ITALIAN V/STOL CONCEPTS OF THE TWENTIETH CENTURY

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ABSTRACT

A number of different types of rotorcraft and jet-powered Vertical and/or Short Take-Off and Landing (V/STOL) aircraft concepts – designs that seek to combine the vertical take off and/or landing capability of helicopters with the high speed flight of a fixed-wing aircraft – were considered in Italy during the Twentieth Century, primarily during the 1960s. This paper discusses the various concepts studied and the extent of development. This paper includes fighter/attack aircraft (the Fiat 95 series and VAK 191B variants), transports (the Fiat G.222 and Aerfer AE-130, BAC 224, and 2102 lift engine concepts and the Agusta A119 tiltrotor), and compound helicopters (the Agusta A110, A118, A120, A123, the SIAI-Marchetti SV-20, and the Fiat 7005). In addition, more recent work at Agusta on tilt-rotors (EUROFAR, ERICA and the BA609) will also be examined. Although none of these designs except the VAK 191B and the BA609 were ever built, significant component, wind tunnel and sub-scale tests for the other concepts were conducted. This paper catalogs all known Italian V/STOL designs for the benefit of future high speed development efforts. This paper is the sixth in a series examining V/STOL designs from around the world during the Twentieth Century.

FIAT

In the early 1960s, several NATO countries funded design studies for supersonic V/STOL strike aircraft able to survive a Soviet nuclear attack that was expected to annihilate conventional runways. Two formal NATO requirements were released: the NATO Basic Military Requirement (NBMR) 3 for a large Mach 1.5+ nuclear penetrator (1961), and the *Vertikalstartendes Aufklärungs- und Kampfflugzeug* (Vertical Take-off and Landing Reconnaissance and Strike Aircraft) or VAK 191 for a smaller, Mach 1+ nuclear strike aircraft (1964).

In Germany, Focke-Wulf developed a design, the FW 1262, that was eventually built as the VAK 191B; in England, the Hawker P.1127 Kestrel was in development and would eventually see service as the Harrier; and, in France, Dassault was demonstrating VTOL capability for its Mirage fighters in response to NBMR.3. During this time, Fiat was also conducting studies and hardware demonstrations, funded by the Italian government, of a V/STOL-capable replacement for the Fiat G.91, then in service with the *Aeronautica Militare Italiana* (AMI), the Italian Air Force. The concepts – dubbed the G.95 series – evolved from the G.91, as shown in Figure 1, and were designed under the leadership of project chief engineer, Giuseppe Gabrielli. (Fiat, it should be noted, had been involved in aviation since 1908.)

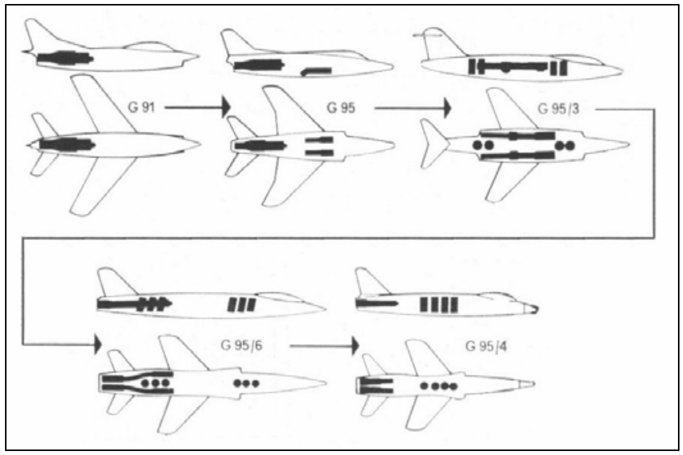

Figure 1. Evolution of Fiat G.95 designs. [7]

G.95

Fiat's first design for a G.91 replacement, the G.95, used a single cruise engine, permitting the same installation as the G.91 and an identical rear fuselage, but this was supplemented by two small turbojet engines. These engines exhausted just forward of the center of gravity to provide a Short Take-Off and Landing (STOL) capability to minimize field requirements, but was not capable of vertical operations. Like all the subsequent G.95 designs, this concept used bifurcated inlets and an ogival nose section. Later versions of the G.95, however, varied widely in planform and propulsion scheme and were designed to be capable of V/STOL operations.

G.95/3

The G.95/3 used two pairs of lift engines, one pair forward and one pair aft, as well as two lift/cruise engines capable of deflecting their exhaust from vertical (to supplement the lift engines for vertical operations) to horizontal (for cruise). In contrast to the other G.95 designs, the G.95/3 had a T-tail (see Figure 2).

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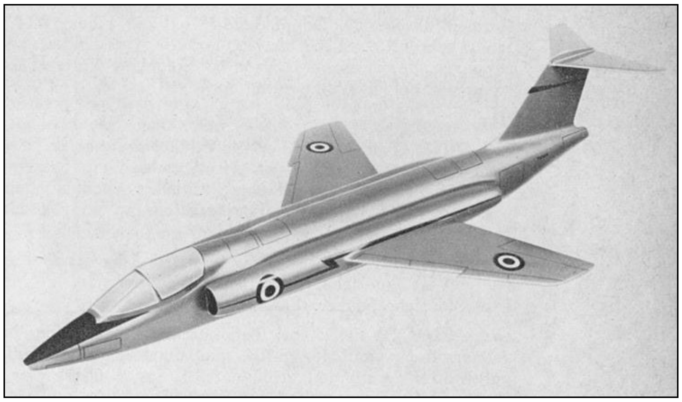

Figure 2. Model of the Fiat 95/3. [21]

G.95/6

The G.95/6 – derived from the G.95/3 – was Fiat's proposal for the NATO NBMR.3 requirement. The concept was powered by six lift engines and two cruise engines with afterburner, which allowed the aircraft to reach Mach 2 at medium altitude. Interestingly, the afterburners were separated somewhat from the turbomachinery to permit area ruling with the empennage. The inline arrangements of the lift engines permitted a high fineness ratio (narrow fuselage) to facilitate supersonic flight. [1]

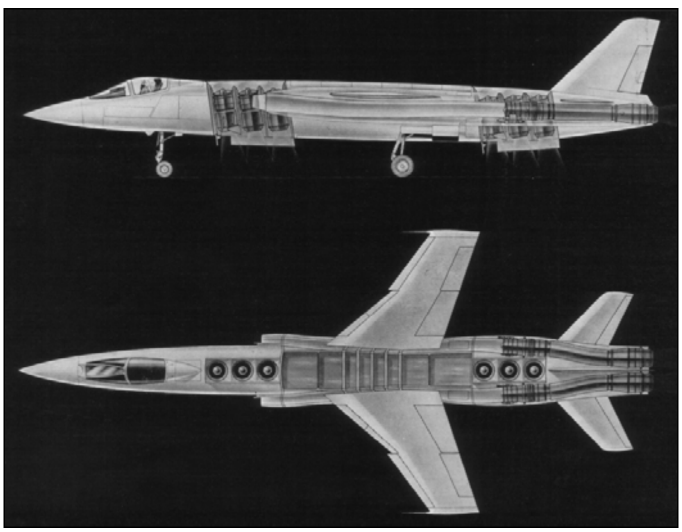

Figure 3. Fiat G.95/6 propulsion system layout.

The location of the engines and the high wing was seen to allow a favorable distribution of the flow from the lift engines while reducing negative ground effects. The undercarriage was designed with long-stroke, articulated struts and high energy absorption for emergency landings with touchdown speeds of up to 16 ft/sec and the possibility of STOL operations from semi-prepared terrain. The ability to land at high touchdown speeds, the possibility of separately controlling the two groups of lift engines, and the instant application of maximum energy rate should one of the lift engine fail during take-off or landing were intended to maximize pilot safety. [1]

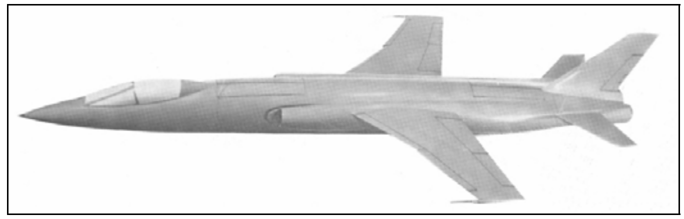

Figure 4. Model of the Fiat G.95/6. [1]

As can be seen in Figure 5, each lift engine group had a pair of side-hinged doors covering the inlets and exhausts. A smaller, forward hinged door below was used as an air deflector to minimize the airflow buffeting on the lift engines. The lift engine exhaust was tilted aft to improve transition to forward flight from a hover and to assist with a small inherent STOL capability. The center fuselage was primarily comprised of large fuel tanks to meet the range requirement for the baseline mission.

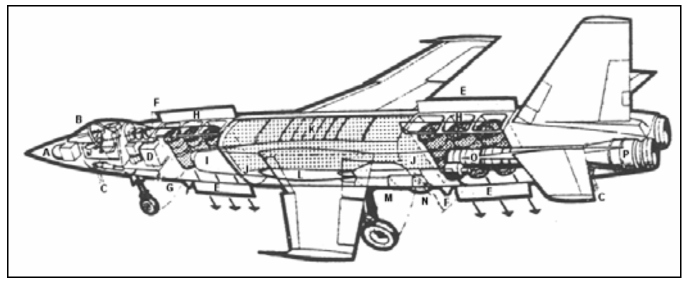

Figure 5. G.95/6 cutaway: A – radome and fire control package in di-electric nose cone; B – cockpit with mission electronic pack and pilot's radar screen; C – fore and aft bleed air "puffer pipes" fed from lift engines; D – radio and electronic packs; E – twin sideways-hinging lift engine bay doors; F – retractable ventral doors to forward lift engine bay; G – bay for rearward-retracting nosewheel; H – Rolls-Royce RB. 162 lift engines (six); I – D-shaped air intake for RB.153 engine with boundary layer bleed plate; J – air inlet duct; K – fuselage fuel tanks built around wing center section; L – internal weapons bay; M – port main undercarriage bay; N – port air brake (dotted); O – Rolls-Royce RB.153 cruise engines; P – afterburner section. [26]

G.95/4

In 1962-63, the German, British, and Italian governments agreed that a joint effort be made to field a common NATO V/STOL strike aircraft and reconnaissance aircraft, since all three nations appeared to be interested in a very similar capability. The three countries agreed to work together to sponsor a formal NATO requirement, participate in a joint source selection for the replacement aircraft, and then jointly fund and develop the selected aircraft design. Fiat began studying a scaled down version of the G.95/6, dubbed the G.95/4 and the G.95/4A reconnaissance variant, funded by the Italian Air Ministry.

The estimated performance and general characteristics of the FW 1262 design were used as the basis for the formal VAK 191 NATO requirement. Designs that would compete against this requirement were allocated the generic "VAK 191" designator along with an identifying letter. The VAK 191 requirement called for a lightweight (15-16,000 lb takeoff gross weight) VTOL strike aircraft. This aircraft was to deliver a single nuclear weapon at high speed (Mach 0.92 or more than 600 kt on the deck) flying a low-low mission profile over a combat radius of 320 km (about 180 nm). The concept included VTOL operations from dispersed hardened sites to provide enhanced deterrence in a nuclear threat environment. It was also desired that the new strike aircraft should have a supersonic (Mach 1.2 to 1.4) dash capability at medium to high altitudes.

Figure 6. Diorama of the Fiat G.95/4. [16]

Four designs were evaluated in the VAK 191 competition: these were a derivative of the subsonic British Hawker P.1127 Kestrel (which had first flown in late 1960 and was designated the VAK 191A for the NATO competition); the low-supersonic German VFW 1262 (the VAK 191B); the high-supersonic German EWR 340 (designated the VAK 191C); and the low-supersonic Italian Fiat G.95/4 (assigned the designation VAK 191D).

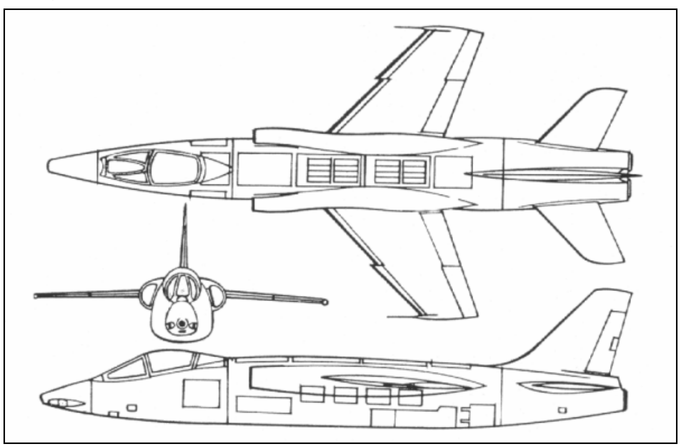

Figure 7. Fiat G.95/4A three-views.

The competition for the NATO G.91 replacement soon narrowed to two designs, one German and one Italian. The German design was the VAK 191B, submitted by Vereinigte Flugtechnische Werke (VFW). VFW was a consortium that had been formed in 1963 by a combination of Focke-Wulf and Weser Flugzeugbau, with Heinkel being added in 1965. VFW had proposed (as the VFW 1262) the Focke-Wulf FW 1262 design. The other finalist (the VAK 191D) was the Fiat G.95/4 design.

The Fiat G.95/4 had initially been designed around two U.S. General Electric J85-GE-15 turbojet cruise engines and four Rolls-Royce RB.162-31 lift engines with swiveling nozzles (each of 5,500 lb static thrust). VTOL takeoff weight was in the region of 16,000 lb for the G.95/4 and as high as 17,600 lb for the G.95/4A. Following discussions with the German government, the Italians agreed that if the G.95/4 were selected, the J85 engines would be replaced by RB.153-61 cruise engines of about 7,000 lb static thrust each; this engine was a version of the RB.153 turbofan engine that was in joint development by Rolls-Royce and the German MAN Turbomotoren company.

Designation:	Fiat G.95/4	
Cruise Engines:	2 x R-R/MAN R.B.153	
Cruise Thrust:	2 x 3,175 kg	2 x 7,000 lb
Lift Engines:	4 x R-R R.B. 162-31	
Lift Thrust:	4 x 2,495 kg	4 x 5,500 lb
Wingspan:	6.62 m	21.7 ft
Length:	14.0 m	46 ft
Height:	4.6 m	15 ft
Surface area:	14 m^2	150 ft^2
Empty weight:	3,800 kg	8,378 lb
VTOL weight:	7,250 kg	16,000 lb
Range	450 km	243 nm
service ceiling	10,000 m	33,000 ft
Vmax	1,200 km/h	650 kt
Vcruise	920 km/h	500 nm
Max speed (on the deck):	Mach 0.92	
Max speed (at altitude):	Mach 1.2-1.4	

The G.95/4 used compressor bleed air from each of the four lift engines and the two cruise engines to provide high pressure air to the reaction control system's puffer jets at the aircraft nose and wing tips for stability during hover and powered lift flight regimes. The high pressure pipes were interconnected to maintain control in the event one of the engines failed. The lift engines were likely started by cruise engine compressor bleed as well.

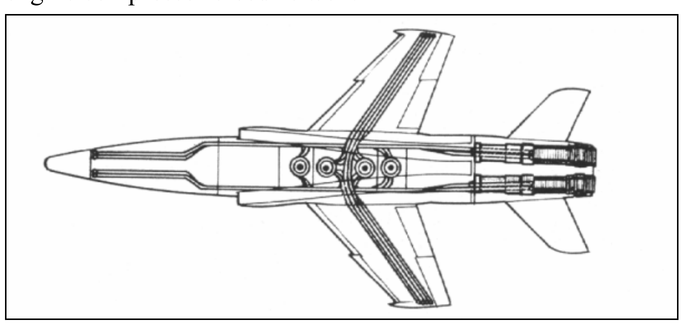

Figure 8. G.95/4 propulsion scheme.

A specialized reconnaissance variant with a different nose section was designated the G.95/4A (shown in Figure 9); it was to replace the existing G.91R reconnaissance aircraft.

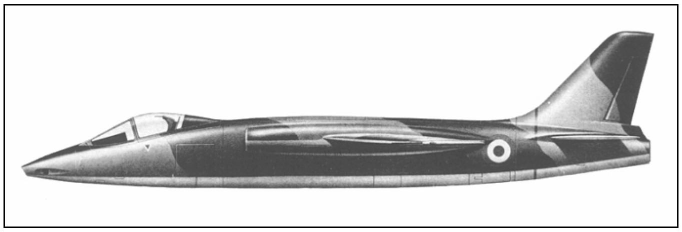

Figure 9. Fiat G.95/4A reconnaissance version.

It was designed to carry two cameras, as can be seen in the cutaway drawing, Figure 10. The cutaway also shows the two pairs of louvered doors that covered the lift engine inlets. The lift engine doors and the spring-loaded louveres would open to maximize airflow during lift engine operation. The doors and the louvers would then close during cruise flight. The lift engine exhausts were covered by ventral doors in the axial orientation, as well as a smaller door used as flow field spoiler, which may have also been intended to capture the fountain effect during hovering in ground effect.

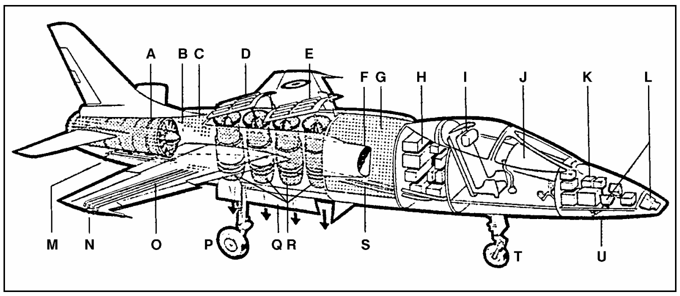

Figure 10. Fiat G.95/4A cutaway: A – right cruise engine; B – cruise engine inlet duct; C – aft fuel tank; D – aft lift engine louvered door; E – forward lift engine louvered door; F – cruise engine inlet; G – forward fuel tank; H – avionics bay; I – ejection seat; J – instrument panel; K – nose avionics bay; L – reconnaissance cameras; M – pitch-down puffer jet; N – roll puffer jets; O – roll jet ducts; P – main gear; Q – lift engine exhaust doors; R – lift engines; S – puffer jet pipes; T – nose gear; U – pitch-up puffer jet. [26]

Fiat also constructed a simulator to permit research work on aircraft behavior in hovering flight, as well as enabling dynamic response to be studied. The hovering rig used two Rolls-Royce R.B.108 lift engines and was suspended from a gantry over a grated surface (to minimize hot gas reingestion). Compressor bleed air from the lift engines provided attitude control via puffer jets at the "wingtips" and both ends of the fuselage. The pilot sat at the forward end in a crude cockpit and characteristics of the rig – such as the moments of inertia and control, weight, and dimensions – were made as dynamically similar as possible to the G.95/4 concept. Suspended under the gantry, the rig was capable of vertical travel, rotation through 360º in the horizontal plane and limited rotation about the other two axes. After the pilots had gotten a basic feel for powered lift and the control system was fine tuned, the simulator was used for untethered hovering. The rig was later used for Fiat's work on the VAK 191B. [11]

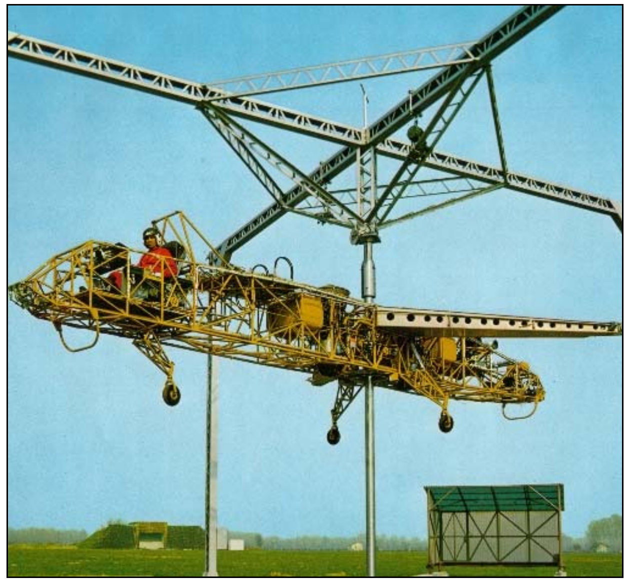

Figure 11. Fiat G.95 test rig in Turin, Italy. [16]

In 1963, early in the VAK 191 concept design/preliminary evaluation phase, the British government withdrew from the project. This was after it had become apparent that the other NATO countries were not interested in procuring a derivative of the British aircraft. The UK was still interested in selling engine technology from Rolls-Royce, but they no longer intended to participate in developing a new common-use NATO VTOL fighter, as they were now committed to development of their own domestic VTOL strike fighter derived from the Hawker P.1127.

VAK 191B

In July 1965, the German VFW VAK 191B design was selected as the winner of the competition for the new NATO nuclear strike aircraft. The potential market for this aircraft was (probably optimistically) estimated at 1,000 aircraft. The German and Italian governments agreed to mutually fund initial VAK 191B development and flight test with costs to be split on a 60-40 basis. As a result of the agreement, Fiat Aviazone joined the VAK 191B design and development team; Fiat became responsible for the wings, nose section and tail section (Figure 12). [32]

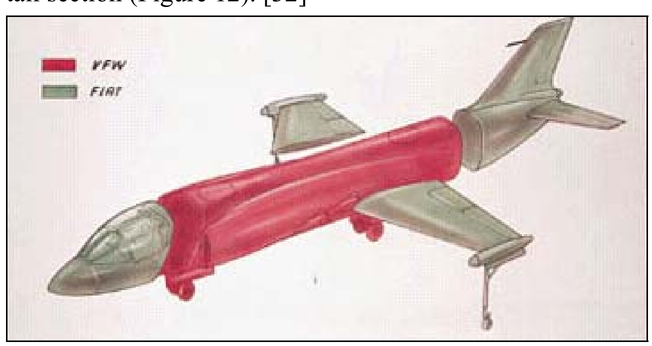

Figure 12. VAK 191 showing work split. [25]

The flight test effort was to be based on the use of three single-seat aircraft – the various parts built as described above, but assembled at Focke-Wulf's Bremen factory in northern Germany – and three two-seaters to be assembled by Fiat at Turin. However, soon after the program began, NATO shifted its nuclear stance to once of flexible response. This meant that strike aircraft had to be capable of employing conventional weapons as well. With the very narrow design point of the VAK 191B and its extremely small wing, the concept was not well suited to this. Despite a number of design studies to develop a useful capability, the necessary new investments in propulsion system development were deemed too prohibitive.

Consequently, in 1966, the focus of the ongoing VAK 191B project was then changed to that of a purely experimental technology demonstrator. Late that year, the two-seat version (Figure 13) was terminated. In February 1967, Italy withdrew from the project to free funds to develop its own G.91 follow-on aircraft, the Fiat G.91Y (the G.91Y was a twin-engine non-V/STOL derivative of the single-engine G.91; it eventually replaced the G.91 in Italian Air Force service, with deliveries begun in 1970).

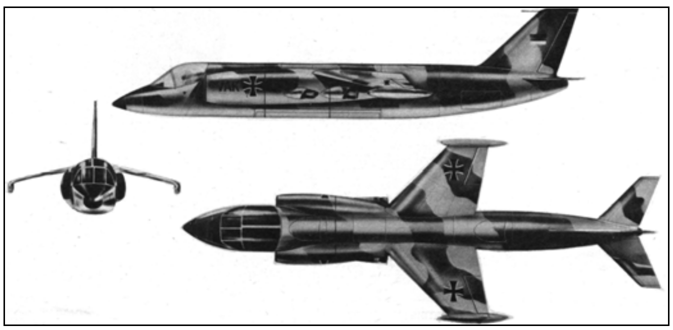

Figure 13. VAK 191B two-seater. [27]

Fiat continued as an associate subcontractor on the VAK 191B single-seat flight test effort. The three single-seat test aircraft were built, with Fiat supplying the wings, tails and cockpits (some of which can be seen in Figure 14). Fiat also used the hover rig simulator and test stand it had developed for the G.95 for early testing of the VAK 191B concept. [25]

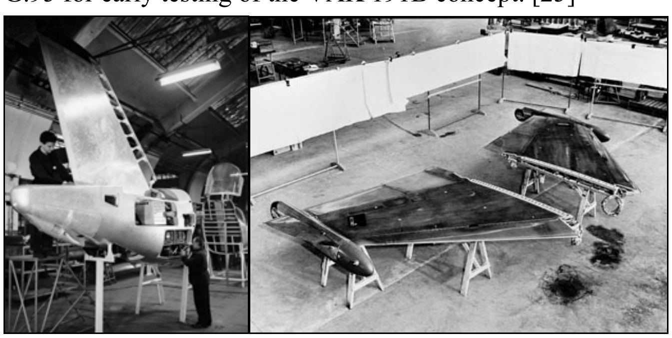

Figure 14. VAK 191B parts in fabrication in Turin. [25]

In 1968, the VAK 191B was again redirected to serve as a testbed for technologies applicable to the NATO Multi-Role Combat Aircraft (MRCA) program then being developed by a consortium created by the German, Italian and UK governments, and eventually materializing as the Panavia Tornado. After limited flight testing in 1971-72, the VAK 191B program was terminated by the German BMVg.

G.222

Today, the Fiat (now Alenia) G.222 is used by nearly a dozen air forces around the world, including the US Air Force. Over 100 aircraft have been delivered since 1975, with production continuing today. The G.222 was conceived in the early 1960s, as a result of another NATO Basic Military Requirement – NBMR.4, which specified a lightweight V/STOL transport to service the V/STOL fighters developed under the NBMR.3 and the VAK 191 specifications. Twenty five different concepts – primarily turbofan designs – were proposed by NATO countries for NBMR.4, which was formally released in 1962.

Figure 15. Model of the V/STOL G.222 transport. [16]

Design work at Fiat began in 1961 under Professor Giuseppe Gabrielli, the director of Fiat's Aviation Division at Caselle, Turin. The Italian Air Force (AMI) awarded Fiat a research contract in the Spring of 1963 based on its proposed concept at that time, a boxy V/STOL design with an unpressurized fuselage, designated the G.222 *Cervino* ("Deer"). The attitude control in jet-borne flight was via twin puffer jets at the fuselage extremes for pitch and yaw, and three jets at each wingtip for roll.

The large loading ramp under the rear of the fuselage could allow easy loading of 40 fully equipped troops, 32 paratroopers, 24 stretchers with medical personnel, or three small trucks. The engines were Dart RDa 10 turboprops, using water/methanol injection to achieve 3,025 eshp, powering 12.5 ft (3.8 m) Rotol four-blade propellers. Each engine nacelle also housed three RB.162-31 lift engines (design studies also looked at as few as one or as many as four lift engines per nacelle), with 5,500 lb (2,495 kg) thrust apiece. An aft-hinged inlet door covered the first lift engine, while a larger door covered the second two; spring-loaded louvers opened for additional air intake. The engines exhausted through large, side-hinged doors below the engine body; a small forward-hinged door dropped down to optimize the airflow.

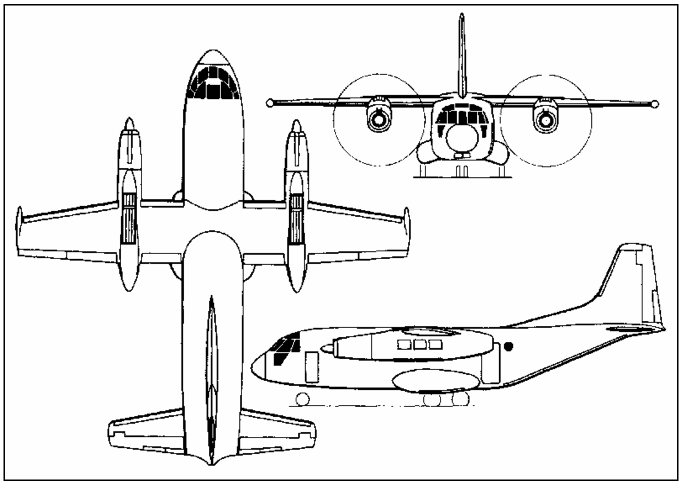

Figure 16. Initial G.222 "Cervino" V/STOL (1963). [10]

Maximum vertical take-off weight was calculated to be 28,000 lb (12,700 kg); only short take-offs could be accomplished at full gross weight of 35,000 lb (15,875 kg). On a tactical mission, after a STOL take-off clearing a 15 m (50 ft) obstacle in 200 m (660 ft), the G.222 would have flown 300 km (186 m) at 4,200 m (13,800 ft), and then ingressed at low altitude another 200 km (108 nm). This would have been terminated with a vertical landing. After unloading, a vertical take-off over the reverse route would have allowed a total combat radius of 500 km (270 nm). [10] First flight of the G.222 at the time was expected in 1966.

Designation:	Fiat G.222 "Cervino"(1963)	
Cruise Engines:	2 x R-R Dart 10	
Cruise Power:	2x 2,255 kW	2x 3,025 eshp
Lift Engines:	6 x R-R R.B. 162-31	
Lift Thrust:	6 x 2,495 kg	6 x 5,500 lb
Wingspan:	18.10 m	59.1 ft
Length:	19.20 m	62.3 ft
Maximum payload:	4,100 kg	9,040 lb
Cruise speed	400 km/h	215 kt
VTOL weight:	12,700 kg	28,000 lb
Range, max wt (STOL):	1,200 km	650 nm

After continued study, Fiat decided to improve the sales potential of the design by designing a 40 passenger commercial version as well. Pressurization required a cylindrical fuselage and a scale-up of 13% wing span and 9% by length. [10]

Designation:	Fiat G.222 (1964)	
Cruise Engines:	2 x R-R Dart 12	
Lift Engines:	6 x R-R R.B. 162-31	
Lift Thrust:	6 x 2,495 kg	6 x 5,500 lb
Wingspan:	20.42 m	67.0 ft
Length:	20.88 m	68.5 ft
STOL weight:	17,500 kg	38,580 lb
CTOL weight:	21,000 kg	46,300 lb

To allow for attitude control during jet-borne flight, two large fans were used at each wing tip and the tail to increase the thrust from the engine bleed over what would be available from puffer jets. Each lift engine was given its own aft-hinged inlet door. [10] The name "Cervino" was also abandoned, prior to the May 1964 Hanover Air Show.

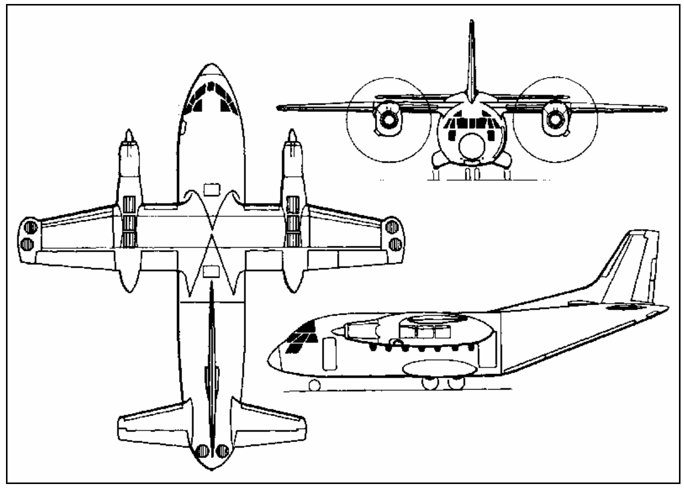

Figure 17. G.222 with control fans (1964). [10]

By 1965, Fiat had expanded the concept of multiple variants to five distinct versions: a V/STOL military transport (now with eight lift engines); a conventional take-off and landing (CTOL) military transport that could be converted to VTOL by the addition of the eight lift engines or to STOL by the use of four; a conventional CTOL military transport; a CTOL commercial airliner/transport; and a maritime patrol/antisubmarine warfare (ASW) aircraft. The primary change required between the variants was differences in the engine pods, as illustrated in Figure 18. [10]

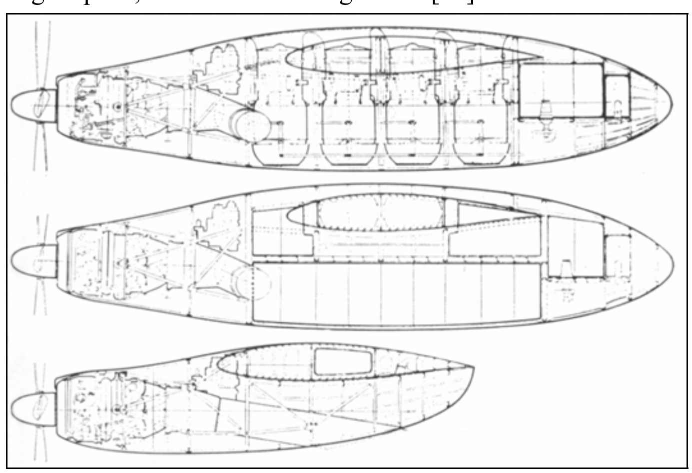

Figure 18. G.222 engine pods: V/STOL variant (top), ASW (middle) and CTOL (bottom).

The V/STOL variant, now with eight lift engines, was able to eliminate the lift fans, and return to the puffer jet attitude control system for yaw and pitch, but control in roll was expected to be possible via differential lift engine thrust. Each lift engine was covered by its own inlet door, with each exhaust cover door now having a fore and aft panel. The dimensions of all five variants were identical, but the lift engines and associated hardware increased the empty weight of the V/STOL variant (shown in the table) 2,000 kg (4,410 lb) over the CTOL military version. [7,10]

Designation:	Fiat G.222 (1965)	
Cruise Engines:	2 x R-R Dart 25	
Lift Engines:	8 x R-R R.B. 162-31	
Lift Thrust:	2,495 kg	5,500 lb
Wingspan:	23.50 m	77.1 ft
Length:	21.50 m	70.5 ft
Height:	8.11 m	26.6 ft
Wing area:	70 m^2	753 ft^2
Max speed:	460 km/h	250 kt
Service ceiling:	7,200 m	24,000 ft
Range (CTOL):	3,700 km	2,000 nm
Empty weight:	11,938 kg	26,320 lb
Gross weight:	18,750 kg	41,335 lb

Continued growth later in 1965 extended the wingspan to 90.2 ft (27.5 m) and length to 75.1 ft (22.90 m). This was an increase in wingspan of more than 50% over that of the original (1963) design. [10]

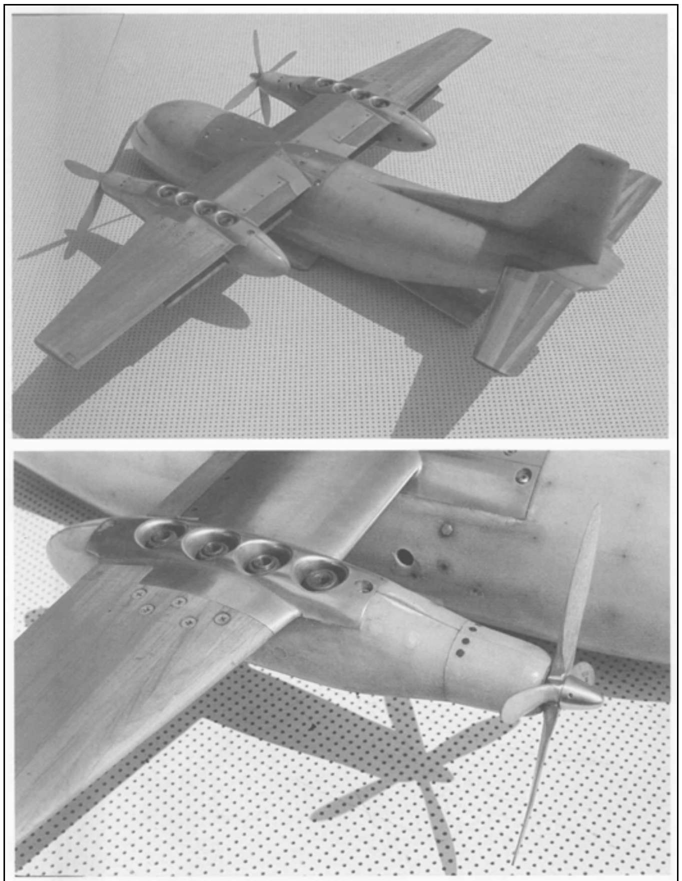

Figure 19. G.222 wind tunnel model.

Nonetheless, in 1966, the Italian Ministry of Defense, presented with the superior payload/range characteristics of the CTOL transport variant (and with the NBMR.4 requirement having been all but forgotten), awarded Fiat a contract for two conventional prototypes. Design work on civil and military V/STOL variants continued for at least another year or two: as detailed design of the CTOL prototypes was underway, provisions were made for V/STOL, but neither airframe was ever converted to a V/STOL configuration. In 1970, the first prototype flew and, sixteen years after it began as a rather small (28,000 lb) V/STOL transport, the G.222 finally went into service in 1976 as a medium weight (61,700 lb) CTOL transport. [10,24]

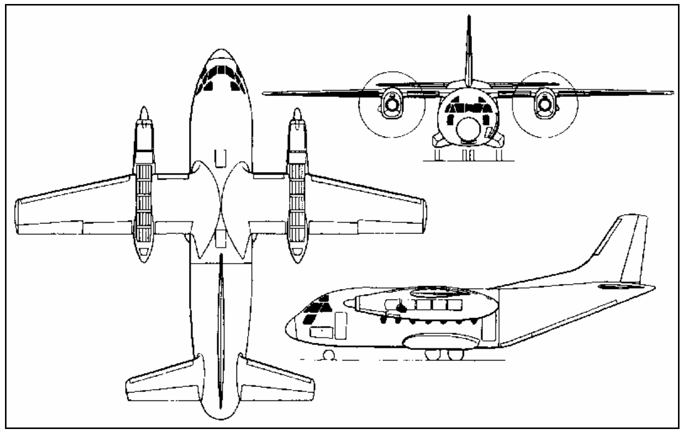

Figure 20. G.222 with eight lift engines (1965). [10]

Fiat 7005

Fiat, which had flown its 7002 reaction rotor helicopter in 1961, also had a design for a compound rotorcraft, called the 7005. This work was also a result of the work Fiat had done with Sud Aviation in the design and manufacture of transmission gears for the Super Frelon helicopter. As a result of this cooperation, Fiat started to design its own high-speed helicopter. [13]

This three-seater used a streamlined fuselage and a pusher propeller, blowing over a cascade of vanes at the rear of the fuselage for counter-torque and yaw vectoring. Note that the vanes could vector 37º and the vane box could pivot a further 33º in order to vector the efflux a total of 70º. The Allison 250 turboshaft engine powered both the three-blade main rotor and the four-blade variable pitch propeller. [12,17]

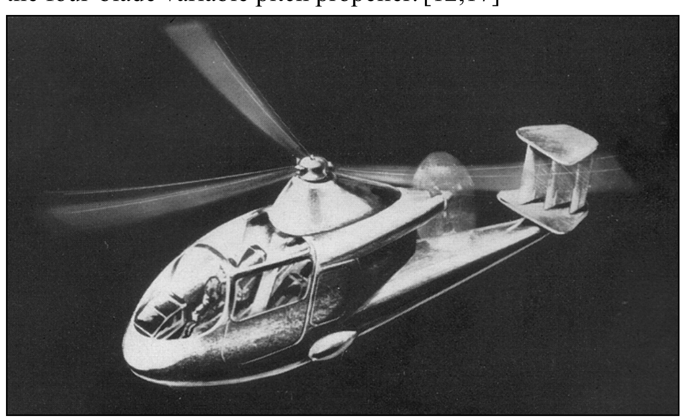

Figure 21. Fiat 7005. [5]

The 7005 fuselage was 7.92 m. Rotor diameter was 8.4 m and the propeller was 1.2 m. Total height was 2.6 m. The landing gear retracted into blisters to minimize drag. [5]

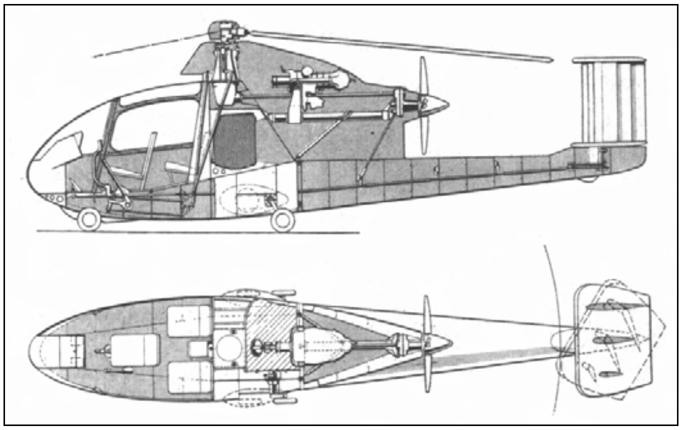

Figure 22. Fiat 7005 side and top views. [18]

AERFER

The *Industrie Meccaniche e Aeronautiche Meridionali-Aerfer*, based in Naples, was formed in 1955 by merger of legacy companies whose heritage began in 1922. During the 1950s and 60s, Aerfer produced parts and spares for F-84, F-104G, and DC-9 aircraft. Aerfer developed the Sagittario 2 fighter prototype – the first Italian aircraft to exceed Mach 1 – and, with Aermacchi, the three-seat AM.3 military STOL.

AE-130

The engineers at Aerfer understood that to benefit the Italian aeronautical industry, a fast commuter aircraft, capable of using small airfields in Italia, was needed. The only formula that would allow such a mission would be a V/STOL aircraft.

The first project studied was the AE-130. Work began on this project in 1955. It was a large aircraft with a short high wing that sported two engine pods each containing a Napier Eland L-4 turboprop. Each 4,000 shp engine drove a large four-blade propeller. A notional sketch is provided in Figure 23.

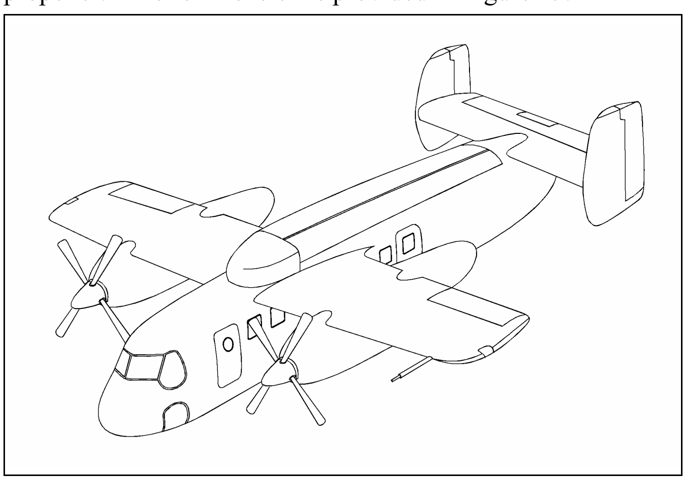

Figure 23. Provisional sketch of Aerfer AE-130.

Vertical take-off was accomplished with a two-blade rotor 20 m in diameter with a chord of 0.92 m. The rotor was powered by the two turboprops. Once the aircraft transitioned to horizontal flight, the rotors were folded and retracted against the upper fuselage so as not to interfere with the aerodynamics of the aircraft. [25]

Designation:	Aerfer AE-130	
Cruise Engines:	2 x Napier "Eland" L-4	
Cruise Power:	2x 2,983 kW	2x 4,000 eshp
Rotor Diameter:	20 m	65.6 ft
Wingspan:	14.2 m	46.6 ft
Length:	24 m	78.7 ft
Max speed:	640 km/h	345 kt
Useful load:	4,000 kg	8,800 lb
Passengers:	26-30	

BAC Type 224

In 1961, Aerfer collaborated with the British Aircraft Co. (BAC) on a V/STOL tactical transport under the NATO NBMR.4 specifications. The project, known as the BAC Type 224, was to compete with the FIAT G.222 V/STOL design. The short range tactical transport design was powered by two Bristol Pegasus 5 engines – then in use on the Harrier predecessor, the P.1127 Kestrel – installed at the root of the high wings. These provided thrust for both lift and cruise. At each wing tip, there was a pod with four Rolls-Royce lift engines, which helped augment the lift thrust for take-off and landing. The maximum gross weight was 35.6 metric tons (78,500 lb). The combined "lift plus lift/cruise" configuration was essentially the same as the competing Dornier Do 31, which would eventually be built and reach flight testing in 1967. [25]

Project 2102

In addition to the V/STOL work by Fiat discussed previously, the AMI also send to Aerfer a request for proposal for the NBMR.4 transport. On 10 July 1962, the AMI send Aerfer a request for proposal for the NBMR.4 transport. The specification requested designs for a V/STOL aircraft with lifting powerplants completely independent from the main propulsive powerplant (i.e. "lift plus cruise"). [25]

Aerfer proposed its Project 2102 with a turbofan on the tail group and a series of lift engines on wing pods. The take-off weight was set at 17.3 metric tons (38,000 lb) with a useful load of 5 tons (11,000 lb). The range was estimated at 1,200 km (650 nm). A General Electric CF-700/2B was selected for the turbofan and RB-162s for the lift engines. When Aerfer merged with Fiat and Salmoiraghi to form Aeritalia on 12 November 1969, the project was shelved. By this time, the G.222 was under assembly and any VTOL transport would clearly be based on it. [25]

SIAI-MARCHETTI

Società Italiana Aeroplani Idrovolanti-Marchetti, based in Sesto Calende, Varese, in northern Italy, was founded in 1915, and developed its first helicopter, the SH-4, in cooperation with Silvercraft in 1965. As a result of the seeming success of the SH-4, SIAI-Marchetti's *Sezione Volo Verticale* (Vertical Flight Division) was formed in 1968 under the leadership of Dr. Emilio Bianchi. [19]

SV-20C

In July of that year, development began of the SV-20A (A = *Alato* or "winged") – a 14-seat twin-engine, winged, high-speed helicopter – as well as the SV-20C (C = "compound") – an improved performance version with a pusher propeller. The SV-20 was an ambitious project to design a helicopter that weighed 4,000 kg (8,820 lb) when carrying a load greater than its empty weight and cruised at 390 km/hr (210 kt). The sale price of the SV-20A was estimated at 200 M Lire.[9]

In December 1968, fabrication of dynamic components and major dynamic assemblies, as well as a number of airframes, was begun (first flight was originally expected in 1970). A full-scale mock-up of the SV-20A was also completed and was shown at the Paris Air Show. By the end of 1972, about 200,000 manhours had been spent on the SV-20 design, including wind tunnel testing at the Universities of Turin, Milan, and Pisa, but a prototype was not completed. [6]

Figure 24. Mock-up of the SV-20A helicopter.

The SIAI-Marchetti SV-20 had a two-blade teetering-hub main rotor, anti-torque rotor and a high mounted cantilever wing. The SV-20C compound added a three-blade variable pitch pusher propeller driven by the right engine. The two United Aircraft of Canada PT6C engines would have been built under license by Motoren-und-Turbinen-Union (the successor to MAN) in Germany. Each engine had a maximum rating of 900 hp, and were located in two nacelles on the wing; the Turboméca Astazou XIVA or Rolls-Royce RS.360 were considered as alternates based on customer preferences. The cabin was designed to transport 12 passengers or 1250 kg (2,755 lb of cargo) in addition to the two pilots. The SV-20C was projected to be about 80 kg (175 lb) heavier than the SV-20A, but about 60 kt faster. Data given below are as of mid 1970; empty and maximum weight reached 2,420 kg (5,300 lb) and 4,536 kg (10,000 lb), respectively, by 1972.

Designation:	SIAI-Marchetti SV-20C	
Cruise Engines:	2 x PT6C-30	
Cruise Power:	2x 671 kW	2x 900 shp
Main rotor diameter	12.86 m	42.19 ft
Tail rotor diameter	2.50 m	8.20 ft
Maximum length	15.63 m	51.28 ft
Maximum height	3.55 m	11.65 ft
Wing span	6.0 m	19.69 ft
Empty weight	1,950 kg	4,300 lb
Useful load	2,050 kg	4,500 lb
Maximum weight	4,000 kg	8,820 lb
Maximum speed	390 km/hr	210 kt
Cruise speed	352 km/hr	190 kt
OGE hover ceiling	4,400 m	14,400 ft
IGE hover ceiling	6,000 m	19,700 ft
Rate of climb	9.65 m/s	1,900 ft/min
Range	815 km	440 nm
Flight endurance	3.7 hr	

The wings of the SV-20 had movable surfaces acting as flaps or ailerons, allowing the pilot to vary the load between the rotor and the wing. During high speed flight, the rotor was to be partially unloaded by the wing and the surfaces were used to augment roll control. [6] A version with a "Fenestron" type tail rotor was planned in 1970.

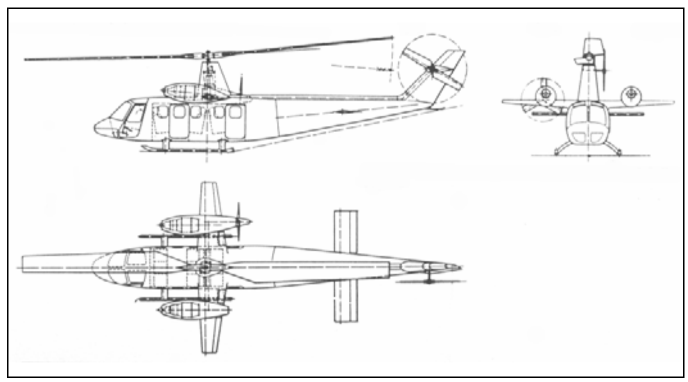

Figure 25. General layout of the SV-20C compound.

Larger versions, such as 20 seat models of both compound and conventional helicopters, were envisioned. SIAI-Marchetti had plans to design a compound helicopter capable of 250 kt (460 km/hr) by 1975 and a stowed-rotor compound capable of 500 kt (920 km/hr) by 1980. [2]

Production jigs reportedly had produced numerous examples of many components by the end of 1972. A market of 500 units was expected, producing 40-60 SV-20s per year. [6] Three prototypes were planned, but, despite initial talks with the FAA and the *Registro Aeronautico Italiano* (RAI) in January 1972, none of the prototypes were ever completed and the project was abandoned the following year. Agusta, which had acquired 30% of SIAI-Marchetti in 1970, had increased its stake to about 60% by 1973 and reached complete ownership in 1983. [19]

AGUSTA

The *Construzioni Aeronautiche Giovanni Agusta* was originally founded in 1907 and has a long history of involvement with rotorcraft, beginning with its first Bell 47 license in 1952. Agusta began development of its own helicopter designs in 1958 – including the A101G, the A102, the A104, and the A105 – but none of these designs in the early and mid-1960s progressed beyond the prototype stage. Agusta also pursued a number of V/STOL configurations, which continue today.

Agusta A110

The Agusta A110 (Figure 26) was a large compound studied from around 1961-1965 as a derivative of the Agusta A101G. It used a similar fuselage and five-bladed rotor system; it was capable of transporting 35 passengers or paratroopers. It used two four-blade tractor propellers at the mid-span of wings that had a slight "V" shaped dihedral/anhedral. The engines for the propellers were at the crux of the "V" and were interconnected with the two main engines driving the rotor, to provide for safe flight in the event of engine failure. It appears that the outer wing panels were capable of rotating downward, possibly as floats for water landings. The A110 was expected to reach 500 km/hr (270 kt) at 8000 kg. [14,15]

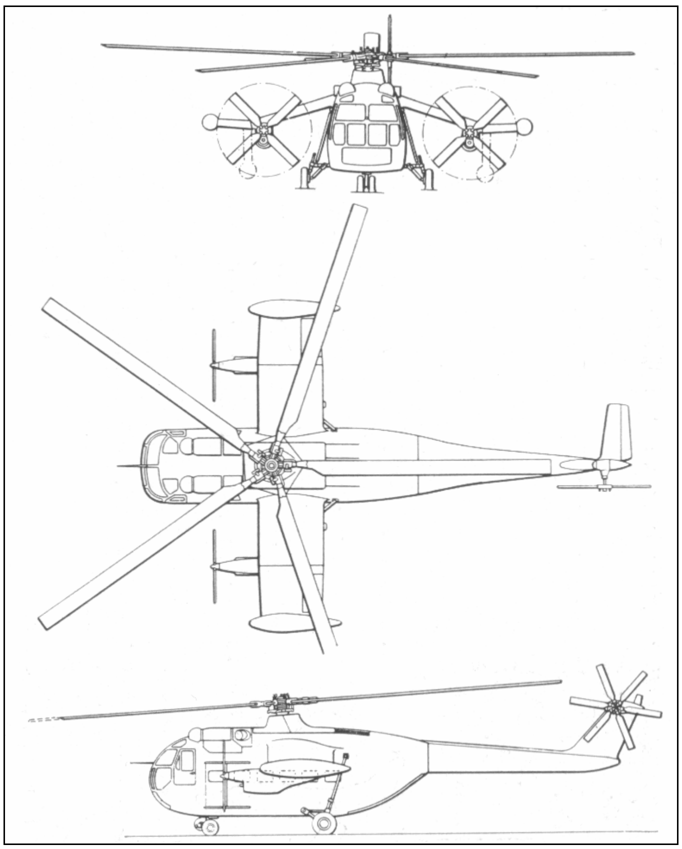

Figure 26. Agusta A110 compound.

Another version of the A110 used a conventional airplane-like tail, without a tail rotor, as shown in Figure 27. The loading ramp and cargo hold are also shown. Also notable is the use of a four-blade rotor and differences in the cockpit glazing.

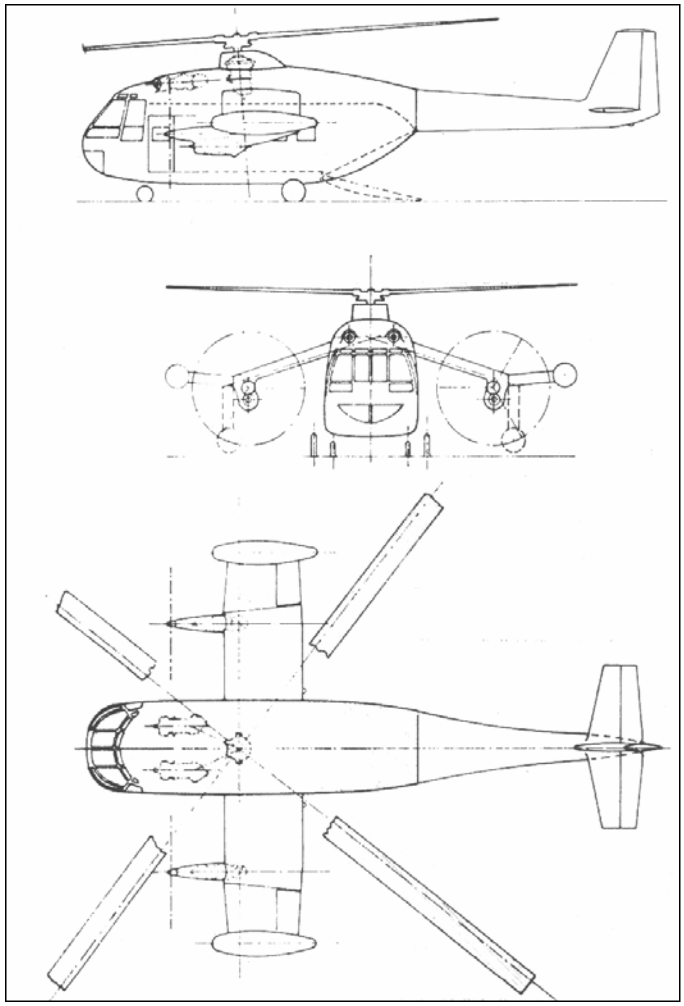

Figure 27. A110 compound without a tail rotor.

Agusta A118

The A118 was a compound helicopter studied by Agusta in 1961 to participate in the NATO NBMR.4 competition. Similar in configuration to the contemporary Soviet Kamov Ka-22 Vintokryl, the A118 had dual compound unit at either end of a long straight wing, consisting of a large 4-blade rotor and a tractor propeller, powered by three engines in each nacelle – based perhaps on the A101G helicopter. Cargo could be loaded via a large loading ramp at the rear of the A118.

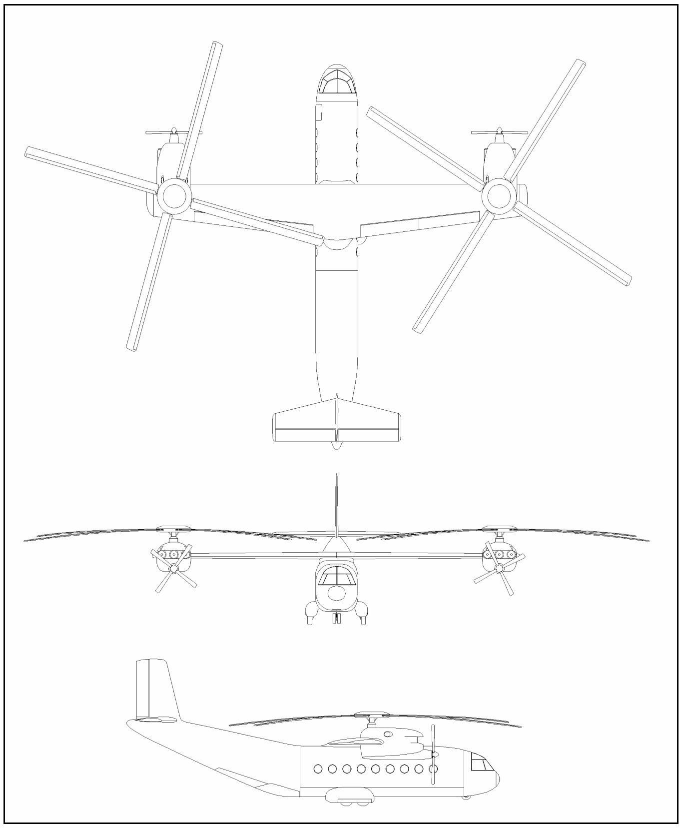

Figure 28. General layout of the A118 compound.

Agusta A119

The A119 was a quad tiltrotor studied by Agusta in 1961 for the NBMR.4 competition. The forward pair of rotors tilted up and were somewhat larger than the rear pair, which tilted down. It appears that there were two turboshaft engines on either side – adjacent to the forward rotors – and were most likely cross linked to all four rotors. Clamshell doors opened in the rear for cargo loading.

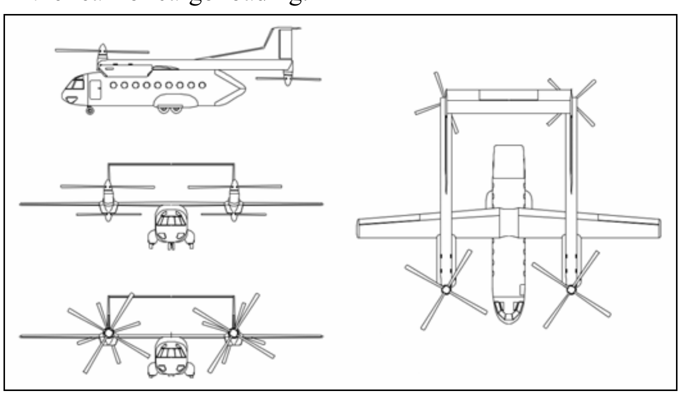

Figure 29. General layout of the A119 tiltrotor.

Agusta A120B

The A120B "Elibus" (sometimes written "Helibus") was a large high-speed compound helicopter studied in 1968. The A120B was fitted with a six-bladed main rotor, a tail rotor, two tractor propellers and a small wing. The powerplant consisted of three T64-GE-12 turboshaft engines, each with a maximum rating of 3,435 hp (2460 kW); the engines were interconnected and had an emergency power rating of over 7,000 hp (5,200 kW), allowing the continuation of the mission in the event of an engine failure. One engine was located in each wing nacelle and drove a tractor propeller through a special gearbox. A third engine was located above the fuselage and drove the main transmission directly.

Designation:	Agusta A120B Elibus	
Diameter main rotor	22.0 m	72.2 ft
Diameter tail rotor	4.87 m	16.0 ft
Diameter propeller	3.70 m	12.1 ft
Cabin length	13.00 m	42.7 ft
Maximum length	26.20 m	86 ft
Maximum height	8.18 m	26.8 ft
Wing span	17.20 m	56.4 ft
Empty weight	14,200 kg	31,306 lb
Normal gross weight	23,500 kg	51,809 lb
Maximum speed	425 km/hr	230 kt
Cruise speed	388 km/hr	210 kt
Rate of climb	10.16 m/s	2000 ft/min
OGE Hover ceiling	1800 m	6,000 ft
IGE Hover ceiling	3000 m	10,000 ft

The features of this helicopter made it particularly suitable for transport of passengers and goods over ranges of 600-700 km (325-375 nm). It was intended to operate between city center heliports or to remote mountain or island destinations. The cabin was designed to accommodate 65 passengers with luggage. The crew consisted of a pilot, co-pilot and two flight attendants. The cockpit and passengers cabin were pressurized.

Figure 30. Agusta A120B Elibus.

The development program was estimated at $70M. An American or other development partner was sought, without success.

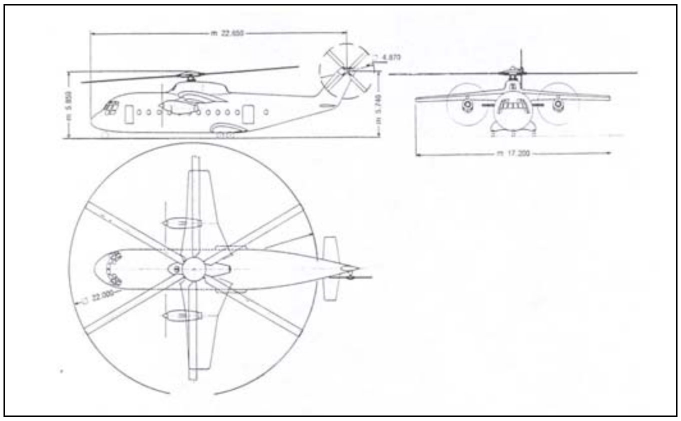

Figure 31. General layout of the A120B helicopter.

Agusta A123

The Agusta A123 was a medium-size compound helicopter design studied in 1969. It was to be capable of high performance and suitable for high-speed transport of passengers and goods. It was also to carry hook loads up to 8,300 lb (3,765 kg).

Designation:	Agusta A123	
Diameter main rotor	14.5 m	47.6 ft
Diameter tail rotor	2.80 m	9.2 ft
Diameter propeller	2.80 m	9.2 ft
Maximum length	17.65 m	57.9 ft
Maximum height	4.05 m	13.3 ft
Wing span	8.00 m	26.2 ft
Empty weight	3,720 kg	8,200 lb
Normal gross weight	6,804 kg	15,000 lb
Gross weight for hook	7,484 kg	16,500 lb
Maximum speed	417 km/hr	225 kt
Cruise speed	400 km/hr	216 kt
Range (tanks, no reserve)	580 km	313 nm
OGE Hover ceiling	3,000 m	9,850 ft
IGE Hover ceiling	3,800 m	12,500 ft

This compound design was fitted with a four-blade main rotor, anti-torque rotor and a pusher propeller. The powerplant consisted of two Lycoming T53 turboshaft engines with a maximum power rating of 1800 hp (1,340 kW) on each engine. The helicopter was provided with a wing to offload the rotor, and had a completely retractable tricycle landing gear.

Figure 32. Agusta A123 compound helicopter.

The cabin was designed for the transport of 14-17 passengers in addition to the two pilots; a large cargo capacity was designed for the luggage. It was expected that the A123 would see service in roles such as Medevac (with 6 litters), transport or attack (due to its speed and maneuverability).

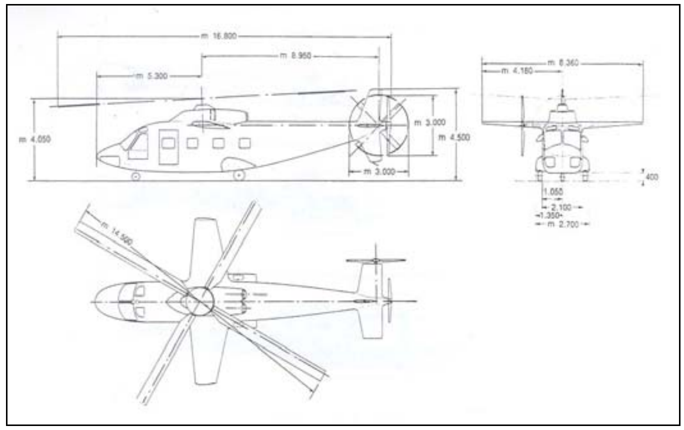

Figure 33. General layout of the A123.

EUROFAR

Several European companies and governments have for many years cultivated a strong interest on tiltrotor technology. Politically and economically, members of the European Union do not want to be left behind on this potentially important sector of V/STOL aircraft. Italy, represented by Agusta, joined Spain, the United Kingdom, Germany and France in order to develop their own indigenous tiltrotor, to counteract what was perceived as an American advantage on this field. The companies begun joint studies in 1986, and the program was subsequently launched in September 1987. [20]

Beginning with the EUROFAR concept, Germany, France and Italy provided funds to create a tiltrotor concept under the EUREKA research and development initiative. (Launched in 1985, EUREKA is a framework through which industry and research institutes from 31 countries and the European Union bring high quality research and development efforts to the market and supports the competitiveness of European companies through international collaboration.) The program was called EUROFAR (European Future Advanced Rotorcraft) and had the goal to determine, within a three year period of time, the feasibility of a baseline civil tiltrotor design for a 30 passenger commuter vehicle. Wind tunnels tests, rigs and other technologies, however, were pursued for more than ten years. Unfortunately for the ambitious tiltrotor engineers, little has been done towards building a flying prototype.

EUROFAR addressed several critical topics of the general vehicle design – specifically, the choice of the most suitable rotor, wing, nacelle / drive train / engine design features among the extensive trade-offs – and, in order to validate some of them – rotor aerodynamic and dynamic design, air vehicle control laws, structural feasibility of a pressurized composite fuselage cabin – a set of experimental activities was established and performed, giving an early proof of the technologies adopted. A layout of an early EUROFAR concept is shown in Figure 34. Overall length was 19.4 m (63.6 ft), wingspan was 15.3 m (51.3 ft), and rotor diameter was 11.2 m (36.7 ft).

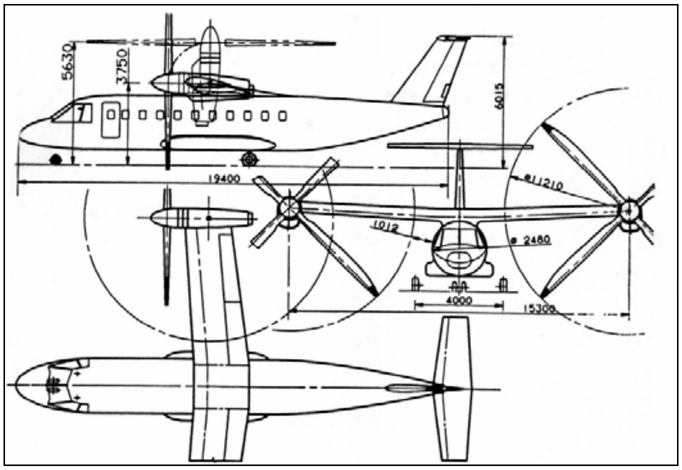

Figure 34. Three-view of the baseline EUROFAR.

A low wing concept and many other variations were studied, finally resulting in a rotor that tilted independently of the nacelles (i.e., stationary engines), as shown in Figure 35. The EUROFAR studies allowed the Europeans to gain experience on the complexities of tiltrotor design. The research results will be used (and are being used) on any future vehicle slated to follow.

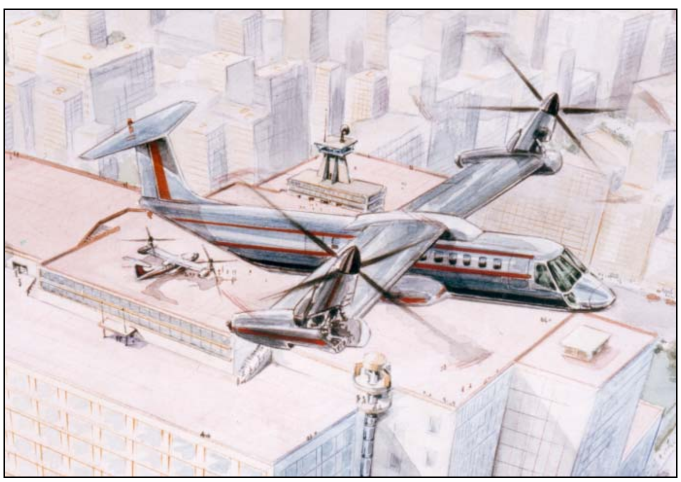

Figure 35. EUROFAR tiltrotor in conversion.

The Figure 36 shows the Model n.2 Rotor system, tested in the ONERA S1 wind tunnel in the early 1990s with a full investigation of the helicopter mode, aircraft mode (up to Mach 0.53), and the conversion corridor envelope. The hub was representative of a full scale articulated rotor design (proposed by Agusta as a backup of the selected gimbal solution) and the blades (also developed by Agusta) were Mach scaled from the aerodynamic RC4 ONERA and Agusta structural and dynamic full scale design. [20,22,23]

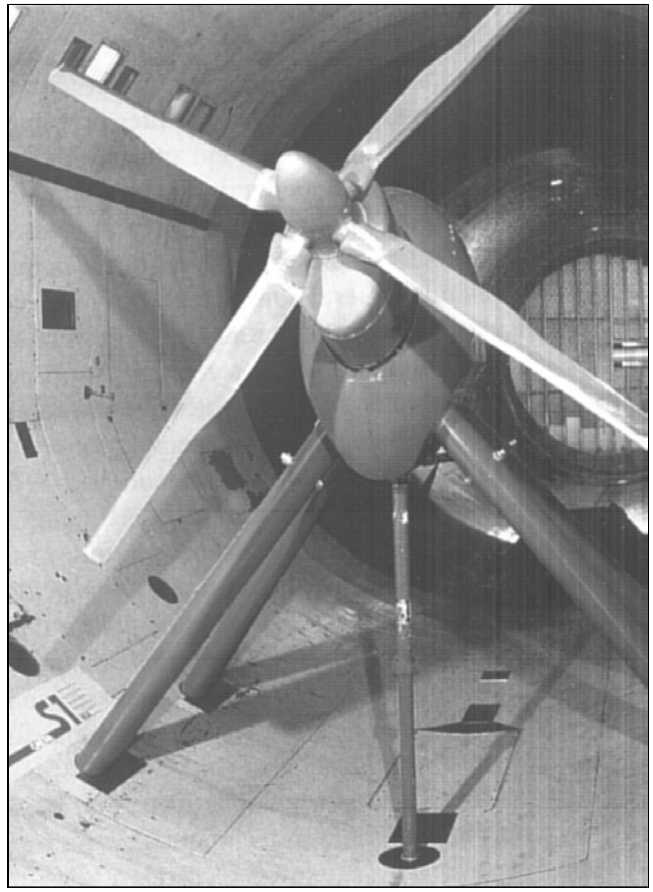

Figure 36. Eurofar tiltrotor under test in cruise mode.

Also in the early 1990s, however, the EUROFAR concept gave way to the Eurocopter EUROTILT (without Agusta), with a configuration very similar to that of EUROFAR. Again, this design tilted only the rotor rather than the entire engine nacelle, hence the powerplants did not require a modification to run vertically. This also allowed a simpler wing design due to the reduced weight of the rotating element.

EUROTILT was in the 10 metric ton (22,000 lb) class, seating 12 to 19 passengers, with a range of 750 nm (1400 km) at more than 330 kt (610 km/hr). Eurocopter assembled a team of 33 partners from nine countries (not including Italy's Agusta) to develop the aircraft. [30] The program was put forward for European Commission funding under the European Union's Fifth Framework Technology Research effort (FP5), but its support conflicted with the ERICA project proposed by Agusta. The FP5 set out the priorities for the European Union's research, technological development and demonstration.

The European Commission attempted to get Eurocopter and Agusta to propose a joint solution. As a result, the 2nd Generation European Tilting Highly Efficient Rotorcraft (2GETHER) was proposed in 2001 for €50M – containing the Eurocopter EUROTILT and the Agusta ERICA as alternate solutions – but this concept was also rejected. A €3.7M project, however, studying the aerodynamics of tiltrotor interactions was selected for funding. In the second call of the same Framework, the European Commission finally decided to fund four other Critical Technology Projects (CTPs) with the purpose to analyze the most critical aspect of a new tiltrotor (dynamics, rotors, etc.), all based on the same configuration: the Agusta ERICA tiltrotor concept.

ERICA

As discussed above, the EUROFAR concept did not reach the prototype stage, and by 2000, Agusta initiated a follow-on program called ERICA, shown in Figure 37. ERICA (Enhanced Rotorcraft Innovative Concept Achievement) was the brainchild of Agusta's Santino Pancotti and his team of talented rotorcraft engineers. ERICA's main objective is to form the basis for a second generation tiltrotor, applying the lessons learned on the EUROFAR and BA609 concepts, but introducing innovative tiltrotor technologies.

Figure 37. Rendering of ERICA tiltrotor in transition.

The main distinguishing feature of the ERICA concept is the change from tilting nacelles at the wing tips to tilting outer wing panels. A continuous shaft or tube that also serves as the main spar of the wing supports and rotates the nacelles. The tilting portion of the wing rotates around this shaft. Figure 38 shows the general layout of the ERICA concept as of late 2001.

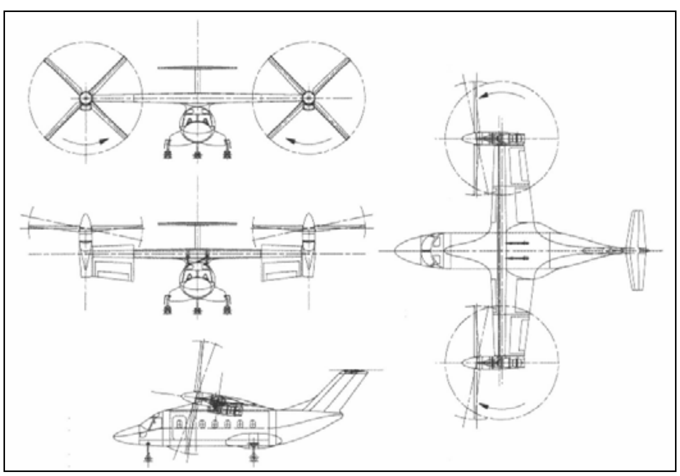

Figure 38. Three-view drawing of the ERICA tiltrotor. [30]

ERICA is designed for increased flexibility with respect to current tiltrotor designs – the Bell Boeing V-22 and the Bell/Agusta BA609. The prop rotors are small enough to permit STOL landings and higher cruise speeds. The tilting of the outer wing panels allows efficient wing angles of attack and reduces the rotor download during hover. Figure 39 shows the inboard profile of the ERICA tiltrotor in the STOL configuration.

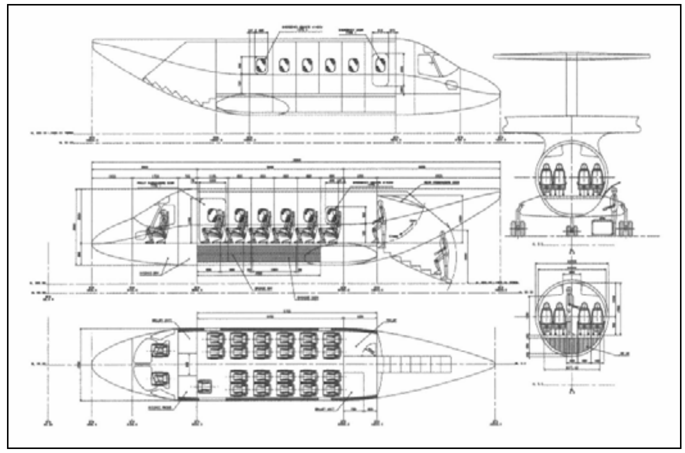

Figure 39. Inboard profile of the ERICA tiltrotor. [29]

The rotor hubs use a patented design using composite and elastomeric elements. The four-blade rotor is stiff in plane and controlled by an external cuff through an inner pitch arm, providing a compact arrangement without sacrificing pitch-flap coupling requirements. [29] The engines for ERICA are envisioned to be dual Pratt & Whitney Canada PW127Es. Curiously, these engines do not currently have a rotorcraft application. Note the rear loading ramp with integral steps and the standing headroom in the cabin.

Designation:	AgustaWestland ERICA	
Engines:	2 x P&WC PW127E turboshaft	
Power:	2x 2,400 shp	2x 1800 kW
Passengers (VTOL):	19 + 2 crew	
Passengers (STOL):	22 + 2 crew	
Wingspan:	46 ft	14 m
Length:	50 ft	15.2 m
Height:	19.7 ft	6 m
Fuselage Diameter:	9 ft	2.7 m
Proprotor Diameter:	24 ft	7.4 m
Max VTOL Useful Load:	4,189 lb	1,900 kg
Max STOL Useful Load:	4,840 lb	2,200 kg
VTOL Gross Weight:	22,000 lb	10,000 kg
STOL Gross Weight:	24,200 lb	11,000 kg
Empty Weight:	14,300 lb	6,500 kg
Fuel Weight (VTOL):	3080 lb	1,400 kg
Fuel Weight (STOL):	4,400 lb	2,000 kg
Range:	650 nm	1,200 km
Cruise altitude:	24,600 ft	7,500 m
Vmax (at cruise):	350 kt	650 km/h

Agusta merged with Westland on July 2000, further consolidating the European helicopter industry. Agusta's merger with Westland has not diminished the new company's support for the ERICA program and work continues. [28]

BA609

The Agusta collaboration with Bell on tiltrotor development (their mutual agreement was signed in 1998) has placed the Italian manufacturer in an advantageous position, since the experiences in the BA609 program will benefit Agusta on ERICA. The BA609 (Figure 40), now undergoing taxi tests in preparation for its first flight, is moving along at a fast pace after a dormant and uncertain period.

The Fort Worth Alliance Airport-based Bell/Agusta Aerospace Company has received more than 85 orders for the aircraft. With the Bell Boeing V-22 Osprey undergoing flight tests after a highly publicized grounding, officials at BAAC appear to be in a better position to continue the test program on the first commercial tiltrotor aircraft.

Approximately 50 hours of ground tests will be conducted with a first flight scheduled for the first quarter of 2003. Powered by two Pratt & Whitney PT6C-67A turboshafts rated at 1,940 shp (standard conditions), the BA609 will be able to transport six to nine passengers. The avionics suite consists of state-of-the-art instrumentation provided by Collins and its Pro Line 21 displays. The test program is expected to last 36 months with FAA certification planned for January 2007. [31]

Figure 40. BA609 ground tests at the Bell Arlington (Texas) Flight Test Center in December 2002. [3]

It appears that Agusta (as part of AgustaWestland) will most likely be the first European company, ahead of Eurocopter, to realize the dream of tiltrotor flight. The Italians, as seen on the many concepts presented herein, have participated as partners on many European V/STOL projects; however, by cooperating with the only company in the world with practical tiltrotor experience, the Italians – and indeed Europe – seem to be poised to reach a viable tiltrotor capability. If successful, the BA609 could be the realization of the long sought goal of commercial tiltrotor flight, and by default, an outstanding model for transatlantic civil V/STOL cooperation.

Designation:	Bell/Agusta BA609	
Engines:	2 x P&WC PT6C-67A turboshaft	
Passengers:	6 to 9 pax + 1-2 crew	
Engine Power:	2 x 1,940 shp	2 x 1,450 kW
Wingspan:	33.8 ft	10.3 m
Length:	46 ft	14.0 m
Height:	15 ft	4.5 m
Proprotor Diameter:	26 ft	7.9 m
Max Useful Load:	5,500 lb	2,500 kg
Max Gross Weight:	16,000 lb	6,974 kg
Range:	750 nm	1,389 km
Service ceiling:	25,000 ft	11,364 m
Vmax (at cruise):	275 kt	509 km/h

SUMMARY

In Italy, as in the rest of the world, a wide variety of concepts were considered that would combine vertical flight with high-speed flight. Numerous concepts were studied and extensive research was conducted on test rigs and components.

Initial work on the V/STOL G.222 resulted in the CTOL G.222 reaching operational service. Furthermore, over twenty years of research into tiltrotors at Agusta positioned them to be valuable contributors to the BA609 and ERICA projects.

Today, the Bell Boeing V-22 Osprey and the BAE/Boeing Harrier are the only V/STOL aircraft that have ever reached production, and operational service of the Osprey and its commercial derivatives remains in doubt. As European tiltrotors or other V/STOL designs continue to be considered for civilian use in Europe, the work discussed here demonstrates the historical basis for that effort. In addition, the designs covered here provided valuable lessons learned to these development programs and may still suggest innovative approaches that may now be more technically and economically viable, after a half century of technology development.

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