An Open-Rotor Distributed Propulsion Aircraft Study

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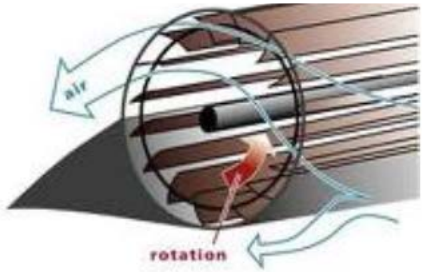
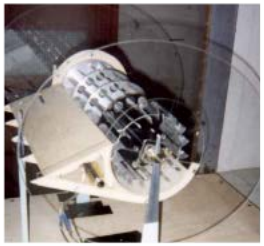
DLR

Agenda

- FanWing Early Development
- SOAR Background
- 3 Research Questions & Results
    - Scalability
    - Power Required
    - Economic Competitiveness
- Conclusions and Questions

FanWing Early Development

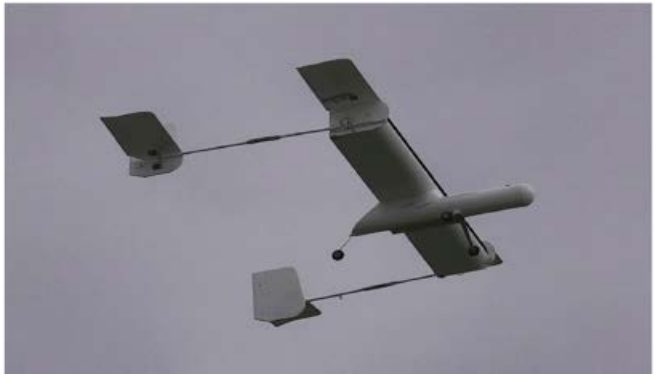




FanWing Early Development

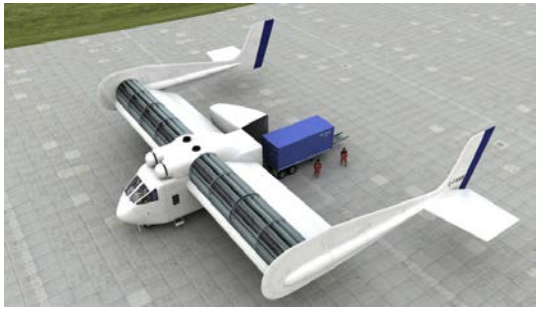
10kg model

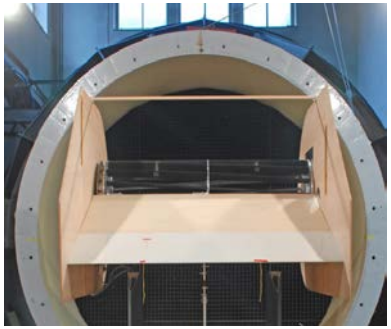
1kg model



Flies more efficiently,
Faster

SOAR Background



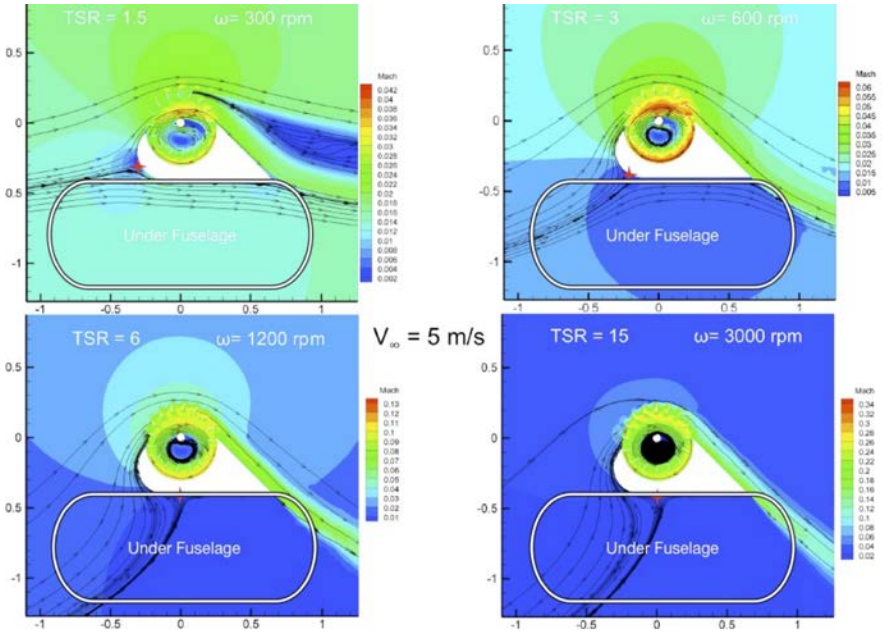


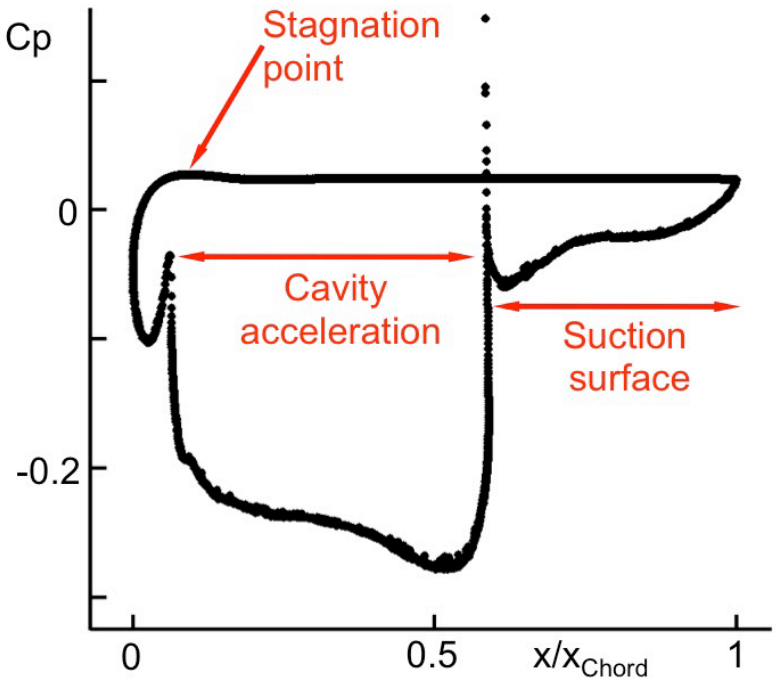
- EU sponsored project, 4 partners
- 3 key research questions: scalability, power requirements, and economic competitiveness
- 1 wind-tunnel test, 1 bench test, unsteady cfd, market & econ analysis
- 4 publications, youtube documentary: soar-project.eu

3 Research Questions

- Scalability
  - Does the vortex scale up to higher fan radii?
- Power Required
  - What is the required power to takeoff mass ratio?
- Economic Competitiveness
  - Is the FanWing Competitive in its selected target markets?

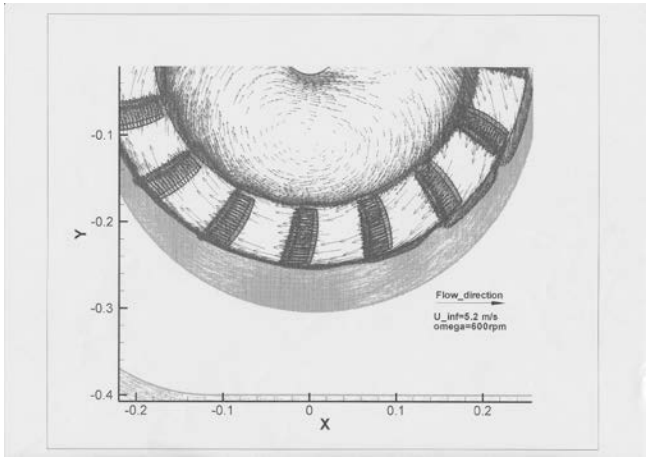
Scalability: Unsteady CFD

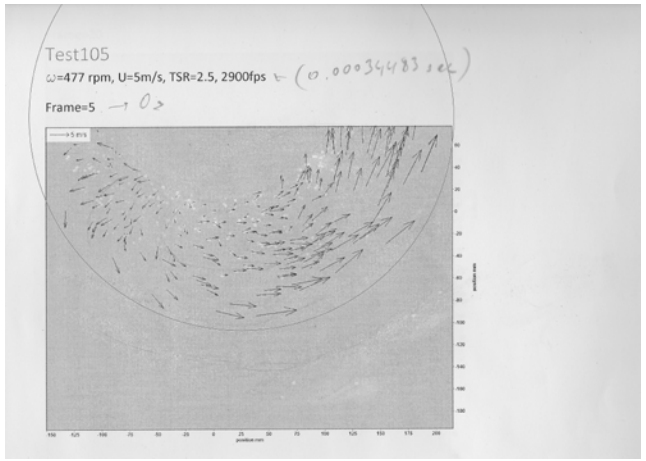


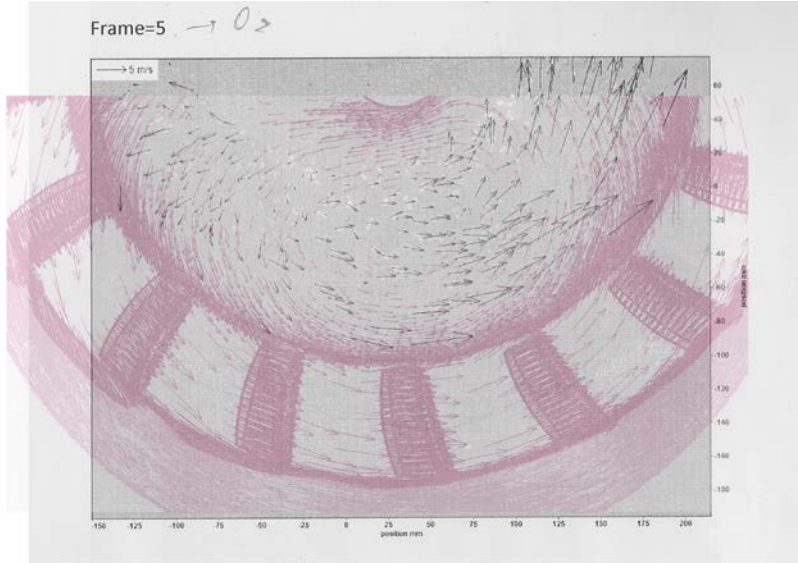


- CFD Shows that vortex is present at various operating conditions, even with variations of turbulence model
- Vortex creates a *very* low pressure zone above the curved section generating higher lift coefficents

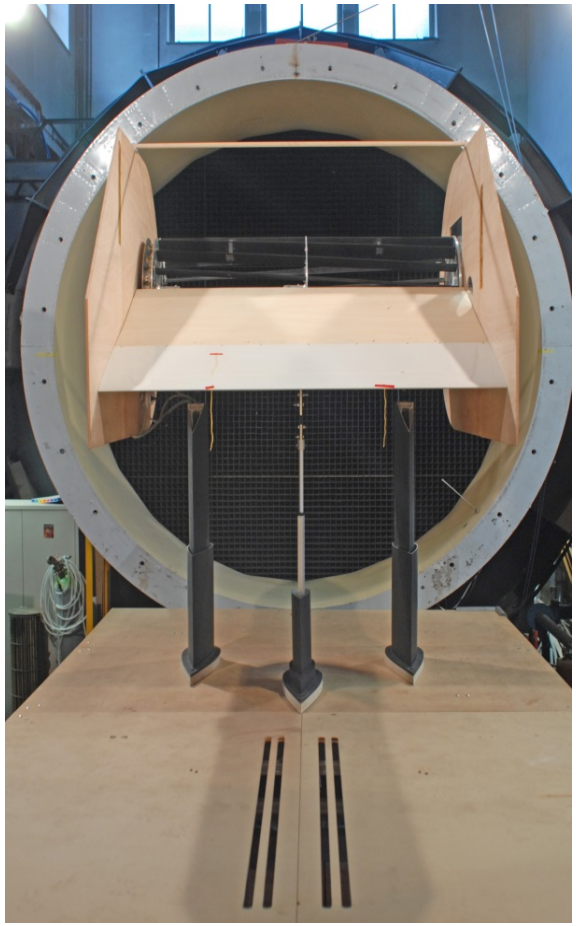
Scalability: VKI Test

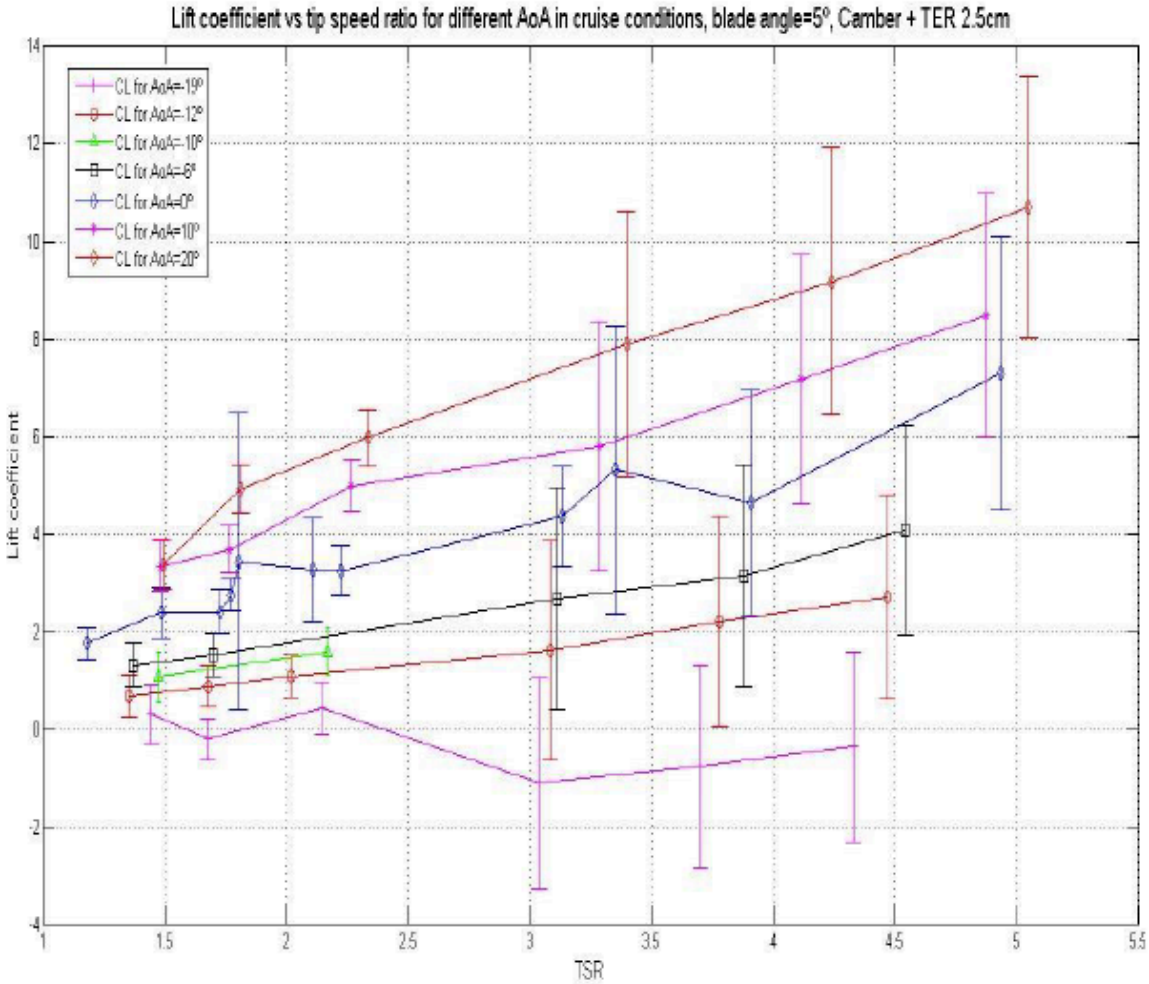




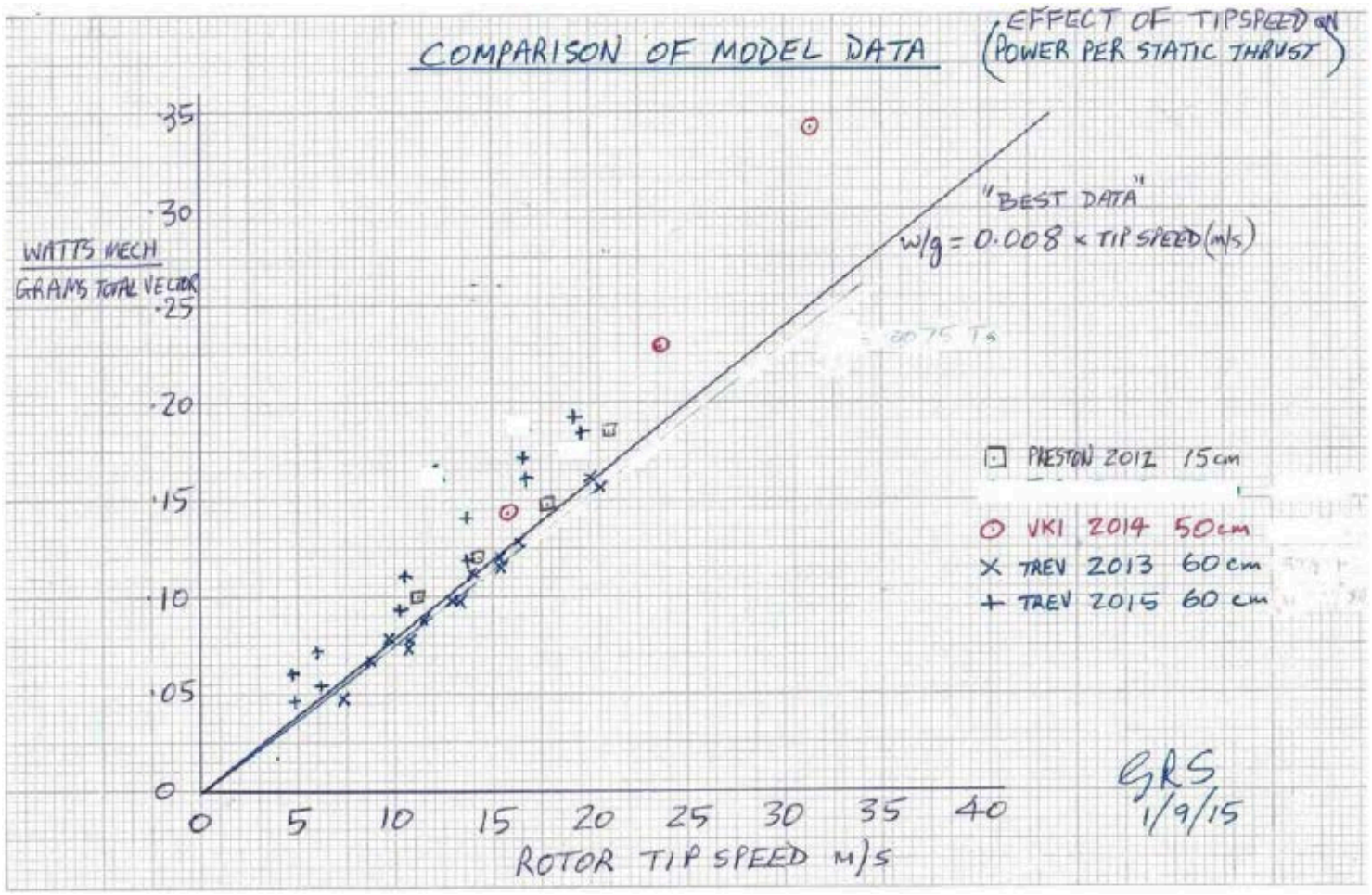


Scalability: VKI Test

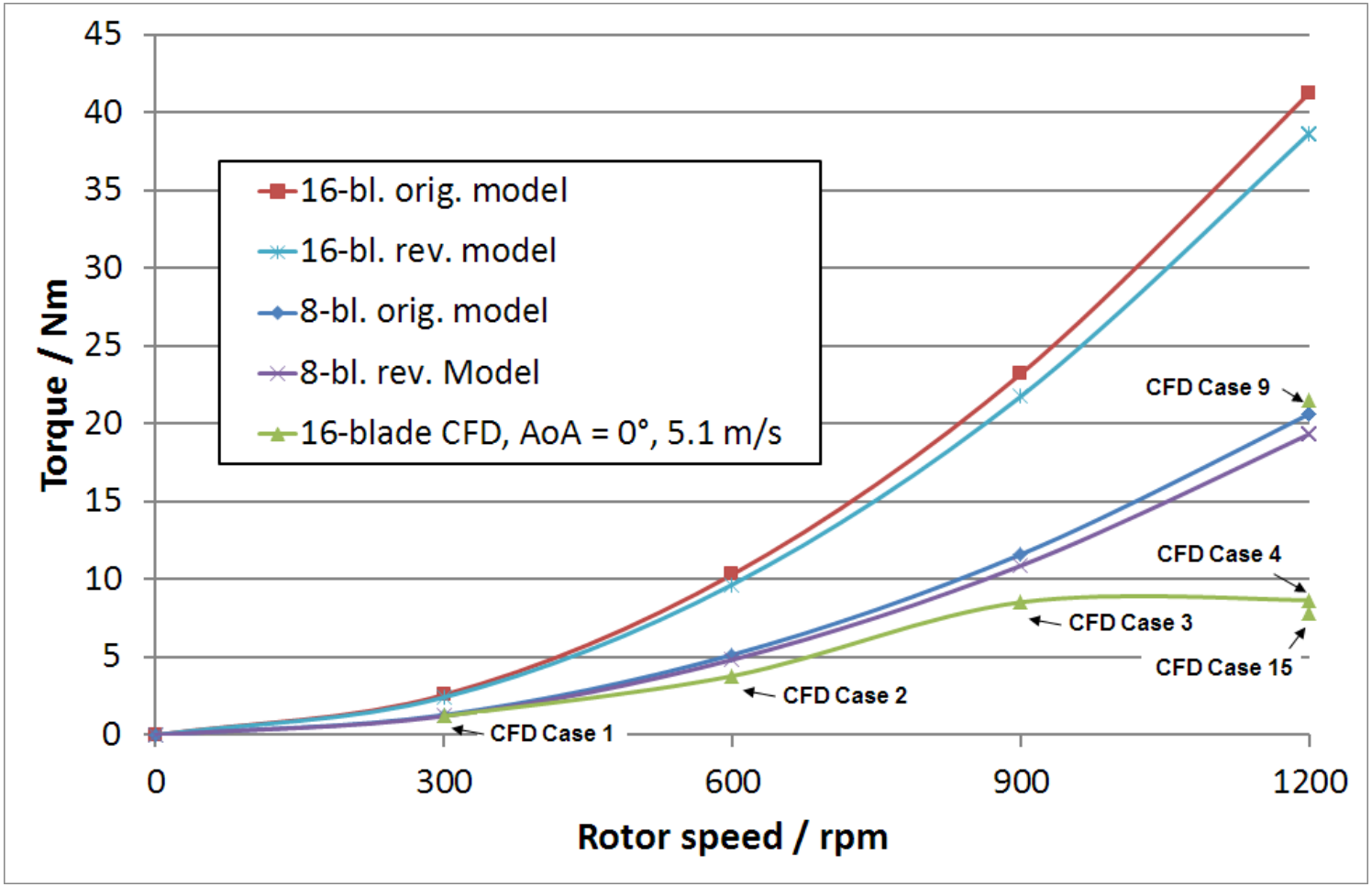




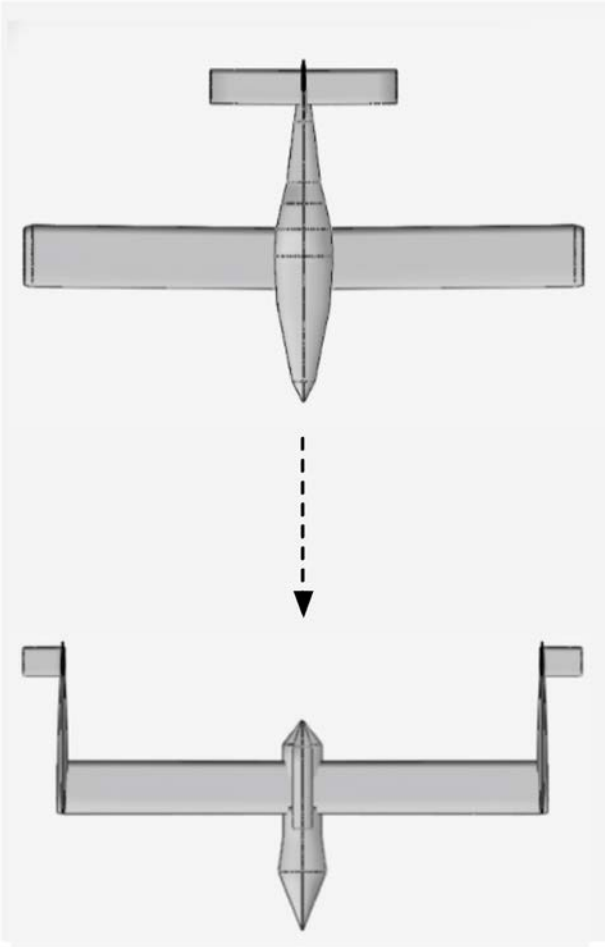
Scalability: Bench Test

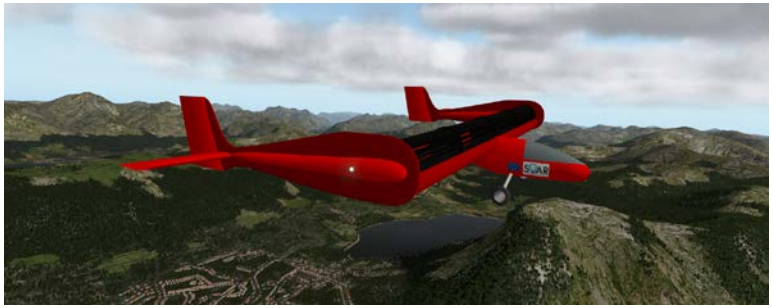


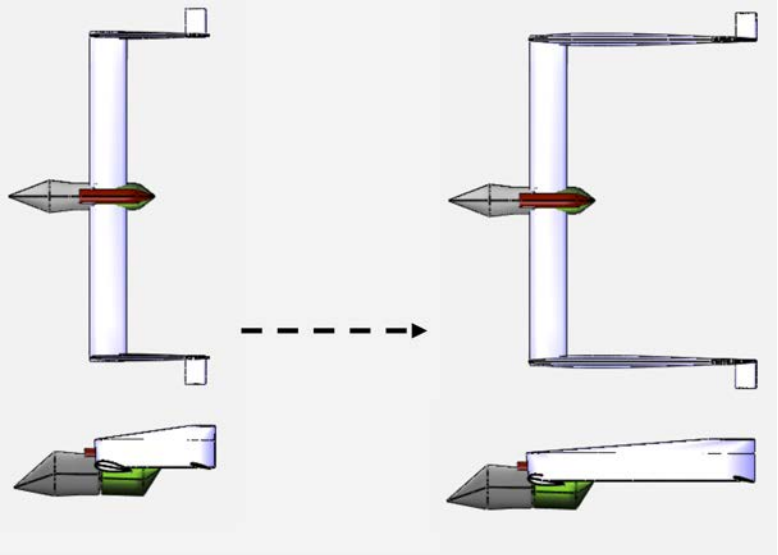
Power Required: Torque Comparison



Power Required: Aircraft Design Changes







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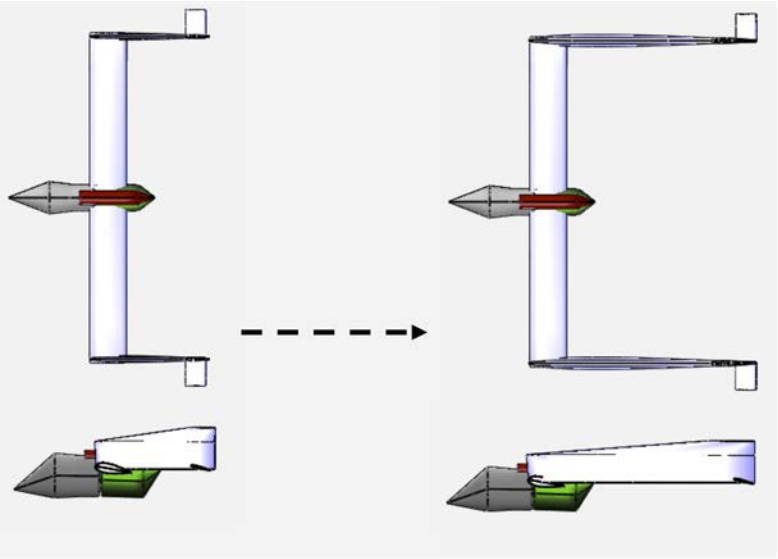
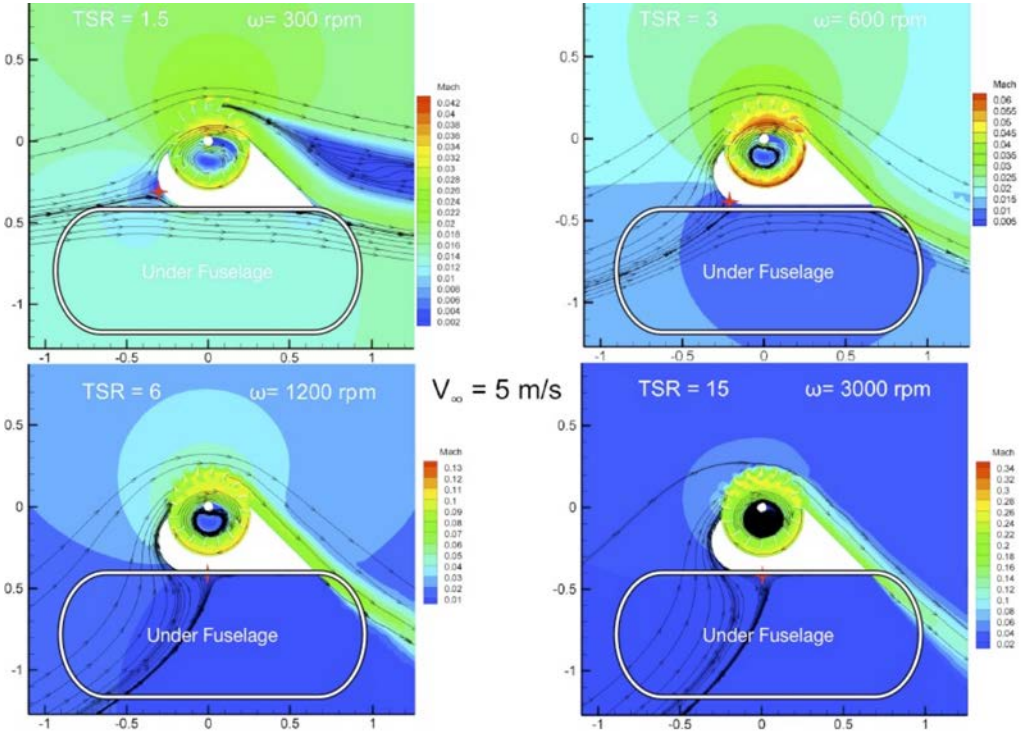
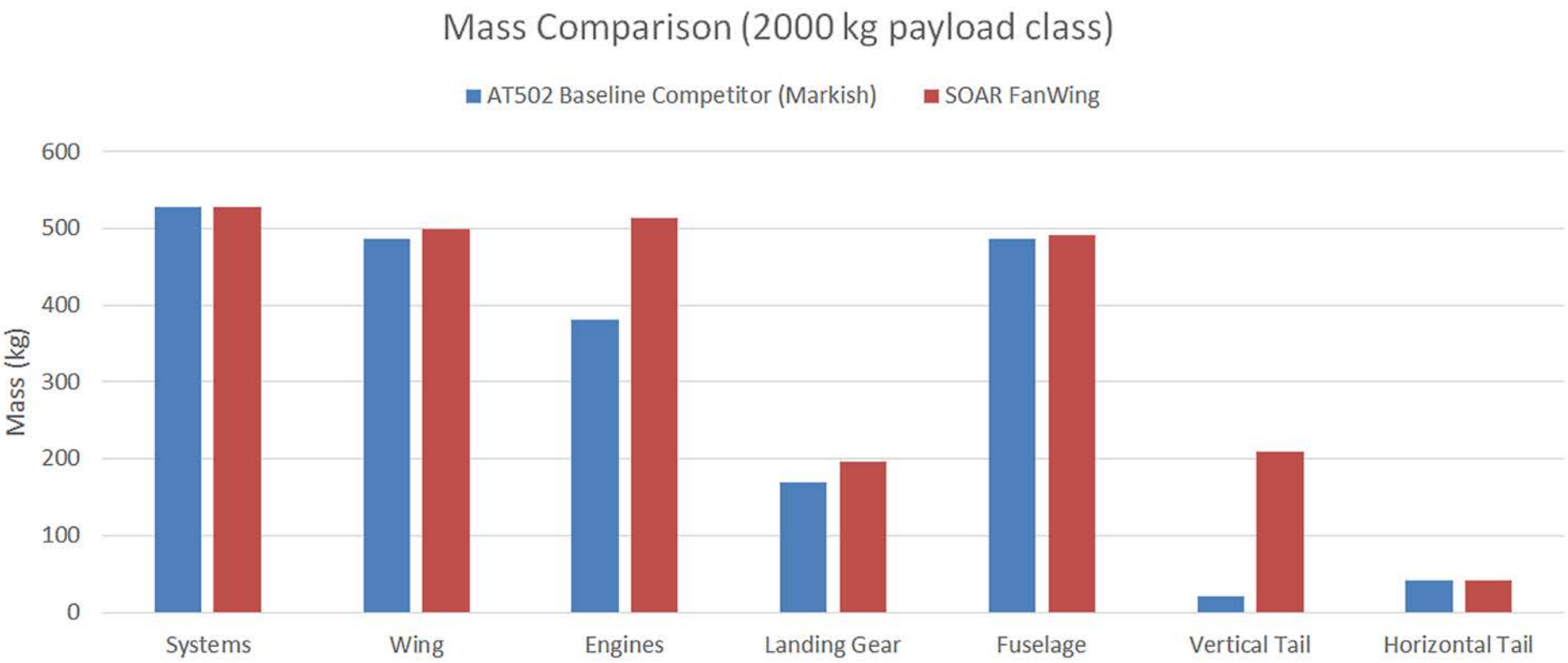


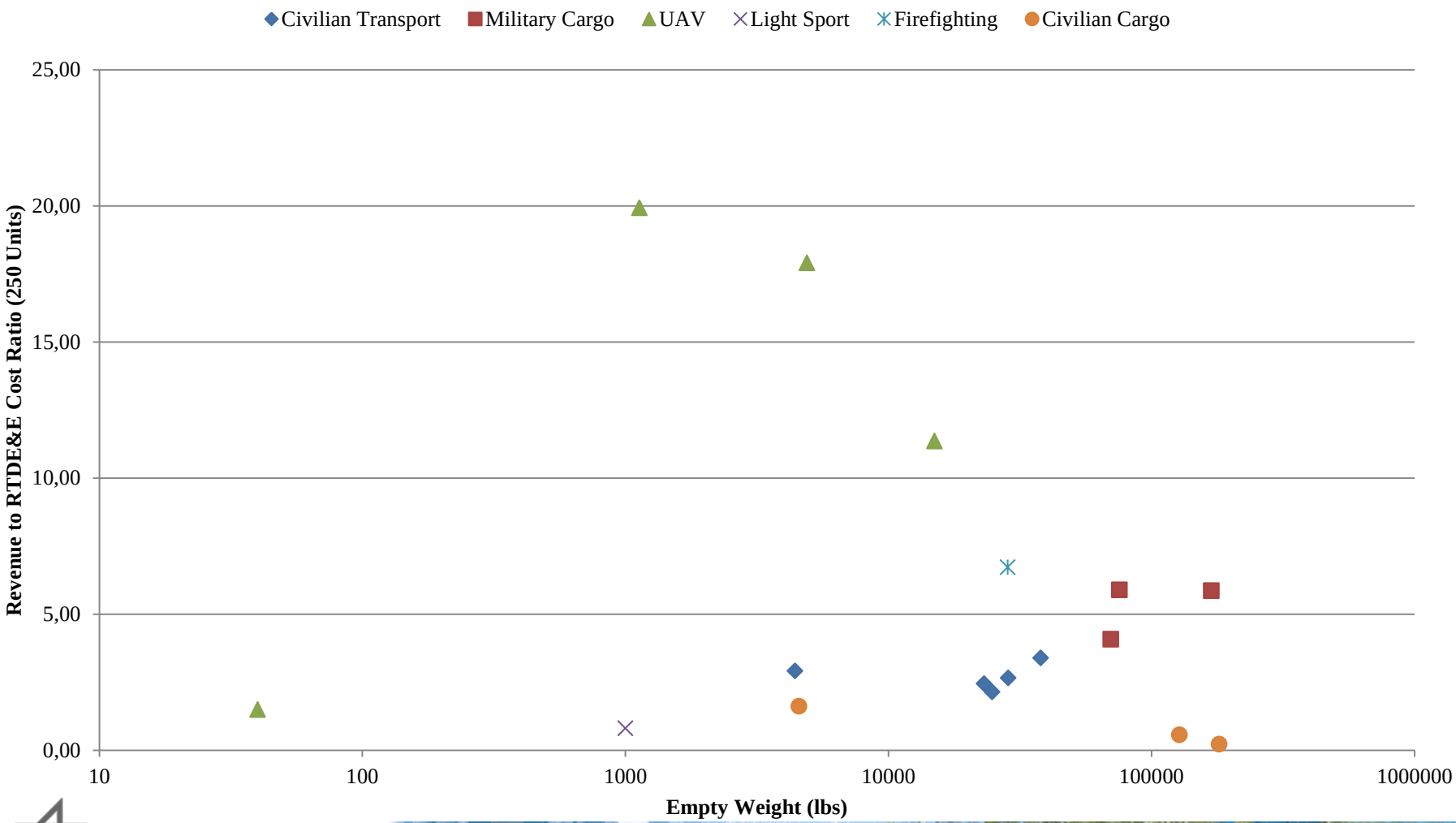


- Engine (red)
- Cockpit (grey)
- Payload (green)
- Ohs/Wing (light blue)

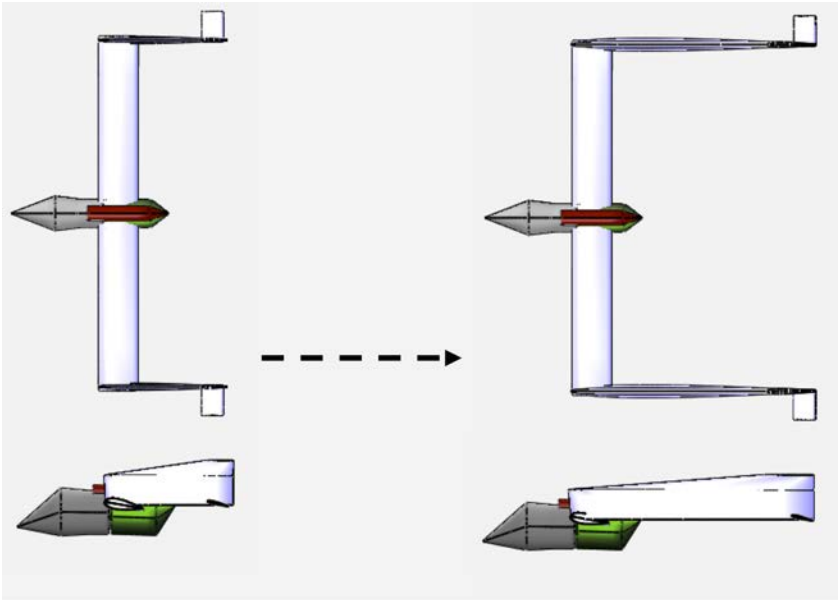
Power Required: Changes to Empty Mass



Economic Competitiveness



Power Required: Results



FanWing Design Changes	
Design Category	Change Factor
Payload Volume	2x
Empty Mass	1.17x
Required Operational Power	1.3x

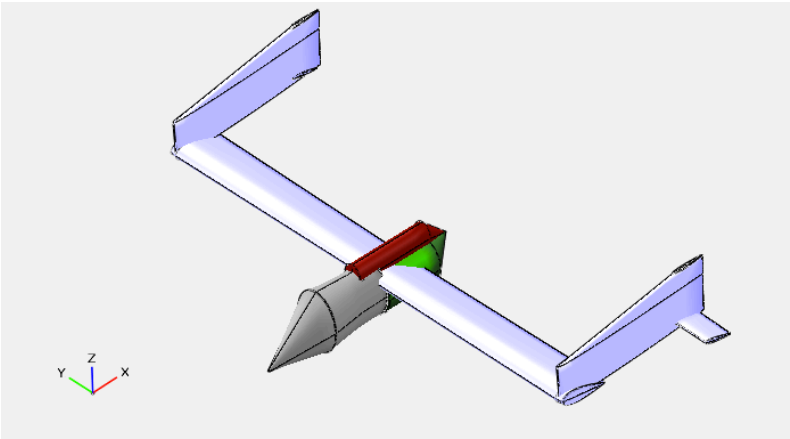
Power Required Comparison		
	Power to Maximum take-off Mass Ratio (kw/kg)	Take-off Rotation C_L
V-22 Tiltrotor	0.384	
VH-71 Kestral	0.361	
Sikorsky S-92	0.313	
AW109 Utility Helicopter	0.293	
FW. firefighting	0.231	4.3-5.7
FW. agricultural	0.223	4.3-5.7
Bombardier CL-415 STOL firefighter	0.178	1.45
AT 502 agricultural aircraft	0.172	1.55
Cessna Caravan Utility Aircraft	0.162	1.91

Economic Competitiveness

- Crop dusting 4000k built, 800-1000 per program
- ~5,000 kg MTOW
- Stall speed ~55 kts
- Takeoff Distance: 351m

- Firefighting (~400 built, 100 per new program)
- 217% acquisition premium over similar sized/powered passenger aircraft
- ~20,000 kg MTOW
- Stall speed: 68 kts
- Takeoff Distance: 815 meters

Economic Competitiveness: 1000kg-2500kg class



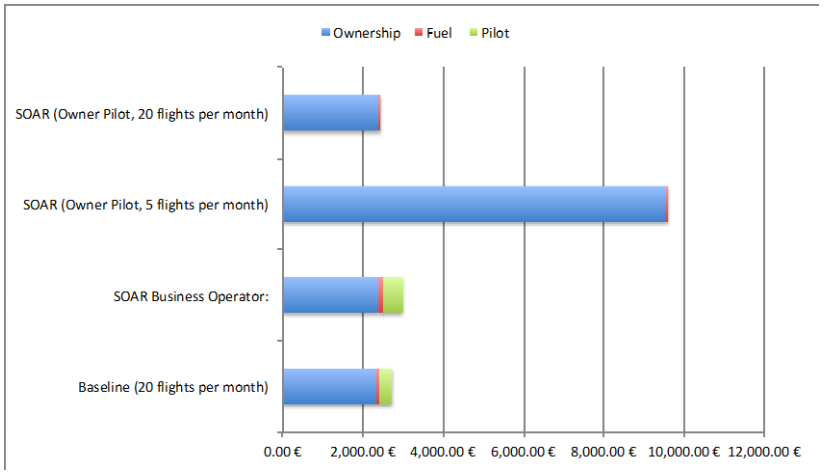
Existing Markets

- Agriculture
- Firefighting
- 7000 Units, 4000 Units / year

New Markets

- Short haul freight, tourism

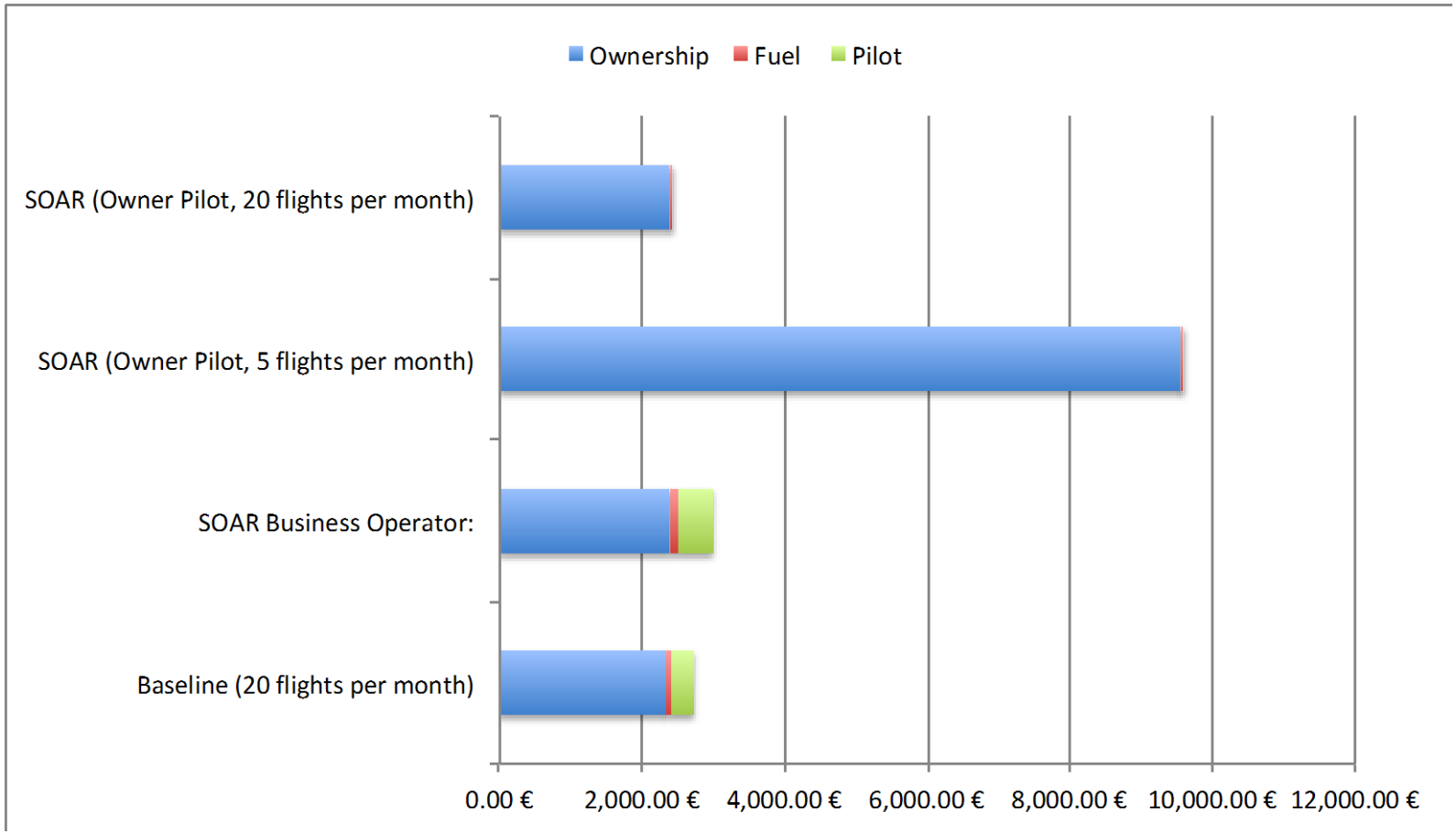
Cost per flight:



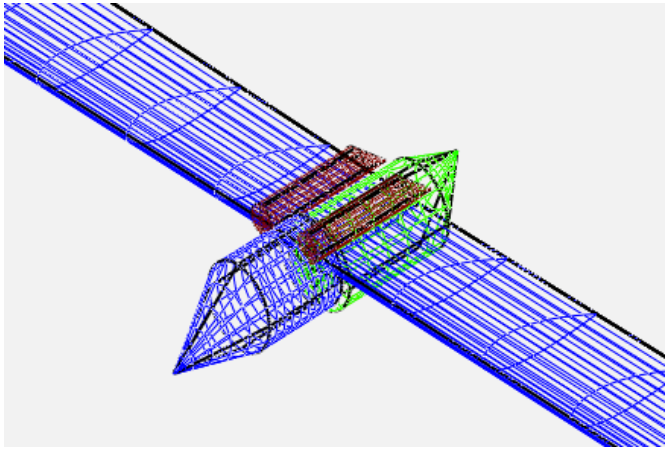
Performance Characteristics

- Chemical drop occurs at cruise speed for baseline
- Mission time increases from 3 to 5 hours @ 40m/s for 200km
- 1.2% increase in acquisition cost for FanWing
- Ownership costs / asset utilization dominate operating economics
- 80 m takeoff distance

Economic Competitiveness : 1000kg-2500kg class



Economic Competitiveness: 10000 kg class



Existing Markets

- Firefighting
- 100 Units, 30 Units / year
- 125% above market for new aircraft

New Markets

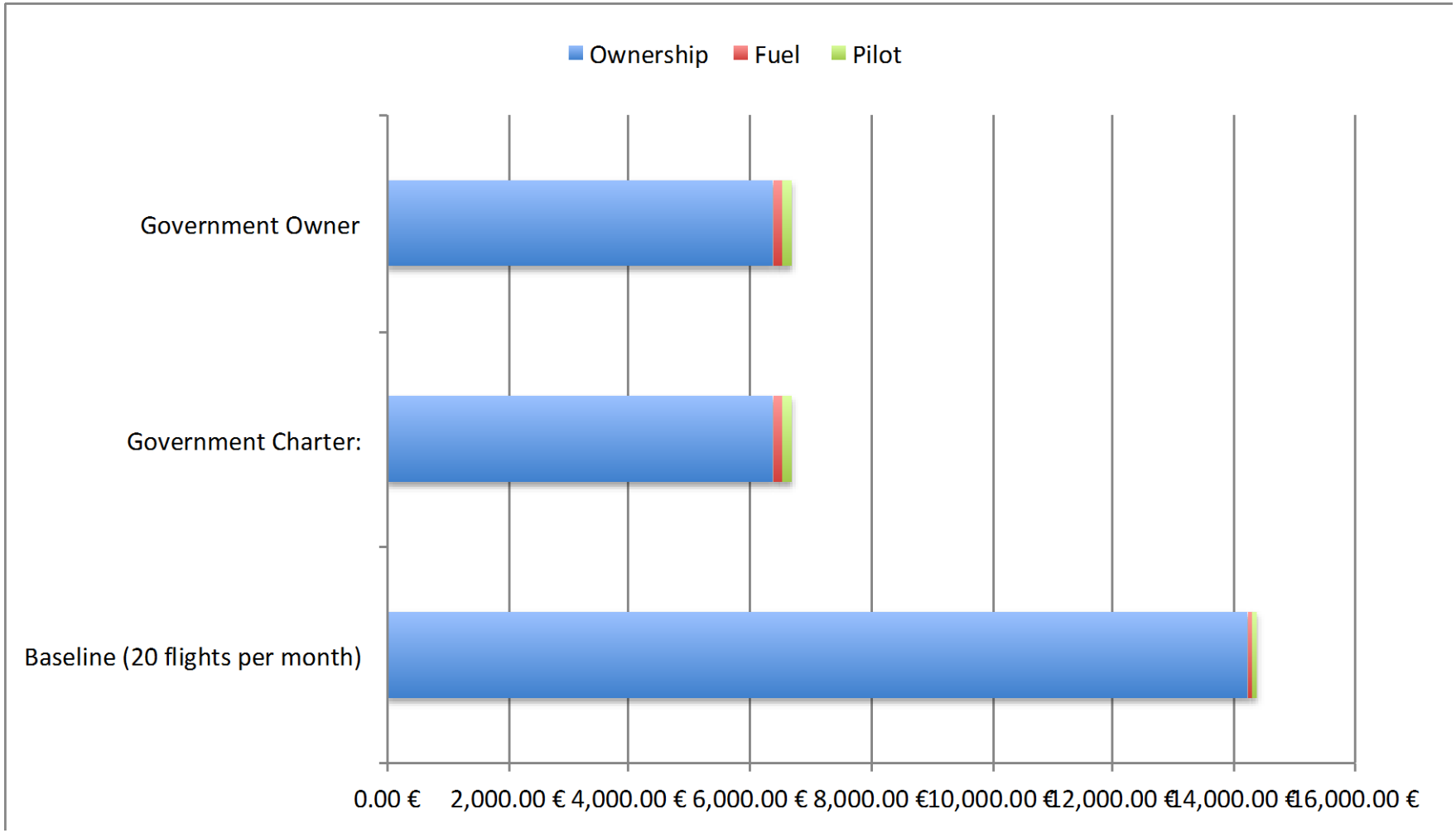
- Short haul freight

Operating Costs

- 178 km mission with 3 lowspeed fuel drops
- Mission increases from 47 to 99 minutes at 40 m/s
- Ample room to take premium from competitor aircraft

Cost per flight:

Economic Competitiveness: 10000 kg class



Conclusions

- Scalability: Does the vortex scale up to higher fan radii?
  - Inconclusive but some potential
  - 60cm test showed presence of vortex
- Power Required: What is the required power to takeoff mass ratio?
  - ~30% more than a fixed wing equivalent but less than an equivalent helicopter
- Economic Competitiveness: Is the FanWing competitive in its selected target markets?
  - Agri: yes when based at the field with high utilization
  - Firefighting: yes due to premiums commanded by scooping payload multiplier capability

Questions?