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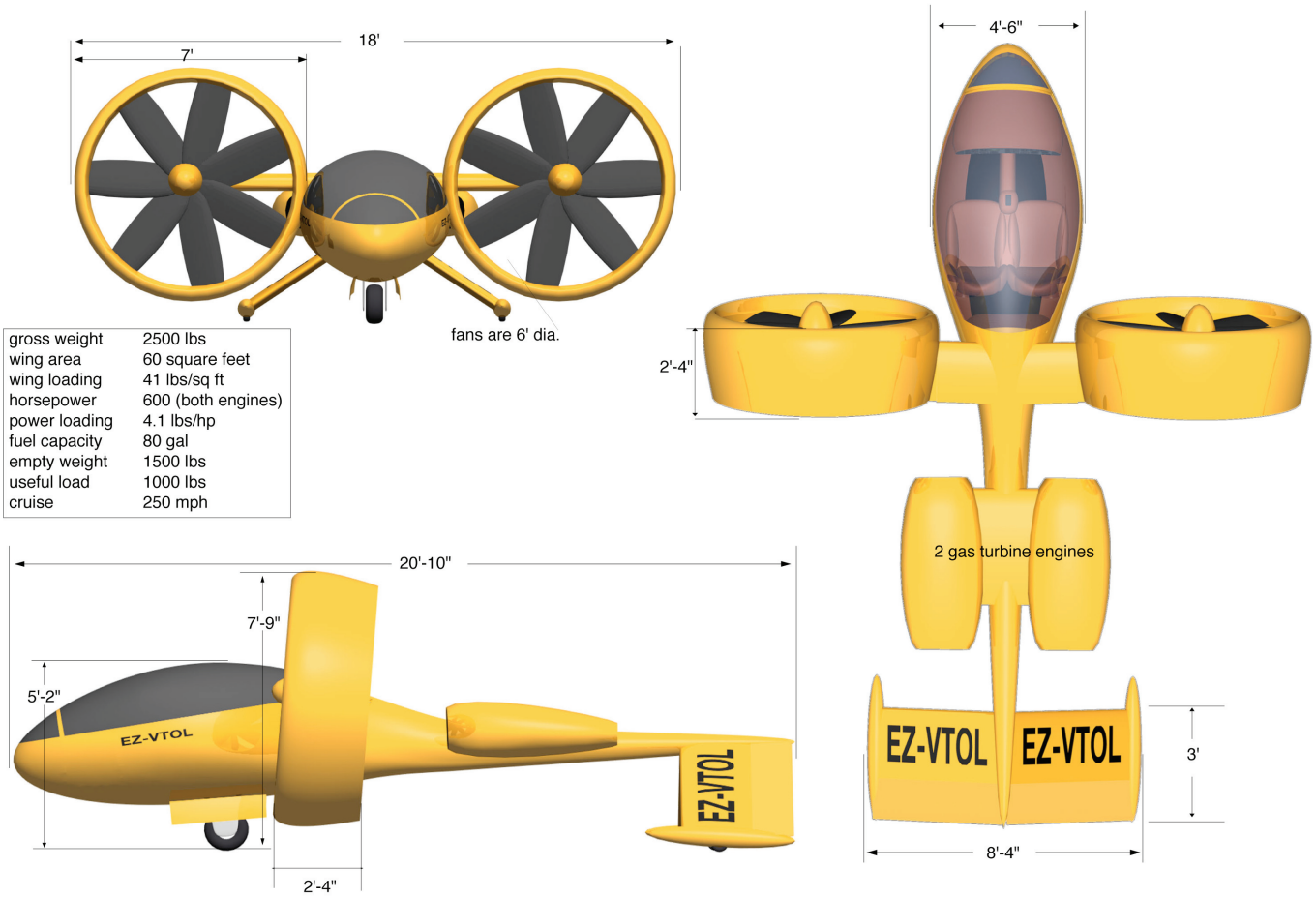
Preliminary design for a personal air vehicle (PAV) by Robert Mason

EZ-VTOL

2-passenger, vertical take-off and landing personal air vehicle designed by Robert Mason



gross weight	2500 lbs
wing area	60 square feet
wing loading	41 lbs/sq ft
horsepower	600 (both engines)
power loading	4.1 lbs/hp
fuel capacity	80 gal
empty weight	1500 lbs
useful load	1000 lbs
cruise	250 mph

Overview:The EZ-VTOL is a two-to-four passenger, fast, ring-winged airplane which will take-off and land like a helicopter by tilting its wings. The aircraft's twin shrouded propellers are designed to be annular wings in cruise flight and ducted fans in hovering flight.

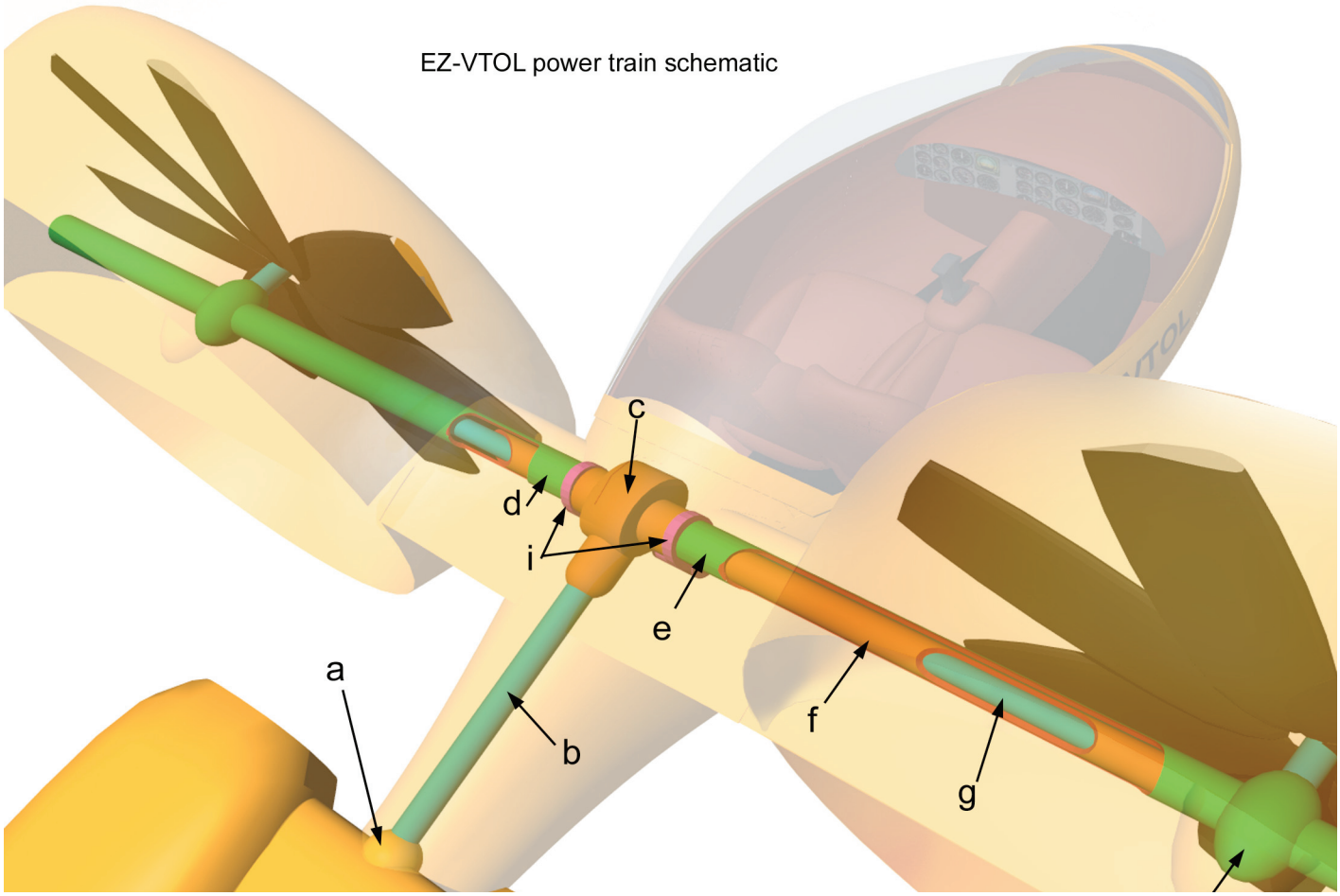
The aircraft is powered by twin gas turbine engines of 350 HP each which are coupled and cross-shafted to drive both propellers with either one or both engines operating. EZ-VTOL will be capable of extended hovering flight for take-off and landing, and high-speed cruise performance (>300 MPH) well beyond the speed range of most helicopters. It's quiet (shrouded propellers will greatly reduce rotor tip losses as well as the noise), economical (aircraft will routinely cruise at reduced power) Its all composite construction, simplified power train, and computer assisted control system, will make it relatively cheap to build. That is to say it would cost less to make than a helicopter, and about the same as an equivalent executive aircraft (which does not take off and land vertically).

EZ-VTOL will be a fly-by-wire aircraft with a computer-controlled flight stabilization system. A single 4-axis control grip provides all control input for all flight functions. EZ-VTOL will be ready for a computer-controlled high-traffic environment (direct fly system) planned for the near future. With its computer-controlled flight system and modern navigational devices, the EZ-VTOL will be a highly maneuverable, safe aircraft, which will be as simple to use as a car.

Annular Wings and Shrouded Propellers. The term shrouded propeller is used rather than ducted-fan because the differences effect top-end cruise speed. Ducted-fans can cause high drag at higher speeds because they are designed to compress the incoming air in order to add additional velocity, producing greater thrust. At higher speeds (>200 MPH) this compression process causes air to slow upon entering the duct, adding to induced drag and degrading high-speed performance. Calculations have shown that EZ-VTOL's shrouded propeller system will provide for cruise speed in excess of 325 MPH with a single engine (the other running at flight idle). The shrouded propellers, driven by 2 350HP gas turbine engines will produce up to 3500 pounds of static thrust. The thrust to weight ration (T/W) of the 2800-pound 4 passenger EZ-VTOL (max gross operating weight), will be 1.25. (For comparison, the Harrier has a T/W of 1.2).

Wind tunnel tests have demonstrated that annular airfoils can exceed the efficiency of "straight" wings because of they don't suffer the wing-tip vortex losses of standard wings (NACA TN 4117, 1957). In addition to providing most lift, all hover control, and most flying control, the shrouds offer increased propeller efficiency and eliminate drag caused by moveable control surfaces.

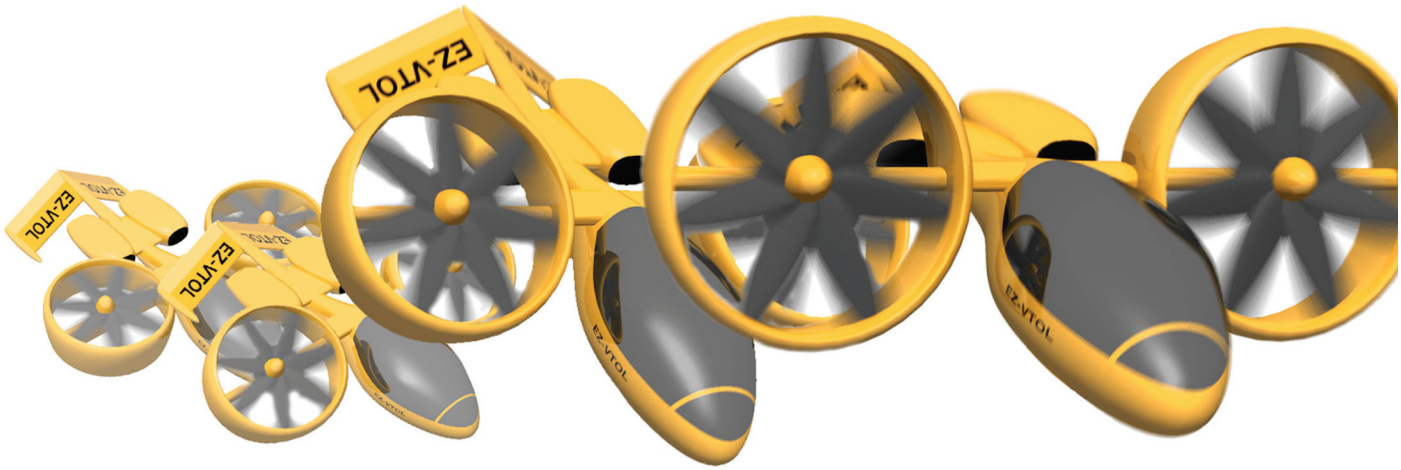
The annular wing shrouds are optimized on the EZ-VTOL for high speed cruise flight. They do not attempt to compress incoming air flow and thus do not suffer inordinate drag. As annular wings, the shrouds will allow economical cruise flight, greater cruise range, longer on-station time, and reduced propeller noise. Over all, the aircraft is clean of traditional surfaces such as a vertical stabilizer, winglets, flaps and ailerons. The EZ-VTOL will be aerodynamically cleaner than a traditional twin turbine executive aircraft.



(a) Twin turbine engines ganged to single driveshaft **(b).** Differential **(c)** splits power to left and right propellers via left and right drive shafts **(g)** which run through the main spar **(f)** to the 90-degree propeller drive gearboxes **(h)**. The ducts rotate on support sleeves **(d & e)** which are rotated on the main spar by two separate servo motors **(i).** (Support components not shown).

Hovering. The disk area in EZ-VTOL's shrouded propeller system (is larger in proportion to the aircraft gross weight than has been the case in previous designs. Lower disk loading increases the static thrust and the . EZ-VTOL's shrouded propellers have a combined propeller disk area of about 55 square feet supporting 2800 pounds of gross weight, or about 50 lbs/$ft^{2.}$ The Bell X-22a (1968) used about 150 ft^2 for the 16,000 lb aircraft, or about 106 lbs/ ft^2. The Doak 16 (1965), a twin ducted-fan VTOL used 24 ft^2 of disk area to lift 3000 lbs gross weight, or 125 lbs/ $ft^{2.}$ In these ducted fan VTOL aircraft, static thrust was generated with proportionally more induced velocity in the airstream, requiring more power. The EZ-VTOL's greater disk area results in increased static thrust using much less power.

• **Quiet operation**. The EZ-VTOL will operate much quieter than any free-propeller aircraft because the propeller sounds are blocked by the shrouds. The two relatively small gas turbine engines are enclosed and quiet by their nature. Most of the noise coming from conventional propeller-driven aircraft, especially helicopters, comes from the rotors and propellers. EZ-VTOL's shrouded propellers nearly eliminate propeller blade tip losses and the resulting noise generated by such losses.



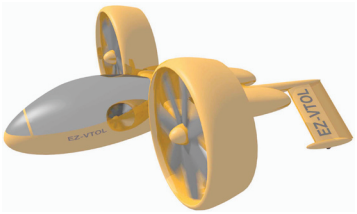
Economy. The mechanical components of the aircraft will be simpler and less expensive to make than the more complex powertrain and control systems necessary with helicopters. The all composite hull and wings are very light, very strong, and readily adaptable to quantity production.

The EZ-VTOL will only require the power of one of its engines in cruise flight, alternating flight idle time between them to distribute wear. In addition to fuel savings, this provides an extra engine running and in reserve if needed. In flight mode, EZ-VTOL will compete with most equivalently powered two- or four-passenger single-engine airplanes, with a calculated cruise speed of >300 MPH. In cruise flight, EZ-VTOL will outperform any helicopter, regardless of power or size. Prior to landing, the second engine automatically comes back on line. (In the event of an engine failure, the aircraft is still capable of a safe powered landing.) EZ-VTOL will operate like a S/VTOL aircraft (short take-off and landing)--that is with the shrouded propellers tipped forward--but it is designed to make vertical take-off and landings so that it can safely utilize small fields, backyards, heliports, even rooftops.

Performance. The EZ-VTOL is compact (wingspan 18', length 21', 5' at top of cabin), with all of its moving parts quietly operating, protected from contact with obstacles and people by its shrouded propellers. One of the benefits of using annular wings on the EZ-VTOL, besides compactness, sound attenuation, and increased thrust, is that they make the aircraft capable of maneuvers otherwise not possible to perform with any other aircraft. Annular wings offer very high directional stability because straight and level flight, inverted, rolls, and knife-edge are all the same for these wings, which know no up, down, or sideways. These wings will allow the EZ-VTOL to make nearly instantaneous changes in heading because it does not have to roll in order to enter a turn, adding an extra dimension of control unique to ring-winged aircraft.

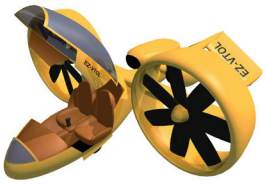
Maneuverability. EZ-VTOL's directable-variable-thrust flight control system responds almost instantly, making the aircraft very stable and responsive to pilot/computer input. Hovering in gusty conditions, for example, will be easier than

with a standard helicopter because of EZ-VTOL's direct-action independantly rotatable shrouds which will tilt the shrouds in opposition, turning the aircraft with aggressive force. The shrouds will tilt fore and aft, coordinated or independently, to control aircraft pitch, and heading. Roll control and sideways flight in a hover is facilitated by adjusting the pitch angles of the variable pitch propellers to produce more thrust on one side than the other.



• **Safe.** The shrouded propellers not only allow a compact footprint, but they also keep foreign objects, including people, away from the spinning blades. Twin engines offer redundant power, can land with any wing pitch angle. Its twin engines provide power redundancy. The variable pitch propellers will automatically feather in the event of total engine power loss, allowing for a controlled glide for safe forced landings.

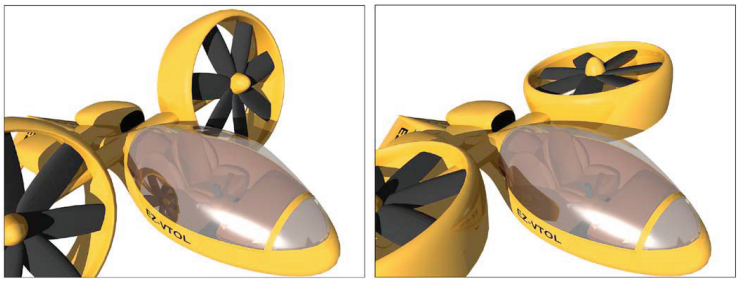
• **Simple to fly.**
Because the EZ-VTOL will be controlled by just the movements of the shrouded propellers input electronically via a single control stick, it will relatively simple to program it for autonomous flight. In this kind of control system, control stick movements are taken as instructions to the flight computer, rather than directly moving the control surfaces. This will allow an ordinary person, after a simple course, to fly the EZ-VTOL safely and effectively. For example, In hovering flight, if the stick isn't moved, the EZ-VTOL will remain motionless. Press forward and it will move forward. Press more, and it will accelerate and the shrouds will rotate forward. Upon entering controlled airspace, the EZ-VTOL could be directed by the national FAA flight control system directly. During these automatically controlled cross-country flights, the "pilot" would have little to do but read the paper.



We plan to build the EZ-VTOL upon completion of further engineering. Please treat this information as proprietary.

Sincerely,

Robert Mason



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