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► **To cite this version:**

Philippe Varnoteaux, Nicolas Bérend. ONERA at the Beginning of Space Exploration (1950-1963). International Astronautical Congress (IAC) 2022, Sep 2022, Paris, France. hal-03797345

HAL Id: hal-03797345

<https://hal.science/hal-03797345v1>

Submitted on 26 Oct 2022

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ONERA AT THE BEGINNING OF SPACE EXPLORATION (1950-1963)

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Created on May 3rd 1946 as Office National d'Etudes et Recherches Aéronautique (French National Aeronautics Research Center), Onera is in charge of conducting scientific and technical research for aeronautics, for both civil and military purpose. Not limiting itself to pure aeronautical applications, Onera's research spans a wide range of technical fields from aerodynamics to material/structure and rocket propulsion (solid, liquid and hybrid). Since many of these technologies cannot be fully tested on ground, series of "self-propelled flight models" ("maquettes autopropulsées"), named according to the Onera divisions in charge (OA, OE, OR, OPd), are developed. Following the launches of the first Sputnik by USSR in 1957 and especially the creation of Nasa in the USA in 1958, Onera's head understand that the institute's skills could be used to design sounding rockets in order to contribute to space exploration. At the same time, Onera designs technology demonstration rockets based on the OPd series, as a contribution to ballistic missiles development. These rockets could be used as suborbital sounding rockets for other applications as well. Effectively, on January 27th 1959, the Daniel-01 rocket carries out the France's second space experiment (after Véronique in 1954), consisting in radioactivity measurements at an altitude of 130 km. Following this success, Onera ambitions to become a "french Nasa". Nevertheless, the French government chooses to create a dedicated space agency Cnes (Centre national d'études spatiales) in December 1961, while Onera continues to contribute to scientific and technical research for space applications. Notable contributions are the development of a wide range of sounding rockets (totalling 400 launches until 1976) and scientific payloads for space experiments (satellite or suborbital rocket payloads). Some little known projects (eventually unrealized) illustrate the diversity of Onera's activity and its ambitions, like the Satmos project, for the launching of a small satellite using an enhanced 4-stage Bérénice rocket (which could have occurred before Diamant), and a satellite for the on-orbit demonstration of solar thermal propulsion name Héliotrope. As an acknowledgement of its important commitment to space activities, Onera's designation is changed to Office National d'Etudes et Recherches Aérospatiales (French National Aerospace Research Center) in 1963.

1. A difficult start

Following World War II, the French aeronautical civil and military landscape is in a terrible situation (devastated plants, dispersed workforce, lack of supplies, etc.). The French Minister of Air then creates the Interim Scientific Air Superior Council (Conseil supérieur provisoire scientifique de l'Air, CSPSA).¹ Made of specialists in aeronautical science and technology, this council is in charge of assessing the situation and make propositions to support the restart of aeronautics activities.²

Under the impulse of general engineer Suffrin-Hébert – head of Aeronautics Technical and Industrial Directorate (Direction technique et industrielle de l'aéronautique, DTIA) – and

communist minister Charles Tillon,³ the decision is made in summer 1945 to set up a company aimed at coordinating and supporting the efforts for the reconstruction of French aeronautics.

Thus, law bill n°46-895 of May 3rd 1946 voted by the national constituent Assembly establishes National Office for Aeronautics Research and Studies (Office National d'Etudes et de Recherches Aéronautiques, Onera). Three main objectives are set : « to develop, orientate and coordinate scientific and technical aeronautical research » civil and military ; « design, manufacture and use the necessary means for research activities » and « ensure dissemination of research results at national and international level ». While it is not a joint military organization, Onera, through the July 11th law bill, is allowed to resort to industry, to private⁴ or public⁵ establishments, institutes or

¹ In 1946, CSPSA becomes Onera's scientific and technical Committee.

² Among CSPSA members, scientists such as Louis de Broglie, Frédéric Joliot-Curie (chemistry Nobel prize), René Jugeau, Joseph Pérès, Maurice Roy ; general engineers such as Maurice Suffrin-Hébert, Louis Bonte (head of CEV at Brétigny in 1948), Paul Dumanois, etc.

³ Charles Tillon is Minister of Air from September 1944 to November 1945, then minister of Armament from November 1945 to December 1946.

⁴ Dassault, SEPR, SNCAN, SNCASO, etc.

⁵ Institut de mécanique des fluides de Lille et de Toulouse (Institutes of Fluid Mechanics at Lille and Toulouse), the Etablissement de recherches aéronautiques de Toulouse (Toulouse Aeronautical Research Institute), the

laboratories and to military establishments.⁶ The head, made of a president and an executive officer, is appointed by the minister in charge of aeronautics industry, in agreement with the ministry of defense, armament or army (the minister's designation varies with governments). In October 1946, general engineer Dumanois is appointed first president of the executive board, while René Jugeau,⁷ former chief of staff of Charles Tillon, is executive director.

Starting from its early years, Onera has to deal (as other institutes) with the problem of re-starting the activities, completely disbanded by war, and the lack of qualified workforce. Furthermore, the presence of a communist at the head of the institute generate contestations, with some people accusing him of wanting to "colonize" the institute with communists and unionists, or even to fund the Communist Party using funds from the army.⁸ The situation is so tense that Onera's executive and scientific boards are dismissed on July 1948.

Onera gets headless during several month. The situation only improves in 1949 when Maurice Roy is appointed as chief executive officer.⁹ A Polytechnician with a strong character, he restores tranquility and discipline at the institute.



René Jugeau



Maurice Roy

© Onera

In order to carry out its researches, Onera is organized into five directorates: « Aerodynamics »

Laboratoire d'études de carburants de remplacement d'Arles (Arles laboratory of fuel substitutes studies), etc.

⁶ Service des recherches aéronautiques de l'Air (ministry of Air's Aeronautical Research Service, merged into Onera from September 1st 1946), Ateliers de Puteaux (Puteaux Factories), Arsenal de l'Aéronautique (Aeronautical Arsenal), Service des Poudres (Powders Service), DEFA, DTIA, etc.

⁷ Jugeau René, chemical engineer graduated in 1927 from ESPCI (Paris Ecole supérieure de physique et de Chimie industrielles), is in charge of a research laboratory before WWII. In 1945, he is in charge of Onera's inception.

⁸ Pinault Michel, *Frédéric Joliot-Curie*, Odile Jacob, p.324.

⁹ Roy Maurice (1899-1985), a polytechnician, (Ecole polytechnique alumni) general mining engineer, forecast as soon as 1929 the future of reaction propulsion. He teaches flight mechanics at Supaero (1930-45) then at Ecole Polytechnique (1947-1969), head of Onera from 1949 to 1962. Member (1949) and president (1966) of French Academy of sciences.

(OA), « Energy and Propulsion » (OE), « Structures design » (OR), « Materials » (OM) and « General Physics » (OP). The first studies are carried out on airframes or aircraft structure (long duration creep behavior of aluminum alloys, protection coating for turbine blades, refractory superalloys, etc.), but also on specific devices (sensors, measuring instruments, etc.). Due to recent progress in aviation, the question of reaction propulsion naturally retains the attention of Onera's engineers.

2. Propulsion studies.

All types of propulsion are tackled (solid, liquid, hybrid). Thus, since the beginning, an important workforce of 150 to 200 engineers and technicians (in a total around 900) is allocated to rocket motor studies. Among them, couples Simone and Marcel Barrère¹⁰ and Hélène and André Moutet¹¹ and also Pierre Larue. Many of these specialists are chemists from the Toulouse area. Onera integrates in that way several specialized institutes such as Toulouse's Aeronautics Institute (Etablissement aéronautique de Toulouse), from which originate figures like Marcel Barrère, one of the greatest french rocket propulsion scientists, who was the first to publish a reference handbook in French dealing with this subject (along with three Belgian co-authors),¹² and to produce a second manual which was translated to german, english¹³ and even russian.



Marcel Barrère

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Since 1947, Marcel Barrère and Hélène Moutet work on a german engine from a V1 vehicle. Then, Barrère studies the behavior of nitrogenous oxidizers, the problems of liquid propellant rocket ignition, combustion instability (with Hélène Moutet and others), and also high altitude propulsion.

¹⁰ Barrère Marcel (1920-1996), engineer (1950), joins Onera in 1946, where he spends his whole carrier. He becomes one of the rocket propulsion experts, for both solid and liquid.

¹¹ Moutet André was a pioneer in new propellant synthesis; he has worked in particular on solid propellant ramjet.

¹² Barrère M., Jaumotte A., Beubeke B., Vandekerckhove J., *La propulsion par fusées*, Dunod, 1957.

¹³ Barrère M., *Rocket Propulsion*, Elsevier, 1960.

When Onera develops its first rocket test-beds vehicles, the choice is made of solid propulsion. The rationale is twofold: simplicity and immediate availability. Indeed, in a solid rocket, the whole propulsion charge is stored in the combustion chamber under the form of grains, so engines can be easily stored and handled, without the risks of toxicity, corrosion and volatility that occur with liquid propellants.

3. Ramjet engines

The first test-bed rockets designed by Onera have ramjet engines, due, incidentally, to their “simplicity” and lower cost, and the fact that they are considered promising. The first vehicles are developed between 1948 and 1951 par the team of engineer Louis Viaud, from OE¹⁴ directorate. In the first experiments, ramjets, which are air launched from an airplane or ground launched using a ramp (at Mailly-le-camp) are inactive (VD 2010, 2020, 2040, 2070 and 2080). They provide some insight on aerodynamics. The first active ramjet is VD 2050, tested between 1951 and 1956.



VD 2120 n°25, Levant island, November 4th, 1958
© Onera

As resources were limited at that time, the first studies are theoretical. Pushing research further required flight tests to validate hypotheses, as no ground facility could do it. Hence, the main purpose of the first VD vehicles is to help develop an experimental flight-test procedure. A second generation is developed in 1956-59 with VD 2140 and VD 2120. The latter vehicle allows the test of two side engines¹⁵, instead of one single ramjet integrated into the missile body. The 2140 and 2120

¹⁴ Viaud Louis begins his research at Onera on scramjet engines.

¹⁵ Onera provides support to other institutes for some vehicle design studies, such as the CT-20 target-vehicle from Arsenal de l’Aéronautique (tested in SIMA wind tunnel at Modane-Avrieux, which starts industrial activities in 1954), the CT 41 supersonic target-vehicle from Nord-Aviation, etc. Like VD 2120, CT 41 is equipped with two side ramjet engines.

vehicles can accelerate higher than Mach 2, with a range between 10 and 15.

With vehicles getting more powerful, the flight experiments move to Levant island in 1956, where Onera can rely on the logistic support of the Navy and its Special vehicle research centre and test range (Centre d’essais et de recherches des engins spéciaux, CERES).

While Onera works for the development high-speed, low altitude missiles (in order to reduce vulnerability), it expands its research scope to ramjet engines capable of flying at higher altitude. To this end, a new missile is designed, named ADX or Ardaltex (acronym for “Allumage d’un Réacteur Déterminé à haute ALTitude EXpérimental”, or “High altitude ignition of an experimental specific engine”). The operations of this vehicle require a two-stage rocket booster, enabling an ignition around 20 km in altitude. The first ADX is tested on January 27th 1958.

Jointly organized by OA, OE and OP directorates, this program nevertheless meets many technical problems...



Ardaltex 04, June 24th 1958, Levant island
© Onera

In 1957, the Armament design and manufacturing directorate (DEFA, Direction des études et fabrication d’armement) of the Land forces discards its ramjet research. Onera gets back some experts in the field, including Roger Marguet¹⁶ who was then working on NA 250. From 1958, Marguet designs two other ramjet engines: Statex and Staltex. The experiments continued till 1964, when the ramjet program is stopped, because the government favors the investment on ballistic missiles, let alone the fact that « *The Americans went to great length to deter us from following this path, arguing that ramjet missiles have no future* », as Roger Marguet eagerly points.¹⁷

¹⁶ Marguet Roger (1924-2019), begins his engineer career at LRBA (Laboratoire de recherches balistiques et aérodynamiques) in Vernon, then at Satory within Direction technique de l’armement terrestre (DTAT). He joins Onera in 1957, where he works on ramjet propulsion and become one of the best world-class experts.

¹⁷ Interview of Roger Marguet with Philippe Varnoteaux, April 3, 2000.



Roger Marguet
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4. From self-propelled test-beds to technology demonstration rockets

In order to test correctly the ramjet engines, the OE directorate needs electromechanics and electric hardware. For their validation and operations, the OP directorate proposes a cheap but efficient solution, as recalls its initiator engineer Paul Lygrisse: «*I had the idea of designing small rocket-propelled test-beds, later called OPd, that would allow testing at little cost a wide of range of devices in ambient conditions prescribed by their launch and their flight.*¹⁸ Back then, the initial design process of these vehicles is closer to that of scale models than rockets: the test-bed model integrates in its back a solid rocket grain that could be supplied by various institutes (Service des Poudres, SEPR, etc.).



OPd 220-Lp attached under an airplane, Brétigny, 1952

© Onera

Designated OPd¹⁹, after the directorate which was set up to take care of the launches and the monitoring of the flight experiments, the first 1952 vehicles are rather simple: with a length from 0,80 to 1,8 m and a weight hardly exceeding the 10 to 15 kg range, the small OPd 80 rocket allows not only to perform telemetry tests, to qualify recording devices, to perform tracking, but also to understand and master the dynamics of a self-propelled vehicle at the time when its exists the launch ramp. In order

¹⁸ Correspondance from Paul Lygrisse to Philippe Varnoteaux, Mars 2nd 2000.

¹⁹ For instance, OPd 220-Lp is the designation of a vehicle developed by the **OPd** division, with a **220** mm diameter, **L**argué (meaning "Jettisoned", from an airplane) and (self) **P**ropelled.

to move to higher and better experiments, which are rapidly upgraded, a second generation appears in 1954, with OPd 100, 220, 250 and 320. While the concept and visual design do not change, these vehicles turn into full-fledged modular systems with one, two or even three stages, with lengths between 2 and 11 m, and weights ranging from 80 and 850 kg.²⁰ On their launch ramp, the heavier OPd rockets are now akin to genuine technology demonstration rockets rather than mere self-propelled test-beds.²¹



OPd 220, 1955

(Mailly-le-camp)

3-stage OPd 320, 1957

(Levant island)

© Onera

The success of OPd vehicles is such as OP put them at the disposal of other Onera scientific directorates as well as studies managed by other institutes (SNCAN/Nord Aviation, Dassault, etc.).²² This is the reason why a new directorate, the System and Test hardware directorate (Division des systèmes et moyens d'essais, DSME) is formed in 1958. This new structure regroups concerned Onera workforce in order to perform flight experiments more efficiently.

Thus, until around 1958, Onera's technology development rockets make possible many research spanning five fields: the design of flight test hardware and methodologies; flight mechanics and aerodynamics; guidance and control; flutter; propulsion. In 1958-59, two other fields appear: aerothermodynamics and atmosphere measurements – later followed in the 1960s by space experiments (geophysics, astronomy).

²⁰ Note that this approach is not new; other institutes had it like SNCASE. It was also used in the USA to test several technologies. See Thibodaux J., *A Brief summary of experience in boosting aerodynamic research models*, Washington, NACA, July 1956.

²¹ More details about the development of OPd rockets in « *A History of Onera's OPd Rockets: Experimental Aircraft to Space-Probe Rockets, 1952-1966* », 35th IAA History of Astronautics Symposium, Toulouse, France, 1-5 October 2001.

²² Several OPd rockets have been used to flight-test the airfoils of Gerfaut, Mirage IV aircrafts, as well as the tail fins of CT41 target vehicle (Nord Aviation), etc.

5. Consequences of the first Sputniks

During the 1950s, the International Geophysical Year (Année Géophysique Internationale, AGI) takes place. This scientific event, organized between July 1st and December 31st 1957, aims at studying Earth as a whole, including the upper atmosphere. Several nations intend to use modern tools like sounding rockets, which has just emerged as a means to explore the Earth neighbourhood. The US and USSR even announce that they will take the opportunity of this event to launch the first artificial satellites into orbit. On October 4th and November 3rd 1957, the Soviets springs a surprise by launching into orbit the history's first and second artificial satellites Sputnik 1 and 2. The age of space has just begun.

In France, a sounding rocket program for the exploration of the higher atmosphere (Véronique AGI) existed, but its future was uncertain.²³ At that time, exploration of the higher atmosphere is not Onera's realm, nor, furthermore, the subject of artificial satellites. Thus, the occurrence of the first Sputniks did not triggered immediate reaction, as recalls former engineer André Rémondère²⁴ : « *Sputnik? Yes, it was discussed, but this had no impact on our activities, at least at the beginning. We were not really concerned* ». ²⁵ Indeed, Onera was not a straightforward choice for this type of activity. Nevertheless, Onera's head is not insensitive to the subject of the rocket that would be used for orbital launch, as states Paul Lygrisse: « *At the end of 1957, when the subject of ballistic missiles and outer space was in the air, chief executive Maurice Roy got interested in our modest OPd rockets. He probably realized that he could take advantage of them, especially when he learned that these rockets could be upgraded to four-stage vehicles. Ever since, these rockets became very*

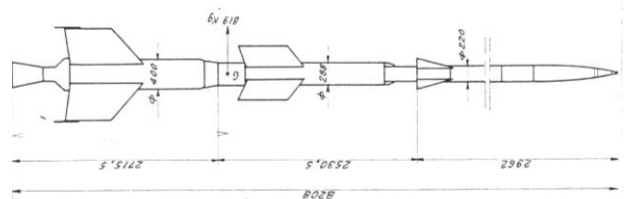
²³ On October 29, 1954, since Hammaguir, physicist Etienne Vassy made a VLF (Very Low Frequency) transmission experiment (104 km) using a Véronique NA. As it was not equipped with telemetry system, it was not recovered before several months! This event has induced doubts and critics, leading to a fund cut during two years. Since 1956, thanks to the intervention of CASDN's military (Comité d'action scientifique de la défense nationale), the funding are restored, but a two-year additional delay occur for two reasons: the time to set up the workforce back again for the manufacturing of Véronique AGI and also the need of identifying relevant ideas of experiments (later brought by physicist Jacques Blamont during summer 1958).

²⁴ Rémondère André (1930-2019), Onera engineer from 1954 to 1969, is the leader of research group studying automatic control and stabilization of rockets. In 1969, he joins CNES, where he is in charge of several departments (sounding rockets, aerospace technology, satellites). From 1986 to 1991, he heads the Guyana Space Centre.

²⁵ Correspondence from André Rémondère to Philippe Varnoteaux, Mars 25th 2009.

useful to develop specific strategic missile technologies and become familiarized with them ».²⁶

Indeed, one important question for France at that time was the one of the ballistic missile it could eventually develop for the nuclear deterrence, currently in the making.²⁷ Until the return to power of general de Gaulle, this question was not settled at the political level. Meanwhile, Onera deploys intense lobbying for rockets. A special operation at Levant island is undertaken on November 28th 1957, i.e. twenty-five days after Sputnik 2: an OPd 220-ADX rocket is launched, reaching around 70 km. It is a three-stage rocket based on the booster for ADX, on which the ADX ramjet is replaced by a small OPd 220 rocket. Carrying an atmospheric probe, this vehicle flirts with the boundary of space. Shortly later, at a meeting of Onera's executive committee, Maurice Roy underscores that the November 28 launch make possible to « *carry out an experiment in the higher atmosphere with a faultless professional discipline* »...



Sketch of OPD 220 ADX rocket
© Onera



2012 rocket, Le Bourget, May 1957 © All right reserved

Even though this operation has no immediate follow-on, Onera nevertheless use all possible

²⁶ Correspondence from Paul Lygrisse to Philippe Varnoteaux, March 2nd 2000.

²⁷ Remind that the nuclear deterrence force was decided between 1954 and 1956, a decision driven by Presidents of the Council Pierre Mendès-France and Guy Mollet. Regarding the launch vector, the initial choice was strategic bomber Mirage IV, a technology that more easily accessible than ballistic missile. In 1958, when he returns to power, de Gaulle confirms the order for the experimentation and series constructions of Mirage IV.

means to interest and convince the political authorities to support the development of rockets, including through exhibitions. In this way, at the Paris Air Show of May 24-June 2 1957, Onera displays a 3-stage rocket (Rocket 2012), that could admittedly carry out experiments in the upper atmosphere. One year later, on May 2-3 1958, on the bank of river Seine below Eiffel tower, a scale-1 OPd 56-39-22/D rocket mock-up is shown during the « Earth and Cosmos » exhibit. While the details about this rocket highlight that “*In the descent phase, it allows to carry out atmospheric reentry experiments that would normally require much more powerful and excessively costly*”, they also mention that this rocket will be “*capable de sending to a 350 km altitude equipment for observation and scientific measurements*” ...²⁸, in other words, it could be used as a sounding rocket for space exploration.



“Earth and Cosmos” exhibit. In the foreground: OPd 56-39-22/D; in the background: Véronique

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6. The turning point of 1958-59

Since June 1958, when de Gaulle returns to power, a wave of reforms blows of France, at the institutional as well as economical and financial levels, with, at the heart of gaullian way of mind, an emphasize on science and technology. Military forces are not forgotten by this endeavour. In that way, at the level of the nuclear deterrence force, the subject of ballistic missile is back again, but with two alternatives: buying it through an american license or develop it alone ...

Considerable that the current context is now favorable, Maurice Roy foster preliminary studies related to ballistic missile, starting with the field of aerothermodynamics. In order to get real-flight data, the OPd 56-39-22/D demonstrator is then used: during the test, the first three stage ensure the

ascent phase (up around 150 km)²⁹, and the fourth stage accelerated the head during descent, in which the experiment itself occurs. While the first test at Levant island on May 2 1959 demonstrates the quality of instruments and transmission means, the second test on October 22 in the same year flies an instrumented head which collects data about the thermal and aerodynamical phenomenon during reentry.

However, to the great disappointment of Maurice Roy, the french government decides the attribution of ballistic research to a dedicated institute: Société d'étude et de réalisation d'engins balistiques (Society for the study and design of ballistic vehicles, SEREB). Founded on September 17 1959, SEREB is at a central place within the most experienced companies and institutes of that time, who are shareholders: Nord-Aviation, Sud-Aviation, SEPR, SNECMA, Dassault, Matra, CEA, military technical directorates (DEFA, DTIA, DCCAN), the Power directorate... but also Onera. Thus, Onera's works are recognized and supported but, as for May 1960, they are carried out under contract from Sub-Aviation contracts (which is the provider of reentry heads), SEPR (which provides solid grains) and SEREB (which manages the whole activities). A total of twelve OPd 56-39-22/D rockets – renamed Antares on October 1960 – perform tests until March 1961 of different heads with velocities up to Mach 8. Out of these twelve, seven rockets deliver promising but insufficient results. For this reason, Bérénice, a new research missile with higher performance is developed to increase knowledge in flight mechanics, guidance and control, and aerothermodynamics up to velocities around Mach 12.

Having lost the high ground on the subject of ballistic missile, Onera hopes to have a lead role in the one of space exploration, especially in sounding rockets, for which a potential already exists. Furthermore, the creation of NASA in the United States, between July and October 1958, apparently strikes Maurice Roy, as Paul Lygrisse remembers: « *Ever since we heard about NASA, but also when the Americans launched their first satellites, space became a serious affair* ». ³⁰ « *Maurice Roy was looking with great interest what NASA was doing* », recalls physicist Jacques Blamont. He, at that time one of the first french scientists taking part in the emerging space activities, contributes in October 1958, to the establishment of Aeronomy Department (Service d'aéronomie, SA) within CNRS. Together with the Laboratory of atmosphere physics of Faculté de Paris (Etienne Vassy), Blamont's SA is about to explore the upper

²⁸ Anonymous, « *La fusée française à quatre étages...exposée pour la première fois à "Terre et Cosmos"* », in *Le Figaro*, Mai 1, 1958.

²⁹ The engines of the first two stages were the ones of Navy's Masurca Mk1 missile.

³⁰ Correspondence from Paul Lygrisse, op. cit., March 2 2000.

atmosphere using the first Véronique AGI sounding rockets (ready at last); a test campaign is being prepared for March 1959 since the Hammaguir range in the Algerian desert. In order not to be outdone, Onera also prepare an operation with the scientists of Commissariat à l'énergie atomique (Atomic Energy Institute, CEA).

During fall of 1958, Onera announces that it now have the ability to explore the higher atmosphere using a sounding rocket based on OPd 220 ADX: with a 8.48 m length and weighing 812.6 kg, this sounding rocket – a first for Onera – is made of three solid-propulsion stages, the first and second stages being an upgrade of the ADX booster and an OPd 220 rocket as a third stage.³¹ The vehicle can carry a payload between 12 and 15 kg up to an altitude of 110 to 130 km. On December 11 1958, this rocket is given the more appealing name of « Daniel », as Paul Lygrisse recounts: « Maurice Roy, smiling, then asked me: "Than what would it be? " I had my calendar in sight, it was Saint Daniel day, so I answered: "It will be Daniel"... As you see, you not always need to search solutions very far! ». ³² As for the mission itself, it is proposed by CEA, which identifies two major problems: the lack of knowledge about high-energy fluxes in the Earth near neighborhood, and concerns about the whereabouts of radioactive dusts from the atmospheric nuclear tests carried out by several countries, particularly numerous in year 1958.³³ In order to know more, Henri Le Boiteux, head of science at Onera and Jacques Labeyrie, head of the Electronics for physics unit (Service électronique physique, SEP) at CEA, get in touch to identify possible cooperation between the two institutes. Negotiations are completed in fall 1958: CEA brings the scientific hardware including three Geiger-Muller detectors, which are sensible to ionizing radiations (with sensors located on the rocket body), while Onera provides the sounding rocket and the interfaces that are necessary for the operation (telemetry, power supply, instruments connections, etc.).

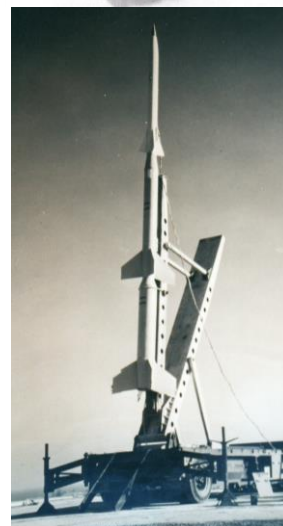
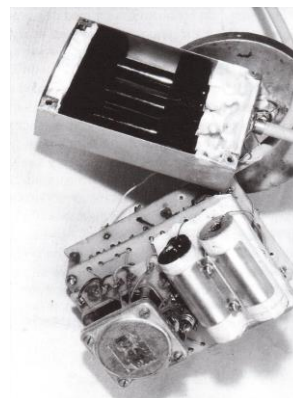
7. Onera's sounding rockets explore the higher atmosphere

³¹ While the first stage remains the same, with the SPRAN 50 grain, le second one has Jericho II, an upgraded version of Jericho I. As for the third one, it is equipped with the Mélanie grain from Onera.

³² Testimony of Paul Lygrisse to Philippe Varnoteaux, correspondence of January 30, 2001.

³³ Year 1958 is a record in terms of nuclear bomb tests. In the atmosphere, the US carry out 60 tests (including 6 at high altitude), the Soviets 34 and the British 5. See the list of nuclear tests for the different nations : <https://atlasocio.com/classes/defense/nucleaire/liste-essais-nucleaires-etats-unis.php>

On January 27 1959, Daniel 01 lifts off successfully at Levant island, the third stage and the head reach 137 km. However due to a technical glitch, a part of the data from beyond 60 km is partly lost. While sensors can detect a certain radiation intensity around 18-20 km, they cannot identify precisely the nature of the detected particle. Nevertheless, what Onera and CEA had just carried out was the second french space experiment, following the one of October 1954 (see footnote 23).



Scientific instruments carried by Daniel 01
© Onera/CEA

On May 13th 1961, a new joint Onera-CEA operation is organized using an Antares rocket adapted as a sounding rocket, at Hammaguir test range in Algeria. At this occasion, Antares 13 carries more precise instruments in order to measure gamma et Lyman radiation... five month after the third French nuclear test carried out at the Reggane centre (more than 650 km away south of Hammaguir).³⁴ Finally, on October 5 1961, at Levant island, Daniel 03 is launched and

³⁴ Particularly polluting, the first three nuclear tests have been carried out on February 13 (Gerboise bleue operation), April 1st (Gerboise blanche) and December 27, 1960 (Gerboise rouge).

successfully measures the ionization rate of the boundary layer. Onera's endeavor in sounding rockets is apparently on good tracks.

However, Daniel and Antarès are not enough performant and « competitive ». Scientists have a preference for Véronique and especially the new vehicles from Sud-Aviation (Bélier, Centaure, etc.), which are cheaper, easier to handle et manufactured industrially.³⁵ At that time, the political leaders decide to establish a new national space agency.

8. « CNES » vs. « French NASA »

At the time when Onera carries out the Daniel 01 experiment, the french government, under pressure from scientists; establish on January 7, 1959 the Committee of Space Research (Comité des recherches spatiales, CRS) – under the supervision of physicist Pierre Auger. The scientist' goal was to have a federating institute, that could, on the one hand inform politicians about what could be done in France at the level of space studies, and, on the other hand, to represent themselves at international conferences like COSPAR.³⁶ Members of the CRS executive committee include the CASDN chief executive officer (general Guérin, also head of the Hammaguir military test ranges), the CNRS chief executive officer (Jean Coulomb) , the Observatoire de Paris chief executive officer (André Danjon), the general director of Higher education (Maurice Bayen), the general director of Cultural and technical affairs of the Ministry of Foreign Affairs (Roger Seydoux), one representative of the Ministry of finances, and Onera's chief executive officer.

The first months of CRS are sometime difficult, namely when budget questions are discussed. In addition, Onera's chief executive officer is sometime critical about some decisions of the Committee. In that way, when the first national space program is proposed, Maurice Roy reacts by noting his institute could be in charge of some parts of the activities like sounding rockets, provided it is appropriately funded.

Within CRS, the scientists find less and less the room they need. The idea is raised to make it evolve towards an institute that could play a role

akin to the one of a space agency. Supported by Pierre Auger, the idea of a National Centre of Space Studies (Centre national d'études spatiales, CNES) gets more precise. For their side, the SEREB engineers take a stand by noting that, based on the Test vehicles (Véhicules d'essais) of the Ballistic basic studies program (Etudes balistiques de bases, EBB) or Gem stones (Pierres précieuses), they could design a rocket (Diamant) to loft into orbit the first French satellites. This is the moment when Maurice Roy tries again to convince the political leaders to transform his institute into a sort of « French NASA ». The rockets are used for this lobbying: in October 1960, OPd 59-36-22/D is given the name of giant star Antares. A sign of ambition... Several witnesses from that time confirm the tenacity of Onera's head: « *Mister Roy had an excessive ambition towards space. At the beginning of the sixties, he wanted to make Onera his own "CNES"; he could not stop claiming to whoever was hearing: « The french NASA, it's me!* », reminds Jacques Blamont. According to former Onera engineer Roger Marguet, « *Mister Roy did all he could to be the head of space* », but « *he made a lot of enemies, including at the Ministry!* ». Note that at that time Onera is under the direct supervision of the Prime minister and the Minister of Defence. Roger Marguet goes even further by noting that « *Maurice Roy did not have many friends among political leaders and, he adds, I am convinced that had it been someone else than Maurice Roy, Onera certainly would have been in charge of space affairs eventually* »³⁷ and would have been an institute similar to the American. Nevertheless, unfortunately, his strong character eventually played against him, as other former Onera members acknowledged several years later: « *Mister Roy a member of the Academy of sciences, he was a great man, but with a certain temper! Anyone who met him reminds this! At that time, there was a particular atmosphere at Onera; there was a true leader cult* », notes, among others, Jean-Claude Théodore.³⁸ However, the most nocuous was his hostility towards University scientists, as notes Paul Lygrisse: « *When CNES was established, Maurice Roy was in a uncomfortable position. The University scientists suddenly awoke and literally besieged Onera* ». ³⁹ Let alone Maurice Roy's personality, two other reasons explain the failure of his project, as believed Jacques Blamont : « *The failure of Onera, in addition to the certainly*

³⁵ Following four technological tests in Mai 1961 (all successful), the first Centaure rockets are exploited by scientists starting December 1961.

³⁶ At an ICSU meeting (*International Council for Scientific Unions*) in Washington from October 2 to 4, 1958 the decision is made to create COSPAR (*Committee on Space Research*). COSPAR's mission is to « *provide the international scientific community with the means to exploit for scientific goals the capabilities of all kinds of satellites space probes and to exchange the resulting data on a cooperative basis* ». The first COSPAR meeting is organized in London on November 14-15, 1958.

³⁷ Roger Marguet interview by Philippe Varnoteaux, Avril 3rd 2000.

³⁸ Jean-Claude Théodore interview Philippe Varnoteaux, Janvier 24th 2000.

³⁹ Indeed, at the beginning of the 1960s, less and less Polytechnicians (Ecole Polytechnique alumni) and more and more scientists join Onera. In 1962, when Maurice Roy resigns, he is replaced by Professor Lucien Malavard, a university scientist...

*decisive attitude of its head, shall be also understood by the fact that Onera did not know how to get out of its "bunker" and work with French and foreign scientists, while as soon as 1960 the Auger committee [CRS] succeeded in [contributing to the] creation of COPERS and allowed me to negotiate the FR-1 satellite project with NASA. Finally, Onera kept the reputation of being a communist lair».*⁴⁰ Then, with Onera kept apart, for the first time, young scientists take over responsibilities that used to be attributed to general engineers.⁴¹ Also, the rejection of Maurice Roy's project is certainly a that the government wants to avoid any monopoly situation, let alone the fact that Onera's status hardly offers the flexibility required in case it should engage itself in space affairs (workforce and contracts management, etc.).

The law bill for the creation of CNES, as an agency in charge of the management of french space programs, is approved by the Ministerial council on August 2nd, 1961, then sent to the Parliament where it is voted on December 7th. As for the decision to develop the Diamant launcher, it is taken at the Inter-ministerial council on December 18. This launcher is manufactured by SEREB under supervision of the military of DMA (Délégation ministérielle à l'armement, Armement Ministerial Delegation). Hence, what margin of maneuver remained for Onera?

9. Bérénice, the last card to play

While during spring 1962, CNES gets its bearing, Onera is working on its later research missile Bérénice.⁴² More powerful than Antarès, Bérénice has a 3 340 kg total weight (vs. 1 785 for Antarès), and a 13.25 m length (vs. 12.3 m). Like Antarès, it relies entirely on solid propulsion (SEPR 739/Stromboli for the first stage, SEPR 740 for the second, SEPR 200/Tramontane for the third, Onera Mélanie grain for the fourth). Bérénice include several innovations, starting with its first stage (BER) equipped with an automated attitude control system using thrust vectoring of four small auxiliary thrusters. In the atmospheric re-entry version, the first two stages brings the missile up to 270 km, and the two others accelerates downward during descent around 55 km; in the sounding rocket version, the four stages are used for ascent, allowing to reach roughly 650 km with 90 kg scientific payload.

⁴⁰ Correspondence from Jacques Blamont to Philippe Varnoteaux, Octobre 28th 2013.

⁴¹ Blamont Jacques, « *La politique spatiale française et son avenir* », in *Cahiers de la Fondation Charles-de-Gaulle*, n°12, December 2003.

⁴² « *After Antarès, we decided to choose again the name of a star or a constellation starting with a B [Bérénice's hair] hence the name Bérénice* », according to André Rémondière's testimony.

The first Bérénice launch occurs on June 27, 1962, but it fails due to the break of a telemetry antenna cable. The second test, occurring shortly later on July 6 is a success⁴³ While Bérénice would be used only once as a sounding rocket (1966),⁴⁴ some of its parts will be the basis of two new sounding rockets: Tacite and Titus.

Tacite (for Tentative Analysis of Earth-Space Infrared Contrast, Tentative d'Analyse du Contraste Infrarouge Terre-Espace) is a single stage vehicle with a 7 m length, weighing 2 tons, equipped with solid propellant grain nearly similar (SEPR 739-2) to the one of Bérénice's first stage, but the stabilization technique is different, as it uses a cruciform empennage. The payload capacity of this vehicle is 285 kg at a 160 km altitude. As for Titus (for Tentative upgrade of Titus for Scientific Use, Tentative d'Itération de Tacite à Usage Scientifique), it is a 11.5 m high vehicle, weighing 3 tons, using the first two stages of Bérénice, with a slightly longer second stage and allowing a high precision trajectory control. It can carry 400 kg of instruments up to a 250 km altitude. Tacite is used four times June 1965 and October 1968 for measurements and observations of the Earth infrared radiation, while Titus is launched twice, on November 1966, at the occasion of a solar eclipse observation from northern Argentine.⁴⁵

Nevertheless, one can only observe that sounding rockets applications do not expands as Maurice Roy hoped, probably due to the lack of sufficient funding, but not only. It is interesting to note Paul Lygrisse's view about this question. According to him, « *the decline [of Onera sounding rockets] became obvious with the creation of CNES. We eventually stopped rocket activities in order not to bother CNES people* » who, as it should be underlined, had henceforth the high ground on the matter of sounding rockets. Another reason for this decline is the surge of artificial satellites during the second half of the 60s, which had the scientists' preference for carrying their instruments rather than sounding rockets, due to the limited testing time of the latter.

10. The Bérénice-Satmos project

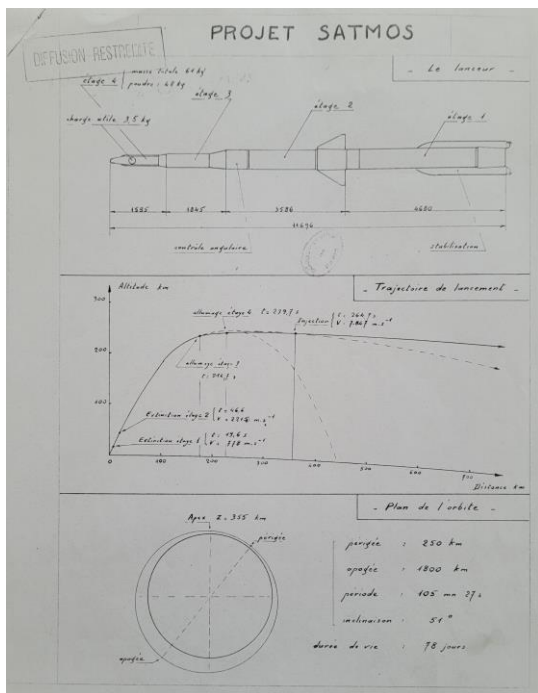
Against all odds, while SEREB has engaged the development of the Diamant launcher, Onera starts in 1962 a feasibility study for the launch of a

⁴³ On June 27th 1963, Bérénice 05 soars up to an altitude around 270 km, then, during descent, reaches Mach 12, a velocity record for that time in Europe.

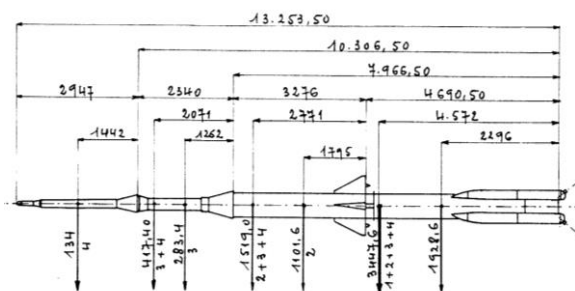
⁴⁴ Bérénice 12 allows on May 4th 1966 to prepare the Titus astronomy mission, consisting in observing the solar corona.

⁴⁵ For more information, see Varnoteaux Philippe, « *En 1966, la campagne d'observation astronomique Titus* », in *l'Astronomie*, vol. 118, March 2004.

small artificial satellite (Satmos) by a rocket derived from the experimental missile Bérénice, an initiative from chief engineer Pierre Contensou.⁴⁶ Comparing a sketch of the SATMOS project (from Onera's archives) with that of the regular Bérénice missile, we observe from the dimensions that only the first stage appears identical, while the others are slightly different: a 3 586 mm length for the second stage (vs. 3 276 mm for the experimental missile), 1845 mm for the third stage (vs. 2340 mm) and 1585 mm for the upper stage (vs. 2947 mm). Unfortunately, this document does not bring information about the solid propellant grains that were considered...



Rocket, launch trajectory and target orbit of the Satmos project (Onera)



Bérénice (n°09) (© Onera)

Roger Marguet, who participated to the Bérénice/Satmos study group, reminds: « Pierre Contensou was the one who asked us to study the

⁴⁶ Contensou Pierre (1914-1987), a polytechnician, joins Onera in 1958 where he holds different director positions (Synthesis studies department 1964; central scientific directorate 1971), then general executive officer (1973-1979).

possibility of designing a small satellite, in order to launch it by 1964 using a Bérénice rocket ».⁴⁷ Weighing 3 to 3.5 kg, this satellite, named Satmos (Satellite pour l'étude de l'ATMOSphère, meaning "Satellite for the study of the ATMOSphere"), would carry instruments for measurements in the atmosphere. But what was Onera's reason for pushing such a project? According to Roger Marguet, « it was an interim solution for Diamant ». However, wasn't the actual reason to show that Onera could be faster than SEREB? Indeed, Roger Marguet acknowledges: « Satmos met a strong hostility, including from SEREB which considered this as a competitor ». This was obvious. There was probably a second reason explaining the demise of Satmos: « One should not forget how important the initial shot is. Yet, Onera's proposal was a satellite of a few kilos, this was ridiculous for a first shot⁴⁸ », eagerly admits Roger Marguet. Satmos would be sent onto an orbit with a 250 km perigee and a 1800 km apogee altitude. The project looked even more ridiculous compared to SEREB's, which targets a 30 to 50 kg satellite inserted onto a 500 × 2200 km orbit. Eventually, Onera's project was considered so embarrassing that State Minister Palewski order its stop on October 7, 1963: « We have been requested to stop our project, while we were about to concretize it, maybe we could have orbited before Diamant! », tells Roger Marguet with some regret. However, later on, during an April 2000 interview, he adds: « I tell you frankly what I think about it now: it is better Satmos was not launch, because it would have been a very risky operation. Our rockets did not have the reliability needed for launching a payload of a few kilograms into orbit. Failure was not very far. Yet, a failure would be poorly looked upon », and would have probably led to mockery on the international scene, hence the intervention of the State ministers.

11. The Héliotrope satellite project

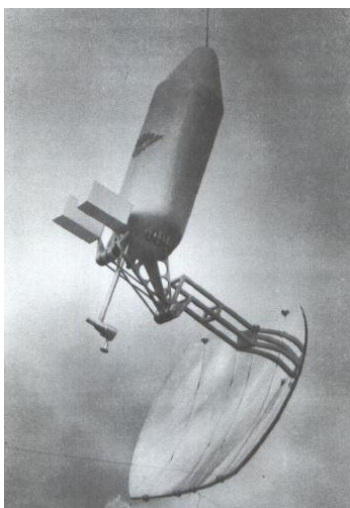
Satmos is not Onera's only satellite project in the early sixties period. Indeed, Onera's rocket propulsion studies deals not only with launcher propulsion by also with on-orbit propulsion. One option for the latter is solar thermal propulsion. It is a combustion-less rocket propulsion mode that consists in heating a fluid using concentrated solar radiation, then expanding it through a nozzle.

⁴⁷ Conversation between Roger Marguet and Philippe Varnoteaux, 3 avril 2000.

⁴⁸ Did not the American ridiculed themselves on December 6, 1957 with their first launch that failed on live TV? This was the launch of Vanguard TV-3 satellite, weighing only 1.5 kg... while the Soviets had just put into orbit Sputnik 2, a 508 kg payload.

In the beginning of the sixties, Onera studies the Héliotrope satellite demonstrator, aimed at testing in orbit this innovative propulsion mode (which was also studied by US companies like Sundstrand). The name of the satellite means “heliotropic”, i.e. “moving with the sun”, because it was equipped with a deployable parabola reflector that should be oriented towards the sun, in order to focus the concentrated solar radiation through a transparent window into the heating chamber. The fluid considered for this demonstrator was ammonia (NH₃).

Unlike Satmos, which weighs a few kilograms, Héliotrope is an ambitious 100 kg satellite. This project is presented at the 1963 IAC conference in Paris⁴⁹ and a mock-up is presented at the Paris Air show in Le Bourget on the same year. Héliotrope is an Onera-funded project, and it did not go beyond the stage of early design studies presumably due to the lack of funding.



Mock-up of the Héliotrope satellite (Onera)

12. Conclusion

While Onera did not evolve into a French space agency, it was nevertheless recognized as one of the foremost actors in the field. Consequently, the “Office National d’études et de recherches aéronautiques” (National institute of aeronautical studies and research) becomes on April 10, 1963 “Office national d’études et de recherches **aérospatiales**” (National institute of **aerospace** studies and research). Onera found its place as a major research center in aeronautics and space and a major partner for institutes like CNES and ESA. Onera brings its multidisciplinary expertise to complex projects.

⁴⁹ Surugue J. Le Grives E., Le propulseur héliothermique-performances théoriques et projet de réalisation ONERA, XIVth International Astronautical Congress, Paris, September 25-October 1, 1963.

In the field of space applications, two examples highlight Onera’s expertise today: the design of the ultra-precise accelerometers that equipped the ESA’s GOCE satellite and Cnes’s Microscope satellite,⁵⁰ and the design of the space surveillance system GRAVES, operated by the Army of Air and Space, that allows maintaining a catalogue of space objects in low earth orbit.⁵¹

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⁵⁰ Launched on March 2009, GOCE measured until November 2013 the Earth gravitational field with very high precision.

⁵¹ Developed for the account of DMA, the Graves system (Grand Réseau Adapté à la Veille Spatiale) starts operations in 2005. It is capable of detecting and cataloguing space objects passing with a range up to 1000 km.

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Glossary

AGI / IGY : Année Géophysique International / International Geophysical Year
ARDALTEX : Allumage d'un Réacteur Déterminé à haute ALTitude EXPérimental
CASDN : Comité d'Action Scientifique de la Défense Nationale
CEA : Commissariat à l'Energie Atomique
CERES : Centre d'Essais et de Recherche d'Engins Spéciaux
CNES : Centre National d'Etudes Spatiales
CNRS : Centre National de la Recherche Scientifique
COSPAR : Committee On Space Research
CRS : Comité des Recherches Spatiales
CSPSA : Conseil supérieur provisoire scientifique de l'Air
DCCAN : Direction Centrale des Constructions et Armes Navales
DEFA : Direction des Etudes et Fabrication d'Armement
DMA : Délégation Ministérielle à l'Armement
DSME : Division des Systèmes et Moyens d'Essais
DTIA : Direction Technique et Industrielle de l'Aéronautique
ESA : European Space Agency
GOCE : Gravity field and Steady-state Ocean Circulation Explorer
GRAVES ; Grand Réseau Adapté à la VEille Spatiale
ICSU : International Council for Scientific Unions
LRBA : Laboratoire de recherches balistiques et aérodynamiques
MATRA : Mécanique Aviation Traction
MICROSCOPE : MICROSatellite à traînée Compensée pour l'Observation du Principe d'Equivalence
NASA : National Aeronautics and Space Administration
ONERA Office National d'Etudes et de Recherches Aéronautiques (before 1963) / Aérospatiales (from 1963)
SA : Service d'Aéronomie
SATMOS : Satellite pour l'étude de l'ATMOSphère

SEP : Service Electronique Physique
SEPR : Société d'Etudes de la Propulsion par Réaction
SEREB : Société d'Etude et de réalisation d'Engins Balistiques
SNCAN : Société Nationale des Constructions Aéronautiques du Nord
SNCASO : Société Nationale des Constructions Aéronautiques du Sud-Ouest
SNECMA : Société Nationale d'Etude et de Construction de Moteurs d'Aviation
SUPAERO : short name of Institut Supérieur de l'Aéronautique et de l'Espace
TACITE : Tentative d'Analyse du Contraste Infrarouge Terre-Espace
TITUS : Tentative d'Itération de Tacite à Usage Scientifique