PERSPECTIVES OF FUTURE DEVELOPMENTS OF VERTICAL FLIGHT
The Point Of View Of Industry

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Abstract

In the airspace future, the vertical flight will have a greater importance than today, both in the civil and military applications and, as recently dramatically appeared, in the increasing demand of security.

In spite of 50 years of experience and technological development, the conventional vehicle for the vertical flight, the helicopter, is affected by constraints and operational limitations, which have confined its utilisation to the applications where it is irreplaceable. However its productivity is always lower than the fixed wing and this have hampered its diffusion as a general air transport mean.

The technologies today available allow to widen the spectrum of utilisation in a significant way by pursuing two architectural solutions:

- *the evolution of the conventional rotorcraft*
- *the revolution of the tiltrotor*

to meet primarily either the vertical flight and hovering or the cruise flight with enhanced speed and range.

The goals the rotorcraft industry is aiming to, can be summarised as follows:

- *Improvement of flight performances and ability to operate in all weather conditions*
- *Reduction of the operating costs and enhancement of the availability*
- *Environmental and public acceptance*
- *Awareness by the institutional bodies of the need of adequate operating procedures and the related infrastructures.*

The advanced technologies are playing a fundamental role in the achievement of the above mentioned goals, such as the aerodynamics, dynamics, structures, avionics and simulation.

Yet the industry is called to transfer technologies assets into products which must satisfy the ever demanding market while must abide industrial and financial constraints i.e. integrating the technology into the business strategy thus creating value from the technology and innovation.

It comes from the above the need of an optimisation of all the concerned parameters (the competitive performance diamond) and, in the most challenging projects, the participation to a collaboration with other industries (collaboration network diamond).

Last year, in this Forum, Prof. Price, at the conclusion of his speech, presented a table titled "Suggested long range VTOL Technology Goals" in which the 2022 targets were outlined.

AGUSTA, in covering both configurations of the vertical flight (helicopter and tiltrotor), has respectively developed a new medium twin engine helicopter, the AB139, already in the delivery phase, and is developing together with Bell the BA609 tiltrotor.

The breakthroughs in the performances and the operating costs of the AB139 in comparison with the current helicopters, are such to project this product already towards the 2022 targets stated by Prof. Price.

The BA609 is well progressing on schedule towards the certification targets demonstrating the predicted performances in the flight test activities.

AGUSTA has already entered the future envisioned by Prof. Price.

1. The Roles of the Vertical Flight

Since its first operational uses in the fifties, the helicopter has earned a growing reputation of invaluable workhorse for civil and military applications. Its unique ability to take off and land vertically and to hover indefinitely over a fixed point is the key of peculiar operations, such as offshore, search and rescue, just to name two, which would be impossible or extremely difficult to perform with other means.

At present, it is reasonable to think that this ability will still be not only indispensable but also growing in the future for uses such as:

- Flexible and customised transport of people and material
- Point to point in flight connection (corporate, VIP transport…)
- Offshore role for the oil operation
- Integration with/substitution of commuters for short range transport in order to increase airport capacity
- Rescue at sea or in impervious areas (mountains, forests) and disaster relief (earthquakes, fires, floods)
- Military air mobility, both for battlefield support and in peace keeping or in peace enforcing tasks
- Helicopter use in all cases related with the new arising tasks of the security front (border control, sea patrolling).

2. Limitations of the helicopter

Notwithstanding its unquestionable operational utility, the inherent physical limitations and mechanical complexity of the helicopter, worsened by the peculiar operational flight envelope (mostly low altitude) have indeed limited its widespread diffusion.

The main reasons can be summarised in the following points:

- Low productivity mainly due to low speed and high operating costs
- Limited ability to operate in IFR conditions outside ATC regulated air traffic (airways)
- Environmental impact (noise and pollution), amplified by the growing ecological concerns within the general public
- Perception of lower safety with respect to fixed wing aircraft due to:
  - Vibration
  - Noise
  - Comfort
- Inadequacy of procedures and rules for simultaneous, non interfering take off and landing operations of helicopters in the airport terminal area.

3. The two solutions

Industries and research centers spent large efforts in order to overcome the barriers illustrated before and two different avenues have been identified (Fig. 1). The first one is to push the advanced technologies to improve the conventional helicopter. The modern technologies in terms of aerodynamics, dynamics, avionics, simulation and structures, can improve the actual status of the helicopter configuration increasing its performance, productivity and environmental impact. But not all the limitations can be overcome, because some of them are inherent in the helicopter configuration (low speed and consequently low productivity as compared with the turboprop). For this reason the most viable solution among the many attempts, resulted to be the TILTROTOR.

Conceived in the US, the tiltrotor is now mature enough to open a new perspective in the aviation. After a development phase lasted 50 years, this innovative aircraft is ready to give a new drive to the aeronautical growth, opening new opportunities and creating space for new roles allowed only by the potentialities of its formula.

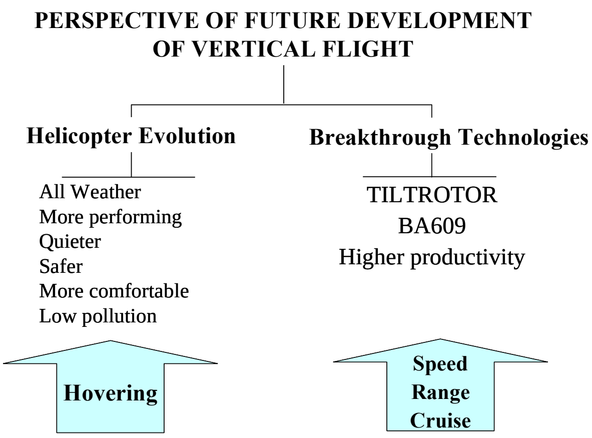

Fig. 1: the two guiding solutions

4. Industry Goals

The implementation of the two solutions should be guided by the identification of the features that enhance the roles outlined above.

These could be summarised as follows:

- Costs: a lower cost per seat mile to be achieved by a reduction in the acquisition and life cycle cost and improved availability
- Performance: tomorrow's VTOL aircraft need improvements in payload, range and endurance. The ability to operate in all kinds of weather should be one of the most important achievement in the next future
- Community acceptance: public acceptance of helicopters can undoubtedly be improved by reducing the level of noise and vibration and increasing comfort
- Infrastructures and air traffic procedures: Industry shall urge an higher awareness by the Regulatory Bodies to introduce sky pathways that can accommodate tomorrow's VTOL airtraffic. The purpose should be to eliminate congestion in the airport and bring efficiency to arrival and departure operations. In order to reach this goal the need of new air traffic procedure is evident for the VTOL aircraft in conjunction with those of the fixed wing.

5. Advanced Technology Solutions

The advanced technology solutions play an important role to achieve the above goals since the challenge of the technology community is to attack the barriers and enhance the VTOL configuration in order to give to air transport system a more efficient and performing aircraft.

Some aspects of the challenges of the new technologies are outlined here below.

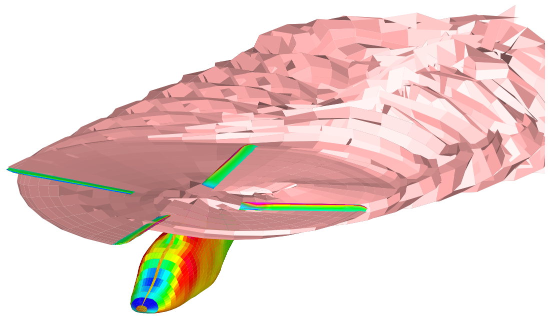

Fig. 2: aerodynamic technology

5.1 Aerodynamics

The aerodynamic design (Fig. 2) should focus the attention to increase the rotor efficiency both in hover and in forward flight, allowing in this way higher payload and productivity, and low fuel consumption with a beneficial effect in the environment. The increase in the simulation capability through full Navier-Stokes codes should permit a more significant noise reduction, the study of the blade vortex interaction (BVI), a new blade optimisation for noise and performance together with a more detailed study concerning the rotor/fuselage interaction.

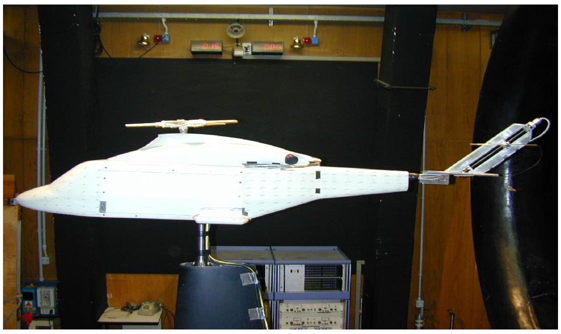

Fig. 3: wind tunnel tests

Also the evolution in the wind tunnel measurements (Fig. 3) will permit the study of complex phenomenon like active flow control, active fiber composite for the optimisation of the twist blade as function of the speed and the study of the interaction phenomena in new configurations like tiltrotors.

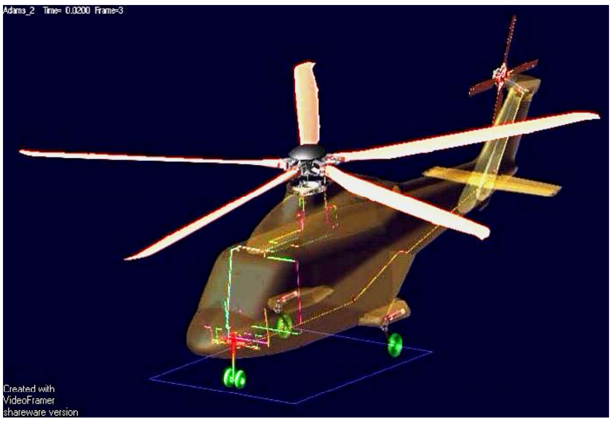

Fig. 4: Dynamic technology
(AB139 ground resonance study)

5.2 Dynamics

Concerning dynamics, current technologies are involved in the development of active rotor control for reduction of rotor/fuselage vibration and noise, in the enhancement of the experimental test methodologies for aeroelastic characterisation of rotor systems and in the development of new analytical methodologies (Fig. 4) for prediction of aeroelastic stability and loads. At moment, dynamics is focused both in the passive and active ways for vibration reduction. In the first case the use of pylon vibration isolation system or inertia characteristics distribution optimised to have vibration reduction are the more promising ones, while, in the second case, the active flap rotor using smart materials, active twist rotor and smart active blade tip are the most improved. Dynamics is developing also a vibration monitoring system screening vibrations in the rotors, engines, interconnect shaft and nacelles, while stability enhancement is at moment more related with the new configurations like tilt rotors especially with the whirl flutter phenomenon.

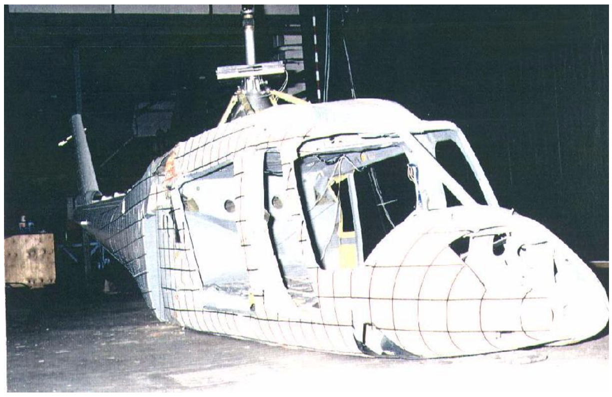

Fig. 5: structural technology

5.3 Structures

The challenge for the structures should be to pass from a traditional metallic structure to a more recent composite solution making at the same time compliance with the new stringent requirements in terms of crashworthiness (Fig. 5), bird strike and engine disk burst impact. Beside that the introduction of the damage tolerance, borrowed from the fixed wing world, for the fatigue evaluation of structures and dynamic components will allow a favorable total weight reduction of the aircraft.

5.4 Simulation

The main research activities in the simulation field are focused to the development and validation of flight mechanics codes and helicopter handling qualities evaluation and improvements. The development and use of flight simulators (Fig. 6), with pilot and hardware in the loop, should help in the definition of advanced control laws, of automatic emergency manoeuvres and loads reduction.

Fig. 6: simulation facility

5.5 Avionics

The research on man-machine interface in the cockpit (Fig. 7) is one of the most promising area for future development. It focuses on integrating advanced information display systems into the cockpit, investigating pilot-vehicle interaction. The primary goal is to extend aircraft operational capability by reducing pilot workload and increasing pilot situation awareness. This goal is more important than ever, as pilots are required today to carry out more complex mission-oriented tasks in addition to the standard tasks for piloting and navigation. Current investigations include the application of Helmet-Mounted-Display, direct Voice Input, tactile control feedback and the use of the fixed wing side stick. All these new features, included the introduction of the differential GPS and the mission computer with three-dimensional flight plans and terrain obstacle database, should contribute to an all weather helicopter that should be the target for the next years in order to improve safety and avoid any delay performing the mission required by the integrated system.

Fig. 7: avionic technology (AB139 cockpit layout)

6. From technologies to product: market needs and collaboration network

The industry is called to transfer technologies assets into products which must satisfy the ever demanding market while must abide industrial and financial constraints i.e. integrating technology into business strategy thus creating value from technology and innovation.

The concept of the merge of the technology with the market need and the network collaboration is illustrated in the following slide (Fig. 8).

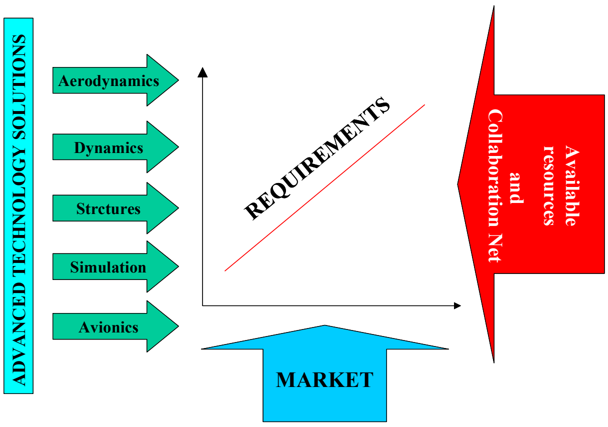

Fig. 8: Technology into business strategy

Industry should apply new technology in their products integrating technology and business strategy to create new value from innovation. This integration must be done with a trade off optimisation between resources and market demand, bringing to the competitive performance diamond (Fig. 9).

The operating cost should be the core of the process imposing the requirements in terms of higher speeds, range, cabin size, useful load, avionics, comfort and hot and high performance in order to answer to the civil and military market in the various application to be met by the various class of helicopters.

Fig. 9: the competitive performance diamond

As an example, the Fig. 9 features the optimized performance diamond for a light twin helicopter such as the Agusta A109 which is the best seller in its class.

In view of the complexity and the effort required by new state of the art products, the performance trade-off shall be associated to an optimized industrial and financial resources application.

In order to face this challenge, a collaboration networks must be sought, were different involved parameters must be duly exploited. The core target of any significant collaborative program should aim to preserve to industry a leading or at least a primary role.

Fig. 10: the collaboration networks

Examples of these collaborations (Fig. 10) are the AB139 and BA609 with Bell Textron Company, the NH90 European team, the EH101 partnership with Westland and the present alliance with Lockheed Martin and Bell Helicopter for the US101. This last joint effort aims to deliver a dependable, reliable, combat ready medium lift helicopter that will incorporate additional U.S. technologies, mission systems, manufacturing and integration expertise, while maintaining the core of AgustaWestland's mature design to provide the U.S. military with a reliable, advanced technology, off-the-shelf aircraft.

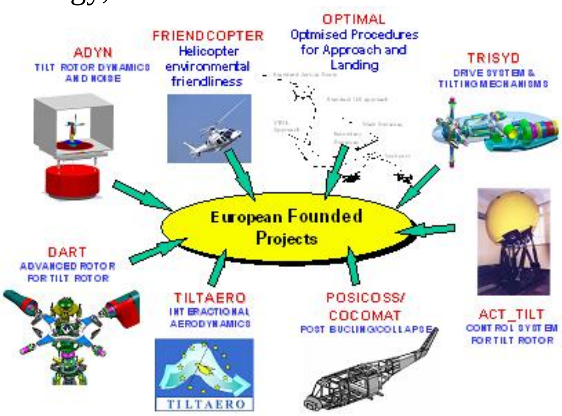

Fig. 11: Agusta R&D collaborations in Europe

Continuing with the collaborations, the AGUSTA effort is also evident in the research projects (Fig. 11). AGUSTA is involved in different European collaborations endorsed by the European Community: from the study of new tools for the analysis of composite structures (POSICOSS and COCOMAT), to the FRIENDCOPTER project having the goal of the enhanced environmental friendliness and public acceptance of the helicopter through a drastic reduction of external noise emission, by reducing gas exhaust and by a strong decrease of cabin noise and vibration levels. Optimised Procedures for Approach and Landing are studied in OPTIMAL with the purpose of defining and validating innovative procedures for the approach and landing phases of aircraft and rotorcraft. The goal is to minimise external aircraft / rotorcraft noise nuisance and increase the ATM capacity while maintaining and even improving operability.

Fig. 12: the ERICA concept

But the most important projects in which AGUSTA is involved are those concerning Tiltrotor technology around the European Tiltrotor Configuration: ERICA (Fig. 12), an AGUSTA patent. These projects deal with areas like aerodynamics, dynamics, acoustics, drive systems and rotors, trying to cover all the challenging aspects of this new promising aircraft.

7. The Agusta state of the art: the future has begun

During the AIAA/ICAS International Air and Space Symposium and Exposition 2003 in Dayton, Prof. George Price [1] presented a table with the “Long Range VTOL Technology Goals” in which the current level and the 2022 target was shown (Fig. 13). AGUSTA is progressing towards these targets. Therefore let me say that “at AGUSTA the future has begun”.

With the last two aircraft born from the AGUSTA collaboration with Bell Textron, the AB139 and BA609, AGUSTA is running the two avenues of the future of the vertical flight: a new medium twin engine helicopter which features a significant performance improvement over the current helicopters, the AB139, and the first medium tiltrotor, the BA609. We have overcome the “current level” in many aspects: from hover and cruise efficiency to the cruise speed and the all weather capability, but, most important, these two machines are the result of the integration of the modern technologies, highlighted above, with the market needs.

SUGGESTED LONG RANGE VTOL TECHNOLOGY GOALS			
ATTRIBUTE	CURRENT LEVEL	AGUSTA Today	2022 TARGET
Vehicle Efficiency	Hover = 0.78	**0.8**	0.87
	L/D*Prop. Eff. = 7 at Vcruise	**10**	13 at Vcruise
	EW fraction = .55 (helo) - .62 (T/R)	**0.55**	30 % reduction
Cruise speed	Helicopter = 170 Kts	**180 Kts**	200 Kts
	Tiltrotor = 250 Kts	**275 Kts**	350-400 Kts
External Noise	FAA requirements	**-3 dB below req.**	60% reduction
Vibration	.04 g	**.04 g**	< .04 g maximum
Intelligent automation & Cockpit Integration	Pilot aiding	**Pilot fully involved in the machine**	Operator "directs" vehicle
All-Weather Capability	IFR capable	**IFR Single pilot**	Fully autonomous zero-zero
	Limited Icing capability	**FULL ICING (EH101)**	No restrictions due to icing

Fig. 13: the technology goals

In order to provide evidence of this statement, a brief description of the two aircraft is presented.

7.1 AB139

The AB139 (Fig. 14) is the new medium twin–engine helicopter designed to meet the stringent standards imposed by the new civil and military requirements. An optimised collaboration network has been achieved through an international collaborative program launched by Agusta to which Bell Helicopter associated with a risk-sharing participation of, among others, Pratt & Whitney, Honeywell, GKN Westland Aerospace.

Fig. 14: the new medium twin–engine helicopter AB139

Built with the state-of-the-art component based on proven technologies, the AB139 is a 12/15 seats multipurpose helicopter, designed around a spacious cabin and baggage compartment for maximum flexibility and passenger comfort.

The primary structure is made of aluminum alloy and nomex/aluminum panels, and, for weight savings, fiber composite material are used for the secondary structure.

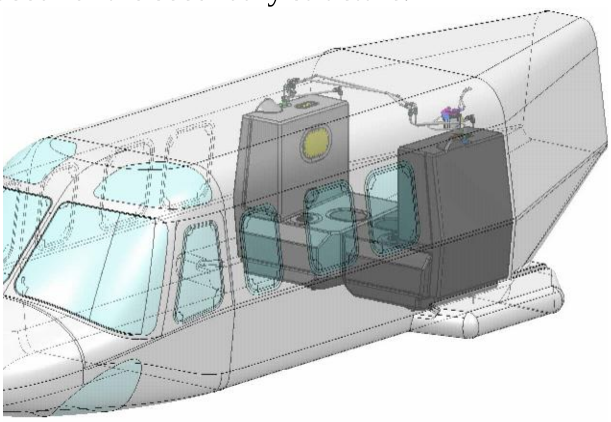

Fig. 15: AB139 fuel tank position

The fuel tanks, instead of being positioned on the bottom of the aircraft underneath the passengers, are wrapped around the baggage compartment behind the main cabin (Fig. 15). This configuration features a number of outstanding advantages such as:

- Better lift/drag ratio due to the smaller cross section
- Better crashworthiness characteristic due to the empty sub floor
- Simple, light weight and crashworthy fuel tank solution
- Passenger cabin floor low over the ground for easy loading and unloading

The high comfort achieved is also associated with the low acoustic and vibration level due to mass lay out and to the aerodynamic design of the blades.

The tail rotor is canted. This allows a shorter tail rotor mast, since the rotor inclination already guarantees the necessary clearance between the blades and the fin, and advantages in term of weight and structural loads. Furthermore, the canted tail rotor gives a sensible benefit in performance both in hover and forward flight.

Concerning the avionics system , the AB139 basic configuration has the Primus Epic^{TM} Avionics System developed by Honeywell, a fully integrated “glass cockpit” based on LCD display technology and on modular avionics concept (Fig. 16).

Fig. 16: AB139 MFD Layout (Digital Map)

The Electronic Display System (EDS) carries out the dual function of presenting flight and navigation data, engines and system parameters and the related caution, warning and advisory annunciation. Pilots can choose traditional controllers or new on-screen cursor control devices, developed to interface with the Windows-style operating system. It will offer a voice command system to control certain functions, and compact, portable Pilot's Personal Assistant for flight planning and information retrieval en route, at home or in the office.

In the following pictures (Fig. 17-Fig. 18) two performance, hoge comparison and productivity index PI = f(speed, range, payload), are illustrated to proof the high possibility of this new helicopter able to merge the high technology aspects with the market requirements.

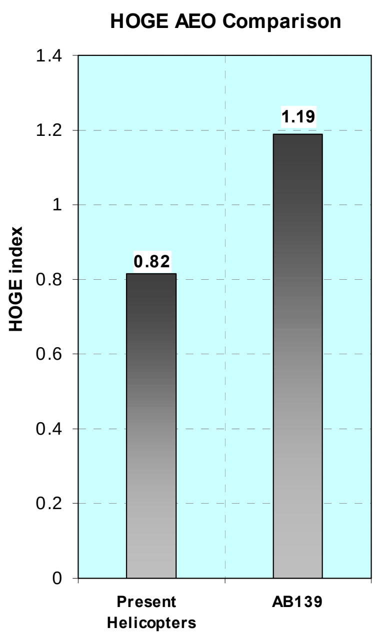

Fig. 17: AB139 hover performance

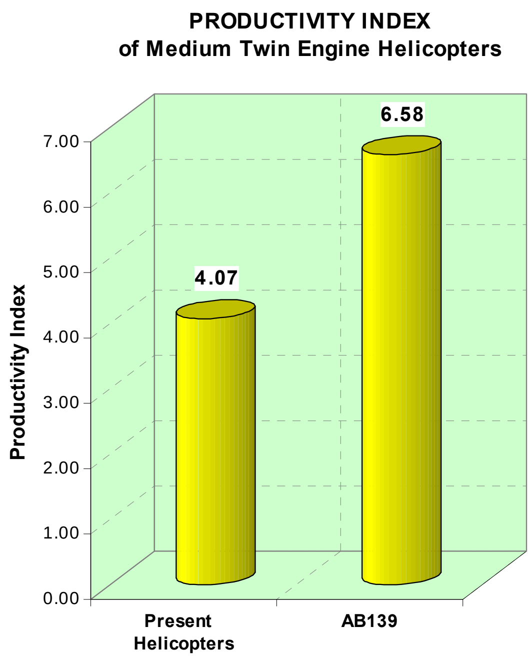

Fig. 18: AB139 productivity index

The Primus EpicTM system provides, also, an integrated maintenance system, consisting in a Central Maintenance Computer (CMC). Specifically it monitors and record aircraft System Failures (engines, transmission, hydraulic, electrics, airframe, etc.) engine exceedances time engine low cycle fatigue (LCF) and avionics failures. The system can be integrated and completed with the installation of an HUMS system further enhancing the system capability.

Concerning the maintainability the values achieved in the AB139 are significantly better than in the previous helicopters as shown in the following picture (Fig. 19) that considers the impact of both scheduled and unscheduled maintenance with the consequent benefit of a reduction in the operative costs.

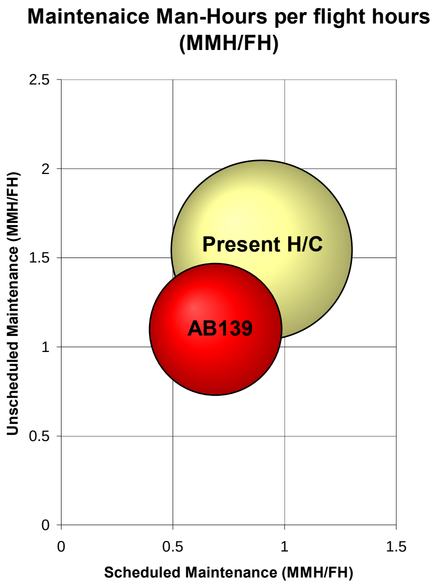

Fig. 19: AB139 Maintenance chart

7.2 BA609

The BA609 (Fig. 20) is the first medium tiltrotor.

Fig. 20: the tiltrotor BA609

It is a highly flexible, nine passenger aircraft designed for natural resource exploration, emergency medical evacuation, search and rescue, executive transportation, governmental support roles and disaster relief (Fig. 21).

Fig. 21: BA609 missions

The Bell-Agusta BA609 provides greatly improved operational performance capabilities when compared with conventional rotorcraft (Fig. 22): twice the speed and range, with improved passenger comfort and cost effectiveness. Designed from the outset for low maintenance and maximum operational flexibility, the medium tiltrotor offers operators highly cost-effective, point-to-point transportation at cruise speeds up to 275 Kts and ranges up to 750 nautical miles.

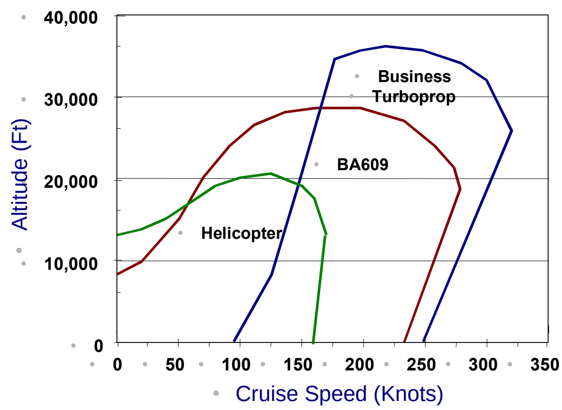

Fig. 22: BA609 flight envelope

It makes use of all the developments in aerospace technologies, from large use of composites materials to last generation glass cockpit. Moreover, for some technological aspects, the BA609 is a unique example. The nacelle tilting system (Fig. 23), which must satisfy severe safety requirements prescribed by civil regulations, is an example.

The actuators, which provide the nacelle motion, are mounted on spindles located in the wingtips and each consists in a double telescoping ballscrew that is driven through a planetary differential gearbox by either a primary hydraulic drive unit or a backup one. An interconnecting shaft runs through the wing leading edge and provides another drive path to the actuator. The system has five angular displacement transducer on each side of the aircraft that provide nacelle position information and allow any mechanical failure to be identified and isolated. The hydraulic power to drive the actuator can be supplied by any of the three independent hydraulic systems moreover there are three independent flight control computers controlling the actuators.

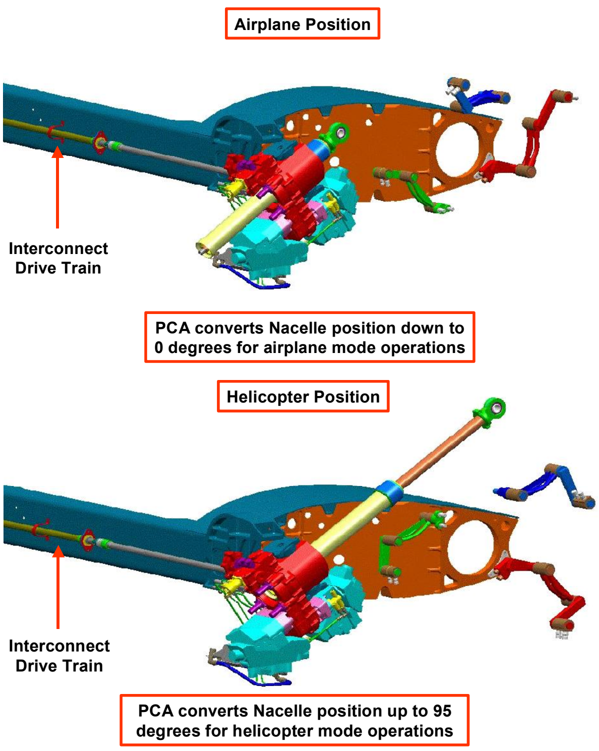

Fig. 23: BA609 nacelle tilting system

The rotor (Fig. 24) is an other example of the advanced technology introduced in this aircraft. The three blades system has a 26 ft diameter and a twist chosen to provide the best balance between hover and cruise flight, to reduce the fuel consumption and also to provide a quiet airplane flight. The blade spar is made of fiberglass with carbon fiber torsion wraps, while the afterbody is made of Nomex core with fiberglass skins. A constant velocity joint in the hub cancels the 2/rev loads that are created when the rotor flaps. The centrifugal force bearings, the drive links, and the hub flapping springs are all elestomeric components. A slipring assembly is mounted on the top of the rotor mast to permit the transfer of electrical power and icing control signals to the rotating blade system.

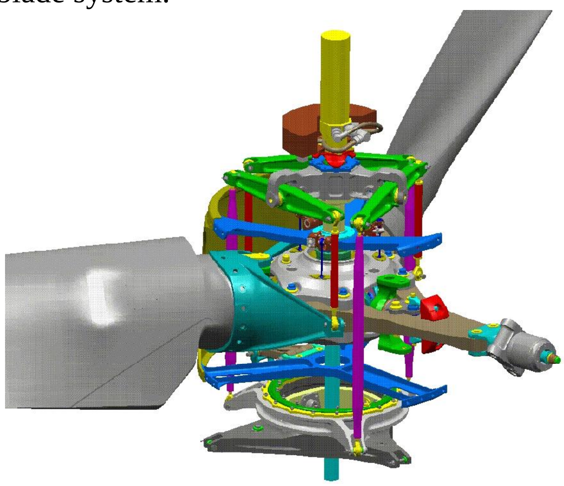

Fig. 24: BA609 rotor system

Concerning the drive system (Fig. 25), its innovation is the interconnect shafting system able to drive both proprotors in the case of a single engine failure. The interconnect shaft allows the aircraft to lose an engine with no asymmetry in flight or controls. In the event of a shaft failure, the control system is capable of synchronisation and maintains symmetric power and control application.

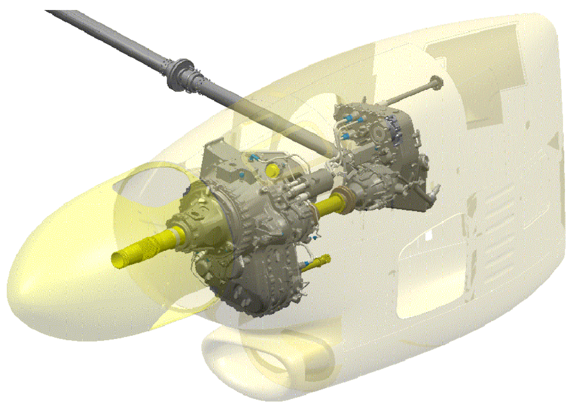

Fig. 25: BA609 drive system

However what makes possible many of the distinctive features of the BA609 is the digital fly-by-wire highly reliable flight control system, which has the function, to minimise the pilot workload and satisfy a stringent set of handling qualities requirements and objectives. The cockpit controls are almost identical to those of a conventional helicopter and the transfer of controls from the helicopter way of doing to the airplane typical control is totally seamless to the pilot and does not require any special action on the pilot's part.

Fig. 26: BA609 Simulation Facility with hardware and pilots in the loop

The heart of the 609's flight control system resides in triplex flight control computer which has three processors to enable each system to be self-checking without the possibility of contamination of another system. Each control input made by the pilot is converted to a digital signal by redundant sensors and transmitted through independent wiring. The computer executes the proper input to the actuators from the flight control law software and send signals to each actuator to implement the pilot's desired command. The control law were fully tested through Pilot-in-the-loop flight simulation techniques. They have been extensively used flying thousands of virtual maneuvers on 3 dedicated simulators in order to optimize the handling qualities of the aircraft and to safely test all possible failures and emergency procedures, simplifying the transition of pilots from either airplanes or helicopter to this new type of aircraft.

The secret of the success of this system is in its capacity for failure management through the redundancy management software that minimizes the risk to the airplane if failure occur ensuring in this way continued operation even in the event of multiple failures.

In March 2003 the aircraft made its maiden flight and a set of flight tests in helicopter mode gave the first confirmations to the project, providing important results to complete and refine the design. In the next months the aircraft will continue the test activities, performing also the transition to airplane configuration and exploring the entire flight envelope.

The challenge of the BA609, first civil tiltrotor, is under way. The key to succeed in such complex program lays in the unique experience in rotorcrafts and tiltrotors that Agusta and Bell have gained.

8. Conclusion

Based on the achievements of Agusta in the vertical flight, as outlined above, our Shareholder, Finmeccanica, has decided to strengthen the helicopter sector as one of its main core business.

In view of the unavoidable process of concentration in the world aerospace industry, Finmeccanica intends to strengthen its industrial positioning by pursing its growth strategy in the Aerospace sector in line with its stated strategic objectives. In this framework, Finmeccanica announced on the 26th May 2004 the agreement with GKN for the acquisition of the latter's 50% shareholding in AgustaWestland.

Finmeccanica will, therefore, acquire full control of a high quality asset that will ensure a further strengthening of its technological positioning. As a consequence, Agusta will benefit of greater resources to reinforce its position to stay in the forefront of the vertical flight business in the years to come in the entire spectrum of the two guiding avenues of both the conventional helicopter and the revolutionary Tilt-Rotor.

References

[1] G. Price, "Prospects for the future of Vertical Flight", *AIAA/ICAS International Air and Space Symposium and Exposition: the Next 100 Year*, 14-17 July 2003, Dayton, Ohio