New VTOL Aircraft Are Coming

Author's byline: Ken Flanigan is General Manager of Advanced Aerospace Technologies, UBO, and the inventor of both concepts. His powered aircraft flying began at 16, and glider flying at 19. His technical background ranges from aeronautical, mechanical, electro-mechanical, and electronic engineering to machine shop and telecommunications. His forte has always been creative problem solving.

In situations requiring vertical takeoff and landing, helicopters have done a great job of transporting personnel and equipment for over half a century. With constant improvement, they have pretty much kept up with requirements. However, as the world becomes smaller, metropolitan airports become busier, businesses become more competitive, militaries require new and better equipment, and with oil companies drilling further offshore, are the requirements for VTOL aircraft out stripping the inherent ability of helicopters to perform? Faster, much faster, and less expensive VTOL aircraft are just what we are talking about. Newly patented VTOL aircraft are about to make their debut into the commercial, government/military, and institutional marketplaces. These aircraft will be a quantum leap from helicopters in terms of reduced purchase price, reduced operating costs, and improved performance. One of these aircraft can be generically termed a Compound, Turbofan Powered, Tip-Jet Driven VTOL Aircraft. The other is a Twin Turbofan Powered, Tip-Jet Driven Tilt-Rotor Aircraft. Both aircraft use tip-jet driven rotor systems, which totally eliminate heavy, expensive transmissions and drive trains. Because of this, a cost savings of about 25 percent along with a large increase in performance can be realized. But there is much more. If 300 mph plus sounds interesting, read on.

COMPOUND HELI-JET

The Compound HELI-jet design of Fig. 1, U.S. Patent 7,275,711, is able to take off and land vertically using its rotor system and several reaction jets for stability and control.

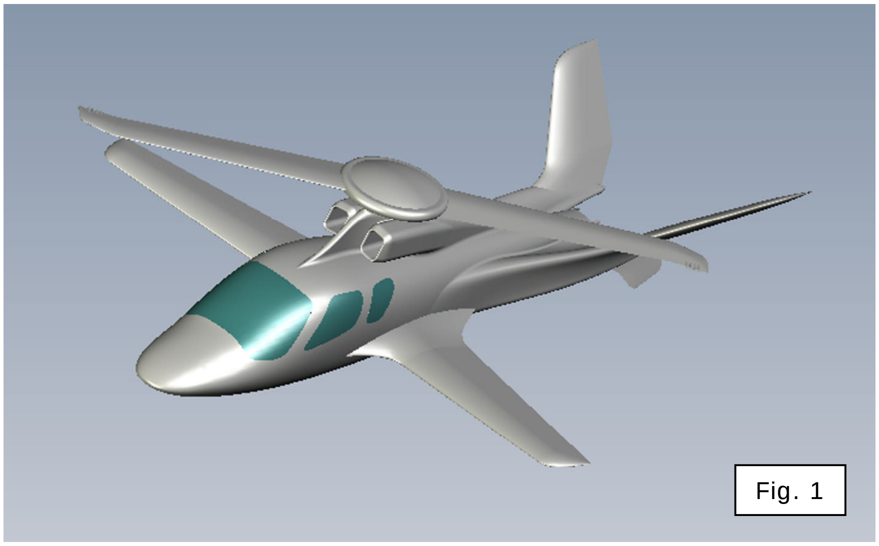

Fig. 1

Once airborne, the Compound HELI-jet will gradually and smoothly transition to forward flight at which time small wings will sustain the aircraft. These small wings are only required to sustain the aircraft above 115 mph; therefore, their reduced size (compared to typical fixed wing aircraft) significantly decreases drag and improves performance. Once flying on the wings, the rotor is no longer needed so it is slowed down to, again, reduce drag.

Slowing down the rotor can be tricky, however, because there are various dynamic free air-stream forces acting on the blades as they rotate. To counteract these forces, the Compound HELI-jet will use morphing rotor blades applying smart materials technology. Piezoelectric smart material technology exhibits the interesting ability of developing a voltage when mechanical stress is applied. Conversely, the piezoelectric smart material will also deform or change shape when a voltage is applied. Thus, this same material is both a sensor and a reactionary substance that changes shape (morph) according to a given programmed input.

ADDITIONAL REDUCTIONS IN SIZE, WEIGHT, AND COSTS

The Compound HELI-jet design no longer needs an anti-torque device such as a tail-rotor, as there is practically zero torque between the rotor and the fuselage. Also, because the main rotor is not driven from its hub, its hub and blade root sections can be much lighter and smaller. This, again, results in a significant reduction in aircraft drag, as these parts of a helicopter account for as much as 25 percent of the total aircraft drag.

A manifold with several valves controls the flow of the engine's exhaust to various parts of the aircraft depending on requirements, Fig. 2.

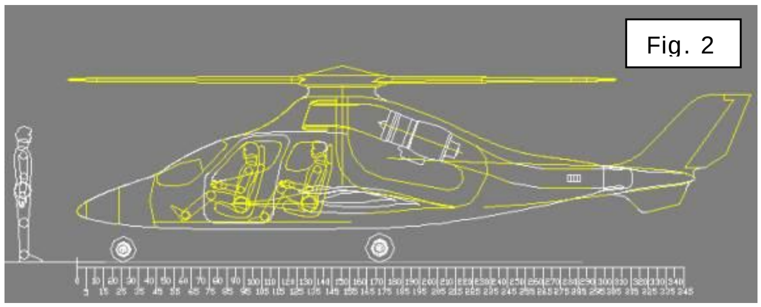
Fig. 2

For VTOL operations, the flow is diverted to the rotor system and several small reaction jets for attitude and stability control. To begin a transition into forward flight, the pilot would slowly begin diverting some of the exhaust to the main exhaust nozzle in the rear of the aircraft. Eventually, only enough exhaust would be diverted to the rotor to maintain its stability at about 150 rpm.

PRELIMINARY SPECS

A computerized Preliminary Design Review has been done on a specific

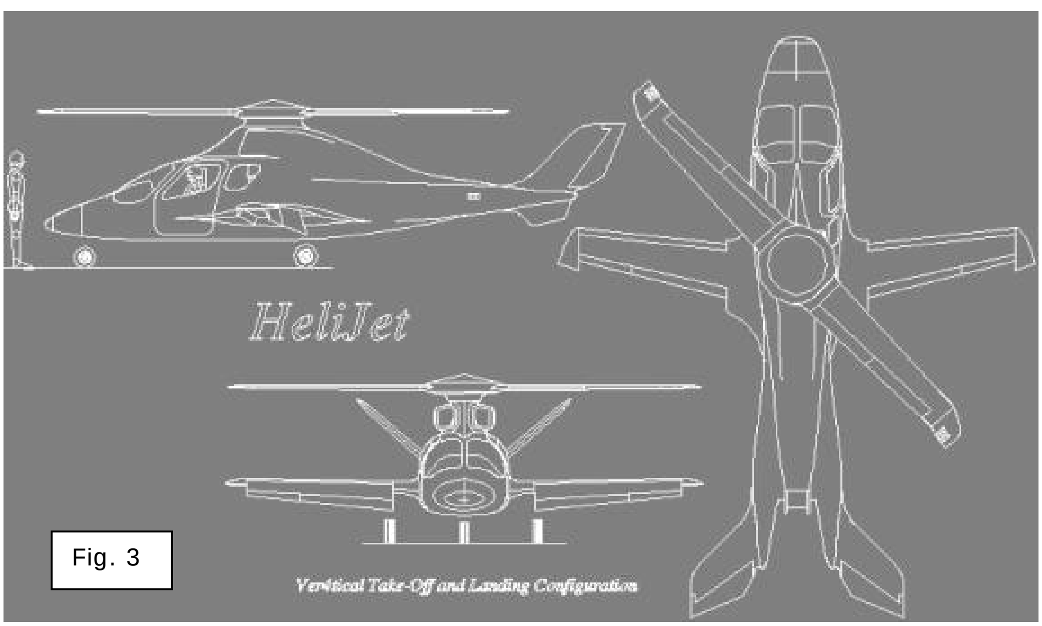

Fig. 3

design of the aircraft shown in Fig. 3.

It is a four place, single fan-jet aircraft grossing 4730 lbs with a useful load of 1945 lbs. It has a wing span of 24 ft, and a rotor diameter of 26 ft. Preliminary specifications include a 1,000 mile range, and sea level flight speed of 300 mph, while at FL250, it will cruise at 370 mph.

SOME R&D REMAINS

NASA has developed a smart materials rotor for the purpose of noise abatement, and it shouldn't be much of a stretch to adopt the design to counteract various dynamic free air-stream forces as the rotor slowly turns at high aircraft forward speeds. The ratio of forward speed of the aircraft to rotor tip speed is known as the mu ratio. Until the year 2006, no one had been able to reach a mu of 1. The Cartercopter, an autogyro type of compound aircraft, was successful at achieving mu-1 for the first time ever. In terms of significance, it was a lot like going through the sound barrier for the first time.

TIP-JET TILT-ROTOR

The Tip-jet Tilt-Rotor shown in VTOL flight mode in Fig. 4, U.S. Patent 7,147,182, will be very interesting to larger corporations with satellite offices within 1,000 miles.Busy executives can lift off from a home-office designated heliport and be at their destination within a couple of hours rather than taking a day to fly commercial. The crème de la crème would be to have a heliport at the satellite office as well. This twin, as configured here, can carry eight people, however, the propulsion concept of this patent can scale to quite large aircraft. It will need some extra space due to its two rotors being out on the wing tips. The one shown here has 19 foot rotors on a wing span of approximately 30 ft. This creates an overall of approximately 49 ft. The aircraft of Fig. 5 is shown in forward flight mode. This 8 place, 7,650 lb aircraft has been calculated to cruise at 385 mph at sea level.

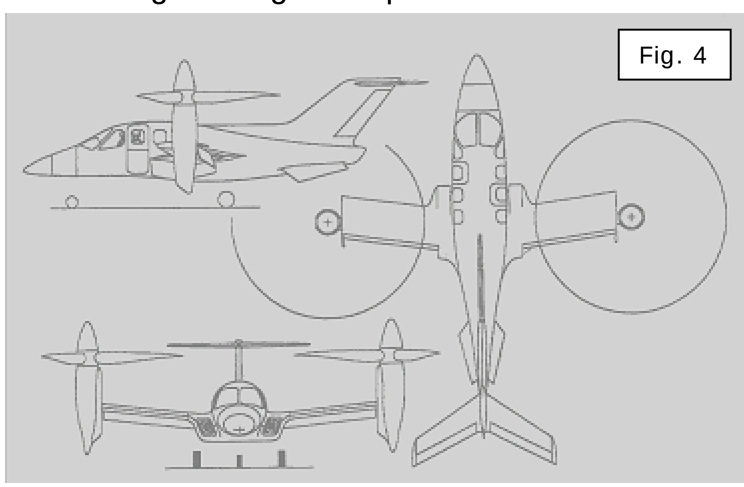
Fig. 4

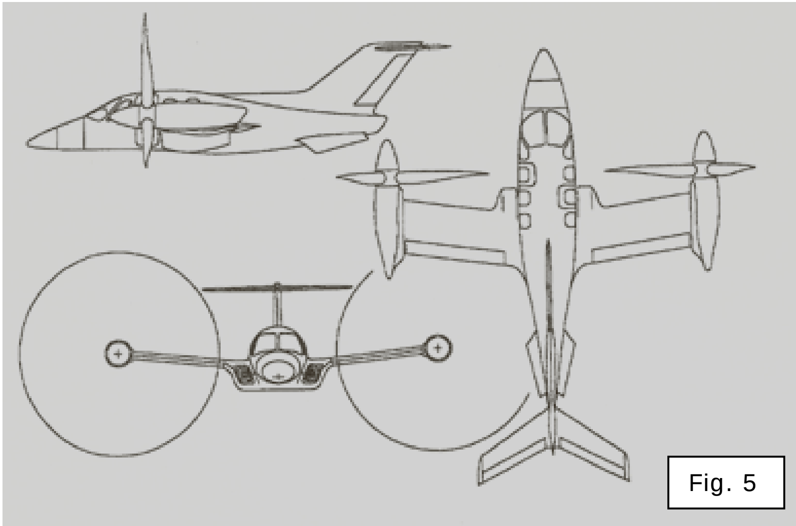

Fig. 5

CURRENT TILT-ROTOR TECHNOLOGY

The two rotors of any tilt-rotor must be coupled by some means in the event of an engine malfunction. All current tilt-rotors have the engines behind/under the prop-rotors at the wing tips. They are typically mechanically coupled through a complicated network of transmissions, clutches, gear-boxes, drive-shafts, and back-up systems. These systems alone could account for over 25% of the empty weight of the current design and an even greater percentage cost of manufacturing and service. In conventional tilt-rotors, this substantial weight is only overcome through the use of larger capacity turbines and rotors resulting in additional increases in weight, and, again, increased component costs and higher fuel consumption. The result is a loss of efficiency, decreased speed, payload, and range. It limits the mission, and inflates the cost of procurement and operation.

The current conventional design is further plagued by the position of the power-plants. The design suffers from complicated CG (center of gravity) restrictions stemming from the position of significant weight at the farthest stations from the CG. This not only frustrates the performance and causes a stability hazard throughout the flight envelop, especially role, but again, adds significant weight because of materials needed to strengthen the wings and the extensive utilization of electronic stabilization systems mandatory for all flight regimes.

PATENTED NEW TECHNOLOGY OVERCOMES ALL LIMITATIONS

Tip-jet technology for the tilt-rotor is extremely important. Tip-jet driven prop-rotors do not require the aforementioned heavy transmissions, gearboxes, driveshafts and a tremendous number of required support, stabilization and ancillary components. Thus, all mechanical linkage between turbines is removed along with its corresponding mass and costly TBO's. The compressed exhaust gas from the fan-jet engines is ducted to a manifold, Fig. 6, having valves that control power to the prop-rotors and to the jet exhaust nozzles as supplemental thrust for forward propulsion and yaw control. Thrust in forward flight is thus obtained from any combination of thrust from the tip-jet driven prop-rotors and jet exhaust directly from the engines. In level flight, computers determine the most efficient use of the jet exhaust stream, as it balances the amount of jet thrust out the rear to the amount used to drive the prop-rotors. This method also allows for adjusting for quietest operation as determined by the mission at hand. Other functions of the computers are to capture, measure and analyze environmental, mission, and flight data to constantly regulate the production and flow of exhaust gases for VTOL operations, and to achieve the most efficient and/or quietest operation.

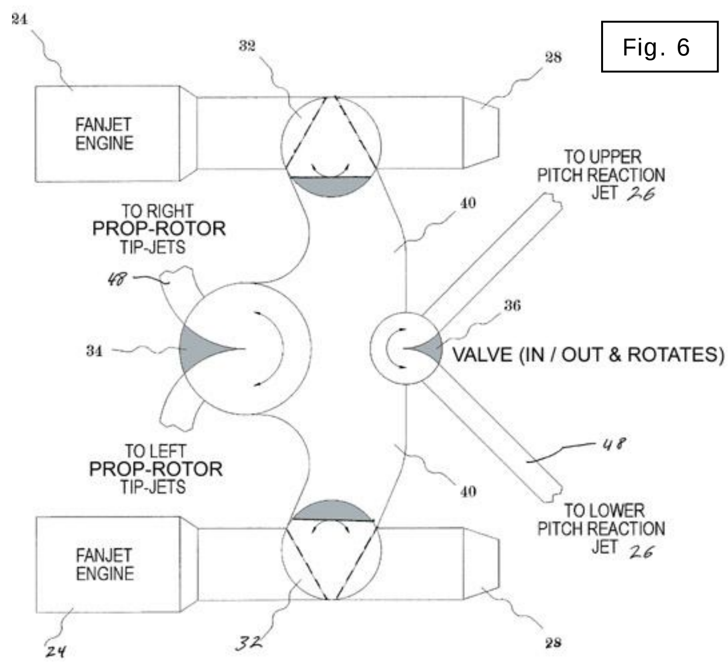

Fig. 6

MULTIPLE POWER PLANT SAFETY

A very important feature is to provide multiple power-plant safety while keeping the mass near the fuselage, under the wings and close to the Center of Gravity. Engines can be placed in any convenient place, and air ducts provide the coupling to the prop-rotors. Safety is dramatically increased in the event of a critical OEI emergency because the manifold and associated valving will instantly balance the compressed exhaust gases to the prop-rotors, exhaust nozzles and/or reaction jets for additional stabilization and attitude control. This design completely eliminates dead or critical engine scenarios.

ESTIMATED 25 PERCENT IMPROVEMENT IN COSTS & PERFORMANCE

If we compare typical 6 to 9 passenger turbo-prop aircraft to today's tilt-rotors of the same class, we would find very large differences in cost, operating cost, weight, weight fraction, and performance. Yet, with tip-jet technology, it is possible for tilt-rotors to be on the same playing field as other turbo-props such as the King Air, the Cheyenne, and the Embraer Xingu in terms of all of the previously mentioned factors. This is extremely significant, and will definitely put the tilt-rotor firmly on solid ground as an aircraft that will see phenomenal growth during the next ten to twenty years.

For those interested in technical details, driving the rotor with tip-jets utilizes a little known principle called multiple-flow thrust augmentation. Basically, multiple-flow refers to more than one thermodynamic cycle, which in this case is the tip-jet cycle combined with the rotor cycle. Turbofans and turboprops are both multiple-flow thrust generators, although a pure turbojet is not. In concept, the transition from a turbo-propeller to a tip-jet driven prop or rotor is a gradual one with the mass flow ratio between the two mass flows increasing as the system essentially becomes a turbine-driven propeller/rotor with a gear ratio of 1.0.

This method provides very high thrust augmentation ratios when morphed into a tip-jet driven prop or rotor. For instance, considering the 4730 aircraft above, we can lift it with only 360 lbs of jet thrust from its 1500 lb thrust fanjet engine. This sounds surreal when it is well known that the Harrier jet will use 1 lb of thrust for every pound of weight. But with a calculated augmentation ratio of 13.2, due to the rotor being tip-jet driven, we can lift this aircraft with only 360 lbs of jet thrust.

The Tip-jet Tilt-rotor also shares the advantage of multiple-flow thrust augmentation. This can make them more efficient than their shaft driven counterparts. The calculated thrust augmentation for the tilt-rotor pictured in this article is 11.8. This means that for every pound of thrust used by the tip-jets, the prop-rotors will produce 11.8 pounds of lift or thrust. Yes, this is very significant!

With this technology, these aircraft are more efficient, faster, immensely lighter, drastically less complex and radically less expensive to purchase and maintain than their shaft-driven counterparts.

Neither of these designs is available at the present time. Both are ready for licensing by manufacturers. Significant interest by users, such as air taxi operators, the military, the offshore oil industry, etc. will have a big impact on how quickly they become a reality.