29 Mar 2007

Analysis of Vertical Takeoff and Landing (VTOL) Unmanned Aerial Vehicles (UA V) With Emphasis on Tilt Duct And Tilt Rotor Systems

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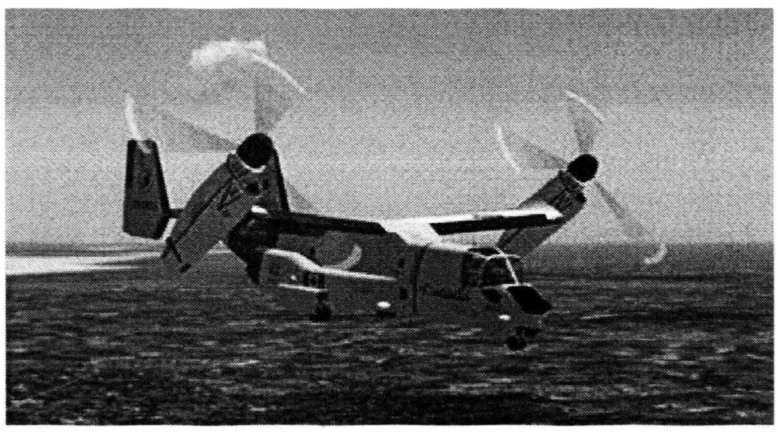

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Through months of investigation on the background of Vertical Takeoff and Landing (VTOL) Unmanned Aerial Vehicles (UAV), I have determined that for most applications pertaining to a UAV, the most effective design incorporates the use of rotor and fixed wing components. Furthermore, the UAVs that have, historically, provided the best results are the tilt-rotor or tilt-duct designs.

Beginning, logically, with the research of current UAVs and manned aircraft using these combined rotor/fixed-wing components, I found several intriguing alternatives for VTOL capabilities, including designs such as the Boeing Dragonfly (Attachment 1), a Canard Rotor/Wing UAV, that uses the engine exhaust to allow the wing to spin like a helicopter rotor during transition to vertical and hover flight phases. Another revolutionary UAV, the Freeing Scorpion (Attachment 2), relies on a variable angle of incidence to give the aircraft its flight characteristics. The resulting aircraft has maintained extremely effective flight characteristics in wind gusts. Other candidates for the VTOL realm include the XC-142 tilt-wing aircraft (Attachment 3). Unfortunately, this type of technology causes several problems with the aircraft and makes it a bit too inefficient for feasible consideration. Designs like the tail-sitter have encountered far too many difficulties in stability and control and efficiency to be logical choices for a VTOL UAV platform.

The tilt-rotor and tilt-duct aircraft, both manned and unmanned, have performed more successfully in field tests and on real time missions than any other type of VTOL aircraft for the applicable missions. The tilt-rotor and tilt-duct designs provide a platform with all the advantageous traits of rotorcraft as well as fixed-wing aircraft. The designs are significantly more stable than other aircraft in forward, vertical, and transitional flight. The tilt-rotor/duct aircraft can travel with the horizontal velocity comparable with fixed-wing aircraft and maintain similar maneuverability. In addition, the design can also transition smoothly and quickly to rotor flight and hover successfully in such flight.

The V-22 Osprey (Attachment 4), a tilt-rotor manned aircraft, has already begun its incorporation with outfits in the United States military. The aircraft has demonstrated its versatility and reliability in a variety of applications from search-and-rescue to military transport into territory unreachable by fixed-wing aircraft. Without the requirement for a landing strip, the V-22 can land in more places than fixed-wing aircraft. It can, however, still achieve forward velocities much greater than comparable helicopters. With Short Takeoff and Landing options, the V-22 can improve range and endurance, while carrying a much greater payload.

The Bell Eagle Eye (Attachment 5) has found its birth from wind tunnel models of the V-22 Osprey. The UAV has been created to meet stringent US Navy requirements for search-and-rescue and reconnaissance missions. It has been designed to replace military pilots in dangerous operations into hostile or inclement territories. The UAV has performed just as expected using the tilt-rotor design.

While many applications call for a unique solution and design of aircraft to respond, the tilt-rotor and tilt-duct aircraft have established themselves across the board in all applications for which they have been used. The design is the best way to incorporate the favorable qualities of both fixed-wing and rotorcraft.

Attachment 1

Boeing Dragonfly (Canard Rotor/Wing)

The Boeing Dragonfly, another of the revolutionary concepts resulting from current technology, is a Canard Rotor/Wing aircraft. It has a conventional turbine engine for propulsion, but the exhaust is rerouted to the rotor/wing tips for transition into the vertical flight and hover phases. The Dragonfly, like many other UAVs, will find itself being deployed in applications from reconnaissance and transport to weapons deployment. The concept employed by Boeing has been around since Howard Hughes experimented with the XH-17 and the XV-9A in the '50's. The design, like the tilt rotor and tilt duct aircraft being developed, combines the advantageous traits of the fixed wing aircraft with the maneuverability of the rotorcraft.

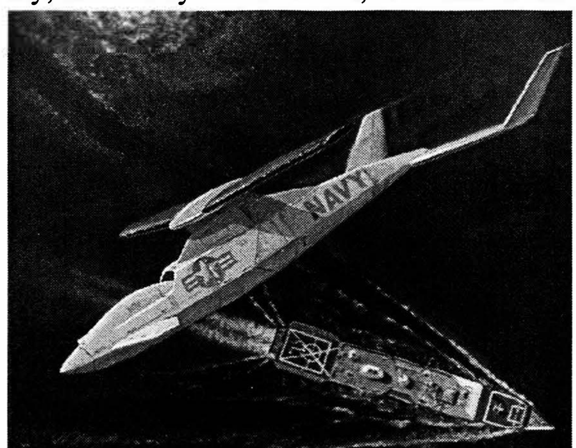

Figure 1.1 Boeing Dragonfly

Attachment 2

Freewing Scorpion/Manta

The Scorpion and Manta UAVs use a very innovative technology and idea that keeps the outer wing at a constant angle of attack while the aircraft itself operates with a different incidence angle relative to the free stream. The aircraft is less vulnerable to gusting and turbulent wind conditions. The Scorpion has a tilt body design and utilizes the concept of thrust vectoring to perform very short takeoffs. The aircraft is so stable that it's even used as a testbed for many extremely sensitive NASA instruments. The design has many very admirable flight characteristics that prove useful for the purposes of the Navy and NASA.

Figure 2.1 Freewing Scorpion

Attachment 3

LTV Hiller-Ryan XC-142 (Tilt Wing)

The XC-142 aircraft, instead of varying the pitch of the thrust components, tilted the entire lifting body, the wing. While the design was a derivative of the more successful tilt rotor and tilt duct designs, it proved to plague the aircraft with mechanical problems, vibrations, and excessive noise, causing the pilot to do a great deal of unnecessary work. With only five actually put into production, there were several problems with the aircraft and it didn't proceed beyond the testing phase. The aircraft design never truly took hold and became a bit of aviation history.

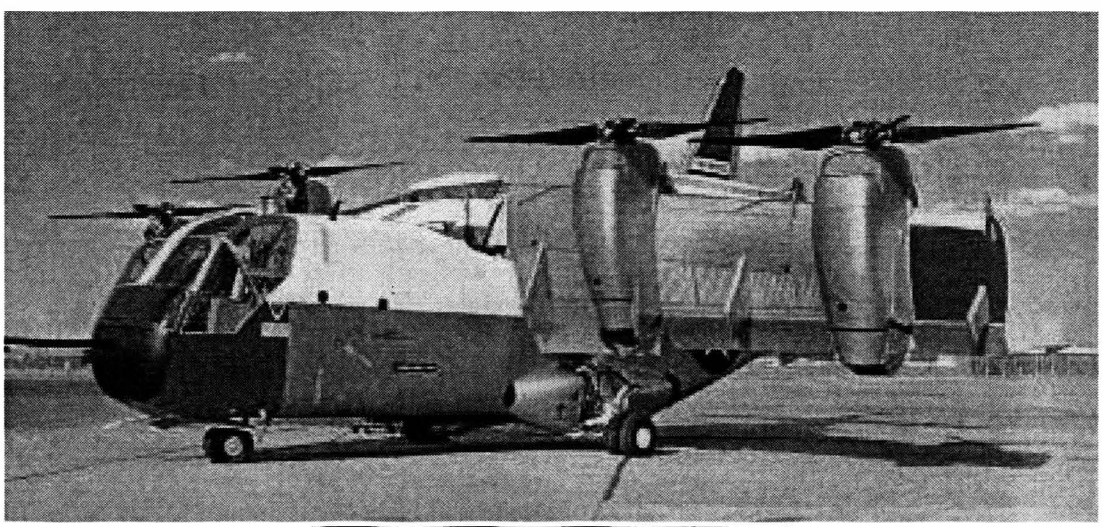

Figure 3.1 XC-142 Tilt-Wing

Attachment 4

V-22 Osprey (Tilt Rotor)

The V-22 Osprey (see Figure 4.1 page 8), though a revolutionary aircraft, has undergone quite the turbulent journey in becoming semi-operational in a military unit. The aircraft uses a technology that finds its roots in the 1950's with a tilt rotor design called the XV-3. The tilt rotor combines the more desirable features of planes and helicopters by allowing for hovering capabilities and vertical takeoff or landing (VTOL), while still maintaining the maneuverability and speed of a conventional fixed wing airplane. The criticism comes mainly from the fact that the Osprey combines an unconventional design with relatively untested technology and there remains a degree of uncertainty on the aircraft's performance under fire. The rotors have been dubbed "proprotors" because of their dual service as helicopter rotors and aircraft propellers. The biggest issue with controlling the tilt rotor aircraft comes with the transition between the helicopter and airplane mode. The aircraft's wings begin to produce effective lift at between 40 and 80 knots, at which time the plane mode takes over and when the tilt rotors are in place, the cyclic controls of helicopter mode are completely locked. With proper procedures and redundant automated systems, however, the transition proves to be a very manageable task. The tilt rotor V-22 Osprey, while not battle hardened, has thus far proven to be a very effective aircraft in combining the technologies and benefits of helicopters and airplanes alike.

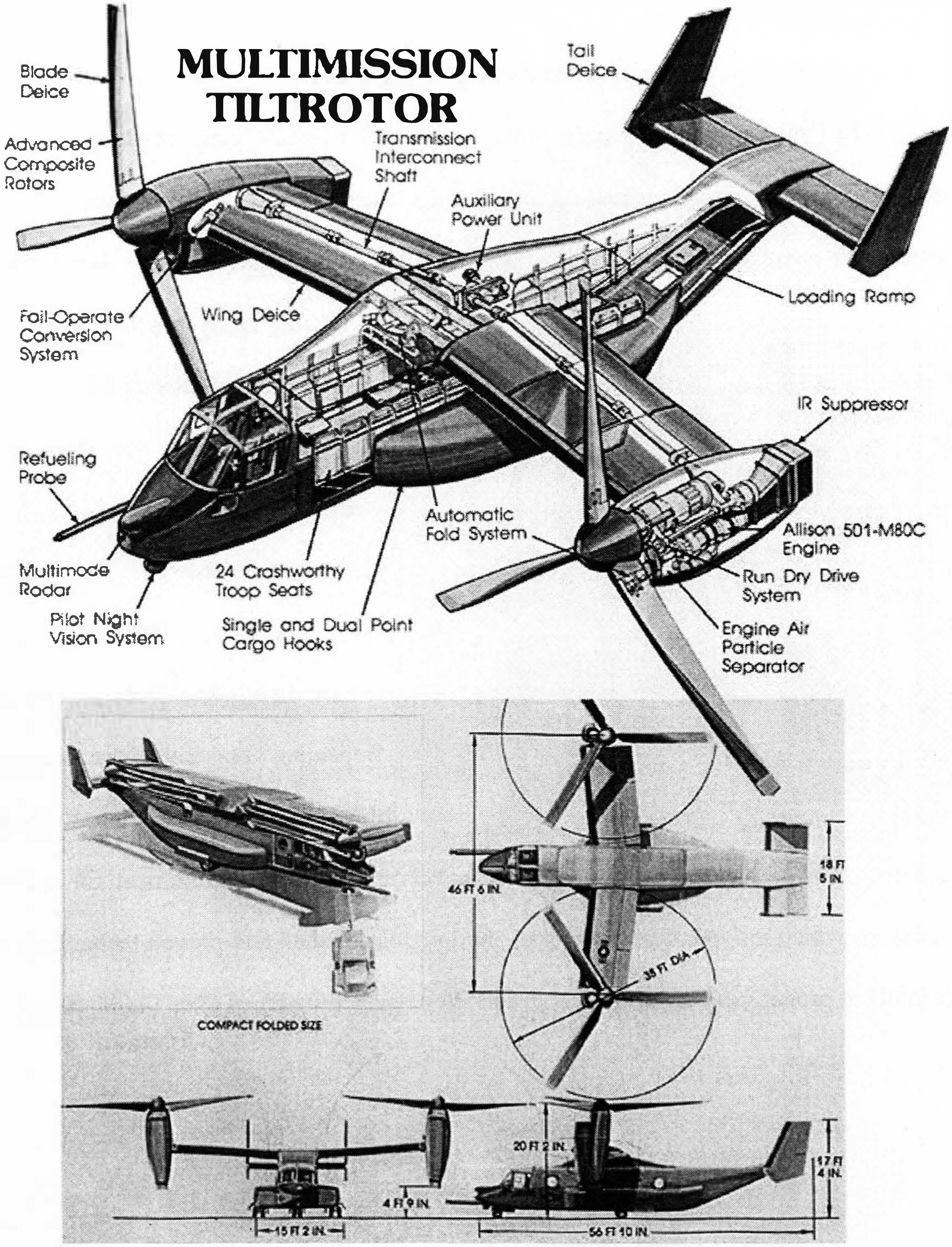

Figure 4.1 Bell V-22 Osprey Configuration

Attachment 5

Bell Eagle Eye (Tilt Rotor)

The Bell Eagle Eye actually sprang literally from wind tunnel models of a V-22 Osprey fitted with helicopter parts. It was built for use with Naval Reconnaissance and Search and Rescue requirements in mind. The aircraft is relatively on a large scale, weighing 2250 lb gross takeoff. It boasts a wingspan of almost 15.5 ft. The Eagle Eye was developed for use with the US Navy and, hence, was required to perform several sea-based tests. The Bell Eagle Eye saves lives simply by replacing the need for manned flights to gather intelligence. The aircraft has proven itself in extensive flight tests with a long hover time and no requirement for a long airstrip on which to land. The UAV uses the long established and proven technology of tilt rotors to propel itself up to 200 knots and even reach altitudes of over 14,000 ft.

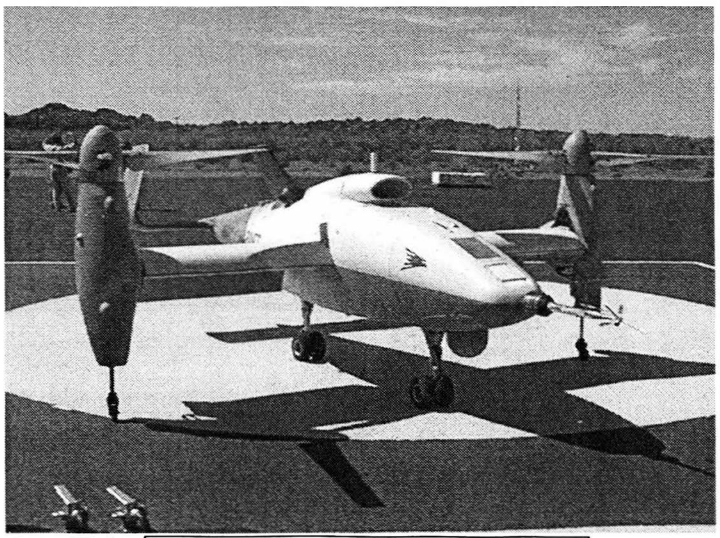

Figure 5.1 Bell Eagle Eye

Attachment 6

Bell HV-609 (Tilt Rotor)

With applications in several fields including the noble efforts of the US Coast Guard, the Bell HV-609 tilt rotor aircraft is already anticipated to find widespread use with its joint capabilities. It has outperformed most of the helicopters in its class and performs like a turboprop aircraft when in fixed wing mode. The aircraft can, in helicopter mode, hover above sinking ships or descend undetected to intercept vessels engaged in illegal activity. It can also be launched vertically from a Coast Guard Cutter. The combination of performance offered by the aircraft's dual capabilities is in itself unparalleled, but combined with the cost-effectiveness it provides it proves to be virtually unrivalled by any other aircraft with a similar mission. Larger variations of the Bell HV-609 may soon find themselves immersed in the world of commercial transportation and charter flights. In the missions for which the aircraft was designed, there is no comparable aircraft that can perform as well under the same conditions. Aircraft such as these may soon find their way into the general aviation field as well. People have a desire and a need for versatile machines to help accomplish business at hand. The innovative technology of the tilt rotor design allows people to have more alternatives to choose from when operating the aircraft.

Figure 6.1 Bell HV-609 Coast Guard Variant

Attachment 7

NASA XV-15 (Tilt Rotor)

Among the first of the innovative tilt rotor aircraft, the XV-15 was developed by NASA and used as a research testbed for future design improvements on the tilt rotor concept . The aircraft proved to be quite successful at combining the vertical takeoff and landing of a helicopter with the better fuel efficiency, speed, and maneuverability of a fixed wing aircraft. The XV-15 boasted such traits as good handling, ease of control, and required little effort by the pilot. With lift produced by both the wings and the rotors, short takeoff and landing (STOL) flight provides the option to carry larger payloads while allowing for a longer range. The aircraft has been a trailblazer for the tilt rotor design and an overall success as a proof of concept for the tilt rotor propulsion system. The aircraft has capabilities to carry more payload than a helicopter while traveling much farther than a helicopter, but still maintaining the ability to perform vertical takeoff and landing. With very short runway requirements in the STOL mode, the aircraft can access more places than any comparable aircraft while carrying a considerable payload. The applications for the features possessed by the tilt rotor design are numerous and vary from military airlift and deployment vehicles to civilian transports for short distance transport flights and commuter services. The versatility of this new aircraft design is only the beginning of a new age of flight out of which stem the unconventional designs as well as the Unmanned Aerial Vehicles (UAV) with similarly useful features.

Figure 7.1 NASA XV-15

Attachment 8

Bell X-22A (Tilt Duct)

The ducted fan allows aircraft to contain a large percentage of the power that might otherwise be lost with a conventional rotor. One such aircraft demonstrating the tilt duct design, the Bell X-22A, was developed in the mid-1960's and proved to be an effective design in producing the V/STOL capabilities that give it great versatility and capability to deploy anywhere. The aircraft set a record for hovering altitude by maintaining a hover at 8,000 ft. The X-22 was able to perform hundreds of successful transitions between helicopter and fixed wing flight. It was a cutting edge technology, harnessing the benefits of its tilt duct design to produce more than ample lift with its four ducted fans and its sufficient wing area. The plane, though incorporating a relatively new design, successfully flew several missions for over 200 hours and hundreds of transitions between flight modes before being retired.

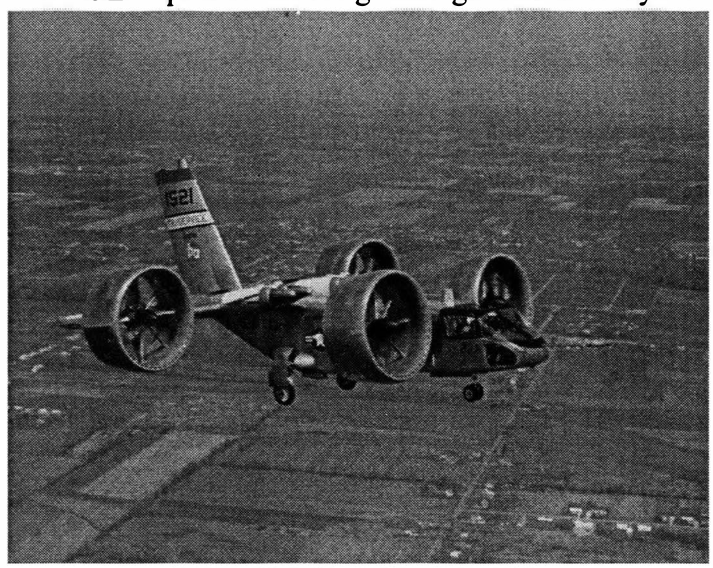

Figure 8.1 Bell X-22

Attachment 9

The Sikorsky MARINER/Cypher II

The Sikorsky Cypher II is a ducted fan design with one ducted fan oriented vertically for hover and VTOL capabilities and the other fan oriented horizontally for forward flight. The aircraft has removable fixed wings that produce sufficient lift during straight and level flight to support the aircraft itself and a payload of 45 lb up to 100 nautical miles away. The UAV is small and maneuverable and can be used for applications such as urban warfare and close quarters operations.

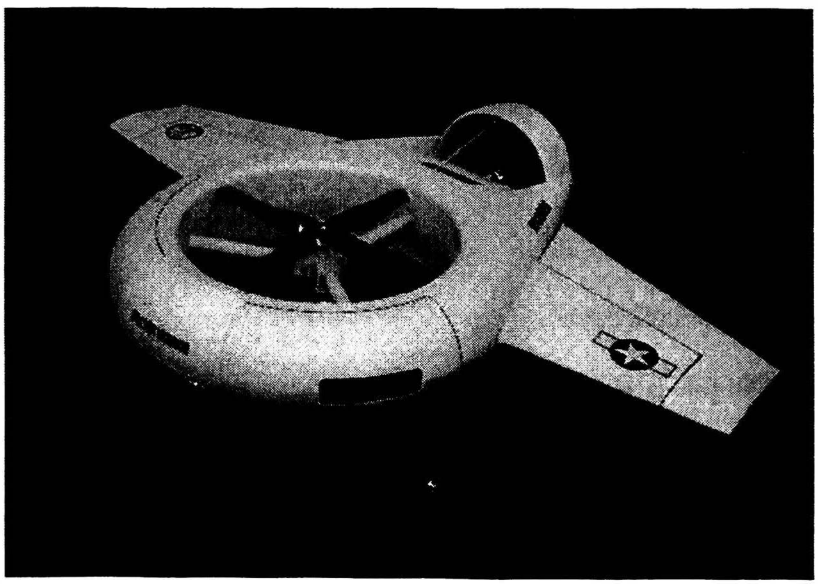

Figure 9.1 Sikorsky MARINER

Attachment 10

Piasecki PA-2C ("Ring-Wing")

The PA-2C Ring-Wing aircraft is a revolutionary design that uses the propeller slip stream to create the necessary thrust for vertical flight and forward flight. The ducted fans used for propulsion have vanes in the aft section that vector the thrust of the propellers 90 degrees toward the ground in hover and vertical flight modes and the vanes are retracted during normal forward flight to provide the necessary thrust. The aircraft's ducts also produce additional lift during forward flight. The PA-2C is capable of high speeds in forward flight and can lift a considerable payload. The concept aircraft has undergone some successful flight tests and may serve as a platform for future designs of a similar nature.

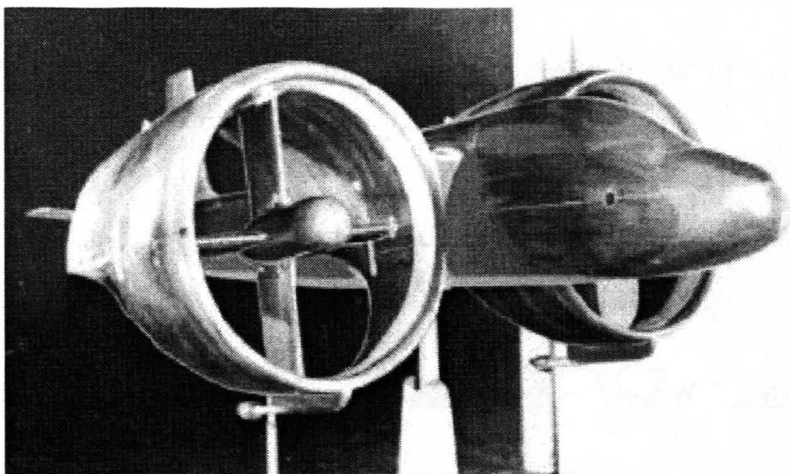

Figure 10.1 Piasecki PA-2C

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