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AEROSPATIALE IS READY TO DEVELOP A CONVERTIPLANE WITH TETHERING ROTORS

by Jacques Morisset

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16. Abstract

This report contains information on the recent study of the converti-plane. The convertiplane has been designed to replace the conventional helicopter. Its speed is much faster than that of the helicopter, it uses less fuel, and can carry up to five passengers. The discovery of the convertiplane was brought about because the helicopter is handicapped by its slow speed and can carry only a few passengers. The convertiplane will not be ready for operation until at least 1981, after undergoing many tests.

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AEROSPATIALE IS READY TO DEVELOP A CONVERTIPLANE WITH TETHERING ROTORS

by Jacques Morisset

A recent study by two researchers from NASA's Ames Center shows that new convertible planes with tethering rotors should replace helicopters in one of the biggest markets for rotary-wing aircraft: the offshore market, i.e., the daily flights made in several regions of the world linking the coast with offshore oil platforms (Gulf of Mexico, North Sea, etc.). /19

Surprising as this may seem, it is nonetheless the logical solution: the helicopter is handicapped by its low speed (under 300 km/hr) and thus, as a passenger carrier, is not highly efficient and registers high hourly rates of use. The speed of the convertiplane, on the other hand, (cruising speed approximately 500 km/hr) will open up possibilities for more rational use and, ultimately, clearly lower km/passenger costs, despite the added complexity of this type of aircraft and the more costly maintenance it will require.

This American viewpoint obviously bolsters the position of Aerospatiale (Helicopter Division) in its proposal to build a motorized scale-model of its X-910 project that can be tested in the wind tunnel. Indeed, the hypothesis adopted by the NASA researchers was, on the one hand, an increase in offshore activity and, on the other hand, Bell's construction of the XV-15, a plane which, after testing (to get under way in a few months) can serve as a basis for the study of an actual craft, well-suited for offshore work.

Aerospatiale's X-910 project is in the class of the XV-15, and while it will not be on the market for several more years, it will have the advantage of a very thorough overall study, perhaps resulting in an aircraft which is closer to an operational machine. In fact, Bell, as Aerospatiale, must go through the intermediate stage of a research and demonstration prototype, since as we shall see, tethering rotors pose numerous problems to aerodynamics experts and designers.

WHY THE TETHERING ROTOR?

The selection of tethering rotors is determined by the experience acquired after years of research and study; the "combination" formula, closer to the helicopter, was studied initially (high-speed autorotation rotor tests were carried out at Modane), but was found to be of little interest (except for military aircraft), since at high speeds, the rotor becomes passive and its drag requires a high degree of motorization. This causes high fuel consumption and a weight penalty (20 to 30%) of such proportions that a double link belt is required, one for the rotors and one for the engines.

This is an artist's conception of an X-910 convertiplane (civil version) making a connection with an offshore platform. With a full load of fuel (500 kg) and 20 minutes of reserve, the plane could carry 5 passengers for 800 km, including 10 minutes of hovering flight with no ground effect. Indeed, the applications of the X-910 are numerous, e.g., surveillance at sea, anti-submarine combat, rescue and evacuation of the wounded, anti-tank warfare, attacking enemy helicopters, and so forth.

The convertiplanes, on the other hand, pose new and unfamiliar problems /20
as revealed by the failure of numerous experimental models developed over the past 20 years: only the tethering rotor formula has proved interesting and has been, additionally, the subject of in-depth research on the part of several manufacturers and a number of laboratories. Actually, in hovering flight, the tethering rotor behaves like a helicopter rotor, the principle of which is well-known; in horizontal flight, it behaves like a propeller, also well-known; in both cases, efficiency can remain high.

Relatively simple from the mechanical standpoint, the convertiplane with tethering rotors and a cruising speed of 500 km/hr requires no more power than a helicopter weighing the same and travelling at 300 km/hr, and its weight penalty does not exceed 10%; with an additional penalty and a higher level of motorization, a speed of 750 km/hr is possible.

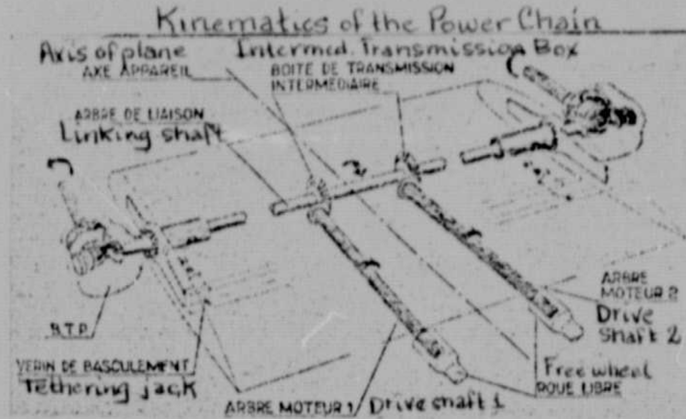
As early as 1970, then, Aerospatiale proposed to the government a policy for developing high-speed VTOL aircraft with tethering rotors. Studies and research that have been carried out since then show that the X-910 project is viable as a test plane and as a prototype for a future commercial plane. Aerospatiale's experience with rotorcraft support this conclusion in full; the development in the United States of the Bell-301 project (XV-15), resembling the X-910 in general design, also demonstrates that this is a reasonable path to follow.

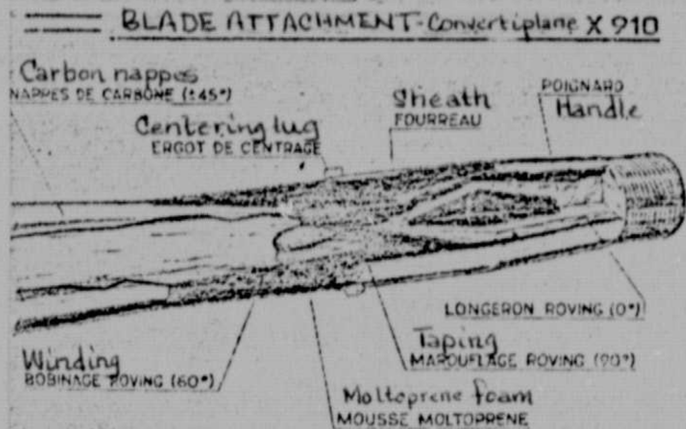
The size adopted corresponds to: /21
- rotors 5 meters in diameter that can be tested at Modane in every area of flight;
- a total weight of 2.5/2.6 tons, and installed power (two Turbomeca "Arriel" turbines) identical to that of the SA.365 "Dauphin" helicopter, now almost fully developed;
- a working capacity and the required resources which remain within reach of French (or European) possibilities;
- a range of use as yet little explored, but which Aerospatiale is capable of exploiting to advantage, as it does with its helicopters.

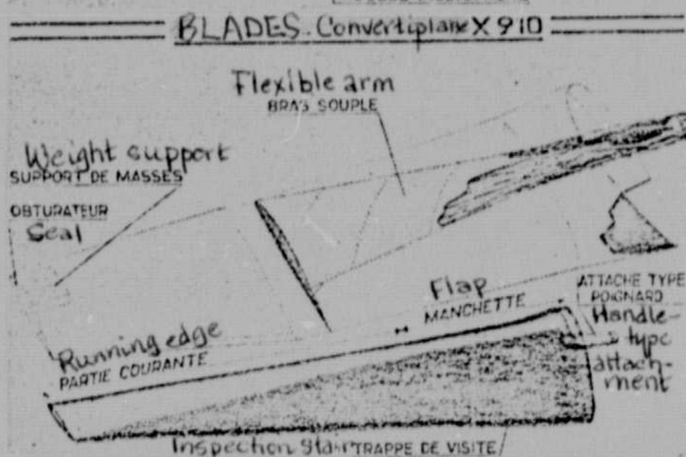
Opposite, from top to bottom: kinematics of the power chain; blade attachment; phantom view of the blades.

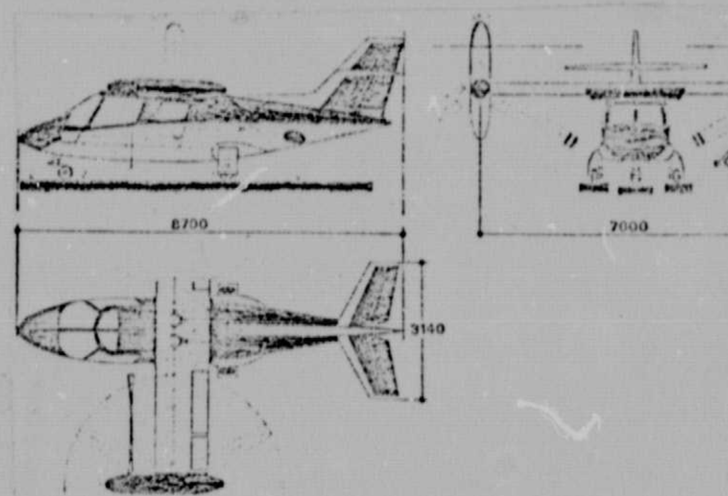
Below, utilization of rotor controls and flight controls for hovering flight and horizontal flight.

Lower left, geometric spin and aerodynamic spin of the blade, expressed in degrees as a function of the relative range.

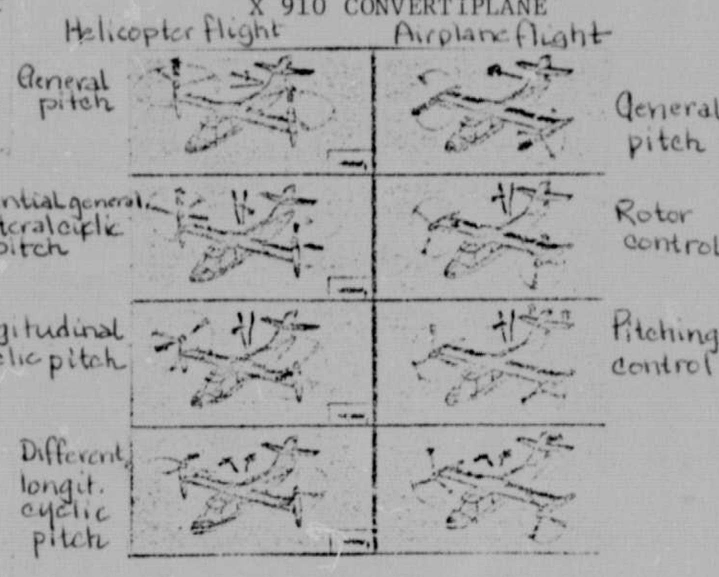








X 910 CONVERTIPLANE



SPIN in degrees

GEOMETRIC SPIN

AERODYNAMIC SPIN

DESCRIPTION

The X-910 is designed to carry 7 persons normally (2 pilots with dual control, 2 + 3 passengers); the cabin of the experimental plane is equipped with measuring instruments and the pilots' seats are provided with Stanely ejection devices.

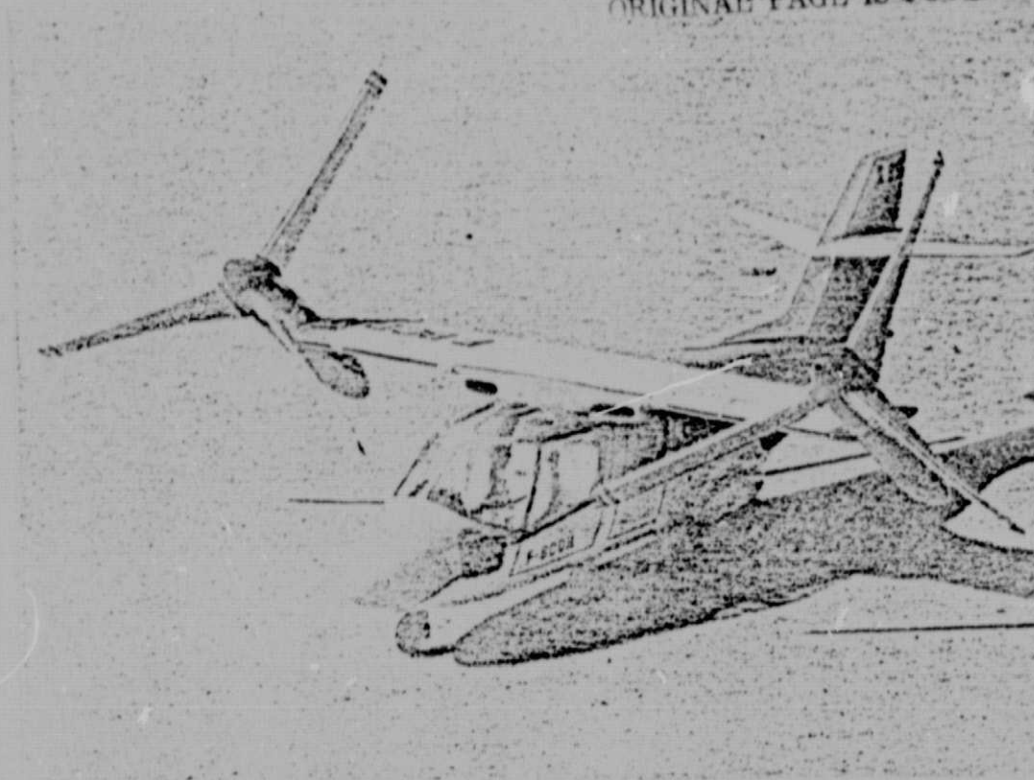
The three-wheel landing gear is retractable. The size of the tail unit and back ridge, traditionally designed, is determined by the destabilizing effect of the large propellers.

The two turbines are placed side by side in the upper part of the frame, behind the wing, inclined towards the rear; they drive the main transmission shaft separately by means of a free wheel and an angle transmission with /22
conical wheels. The air inlets, placed under the wing where it connects with the frame, open into a straightening chamber; additional lateral vents are provided for hovering flight.

The two rotors, superdivergent as a propeller, rotate at 840 rpm and are driven by a main transmission shaft housed in the wing; the end boxes include a conical stage permitting tethering around the main shaft and an epicycloidal stage; they also support the rotor controls (cyclic plate and servo-controls) and the tethering elements (hydraulic jacks), synchronized by control devices.

These rotors have a "rigid" hub; the pitch connection is housed in the body of the hub; the plastic blades have a cylindrical neck made of flexible composite fibers; these blades, which have been fully engineered aerodynamically, achieve the best possible compromise between hovering flight and cruising performances. Geometrically, they form a double trapezium; the profiles, from the NACA 64 family, have a thickness of 22% at the root and 6% at the extremity. The blades have a coiled torsion spar made of carbon fibers and are both light and very rigidly torsioned.

The flight control system is essential on a plane of this type, since the action of the control surfaces is totally different in the two modes of flight, and the transition from one mode to the other must be effected gradually.



CHARACTERISTICS:

Distance between rotors: 7 m; diameter of rotors: 5 m; disc surface: 19.6 m^2 x 2; width of blades: 0.5 to 0.25 m; solidity: 0.115; spin: 38°; NACA 64-552 profiles 64-206.

Wing span: 6.7 m; depth: 1.19 m; surface area, 7.7 m^2; profile: NACA 63A-221; aspect ratio: 5.82; fin surface: 2.5 m^2; horizontal empennage: 2.6 m^2.

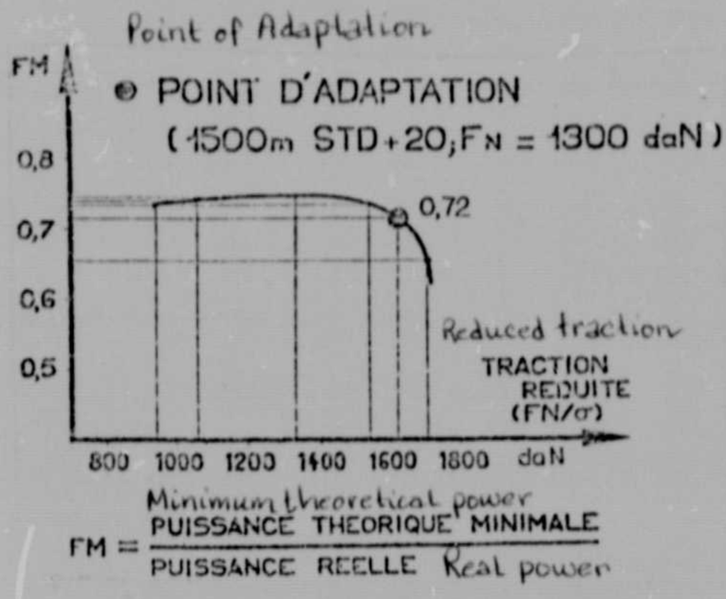
Length of frame: 8.7 m.

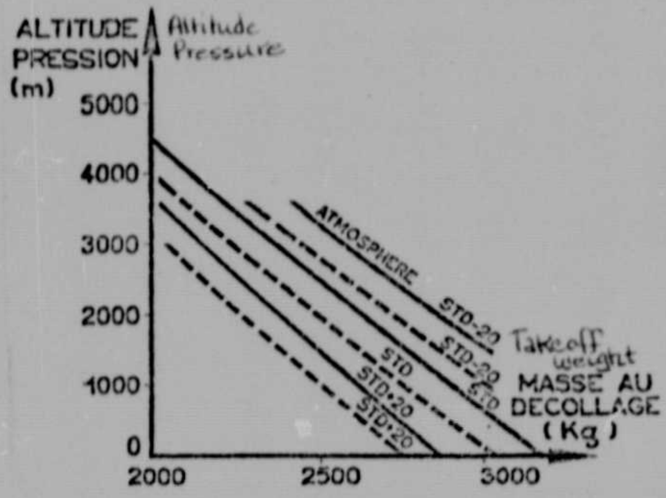
WEIGHTS:

Empty weight: 1,640 kg; total weight: 2,560 kg; fuel capacity: 500 kg; disc load (at 2,500 kg): 63.8 kg/m^2; blade load: 562 kg/m^2; wing load: 340 kg/m^2.

PERFORMANCES:

Merit index: 0.74; cruising efficiency (propellers): 0.83; takeoff weight: 3,050 kg (excluding ground effect); hovering ceiling (h.e.s.) at I.S.A. + 20°: 1,000 m; maximum speed at maximum weight at 2,000 m: 517 km/hr; rapid cruising at 2,000 m: 503 km/hr; range during rapid cruising at 2,000 m with 10 min. hovering and 20 min. reserve time: 800 km with one pilot and 4 passengers, 450 km with one pilot and 6 passengers; consumption per kilometer during rapid cruising: 0.52 kg/km with a weight of 2,560 kg and 0.49 kg/km with a weight of 1,900 kg.



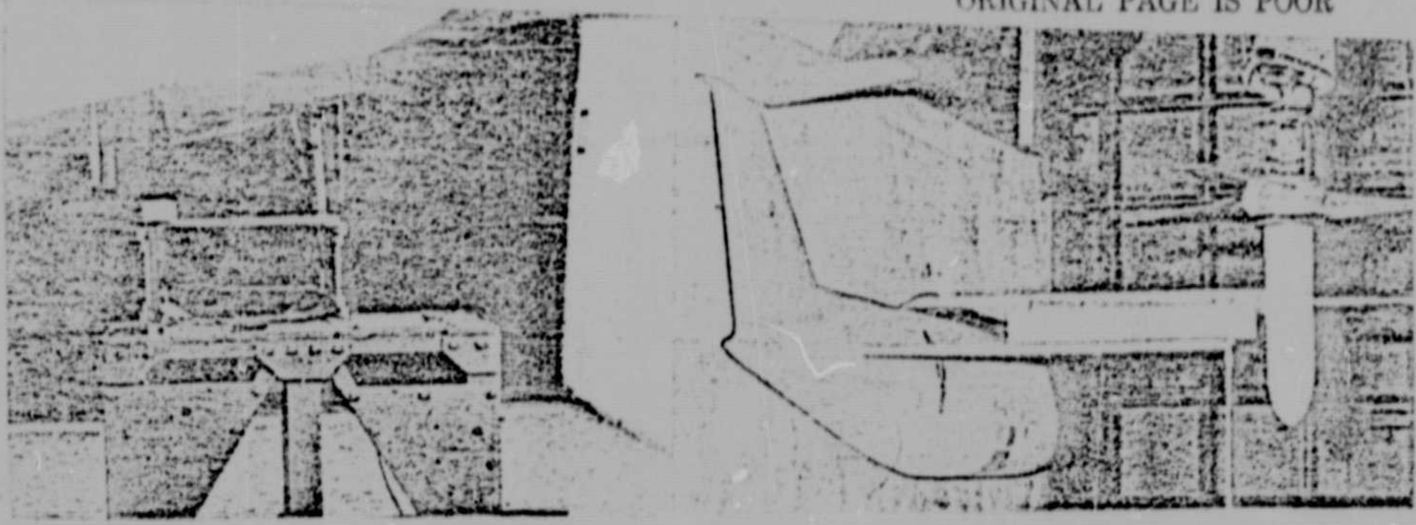


Performances of the 5-meter diameter rotor; left, merit index curve (ratio between minimum theoretical power and actual power) as a function of reduced thrust: at the point of adaptation (Z = 1,500 m, standard temperature + 20°C, I = 1,300 decaNewtons) the merit index is 0.72; right, takeoff weights excluding ground effect using Turbomeca Arriel turbines - 1 of 478 kW (broken lines) and 565 kW Arriel 10's (solid lines).

Thus, the automatic devices required have been planned to lessen the pilot's task as much as possible, especially during tethering, triggered by the pilot at will, but then continued automatically (with possibilities of correction and intervention).

The rotor controls will be electrical, which is exactly what is needed not only because this is the simplest and lightest solution, but also because adjustments can be easily made and the maximum amount of precision can be obtained. Similarly, analogical computers will be adopted initially, because they will facilitate adjustments and connections of all types.

The load-bearing capacities have been established with a 10% margin over no-load weight. The result is a plane weighint 1,640 kg empty and 2,560 kg under load (920 kg of live weight, 325 to 500 kg of which is fuel). The experimental version will weigh 2,445 kg with 250 kg of test equipment.



Wind-tunnel tests on a motorized scale model.

DEVELOPMENT PROGRAM

The work carried out from 1973 to 1977 has covered several fields: theoretical studies in aerodynamics (performances, flight qualities, piloting laws) and in dynamics (precession flutter, wing-rotor coupling); technological study (preliminary project); wind-tunnel tests at Saint-Cyr and CEAT (scale model propeller 1 meter in diameter), Marignane (stationary model, scale 1:5, motorized model, scale 1:7), Meudon (rotor-wing coupling), Modane, in the large ONERA wind-tunnel, where tests on a rotor, scale 1, measuring 5 m in diameter and successfully completed in July 1976 made it possible to improve the aerodynamics of the rotor, to obtain results in total conformity with previsions, to compute accurately the performances of the plane, and to achieve a worldwide "first": two-way conversaion in the wind-tunnel, with the tethering angle, the general pitch and the cyclic pitch controlled by the (variable) velocity of the wind.

If Aerospatiale can have a launching "top" early in 1978, it feels that the first rotations on the endurance bench could occur early in 1980, and the maiden flight early in 1981. However, in order to save time and to take advantage of the current state of the art, it appears highly desirable to begin production as soon as possible on a motorized scale model on a scale of 1:3, to be tested at Modane starting in the spring of 1979. Is that too much to ask?

Jacques MORISSET.

The 5-meter diameter rotor in the duct of the large Paul Dumanois wind-tunnel at Modane Avrieux: the diameter of the duct (8 m) made it possible to test this rotor from all angles, and in the entire range of possible speeds, i.e., actual operating speed. The test device, built by ONERA, is unique in its field and was also used for NASA tests.