Idealized tilt-thrust

(U) All of the UAV options that we've been able to analyze suffer from some deficiency. A diesel, fixed-wing UAV could possibly satisfy the range and endurance objectives, but integration into carrier operations would not be straightforward. A STOVL UAV, such as the tilt-rotor, could be better integrated into flight deck operations but such a vehicle would pay a high price in terms of its range and endurance. A low disk loading helicopter would offer the greatest endurance of all the VTOL options; however, its slow speed would limit its responsiveness.

(U) So, we asked ourselves "what would be the ideal solution if we ignore technological risk?"

(U) Ideally, we desire the following characteristics for the MAE air vehicle:

- High aspect ratio for high endurance
- Mechanical simplicity
- Low empty weight
- STOVL or STOL capability

And for the propulsion system:

- High power-to-weight
- Compact design
- Good fuel efficiency over a range of power settings
- The ability to run on heavy fuels.

(U) While a VTOL capability is not a requirement, a STOL or STOVL capability would be desirable to minimize the impact to flight deck operations, provided that the impact on the UAV’s range and endurance was not too severe. A tilt-wing aircraft is better suited for STOL operations than a tilt-rotor since the tilt-wing concept enjoys better fixed-wing performance, while a tilt-rotor is generally more efficient in helicopter mode. However, potentially more attractive than the tilt-wing for STOL operations is the tilt-body concept pioneered by the Freewing Aerial Robotics Corporation. Freewing suggests that the tilt-body concept is very scalable; however, the takeoff weight of a naval MAE UAV would likely have to be much larger than Freewing's largest UAV currently in production, the Scorpion UAV, which has a takeoff weight of 431 pounds.

(U) Of course, the air vehicle also needs an engine. The engine concept that, in theory, would appear to be best suited for a tilt-body aircraft would be a radial, air-cooled diesel engine due to its high power-to-weight and excellent fuel efficiency.

(U) We asked the Freewing if they could size their tilt-body concept to satisfy the range and endurance requirements for a MAE UAV. In response to our request, they proposed four conceptual tilt-body UAVs. The first was a preliminary feasibility analysis, conducted by Geneva Aerospace at the request of Freewing, that was sized with an off-the-shelf Pratt & Whitney turboprop engine to satisfy the range and endurance objectives; the second employs a Zoche, radial, air-cooled diesel engine (not yet in production); the third concept uses the same basic airframe as the second concept but, like the first concept, uses an off-the-shelf turboprop engine; and the fourth concept was developed by Geneva Aerospace to satisfy the Navy's MAE UAV requirements. Table 31 gives specifications for the four concept vehicles. Figures 95 and 96 give illustrations of the final Geneva Aerospace concept vehicle.

(U) In figure 97, we compare the empty weight ratios of the tilt-body production and concept vehicles to our correlation for land-based, fixed-wing UAVs. Based on the data for Freewing's tactical UAVs as well as our data for other tilt-thrust concepts, we would expect the tilt-body MAE UAV concepts to be somewhat heavier than land-based vehicles; yet, as figure 97 shows, their projected empty weights actually fall below the correlation. This finding suggests that the actual production vehicle may need to be scaled up somewhat, or, alternatively, some compromise on the endurance requirement may need to be made. Given that a tilt-body MAE UAV that is capable of unassisted launch and recovery would place fewer restrictions than a fixed-wing UAV on flight deck operations, a small reduction in endurance may be acceptable.

Table 31. Freewing Aerial Robotics Corp. MAE tilt-body concept vehicles

Unclassified

	Option #1	Option #2	Option #3	Option #4
Engine	700 hp turboprop	300 hp diesel	300 hp turboprop	300 hp diesel
Takeoff weight	4,800 lb	2,613 lb	2,613 lb	2,216 lb
Empty weight	1,300	1,020 lb	925 lb	950 lb
Payload weight	300 lb	300 lb	300 lb	300 lb
Wingspan	66 ft	55 ft	55 ft	35 ft
Endurance[a]	24 hours	24 hours	5 hours	24 hours
Landing distance[b]	<350 ft	<200 ft	<200 ft	<400 ft
Takeoff distance	500 ft	500 ft	500 ft	<500 ft
Design load factor	2.5g	2.5 g	2.5 g	2.5 g

a. On-station at 500 nmi.

b. Landing and takeoff distances for Options #1 thru #3 assume no wind-over-deck; the performance for Option #4 assumes 10 knots wind-over-deck.

Figure 95. MAE UAV tilt-body concept

Unclassified

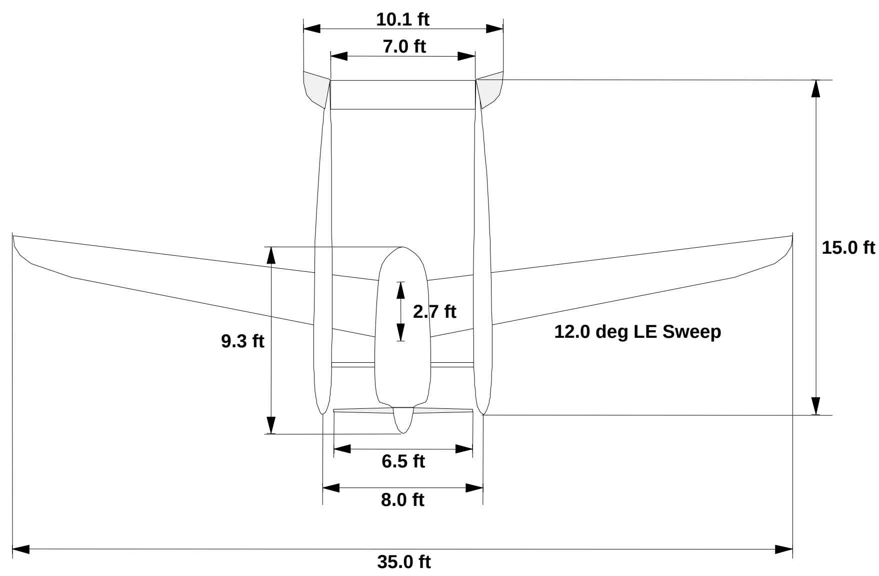


Figure 96. Various views of the MAE tilt-body UAV concept

Unclassified

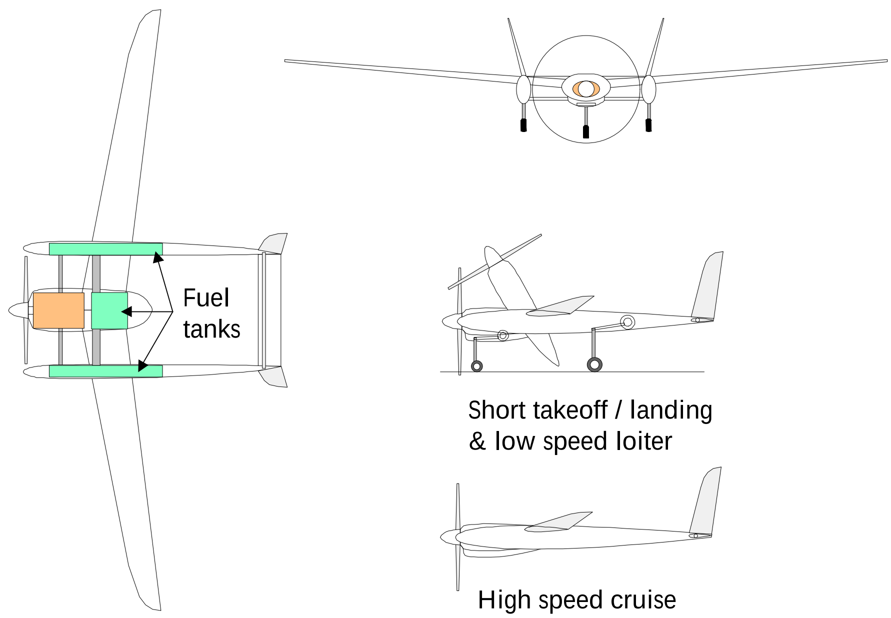
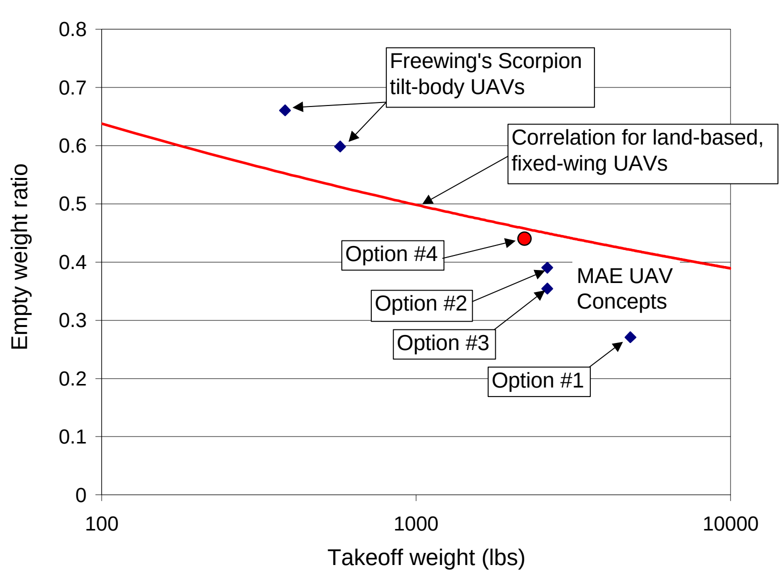


Figure 97. Comparison of tilt-body empty weight ratios to correlation for land-based, fixed-wing UAVs

Unclassified



(U) The low-speed controllability of the tilt-body vehicle is also an area of concern. The tilt-body MAE UAV concept vehicle is much larger than any of Freewing's current production models. Since inertias scale up faster than vehicle dimensions or weight, satisfactory low-speed control on a relatively small vehicle cannot be presumed to automatically apply to a dramatically scaled up vehicle.

(U) Unlike the VTOL concepts which use tail rotors or counter-rotating prop-rotors to maintain lateral-directional control, the tilt-body combines the thrust vector with an inherently "overly stable" airframe to provide a stabilized flight path at low speeds [77]. The MAE UAV concept vehicle features a movable horizontal tail surface as well as body-fixed flaps (located on the trailing edge of the fuselage) to provide vehicle controllability at very low flight speeds. Freewing's smaller production models do not have these control surfaces.

(U) Although the thrust-to-weight ratio of the vehicle may exceed 1.0, the vehicle cannot hover. Rather, there is a minimum controllable airspeed which is determined by the minimum dynamic pressure requirement on the horizontal tail surface. This minimum controllable speed is estimated to be between 20 and 30 knots. Given that the WOD on an aircraft carrier is typically in this same range during recovery, the MAE UAV tilt-body may actually appear to "hover" during its recovery.

(U) Freewing also argues that due to the absence of any vertically oriented surface along the fuselage for the slipstream to act upon, the yawing moments are less severe than the moments that conventional, fixed-wing aircraft experience. A detailed takeoff and recovery analysis, including a time history of the rollout during recovery, is included in appendix F. This analysis was performed by Freewing.