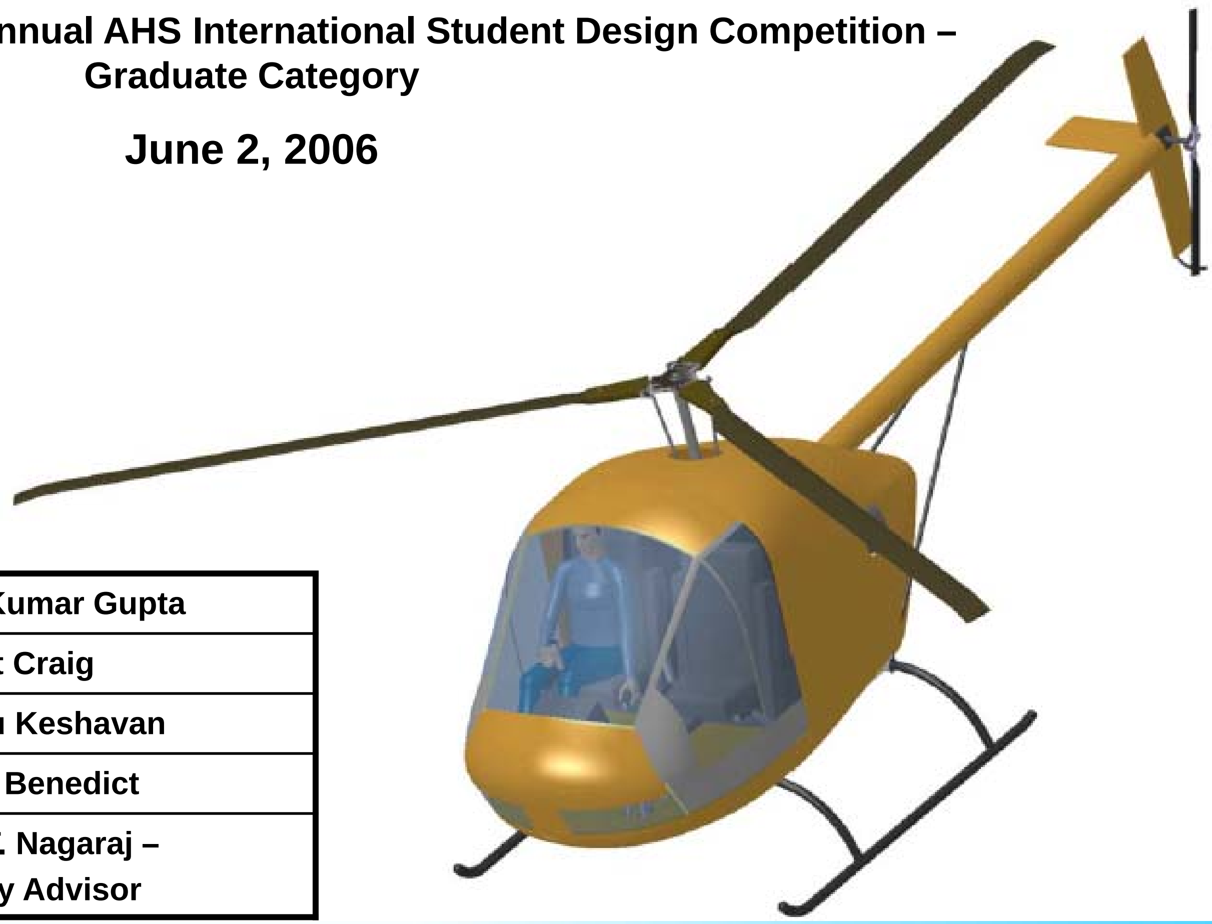
University of Maryland

Penguin Design Proposal

In response to the 2006 Annual AHS International Student Design Competition – Graduate Category

June 2, 2006



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Penguin Turbine Engine Helicopter

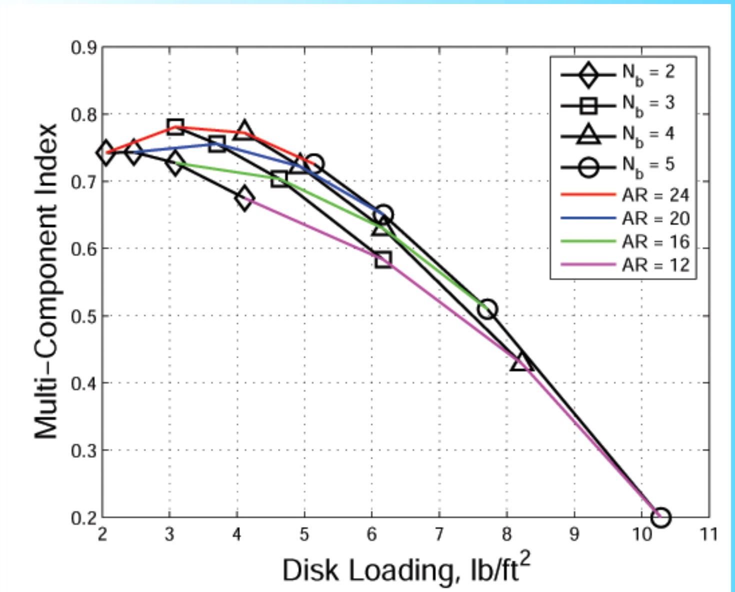
- **Low acquisition cost 2-place single engine turbine trainer helicopter. Includes the design of compact "Pyros" oil-free turbine engine.**
  - **Penguin and Pyros designed in response to 2006 AHS Request for Proposal, sponsored by Bell**
- **State-of-the-art inexpensive training platform:**

  - Provision for *ab initio* and advanced training
  - Superior Performance
  - Incorporates innovative manufacturing cost reduction concepts

Sizing of Penguin

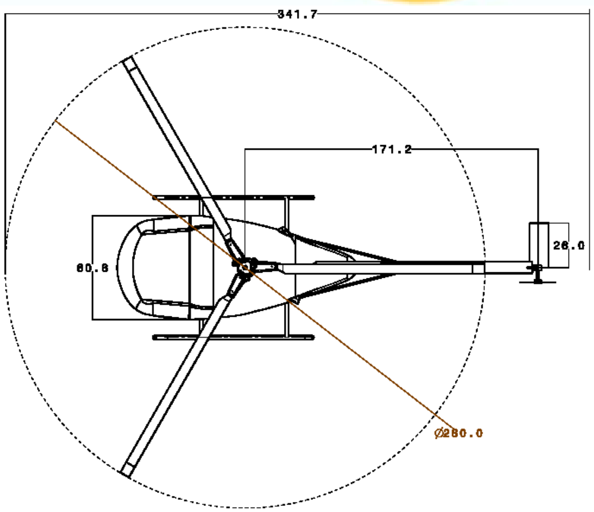
- **RFP requirements:**
  - Capable of lifting two 90 kg people, 20 kg of miscellaneous equipment, and enough fuel to hover out of ground effect at 6000 ft. and ISA +20°C for 2 hours
  - Performance superior to current piston trainers
- **Sizing Methodology developed using Tishchenko method**

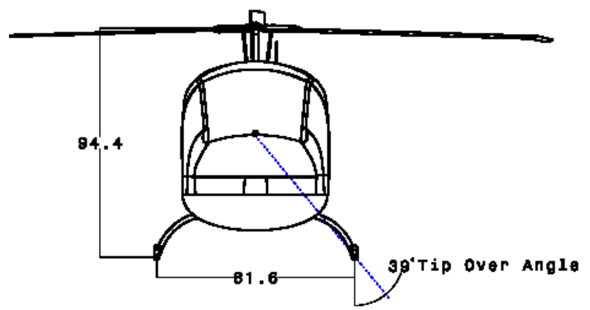
Quality Parameter	Weight
Acquisition Cost	0.45
DOC per passenger Km	0.15
Cruise Speed	0.15
Gross Weight	0.10
Weight Efficiency	0.10
Main Rotor Diameter	0.05
Total	1.00

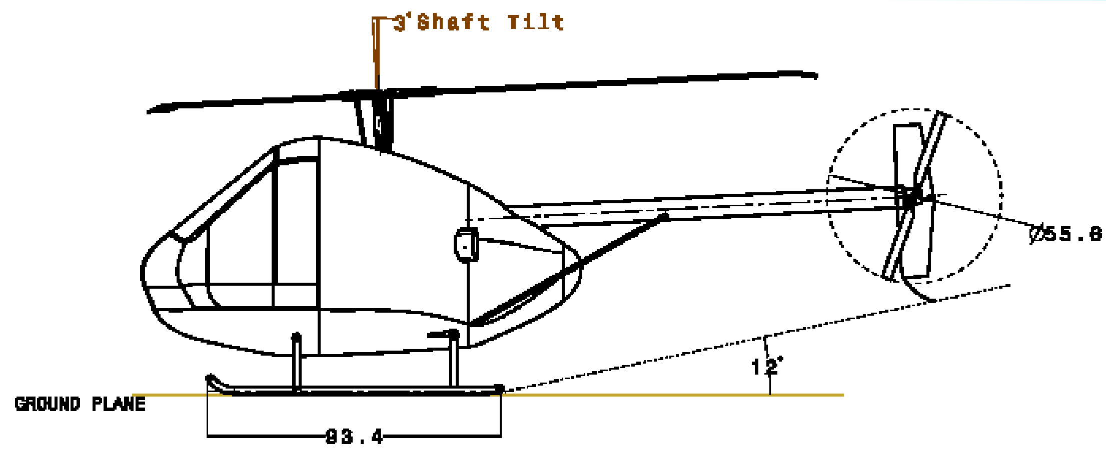


Final Selection: 3 bladed design

Penguin Configuration

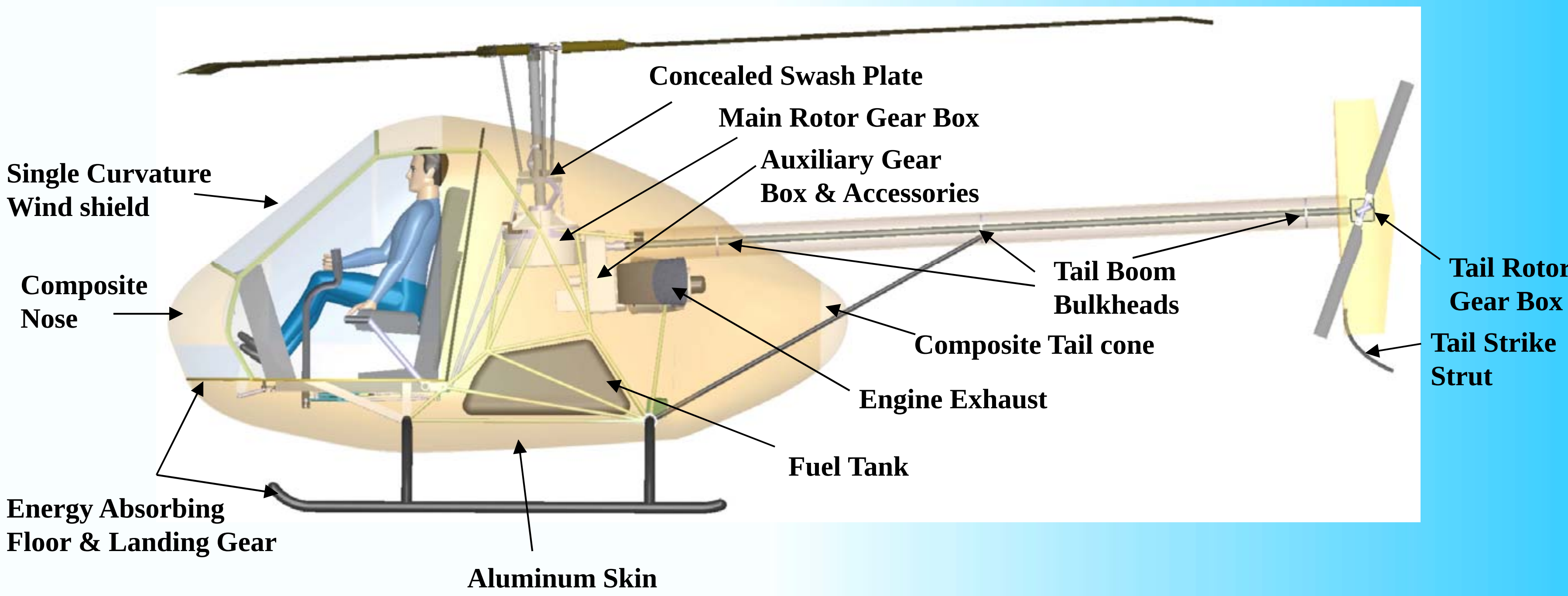






Takeoff Weight (lbs)	1345
Empty Weight (lbs)	743
Transmission Rating (hp)	145
Disk Loading (lb/ft^2)	3.14
Number of Blades	3
Aspect Ratio	24
Main Rotor Dia. (ft.)	23.36
C_T/σ	0.075
Solidity (σ)	0.04
Acquisition Cost	$266k

Inboard View

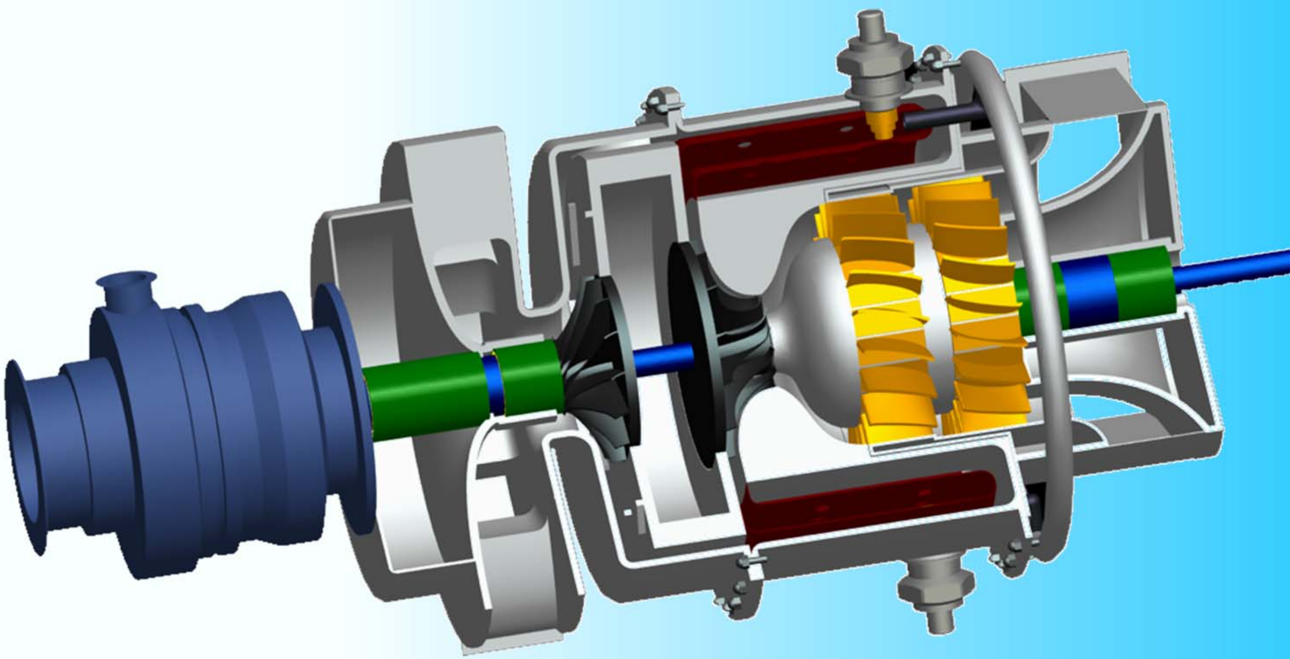


Intake on Starboard and exhaust on port to avoid re-ingestion

Pyros Turboshaft Engine

Configuration:

- Centrifugal compressor
- Radial inflow turbine
- Reverse flow annular combustor
- Axial flow free turbine



- Custom designed to meet requirements of the Penguin trainer helicopter.
- Design driven primarily by acquisition and operational costs.
- State-of-the-art materials and bearing technologies.

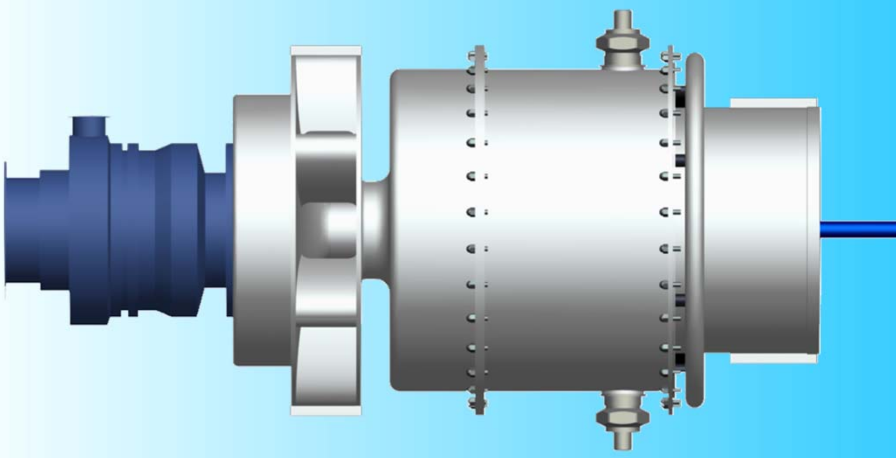
Pyros Turboshaft Engine

Engine performance at design point (6000ft,ISA+20^{0}C):

- •Power: 125 hp (93.21 kW)
- •Gas generator speed: 100,000 RPM
- •Power turbine speed: 75,000 RPM
- •Mass flow: 1.12 lb/s (0.51 kg/s)
- •Fuel consumption: 11.6 gal/hr (0.04 m^3/hr)
- •Turbine inlet temp.: 1790 F (1250 K)
- •Compressor pressure ratio: 7
- •SFC: 0.625 lb/hp-hr (0.381 kg/kW-hr)

Comparison of power plants at sea-level & ISA

Engine	Boeing 502-6	Solar T62T-32	Pyros
Power(hp)	160	160	165
SFC (lb/hp-hr)	1.5	1.4	0.61
Weight (lb.)	200	143	125
Power/ Weight	0.8	1.12	1.32



Lower SFC and higher Power to Weight Ratio

Pyros Turboshaft Engine

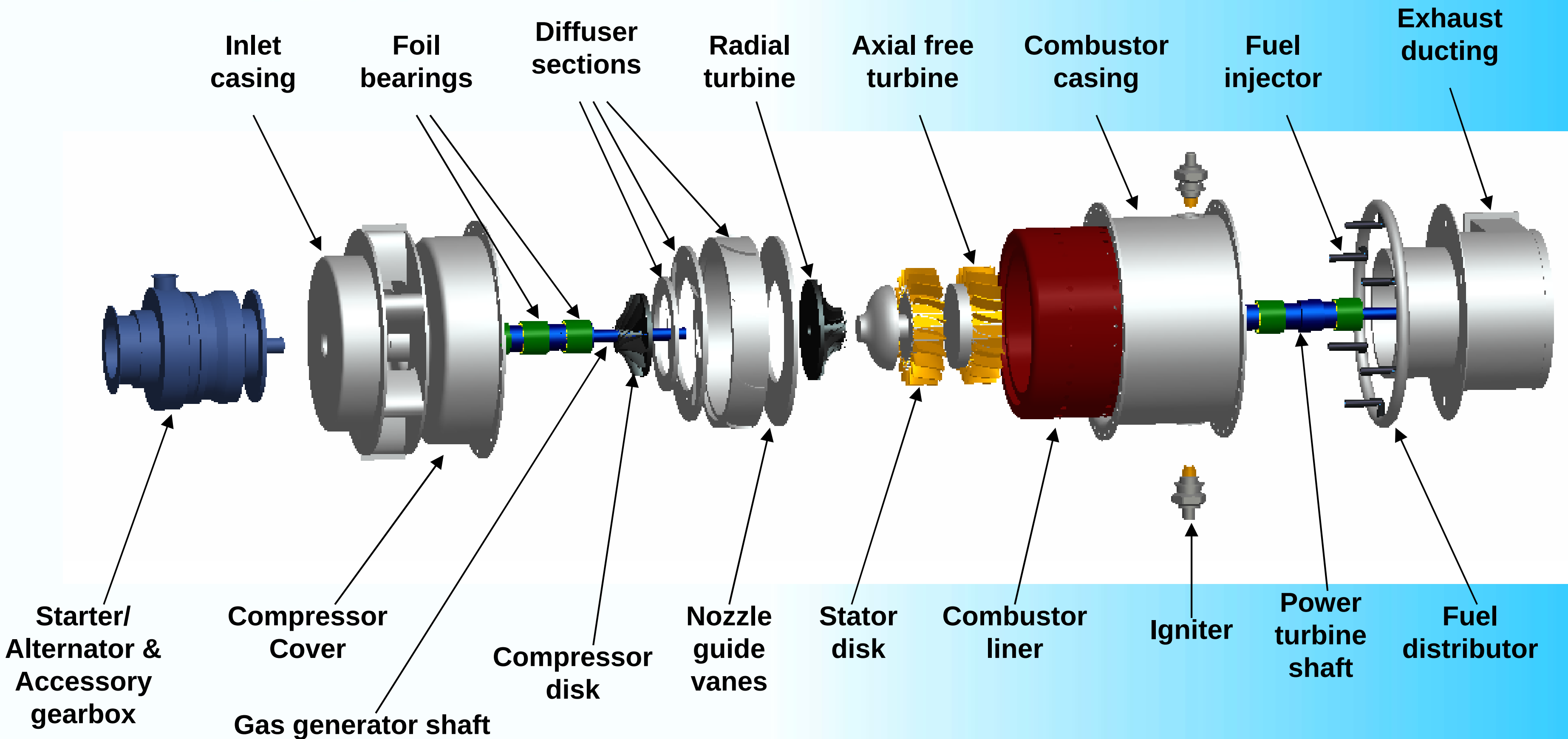
Primary drivers in improving performance:

- High turbine inlet temperature supported by proven superalloys.
- High operating speed aided by the use of foil bearings.
- FADEC system improves engine performance and safety aspects.

Cost reduction strategies:

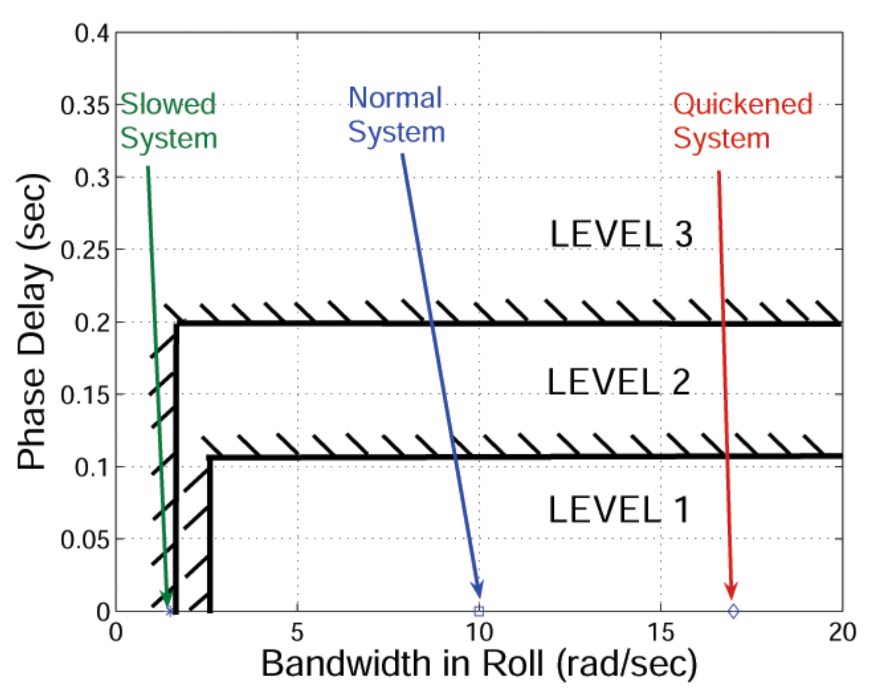
- 15% reduction in DOC by replacing oil lubricated bearing system with foil bearings.
- Appropriate choice of manufacturing techniques allowing low cost turbine blade materials.
- Lean manufacturing techniques save on acquisition cost and DOC.
- Integrated starter-alternator system reduces maintenance & acquisition cost.
- Innovative impeller machining technique reduces acquisition cost.
- Ease of assembly/disassembly reduces overhaul costs.

Pyros Turboshaft Engine



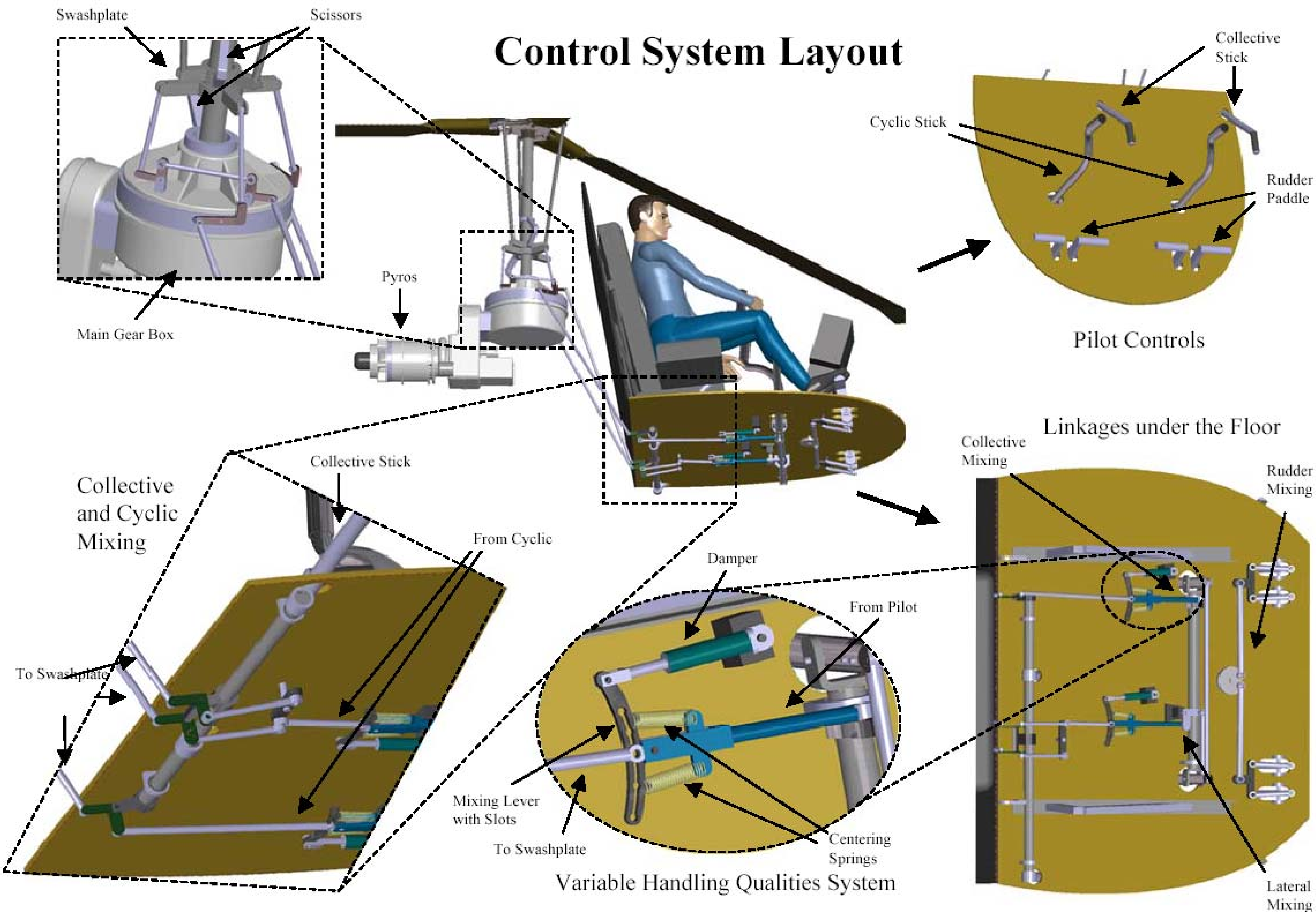
VHQ (Variable Handling Qualities)

Pilot can change bandwidth by moving only one rod underneath cabin floor



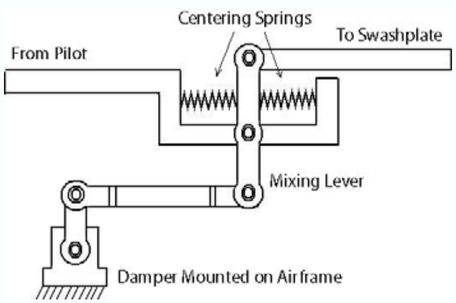
Bandwidth in pitch and roll can be modified. This enables the trainee to start at Level 1 and progress to Level 3 on the same helicopter.

Control System Layout

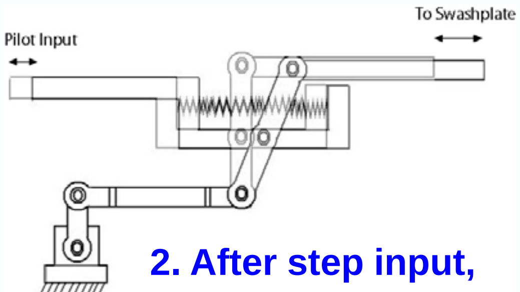


VHQ (Variable Handling Qualities)

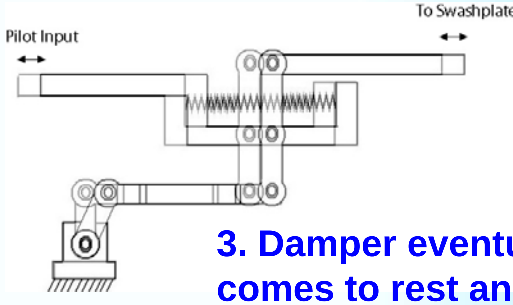
VHQ system modifies the pilot input. This shows how a system can be constructed to increase bandwidth.



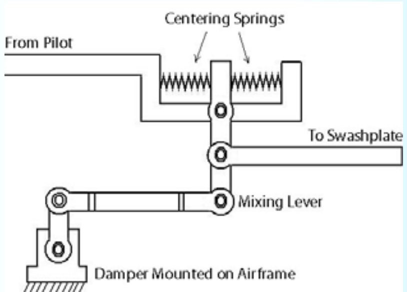
1. System before pilot input



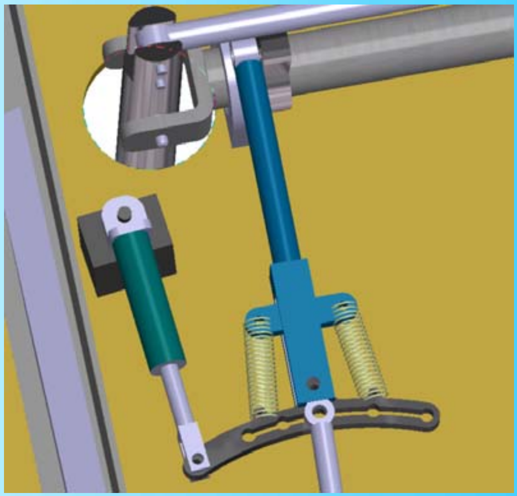
2. After step input, damper does not move so output overshoots.



3. Damper eventually comes to rest and overshoot of pilot input goes to zero.



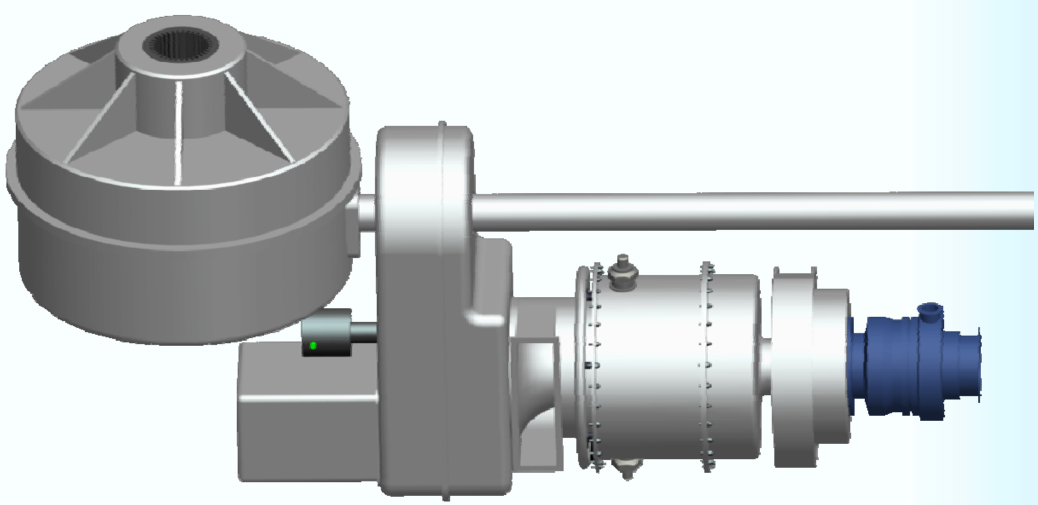
4. If the output position on mixing lever is changed, the system bandwidth will change.

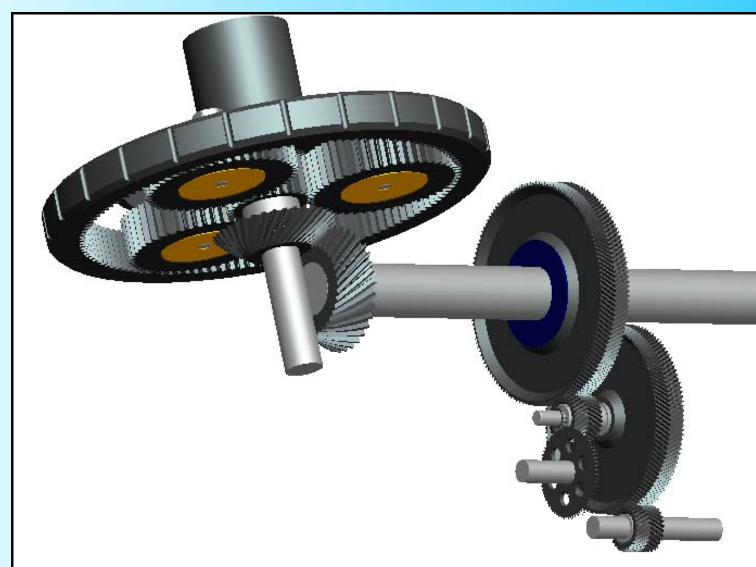


5. This shows a close-up of the embedded VHQ system. By sliding the output rod to a different hold, the handling qualities are changed.

Drive System

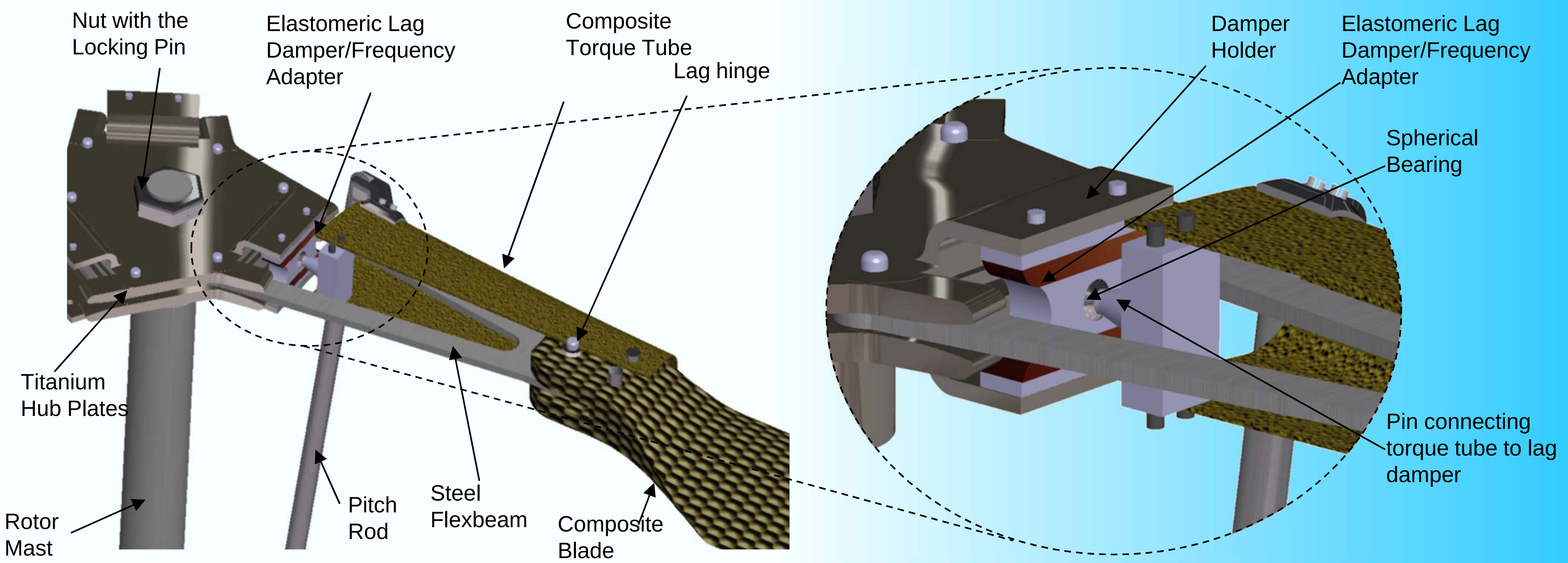
- 136:1 reduction from free turbine shaft at 75,000 RPM to main rotor shaft at 550 RPM.
- Lightweight, compact
- 4000 hour MTBF
- Modular design allows for allows for quick, easy removal of individual components during overhaul, thus reducing the MTTR
- HUMS to detect fault and lower maintenance cost





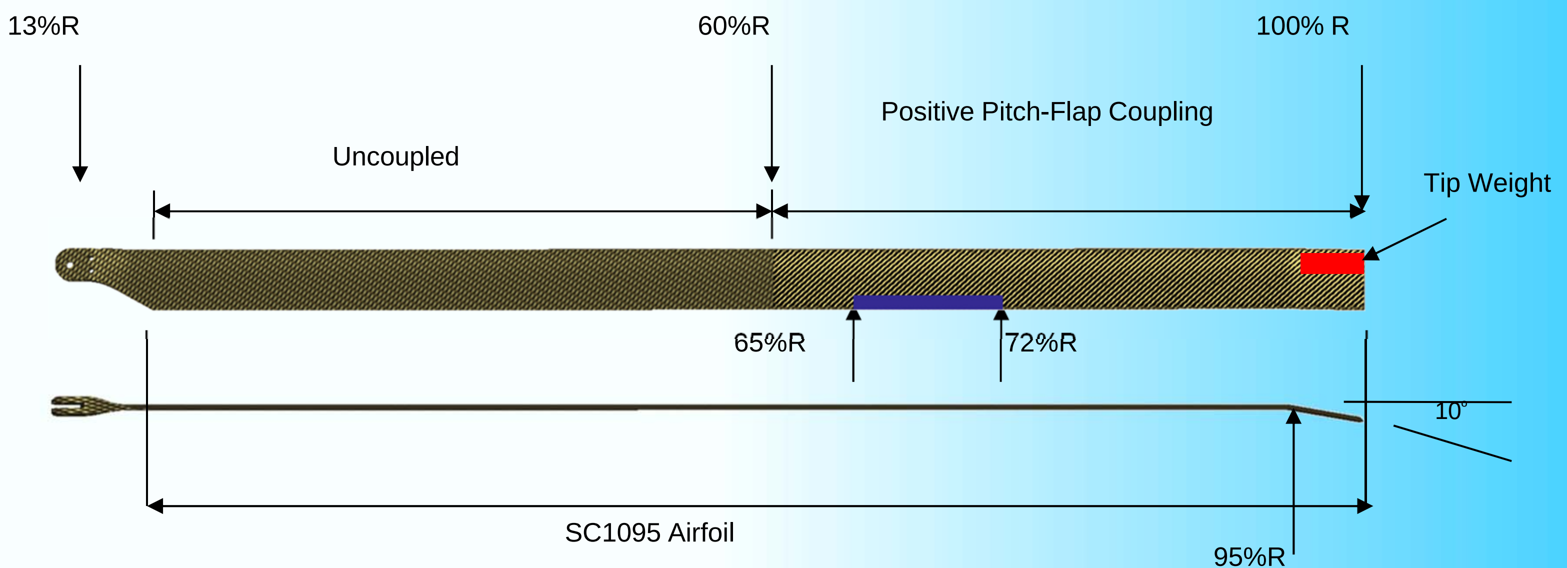
Rotor Hub

- **Advanced soft in-plane hingeless hub for higher control power**
- **Compact design with Elastomeric Lag Damper / Frequency Adapter**



Rotor Blades

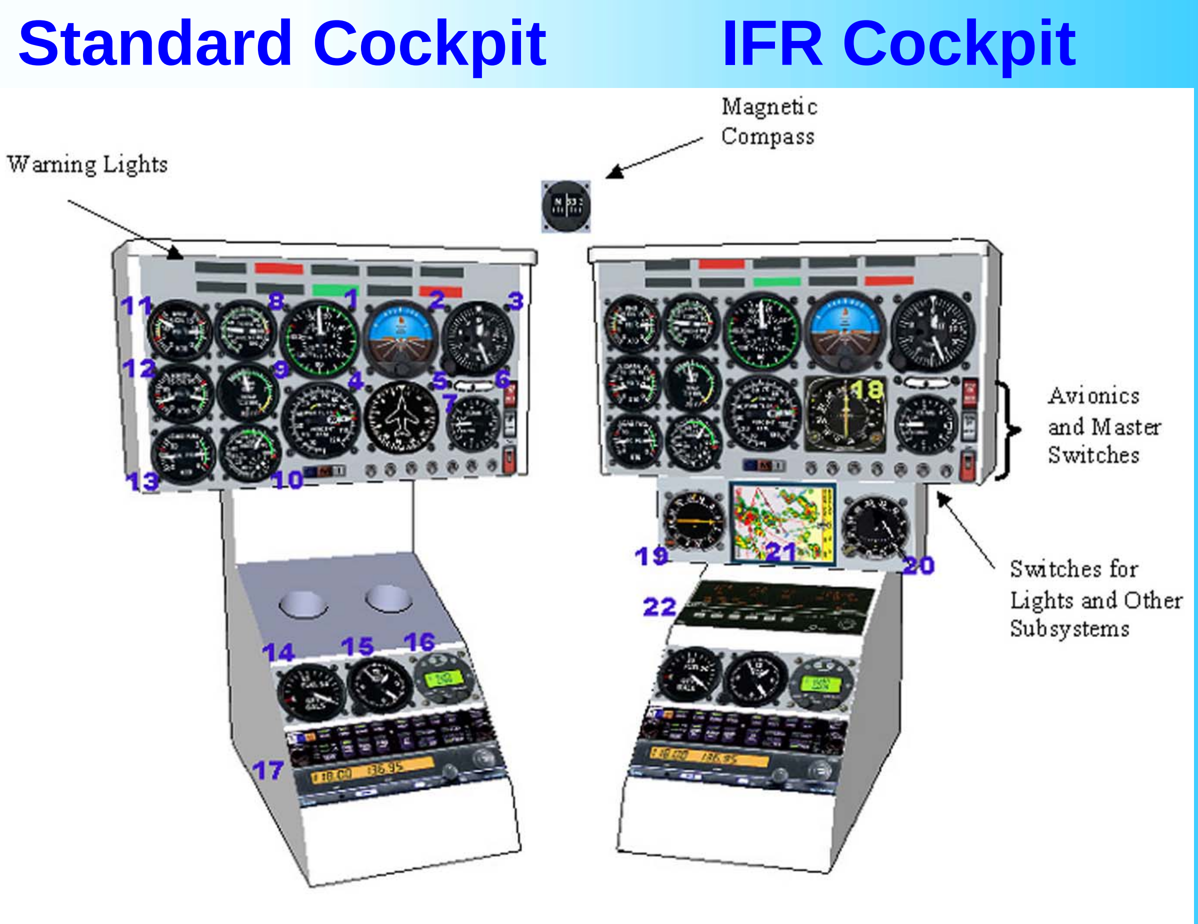
- 3-bladed design
- Graphite-epoxy composite blades for superior specific strength
- Tailored pitch-flap structural coupling for 3/rev vibration reduction
- Tip mass for superior autorotative performance



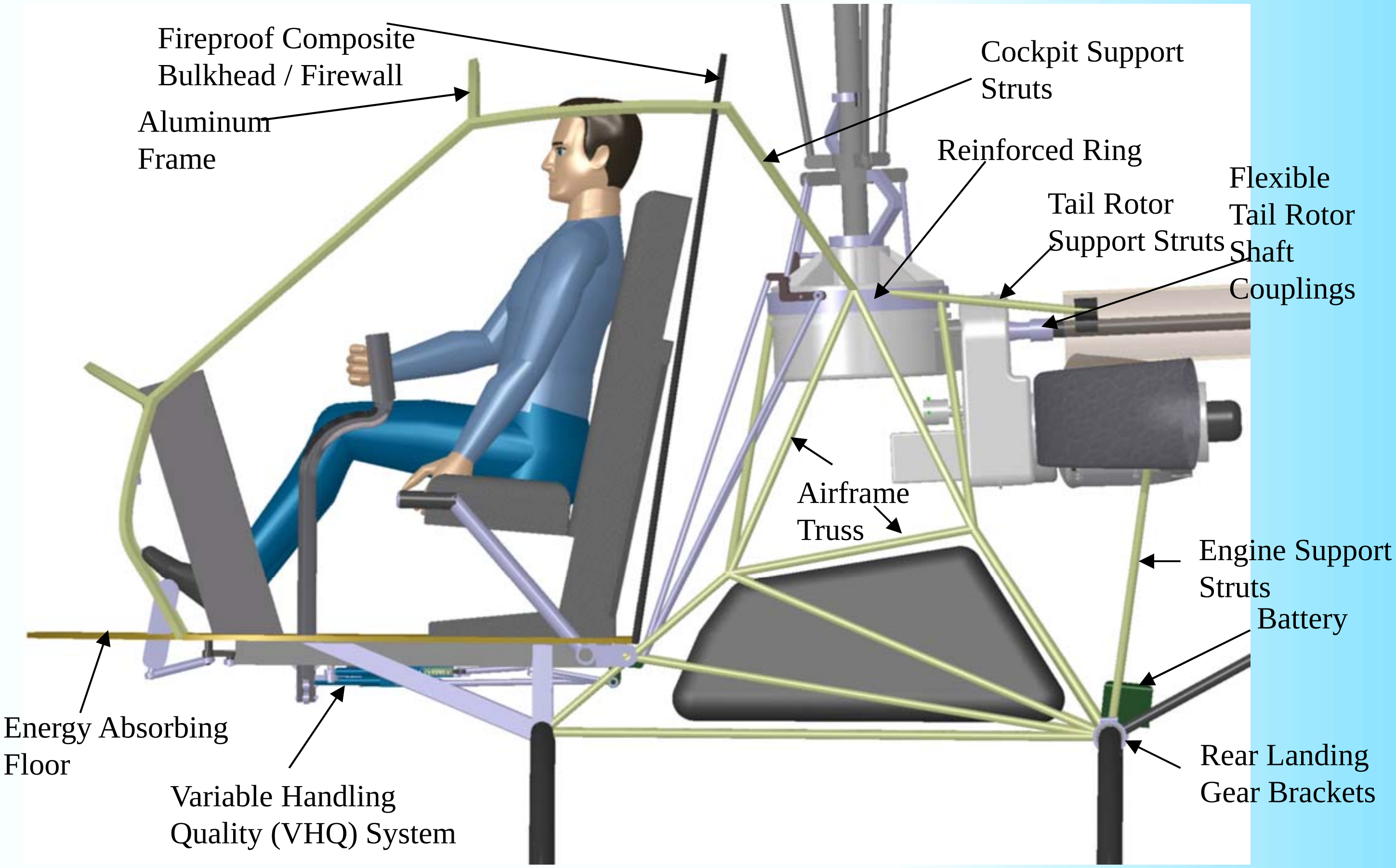
Note: -11° twist over the entire blade span

IFR Cockpit Option

Standard instrumentation or optional IFR instrumentation.



Crashworthiness

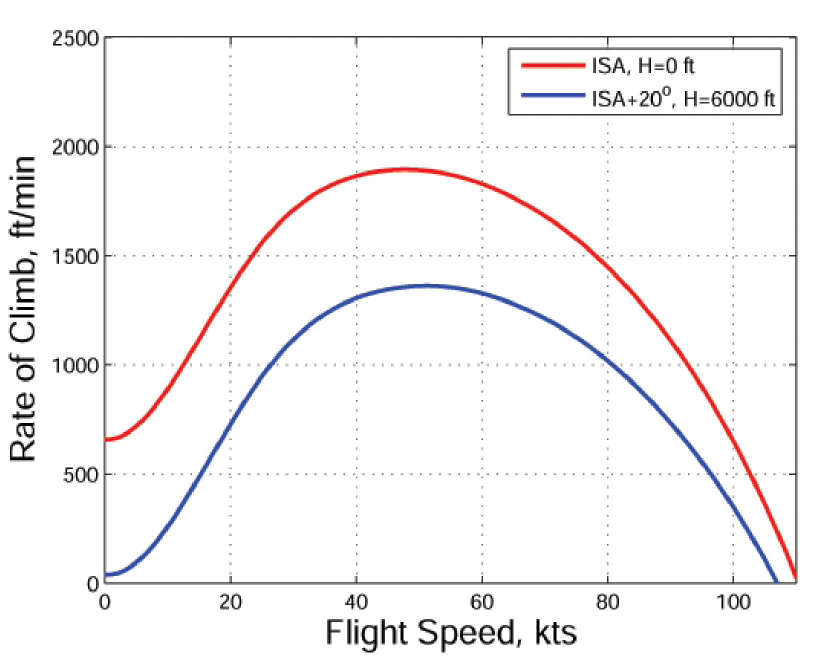


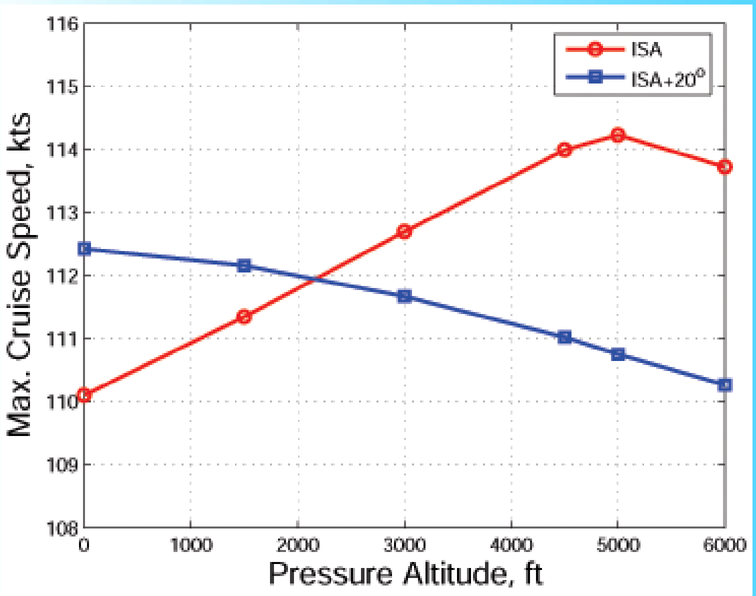
Crew protected by:

- Airframe
- Stroking seats – stroke provided by inexpensive crushable Al foam
- adds $250/seat
- Kevlar-Carbon composite floor absorbs crash energy
- Landing Gear designed to absorb crash energy

Penguin Performance

Rate of climb and cruise speed better than current piston trainers





Innovative Manufacturing

Lower cost achieved by:

- Turbine blades manufactured using powder metallurgy
- Low cost turbine blade material chosen
- New time-saving method to machine titanium impellers using 5-axis milling
- Simple curvatures used for cockpit
- Lean Manufacturing

Conclusion

Outstanding Features

- Pyros Oil-free turbo shaft engine with low SFC and high Power to Weight ratio
- VHQ system
- Compact hingeless soft-inplane hub with tailored composite blades to reduce vibration
- Outstanding cruise speed, range, endurance and hover limit
- Manufacturing Cost Reductions
- Low Acquisition Cost ($266k)
- Good autorotative performance with blade tip weight
- Extra wide cabin (60”)
- Simple, lightweight 4000 hr MTBF transmission with HUMS
- Crashworthy features include landing gear, Kevlar floor, stroking seat