GYRO BLITZ

26th Annual AHS Student Design Competition

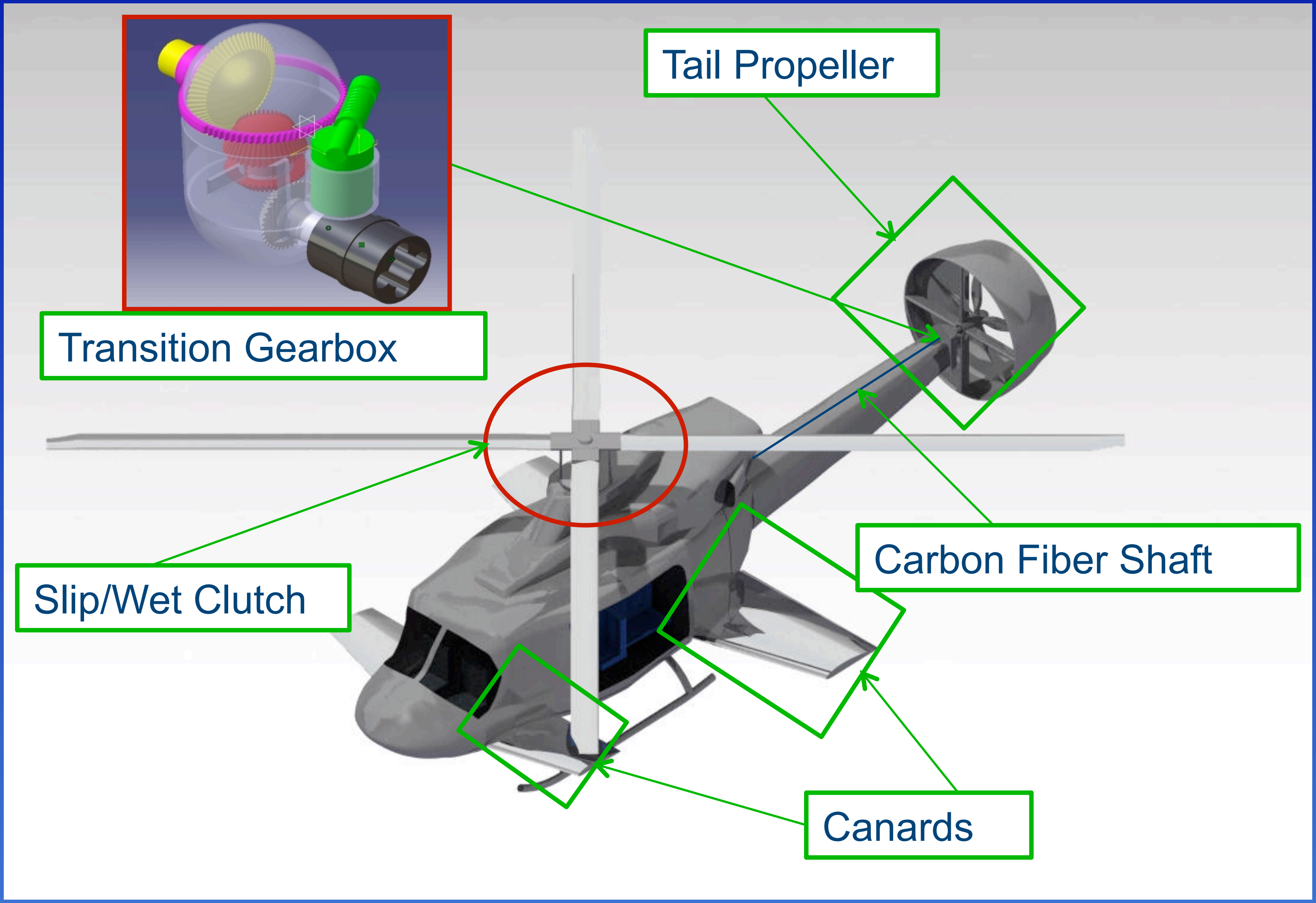
Executive Summary

Georgia Institute of Technology: Undergraduate Blue Team

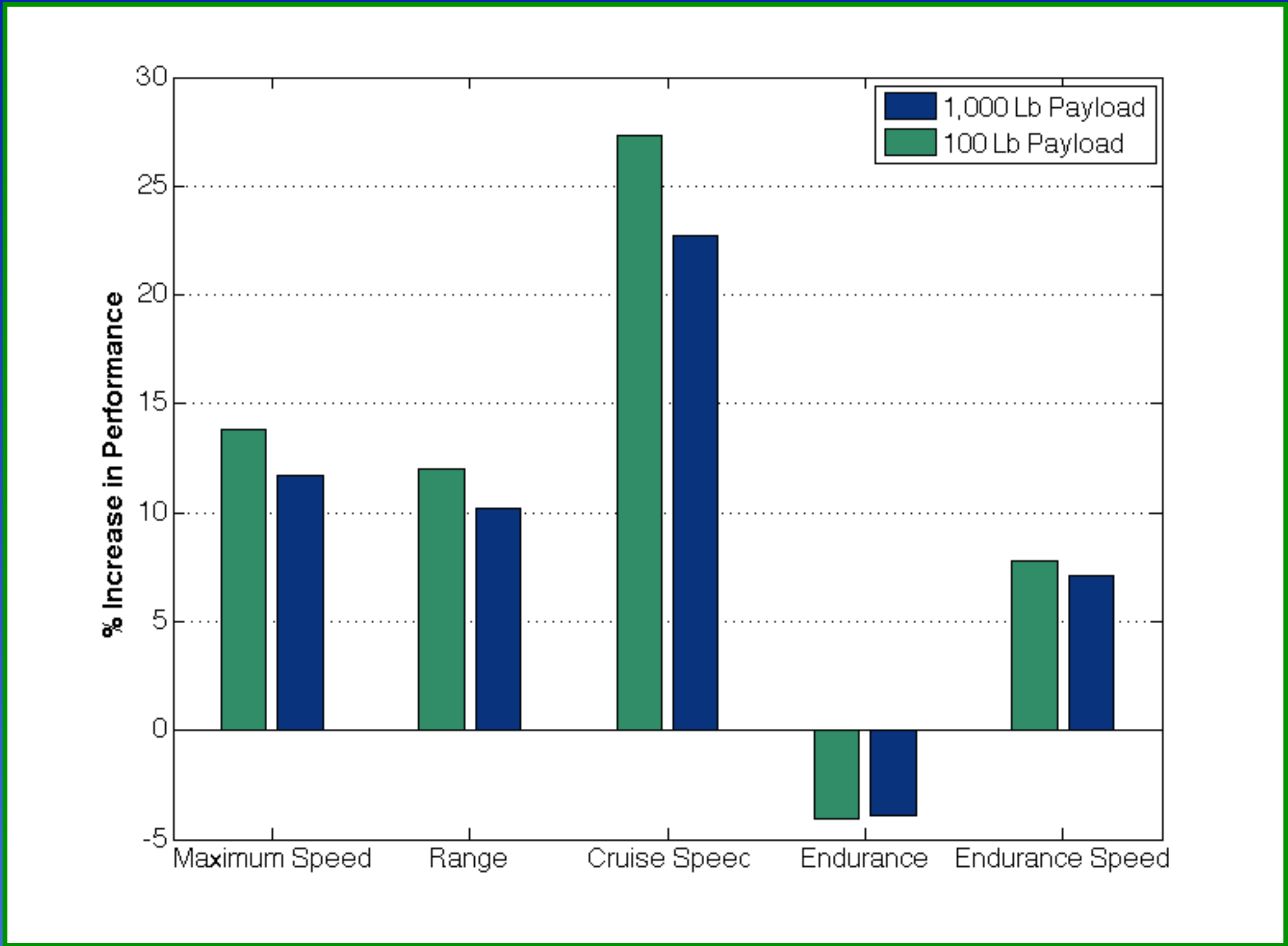
RFP Requirements & Analysis

- New, Nonconventional rotor/drive system
- Improved Performance
  - Speed, range, payload, endurance, noise signature
- Baseline with MTOW between 3500-5500 Kg
- Inability to use physically impossible solutions
- Deviate from designing "upgrade kits"

Innovative Features



Performance Increase Over Bell 412



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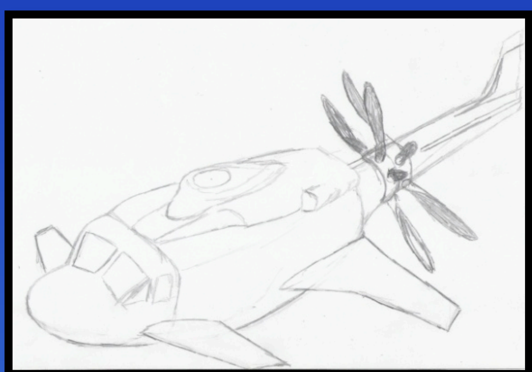
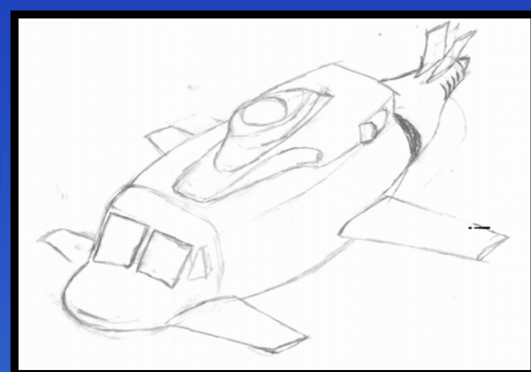
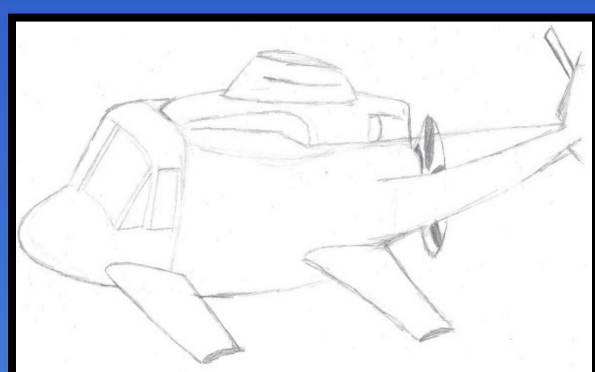
Concept Evolution

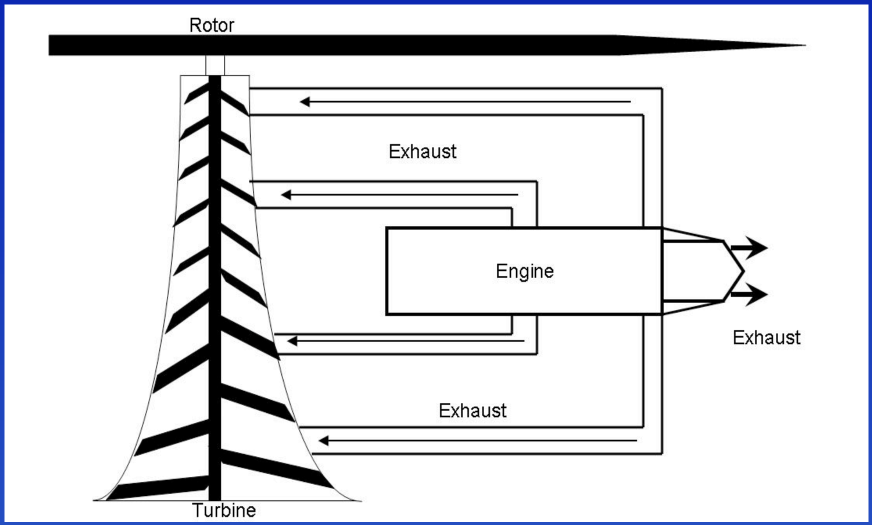






Initial Concepts: The Model Autogyro/Canard Configuration

- Powered main rotor for hover will be disengaged to allow engines to provide high speed forward flight.
- Rotational canards/control surfaces can offset in pairs and provide total anti-torque in hover.
- Canards can provide additional lift or additional control authority.
- Problem: The amount of necessary anti-torque required sizes each canard at 100 ft^2.



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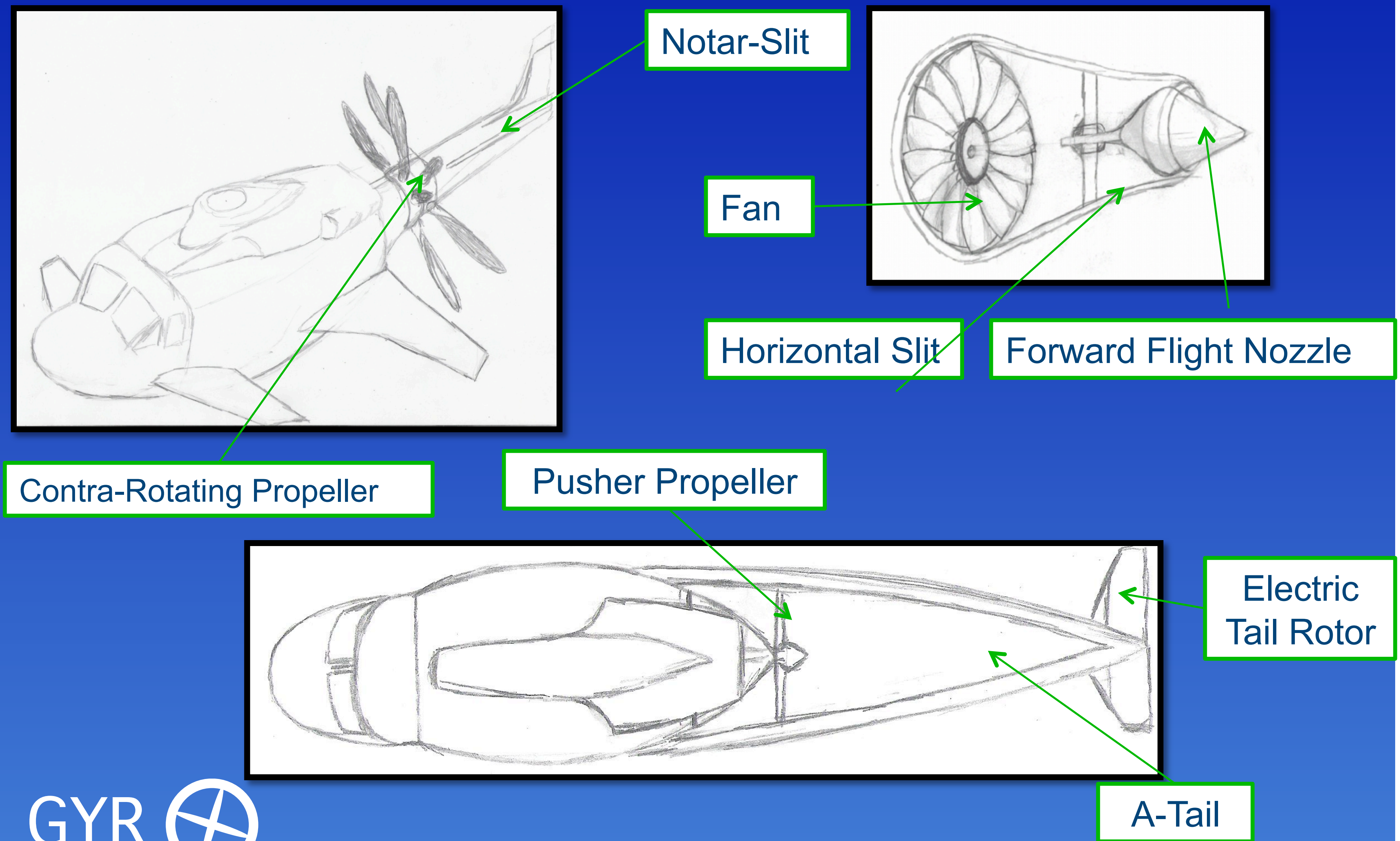
Revision I: Alternatives and Solutions



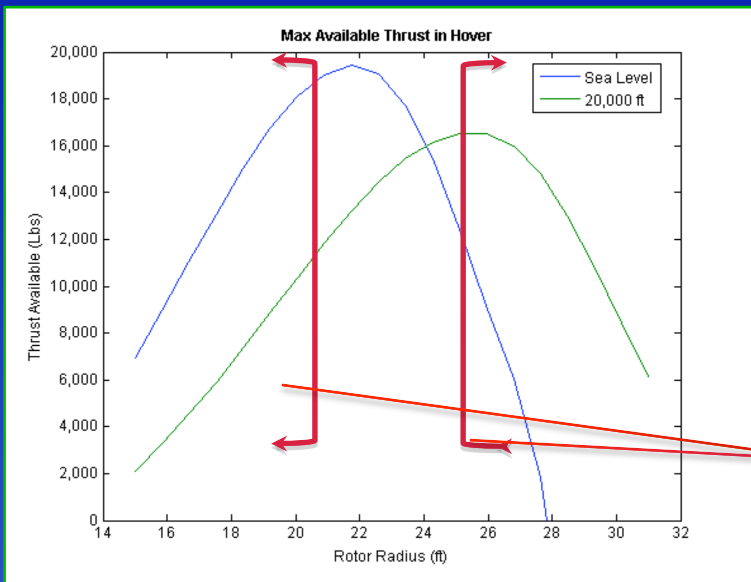
Revision I: Pitfalls

- Innovation for the sake of innovation was detrimental to performance
- Separation of forward flight and hover systems is either:
  - Non-innovative and unrewarding
  - Severely complex and infeasible

Trade Studies: Methodology

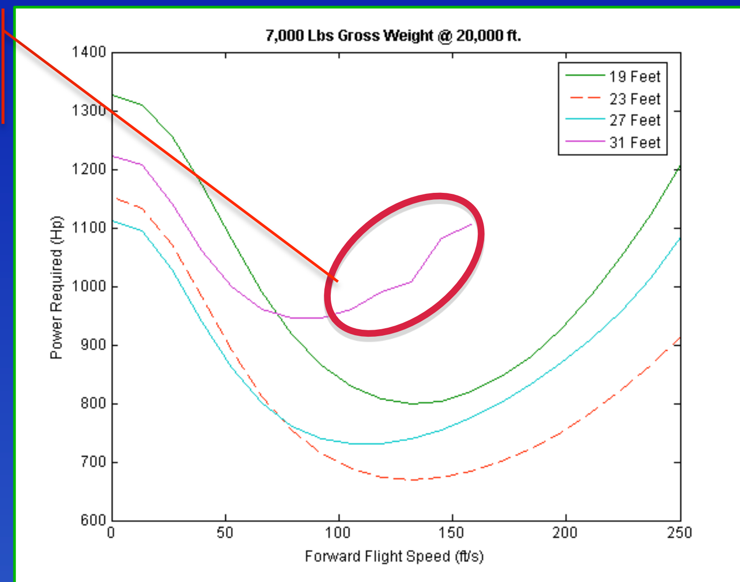
- Emphasis on end performance results to promote a means of achievement
  - Performance results dictate the potential advantage of specific elements of the rotor drivetrain system and determine its time investment
  - Trade study results will guide further concept design

Variable Rotor Radius Trade Study



Supersonic Rotor Tips

Inadequate Thrust Available



- Advantages
  - Shorter Radius
    - Lower Noise
    - Decreased footprint
  - Longer Radius
    - Larger thrust
    - Generally, lower power

- Disadvantages
  - Shorter Radius
    - Less thrust
  - Longer Radius
    - More drag/Noise
  - Technological feasibility/complexity

- Conclusions
  - Disadvantages > advantages
  - No further consideration

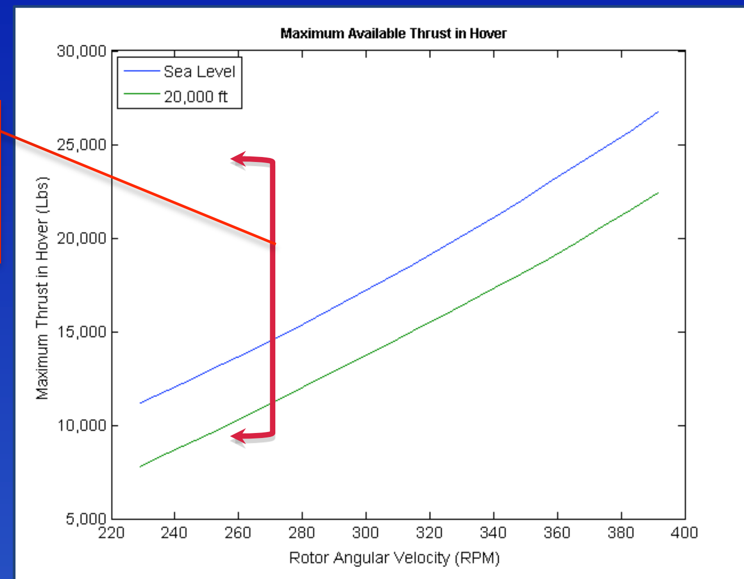
Variable Rotor Speed Trade Study

- Advantages
  - Low RPM
    - Lower power/Noise
  - High RPM
    - Larger thrust

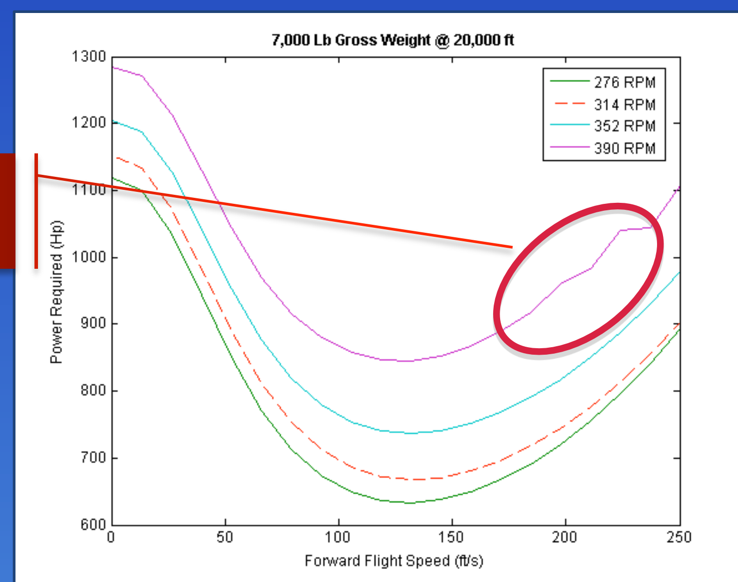
- Disadvantages
  - Low RPM
    - Less thrust
  - High RPM
    - More drag/Noise
  - Dynamical Complexity
    - Vibrational characteristics
  - Complexity for rotor transmission

- Conclusions
  - Application for unpowered rotor mode only
    - Autogyro RPM controlled through standard control inputs

Inadequate Thrust Available



Supersonic Rotor Tips



Battery-Powered Electric Rotor Trade Study

- Advantages
  - Low maintenance
  - Independent of fuel economy
  - Low operating cost
  - No/reduced transmission
- Disadvantages
  - Constant mass
  - Expensive implementation

- Battery weight estimated for hypothetical mission outline
  - Nano-particle $Li_4Ti_5O_{12}$ battery
    - Energy density ~ 60 Wh/kg
  - 250 mile mission for 10,000 lb gross weight
- Conclusions
  - Estimated battery weight:
    - 36,000 kg
  - Impossibly large weight required for energy storage

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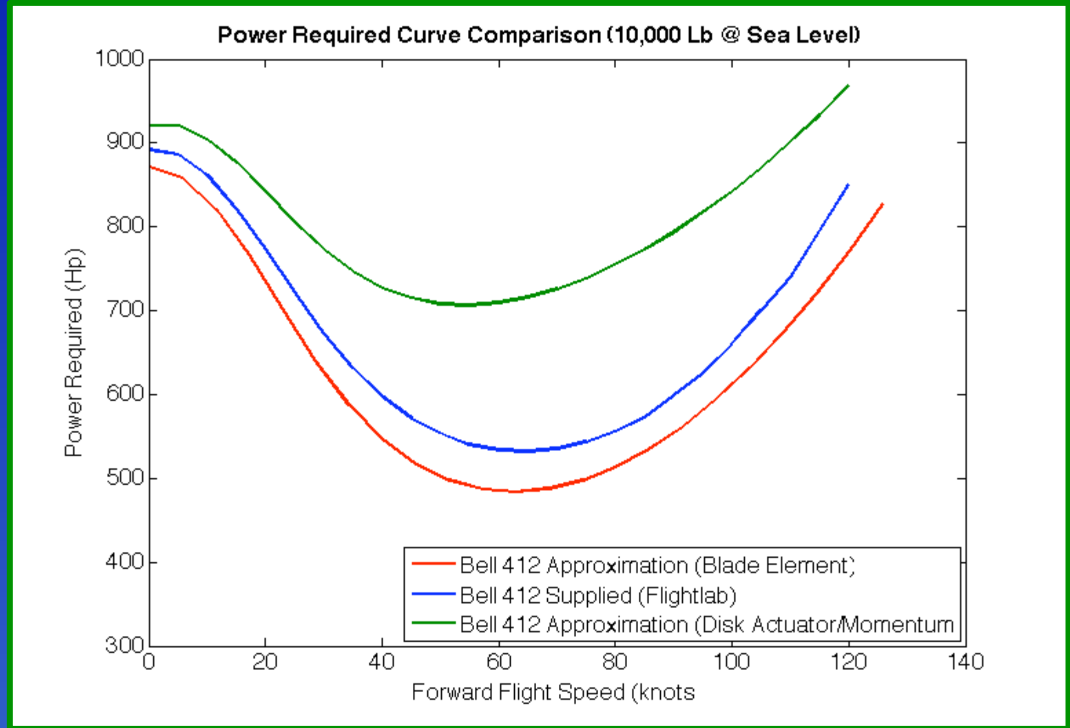
Powered-Rotor Code Validation

- Code run with simplifying assumptions and compared with closed-form solutions
- Computed power-required for Bell 412 compared with acquired Bell 412 power data
- Estimated Bell 412 performance metrics compared with actual values
- Conclusions:
  - Power curves agree fairly well
  - Reasonably small error in performance values



	Predicted	Published	Error
Range Speed (5,000 ft)	141 kts	130 kts	8.5 %
Range (5,000 ft)	378 nm	402 nm	6.0 %
Endurance (S/L)	3.6 hrs	3.7 hrs	2.7 %
HOGE	5,400 ft.	5,200 ft.	3.9 %

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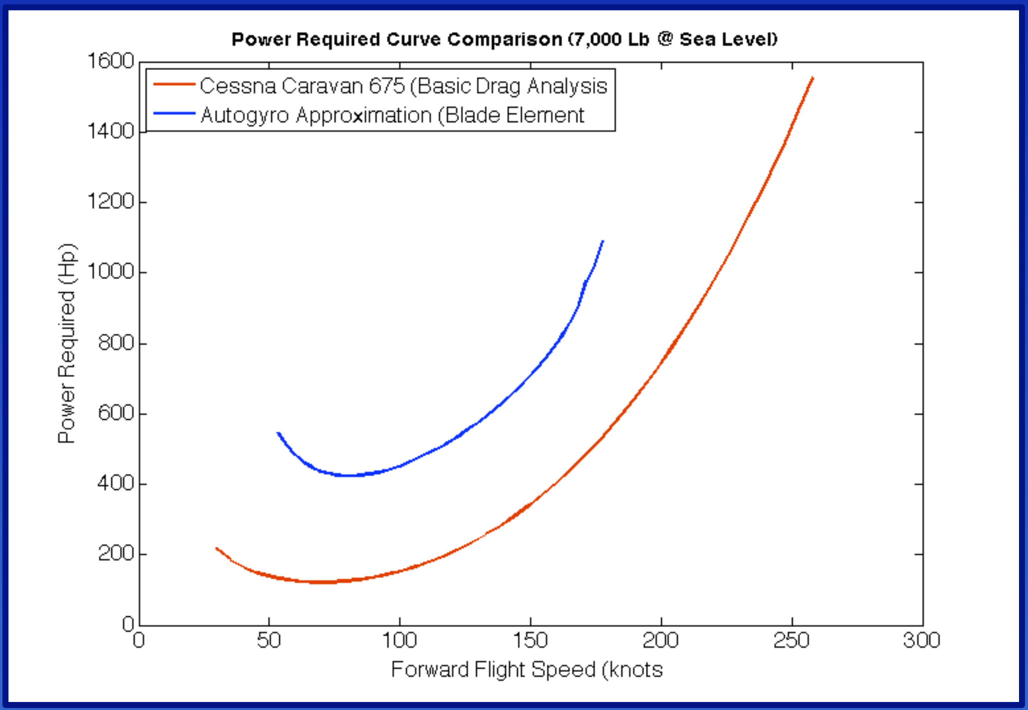
Unpowered-Rotor Code Validation



- Computed power required for Gyroblitz autogyro mode Power curve compared with known fixed wing aircraft
  - Cessna Caravan 675
- Unpowered-rotor blade element code checked against validated powered-rotor blade element code
- Conclusions:
  - Proper sanity check
  - Reasonable power trends

Performance Values

Flight Conditions: Maximum Gross Weight @ 5,000 ft	Bell 412 (Baseline) (Payload: 3,016 Lb)	Gyroblitz (Payload: 2,166 Lb)
Maximum Speed	151 knots	168 knots
Cruise Speed	141 knots	160 knots
Range	378 nm	419 nm
Endurance Speed	75 knots	82 knots
Endurance	3.6 hrs	3.6 hrs

Flight Conditions: 10,000 Lb Gross Weight @ 5,000 ft	Gyroblitz (Payload: 1,066 Lb)
Maximum Speed	177 knots
Cruise Speed	169 knots
Range	443 nm
Endurance Speed	70 knots
Endurance	3.94 hrs

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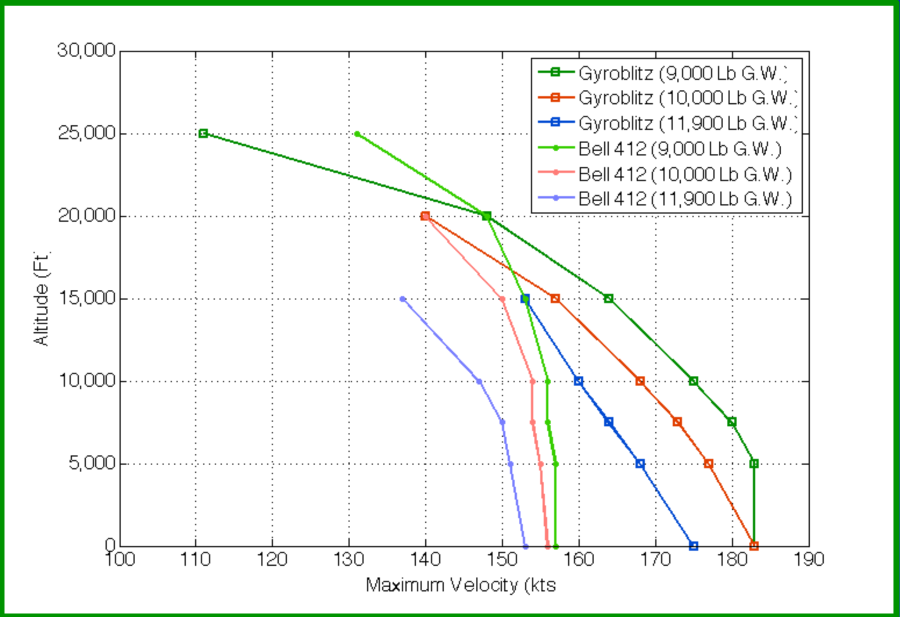
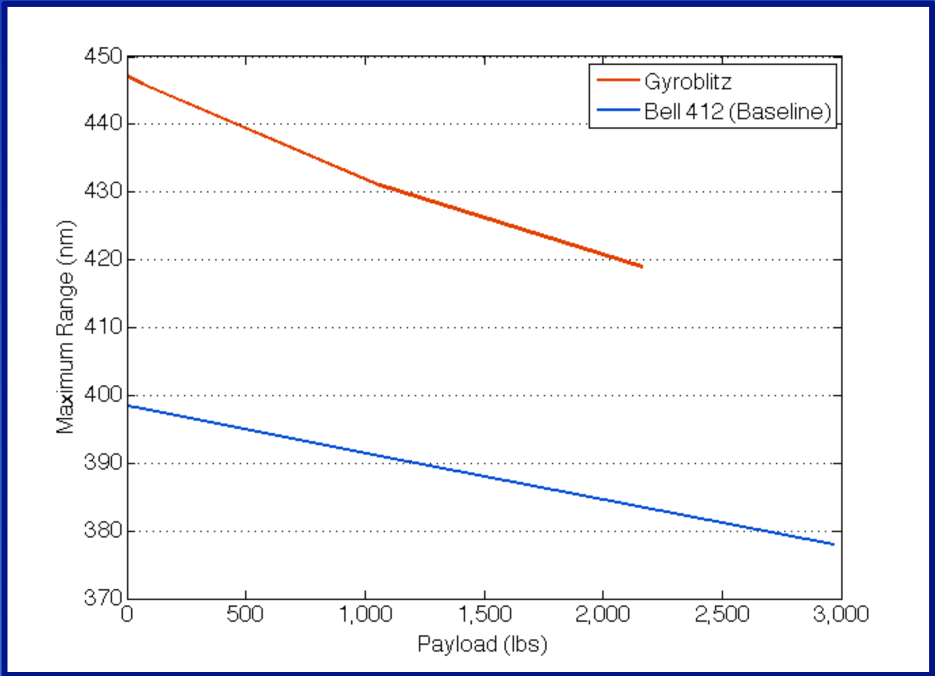
Performance Comparisons



Maximum Velocity

Maximum Range (5,000 Ft.)



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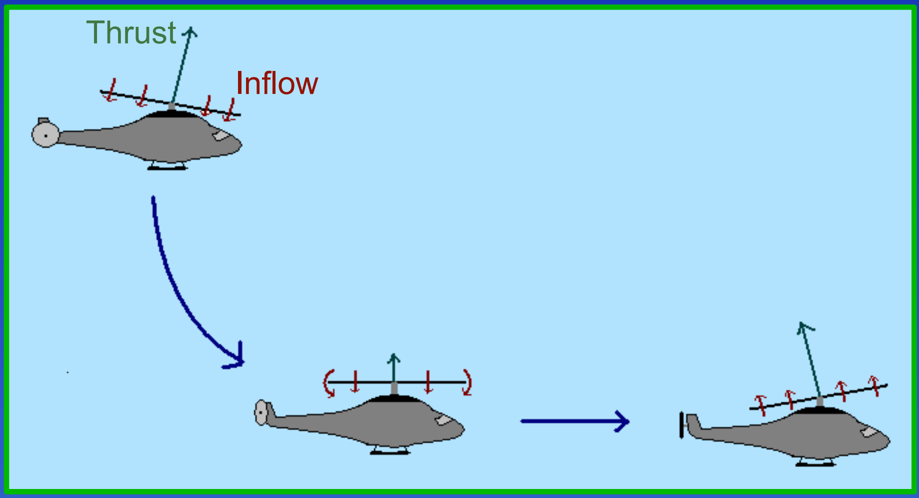
Rotor Mode Transition

- Sufficient forward flight speed attained
  - Minimal necessary rotor-disk angle of attack
  - Minimal autogyro-mode level flight required power
  - ~ 100 knots
- Power decreased to main rotor
  - Drop in collective input
- Power increased to propeller
  - Propeller reoriented
    - Supply both anti-torque and forward thrust
- Rotor enters vortex-ring state
  - Drop in thrust and altitude
  - Slight rotor deceleration
- Rotor enters windmill-brake state
  - Slight rotor acceleration
- Collective and cyclic input readjusted
  - Steady-level flight obtained



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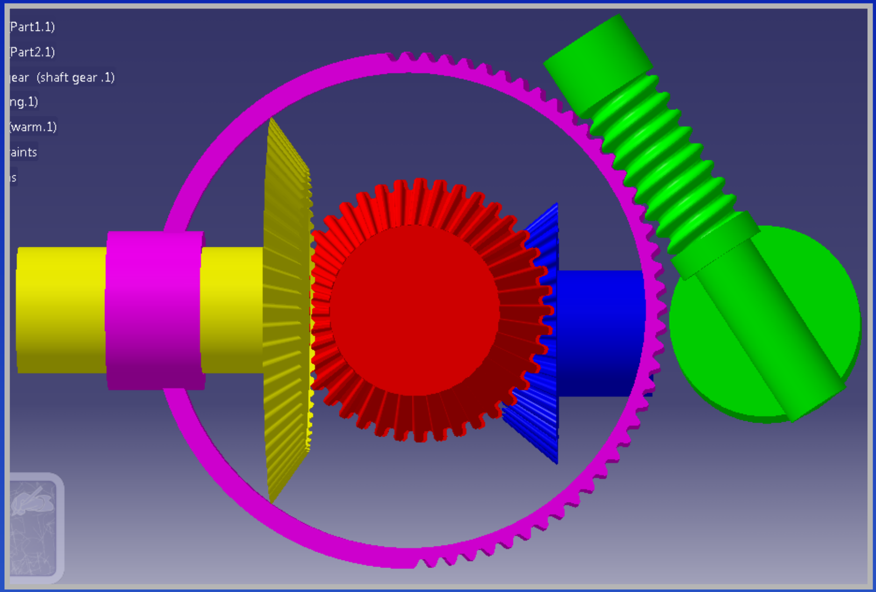
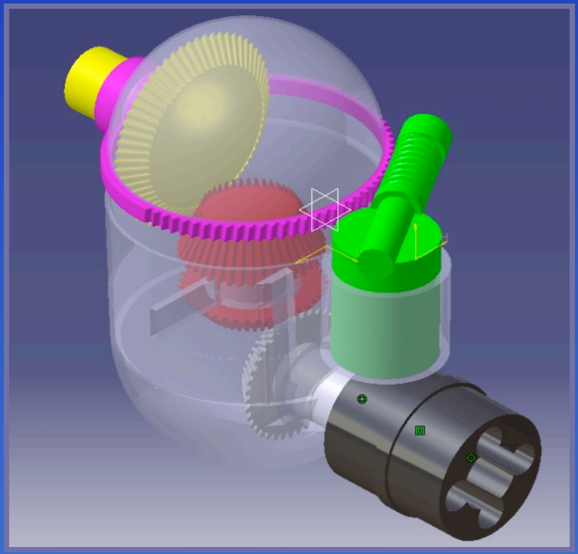
Tail Gear Box

- Two sets of 90 degree beveled gears
- Thrust vectoring control
- Power capacity of gears





$$H = \frac{S \times F \times V \times Y}{P \times 55 \times (600 \times V)} \times \frac{E - F}{E}$$

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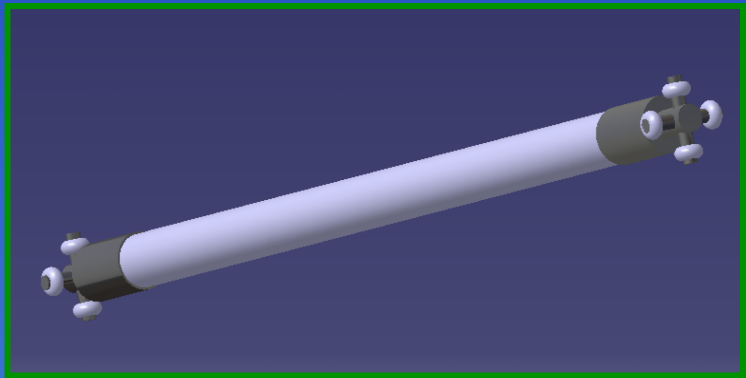
Drive Train Modifications

Slip/Wet Clutch System

- Provides means for Power Transitions
- Power management
- Mast slip/wet clutch
- Tail prop slip/wet clutch

Carbon fiber shaft

- Better weight to strength ratio
- Shaft length (50 in) is limited by rotational speed



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Final Gyroblitz OEC Results

Parameters	Value	Target	Units	Parameters	Value	Target	Units
Interior Noise Level	90	81	dB	Auto-rotation	1	1	
Exterior Noise Level	120	95.6	dB	Time Til Overhaul	900	1250	hrs
Cabin Space	220	220	ft^3	Development	5	5	years
Number of Seats	13	13		Unit Cost	6.7	5.8	Million $
Pitch Control	14	14	%	Operating Cost	900	810	$/hr
Roll Control	21	21	%	HOGE	2400	3000	ft
Yaw Control	13	13	%	Cruise Velocity	155	143	knots
Rate of Climb	1300	1350	ft/min	Cruise Altitude	7500	5000	ft
Fly by Wire	0.4	1		Max Weight	12000	12257	lbs
Yield Airframe	400	400	MPa	Empty Weight	8500	7000	lbs
Yield Rotor System	830	830	MPa	Range	508	442.2	nmiles
HP max cont.	1800	1998	shp	Endurance	4	4.07	hrs
HPoei max cont.	1140	1140	shp	SFC	0.6	0.54	lbs/hp*hr

Gyroblitz Final OEC	0.93

Rotorcraft	OEC Values
Bell 412 EP	0.863
Super Lynx 300	0.858
K-max 1200	0.821
AS365 Dauphin	0.862
S76 Spirit	0.823
Electric Tail (Conceptual)	0.893
Autodyne (Conceptual)	0.937
Intermeshing (Conceptual)	0.925

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