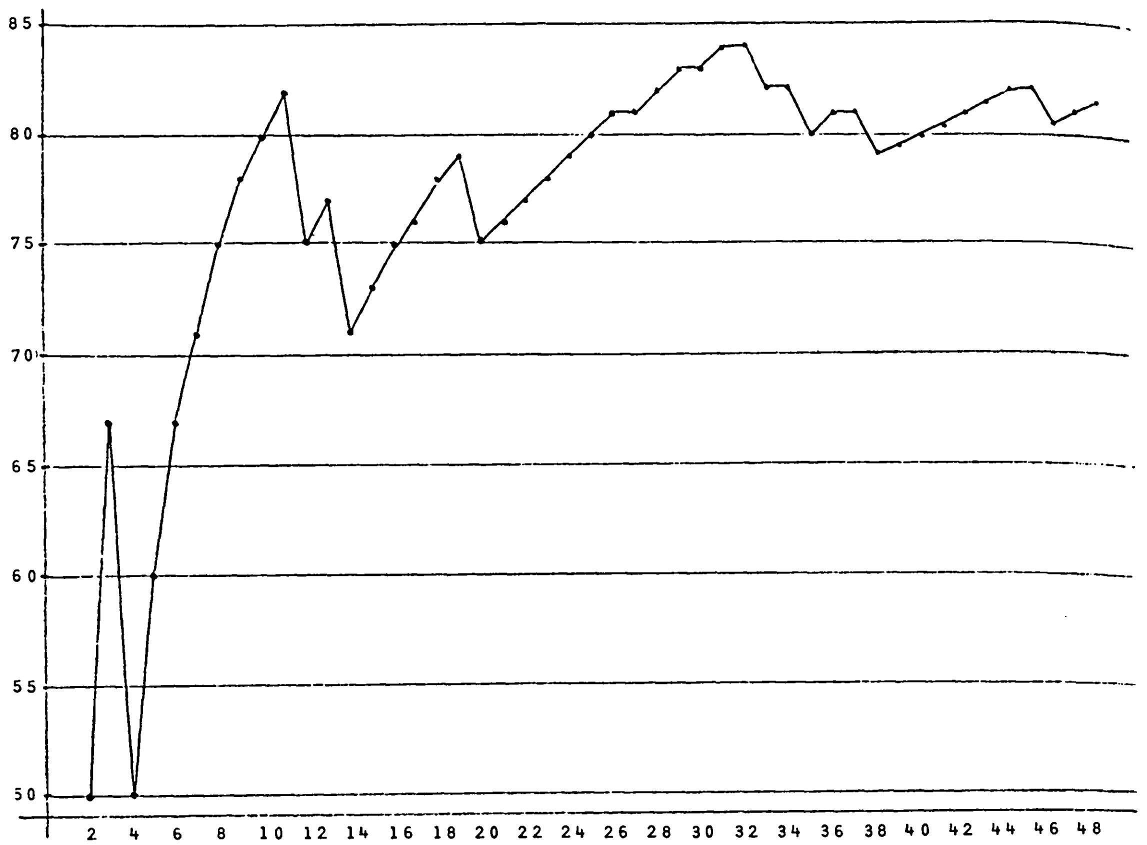

Figure 6 Cumulative percentage of successful launchings of Veronique AGI.

However, this historic factor, important as it is, does not suffice. It was necessary, in addition, that the reliability of functioning be acceptable. Most certainly there have been failures, but on the average, the reliability of 80 to 90% was accepted by the scientific users. It can even be said today, after the last fifteen launchings without failures, they are well satisfied.

In addition to the users' confidence, other qualities of the rocket are important: the vibration and the accelerations attained remain at relatively low levels, if one compares them to the rates reached on solid-propellant propulsion units. But, for certain experiments, those on animals for example, these parameters are very important; besides, the adjustment of the scientific instruments is easier when the vibration environment is less severe. The large volume available in the nose for the payload has also been a favorable element.

Finally, although this point is not the least important, cost must be considered. Indeed, it is on a question of cost that a decision is taken to realize any program. One way of counting the specific costs consists of dividing the total cost by the product in kg x km of the payload by the maximum altitude. The cost of one launching of Veronique 61 being 600,000 Frs. ($125,000), the specific cost amounts to 13 Frs./kgkm ($2.7/kgkm) which is very interesting compared to other sounding rockets. One can think that the European Society for Propulsion and the fabrication plant of Tarbes, which have taken over the work of the Laboratory for Ballistic and Aerodynamic Research for the construction of the Veroniques, will have customers for a long time in spite of the diminished interest nowadays in sounding rocket experiments.

To conclude, I want to express my thanks to all my friends at the Laboratory for Ballistic and Aerodynamic Research, the European Society for Propulsion, and the National Center for Space Studies that helped me to gather the necessary documentation and to re-live an already receding past.

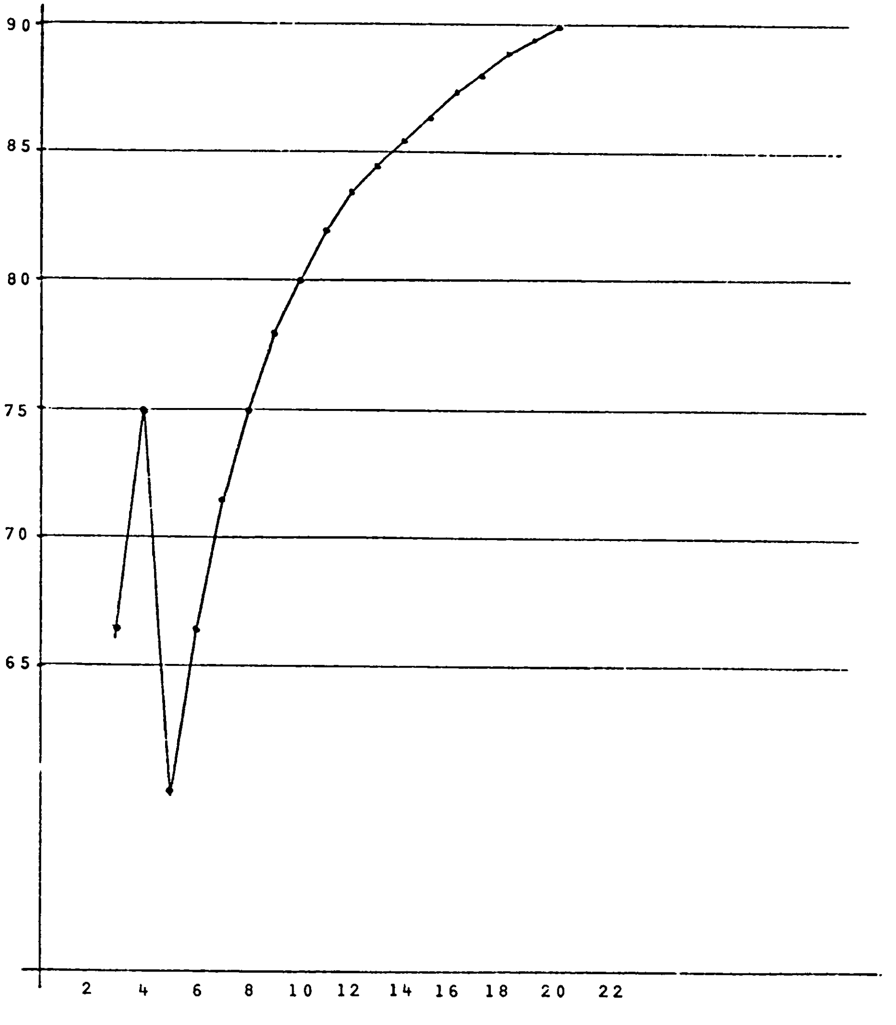

Figure 7 Cumulative percentage of successful launchings of Veronique 61.

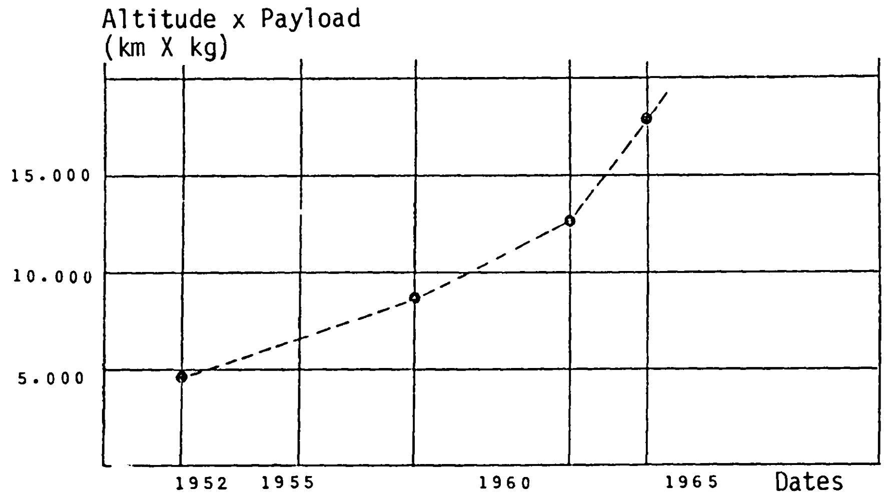

Figure 8 A sounding rocket carries a payload of M kg to Z km of altitude. One can characterize the progress of a sounding rocket by the variation of the product M x Z. The graph gives the variation of this parameter for Veronique.

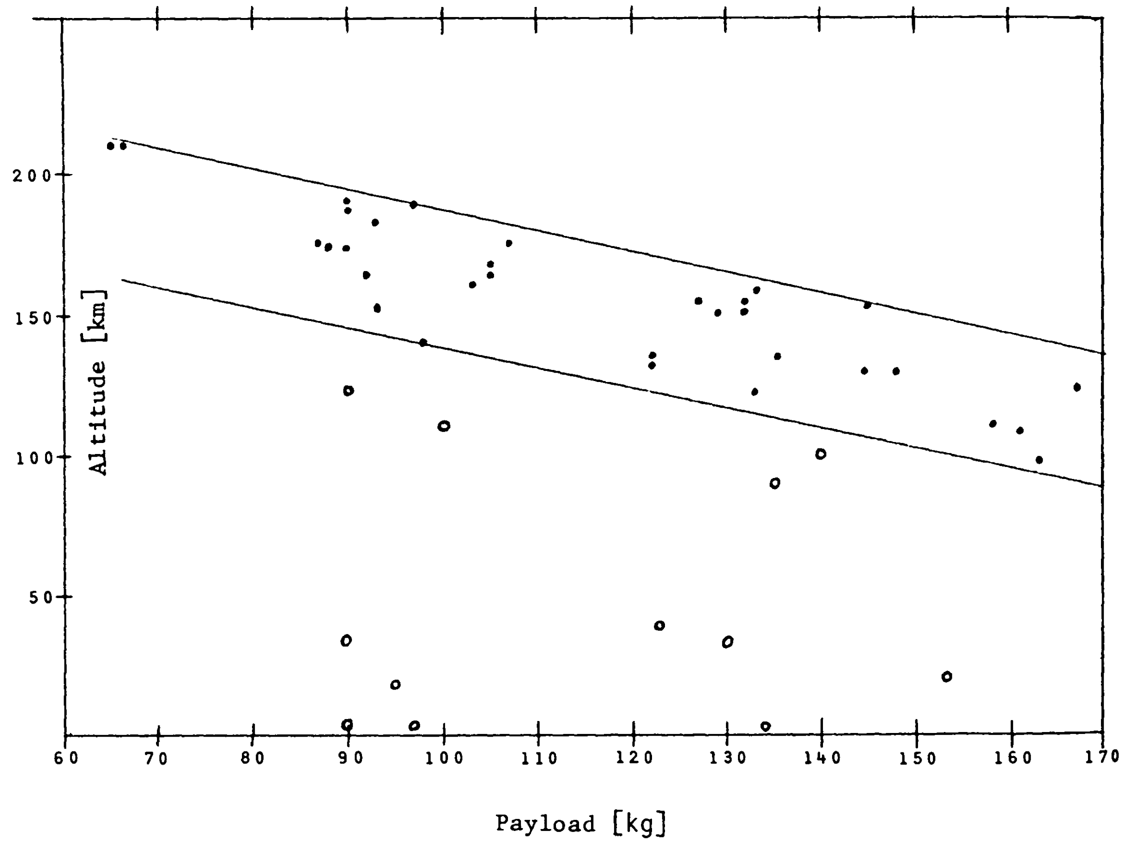

Figure 9 Altitudes reached as a function of payload (Veronique AGI).

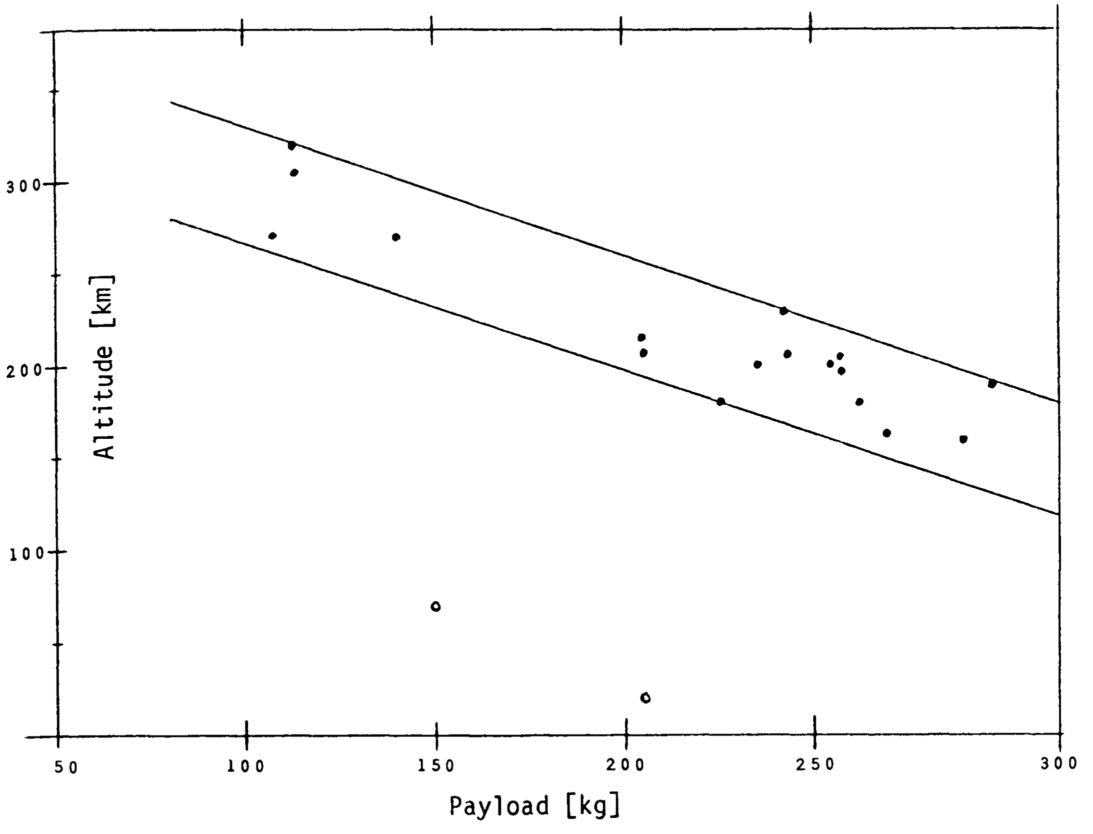

Figure 10 Altitudes reached as a function of payload (Veronique 61).