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Chapter 8

The True Beginnings of French Astronautics 1938-1959 (Part II)*

Philippe Jung†

Introduction

The widely held opinion about the origins of French space activities is that it all started quite modestly during the fifties, with the emblematic Véronique, followed up in 1962 by the Precious Stones rockets and the creation of CNES. Nothing could me more remote from reality.

A first attempt at analyzing rocket activities in France in the aftermath of World War II just reveals a bewildering array of programs. All three French armed forces lost no time after the victory to develop missiles, as a consequence of German achievements in that field. There were two main lines of thrust: the medium range ground-to-ground missile, an alternative to the tactical bomber, and the much sought after anti-aircraft missile, at a time when the horror of the Coventry and Dresden terror bombings was still resonating.

However, each one followed its own route. The Army initially tried to remake the V-2. In a totally opposite way, the Air Ministry decided to start from scratch and launch a wide-ranging prototype policy, covering all missions for all users, including the Army and the Navy. The latter, on its side, adopted an inter-

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mediate position, first building German missiles, before switching to its own products.

All told, an incredible 76 programs probably reached flight status from 1939 to 1959! It truly was *La Furia Francese*, a unique and thus far secret period, unearthed for the first time in this article. Thus, when Charles De Gaulle came to power, and before the creation of CNES, the French armed forces had already mastered the full spectrum of rocketry, with the single exception of inertial guidance.

Last year, Part I of this article, IAA-99-IAA-2.2.05, dealt with the no less than 45 programs that reached flight status in France between 1939 and 1953.[*] The industrial base for rocketry had by then been established and the basic techniques experimented, some of them already mastered. This year's article covers the remaining programs, as Part II of the same study.

SE 4300: The First French Preoperational SAM

As already pointed out, one of the main goals of post-war missile activities the world over was to deploy anti-aircraft systems, essentially directed against strategic bombers. While still in Boulogne-Billancourt, Louis Besson knew well that, for such a surface-to-air missile (SAM) to be successful, it had to be supersonic. In keeping with his philosophy of a progressive approach to solve problems, he decided that the successor to his NC 3500 testbed should essentially cope with the range aspect, that is, reach the higher altitudes of jet aircraft, but still stay within the subsonic flight regime. His proposal for the SA 11 program (SA = sol-air or *surface-to-air*) thus was to be an intermediate step between the SA 10 (represented by the NC 3500, alias SE 4100) and the future, operational, SA 20.

As a consequence, the SE 4300[1] was developed in Cannes, both as a SA 20 testbed, and as a training missile for the future *Armée de l'Air* SAM units, including learning to handle liquid propellant. Since solids at the time only worked for a few seconds, a two-stage configuration with solid booster and liquid sustainer was selected. For schedule reasons, the already existing motor of the Maruca,

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being tested in CERES (*Centre d'Essais et de Recherches d'Engins Spéciaux*) by ECAN (*Etablissement des Constructions et Armes Navales*, in Ruelle – see Part I) was retained. It was however affected by combustion instability problems, which GTC (*Groupe Technique de Cannes*) quickly solved, much to the surprise of Marine technicians, by designing a new injection device. Initial guidance was beam-riding, using a new 10 cm Thomson ground radar and an on-board *Pénélope* 1 receiver, made by either CSF or CNET. The SE 4300 then switched to an on-board seeker, several of which were tested: radio electrical ones (SFENA AD 148, Thomson FS) and optical ones (ECA ADO, ECA 421). Noteworthy, the ECA company today still exists in Toulon, widely selling its robotic subs. The nosecone was recoverable, for testing analyses.

Propelled by a cluster of 5 STRIM solids, operating during 3.3 seconds, SE 4300 E01 rose from its Icare B2 pad at Hammaguir on 27 February 1954. Peaking at 22,750 m, it right away gave SNCASE the full performance bonus and 90 percent of the schedule bonus! Improved versions with fins of increased span and a lighter SEPR 5053 booster were tested in 1955. After curing fin break-ups due, among other things, to the intense Sahara heat, a switch could be made to the pre-series SE 4350.

With its hands full with many rocket programs, GTC decided to subcontract the manufacturing of 150 SE 4350 to its sister factory of Toulouse within SNCASE. This version used the ingenious on/off fuel flow control of the SE 4200[2]: propellant fed the motor as long as the maximal Mach number had not been reached. After cut out, and when speed had decayed to the minimum value, as determined by a contact Machmeter, fuel again flowed.

Such was the interest of Armée de l'Air that five SE 4300 test vehicles were quickly delivered by GTC to SDTA (*Sous Direction Technique de l'Armée de l'Air*), actually personnel from CEAM – *Centre d'Expérimentations Aériennes Militaires*. On May 25th, 1956, launch of E71 thus marked the first use of a SAM by the French armed forces.

A new version was launched on the following 2nd of June with two lateral SEPR 685 solids, from a short inclined ramp, allowing a quicker insertion on the intercept trajectory.

Interception trials began in October 1956, against SE 1524C targets released from Canberra bombers. Later tests involved ground-launched CT 20's. Several failures are clearly recorded, if only because the whole scenario putting aircraft, target and missile together was – and still is today! – rather complicated... The seeker only had 10 to 20 seconds to acquire its target. Was any success achieved? Some old timers say so, but no written unambiguous confirmation has been traced yet.

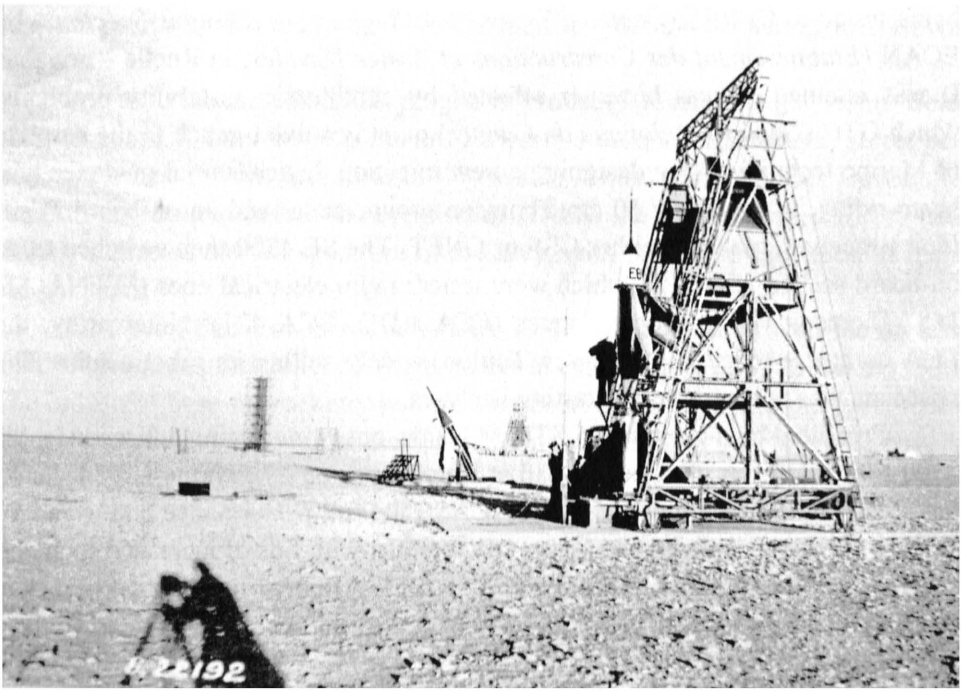


Figure 1: Crowded Hammaguir, with both ramp-launched and pad-launched versions of SE 4300 SAM. Left, SE 4100 launch tower (Courtesy of Philippe Jung).

After three launches on 6 June 1957, the end of the traditional Sahara summer reprieve did not see the resumption of tests. Only 89 SE 4350s had apparently been built, the about 50 remaining ones being scrapped or given to military schools. As explained later, the company had decided to rationalize its missile activities. Obviously, accumulated experience was considerable, obviating the need to continue launching dozens of these so-called "statistical rockets." Furthermore, handling liquid propellant was not easy, so the stage was open to the definitive SA 20, now that CEAM had launched no less than 23 SE 4300s.

Ramjet SE 4400: Fastest and Highest in the World

With the big success of its ramjet-propelled SE 4200, and a flurry of activities the world over on this promising technology, it is no surprise that Besson decided to use such powerplants for its operational SA 20 proposal, the SE 4400.[3] Skipping the potentially difficult transonic phase, the ramjet was to be already ignited at launch, boosted by STRIM or SEPR 505 solids. Separation was above Mach 1, Mach 2 being specified at 19,000 m. Interestingly, a SE 4401 version was also flown, using a second stage propelled by an ONERA SPRA 15 solid (SPRA = *Service des Poudres*/ONERA), as a hedge against problems with the 500 mm diameter ramjet. Guidance again was initially beam riding, with a new *Pénélope* 2 radar, later switching to an on-board seeker (SFENA 148 or Thomson FS).

To this day, the pace of GTC still appears unbelievable: 41 days after the launch of the first SE 4300, it was the turn of SE 4400 F02: on April 9th, 1954, it rose from the CIEES (*Centre Interarmées d'Essais d'Engins Spéciaux*) Icare pad of Hammaguir. But the booster failed, and problems kept hitting the program, only the tenth flight managing to reach Mach 2. Even then, fins kept parting off when maneuvering at supersonic speeds. Ramjet combustion could not be stabilized either. As always, ingenious Laurent then devised a rotating drum with calibrated holes delivering the required fuel flow.

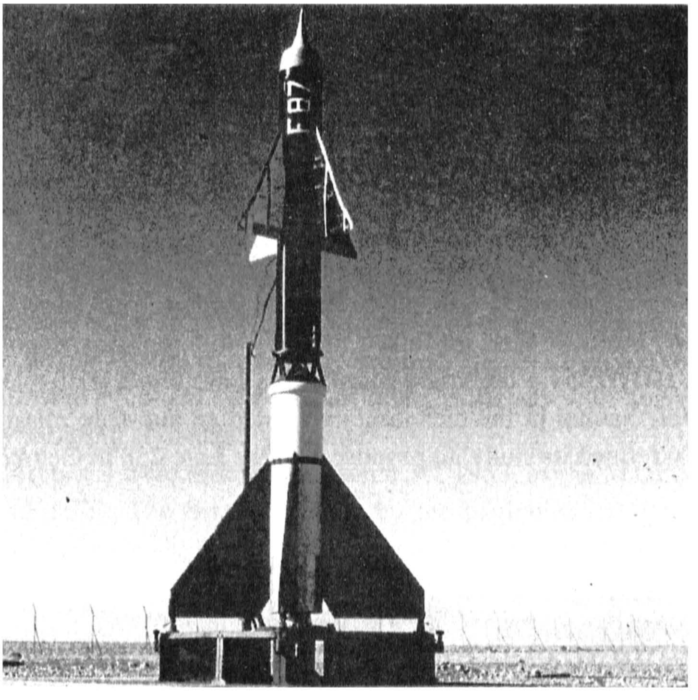


Figure 2: Fastest and highest ramjet in the world, the SE 4400 (pictured F87, which reached an altitude of 40 km on 13 January 1959) (Courtesy of Philippe Jung).

The improvement was remarkable. In October 1955, F41 hit Mach 2.7 on the 5th, followed by F40 on the 8th at M3.15 – Mach Pi as they said – a new world speed record for any air-breathing vehicle! Astonished American engineers rushed to Cannes to try understanding how the French had succeeded where they had difficulties; this was to have some impact on the SE 4500 program. GTC tried some variations, such as various lengths for the main vehicle, to reach still higher performances. A more powerful SEPR 732 booster also was introduced in May 1957. The gains were spectacular: M3.5 by F79 in December, and M3.7 by F83 on April 1st, 1958!

With the rationalization of missile activities of what had become Sud Aviation, and despite the infamous decision by General Crépin to switch to the American Hawk as a SAM, the SE 4400 was not cancelled outright, as its performance clearly made it a national asset for experiments at extreme flight envelopes. It thus was used for testing the equipment of the upcoming *Pierres Précieuses* rockets, such as Turck telemetry, including measurement of flight loads and temperatures (with thermocolor paint). The program had an outstanding conclusion with two last flights in March 1961: zooming vertically, F91 climbed to 65,000 m on the 7th and F92 to an incredible 67,000 m on the 10th. Within a few kilometers of the 80 km floor of satellites, this performance may still be today the absolute height world record for any air-breathing vehicle!

Malaface: The Anti-Ship Precursor

Back in 1948, the Toulouse plant of Latécoère – of Aéropostale fame – had initiated, like many French companies, missile studies. First looking into air-to-air (Laté 240 project), then air-to-sea missiles, the company eventually started studying in early 1951 a defensive missile, the Laté 258D (D for Défense). *Marine Nationale* having in the meantime requested an anti-ship missile, Latécoère considerably refined its study, to propose it as the Laté 258 in October 1951.[4]

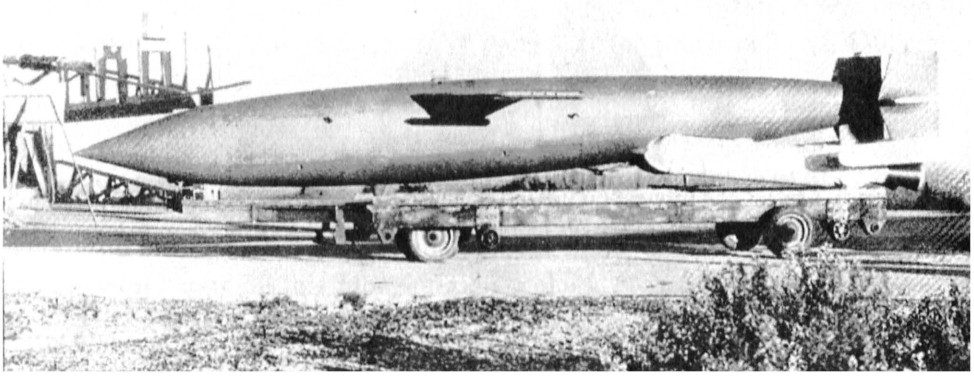


Figure 3: Anti-ship Laté 258 Malaface, with two boosters (Courtesy of Philippe Jung).

Boosted by 2 solids of 2.1 total thrust working during 4 seconds, it was to be powered by a Ruelle liquid rocket (using nitric acid and a mixture of furfurylic alcohol and aniline) during 136 seconds. Its nozzle was cooled by propellant circulation. The structure was made from light alloy, with razor-thin wings. A special Laté 252 reclining ramp was used for launch (a lighter version for ground launches also was studied). Two launch profiles had been defined, one peaking at 490 m, the other at 60 m, followed by a descent to the cruise altitude, at only 50 m, as maintained by an autopilot. It seems only the second profile was used. Guidance in azimuth was by a telepilot on the launch ship, using a stick, and getting telemetry return from the missile, plus radar plots giving the position of the latter and the target. Recovered German gyroscopes were used. A television camera also had been planned to improve terminal accuracy, as exhibited in the Paris Air Show. This camera was tested on a Max Holste MH 1521M Broussard liaison plane during the Summer of 1958, to check its applicability against ground targets. This showed that there would be significant guidance problems to solve. When 500 m from the target, the Malaface was to dive at 25 m height, open a belly panel, and release by electromagnetically actuated gears a 700 kg BT4 bomb, copied from the Luftwaffe BT 700. Maximum range was 38 km. Controls used Wagner spoilers, both for pitch (on the horizontal surfaces) and roll (on the wings). These spoilers were sidebands perpendicular to the trailing edges, alternatively actuated above and below by electro-magnets. Frequency was constant at a few Hertz, but waiting time in the extreme positions was variable, thus corresponding to a signal with pulses modulated in width. Such controls had the advantage of minimizing required energy. For testing purposes, parachutes allowed recovery, the impact being softened with foam and bags, automatically inflating at contact with water.[5]

Five prototypes were ordered on March 3rd, 1953, as the Malaface (*MArine LAtécoère surFACE*). The first was ready by the beginning of 1954, but failed when launched from Ile du Levant. The second was successful, but rough seas prevented recovery. Soon wing pods were added to house the control surfaces motors, as well as flares for optical guidance. It is reported that such guidance, although crude, was precise. At the same time, Marine created GTES (*Groupe Technique d'Engins Spéciaux*) in January 1955 in St. Mandrier, on the tip of the bay of Toulon, within CERES.

Another order for 5 preseries Malaface was obtained, to test various equipment. Different booster configurations also were tried: 4 Mimosa solids at the rear, then a single Vénus solid of 2.2 m length below the fuselage, finally 2 Vénus of 1.4 m length below the rear fuselage, with converging thrust directions.

A total of at least 15 flights were made, some of the vehicles flying several times after having been recovered (N° 6 flew three times). At least one was dropped by a Lancaster of the 10.S test squadron. Latécoère tried to expand the possible applications by studying a submarine variant (but launched from the sea surface), the Laté 258H with folding wings allowing mounting inside a reclining tube. Malaface N° 6 was thus modified, for experimental launch from the ground. The missile was first pushed forward to allow wings deployment, then the two solids were ignited. Two such flights were performed in CERES, on October 15th, 1958 and March 19th, 1959, with good results (the last one may have been the final Malaface flight). The Laté 258 also was planned to be launched from the same ramp as used by the, later operational, Latécoère Malafon.

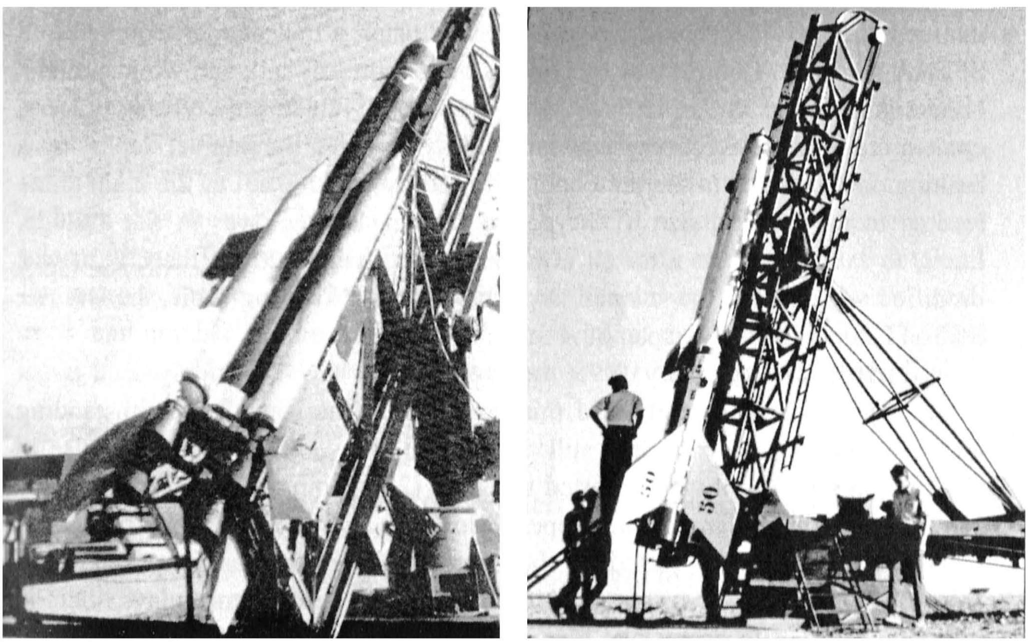
In April 1958, the program budget was severely curtailed, by 50%. At the end of the year, while the manufacturing of a third batch of 5 Malaface was in course (N° 11 at least had been completed), the program was cancelled, for lack of credits combined to expected difficulties in perfecting guidance. Furthermore, Marine was – not unexpectedly – reticent about use of liquid propellant, although Latécoère had studied a Laté 258E with a turbojet engine, the ubiquitous Turboméca Marboré II. As usual, carrier aircraft were preferred, due to their undoubted flexibility. Thus was killed what could have been the first anti-ship missile in the world, a simplified version of the cruise missile. Although the Bereznyak P-20, alias SS-N-2 Styx, had first flown in October 1956, the world would have to wait until October 1967, when it was used to sink the Israeli destroyer *Eilat*, thus vindicating the concept of the anti-ship sea-to-sea missile...

More French Ramjets from DEFA and SFECMAS

Other French companies followed SNCASE in trying to use ramjet propulsion, something in-between the easily used solids, but then still of short combustion time (with the EDB Extruded Double Base, a mixture of nitrocellulose and nitroglycerin), and the high performance bi-liquid, but of cumbersome handling. DEFA was thinking about a Super PARCA version of its in-house SAM equipped with a kerosene ramjet, to increase its range to more than 70 km. Thus Général Carrière initiated in 1950 activities in this field, to be directed by Roger Marguet.

An experimental NA 250 missile was developed using a 250 mm diameter unregulated ramjet.[6] Wind tunnel testing was performed in Vernon. Accelerated at Mach 1.5 by four solids derived from the PARCA ones, the kerosene ramjet operated during about 30 seconds. One missile was equipped with canard controls to check maneuverability up to 20 g load factors and 15° angle of attack. Starting in 1954, about 20 launches were made, from Ile du Levant and Hammaguir.

Discussions also had begun in 1950 between the aircraft section of STAé (STA/A) and *Arsenal de l'Aéronautique* about developing ramjets, as well as aircraft with turbo-ramjets. The former were to be studied by the *Département Moteurs* of the company, headed by Louis Pichon, with Albert Gozlan as his deputy. Possible applications to missiles were planned. Indeed, the ST 450 (for *statoréacteur* – 450 mm diameter) missile was one of the testbeds flown in the frame of the development of the aircraft, the future world speed record holder Griffon, an interceptor prototype. In parallel, the 614 mm diameter ramjet for the R 431 version of the Matra SAM (later called the Matra-Nord, see Part I) was being developed, with M. Jablonski and Katz (possibly a German engineer). The first of 45 vehicles flown was launched in the second quarter of 1954 (62 were manufactured).



Figures 4/5: Left, DEFA ramjet testbed NA 250 N° 2;
Right, SFECMAS ramjet testbed ST 450 N° 50 in Hammaguir
(Courtesy of Philippe Jung).

The goal of the ST 450 was to explore the flight domain for the Arsenal ramjets. Boosted at Mach .8 by two solids, it could be recovered by parachute, and had a SFIM recorder. Some had an autopilot. Later in the program, it was accelerated at an initial supersonic speed (400 m/s) to ease the transition through the difficult transonic phase, and also to reach higher altitudes. Various combustion chambers were flown. The first of 84 flights in CIEES took place in October 1954. A remarkable maximum speed of Mach 3.8 was eventually achieved.

At about the same time, two obscure Marine vehicles were being tested from CERES, the C4R and the Barracuda, possibly targets.[7]

The CT 20: A Highly Successful Target

Continuing in the steps of its simple Arsenal 5501/CT 10 target, SFECMAS proposed for the CT 20 program the recoverable 5510. Of classical aircraft configuration and aluminum construction, it was powered by the widely used Turboméca Marboré II jet engine (used, among others, on the American Cessna T-37 trainer). It was launched by two solid boosters, from a 10 m ramp inclined at 5°. Guidance was by telecommand using a transponder, coupled to a SFENA autopilot. Control was by elevons on its butterfly tail, and wing spoilers. Nine signals were available: right, left, up, down, full throttle, cruise, tracers, camera on, landing. Recovery was initiated by stopping the engine, deploying a braking chute located in the tail cone, followed by deployment of the main chute located in the forward part of the centre section. Descent was in flat attitude. Later, to save what was after all a not so-cheap flying vehicle, the CT 20 was modified to be able to tow a small target behind a 1.2 km long cable, the Dornier SK3L (1.2 m long, with a span of .4 m).

First flown in January 1995, the 5510 became the first widely used target in the world (for AAM and SAM missiles, such as the Hawk), notwithstanding an incredible longevity, as it is still operational today! In addition to its use in CIEES and CERES, it was exported to Egypt (20 examples), Italy, and used by NATO on its firing range, which opened in Crete on March 1st, 1968. The first batch, like for the CT 10, used for their autopilots German hardware, recovered from the *Entrepôt de l'Armée de l'Air* in Nanterre (gyrometers, relays, electric motors). This led to an official blame from EMAA (*Etat-Major de l'Armée de l'Air*, the Air Force Headquarters) to Arsenal, about military hardware theft! A later Version VII had the more powerful Marboré VI. Several additional uses were found, including a reconnaissance version, the R 20 of 1966, one of the first RPV (Remotely Piloted Vehicle), for service with the French Army 17è *Régiment d'Artillerie* in Epernay. Its range was boosted from 120 km to 150 km, accuracy at 100 km being of 300 m. It was equipped with three Omera 32 cameras.

The Royal Swedish Navy bought 100 M 20s, a marine version for coastal defense, which had two applications, either from ships (MM 20, for *mer-mer*) or from the ground (SM 20, for *sol-mer*). Built under licence by Saab, it was one of the first anti-ship missiles. Put into service in 1967 under the Rb 08 designation (essentially on destroyers), and equipped with a dedicated seeker, it however could only hit the ships superstructures.

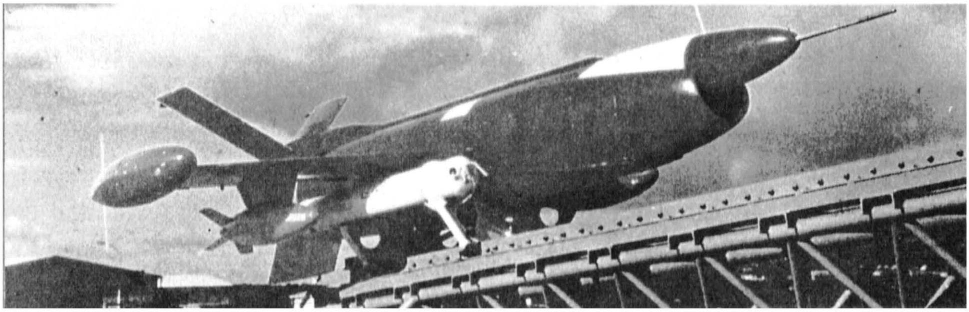


Figure 6: Widely used Nord 5510, a target for the CT 20 program, on its launch ramp (Courtesy of Philippe Jung).

Interestingly, the CT 20 still was considered to be too small for some applications. To obviate the need to use special augmentation devices such as magnifying lenses or transponders, it was decided to transform retired Vampire jet fighters into drones. This was performed by CEV, using Turck telemetry and telecommand. Testing started in October 1957, quickly showing that two telepilots were necessary, one at the extremity of the runway to ensure lateral guidance, and another one on the side of the runway, at the point of flare. The first interception took place in May 1958, with an AA 20 downing Vampire N° 284.

Masurca: The First French Operational SAM

Like everywhere else in France, and the world over, development of a surface-to-air missile was initiated after the end of the war in Arsenal de Ruelle, alias ECAN (*Etablissement de Construction des Armes Navales*). Despite experience gained from the Maruca testbed launches, the Masurca (*MArine SUpersonique Ruelle Contre Avions*) program proved to be protracted, not unlike the Terrier/Talos program in the USA.

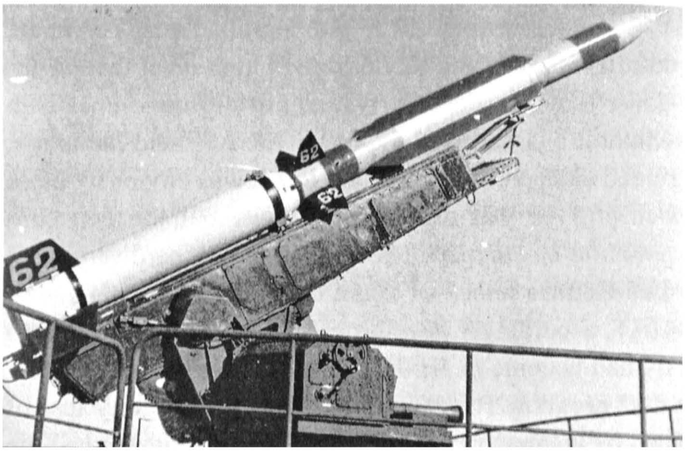
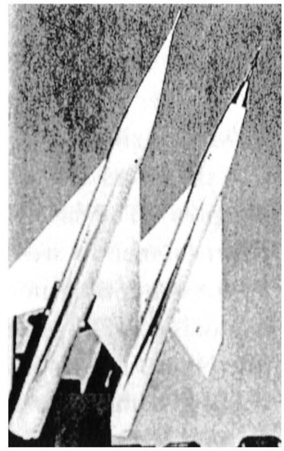
The Masurca used two solid propellant stages, operating during 4.5 s and 32 s respectively. Staging was performed at Mach 1.9. Radio commanded with a

Thomson radar, it was controlled by four rear fins with two ailerons (for roll), and 4 forward mobile canard surfaces (for pitch and yaw). The explosive charge was detonated by telecommand.[8] Ground computers were provided by IBM. Testing was performed in several wind tunnels, like the ONERA S1Ca one in Cannes, for high angles of attack. The LRBA C4 tunnel also was used. Inaugurated in March 1951, its design had been initiated in Emmendingen by the 28 ex-Kochel German aerodynamicists (the Arsenal AA 10 and the Matra R 530 also were tested there).

The first flight, in Ile du Levant, took place in 1955, but guidance trials only began in 1958, CT 20 targets being used by September 1960. Actually, in the wake of the Crépin mission in the USA (coming from Artillery, Général Crépin always had been very interested by missiles), France had in the meantime succumbed to the American promises on the no-more advanced Hawk, and decided to stop all SAM activities in August 1958: the SE 4400, the R 422 and the Parca, plus the SA 30 SAMP (for which Breguet had submitted a Br 920 proposal). Marine refused to comply, arguing successfully about naval specificities. This decision had profound consequences for decades on the French design bureaux and workshops, only elements of the Hawk being subcontracted. Promises of know-how transfer were not fully kept, even after much arguing. Not everything was completely lost however, as something was gained in the electronics and propulsion fields. Concurrently, on August 4th, Pierre Guillaumat, the Defense Minister, decided to give priority to a strategic ballistic missile to carry the French nuclear bomb, the future SSBS (*Sol Sol Balistique Stratégique*). The Masurca eventually went to sea trials in 1960, from the *Ile d'Oléron* research boat. The latter had been specially converted from a former banana and troop transport ship for the French outposts in India. In 1959 it performed operational evaluation of the Maruca, to be used as a training missile for the upcoming Masurca operators (the 50th Maruca was launched in May 1961, while a few dozens remained for training personnel). Shooting against CT 20 targets already was in course by September 1960.

But the program had been reorientated in 1959, with the new Masurca II (or Mq 2) now being self-guided. As a stop-gap measure, Marine bought American Tartar missiles for four Surcouf-class destroyers. Long stubby mid-body fins were used, together with active tail fins. The booster and main stage had *Poudrerie Nationale Polka* and *Jacée* solids operating for 4.6 s and 26 s respectively, staging taking place at Mach 3. Matra was involved in the manufacturing of what became the first French operational SAM (the first flight date is not known, but took place after June 1961). The Mod 2 variant introduced CLOS (Continuous Line Of Sight) beam-riding, and stayed in service until 1975. Mod 3 switched to

SARH (Semi Active Radar Homing) with the Thomson-CSF DRBR-51 radar. Each ship had 48 missiles (the *Suffren* and *Duquesne* frigates, the Colbert cruiser). Two could be launched a few seconds apart, from a double launcher, which could be rotated both in site and elevation.

Figures 7/8: Left, Masurca Mq 2, the first operational French SAM;
Right, The Nord 5301 ACAM SAM (Courtesy of Philippe Jung).

With SFECMAS totally integrated since December 1st, 1954, SNCAN foray in the SAM field in 1956, as could be expected, was based on an extrapolation of its successful 5100 series: the 5301 ACAM (*Arme Contre Avion volant à Moyenne altitude*). It used the trademark swallow shaped fins, with solid propulsion. The first stage brought the missile to its cruising speed of 600 m/s. Guidance was by telecommand, using jet deflectors. Three launch campaigns took place in Colomb-Béchar, with fairly good results.

In the same year of 1956, the Arsenal 5103/AA 20 went into service, initially in the so-called J2RT version (with the two solids operating for 2 and 16 s respectively). It was essentially an Ars 5102 with a bigger payload. The M2RT version followed at the end of 1957, with the second solid operating during 19.4 s.[9] It was stabilized by spinning, but piloted by jet deflectors (the latter had been patented by Stauff back in August 1948, their first application being on the highly successful SS 11 and the AA 10/Ars 5102), via a Derveaux telecommand. Interestingly, *Armée de l'Air* stated that, contrary to fears about the potential difficulty for a pilot to use two sticks for flying both plane and missile, the 5103 gave excellent results, without significant prior training. Nord did try an auto guided version, by July 1958, using the semi-active radar guidance method, the missile beam-riding the radar of the launch aircraft. Both SS 11 and AA 20 also introduced in France the CDB grain (Cast Double Base, an improvement over EDB), here called *Epictète*, and first loaded in 1951. The AA 20 is claimed to have been the first AAM in the Western world, although this should be confirmed, with the Hughes GAR-2 Falcon operational in March 1956, and the Sparrow I in US Navy service also by April 1956.

The idea arose in 1956 to transform the 5103 into a ground attack weapon. This was fortunate, as around 1958, it would be decided at high level that air-to-air missiles would come under Matra responsibility, and air-to-ground ones with Nord. The simpler to use Matra R 511 had won the day in the AA field (although, overall, the missile, autoguided and aerodynamically piloted, was obviously more complex). The second batch of 5103 was canceled, but the order for their containers somehow was forgotten to be stopped. The corresponding hardware piled up for some time in the Les Gâtines annex of Châtillon! Successful trials with unmodified J2RT, then M2RT, accordingly gave birth in early 1959 to the AS 20 (the Nord 5110, as SNCAN had become in January 1958 Nord Aviation). A new warhead came from the SS 12 program. It was bigger, since the proximity fuse of the AA 20 could be replaced by a simpler contact fuse. Initial testing showed the need to cant fins at 30 minutes instead of 20 minutes. After Type A, a new Type B motor, with the new improved *Plastolite* grain (the French equivalent of AP – Ammonium Perchlorate, mixed with PVC – Poly Vinyl Chloride binder) to maintain speed at low altitude, was developed. The AS 20 was tested against the hull of the Georges Leygues. For training, AA 20 with only the new cant angle, were used. In the beginning of the seventies, a target version C 20 also was produced. The first air-to-ground missile operational in Europe in 1961, the AS 20 equipped many aircraft: Aquilon, Etendard IVM, Mystère IVA, Mirage IIIC and IIIE in France; F-104 and Fiat G.91 in Italy and Germany; and Bucaneer in South Africa. License production took place in Germany. The warhead however revealed itself rather small, leading STAé to launch in the beginning of 1959 the AS 30 program for a bigger missile. Retaining the traditional but qualified in-house architecture, Nord AS 30 proposal, the 5401, used the ACAM motor as a basis for what happened to be so successful that to this day, in his laser-guided AS 30L guise, this missile is still in service! In the meantime, old AA 20's were used for training AS 30 operators.

At about the same time, Latécoère, still struggling like all the others with guidance, launched in March 1956 its first MS 21, a testbed supporting the Masalca (see Part I), using the same booster. A simplified half-scale upper stage concentrated on the development of the guidance loop, using German gyros. Lieutenant Commander Max Salmon's brainchild had gone through many variations since his original MS 10, that he had initiated with Matra, where he had been detached in 1950. There are two versions to explain the name of this missile: *MArine Sol Air Latécoère Contre Avions*, or *MArine SALmon Contre Avions*! With wooden surfaces (a fixed empennage and all-moving wings), the MS 10 had an air intake of square section. Four solids boosted the assembly to Mach 1. After four tests had ended in explosion at ramjet ignition, the program had switched in 1952 to a new contractor, Latécoère. The new MS 12 air intake had been initially of pitot type; then ONERA help had resulted in an isentropic shape, before settling on a conical one. Many problems still had to be solved, high hopes being placed on the MS 14 version, the nosecone of which could be recovered, thus helping for the first time to better understand the source of problems. All-moving fins of delta shape, actuated by an electric motor via racks, did not withstand the launch acceleration (the first known launch of a MS 12 took place on December 17th, 1953). They had to be replaced by hydraulically actuated all-moving trapezoidal fins on the MS 15. Ramjet wind tunnel tests had taken place in LRBA in the winter of 1956.

The MS 21 had a solid sustainer, and was among others, used for testing an optical seeker. The target was the cloud resulting from the firing of an anti-aircraft shell. An ECA seeker also had been planned.

With Marine busy on its conventional Masurca, the end was in sight for the Masalca, and the last launch campaign of the MS 15 took place with N° 116 of October 17th, 1958. Launches of N° 118 to 120 were canceled (manufacturing then was in progress up to N° 123). The program had been too ambitious, trying right away to test everything together: it actually took a grand total of 13 years for the US Navy to develop the Talos. Among problems, the seeker kept being affected by interferences. An interested US Navy delegation visited the Toulouse plant of Latécoère, but this was to no avail. Bernard Devilliers, who had been hired in 1955 in the frame of the development of missile activities in the company, coinciding with the end of seaplanes activities, kept a small team, while Latécoère had proposed to STCAN (*Service Technique des Constructions et Armes Navales*) to continue on its own funds. But two months later, any new in-house development in this field was stopped. Marine had "reevaluated" the Masalca on April 14th, before canceling it on February 13th, 1960. All that was left for Latécoère in rocketry was series production of the Malafon, albeit for quite a long time.

The NATO SE 4500

When the French government decided in 1955 to build a nuclear bomb, to be delivered with strategic missiles, GTC thought that an enlarged version of the SE 4200 (in a 4:3 ratio) just being delivered to the French Army, could be used to carry this weapon, provided the latter could be miniaturized. Boosted by two SEPR 684 or two STRIM solids, this X 405 design had a 700 kg capacity for a 100 km range. The SEPR 684, using *Plastolite*, may have been the first use of this improved propellant in France. A SFENA RBA autopilot kept altitude constant, while lateral guidance was by beam riding a CSF radar via a CSF PD receiver. A CSF TM receiver commanded release of the bomb. Anti-radar CR 1 (*Contre Radar*) seekers made by CSF also were tested, as already experimented with the SE 4261 in December 1956, one of the first such applications.

Interestingly, in the same way as the MDAP Mutual Assistance Defense Program saw the USA, in the frame of NATO, pay for the production of European fighters to re-equip their home countries, Larkin contracts were planned for weapons. No doubt stirred by the ramjet activities in Cannes, the Americans thus awarded a contract to GTC in the frame of MWDP (Mutual Weapon Development Program), for building the X 405, now renamed the SE 4500.[10]

Starting on October 10th, 1956, launches from the Icare B2 pad of Hammaguir, did not initially go very well, with repeated guidance failures. But just when the required range was demonstrated in March 1957, the Government elected to take the Mirage IV bomber as the initial carrier for the bomb, its range being much higher than that of the SE 4500. Testing however continued, if only because the Army might use the latter as a follow-on to the SE 4280. Sweden was also very interested, for coastal defense use, negotiating the buy of SE 4200's and the license for the SE 4500 in mid 1958.

The year 1957 was pivotal for GTC, as the management of newly created Sud Aviation (from the merger of SNCASE and SNCASO on March 1st, 1957) questioned the future of missile activities in the company, notably the rationale behind launching dozens of rockets, when the first computers and mathematical models had appeared, allowing shorter development times with fewer prototypes. The decision was taken to continue with missiles, providing some rationalization took place. To this end, a young flight test engineer, Roger Béteille, fresh from certifying the Caravelle, was sent to Cannes as the technical director.

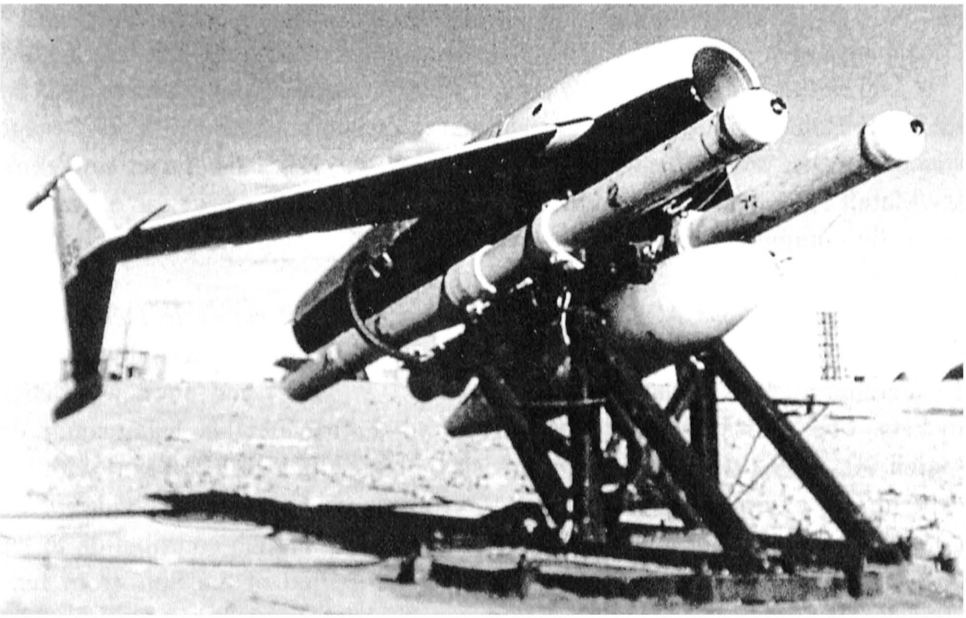


Figure 9: Ramjet SE 4500 G 35, launched from Hammaguir on 22 January 1958 (Courtesy of Philippe Jung).

The return of de Gaulle to power in May 1958 even quickened the pace. Land-based missiles were being considered, both tactical (SSBT *Sol-Sol Balistique Tactique*, or Casseur, of 300 km range) and strategic (SSBS). Engaged in both SSBT studies and SE 4500 testing, GTC was in the unique position of being able to compare ballistic and atmospheric options. To this end, an inertially-guided and enlarged X 406 version of the SE 4500 (1.4 ratio), of 400 km range, was studied.

So the last SE 4500 flew in December 1958, thus killing the about to be signed Swedish contract. Switzerland also had shown interest. Noteworthy, the only European countries to buy ramjet-powered missiles (Blodhound SAM's) in the sixties, were Sweden and Switzerland, no doubt because of their favorable contacts with GTC!

As if it was not enough, in August 1959, the Casseur program that Sud Aviation had just won, was canceled, priority now being exclusively given to strategic missiles. Fortunately, the huge experience accumulated in Cannes (1,150 rockets built!) later gave GTC the responsibility for all the initial test vehicles for the *Force de Frappe* missiles.

Monica: A Low Cost Sounding Rocket System

ATEF (*Association Technique pour l'Etude des Fusées*), created in 1953 by ex-SEPR Robert Pillorget, had been working on the planned SEPR 35 3-stage weather rocket of 1949, first launched under the ATEF-14 guise in February/March 1955, when the opportunity to switch to a higher gear came from the scientific community, which had some difficulty in using the expensive Véronique as a sounding rocket.

In April 1956, CASDN (*Comité d'Action Scientifique de la Défense Nationale*), presided by Général Guérin, came to the help of scientists, by ordering 15 Véronique AGI (*Année Géophysique Internationale*) and 15 new Monica rockets. The AGI version of Véronique (which first flew in Hammaguir on March 7th, 1959*) would be able to reach higher altitudes of 210 km, with the experiments of Professor Etienne Vassy from the *Laboratoire de Physique de l'Atmosphère* in *La Sorbonne*. They implemented the French contribution to the IGY, decided at world level, to study the active period of the Sun, from June 1957 to December 1958. In this frame, the USA had announced on July 28th, 1955, a seemingly science-fiction project: putting in orbit Vanguard, the first artificial satellite of the Earth. Completely unnoticed was the Soviet statement two days later, that they had a similar project...

Monica actually corresponded to a whole family, one of the very first applications of the modular concept. By playing with the diameter and length of solid stages, as well as by varying the payload weight, it was possible to satisfy many particular needs at low cost.

Five main versions have been identified, from Monica I (the former ATEF-14) to Monica V, all of three stage configuration. They could be launched with a 15 kg payload (sub-type a), or with a 7.5 kg one (sub-type b). They used various combinations of 130 mm and 160 mm diameter solids. They were not guided, but unlike Véronique, had on-board telemetry, as required by the scientists (Véronique only got it in February 1961).[11]

The first launch, a Monica I or II, took place at the end of January 1957. During the 1957 and 1959 campaigns in CERES, Vassy was able to measure pressures and temperatures, up to altitudes of 90 km. A maximum of 50 were launched (40 ATEF-14 for weather use and 10 Monica IV/V for scientific use). Several dozens single and 2-stage derivatives, the ATEF-49 target, also were launched. A single-stage ATEF-64 flare rocket was tested around 1959, for use in the forthcoming French nuclear tests. In the sixties, the 160 mm solids became

* It has been found this year that the well-known Le Cardonnet site for the Véronique P6 and R launches of January 1952, actually was located near Montpellier.

the basis for the youth rocket activities in France, through ANSTJ (*Association Nationale Sciences et Techniques Jeunesse*). Monica Ib even had been planned to be used as a Véronique second stage.

With its hands full of rockets being launched from CIEES, the French Air Force test center, CEV (*Centre d'Essais en Vol*) decided in 1957 to create a permanent detachment in Colomb- Béchar.

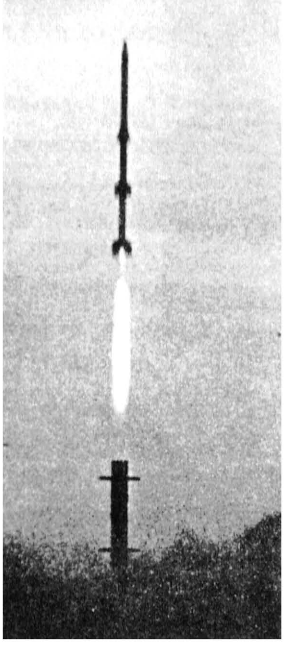
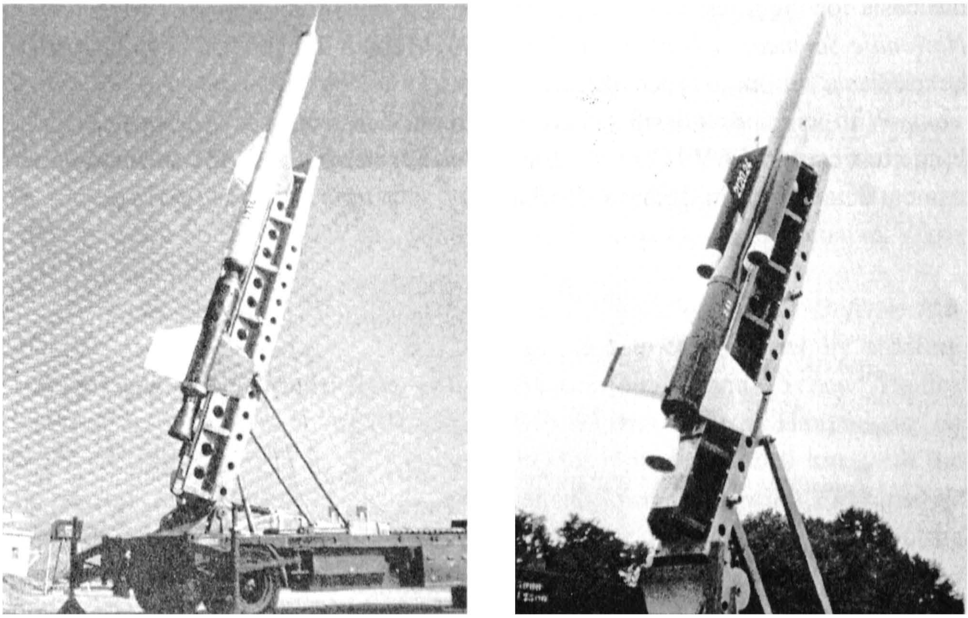


Figure 10: Launch of a 3-stage ATEF Monica sounding rocket, in early 1960 (Courtesy of Philippe Jung).

A Horde of ONERA Rockets

As soon as it had been created, ONERA had begun ramjet activities, as this propulsion device looked very promising. Basic research work fitted well with its missions. Internal aerodynamics with and without central body were analyzed, as well as flame holders with or without obstacles. The wind tunnel of Chalais-Meudon was used. After the launch of small testbeds from Mailly (see Part I, but with the so-called "VD-1" now known to have been a *Viaud Démonstrateur* VD-2050, which had been preceded by test boosters VD-2010, VD-2020, VD-2070 and VD-2080, as well as by the VD-2040 ramjet, starting in 1948), two basic configurations were tested, all using kerosene for fuel.[12]



Figures 11/12: Left, ONERA ramjet 2140 test vehicle N^0 2141; Right, ONERA ramjet 2120 Bi-Stato N^0 24 (Courtesy of Philippe Jung).

The "classical" axisymmetric VD-2140 was accelerated at M1.8 by a solid, whereupon it would accelerate to Mach 3 thanks to an internal thermal protection allowing a longer combustion time. The ramjet diameter was 320 mm. Launched in 1956 from *Ile du Levant*, they showed flow distortion under varying angles of attack.

Thus a new configuration with two opposite podded ramjets, still of 320 mm diameter, was tested in 1958, as the VD-2120. This was just as the high-altitude ADX ramjet started flying, on the 3-stage OPd 220-ADX.

In the meantime DEFA, which had defined with its NA 250 the 500 mm diameter for the Super Parca, decided to cooperate with ONERA. The Marguet team thus went to Châtillon in 1957.

The result was the Statex, of configuration similar to the future Super Parca, using an isentropic frontal air intake. Boosted at M1.5, the 500 mm diameter ramjet already had been ignited at M1. Fuel was housed in a 50 l tank. To keep chamber temperature below 2,000 K, a mechanical device limited the mixture ratio. Configurations with and without canard were tested. The program was however stopped when all SAM activities in DEFA, including Parca, were canceled in 1960.

ONERA actually was active with all sorts of rockets, the *Aérodynamique* directorate OA also entering the fray in 1952, with its OAV-200 for ramjet aerodynamics tests.

ONERA's Propulsion directorate (OP) began launching in 1952 a new testbed for second-generation ramjets, the OPd 80 (80 mm diameter), the brainchild of a specially created "OPd" division. It came in many versions and configurations.

From that successful endeavor, new families were quickly developed by OPd, as general testbeds, both for rockets (for such analysis as aerodynamic roll control) and aircraft (such as wing aeroelasticity): the OPd 100, OPd 200, OPd 217, OPd 220, OPd 250 and OPd 320. The latter came in single and twin-stage versions, with the OPd 320S even combining a single-stage OPd 320 plus an OPd 220, boosted by a SPRA-20. Launches already started in 1953. A two stage OPd 24 22/B also was shown in the "*Terre et Cosmos*" exhibit, inaugurated on June 4th, 1958 at the foot of the Eiffel Tower.

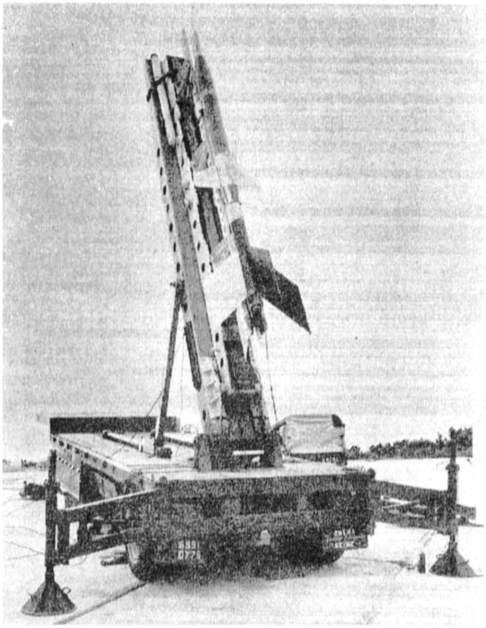
The most used of them all, with 16 versions, the OPd 220 appeared when a real section of its body was put in the S1Ca wind tunnel of Cannes, to test air blowing on its fins for roll control. Three versions of air ramps were tried, inside and outside at half-span, and a medium position, the last one being the best. Maximum speed was M1.9, with M2.6 mentioned.

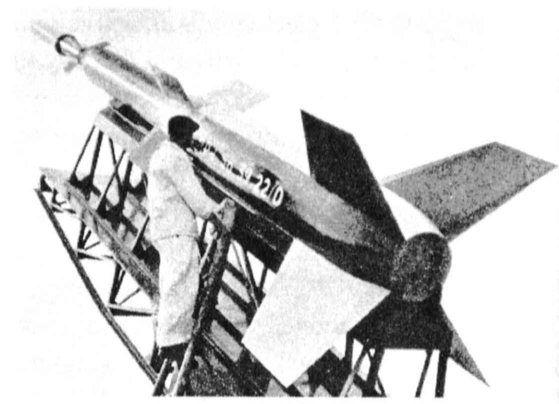
The *Résistance des structures* directorate also started experimenting in 1955, with its OR-180, OR-200 and OR-228 families.

ONERA thus could not fail to be active in high speed research, as was the case at the time in the USA and Great Britain. A 4-stage rocket with the awkward designation OPd 56 39 22/D (corresponding to the diameters of the first three stages), able to reach high altitudes and speeds, started being launched in May 1959.

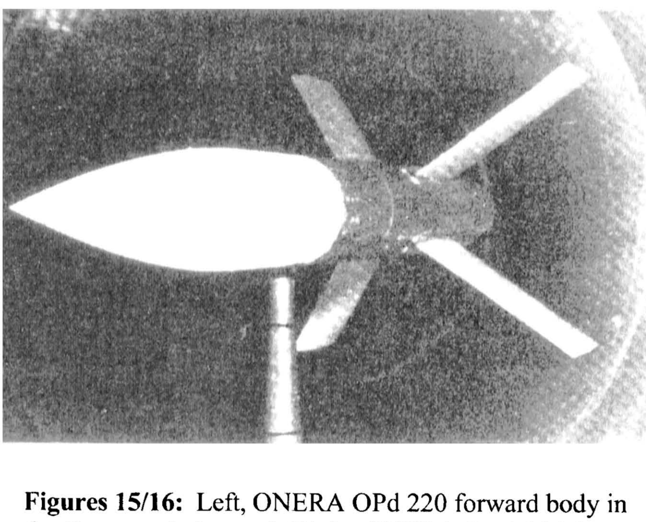
In the same vein, ONERA launched in CERES on January 27th, 1959, the first of 3 OPd 39-22 Daniels.[13] It was a three-stage sounding rocket, re-using the first two stages of Ardaltex, capped by an OPd 220 *Mélanie*, the purpose of which was to perform technical and scientific research. The three solid propellant stages burnt during 5.6 s, 23.8 s and 6 s respectively, to bring the payload at about Mach 8 (Mach 5.1 only is mentioned?). SEPR was a major subcontractor.

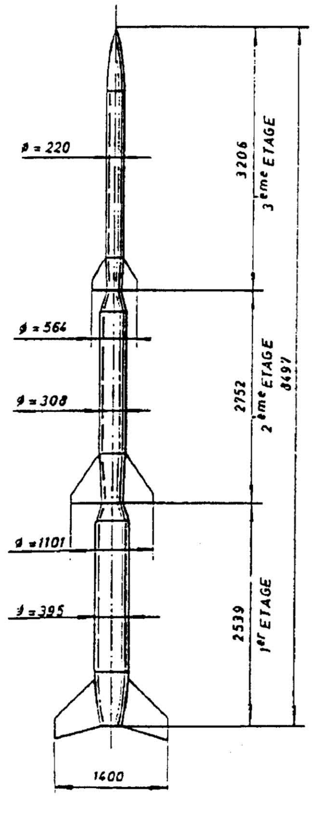
Daniel was unguided, and was equipped with telemetry equipment. The payload compartment, of 1.304 m length and .21 m diameter, allowed a payload of 12 kg to be carried. Batteries provided the necessary power. For its first flight, Daniel performed four aerodynamic measurements (pressure, acceleration,..), as well as radiation measurements with three Geiger counters.





Figures 13/14: Left, February 1959 picture of a 2-stage ONERA OPd 220 rocket for aeroelasticity research. It had on-board telemetry. Right, ONERA OPd 56 39 22/D high altitude rocket in Terre & Cosmos exhibit (Courtesy of Philippe Jung).





Figures 15/16: Left, ONERA OPd 220 forward body in the Cannes wind tunnel; Right, ONERA Daniel high altitude sounding rocket (Courtesy of Philippe Jung).

Meanwhile, the news of the launch by the Soviet Union of the first artificial satellite of the Earth on October 4th, 1957, was sending ripples the world over...

It started things moving everywhere. The existence of the highly secret CIEES was then revealed to the public. In 1958, the CNRS (*Conseil National de la Recherche Scientifique*) created an aeronomy department, under the direction of Professor Kastler, soon to win the Physics Nobel Prize for the invention of the laser. His deputy was Jacques Blamont of *La Sorbonne*, soon to become famous for his experiments with Véronique. In the same year, jet engines expert SNECMA started studies in the field of solid propulsion, and opened a manufacturing workshop in Gennevilliers, near Paris, to build rocket main bodies. Much later, SNECMA absorbed SEP, itself ex-SEPR...

At an even higher level, on January 7th, 1959, a *Comité de Recherches Spatiales* was created, under the direction of Pierre Auger, with three goals:

- identify available means in France,
- propose a space program,
- implement the afore mentioned plan.

It was composed of personalities from the scientific world (CNRS, *Observatoire de Paris*, ONERA) and the concerned ministries (Armed Forces, Post Telephone & Telegraph, Finances, Foreign Affairs).

The Operational Malafon

In 1956 Latécoère began the development of an anti-submarine gliding torpedo, the Laté 231 Malafon (*MArine LAtécoère FONd*, "fond" meaning sea bottom). Of simple glider configuration, it was built of stainless steel. The wing, filled with pyrofoam, had Wagner ailerons. There were also Wagner surfaces in the 3-tail surfaces for pitch control. Two solid boosters under the tail, with their own horizontal stabilizing surface above them, brought the glider to 750 km/h in 4.5 s. The torpedo, simply slipped inside the fuselage, constituted the nose of the missile. An autopilot kept the altitude constant at about 100 m above the sea, thanks to a radioaltimeter, while a radar on the ship guided the Malafon with roll control to keep it in the vertical plane linking launcher and target. To keep the altitude constant, the angle of attack of the gliding ensemble had to constantly increase. When 800 m from the target, the angle of attack was brought down to zero, a braking parachute was opened, and an explosive bolt holding the Alcatel L4 torpedo was fired. The corresponding deceleration naturally extracted from the fuselage the 525 kg torpedo, which was stabilized by a drogue during its free fall toward the water. The missile could be recovered, for reuse and training purposes.

Testing, from *Ile du Levant*, seems to have started in February 1958 (N° 02 was launched on February 21st – a failure). The Wagner spoilers having shown only a low efficacity, and longitudinal stability being affected by a phygoid, an important test campaign was staged in the ONERA wind tunnel of Modane. Third scale models were flight tested, and even full scale models (six in total) were released near St. Tropez by a 10.S squadron Lancaster, initially based in Cuers, and later in Istres. A Laté 232 Malafon Mq 1 version appeared in January 1959 (N° 03), with a longer nose, due to a forward shift of the torpedo. Pods were added to the extremities of the wings, to house the spoiler motors, as well as flares. The horizontal stabilizer of the boosters also changed to a lower position. In 1959, 14 Malafon's were launched from CERES and *Ile d'Oléron* (the first on October 19th). Soon after the beginning of series production, the tail switched to a simpler 2-fins arrangement, while the booster stabilizer went back to its upper position (the Laté 233 Malafon Mq 2). By January 1961, 50 Mq 1's and Mq 2's had been manufactured. After overcoming the stability problems, tests of the complete system could start in January 1962 from the *La Galissonnière* escorter. By March 1963, 50 Malafon's had been launched. The development was completed in 1964 with 22 launches, from January to May. Finally, operational testing was performed from *La Galissonnière* during the first half of 1965. The Malafon was to become the first – and only – Latécoère missile to reach operational status, a few hundreds being produced to equip 18 French ships, beginning with *La Galissonnière* (*Suffren* and *Duquesne* frigates, five converted T.47 destroyers, five new corvettes,...). Apparently, up to 13 Malafon's could be stored on a ship. It began to be progressively retired from service in the early nineties, as too complex and costly.

Figure 17: A Latécoère 233 Malafon Mq 2 with its torpedo in the nose (Courtesy of Philippe Jung).

Véga: A Fast Ramjet

Under the direction of M. Chaulin, Nord Aviation decided to try reaching the highest possible speed with a ramjet. Thus was born the Véga, a steel vehicle, able to cruise in horizontal flight at 25 km and Mach 4.2, during two minutes. A load factor of 10 was to be sustained. Fins had spoilers. Some were guided versions, using small moving foreplanes (for example N° 04 in March 1960). The 645 mm diameter kerosene ramjet was ignited at Mach .9. The latter was under the responsibility of Maurice Ravel, to become later the deputy director of the propulsion department.

Launches started in October 1959, from Hammaguir. In the course of testing, the Véga hit Mach 4.2 in Colomb-Béchar on October 10th, 1961, entering the hypersonics domain, where dissociation effects become significant. Recent research found that this was not a new ramjet speed record, as long believed, France actually having previously taken the record back from Lockheed on December 7th, 1960, when the ONERA Stataltex N° 02 was the first to hit the "hypersonic barrier," reaching Mach 5.

A military SAM version had been planned, with a maximum speed of Mach 5 and an impressive range of up to 600 km, but it was not pursued.

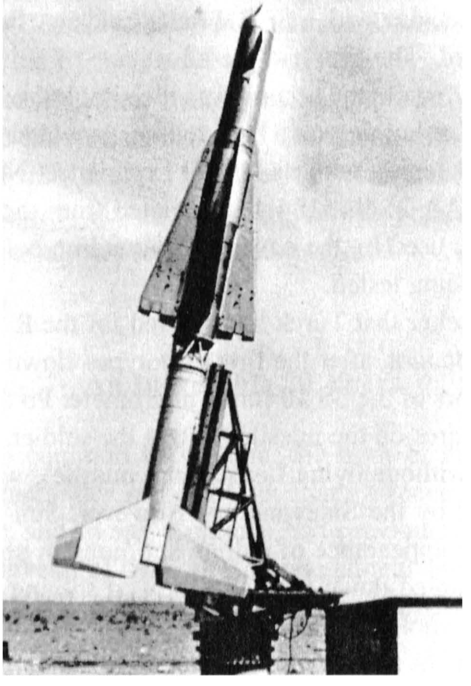


Figure 18: The Nord Véga ramjet at CIEES (Courtesy of Philippe Jung).

Another ramjet testbed was launched by Nord in 1959, the Nord 625, used for the development of the 625 mm diameter Sirius ramjet of the CT 41. The latter had been studied in 1957 as a target of great range simulating supersonic aircraft, with the possibility to be transformed into a surface-to-surface missile, as a prelude to a strategic missile. Its canard already was actuated by a FBW (fly-by-wire) Air Equipement system. Under the direction of Gérard Payelle, 15 were launched in four versions, Nord 625A to D.

A note on the history of the old *La Renardière* range, which had become the ETTN (*Etablissement d'Expériences Techniques de Toulon*) in 1933, and belonged to DEFA, states that Nord tried there ramjets of 150 and 250 mm before 1963. This seems strange, as no known Nord ramjet had a diameter of less than 450 mm.

The Second Generation AAM Matra R 530

Fresh from the success of its homing (infra-red, then radar) R 511 air-to-air missile, Matra made an innovative proposal in the frame of the AA 25 and AA 26 programs for all-aspect air-to-air missiles for the Mirage III fighter (the radio-commanded AA 25 and the autoguided AA 26): to use the same basic AA 26 missile for two versions, one with a SARH radar guidance head, the other with an infra-red guidance head. The first had the advantage of being all-weather, at the expense of complexity, while the second was the simplest one (as exemplified by the US Sidewinder), just homing on a heat source, provided the latter was not the Sun, for example! In-keeping with its AA 20 experience, Nord had proposed for the radiocommanded AA 25 its 5104, extrapolated from the 5103. There is a report of the 5104 being used by the naval 10.S squadron before September 1960: it probably only was being tested.

The infra-red seeker that Turck had studied for the R 511, under the direction of Jean-Jacques Baudot, after the first prototypes flown on the SE 1511, and the operational detectors of the SS 10 (the 2 micrometer Pb Sn detector kept track of the pyrotechnical flares on the missile, so that the soldier only had to aim constantly at the target, without flying himself the missile), worked in the same 2 micrometer band used by the Sidewinder.[14] However, Sun perturbation was too much. Fortunately, the appearance of indium antimonium photodiodes in the 3 to 5 micrometer band, cooled down to 77 K, allowed solving this problem. But to develop these new technologies, Turck needed help. He eventually found it by being absorbed within SAT (*Société Anonyme de Télécommunications*) of Paris in 1957.

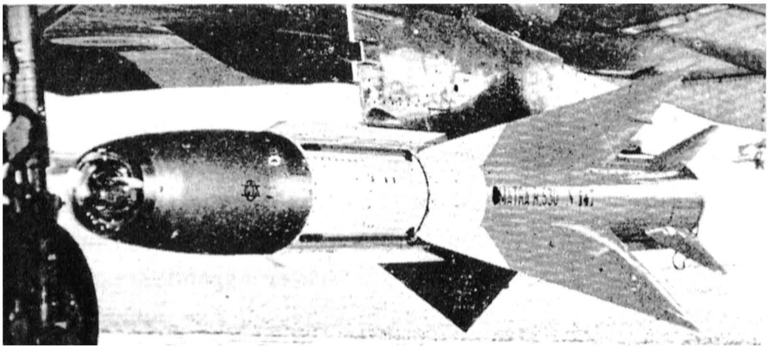


Figure 19: AAM Matra R 530 N° 147 with an infra-red homing head (Courtesy of Philippe Jung).

The R 530, first launched at the end of 1959 from a SO 4050 Vautour bomber, went on to become a big success, being mounted on Crusader, Mirage III and Mirage F1 fighters, 8,500 examples being exported to Argentina, Australia, Brazil, Greece, Iraq, Israel, Kuwait, Lebanon, Libya, Morocco, Pakistan, South Africa and Spain. Its Super 530 derivative still is in service today! A FBW version was studied in 1960 by Air Equipement, but was not retained for series production, as too expensive.

More generally, 1959 saw continuing adaptation to the new situation created by Sputnik. The CEMH (*Centre d'Essais des Moteurs et Hélices*) in Saclay became on May 28th the CEPr (*Centre d'Essais des Propulseurs*). An annex was created in St. Médard-en-Jalles, near Bordeaux, to cast solids (the SSBS and MSBS motors would later be built there). The *Section Engins Spéciaux* and the *Section Armement* of CEV merged together, to become the *Section Armes et Engins*, while a new *Section des Essais Missiles* was created, to handle the new problems linked to the ballistic missiles being studied.

An Incredible 20 Years

Contrary to all common knowledge, the birth of the new Fifth Republic with the venue of Général de Gaulle did not create a space industry in France. An incredible 89 missile and rocket programs had previously reached flight status, from 1939 to 1959, several of them already operational and exported. A complete and qualified industry was in place, with experienced customers, prime contractors, equipment manufacturers and test centers. Only the scale remained to be increased, essentially higher speeds and bigger masses. The only missing element actually was inertial guidance technology, although a ground prototype of inertial platform had just been developed in 1958/9 by LRBA. All the seeds of Force de Frappe actually were sown by the often considered infamous Fourth Republic...

Thus, the widely-known aircraft prototype policy of France in the 1950's had a full-blown and coherent equivalent in the rocketry field. This must be a big surprise for all of those who equated French space during 10 years with a few unguided Véronique's! Proof could be found during the Symposium held in *Ecole Militaire* on September 29/30th, 1997, where a spending peak for the period 1948-1958 was shown to have occurred in 1953.[15] It also puts in proper perspective the contribution of about 120 German engineers and technicians, many of which quickly left France in the period from 1948 to 1951, while fast technical progress was achieved by thousands of Frenchmen – albeit often behind their American and Soviet colleagues. Very few Germans were actively involved; actually the most efficient help came from the USA and Great Britain, thanks to personal relations. The MIT collection, for example, was very useful. The first successful French missile, the SE 1500, even flew in 1946, at a time German engineers were barely arriving in France.

On September 17th, 1959, SEREB (*Société pour l'Etude et la Réalisation d'Engins Balistiques*) was created.[16] The march to Diamant and Ariane had begun.

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	1st flight	Manufactur.	Name	Type/prog	Guidance	Max speed	Max alti	Range	Built	Launch.	Leng x dia	Weight	Motors	Notes
1	End 1939	SNCAM	(flying bomb)	AS	autopilot			8.1 gl.rat	few		?x.735 m	65 kg	-	
2	1943?	Hurel/Turck	BHT38	AS	-				10			160 kg	-	
3	15.3.45	Barré	EA 1941	SS	1 t		100 km	60 km	8	7		100 kg	LO2/gasoline ether .72 t	ONM
4	6.46?	Hurel	Paris-Deauville	Drone					1	1			Piston	
5	7.11.46	SNCASE	SE 1500 to 1524 SE 1503 SE 1531	AS 10	Radio or IR	450 km/h	13 km	14 minu	118tot	173tot	6.18x4.34 m	650 kg	- Turboméca Piméné .11 t SEPR 401 1.25 t (HNO3+tonka)	
6	12.46?	Arsenal	Ars 5101	AA 10	wire	M.9		5.5 km	~20		2x.58 m	60 kg	SEPR 16 or 21 (HNO3+tonka) .2 t	X-4
7	20.8.47	DCCAN	Pluvier	AS	radio	280 m/s	6 km	5 km		>36	3.26x1.35 m	1,570 kg	-	X-1 FritzX
8	1947?	ECA	S.20	AS	autopilot	500km/h			(N° 52)		3.86x4.32 m		-	
9	<1.48	DCCAN	Macreuse L50	AS	autopilot		2 km	15+ km		60			-	
10	Early.48	Arsenal	Ars 5201 Ars 5202 to 5203	SS 10	wire	 300 km/h	-	 1.6 km	20 29,849		.88x1.2 m .86x.75 m	12 kg 15 kg	1 solid 2 solids (EDB)	 9 countries
11	<10.48	DCCAN	CN	Target	-		9 km	towed			?x3 m		-	
12	2.12.48	DCCAN	X-8	AS	radio	>M1	6 km		>4	>2				
13	1948	ONERA	VD-2010	Experim						20	1.5x.1 body	22 kg	solid+inert ramjet	
14	<13.1.49	DCCAN	Palombe	AS	radio	900 km/h	2 km	18 km	74		3.58x3.14 m	1,045 kg	Walter 109-507 .6 t (H^{2}O^2/CaMnO4) or solid	Hs 293
15	>1.49	DCCAN	Torpille autogyre	AS	autopilot				5	3			-	

	1st flight	Manufactur.	Name	Type/prog	Guidance	Max speed	Max alti	Range	Built	Launch.	Leng x dia	Weight	Motors	Notes
16	2.4.49	Arsenal	Ars 5501	CT 10	radio	540 km/h	5 km	320 km	413		6.01x4.32 m	660 kg	2 solids(EDB)+pulse jet .18 t(gasolin)	Mar :Toréador
17	29.9.49	SNCASE	SE 4100 to 4140 SE 4110 to 4119	SA 10	radio+opt/radar hom	1,000 km/h	11.2 km		81tot	78tot	5.12x2.24 m 7.3x2.7 m	1,480 kg 1,720 kg	2 SEPR 4(HNO3+tka)1.25 t+SEPR 2 6 STRIM solids 1.25 t + SEPR 2 1.35 t (HNO3+tonka)	or SEPR 202
18	1949	ECA	ECA T50	Target					20?					
19	1949	ONERA	VD-2020	Experim						7	3.7x.1 m body	100 kg	solid + inert ramjet	Air launch ?
20	1949	SEPR	SEPR 35	SA						1			.45 t (EDB)	+ 2inert stages
21	8.2.50	SNCASE	SE 4200 to 4280	SS 40	radio+opt/rada ho	M.8	2.5 km	127 km	608	567	3.57x2.96 m	592 kg	2 STRIM 3100 or 3340 2.8 t or 3360 or 3370 3.2 t (EDB) + SE ramjet .19 t (kerosene)	
22	5.50	MATRA	M04	AS	autopilot	M1.4	4.5 km	35 km	(N° 12)		4.6x1.8 m	460 kg	SEPR 12 1.25 t (HNO3/tonka)	Exp.for SA
23	2.8.50	LRBA	4213 Véronique Véronique 61	SA/sounding	-	1.9 km/s 2.4 km/s	220 km 315 km			98tot	7.3x1.35 m 9.5x1.35 m	1,342 kg 1,932 kg	HNO3/kerosene 4 t HNO3/turpentine gasoline 6 t	
24	8.50	DEFA	PARCA	SA	radio	M1.7	25 km	32 km	120		5.48x1.6 m	1.1 t	4 EDB, Artemon or Artemis CDB,SEPR Mimosa AP/PVC +HNO3/turp. gaso 2 t or Ajax/Atlas/Irène/Jason CDB or Mathurin AP/PVC	
25	1950	ONERA	VD-2040	Experim						7	3.7x.29m bod	100 kg	SPRAN ? solid + ONERA ramjet	Air launch ?
26	1950	ONERA	VD-2070 VD-2080	Experim						3 ?	2.5x.2 m body 2.3x.2 m body	40 kg 40 kg	solid + inert ramjet ? + inert ramjet	

	1st flight	Manufactur.	Name	Type/prog	Guidance	Max speed	Max alti	Range	Built	Launch.	Leng x dia	Weight	Motors	Notes
27	26.5.51	Brandt	Mabranca A/B1/B2	SA						(N° 33)				
28	<29.6.51	Ruelle	Maruca A1 to A5 Maruca A6	SA	homing	M.72 M.85	13 km 18 km	15 km 22 km	200tot		6.1 x 2 m 5.8x2 m	525 kg 450 kg	4 Nebelwerfer or 2 or 4 EDB or 2 Mimosa 3 t solids ECAN (HNO3+furf.alcoh & aniline)	
29	11.51?	Arsenal	Ars 5102	AA 10	radio								2 solids + 2-stage solid	
30	11.51	ONERA	OAV-200 OAV-200M	Exp.aerod	-	M1.4				12 3	4x.2 m body 2x.2 m body	250 kg 56 kg	PN solid SPRA 6 solid	Aircraft launch
31	1951	MATRA	R05, R510/511	AA 20	IR/rada homing	M1.8	18 km	4.5 km	1,600		3.09x1 m	184 kg	STRIM(EDB)or2 H-Br 1.6+.2 t(ED	
32	<12.2.52	ECA	ECA 30	Target						(N° 3)				
33	15.2.52	SNCASE	SE 1900/1910	Sled	railtrack	328 km/h	-	3 km	4	50	7.3x8.15 m	4.4 t	4+2 SEPR 9 1 t (H^2O^2 + CaMnO4)	
34	2.52?	Arsenal	Ars 5103 Nord 5110	AA 20 AS 20	radio	M1.7 M1.7		4 km 7 km	2,000? 5,737		2.6x.8 m	135 kg 156 kg	AP/PVC+Supra(CDB) Aspic (AP/PVC)+Icare(CDB)	C 20 target
35	Early 52	SNCAC	NC 1110	Target	-	580 km/h		towed	3		10x9.6 m	360 kg	Towed (MS 500,Bl 175)	
36	2Q52	ONERA	OPd 80N, NL OPd 80NV OPd 80S	Exp.equip	-	360 km/h 360 km/h M1.3	2 km 10 km			88 >20 >20	1x.08 m bod .9x.08 m bo 1.87x.08 m	5 kg 6.5 k 21 kg	STRIM solid STRIM 750 solid PN solid?	

	1st flight	Manufactur.	Name	Type/prog	Guidance	Max speed	Max alti	Range	Built	Launch.	Leng x dia	Weight	Motors	Notes
37	9.52	MATRA	R04	SA	radio +radar homing					192tot?			4 SEPR 43 1.25 t (acid + tonka) + SEPR 44 1.5 t (acid + tonka)	
			R042/422			M2.5	20 km	50 km			9.33x3.32 m	1.7 t	4 SEPR 50 10t (EDB), or SEPR 732 20t (EDB) or SEPR 734 Vésuve 23.2 t (AP) + SEPR703or705 Jericho1.45 t(CDB	or 441 2 t or 502* or 706 1.5 t
			R043/431			M3.3	22 km	100 km			8.78x2.76 m	1.43 t	4 STRIM (EDB) or SEPR 73 20 t (EDB) + Nord ramjet .19 t	or 5052 13.5 t or 732
38	22.11.52	Barré	4211/EA 1951 Eole	SS	9.5 t	1,130 km/h	3 km	4 km	5	2	7.46x m	1.788 t	LO^2 + ethylic alcohol	
39	1952	DEFA	Entac	SS	wire	300 km/h	-	1,8 km	119,417		.82x.38 m	12 kg	2-stage solid (EDB) dia.15	
40	1952	Breguet	Br 910	AS 10	radio	800 km/h	5 km	50 km	6		4.81x4 m	1.36 t	-	
41	1952	SEPR	SEPR 50	Experim						2?				
42	1952	ONERA	VD-2050	Experim		M1.8	5 km			>10	3.9x.3 m bo	130 kg	SPRAN 30+ ONERA kero ramjet	
43	<26.3.53	DCCAN?	Gertrude	AS										
44	<21.4.53	DCCAN?	Hirondelle	S-to- ?						(N° 25)				
45	<6.53	ECA	ECA 27	Target						(N° 8)				
46	?	ECA	ECA 57	Target	autopilot	720 km/h	6 km	40 km			1.48x1.35 m	240 kg		
47	?	ECA	ECA 58	Target	-	290 km/h		towed			2x.3 m	60 kg	-	
48	?	ECA	XC 13	Target	-			towed					-	

	1st flight	Manufactur.	Name	Type/prog	Guidance	Max speed	Max alti	Range	Built	Launch.	Leng x dia	Weight	Motors	Notes
49	<9.53	ECA	ECA 21	Target?						>2				
50	15.10.53	MATRA	R062	AS	radio							1 t		
51	12.53	SFECMAS	Ars 5210	SS/AS 11	wire	500km/h	-	3.2/7 km	179,347		1.22x.5 m	30 kg	Simplet+Sophie CDB	+lic.prod.
52	<17.12.53	Laté	MS 10 Masalca	SA	radio				120tot	117tot			4 solids + Matra ramjet	
			MS 12/15		+ opt. homing	M2.5		100 km			8.7x2.2 m	580 kg	Popeye->Vénus (AP/PVC)	
													+ ONERA ramjet (kerosene)	
53	1953	ONERA	OPd 100	Exp.		M1.9	10 km			>10	2.7x.1 m body	28 kg	T10 solid	
			OPd 100S			M3	15 km			>10	3.7x.1 m body	56 kg	1 DEFA solid + T10	
			OPd 10-12D			M2.4	30 km			1	1.5x.1 m body	109 kg	3 DEFA solids + T10	
54	1953	ONERA	OPd 200Pp	Exp.		M1				3	2.5x.2 m body	47 kg	STRIM 750 soild	
			OPd 200L, LF							8or9	2.41x.2 m bod	41 kg	-	air-launch
55	1953	ONERA	OPd 217	Exp.			3 km			1	2x.22 m body		-	air-launch
			OPd 217LP			720 km/h	4 km			12	2x.22 m body		STRIM solid	air-launch
56	27.2.54	SNCASE	SE 4300/4350	SA 11	radio +	M.85	23.5 km	35 km	175	125	6.87x3.62 m	1,225 kg	5 STRIM 4 2.2 t or SEPR 5053 8.5 t	
					opt/radar homing								(EDB) or 2 SEPR 685 Mimosa 3.8 t	
													+ ECAN .55 t (HNO3+anil./furf.alc)	
57	9.4.54	SNCASE	SE 4400	SA 20	Radio	M3.7	67 km		97tot	92tot	8.09x3.07 m	1,225 kg	4 STRIM 3.1 t or SEPR 505 11 t(EDB)	or 5052
					+ radar homing								or SEPR 732 Vésuve 20 t (AP/PVC)	13.5 t
													+ SE ramjet .17 t (keros.)	
			SE 4401										?+ ONERA SPRA 15 or 20	

	1st flight	Manufactur.	Name	Type/prog	Guidance	Max speed	Max alti	Range	Built	Launch.	Leng x dia	Weight	Motors	Notes
58	10.54	SFECMAS	ST 450	SA	autopilot	M3.8	27 km			84	4.7x1.05 m	265 kg	2 solids (SPRA?) + Sf. Ramjet .08 t	
59	1954	DEFA	NA 250	SA	autopilot	M3	20 km			40			4 SEPR solids+DEFA ramjet (keros)	
60	1954	ONERA	OPd 220L,LΔ	Exp.aerod	-					20	3.6x.22 m bod	80 kg	- (air launch)	16 versions
			OPd 220 LP			720 km/h	4.5 km			10	2.8x.22 m bod		SERAM + 2 solids	
			OPd 220MEP,P,V			M1.1				>2	2.88x.22 m bo	100 kg	STRIM 750 solid	
			OPd 220P,Pp,S,...			M1.8	5 km			>32	4.9x .22m bod	200 kg	SPRAN-4 + SPRAN-4 or SPRA-6solid	
			OPd 220Clj,P,S,...			M1.9	15 km			>22	5.2x.22 m bod	230 kg	SPRAN-6b,10,15 or H + SPRAN-4 or SPRA-H Mélanie	
61	1954	ONERA	OPd 320LP, P	Exp.		M1				>4	3.69x.32 m bo	180 kg	SPRA-10 solid	air-launch
			OPd 320Pp							>1	?x.32 m body		? + ?	
			OPd 320S/1667P			M2.3	15 km			>4	7.6x.32 m bod	450 kg	SPRA-15 or 20 + SPRA-10 or 15 sol	
			OPd 320S/2012P			M5	120 km			2	11.13x.32 m b	850 kg	SPRA-20 + SPRA-10 or 15 + SPRA-H	
62	?		C4R	CT?										
63	?		Barracuda	CT?										
64	10.1.55	Latécoère	Laté 258 Malaface	SS	radio+TV	900 km/h	490 m (50 m crui)	50 km	15	15	6.3x2.5 m	1.43 t	2 x 1.05 t solids or 4 Mimosa or 1 PN Vénus or 2 Vénus + ECAN .2 t (HNO3+aniline/furf.alc)	
65	1.55	SNCAN	5510	CT 20	radio+homing	950 km/h	15 km	250 km	1,569		5.72x3.72 m	1,100 kg	2EDB+Turb.Marboré II .4t or VI .48t ->2 Agnès or Trèfle AP/PVC	M 20, R 20

	1st flight	Manufactur.	Name	Type/prog	Guidance	Max speed	Max alti	Range	Built	Launch.	Leng x dia	Weight	Motors	Notes
66	2/3.55	ATEF	ATEF 14/Monica I	Weather	-	990 m/s	53 km		50	40 ?	3.6x.16 m bod	70 kg	Mélanie .62t (AP/PVC) + Théodore .18 t (CDB) + Oreste .09 t (CDB)	
			Monica II	«		1,300 m/s	103 km				3.9x.16 m	78 kg	Mélanie + 2 Théodore	
			Monica III	«		1,615 m/s	106 km				5.4x.16 m	125 kg	Mélanie 1.24 t + Prosper .45 t (AP/PVC) + Théodore .19 t	
			Monica IVA, B	Sounding		1,390 m/s	145 km		10	10 ?	5.37x.16 m	123 kg	Mélanie + 2 Prosper or 3 Mélanie	
			Monica V	«			180 km				6.26x.16 m		Mélanie long + 2 Prosper	
67	1955	Ruelle	Masurca I	SA	radio	650 m/s		25 km				1,450 kg	Mathurin or Vénus 20 t + Irène,Célestin or Neptune CDB 2 t	
			Masurca II		radar homing	M3	23 km	50 km			8.6x1.5 m	2,080 kg	PN Polka 34.78 t (AP/PVC) + PN Jacée 2.42 t (AP/PU)	
68	1955	ONERA	OR-180L	Exp.aerod		M1.4				93	4.5x .18 m	450 kg	none (aircraft launch)	
69	1.56	ATEF	ATEF 49A, B		target					>50tot	?x.16 m		Mélanie	
			ATEF 49C, D										2 Mélanie	
70	3.56?	Latécoère	MS 21	SA	radio+opt.homin					(N° 35)		147 kg	? + Mathurin	
71	10.10.56	SNCASE	SE 4500	SS	radio +radar homing	M.8	2 km	138 km	67	62	4.25x3.9 m	1,905 kg	2 SEPR 684 11.4 t (2 Mimosa AP/P) or 2 STRIM 6.7 t (3 Pégase each) + SE ramjet	
72	8.11.56	ONERA	OPd 250LP	Experim		M.96	5 km			5	3.7x.25 m bod	125 kg	SERAM T1000 or T1500 solid	air-launch
			OPd 250P/DES400							1	6.1x.25 m bod	331 kg	SPRA-10/D-400 + OPd 250	
73	1956?	SNCAN	5301 ACAM	SA	radio	600 m/s	15 km	15 km			4.5x1.5 m	480 kg	2 solids	
74	1956	ONERA	VD-2140	SA		M3	15 km			10	?x.32 m bod		solid + ONERA ramjet (kerosene)	

	1st flight	Manufactur.	Name	Type/prog	Guidance	Max speed	Max alti	Range	Built	Launch.	Leng x dia	Weight	Motors	Notes
75	12.10.57		Vampire TC	CT	radio				44					+6?
76	28.11.57	ONERA	OPd 220-ADX Ardaltex	Experim.		M2				7tot	9x? m	735 kg	SPRAN 50 + SEPR 707 Jéricho 1.45 t (CDB) + Mélanie	
						M2.1	130 km				9.9x? m	840 kg	SPRAN 50 + Jéricho I or II+ADX ram	
77	1957	ONERA	OR-228/OPd 220Δ	Experim		M1				>5	4.96x.23 m bo	100 kg	SPRA-10 + SPRA-4 solids	
78	1957	ONERA	VD-2120A	Experimen		M2.5				2	8.82x.26m b	721 kg	SPRAN-50 + 2 ONERA ramjets (kero)	
			VD-2120B			M2.5	15 km			4	?x.32 m bod	800 kg	SPRA-62 + 2 ONERA ramjets (kero)	
79	2.58?	Latécoère	231 /233 Malafon	SS	radio	750 km/h		15 km	400?		6.15x3.3 m	1,450 kg	2 SNPE Vénus (AP/PVC)	
80	7.58	DEFA/ONER	Statex A	SA	autopilot	M2+	15 km		10	10	9x.5 m body	940 kg	SPRAN-50 or 57 + ONERA ramjet (kerosene)	
			Statex B			M3.4	20 km			10	11.5x.56 m bo	1,650 kg	SPRAN-75 or SEPR 732+ONERA ram	
81	1958?	ONERA	OPd 24 22/B										SPRA 10 + SPRAL	
82	27.1.59	ONERA	OPd 39 22 Daniel (OPd 220-ARD)	Sounding	-	M5.1 (~M8?)	130 km	10 km	3?	3	8.5x1.4 m	828 kg	SPRAN 50 + Jéricho I or II (SEPR 7062) + Mélanie	
83	1.59 ?	Nord Aviation	CT 41 Narval	CT		M3			62	29			2SEPR200 Tramontane AP+2 Sirius	
84	5.59	ONERA	OPd 56 39 22/D Antarès	Experim/ sounding		M7	280 km			13	12.3x.56 m bo	1,785 kg	SEPR 734 + Neptune + SEPR 685 + OPd 220	
85	10.59	Nord Aviation	Véga	SA	autopilot	M4.2	33 km	200 km	18	17	6x1.9 m		solid + Nord ramjet .63 t (kerosene)	
86	Fin .59	MATRA	R 530	AA 26	IR/radar homing	M2.7	30 km	18 km	8,500		3.28x1.1 m	194 kg	HB Marie-Antoinette 8.5 t (AP/PVC)	
87	1959	Nord Aviation	625	SA		M2.7	23 km			15			2 solids + Nord Sirius ramjet .18 t	
88	1959?	Nord Aviation	5104	AA 25	radio									

	1st flight	Manufactur.	Name	Type/prog	Guidance	Max speed	Max alti	Range	Built	Launch.	Leng x dia	Weight	Motors	Notes
89	1959?	ATEF	ATEF 64	Smoke			4 km			10's?	?x.16 m		Mélanie long solid	

Notes : tonka = 50% xylidine + 50% triethylamine, EDB Extruded Double Base (French SD = *Sans Dissolvant*, nitrocellulose+nitroglycerin), CDB Cast Double Base (French Epictète),

AP/PVC Aluminum Perchlorate/PolyVinylChlorine (French Plastolite) AP/PU PolyUrethane (French Isolane)

*also SEPR 5043, 505, 5051

PN = Poudrerie Nationale (became SNPE in 1971), ONM = Office National Météorologique

The 89 French missile programs that flew 1939-1959 (note : this table corrects and completes the table of Part I) [ed. 21.2.09]

Other SEPR motors :

SEPR 5047	1.57	10 t	AP/PVC booster for ONERA
SEPR 52	?	.45 t	APK for Cogel
SEPR 6851	11.58	4.2 t	AP/PVC for ONERA rocket
SEPR 7341	10.58	23.2 t	AP/PVC booster for ONERA
SEPR 99	4.58	9.5 t	AP/PVC for ONERA rocket