ENergy LITEracy WEEK

Gregor Veble

Designing for extreme energy efficiency of electric aircraft

ORGANIZED BY

IN COOPERATION WITH

SPONSORS

Italian
pipistrello /pipisˈtrɛllo/ *m.*
[zool.] bat

PIPISTREL

Est. 1987


Manufacture and Service dept.
Prototyping & Testing
Research & Development


VIRUS


VIRUS


WINNER
NASA
PAV 2007
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ELECTRO
TAURUS
THE FUTURE NOW!

PANTHERA

Green Flight Challenge

2011

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Prizes provided by NASA

Conducted by CAFE FOUNDATION

Taurus G4

“Form follows function”

Louis Sullivan, 1896
(according to Wikipedia entry)

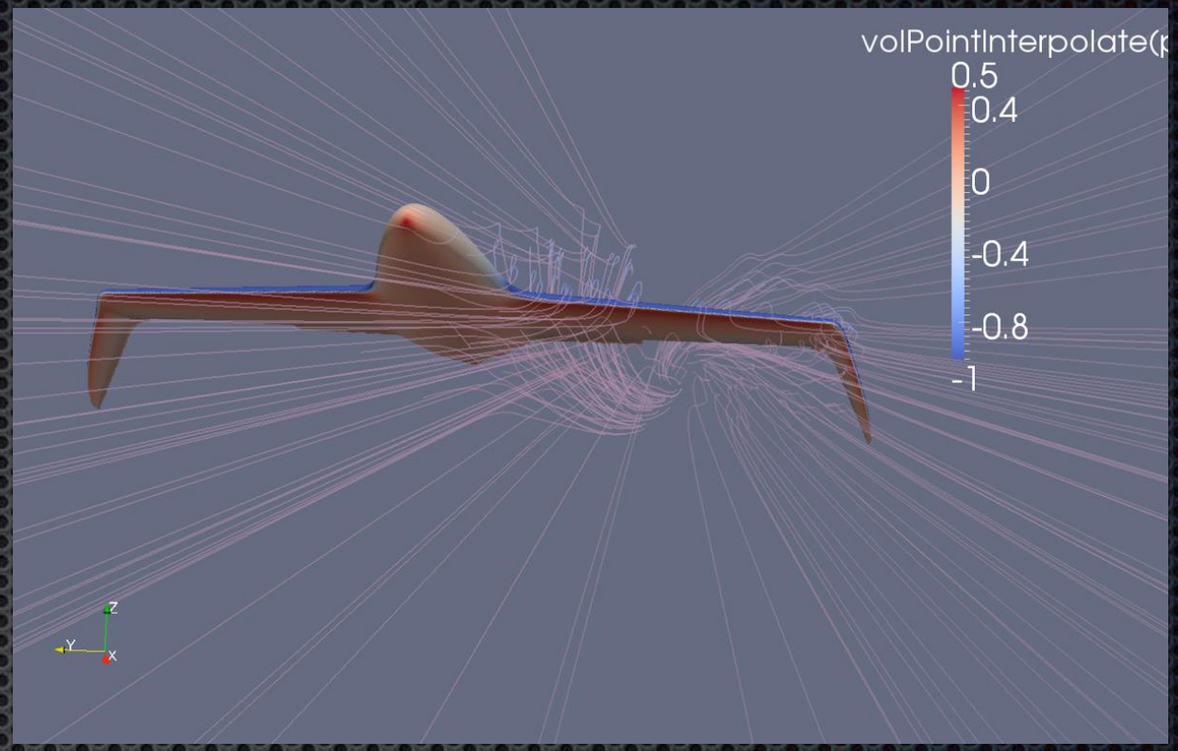
“Modernists believed, perhaps incorrectly, that airplane design did not involve any aesthetic decisions by the airplane designers.”

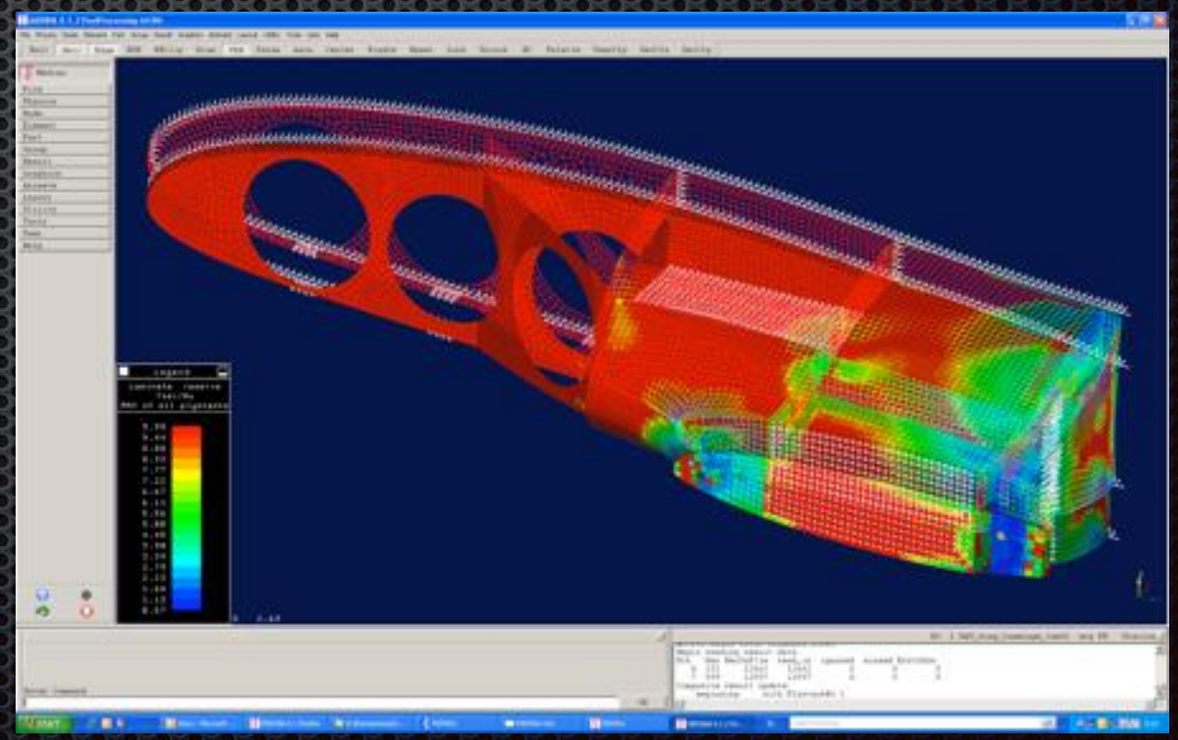
(Same page)

Form equals function.

Aircraft design - horizontally

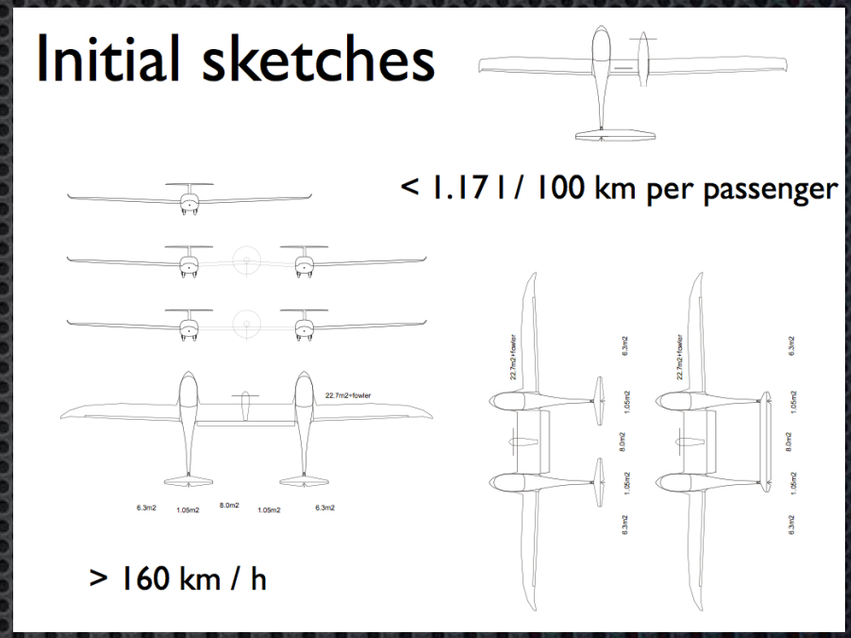
- Aerodynamics
- Structures
- Propulsion
- Controls
- Marketing
- ...

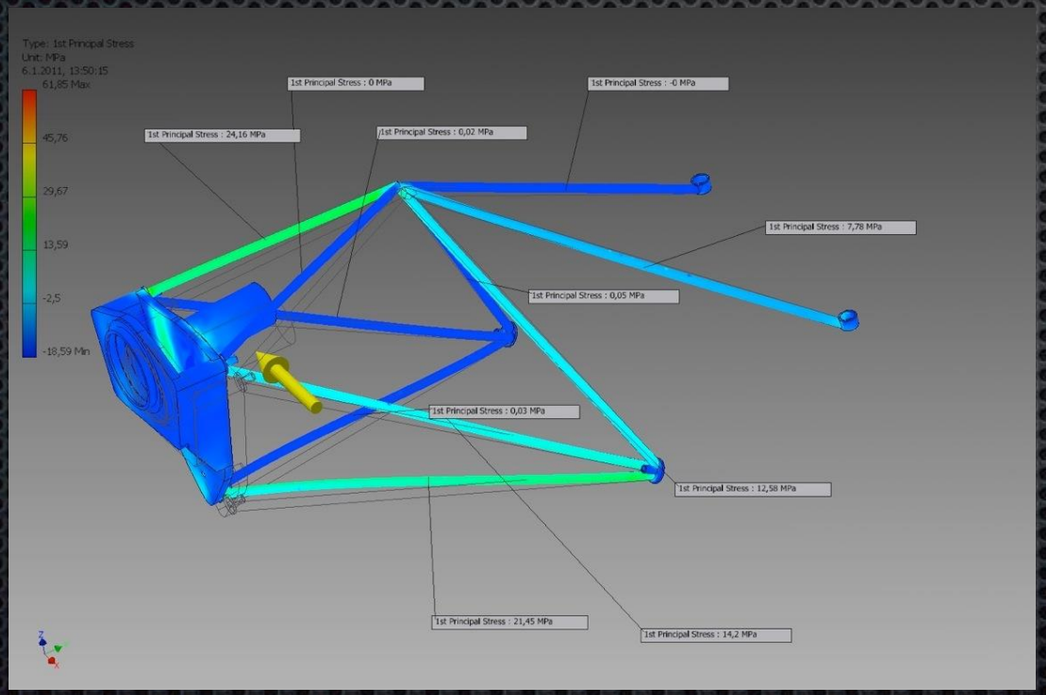


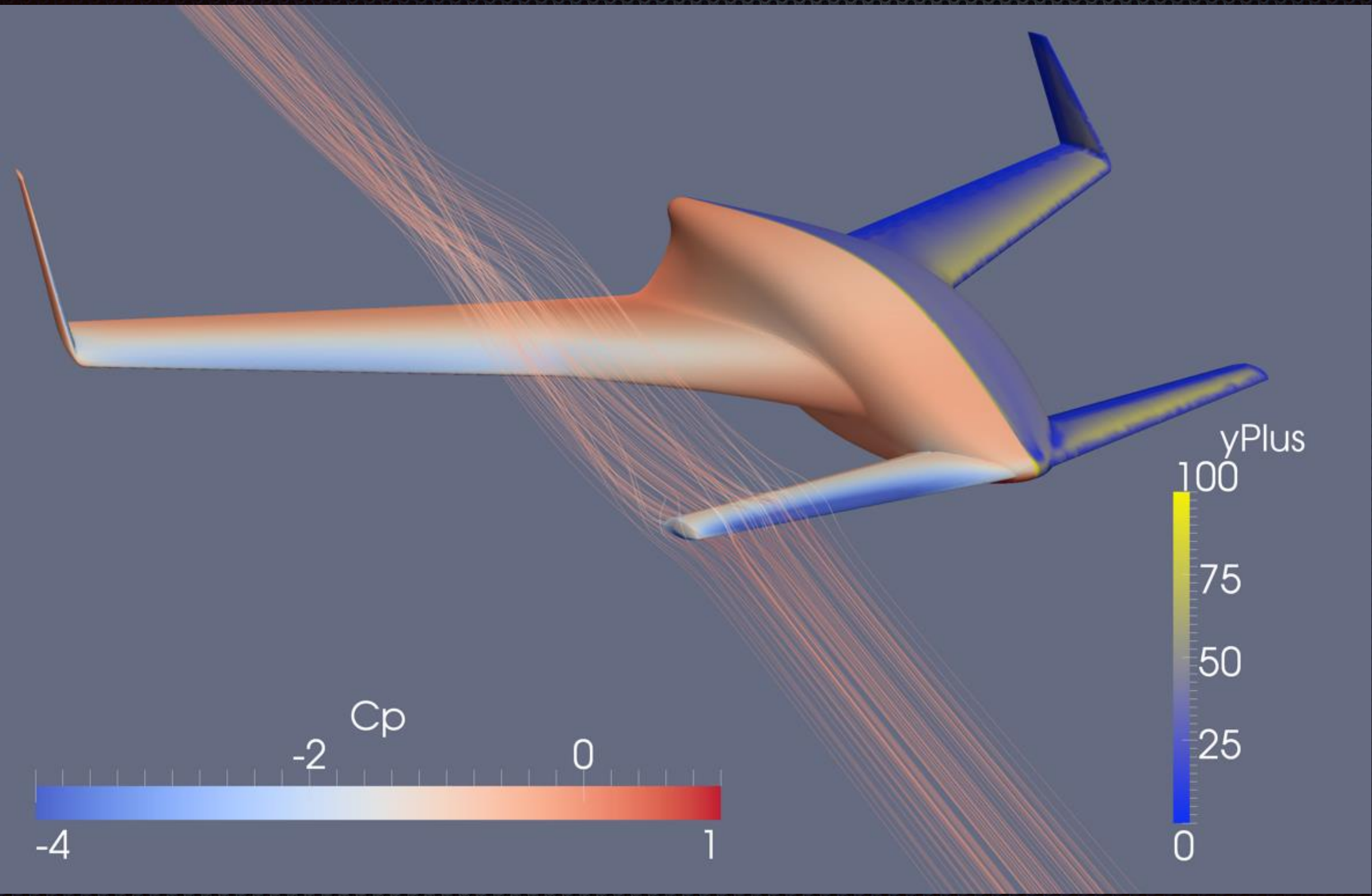


Aircraft design - vertically

- Sizing
- Preliminary design
- Detail design



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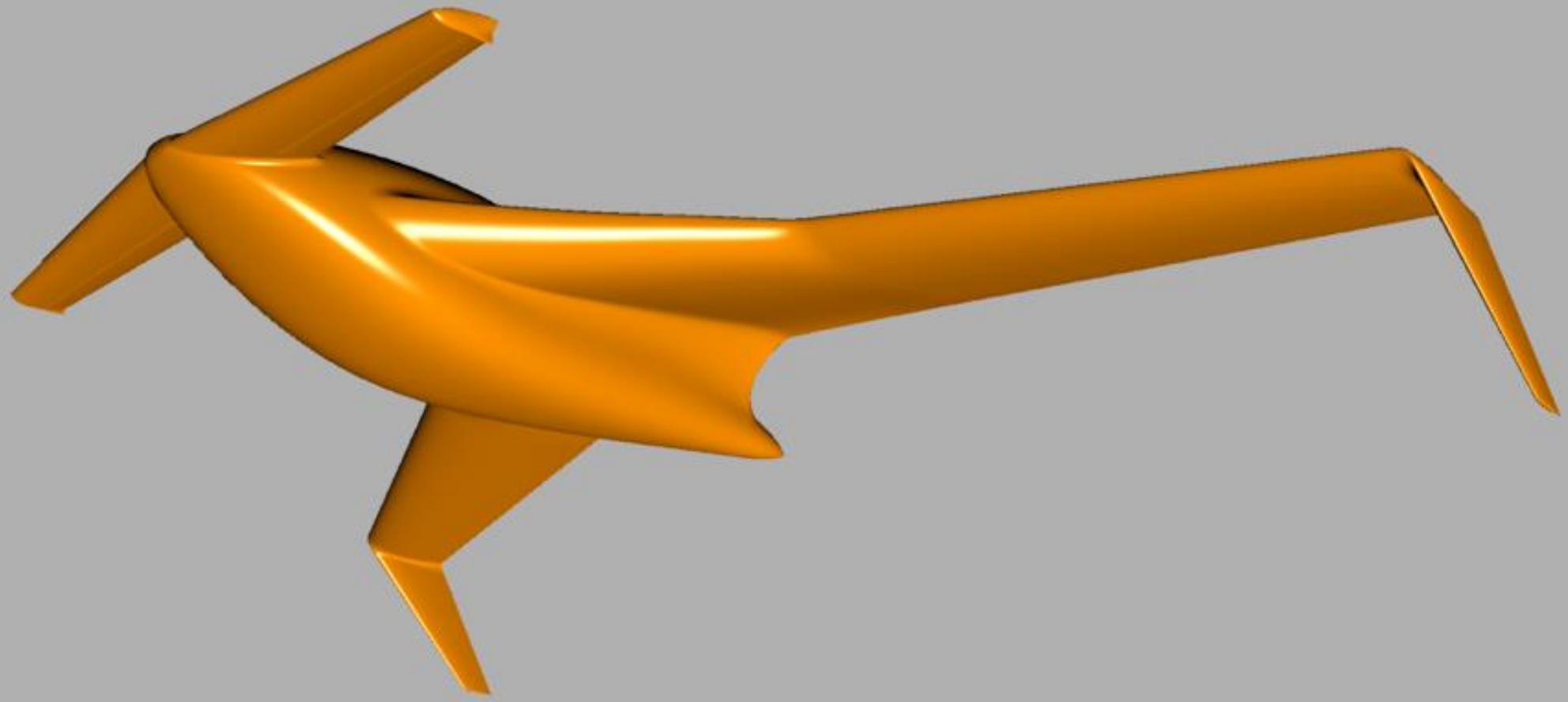
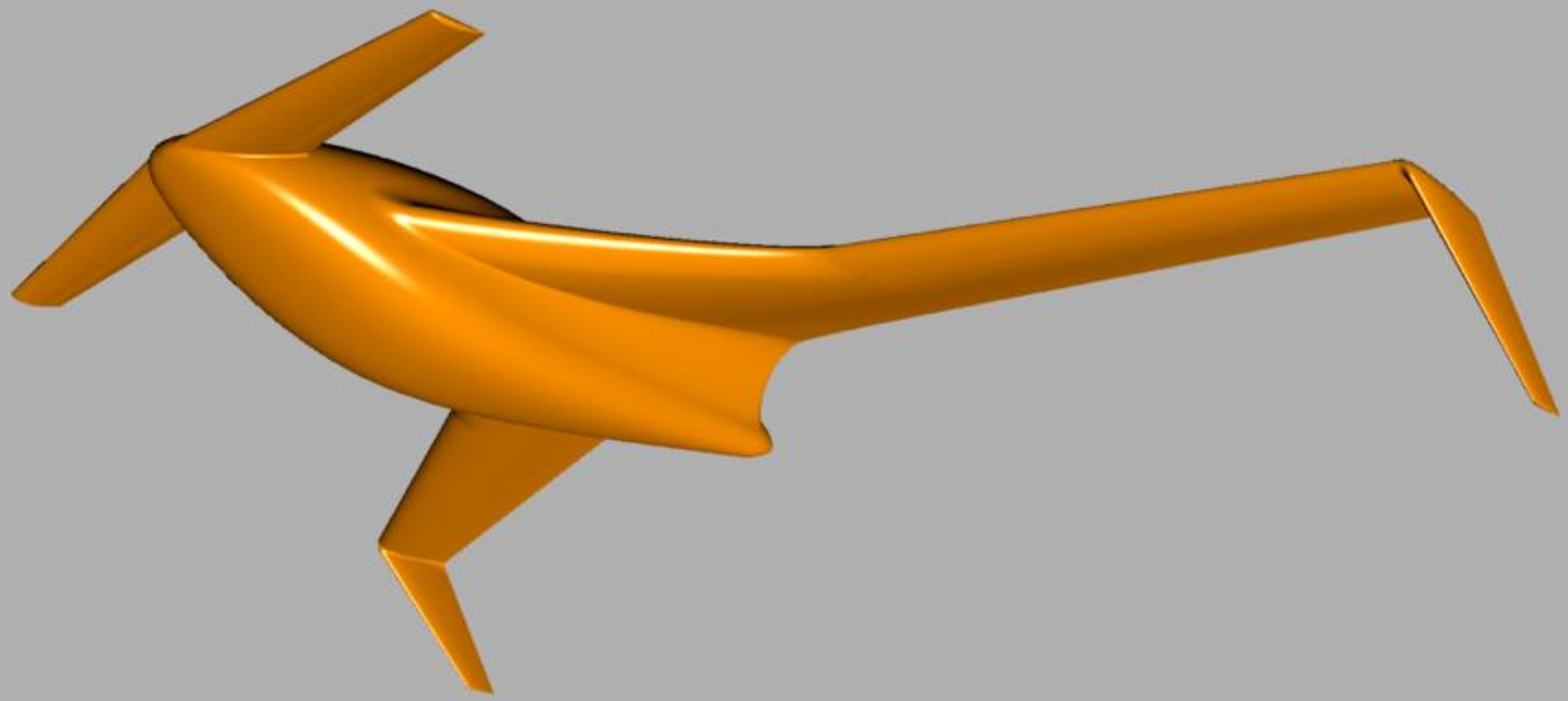


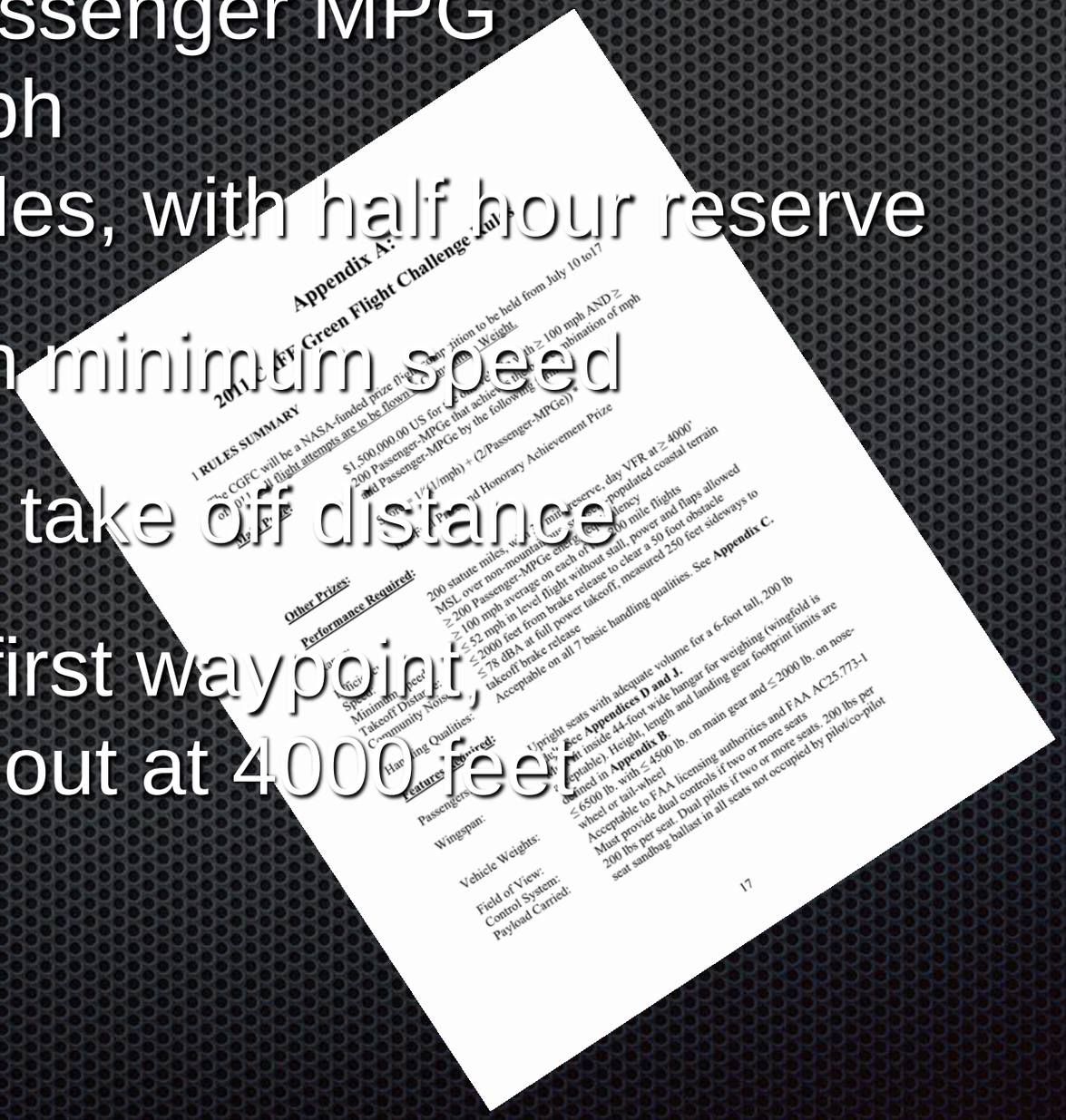


Good design achieves difficult, relevant goals


PIPISTREL

Green Flight Challenge

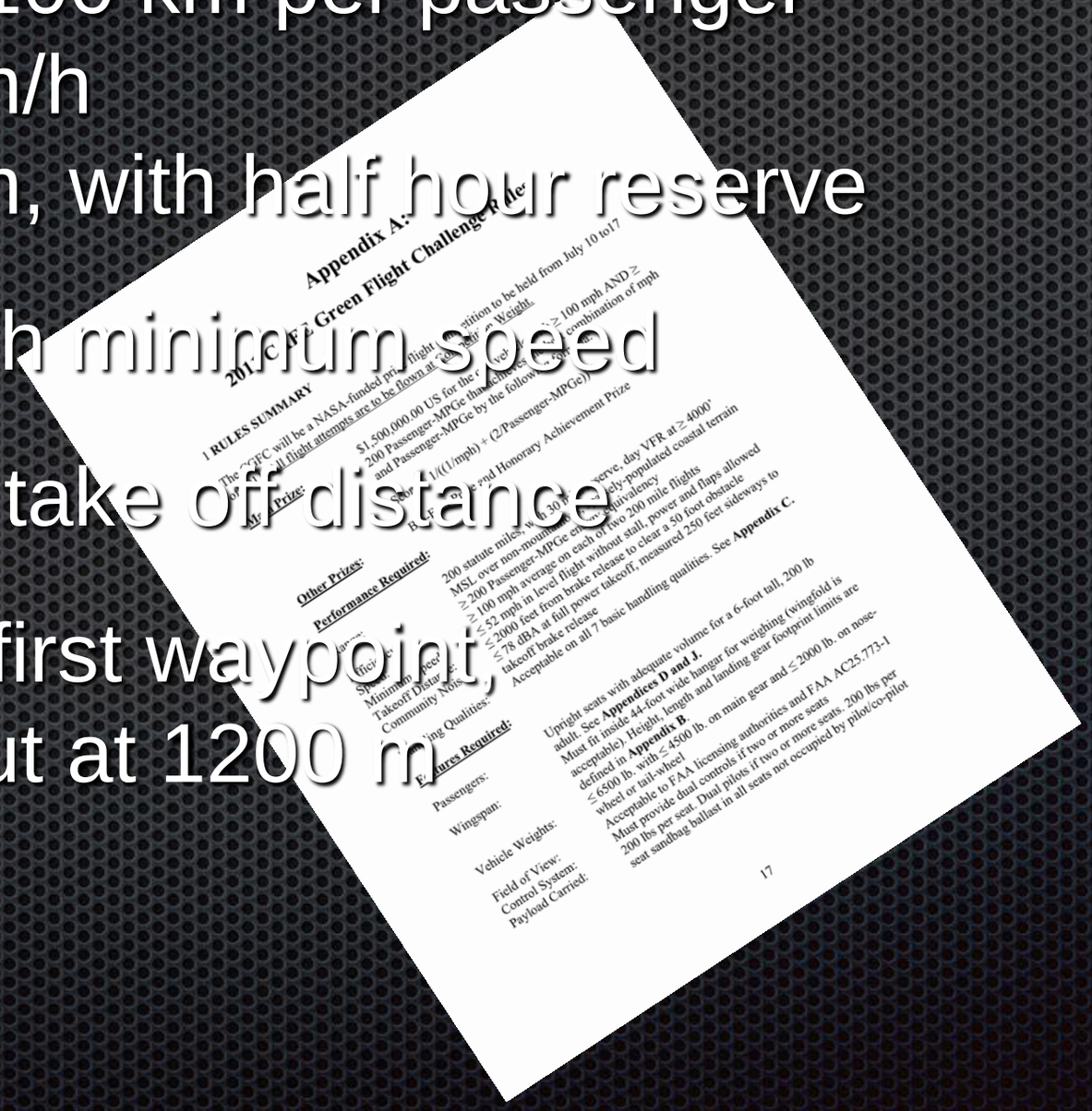
- > 200 passenger MPG
  > 100 mph
  > 200 miles, with half hour reserve
- < 52 mph minimum speed
- < 2000 ft take off distance
- climb to first waypoint,
  15 miles out at 4000 feet


Appendix A:
2011 AFF Green Flight Challenge Rules
1 RULES SUMMARY
Other Prizes:
Performance Required:
Features required:
17

Green Flight Challenge
2011
Sponsored by Google
Prizes provided by
NASA
Conducted by
CAFE FOUNDATION

Green Flight Challenge

- < 1.17 l/100 km per passenger
  > 160 km/h
  > 322 km, with half hour reserve
- < 83 km/h minimum speed
- < 600 m take off distance
- climb to first waypoint,
  24 km out at 1200 m


Appendix A: Green Flight Challenge Rules

2011 CAFE Green Flight Challenge

1 RULES SUMMARY

The CAFE will be a NASA-funded pr… flight … petition to be held from July 10 to17
… all flight attempts are to be flown at … Weight.

Prize: $1,500,000.00 US for the … ≥ 100 mph AND ≥
≥ 200 Passenger-MPGe … combination of mph
and Passenger-MPGe by the follow…

Other Prizes: … 1/((1/mph) + (2/Passenger-MPGe))
… and Honorary Achievement Prize

Performance Required: … 30 … serve, day VFR at ≥ 4000'
200 statute miles … MSL over non-mountainous … ely-populated coastal terrain
≥ 200 Passenger-MPGe … equivalency
≥ 100 mph average on each of two 200 mile flights
≤ 52 mph in level flight without stall, power and flaps allowed
≤ 2000 feet from brake release to clear a 50 foot obstacle
≤ 78 dBA at full power takeoff, measured 250 feet sideways to
takeoff brake release
Acceptable on all 7 basic handling qualities. See Appendix C.

Features Required:
Passengers: Upright seats with adequate volume for a 6-foot tall, 200 lb adult. See Appendices D and J.
Wingspan: Must fit inside 84-foot wide hangar for weighing (wingfold is acceptable). Height, length and landing gear footprint limits are defined in Appendix B.
Vehicle Weights: ≤ 6500 lb. with ≤ 4500 lb. on main gear and ≤ 2000 lb. on nose-wheel or tail-wheel
Field of View: Acceptable to FAA licensing authorities and FAA AC25.773-1
Control System: Must provide dual controls if two or more seats
Payload Carried: 200 lbs per seat. Dual pilots if two or more seats. 200 lbs per seat sandbag ballast in all seats not occupied by pilot/co-pilot

17

Green Flight Challenge

2011

Sponsored by Google

Prizes provided by

NASA

Conducted by

CAFE FOUNDATION

Competition

Scheduled for July 2011

- Maximum efficiency flight
- Maximum speed flight

Both at >200pMPG, >100 mph, >200 miles

Both using the same battery configuration

$$\text{Score} = \frac{1}{\frac{1}{\text{Speed}} + \frac{2}{\text{Mileage}}}$$

Green Flight Challenge

2011

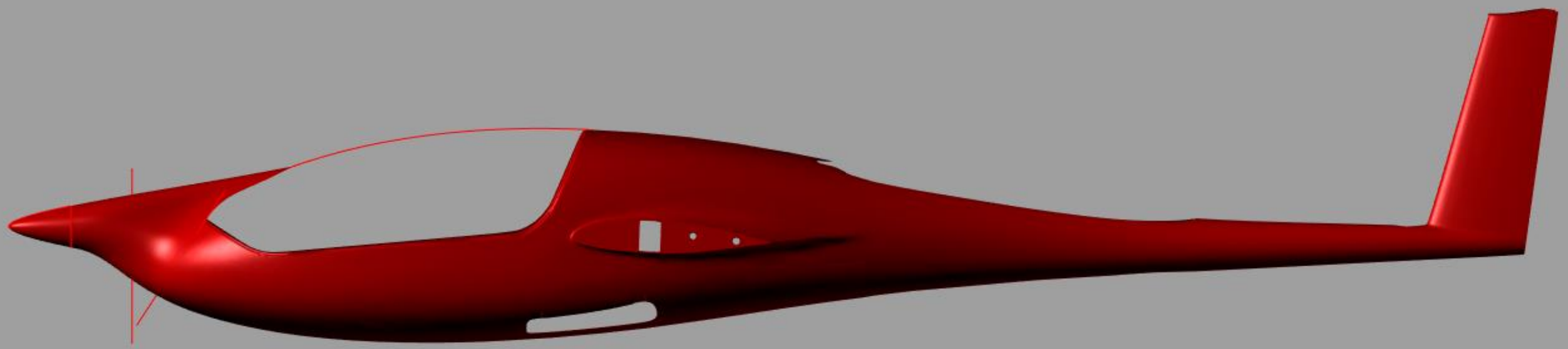
Sponsored by Google

Prizes provided by NASA

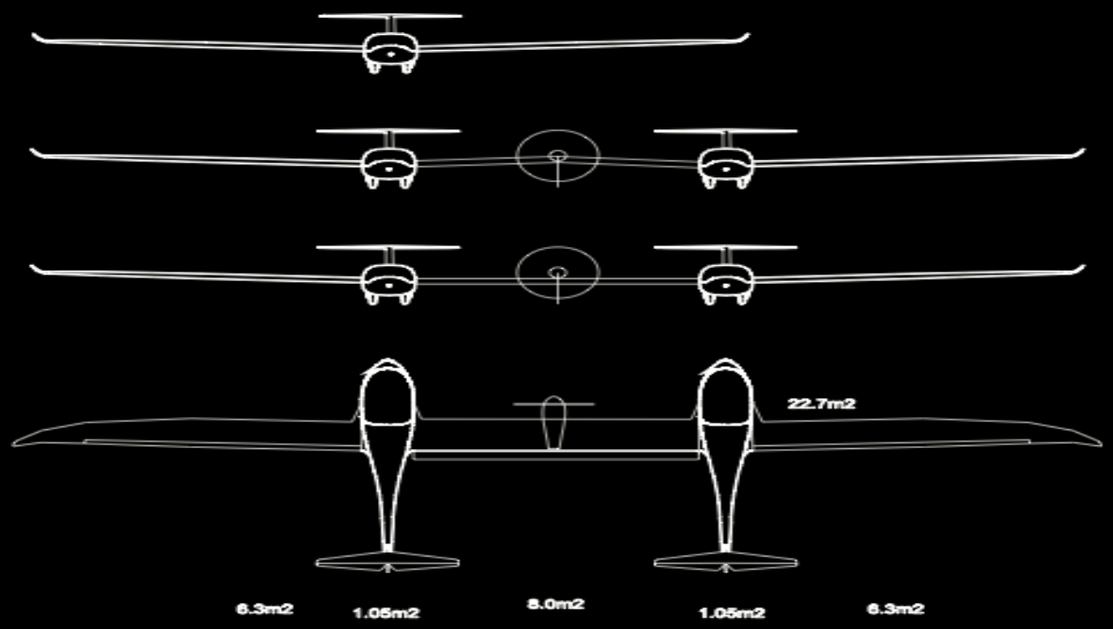
Conducted by CAFE FOUNDATION

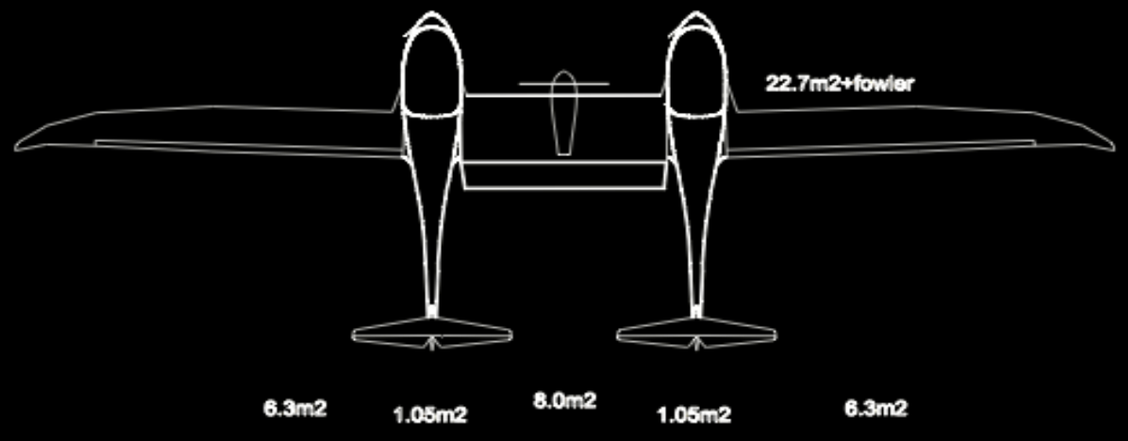
April 2010

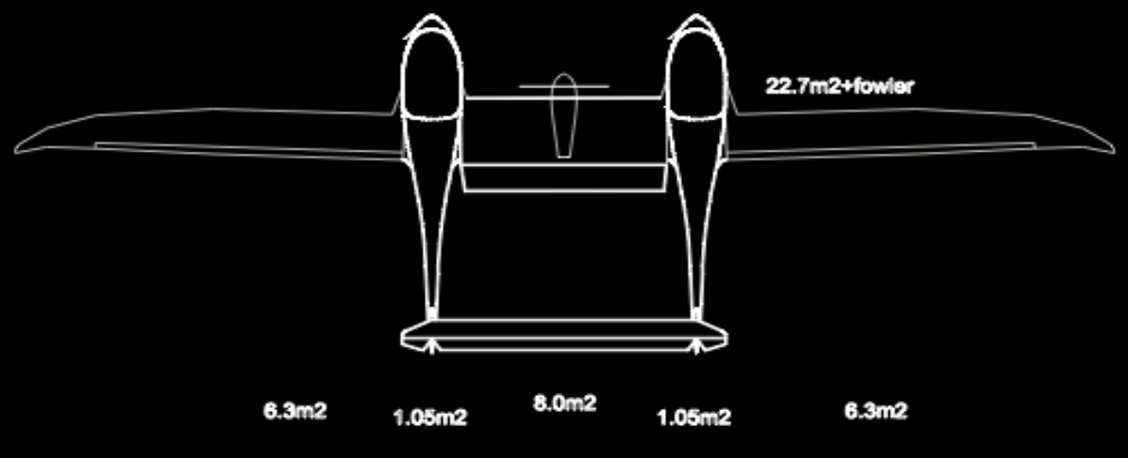
2 seat concept study

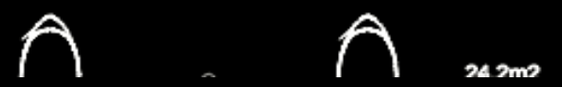


Twin fuselage concepts

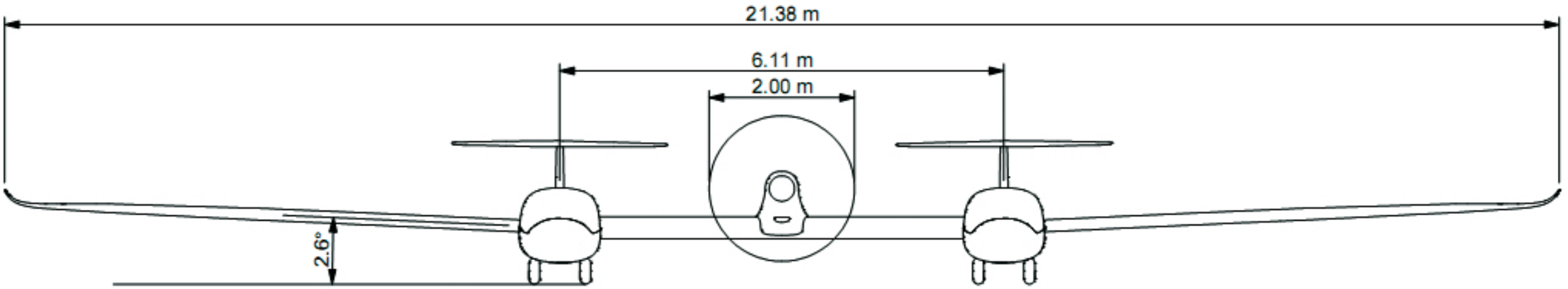


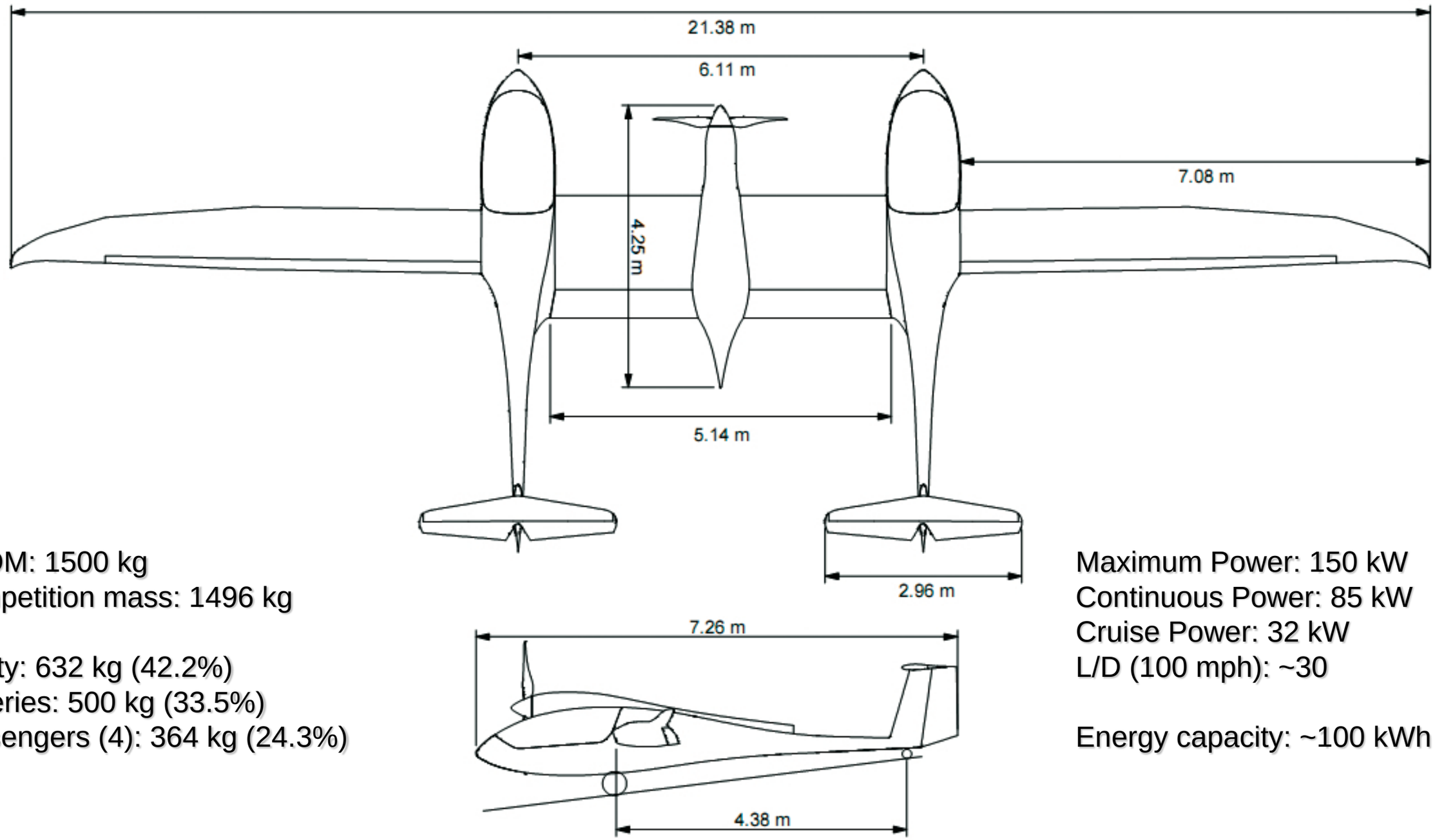






December 2010





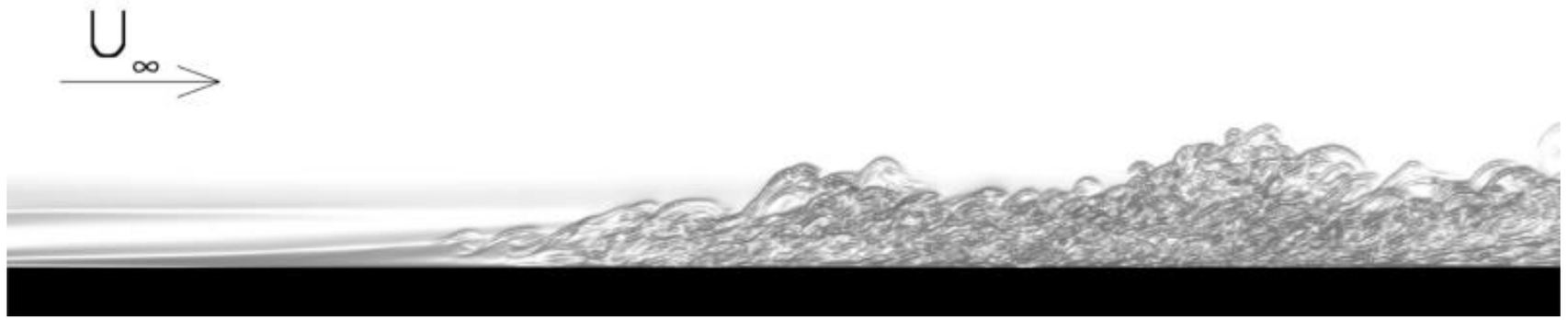
MTOM: 1500 kg
Competition mass: 1496 kg

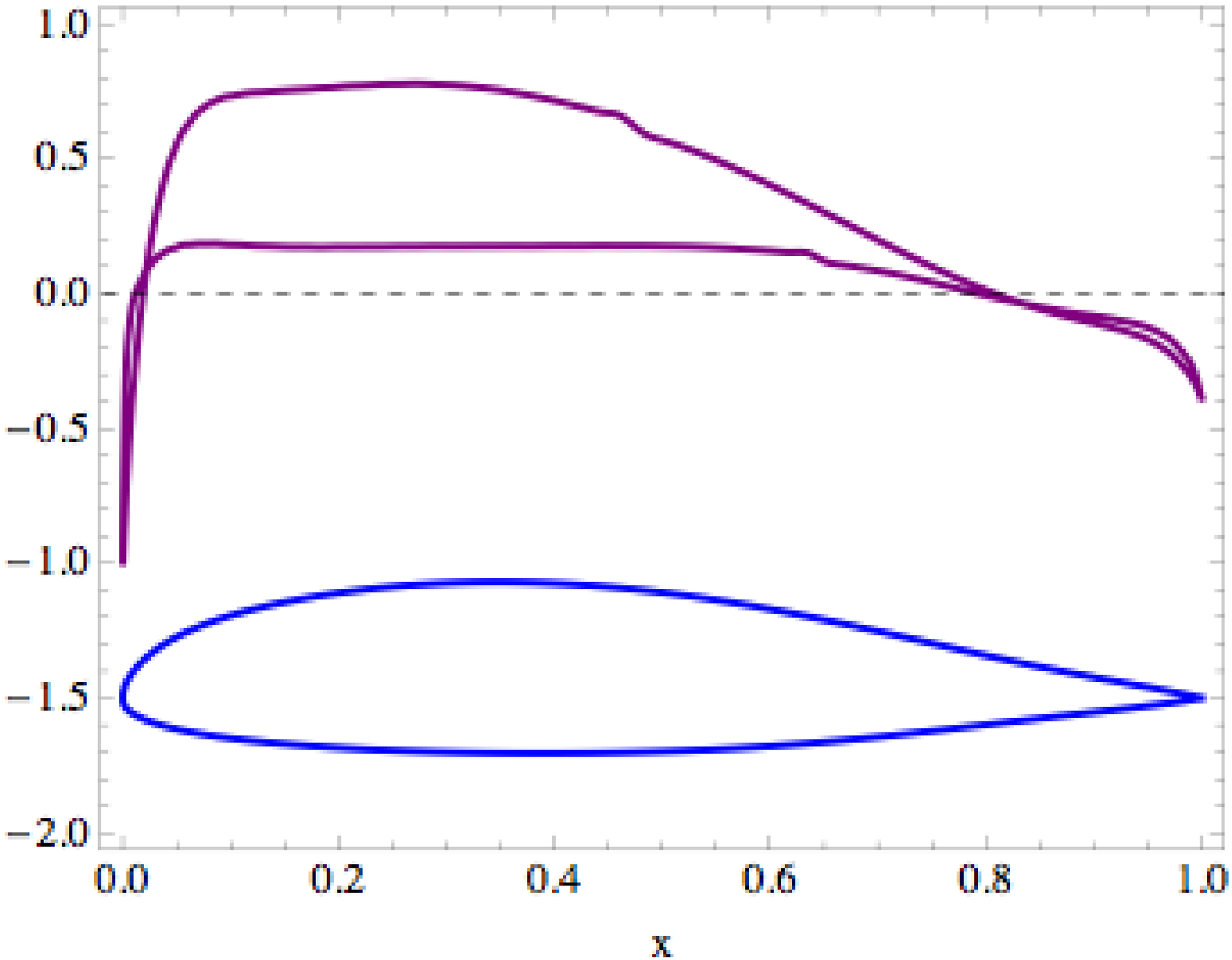
empty: 632 kg (42.2%)
batteries: 500 kg (33.5%)
passengers (4): 364 kg (24.3%)

Maximum Power: 150 kW
Continuous Power: 85 kW
Cruise Power: 32 kW
L/D (100 mph): ~30

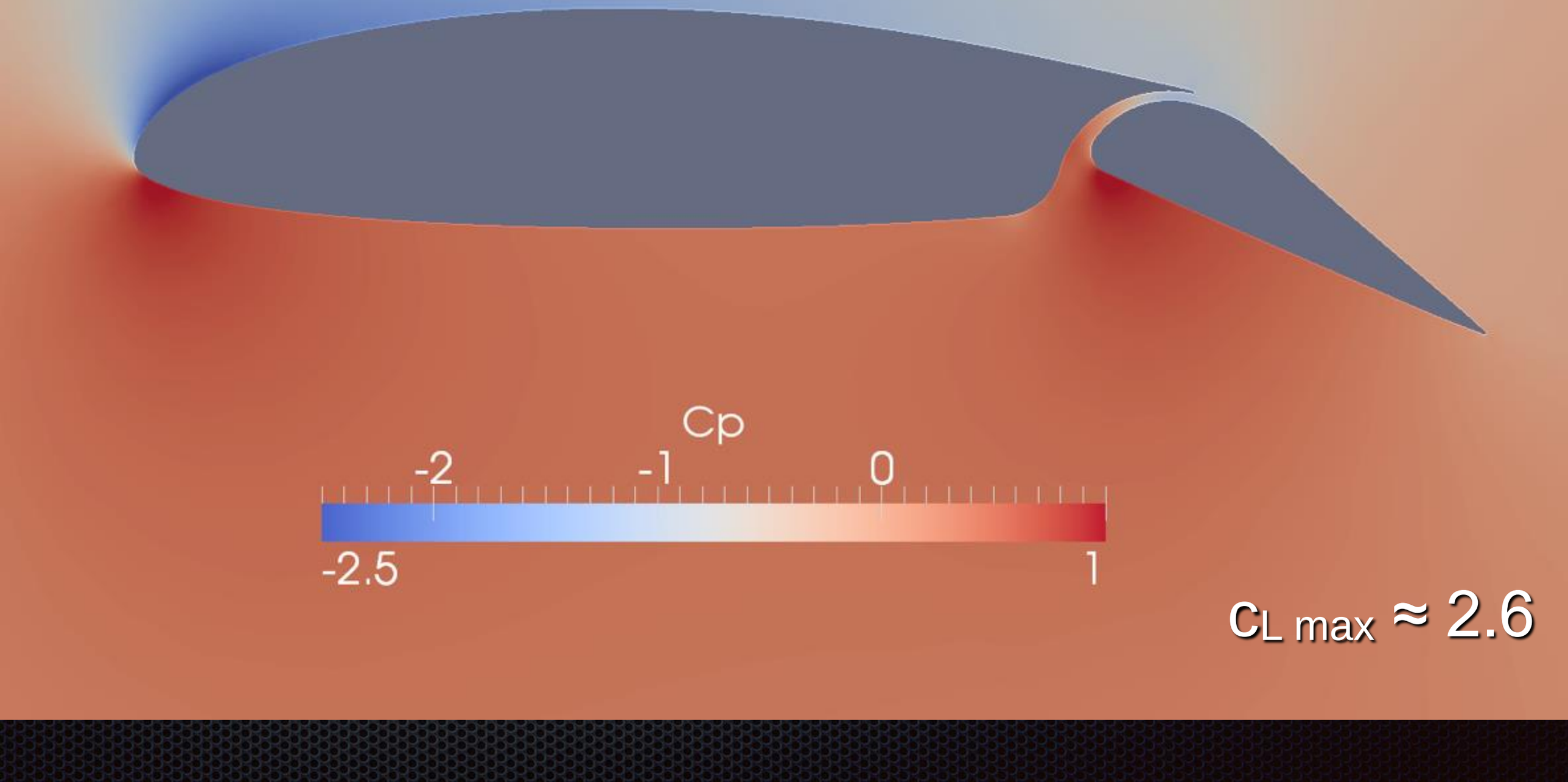
Energy capacity: ~100 kWh

Central wing airfoil





Slotted flap design

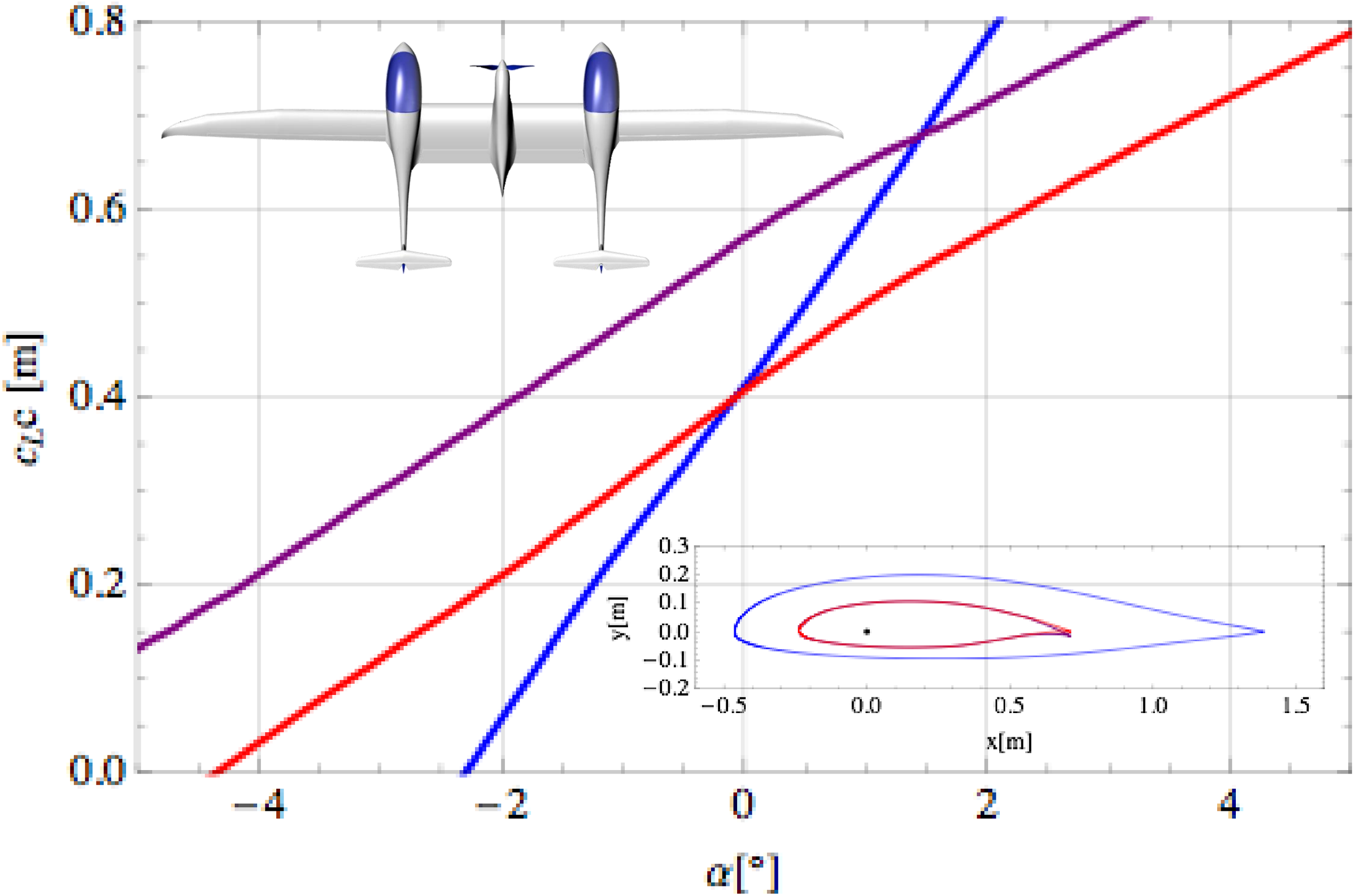


$c_{L\,max} \approx 2.6$

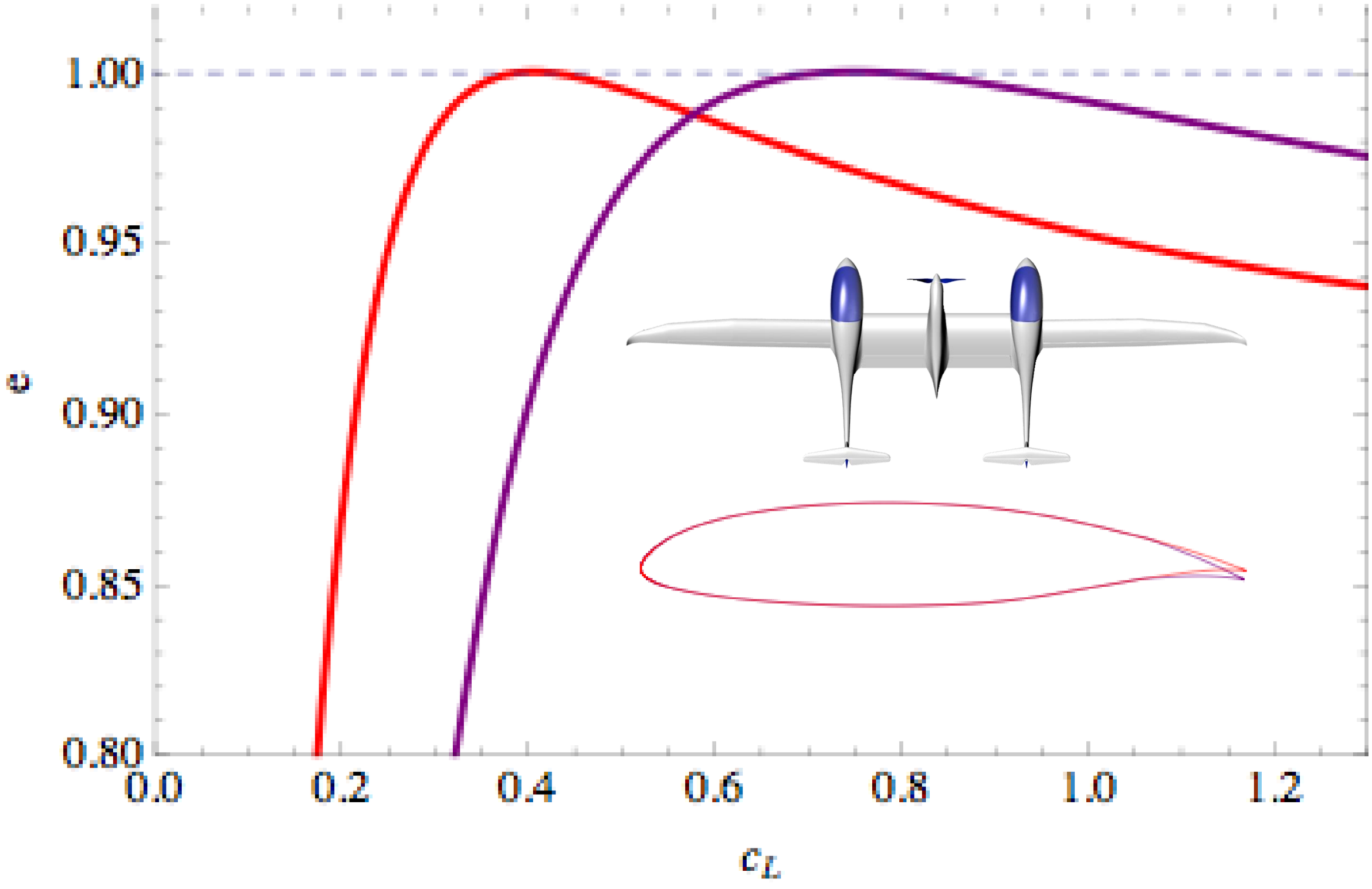
Lift induced drag

Spanwise vorticity distribution

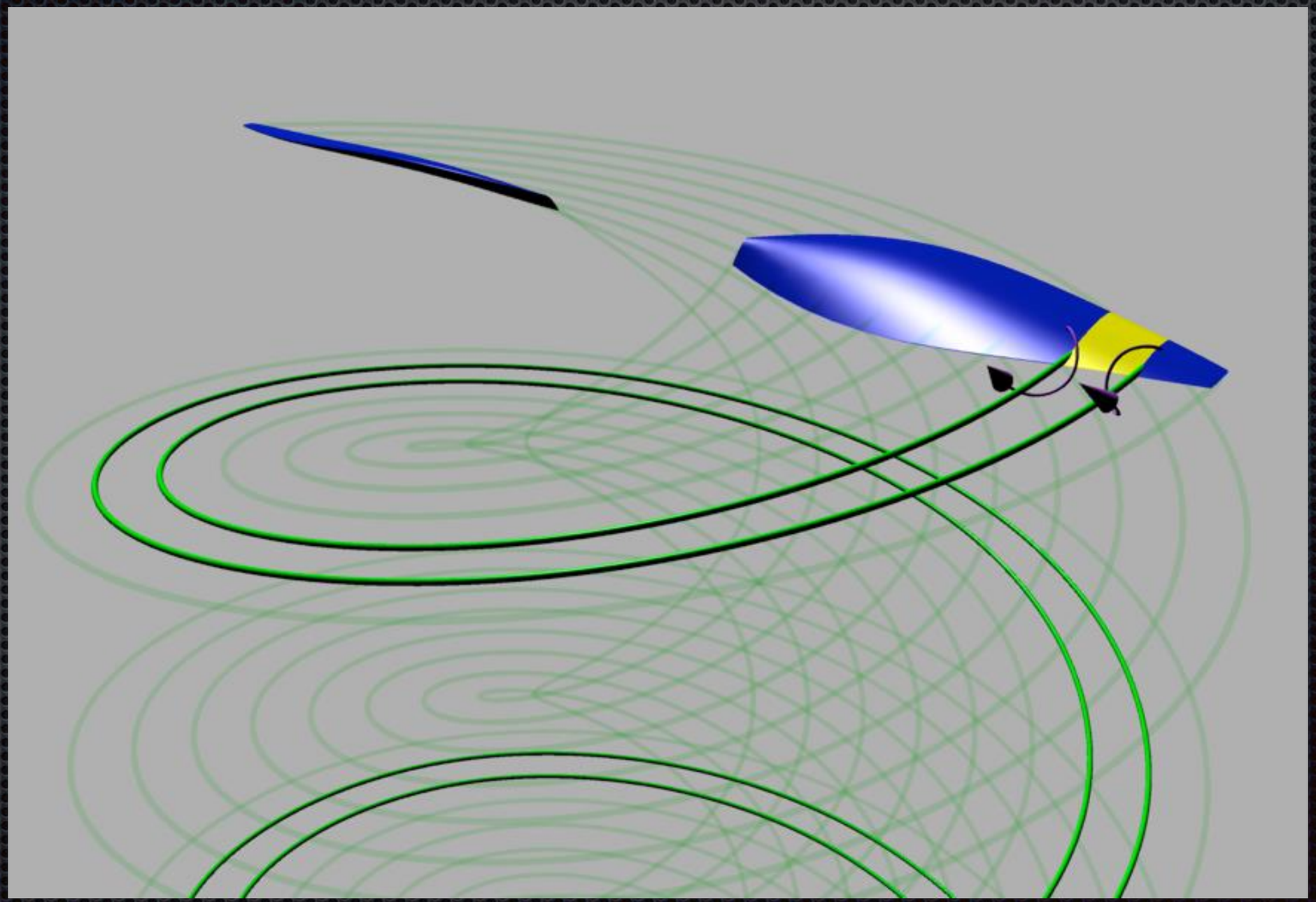
Lift distribution matching



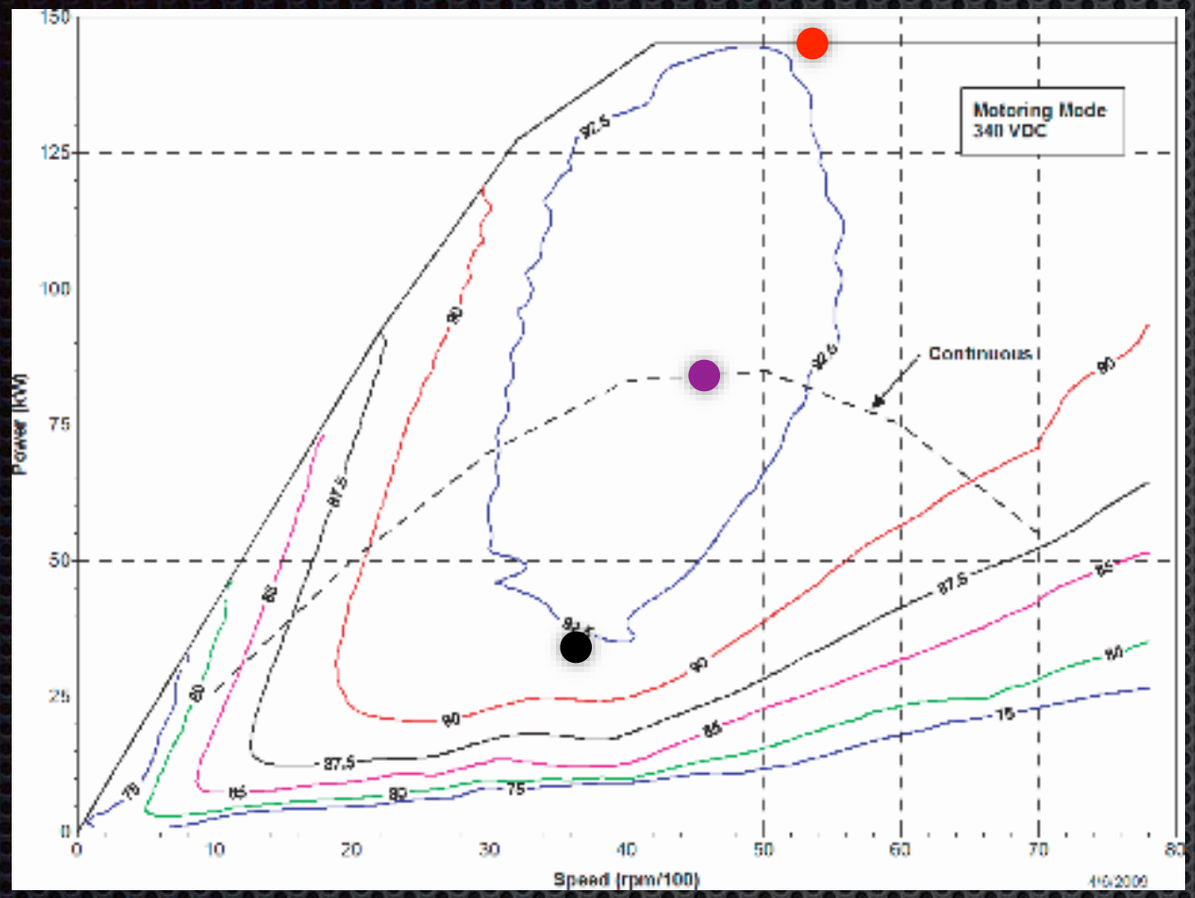
Span efficiency

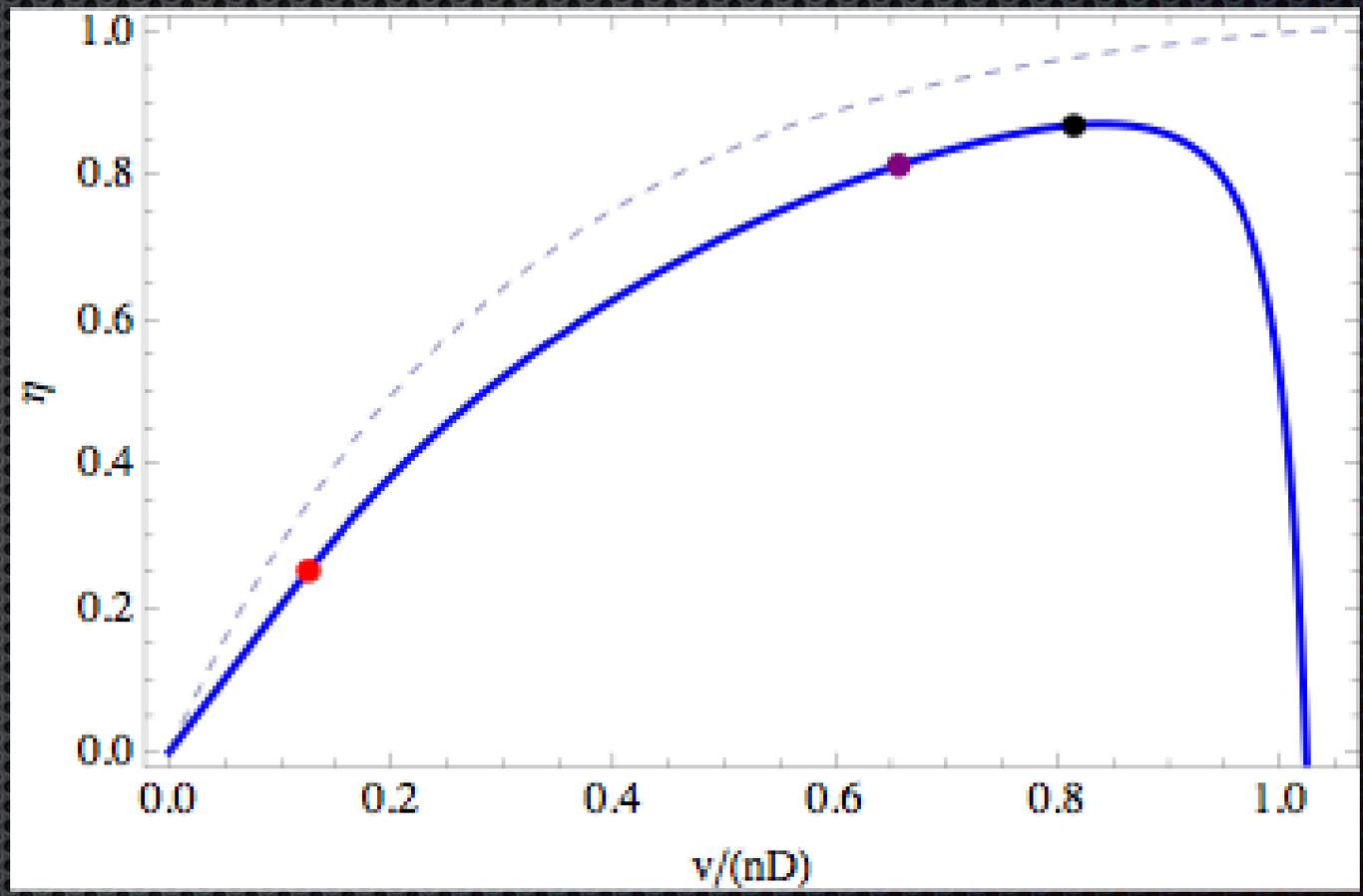


Lifting line theory for propeller design

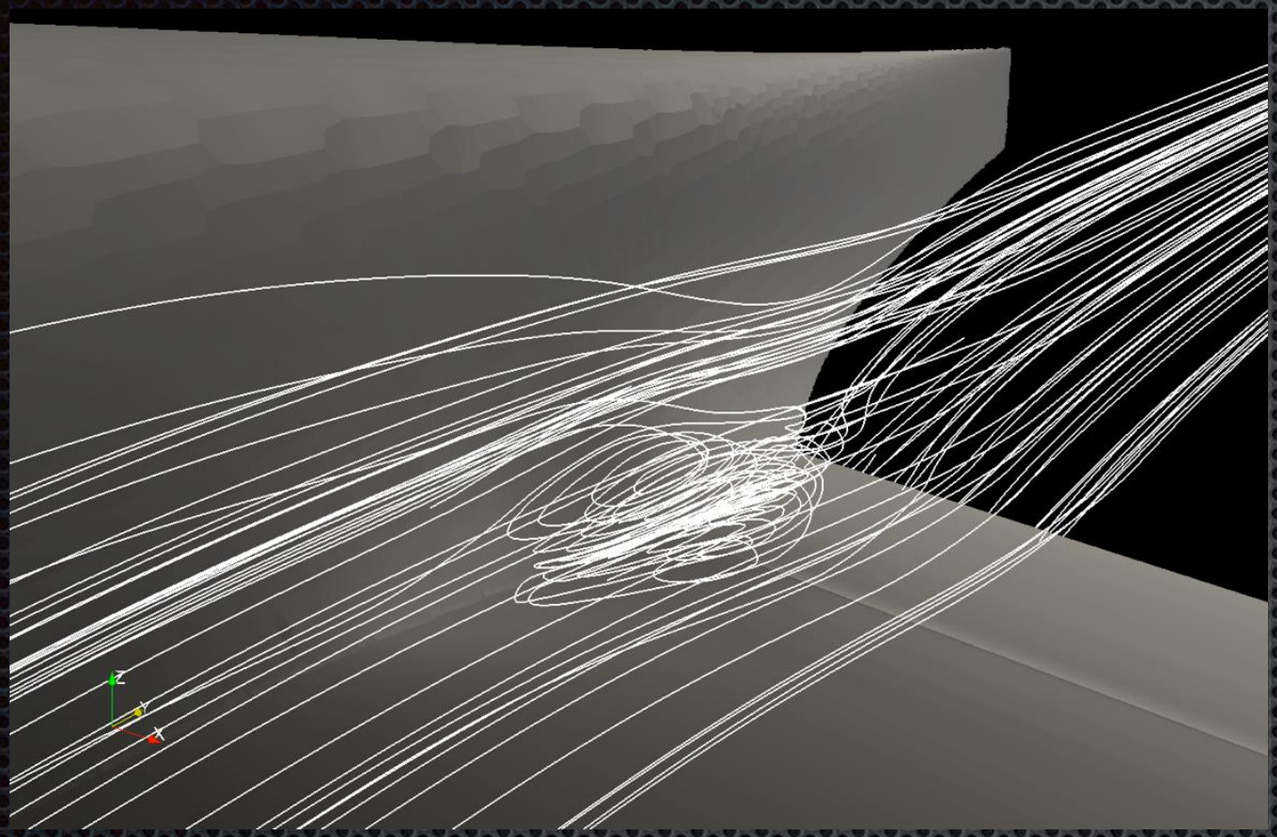


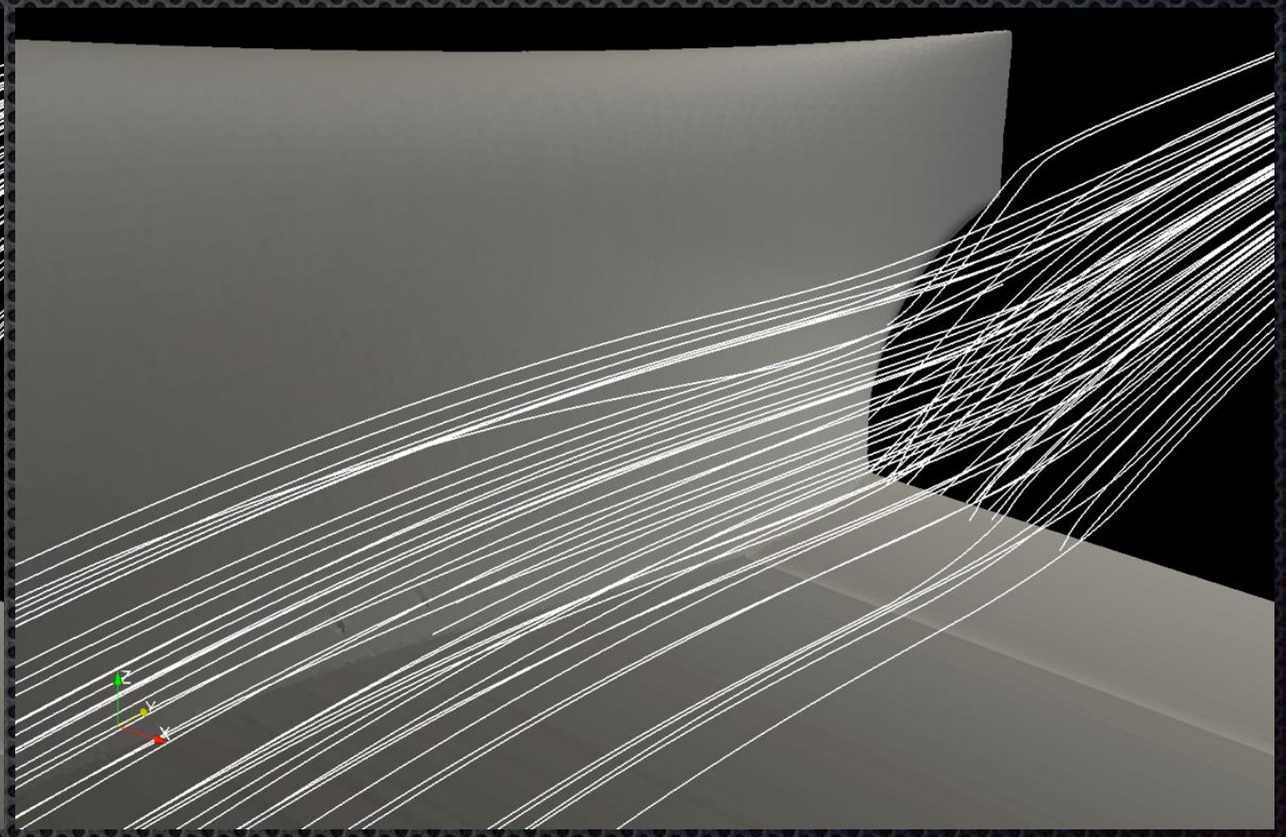
Propeller design





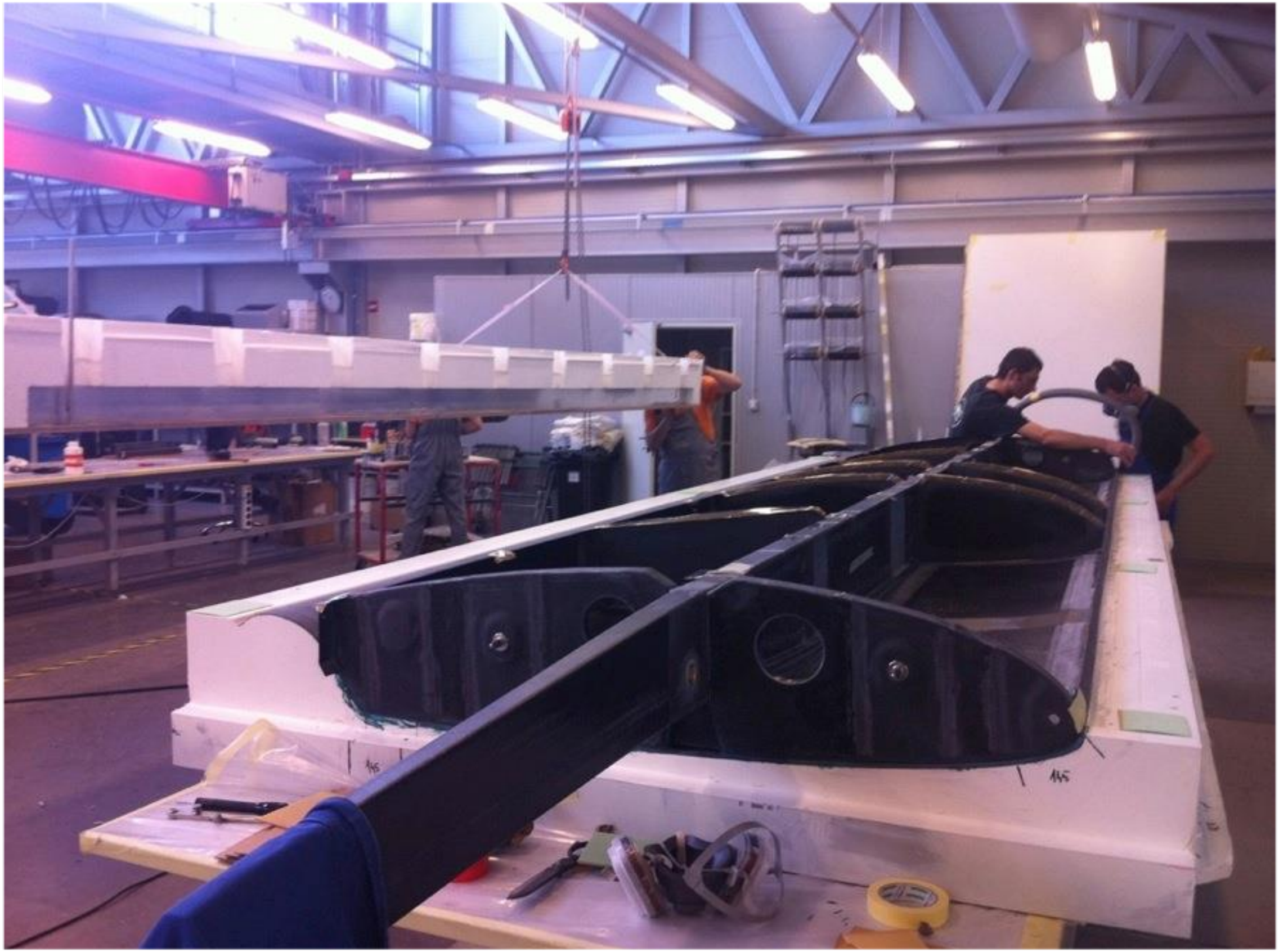
CFD analysis and modifications





22 January 2011


Sikablock



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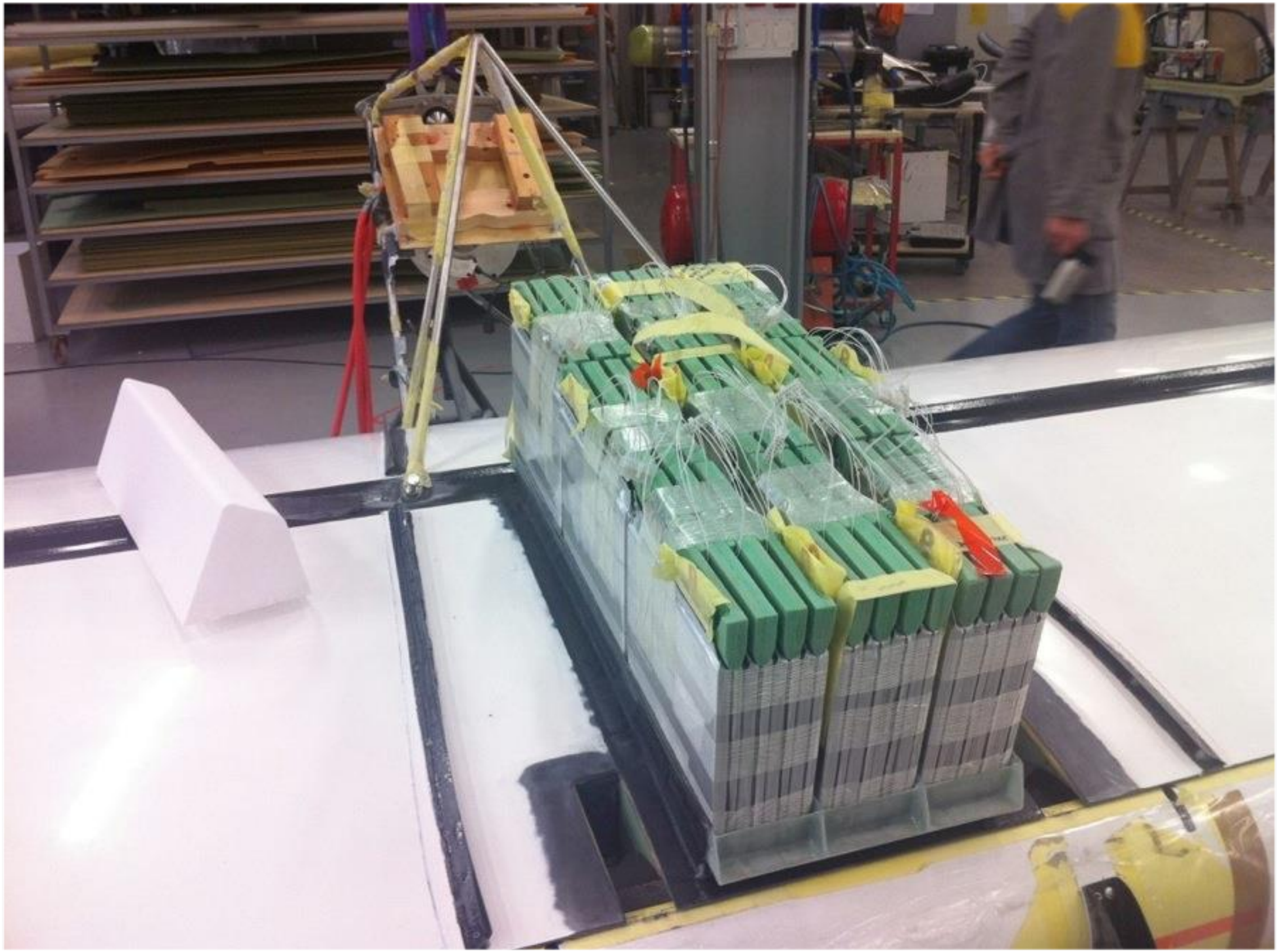

30 March 2011


SALONIT ANHOVO
SALONIT ANHOVO

28 April 2011


S5-MAP


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4 May 2011


NASA
PIPISTREL

4 August 2011

Oshkosh, 12 August 2011


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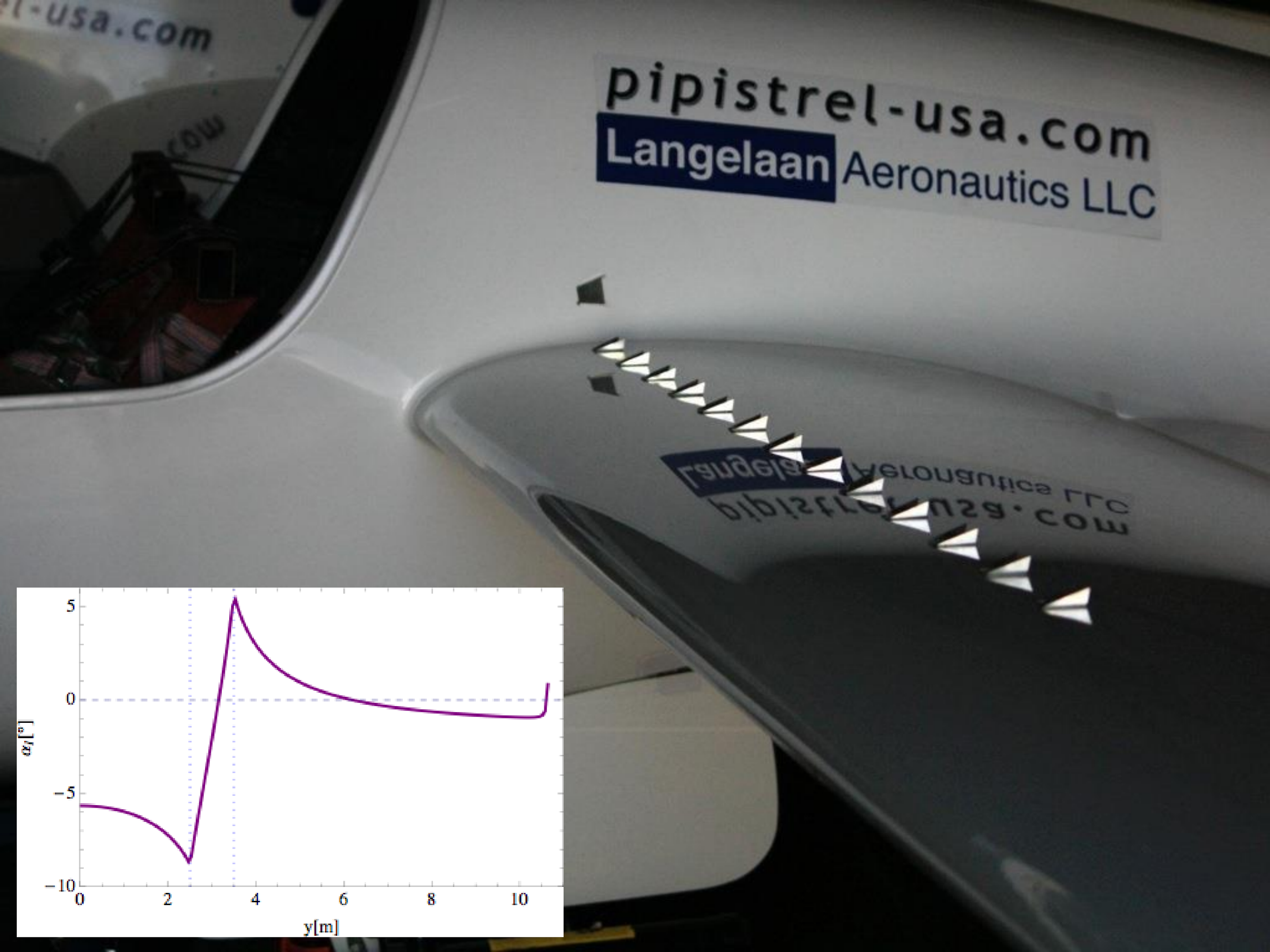
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Outboard flaps -5°, inboard flaps 40°
thrust reverser on touchdown

24 September 2011

Hollister, CA, United States - Google Maps

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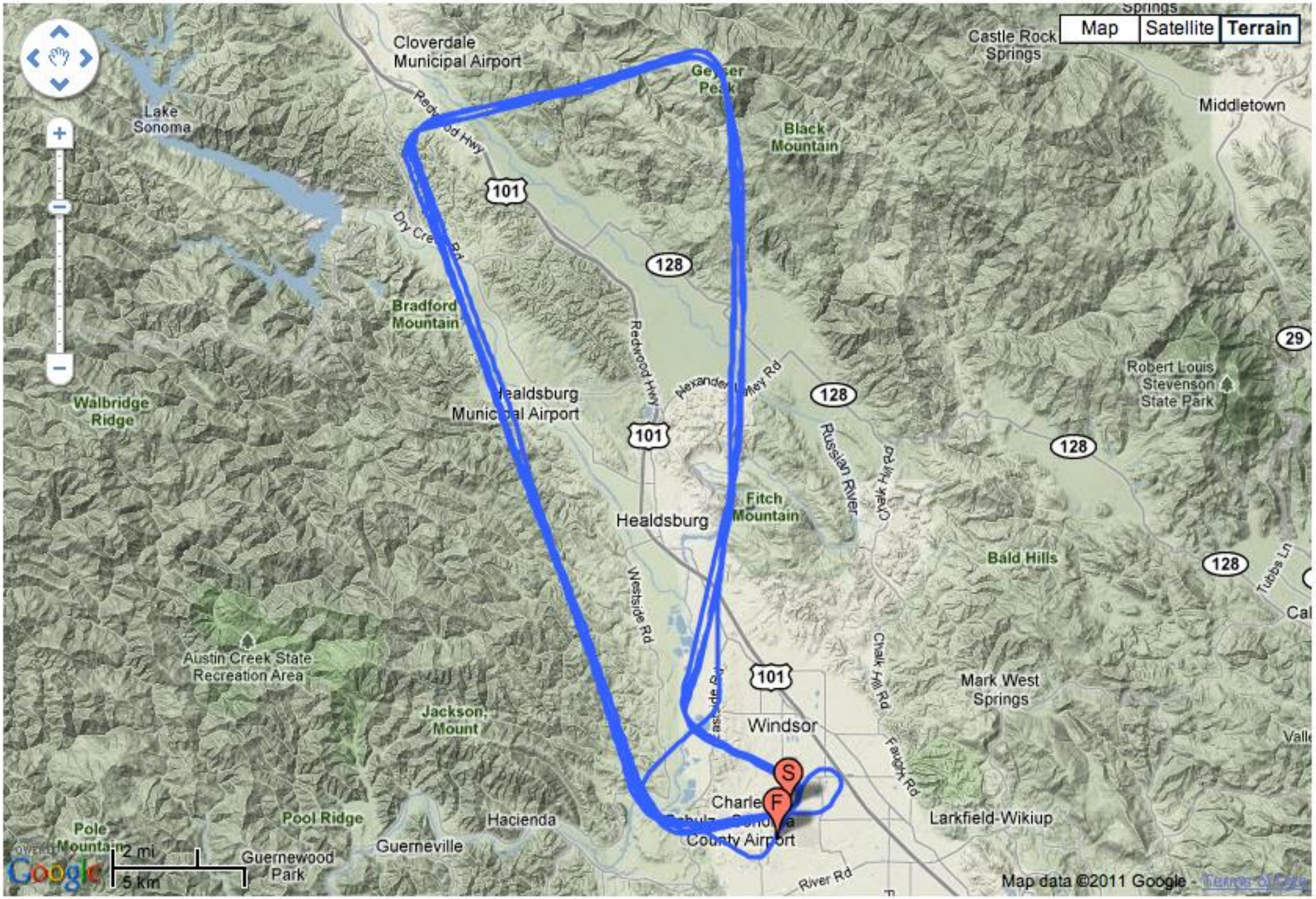
Map : geographic trace only



PIPISTREL, N448EC


Ames Research Center
Moffett Field
Flight Operations


NASA CENTENNIAL CHALLENGES
2011 GREEN FLIGHT CHALLENGE
First Place
TAURUS G4

Green Flight Challenge Sponsored by Google - Final Results

Efficiency Competition

Team	**Pipistrel**	e-Genius	Phoenix	Embry-Riddle	Metric
Fuel used			3.82	3.82	Gallons 100LL
Energy used	65.4	34.7		3.8	kWh
Equivalent fuel used	1.94	1.03	3.98	4.10	Gallons (auto fuel)
Flight time (for speed)	1:47:16	1:48:27	2:25:01	2:00:48	Time
Flight time (for mileage)	1:49:37	1:50:23	2:25:43	2:04:07	Time
Distance (for speed)	192.0	191.0	186.7	142.5	Miles
Distance (for mileage)	195.9	193.7	187.8	148.1	Miles
Mileage	**403.5**	375.7	94.3	72.2	ePMPG
Speed	**107.4**	105.7	77.3	70.7	MPH

Speed Competition

Team	**Pipistrel**	e-Genius	Phoenix	Embry-Riddle	Metric
Fuel used			6.61	4.19	gallons 100LL
Energy used	68.3	37.5		3.0	kWh
Equivalent fuel used	2.03	1.11	6.90	4.47	gallons (auto fuel)
Flight time (for speed)	1:41:55	1:47:45	1:22:11	1:43:21	Time
Flight time (for mileage)	1:44:10	1:50:24	1:22:57	1:44:53	Time
Distance (for speed)	193.0	192.7	188.4	143.9	Miles
Distance (for mileage)	196.8	196.2	189.5	146.2	Miles
Mileage	**388.4**	352.4	55.0	65.5	ePMPG
Speed	**113.6**	107.3	137.5	83.5	MPH
Score	**72.7**	68.3	35.1	25.2	GFC Score

Score = 1/(1/Speed + 2/Mileage)

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NASA Awards Historic Green Aviation Prize

NASA has awarded the largest prize in aviation history, created to spark the start of a new electric airplane industry. First prize of $1.35 million in the CAFE Green Flight Challenge, sponsored by Google, was awarded to team Pipistrel-USA.com.

› Learn More | › Green Flight Challenge | › Flickr Gallery→

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Awards

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Awards News > 2011 Collier Trophy Nominees and Solection Committee Announced

2011 COLLIER TROPHY NOMINEES
AND SELECTION COMMITTEE ANNOUNCED

Arlington, Virginia, February 2, 2012 -- The National Aeronautic Association (NAA) announced that former Collier Trophy recipients Dick Rutan, Joe Lombardo, Bobby Sturgel), and Jeff Pino will be among the aviation leaders who will participate in the Selection Committee for the 2011 Robert J. Collier Trophy. In addition, NAA released the list of nominees as well as the entire Selection Committee.

The nominees are:
• Boeing 787 Dreamliner
• C-5M Super Galaxy
• The Gamera Human-Powered Helicopter
• Taurus G-4 Electric-Powered Aircraft

The Collier Trophy, the "Greatest Award in Aviation," has been the benchmark of aviation and aerospace achievement for over 100 years. Awarded annually "….for the greatest achievement in aeronautics or astronautics in America," it has been bestowed upon some of the most important projects, programs, individuals, and accomplishments in our nation's history.

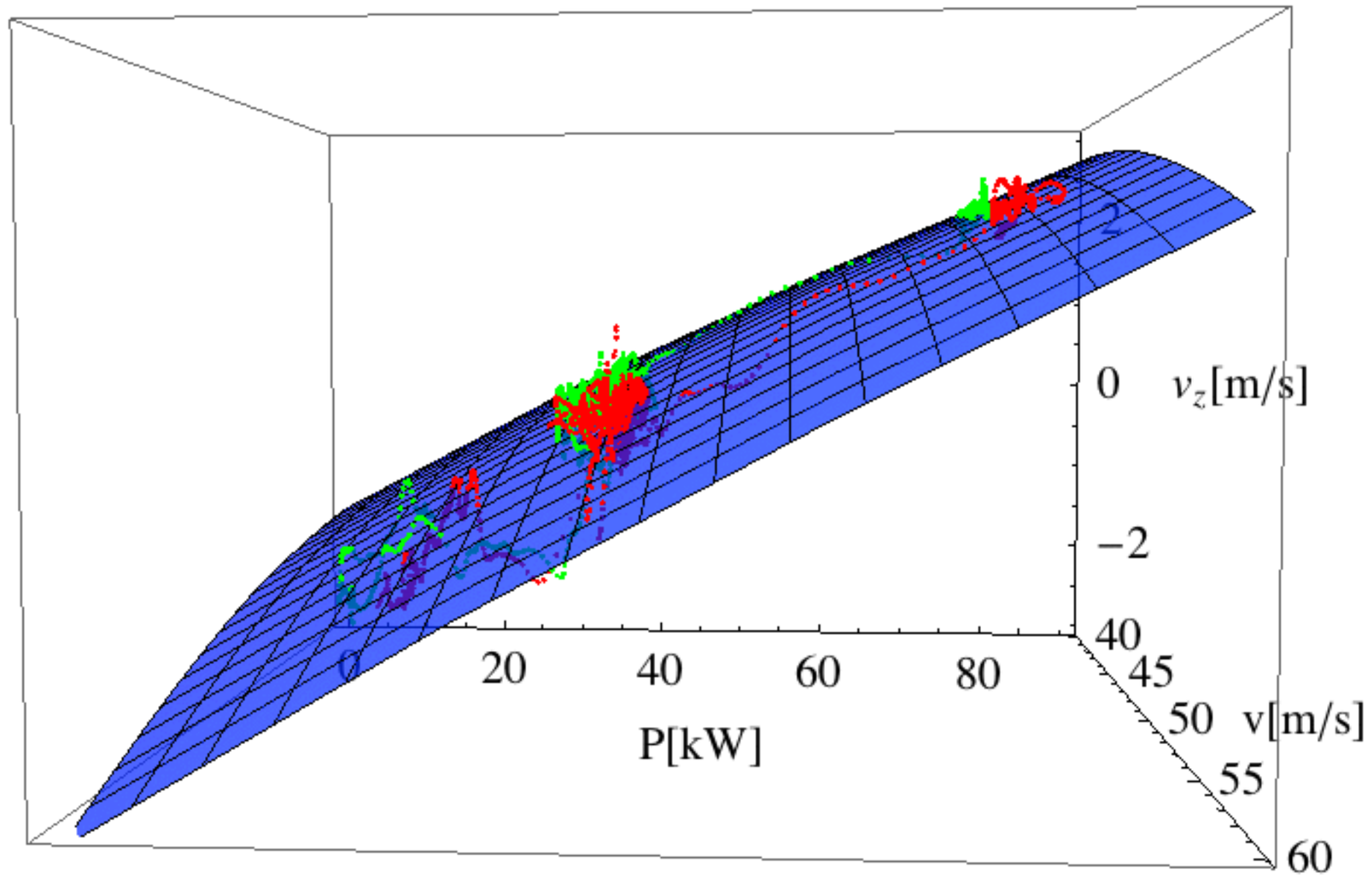
Past winners include the crews of Apollo 11 and Apollo 8, the Mercury 7, Scott Crossfield, Elmer Sperry and Howard Hughes. Projects and programs which have been the recipient of the Collier include the B-52, the Polaris Missile, the Surveyor Moon Landing Program, the Boeing 747, the Cessna Citation, the Gulfstream V, the F-22, and the International Space Station. The 2010 Collier was awarded to the Sikorsky X2 Technology™

LATEST WINNERS GALLERY

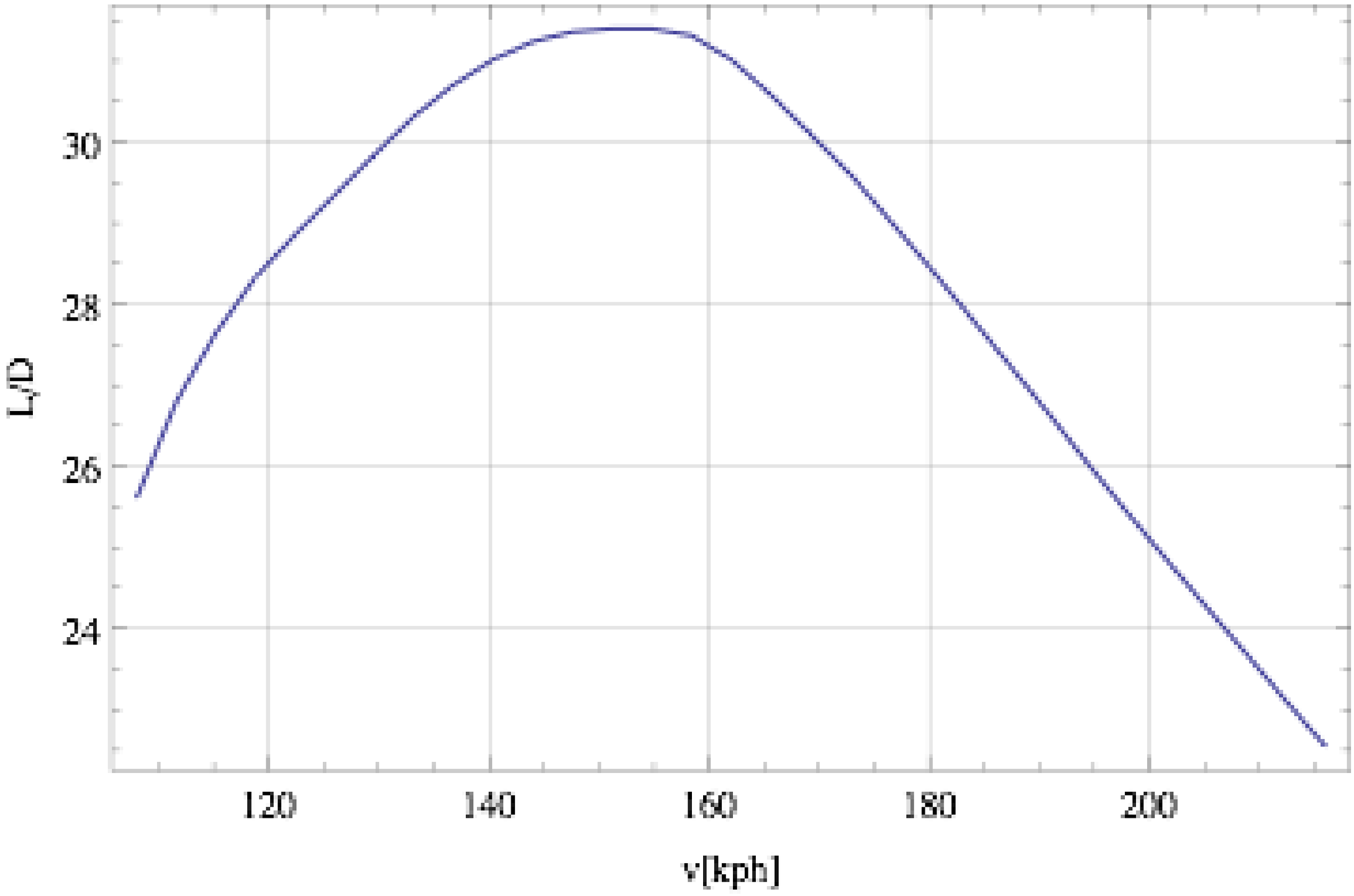
> View the Awards Gallery

NAA THANKS:
- Aurora Flight Sciences

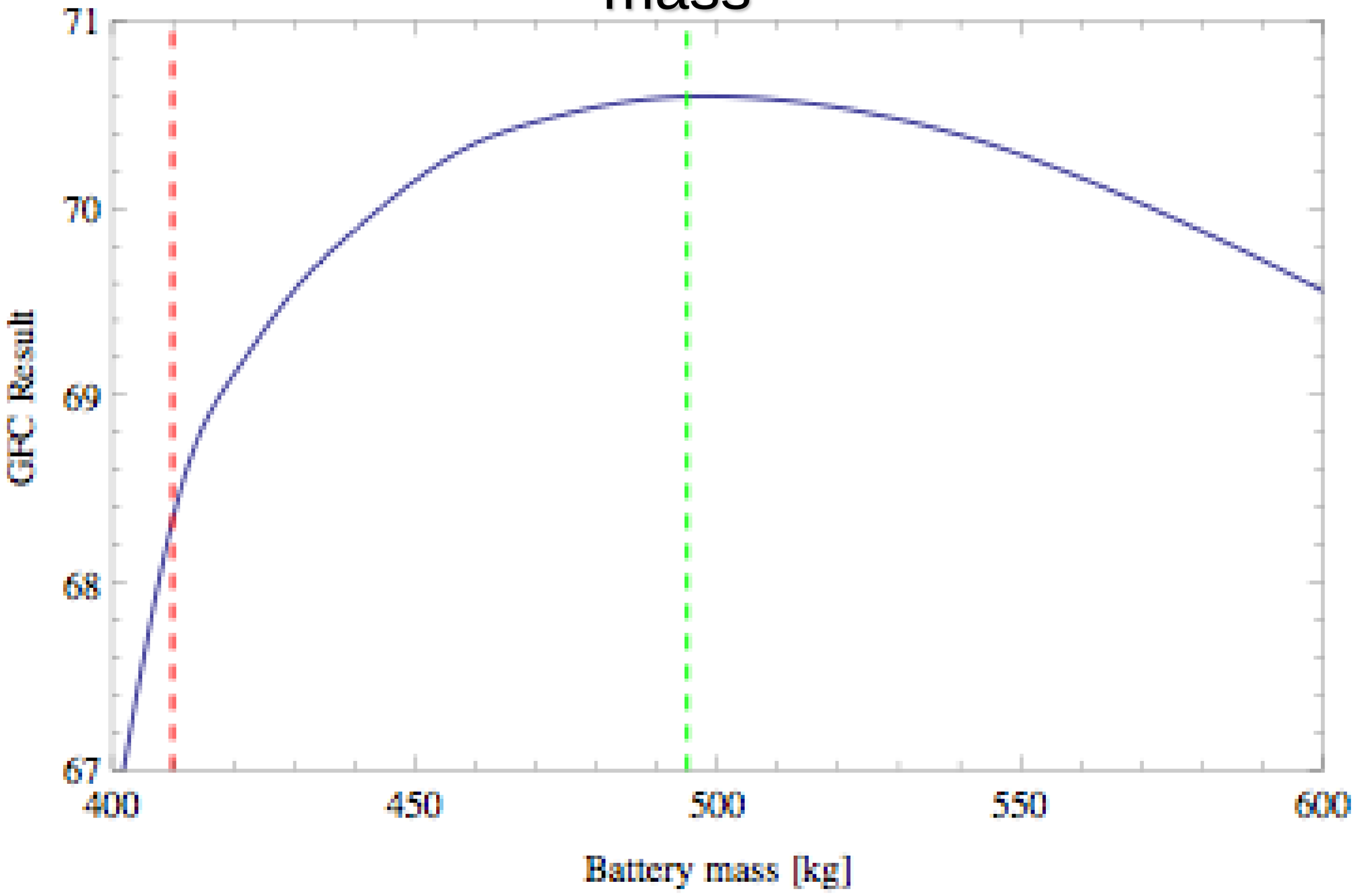
Competition performance and calibrated aircraft model



Calibrated lift to drag ratio



Competition result vs. battery mass

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