Mono Tiltrotor (MTR) Validation Activities

AHS International Forum
Montreal, Canada

30 April 2008

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Outline of paper

- Introduction
- Methodology
- Results and Discussion
- Conclusions

Introduction

- 2004 Concept Study and 2006 Preliminary Design indicated breakthrough performance
- Design Team for the 9400 LBS GW, 3000LBS payload weight, 200 KTS cruise, 750 NM range aircraft consisted of Eagle Aviation, Army Research Labs, and U of Maryland
- In 2007, hired independent authorities to check the work of the Design Team
- Also, demonstrated fundamental features of the Preliminary Design

Methodology

- Demonstrated fundamental features using Remote Control Platforms at Georgia Tech
- Hired Bell Helicopter to perform an independent assessment based solely on the 2006 Design Report
- Streamlined design and assessed drag using methods that have been validated at the AIAA Computational Fluid Dynamics Workshop

Demonstrations presented in the accompanying video.

Weight Validation

Design Group	2006 Report	Bell Assessment	Delta (LBS)	Risk
Wing Group	539	512	-27	Low
Rotor Group	754	705	-49	Low
Tail Group	229	165	-64	Low
Body Group	180	201	21	Medium
Landing Gear Group	104	107	3	Low
Nacelle Group		113	113	High
Propulsion Group	891	848	-43	Low
Drive System Group	1075	1046	-29	Low
Flight Controls Group	179	375	196	High
APU Group	101	118	17	Medium
Instruments/Avionics	100	130	30	Medium
Hydraulics Group	71	85	14	Medium
Electrical Group	90	119	29	Medium
Load & Handling	49	52	3	Low
	4362	4577	215	Low / Medium
Cargo Pod	538	538		
Empty Weight	**4900**	**5115**	**215**	Low / Medium

Agree within 4%

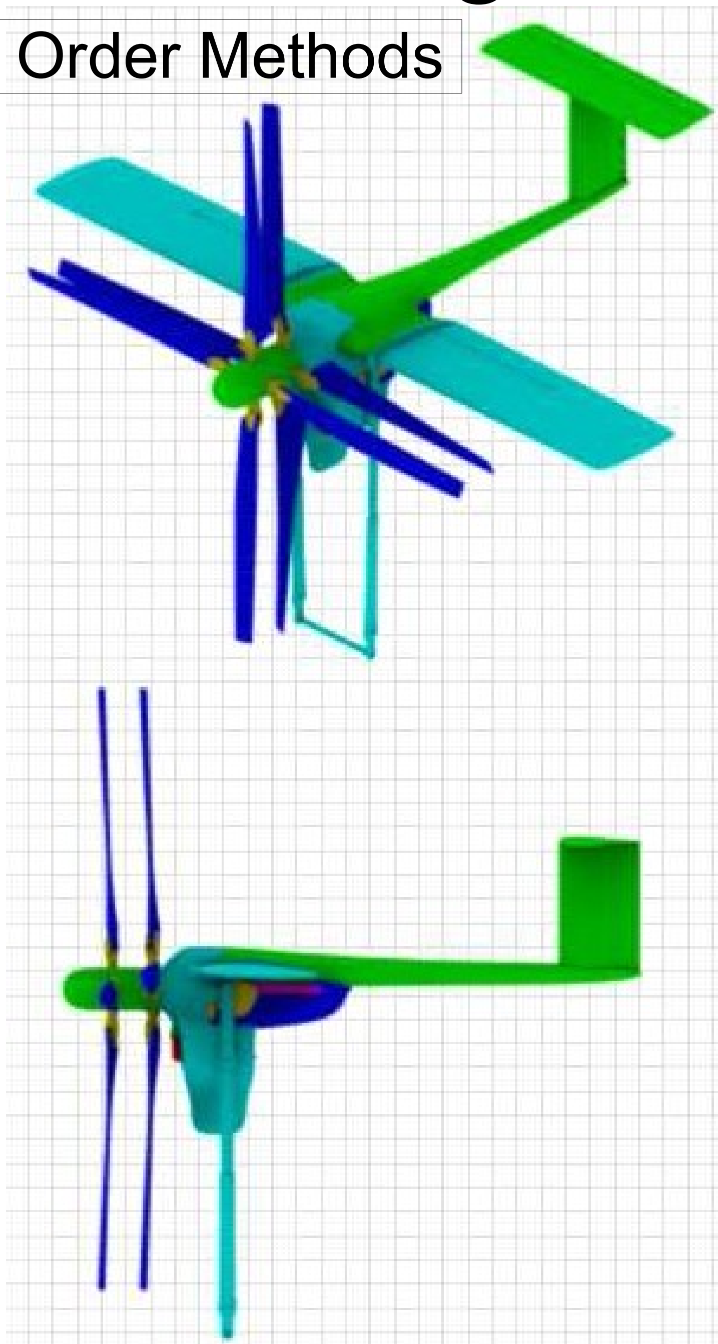
Drag Validation (helo)

Helo Mode Item	Baldwin	BHTI	Δf_e	
Spinner	2.254	4.200	1.946	
Exp Hub & grips	0	3.120	3.120	
Tailboom	0.246	0.459	0.213	
Nacelle/Fuel Tank	12.797	7.748	-5.049	(engine area extracted)
Wing Panels	1.223	1.670	0.447	
Alighting Gear	0.038	0.44	0.402	(deployed in helo mode)
V & H Tail	0.540	0.263	-0.277	
Struts	0.617	0.364	-0.253	
Fuselage fairings	0.014	0.0	-0.014	(included in fuselage)
Fuselage	1.013	1.287	0.274	(frontal only)
Fuse V-Tails	0.181	0.239	0.057	
Interference	3.785	0.0	-3.785	(included in each component)
sub totals	22.709	19.791	-2.919	
Protuberances	0	0.836	0.836	(% component total)
Trim	0	0.500	0.500	(estimated)
Momentum	0	0.383	0.383	(xsmn cooling, eng, etc.)
$fe_{\text{HELO MODE}}$ =	**22.71**	**21.51**	**-1.20**	

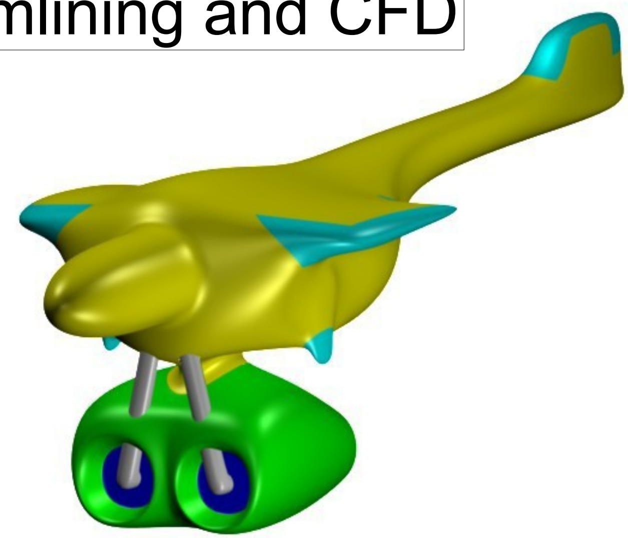
Agree within 4%

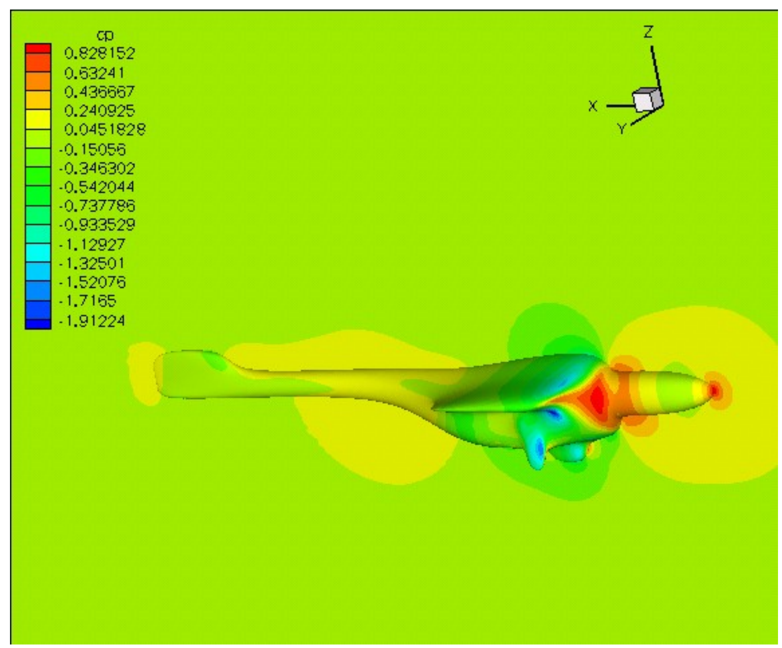
Drag Methods (plane)

First Order Methods



Streamlining and CFD





Drag Validation (plane)

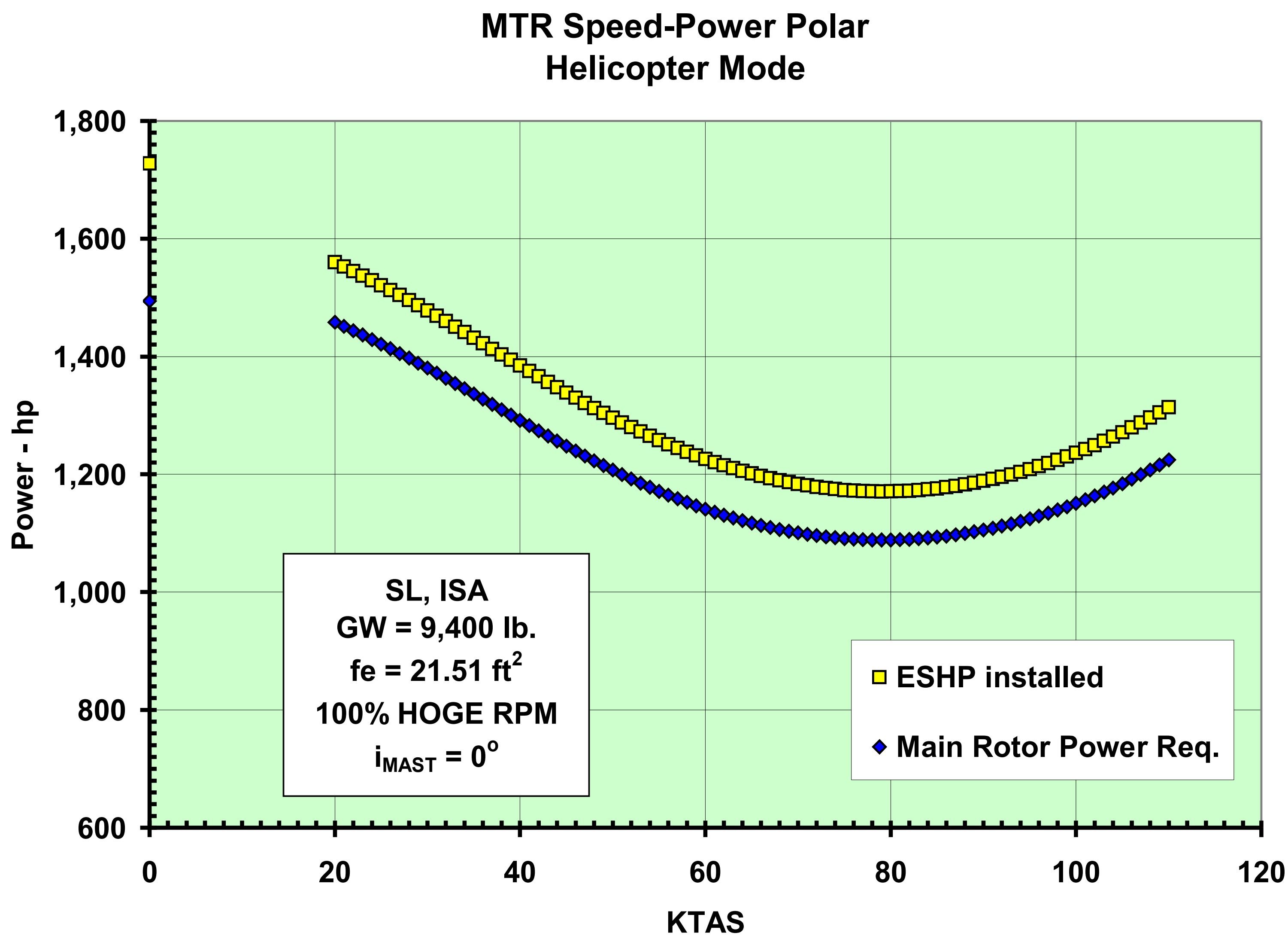
First Order Methods | Streamlining and CFD

A/P Mode Item	Baldwin	BHTI	Δf_e	Comment	CFD w/ BHTI	Δf_e
Spinner/Tailboom	0.273	0.459	0.186	(included with fuel tank)	0	-0.273
Nacelle/Fuel Tank	2.786	4.076	1.290	(engine area extracted)	1.114	-1.672
Wing Panels	1.134	1.670	0.536		1.670	0.536
Alighting Gear	0.035	0	-0.035	(not deployed in fwd flight mode)	0	-0.035
V & H Tail	0.500	0.263	-0.237		0.263	-0.237
Struts	0.566	0.364	-0.202		0.364	-0.202
Fuselage fairings	0.013	0	-0.013	(included in fuselage)	0	-0.013
Fuselage	0.944	1.287	0.343	(frontal only)	0.716	-0.228
Fuse V-Tails	0.168	0.239	0.071		0.239	0.071
Interference	1.284	0	-1.284	(included in each component)	0	-1.284
sub totals	7.704	8.358	0.654		4.366	-3.338
Protuberances	0	0.836	0.836	(% component total)	0.437	0.437
Trim	0	0.500	0.500	(estimated)	0.500	0.500
Momentum	0	0.383	0.383	(xsmn cooling, eng, etc.)	0.383	0.383
$fe_{A/P\ MODE}$ =	**7.70**	**10.08**	**2.37**		**5.686**	**-2.018**

Excluding the two difficult shapes, agreement within within 5%.

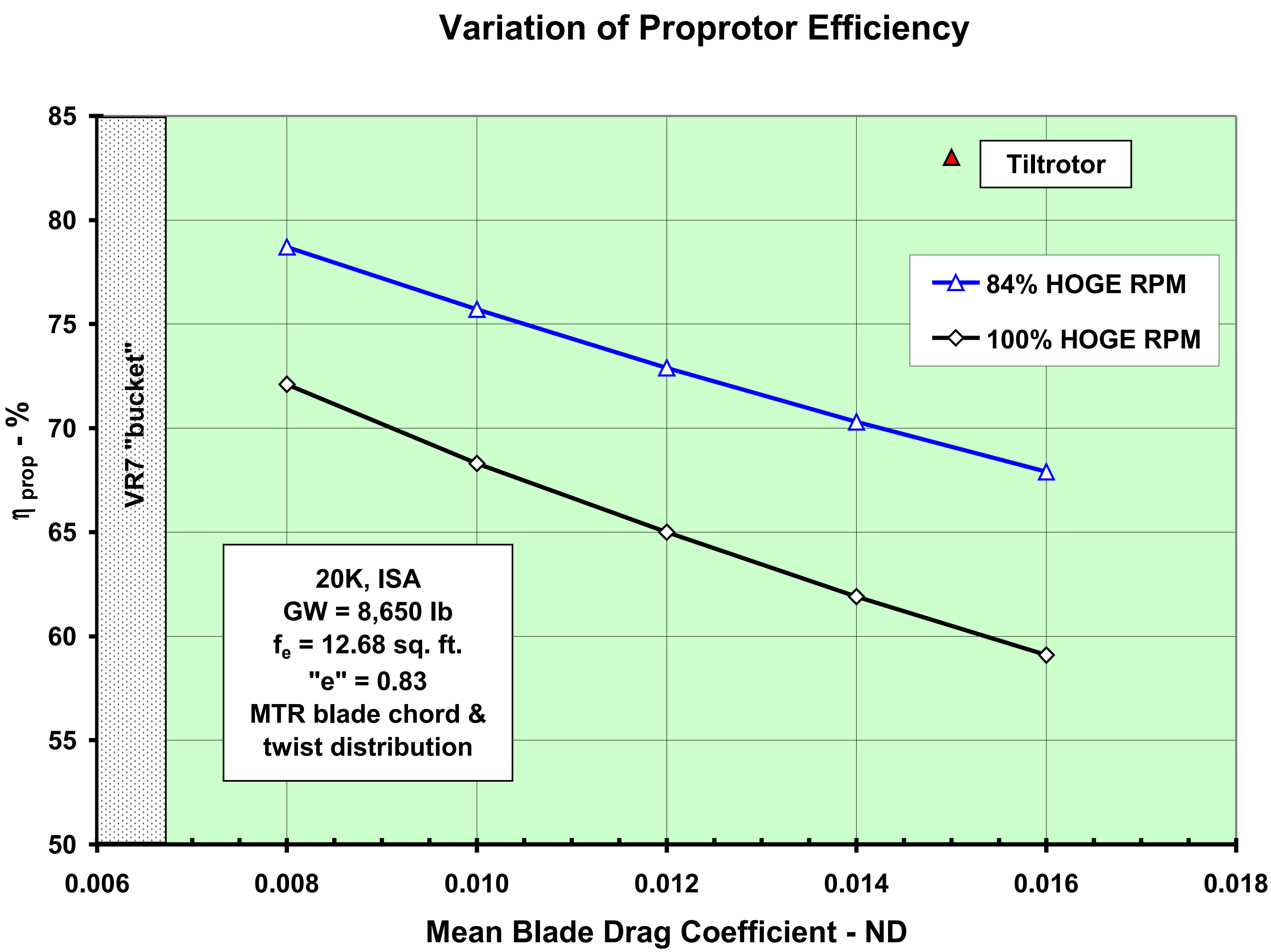
Benefits of streamlining are significant.

Power Validation (helo)



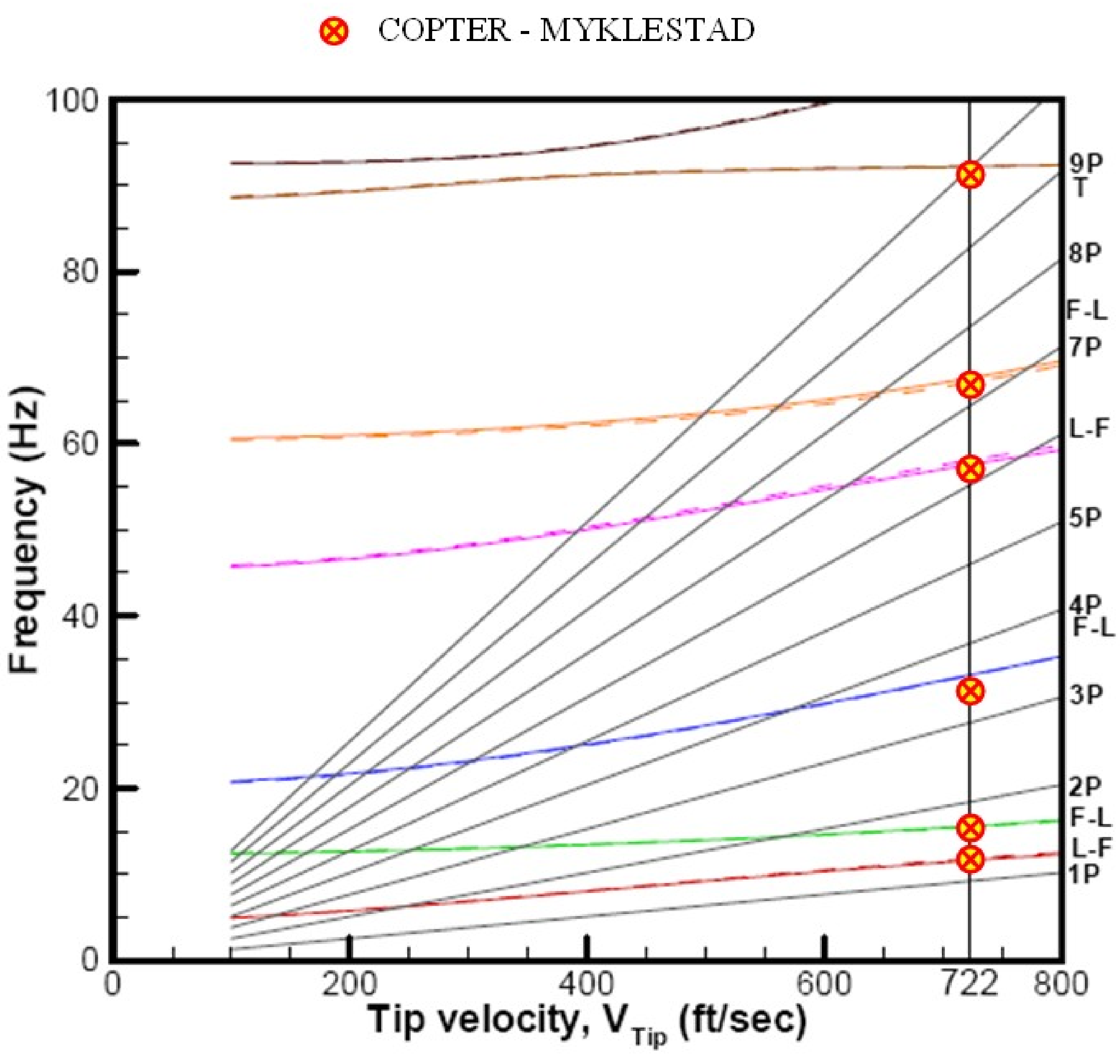
Excess power margin under all helo flight conditions.

Prop Efficiency Validation



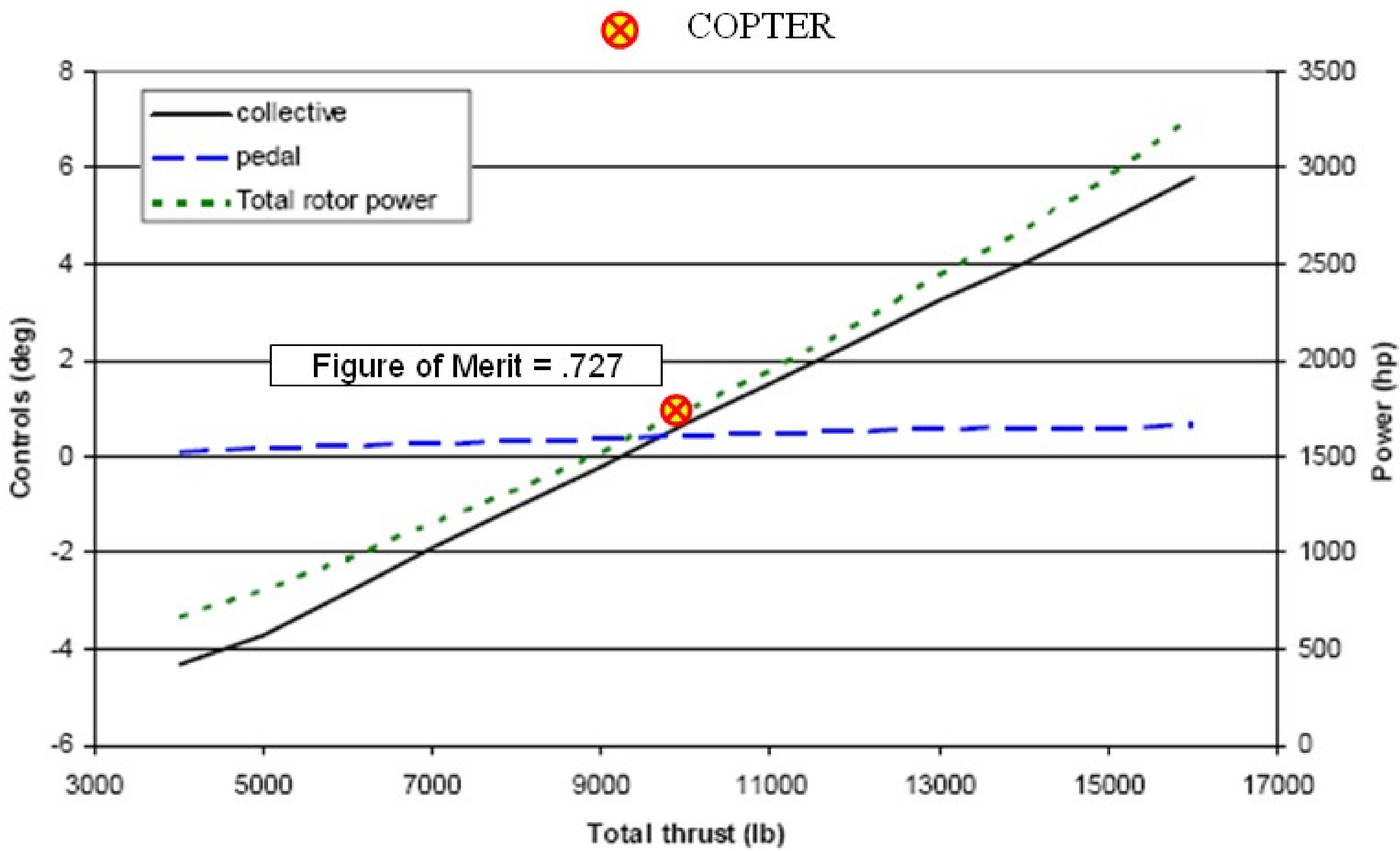
Lowered RPM to achieve efficiency target.

Frequency Validation



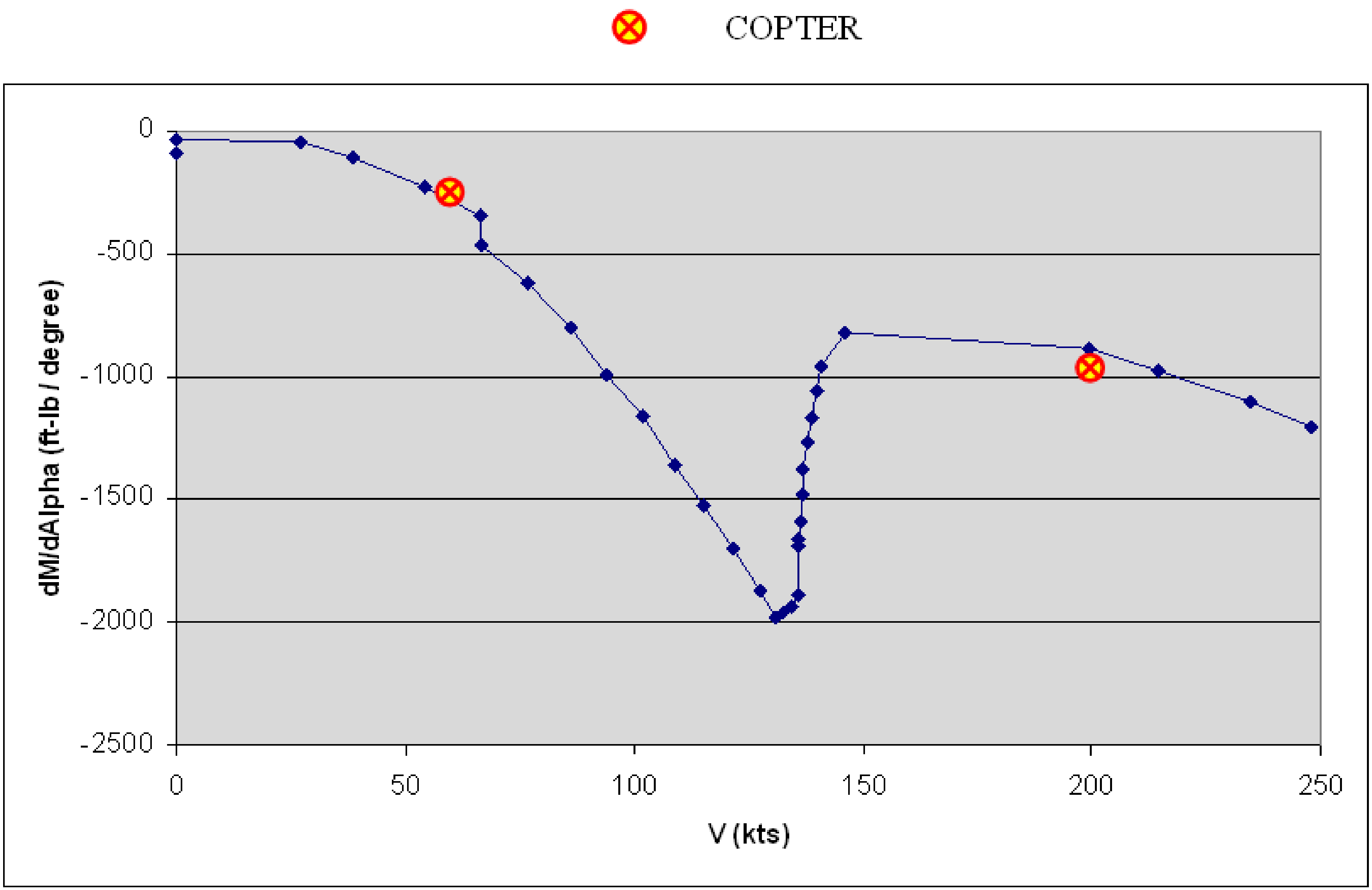
COPTER confirms CAMRAD II results.

Hover Power Validation



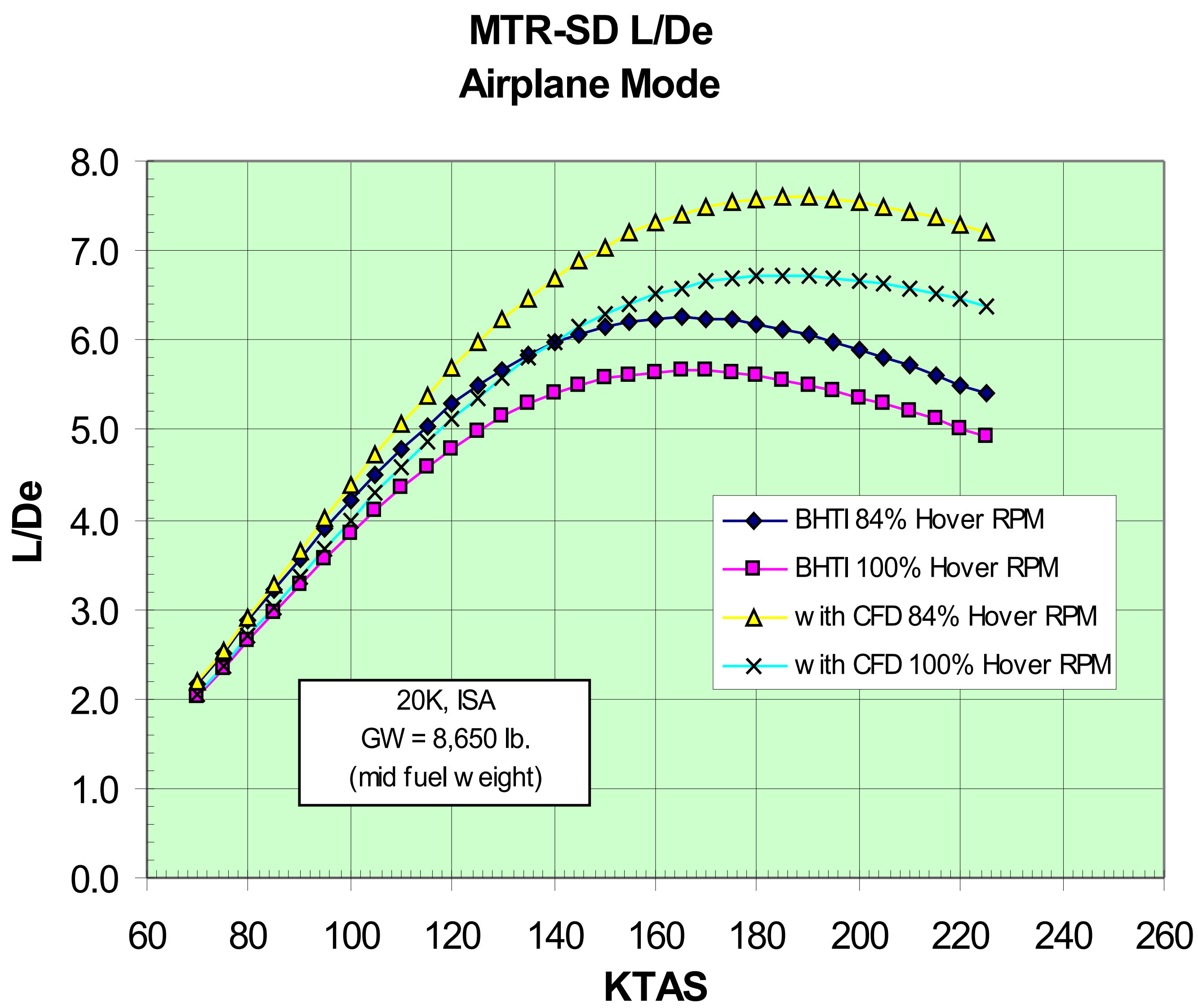
COPTER confirms CAMRAD II results.

Stability Validation



COPTER confirms longitudinal stability analysis.

Cruise Efficiency Validation



CFD shows that L/De target of 7.0 is achievable.

BTC

Results and Discussion

- The key innovative features have been demonstrated at a Remote Control scale
- Independent authorities have essentially concurred with all quantified facets of the Preliminary Design
- These two results validate the Conceptual Design Study, which in 2004 concluded that the MTR offered double the cruise speed at half the rotor diameter, 1/3 the gross weight, and 1/3 fuel burn of legacy helicopter concepts when compared for a 1000 NM mission profile

Conclusions

- Wing deployment and recovery are feasible, controllable, and repeatable
- Pitch axis suspended cargo pod is feasible
- Centerline rotor can be tilted between a helicopter mode and an airplane mode of flight. Control laws demonstrated.
- 50 LBS MTR Functional Demonstrator designed to incorporate all three features
- Validation of MTR-SD weight, drag, hover performance, propulsive efficiency, longitudinal stability, rotor dynamics, & cruise performance