Appenidix E: Freewing MAE UAV analysis

The vehicle summary is presented in the form of plots and descriptive text. Two alternative mission altitudes were analyzed and both meet the desired mission duration. Additional trade studies should be conducted by the user to determine a preferred operational altitude for a real mission. Actual engine performance at higher altitudes must also be verified. It appears that there exists a wide range of vehicle sizes, using this basic configuration, that could meet the MAE UAV mission requirements. This could allow for additional tradeoffs for shorter takeoff/landings, faster transition to and from mission areas, etc.

Both missions used the same vehicle configuration, which was derived from a series of preliminary trade studies to arrive at a vehicle size. An engineering build-up of the aerodynamics database was performed and weight fractions were checked for reasonableness using past experience and empirical data.

The basic vehicle description is given as follows:

Takeoff Gross Weight (TOGW):	2200 lbs
Reserve Fuel Weight:	100 lbs
Wing Span:	35 ft
Root Chord:	2.68 ft
Tip Chord:	1.21 ft
Propeller Diameter:	6.5 ft
Propeller Type:	4-Blade variable pitch
Engine:	300 hp maximum (limited to 250 hp during mission, 300 hp at takeoff)

Freewing MAE UAV weights analysis

Component	Weight
Structure	310
Lndg Gear	180
Payload	300
Propulsion Syst	460
Zero Fuel Weight	1250
Fuel	950
Total T/O Weight	2200

Wt Fraction Summary	
Airframe, less eng	25.96%
Structure	13.06%
Systems	4.78%
Langing Gear	8.12%
Propulsion	17.64%
Payload	13.54%
Fuel	42.86%
	100.00%

Component Weight Buildup

Weights taken from actual measurements on components of Freewing Scorpion 100 UAV, using molded prepreg carbon/honeycomb sandwich construction

Component	Density/ Weight	Area/ Quant	Comp Weight	Syst Weight	Weight Fractions
Airframe Structure				239	10.80%
Wings	1.24	51.0	63		2.85%
Body	2.72	36.5	99		4.48%
Horiz Stab/Elev	1.24	10.7	13		0.60%
Vertical Stabs	1.24	15.0	19		0.84%
Pods	1.80	25.0	45		2.03%
Lndg Gear			180	180	8.12%
Tilt System			50	50	2.26%
Systems				106	4.78%
Avionics	15	1	15		0.68%
Wiring/Elec (1)	50	1	50		2.26%
Fuel Sys	25	1	25		1.13%
Actuators	2	8	16		0.72%
Propulsion System				391	17.64%
Engine (2)	271	1	271		12.23%
Propeller	80	1	80		3.61%
Ext Alternator (3)	20	1	20		0.90%
Eng Mount,Baffling	20	1	20		0.90%
Payload			300	300	13.54%
Zero Fuel Weight			1266	1266	57.14%
Fuel				950	42.86%
Total T/O Weight				**2216**	

Notes

(1) Includes battery

(2) Zoche Spec Sheet - includes 1 kW alternator, turbo/super charger hydraulic prop governor, oil and fuel filters

(3) External alternator required to achieve 2.5 kW elec power

Vehicle dimensions

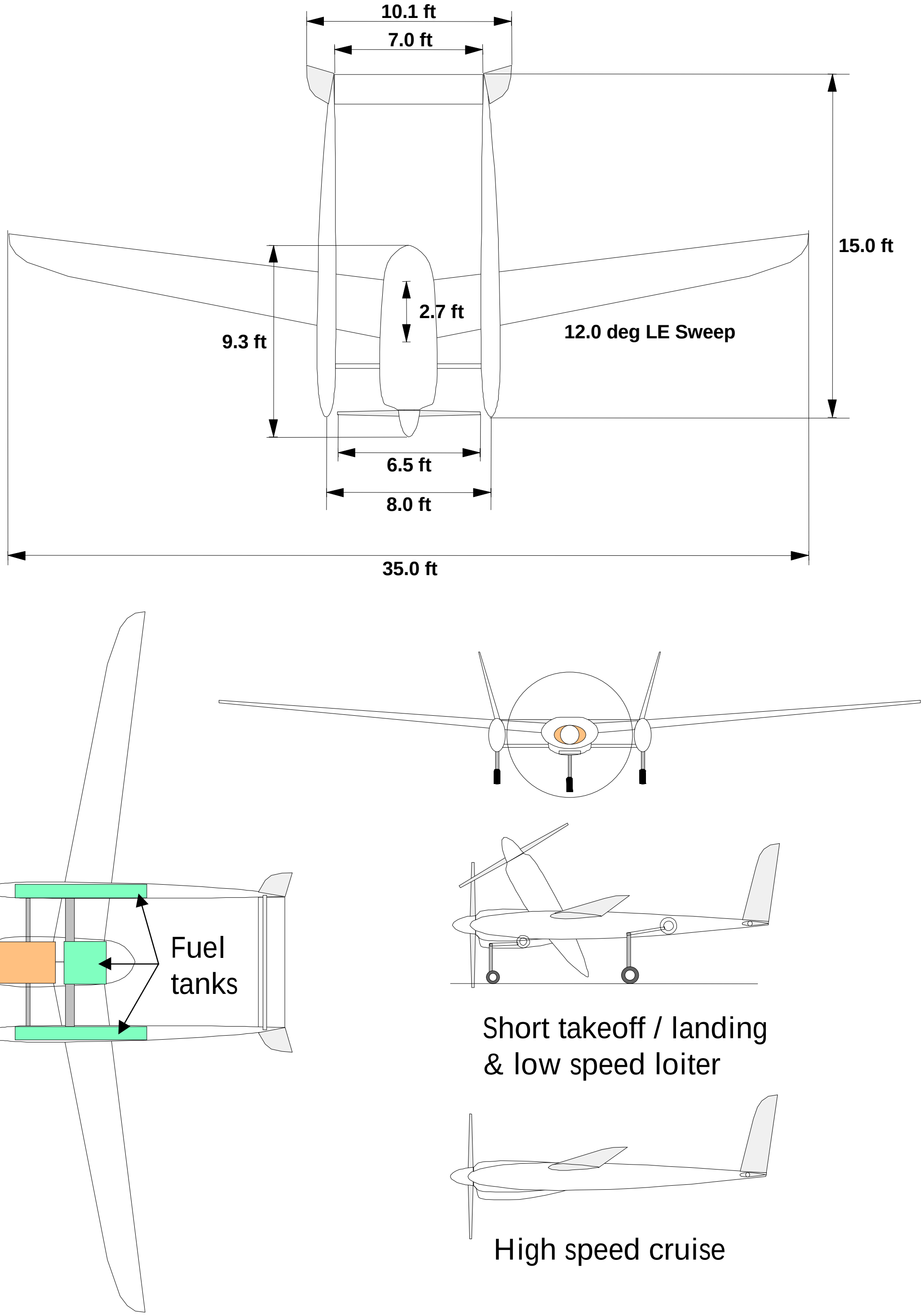

Figure 1 Various views of the tilt-body MAE UAV concept vehicle

Mission performance graphs

The following figures were plotted from integrated mission computations.

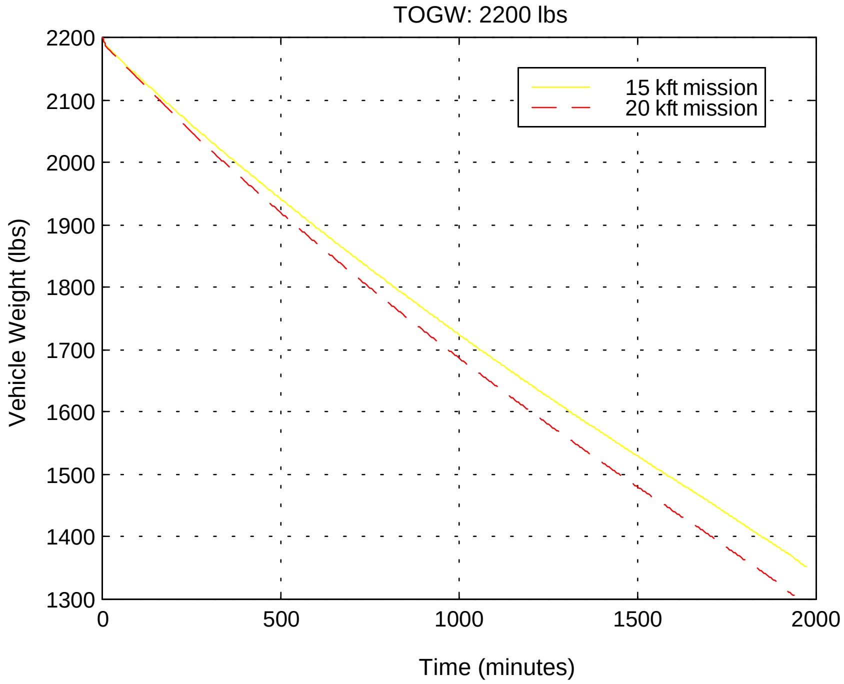

Figure 2 Vehicle weight

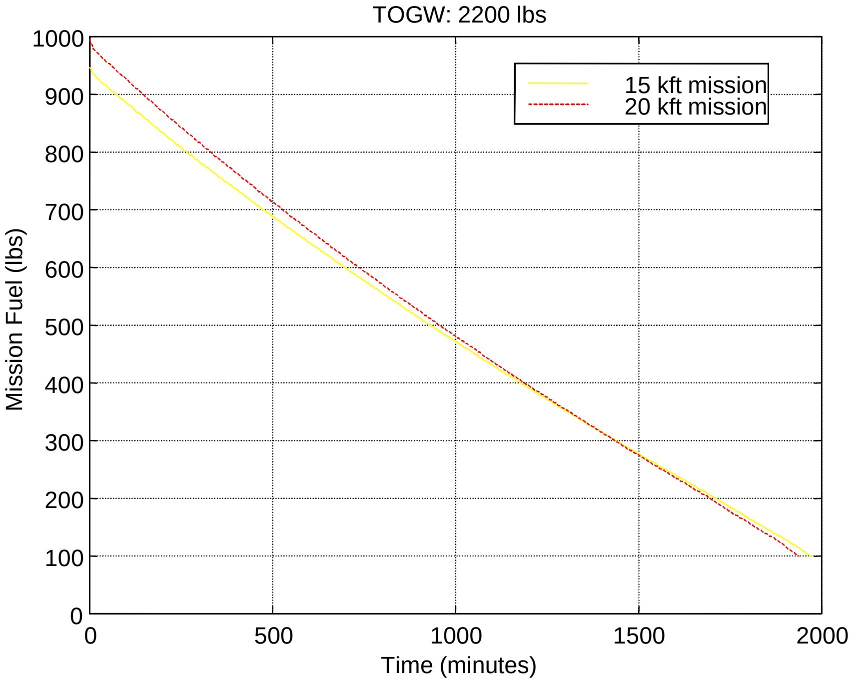

Figure 3 Mission fuel

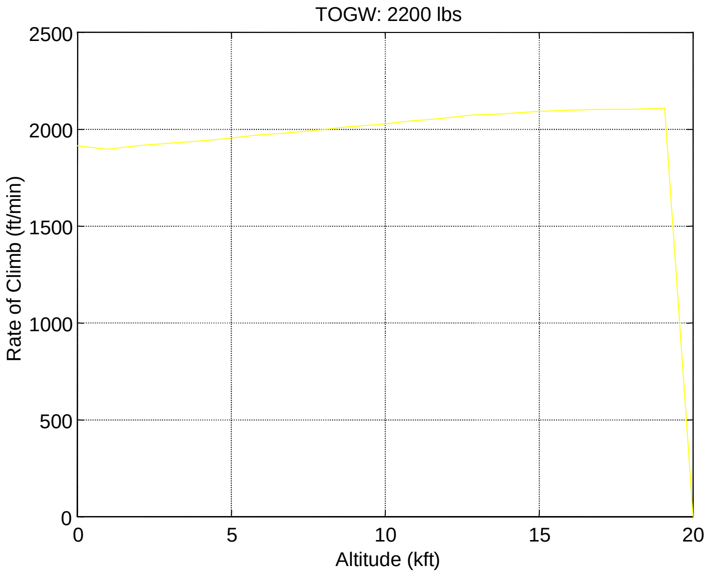

Figure 4 Rate of climb

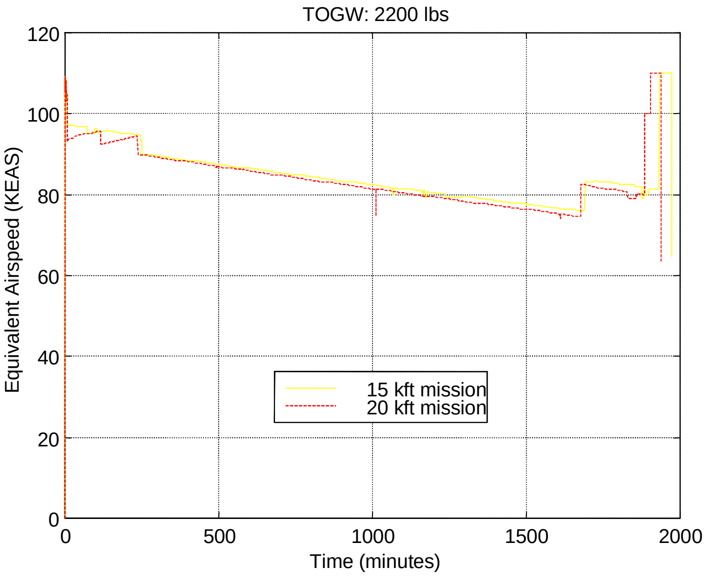

Figure 5 Equivalent airspeed[1]

Times to 500NM	Times to Return from mission area
15K ft - 249.6 min	15K ft - 281.1 min
20K ft - 234.4 min	20K ft - 261.8 min

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[1] The sawtooth shape of the airspeed curve during the climb portion of flight is due to problems the simulation was having calculating the optimal climb speed. This is due to the engine model we used, which is not as detailed as we'd normally use with this simulation.

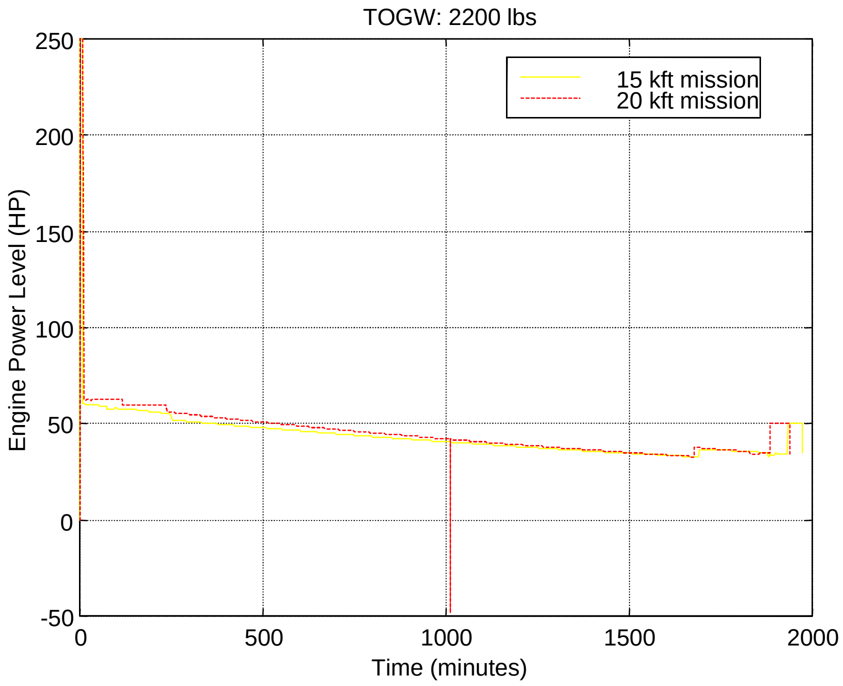

Figure 6 Engine power

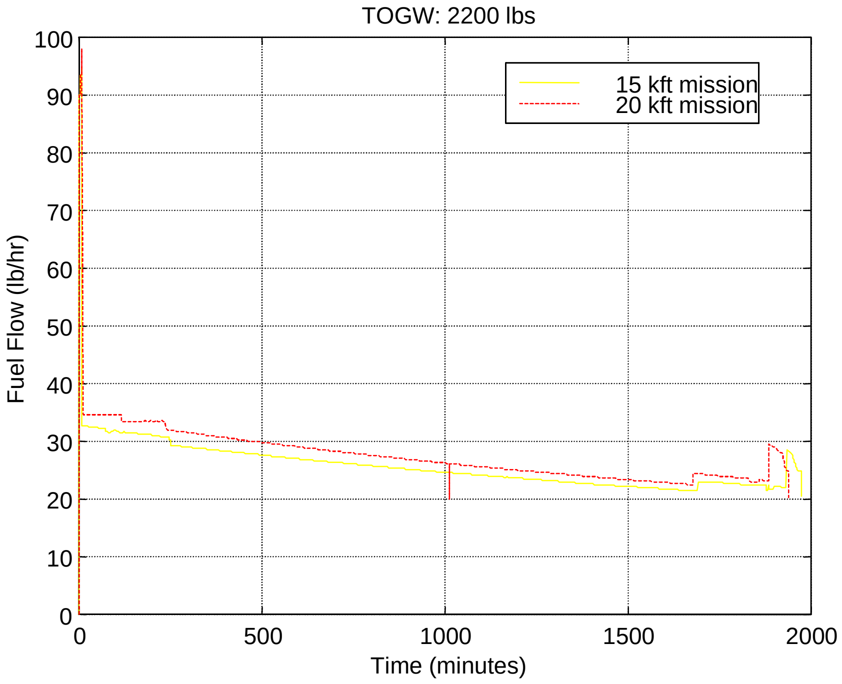

Figure 7 Fuel flow

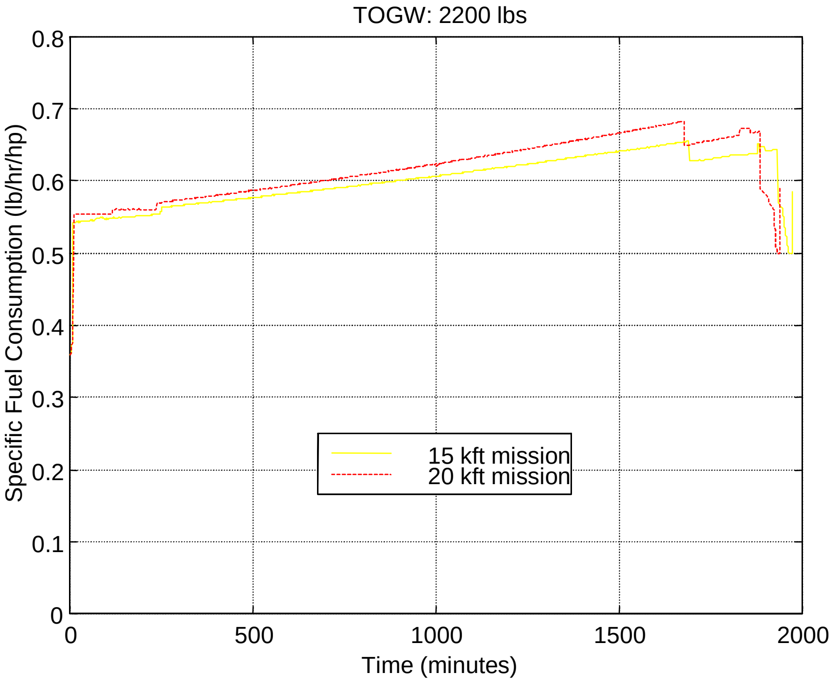

Figure 8 Specific fuel consumption

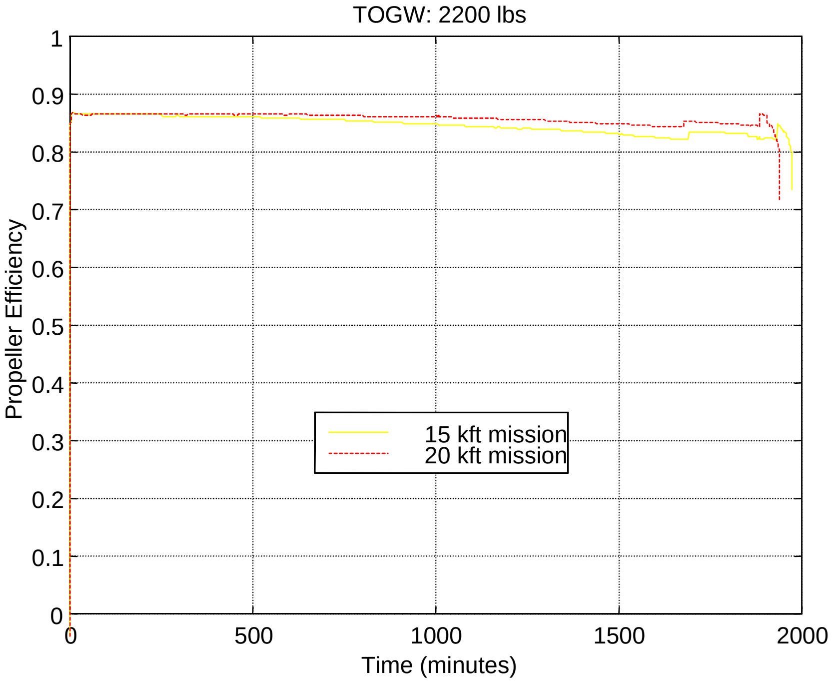

Figure 9 Propellor efficiency

Take-off and landing analysis

Take-Off and Landing Analysis
Maritime Medium Altitude Endurance UAV
Freewing / Tilt-Body Design Concept

Overview / Assumptions

The Freewing Tilt-Body maritime UAV is designed to accommodate short take-off and landing distances required for integration into Navy carrier operations. The proposed design concept will feature 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. Also to be considered in the design is a higher performance actuation system (ie, increased bandwidth over the jack-screw system currently employed in the Scorpion design) controlling the body tilt angle to provide a mechanism for commanding a variable body tilt angle during the take-off ground roll.

The preliminary vehicle sizing analysis provided a detailed drag polar for concept design for the zero degree body tilt configuration. To perform the take-off and landing analysis, however, the drag polars corresponding to non-zero tilt angles were needed. For cursory feasibility analysis, extrapolations were made on the drag polar data based on trends in the Scorpion 100-50 aerodynamic data. The figure 1 shows the ratio of total vehicle drag coefficient (power-off) at various boom angles relative to the 2 degree boom angle configuration on the Scorpion UAV. Also shown on this figure is the corresponding drag ratio estimated for the conceptual maritime MAV. The reduction in drag ratio for the MAV design corresponds to an overall reduction in the total percentage of wetted surface area of the MAV fuselage relative to the rest of the vehicle as compared to that of the Scorpion design. This new drag ratio curve is used in the take-off and landing analysis to account for increased drag in the body tilt configurations.

Other key assumptions were made pertaining to the equivalent friction coefficient during take-off and landing ground rolls as well as time delays associated with the application of the brakes and throttle cut-off. The following table summarizes the parameters used for this cursory feasibility study.

Parameter	Value
Dry pavement friction coefficient, no brakes	0.02
Dry pavement friction coefficient, max brakes	0.4
Brake delay (seconds)	0.5
Brake time constant (seconds)	0.5
Throttle decay time constant (seconds)	1.5

Note that these parameters represent a case study only and are not intended to reflect requirements or actual system design parameters. The parameters were chosen well inside of expected design thresholds.

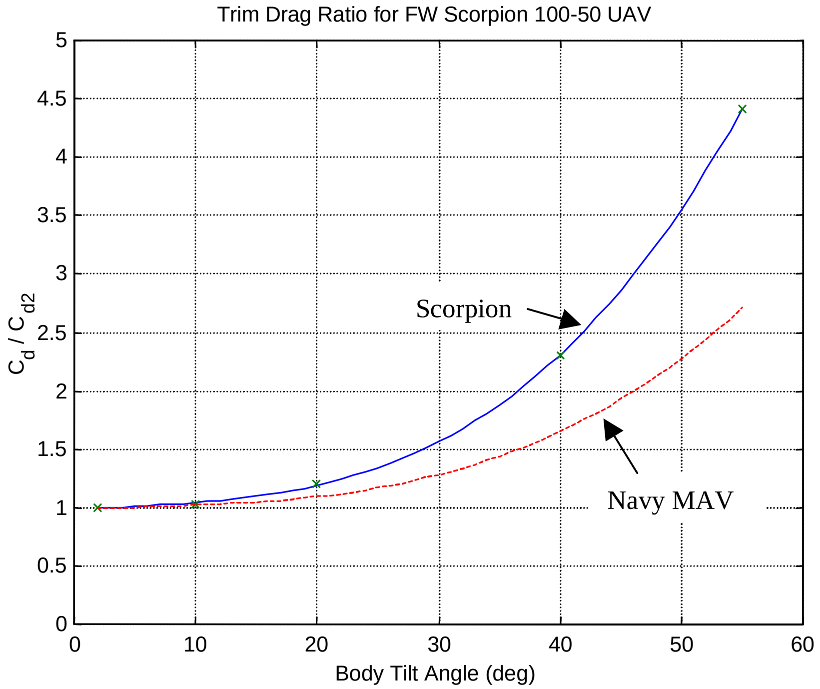

Figure 1

Landing Analysis

A 4 degree approach glide slope is assumed for the landing analysis. Figure 2 shows a contour of lift coefficients required to sustain a 4 degree glide slope for various air speeds and throttle settings. This chart assumes a body tilt angle of 60 degrees. Note that the engine produces sufficient thrust to support very low flight speeds (<30 kts @ C_{Lmax}<1.2). The control configuration highlighted in the overview will allow for controllability at these low flight speeds. The trailing edge body flaps will take advantage of prop-induced flow to maintain longitudinal and lateral trim through this flight regime. High body tilt angles (>65 deg) combined with drag inducing devices will allow for speed trim through these low-speed regimes on landing approach. For preliminary feasibility analysis, however, a case study was chosen well inside of the expected design envelope to demonstrate that the proposed conceptual design presents a low-risk approach for carrier-based landings. The landing distances shown in figure 3 represent a case study in which the touchdown speed is 50 kts, with the corresponding C_{Lmax} of 1.0 (well within the lifting capabilities of the proposed design).

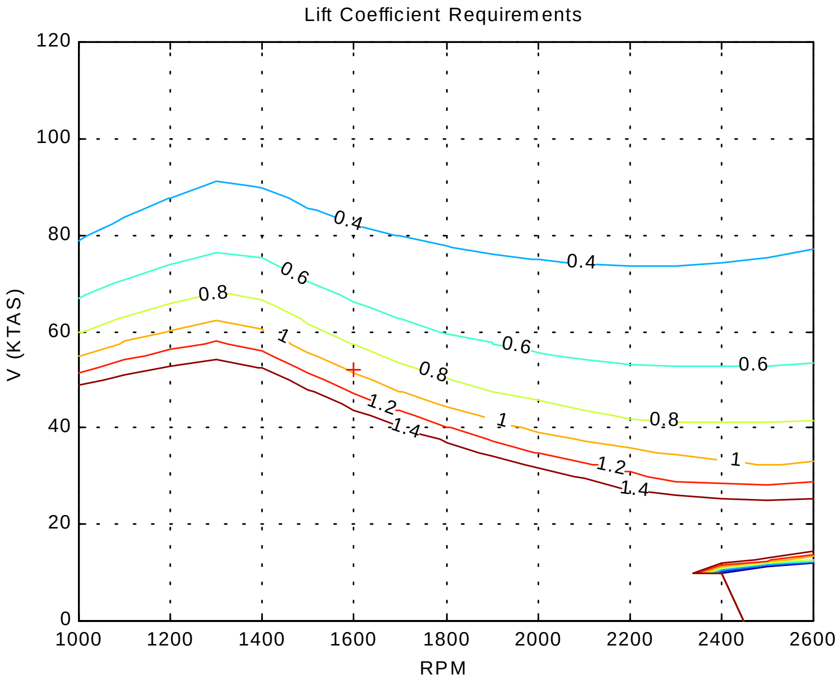

Figure 2

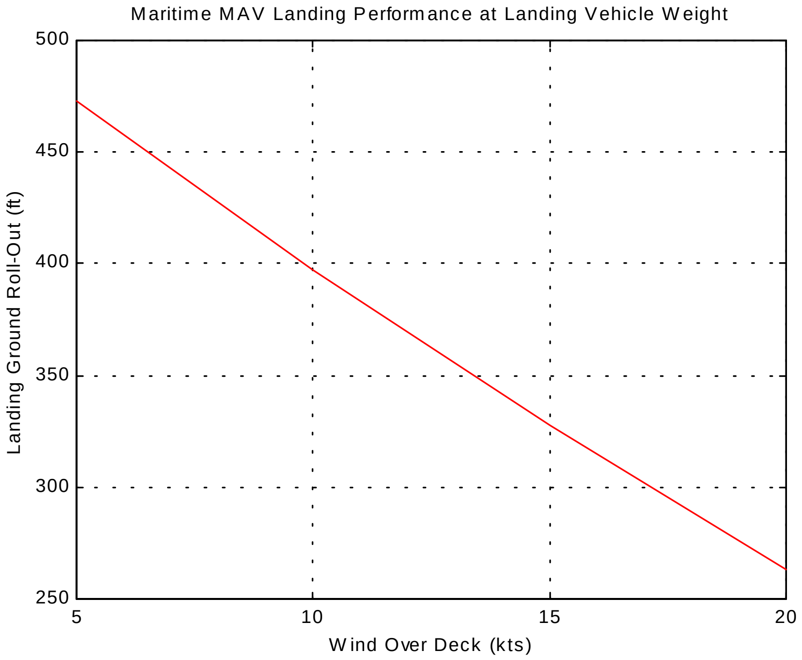

Figure 3

Figure 3 indicates that with a wind over deck of 20 kts, the landing rollout is approximately 265 feet, for the subject case study under the assumptions presented for a 1300 lb vehicle (empty weight plus 100 lb of fuel reserves). Figure 4 shows a detailed time history of the rollout.

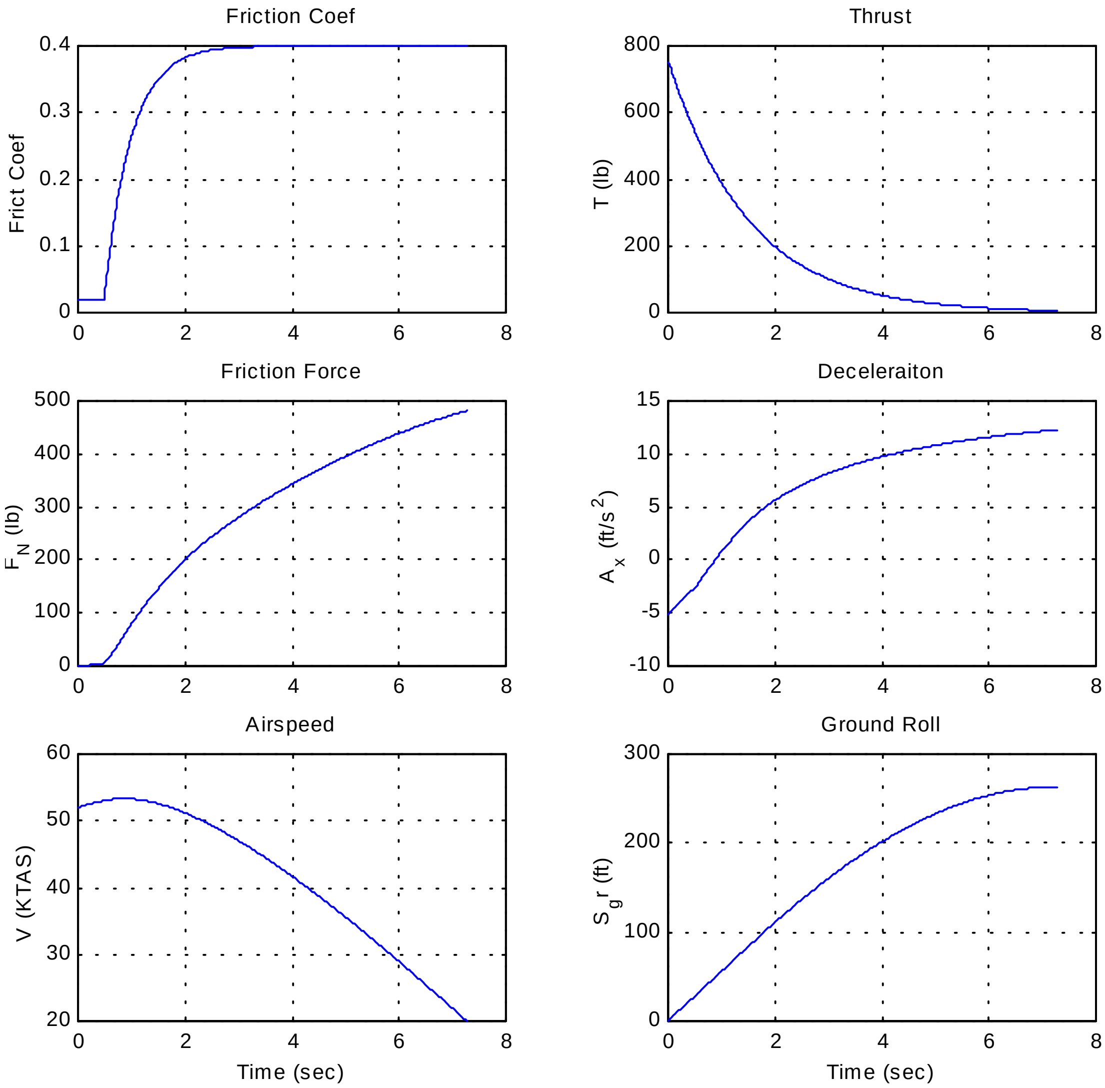

Figure 4

As mentioned previously, the above data is expected to be well within the vehicle design envelope and provides a good representation of feasibility for carrier-based landing.

Take-Off Analysis

The take-off problem is a greater challenge in that the vehicle is significantly heavier at gross take-off weight (~2200 lb). Preliminary feasibility assessments, however, show that a carrier-based take-off is achievable when the ground roll is tuned to employ the lifting control devices (wing elevons, body flaps, and additional body tilt) after accelerating the vehicle but prior to achieving the required lift-off speed. Figure 5 shows three case studies for a body tilt configuration of 20 degrees:

1. take-off ground roll as a function of wind-over-deck at min drag configuration for entire ground roll
2. take-off ground roll as a function of wind-over-deck at min drag configuration up to 0.8 $V_{\text{lift-off}}$, with additional lifting aerodynamic surfaces (elevons, etc) employed at 0.8 $V_{\text{lift-off}}$
3. case (2) with additional 10 degrees of body tilt commanded at 0.8 $V_{\text{lift-off}}$

This figure indicates the feasibility of achieving successful carrier-based take-off runs using the proposed concept vehicle.

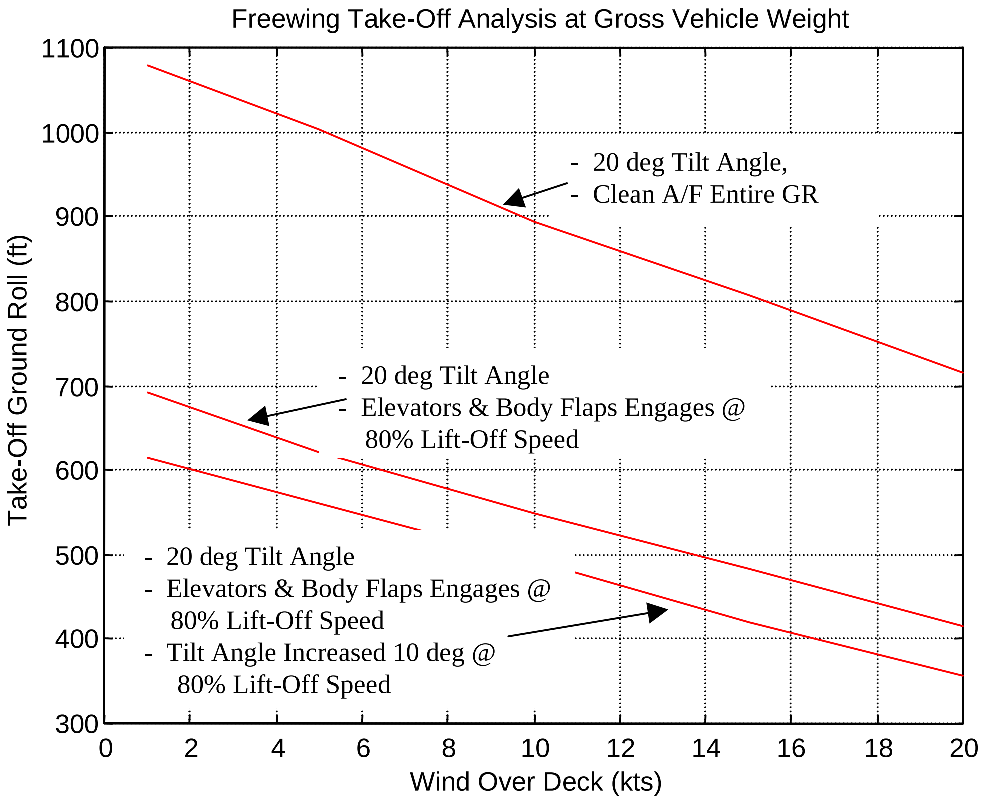

Figure 5