Executive Briefing

30th Annual AHS Student Design Competition

Graduate Category

STERNA

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Key features and technologies

Composite airframe and skin

Unidirectional carbon fiber epoxy composite material for high strength and lower weight

NOTAR

Anti-torque minus the mechanical complexity

Hingeless Rotor

Greater control authority, added maneuverability

Tailored Avionics

TCAS, TAWS enable coordinated operations over difficult terrain

Pusher Propeller

Enables Quick response through greater speed

Wings

Share most of the lift at high speeds resulting in High cruise efficiency and hence greater range

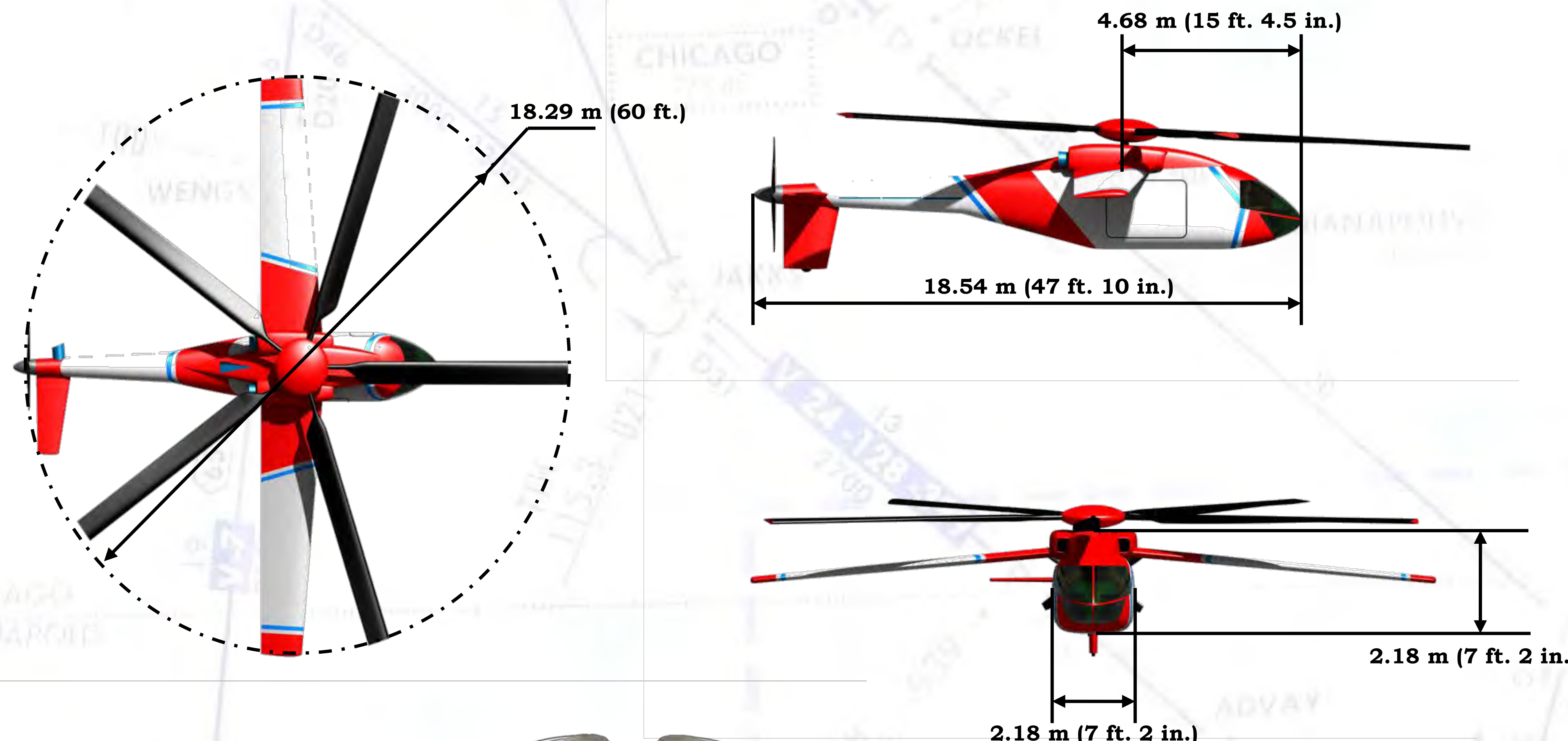
Spacious cabin

14000 liters of space ideal for carrying wounded, medical equipment or aid.

Optimized, advanced twin turboshaft engines

Consume 22% less fuel than the CT7-8 engine

Sterna: Aerial Succor - Whenever, Wherever



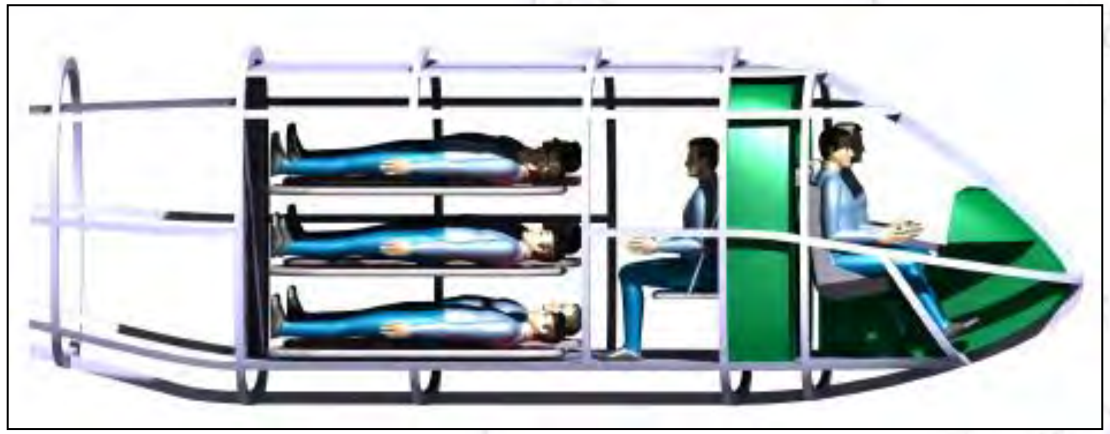
Vehicle Specifications

Design GW	15000 kg	33070 lb
Empty Weight	8054 kg	17,757 lb
Fuel Tank Capacity	5470 L	1445 gal
Fuel Weight	4391 kg	9681 lb
Useful load	6850 kg	15100 lb
Cabin height	1.78 m	5.8 ft
Cabin length	3.96 m	13 ft
Cabin Width	1.98 m	6.5 ft
Crew Seating	3 (4 Max)	

Performance at a glance

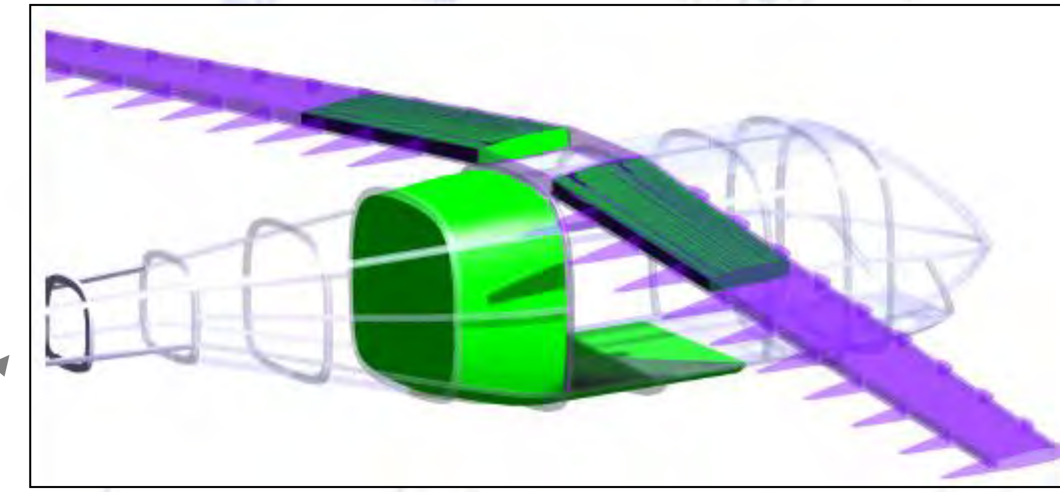
	Sea Level ISA	3000m/ISA+15	6000m/ISA+15
Maximum Forward Airspeed	241 kts	253 kts	246 kts
Maximum Range	2754 km (1487 nm)	3206 km (1731 nm)	3684 km (1989 nm)
Maximum Range Airspeed	105 kts	125 kts	150 kts
Maximum Endurance	14.2 hrs	13.9 hrs	13.2 hrs
Maximum Vertical Climb	26.6 m/s (5262 ft/min)	20.6 m/s (4083 ft/min)	5.6 m/s (1125 ft/min)
Service Ceiling		7010m (23,000 ft)	

Anatomy of the Sterna



Suggested Layout for Medevac Missions

Conveniently fit 6 litters with a crew member in the cabin



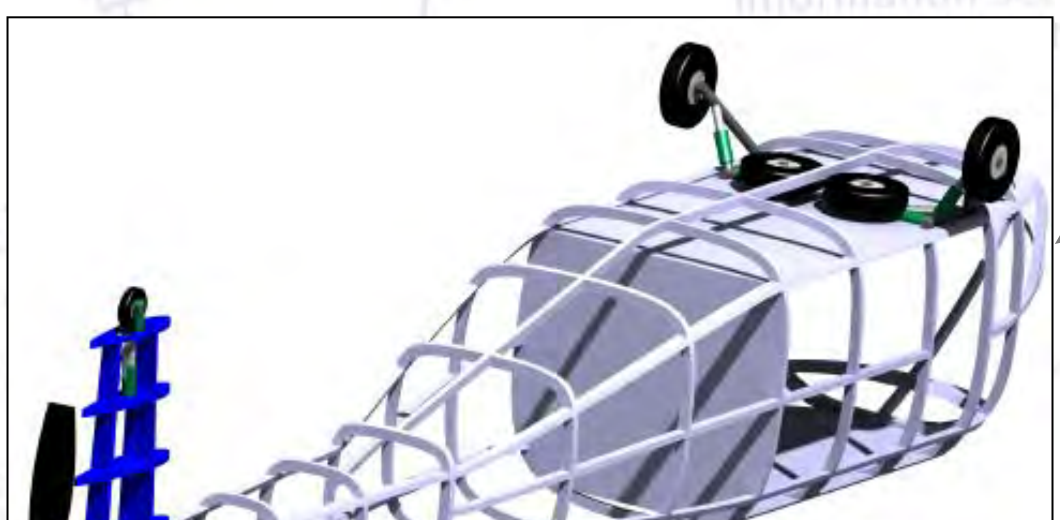
Arrangement of fuel tanks in the wing

Excess fuel tank capacity helps exceed the range requirement.

Retractable landing gear for a cleaner, low-drag configuration

Resulting in a flat plate drag area of 19.73 ft^2

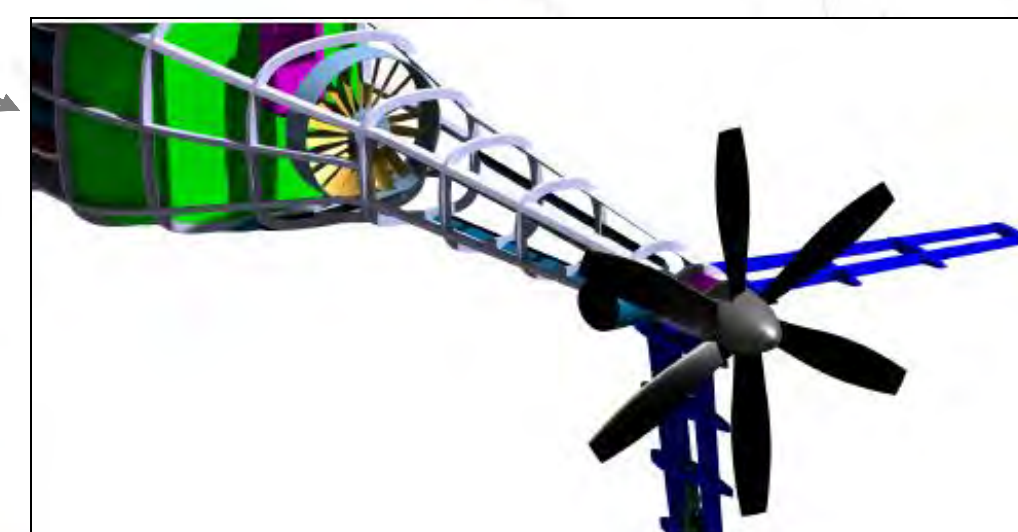
(Please refer the section on Drag in this document)



Empennage with NOTAR and propeller

Apart from low noise emissions, NOTAR enables a high fuselage contraction angle thereby reducing drag.

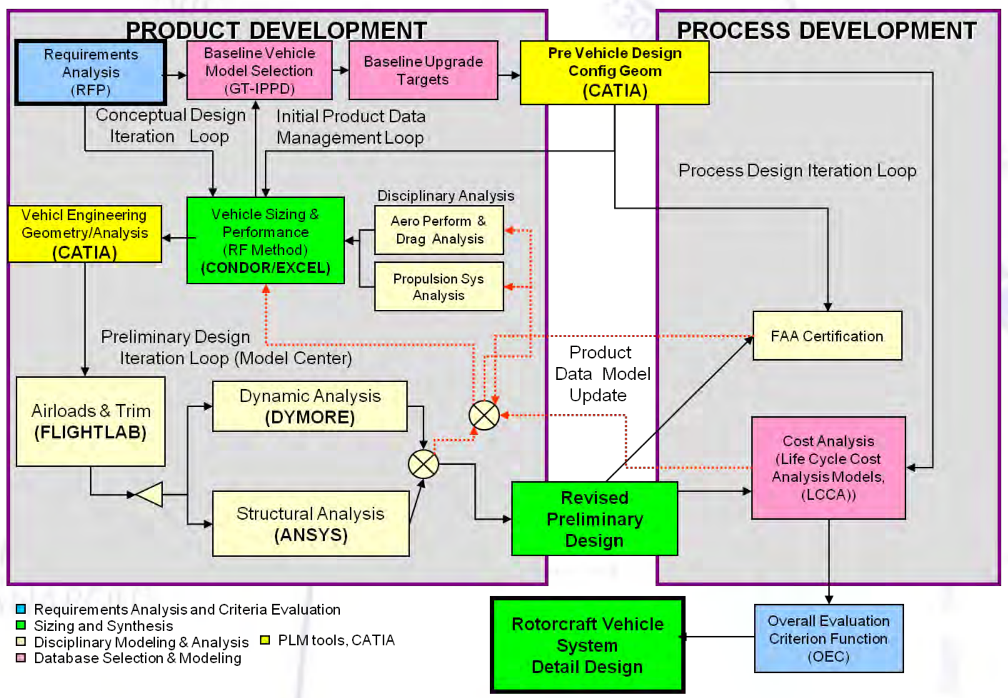
The constant speed propeller aids in the high speed performance.



Creating the Sterna: Design Process

Modified GIT Rotorcraft IPPD Preliminary Design Methodology

I



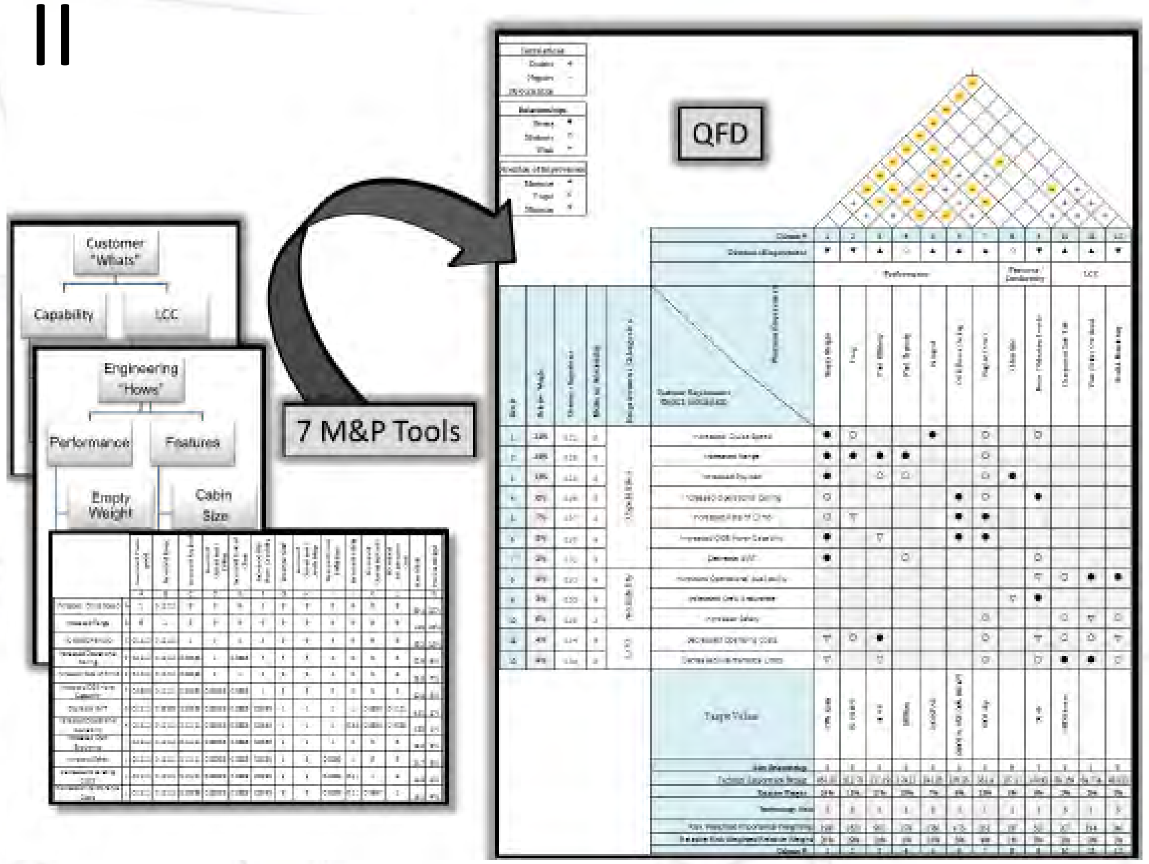
I The Georgia Tech Rotorcraft IPPD preliminary design methodology is tailored to suit the current design task.

II The 7 Management and Planning tools (M&P) are used as inputs to obtain a Quality Function deployment matrix, which is used as a means to understand customer needs and establish a base for tradeoffs.

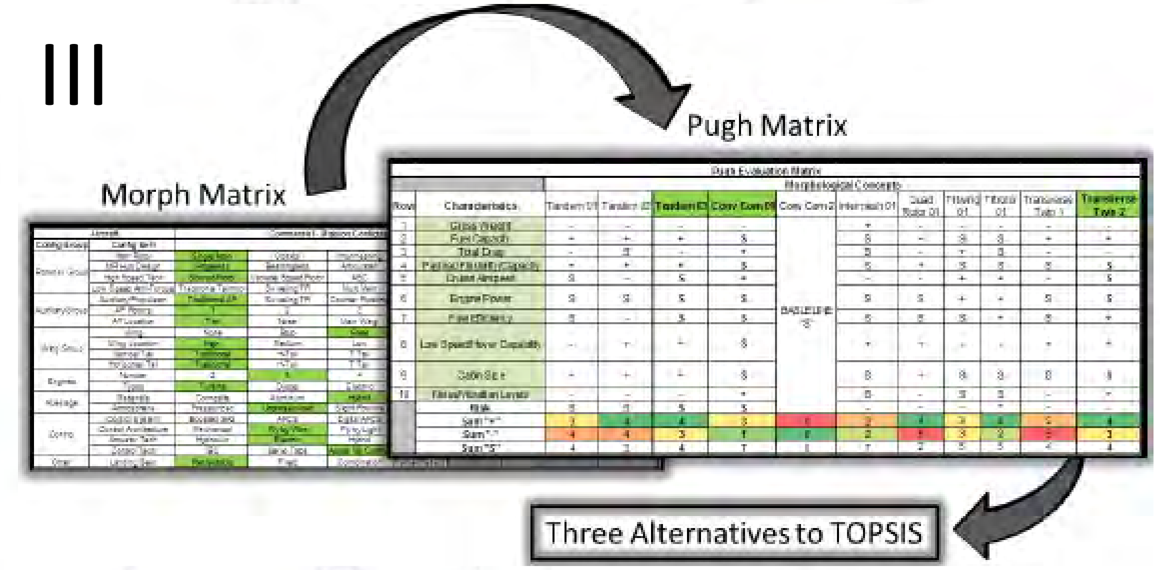
III Morphological and Pugh matrices are used to generate alternative configurations. Three are selected.

IV The RF method is used for sizing the three alternatives. Model center is used to optimize the three alternative configurations, using a Darwin algorithm optimization routine. The configuration data is then used to rank the alternatives, using TOPSIS. The Single main rotor configuration is found to be the best.

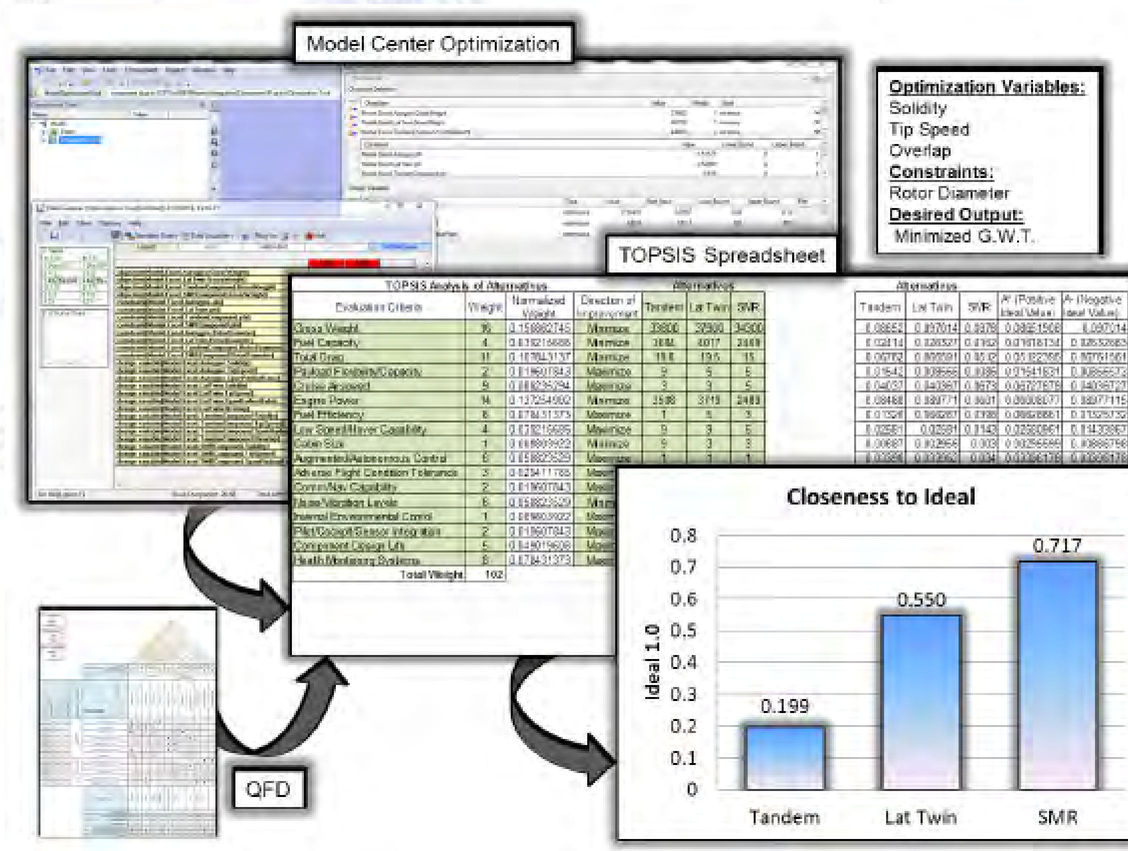
II



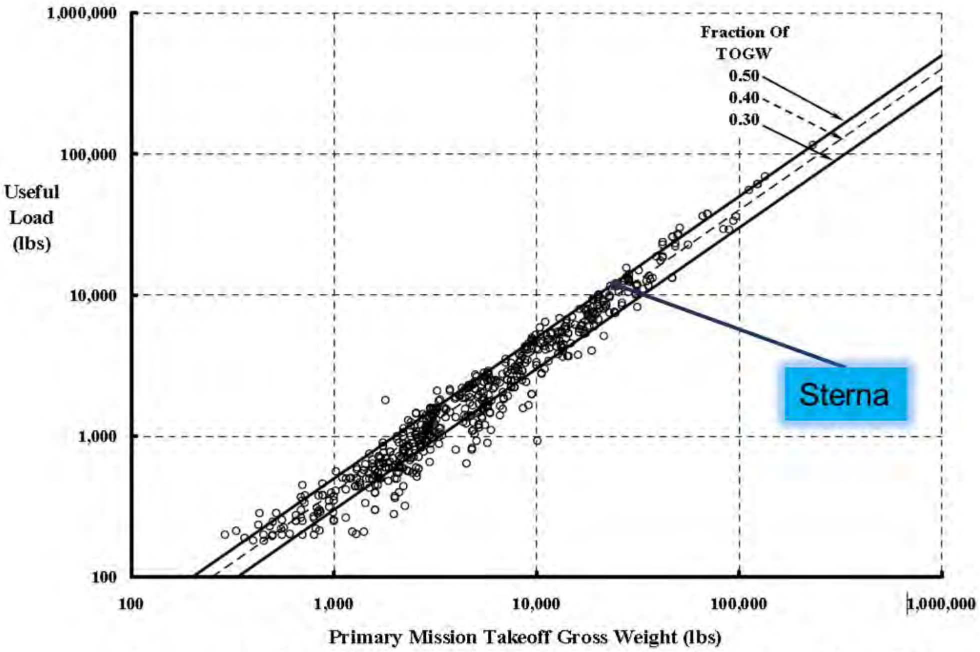
III



IV



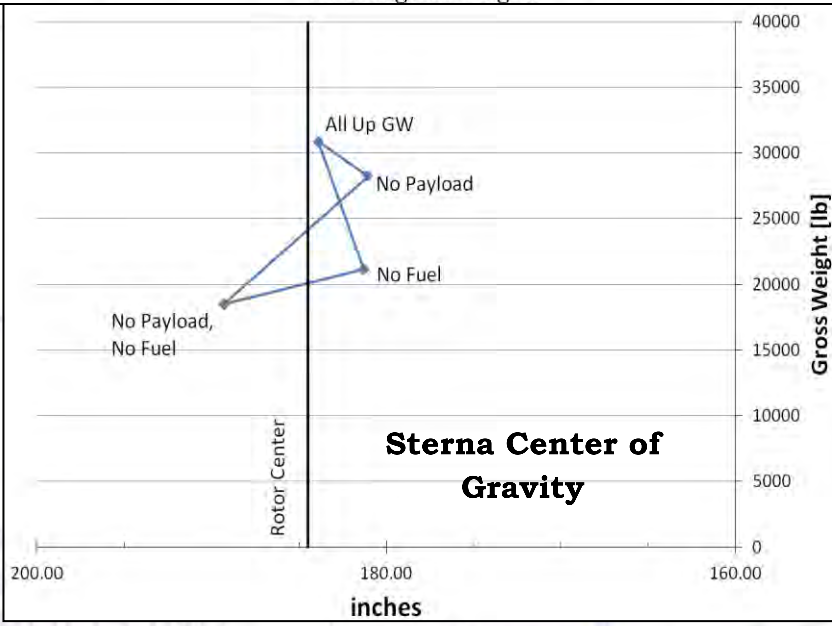
Weight Breakdown



On average, the rotorcraft industry can obtain 40 percent useful load from takeoff gross weight.

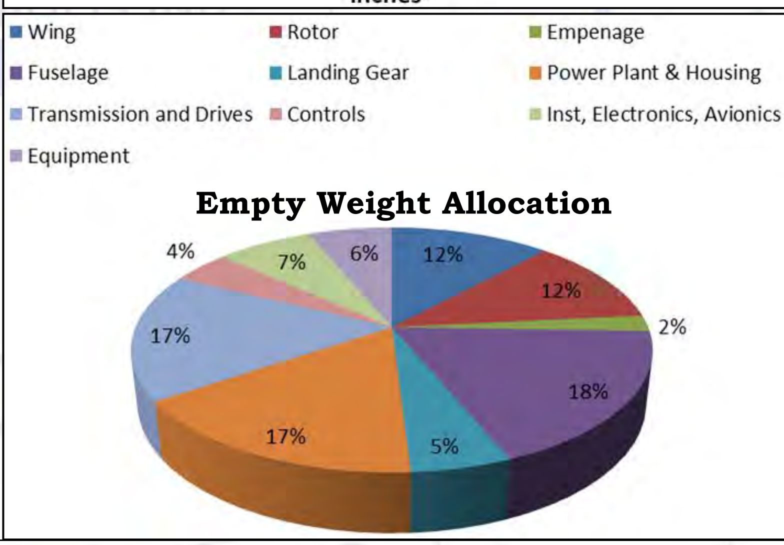
Component	ft	lbs
Vertical center of gravity	4.667	30865
Tail distance (vertical)	7.000	518
Fuselage cg	4.856	15233
Wing cg	7.000	2005
other	4.000	750
Fuel cg	4.000	9729
Payload cg	4.000	2630
Engine cg	6.000	1305
engine cooling etc. cg	6.000	716
nacelle cg	7.000	455
landing gear cg	1.000	1044
fuselage Structure cg	3.500	2432
drive system	7.000	3476
rotor	10.000	2050
control system	2.000	374
avionics	2.000	377
equipment + a/c + anti-icing	2.000	671
electrical	2.000	983
aux power	6.000	147
instruments	3.000	94
fuel system	3.000	576
furnishing	0	533

Vertical CG buildup



Component	ft	lbs
Longitudinal Center of Gravity	15.074	30865
Tail distance (horizontal)	42.800	518
Fuselage cg	14.693	15233
Wing cg	17.000	2005
other	5.	750
Fuel cg	15.000	9729
Payload cg	13.500	2630
Engine cg	16.750	1305
engine cooling etc. cg	16.750	716
nacelle cg	16.750	455
landing gear cg	7.	1044
fuselage Structure cg	17.600	2432
drive system	17.000	3476
rotor	15.375	2050
control system	11.663	374
avionics	6.	377
equipment + a/c + anti-icing	7.	671
electrical	15.375	983
aux power	17.000	147
instruments	3.	94
fuel system	15.000	576
furnishing	8.	533

Longitudinal CG buildup



	Baseline	Sterna
Max Gross Weight, kg (lbs)	15558 (34300)	15000 (33070)
Weight Empty, kg (lbs)	8333 (18371)	8054 (17757)
Useful Load, kg (lbs)	7225 (15928)	6946 (15132)
WE / GWT	0.54	0.54
Useful Load / GWT	0.46	0.46

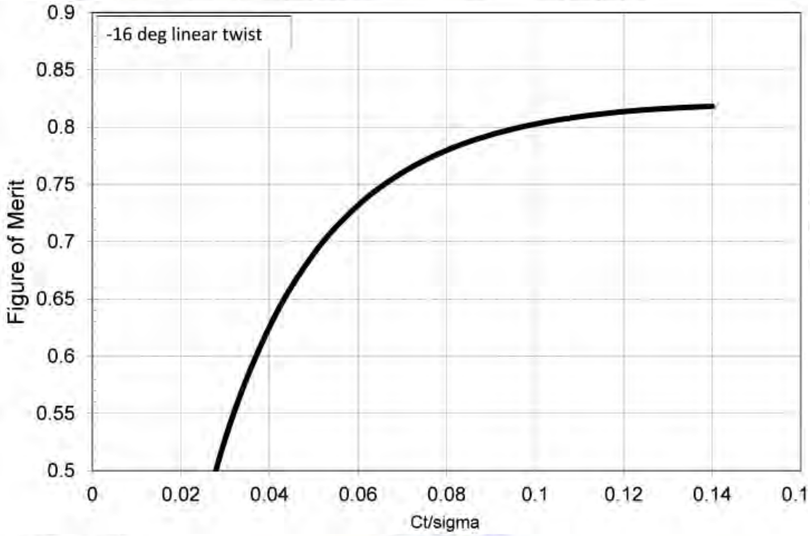
Drag Estimate

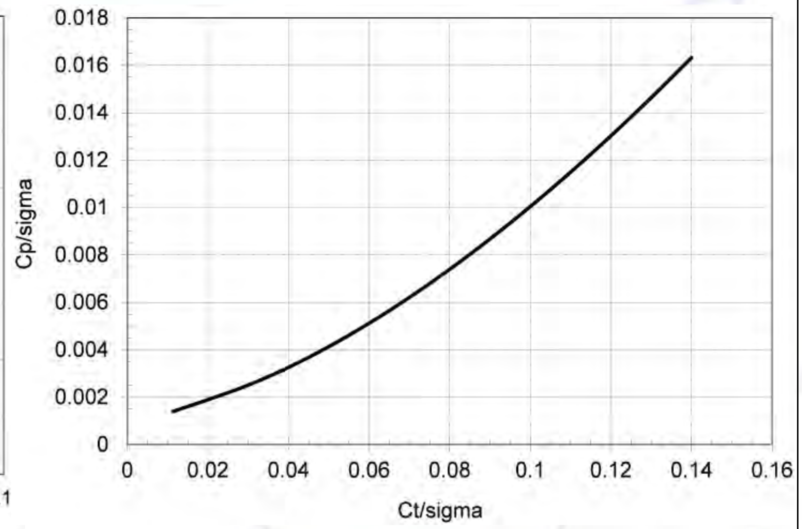
6000 m ISA + 15 C	
Temperature (deg. C)	-9
Density (slug/ft^3 or kg/m^3))	0.0012076 or 0.6223
Viscosity (slug/ft-s or Kg/m-s))	3.49E-07 or 1.67E-05
Cruise Speed (ktas)	240

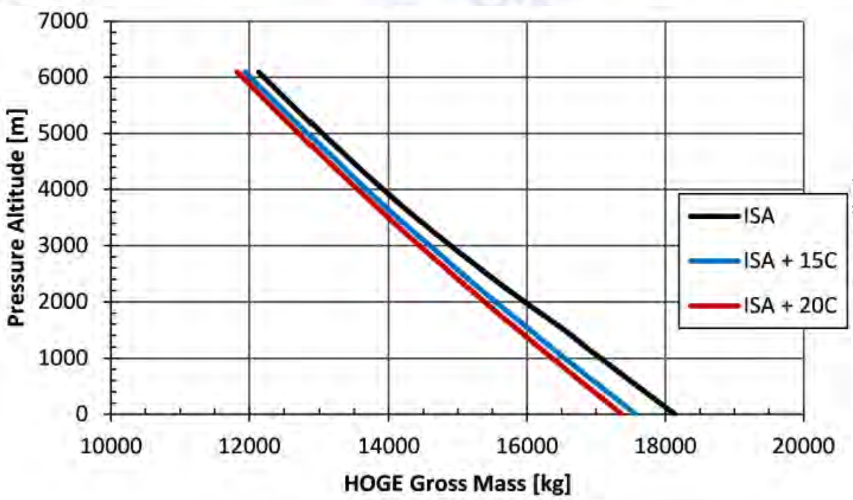
Component	Front Area		Wetted Area		Characteristic Length		Re	Cd (frontal)	Cf	dfe	
	ft^2	m^2	ft^2	m^2	ft^2	m^2				ft^2	m^2
Fuselage	51.3	4.763	796	74	47.8	4.443407	6.70E+07	0.1	0	6.96	0.65
Wing	---	---	636	59.1	5.78	0.536962	8.11E+06	---	0	2.54	0.24
Hor. Stabilizer	---	---	51.6	4.79	3.16	0.293564	4.44E+06	---	0	0.21	0.02
Vertical Tail	---	---	51.2	4.75	4.33	0.402257	6.07E+06	---	0	0.2	0.02
Engine Inlets	---	---	---	---	---	---	---	---	---	1.5	0.14
Rotor hub	9.19	0.854	67.1	6.23	6	0.5574	8.41E+06	0.6	---	5.51	0.51
NOTAR Nozzle	2.14	0.199	---	---	1.33	0.123557	1.87E+06	0.75	---	1.6	0.15
Protuberances										1.2	0.11
									Total	19.7	1.83

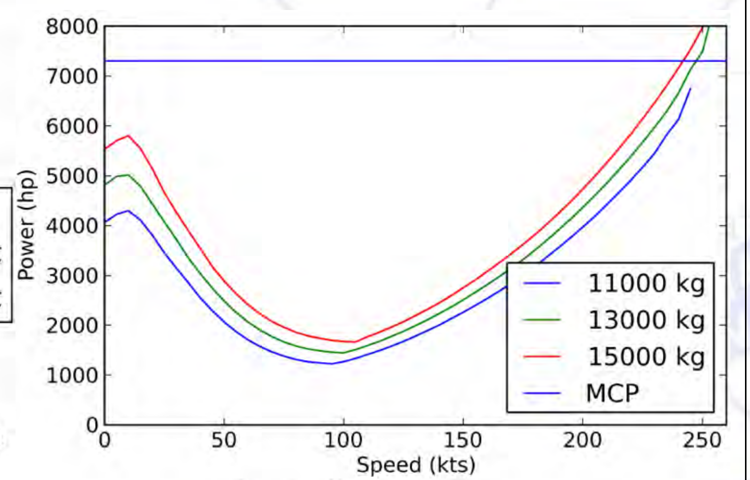
Drag Breakdown

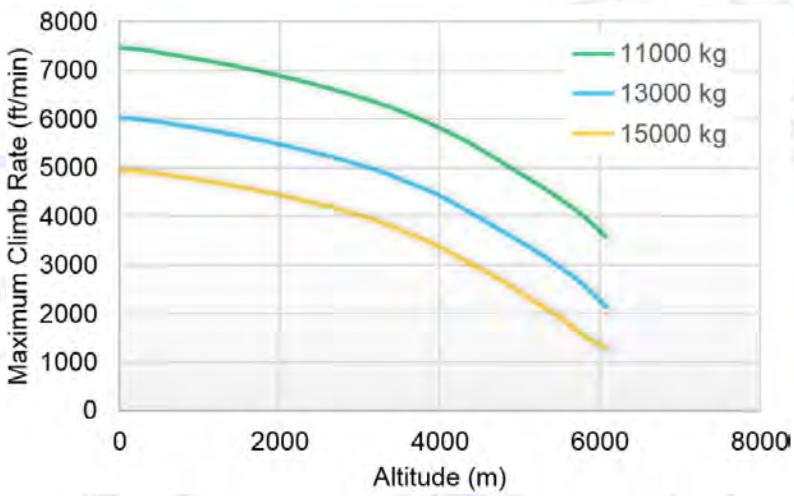
Performance



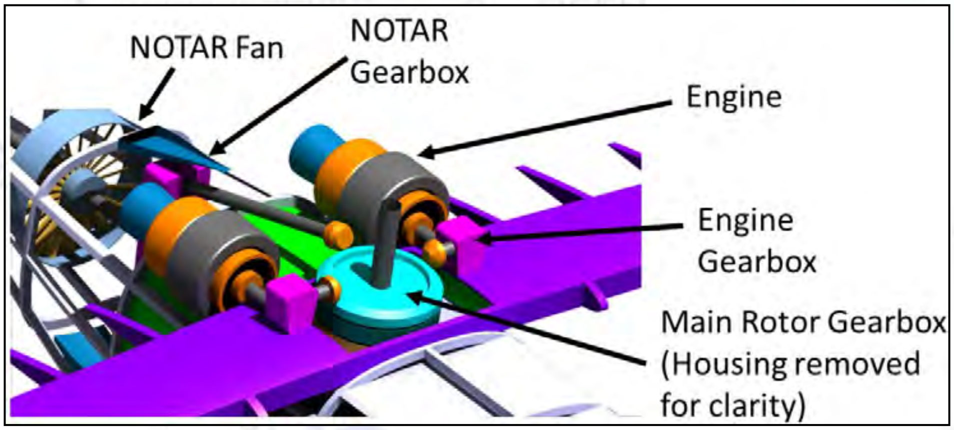








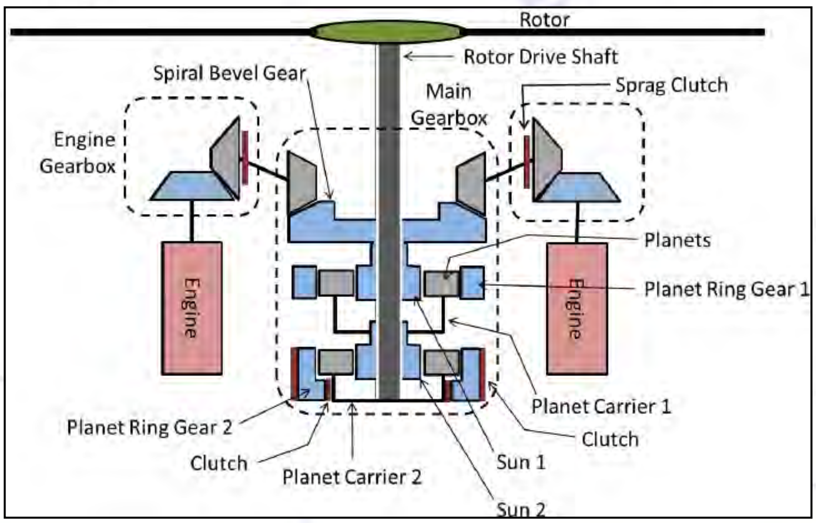
Drive System

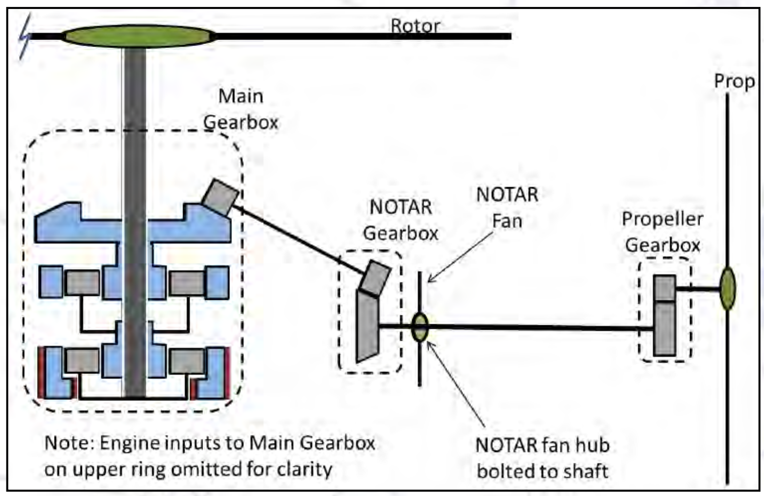


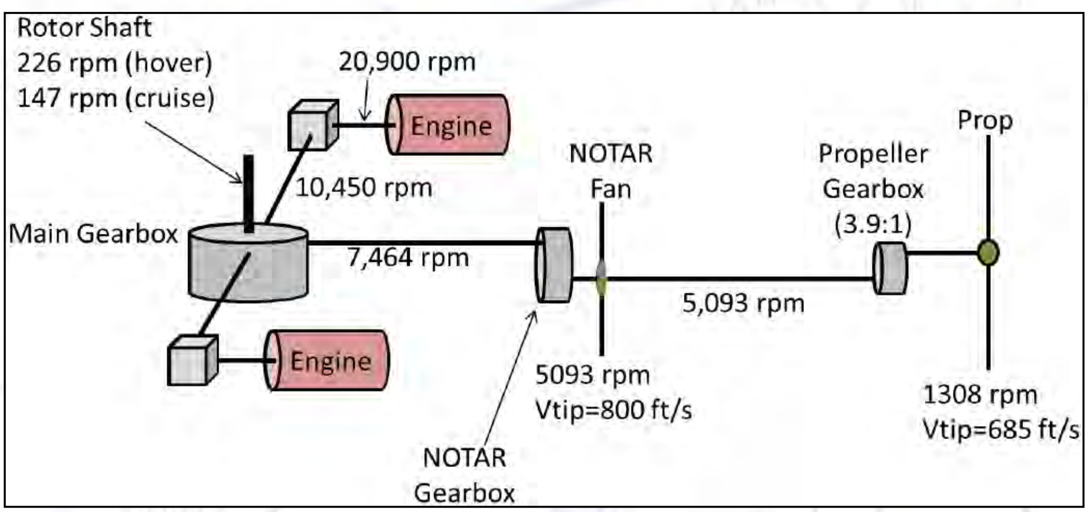
The primary role of the Sterna drive system is to deliver power from the engines to the main rotor, propeller, and NOTAR fan.

The propeller tip speed is fixed at 208.8 m/s (685 ft/s)

The system is comprised of five gearboxes and necessary interconnecting shafts

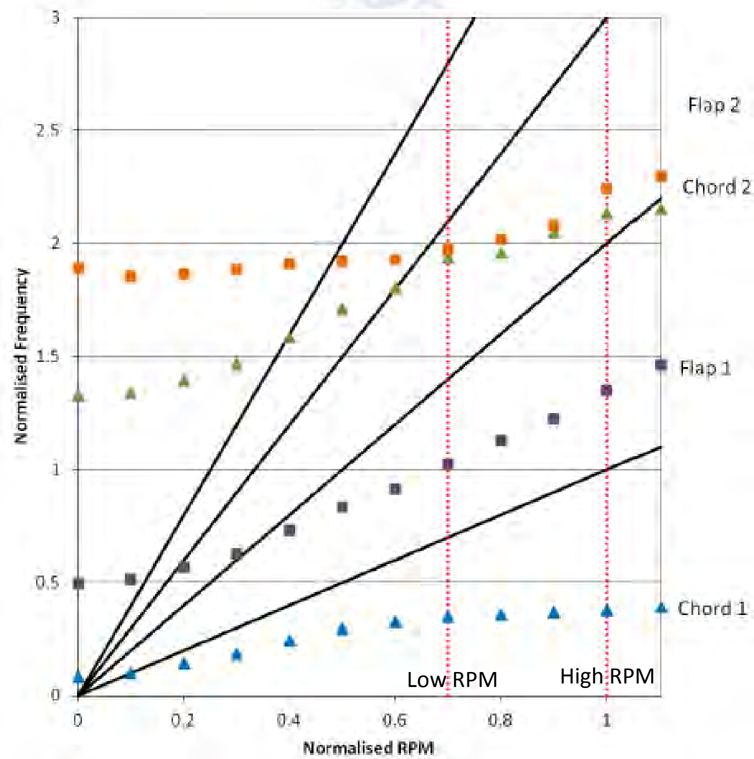






Rotor System

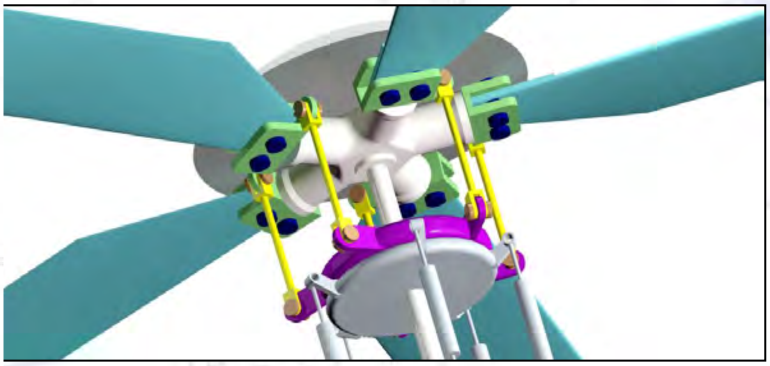
Type	Hingeless	
Radius	9.14 m	30 ft
Chord	0.747 m	2.45 ft
Number of Blades	5	
Solidity	0.13	
Hover Disk Loading	57 kg/m^2	11.7 lb/ft^2
Tip Twist (linear)	-16°	
Tip Speed - Low speed flight	221 m/s	725 ft/s
Tip Speed -High speed flight	144 m/s	471 ft/s
Tip Mach - High speed cruise	0.82	
Gear reduction	0.65	
Shaft speed - Low speed	231 rpm	
Shaft speed - High speed	150 rpm	
Mast tilt (forward)	3°	
Rotor airfoils	VR12 (root - 85%R) VR15 (85%R - tip)	



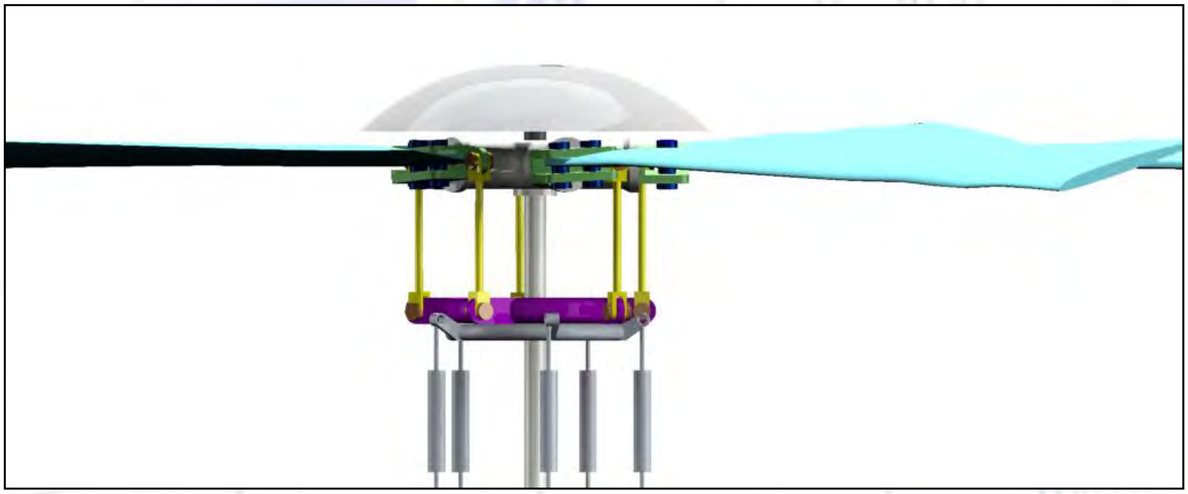
<u>Dynamic Rotor Analysis:</u>

No problems at High RPM (226)

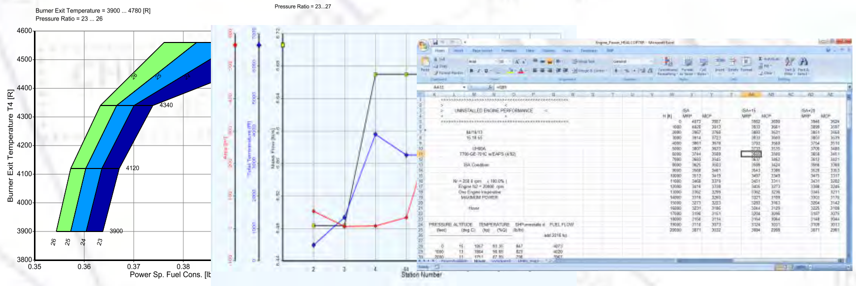
At reduced RPM (150) 2 modes are close, but distant enough to not cause serious problems



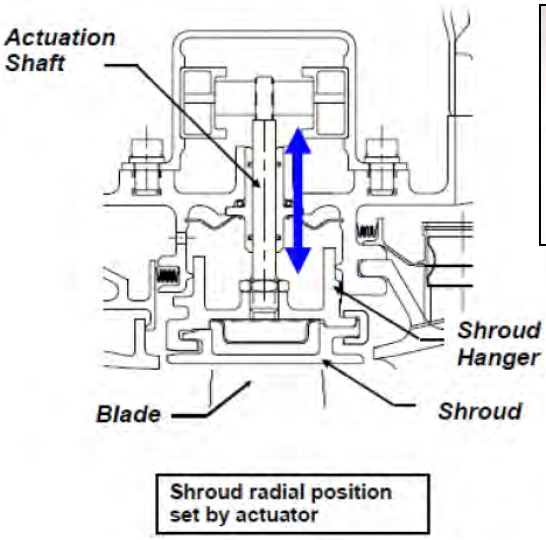
Sterna Rotor



Optimized Propulsion System



Optimization: GasTurb and Excel code were used for Parametric Analysis and optimization



Mechanical Active Tip Clearance control

Blisk

Technology infusions:

Active Tip Clearance Control: Improved compressor efficiency

Advanced Compressor manufacturing and design: Each stage manufactured as a single bladed disk or "blisk". Result is a low parts count.

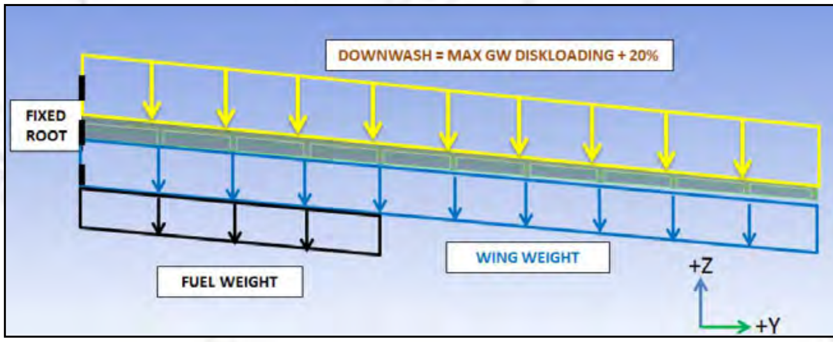
Vacuum cast Single crystal nickel alloy turbine buckets: Enables higher turbine inlet temperatures

Twin Annular Combustor: Steadier flame, lesser hot spots

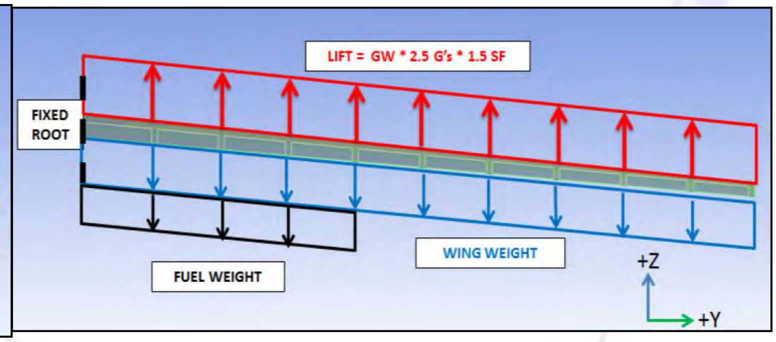
The Result: An improvement in Specific fuel consumption of 32% over a sized Rolls Royce CT7-8 engine.

Results	1st Iteration		2nd Iteration	
	Baseline	Improved	Baseline	Improved
Power Required (HP)	3000	3000	3657	3657
SFC (lbm/(HP*hr))	0.47	0.354	0.544	0.369
W2A (lbm/s)	25.25	15.21	31.77	21.43

Structural Analysis: Wing



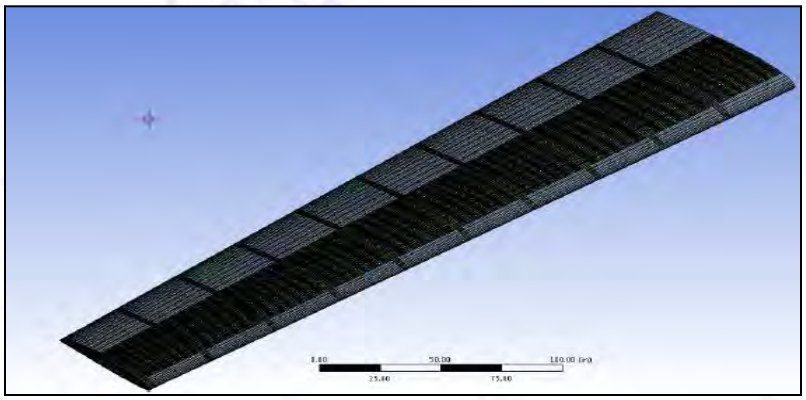
Loading scenario - Hover



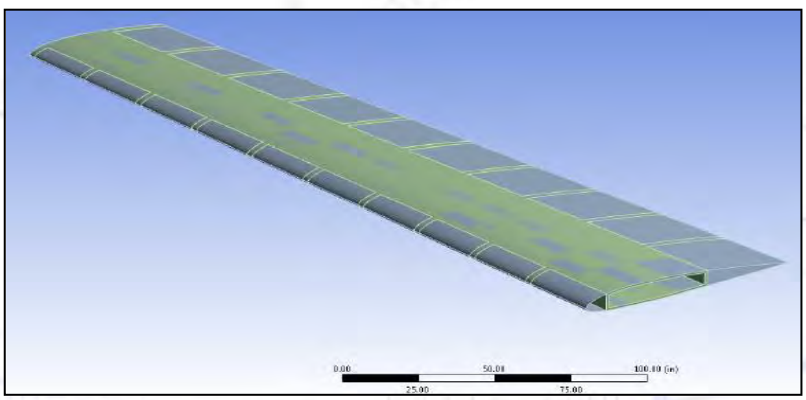
Loading scenario - Forward flight

A finite element analysis (FEA) was performed on the wing to determine the structural integrity of the airframe and skin.

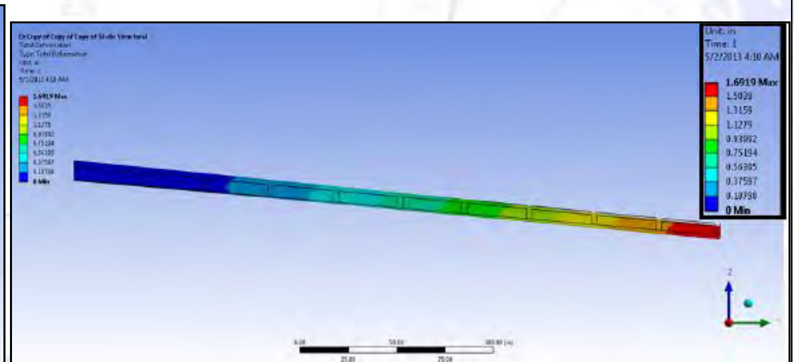
The resulting stresses and deflections helped determine that wing structure is adequately designed to withstand the various loads while minimizing tip deflection and meeting wing-to-rotor clearances.



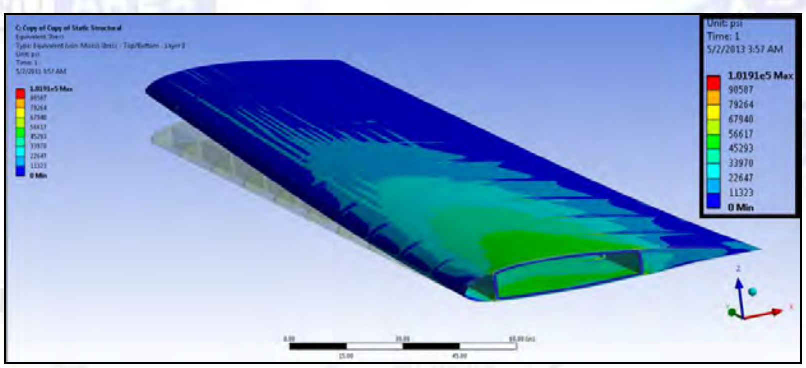
ANSYS Model - Mesh Quality



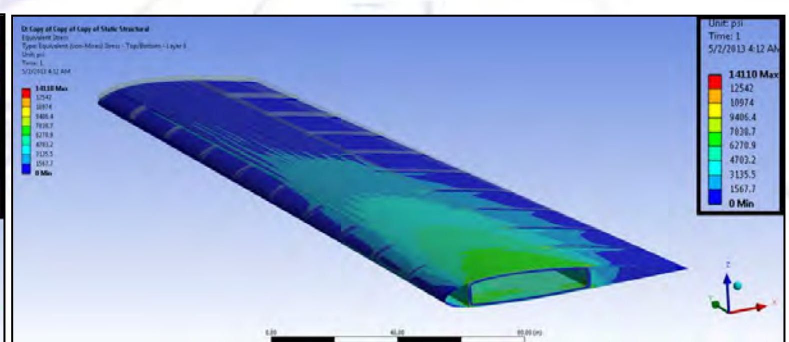
ANSYS Model - Wing Airframe and Skin Surfaces.



FEA Results - Hover - Total Deformation

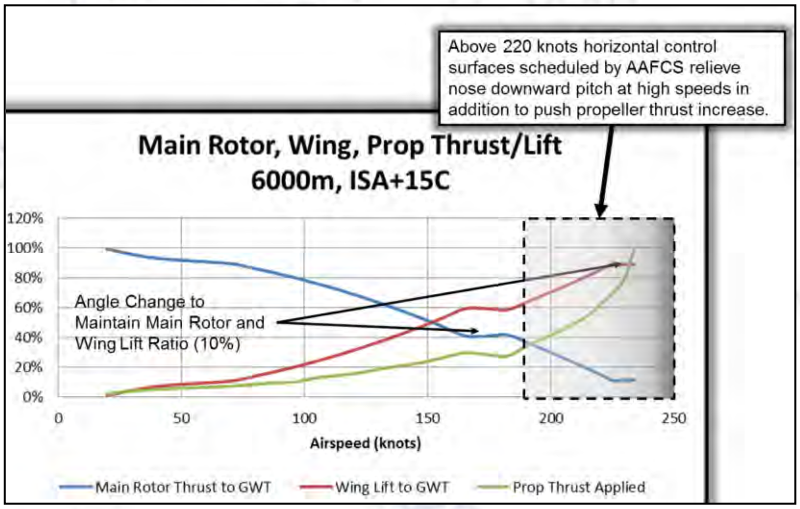


FEA Results - Forward Flight - Equivalent Stress (Von- Mises).



FEA Results - Hover - Equivalent Stress (Von-Mises).

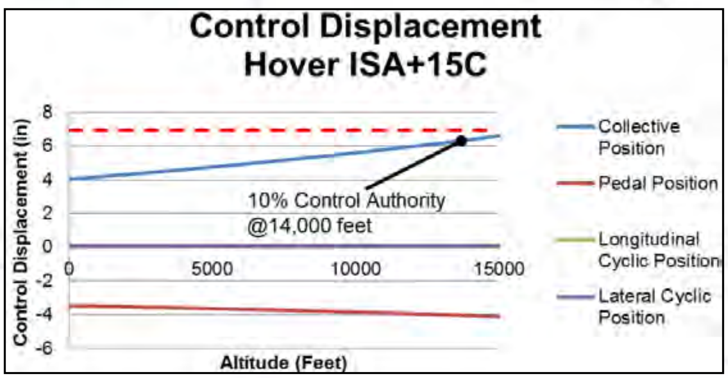
Trim

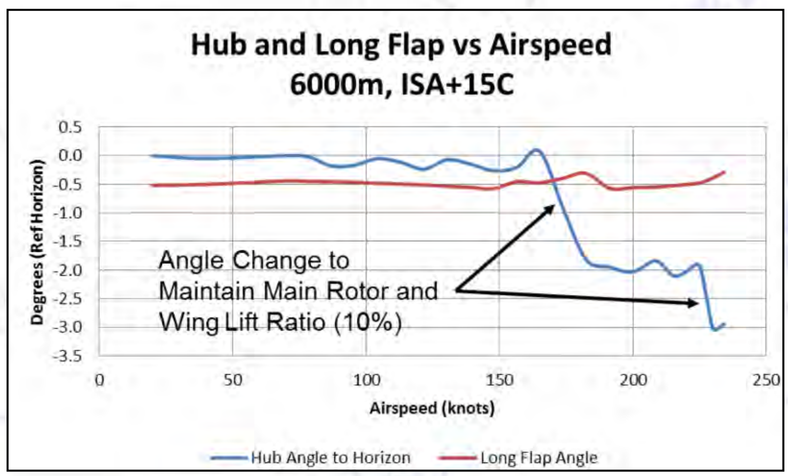


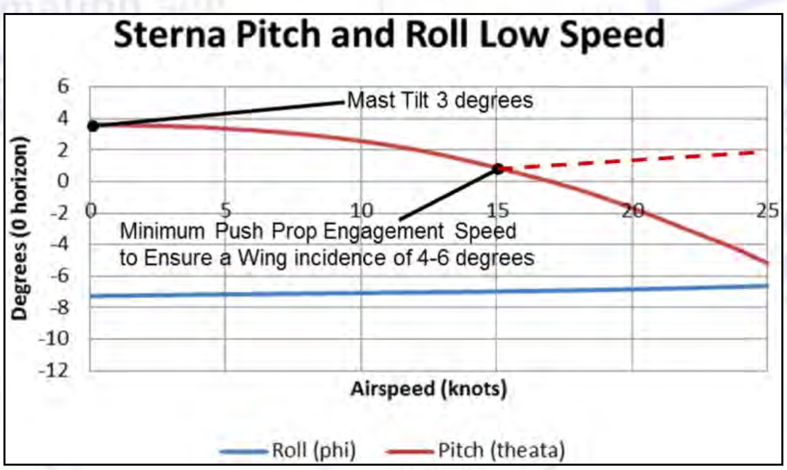
The charts provided herein are generated in Helidyne and reflect the results of hover and low speed trim values for the Sterna at maximum gross weight.

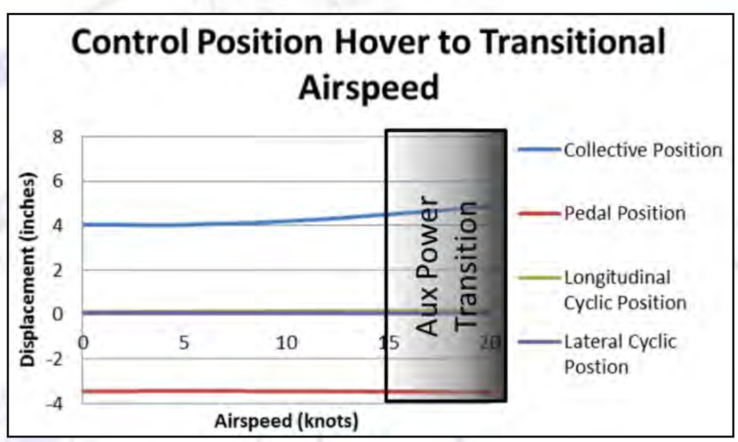
The values do not reflect push propeller engagement, rudder, or aileron use.

Below 15kts the Sterna is modeled as a traditional helicopter (although this would not preclude the engagement of the push prop for pitch adjustment.)

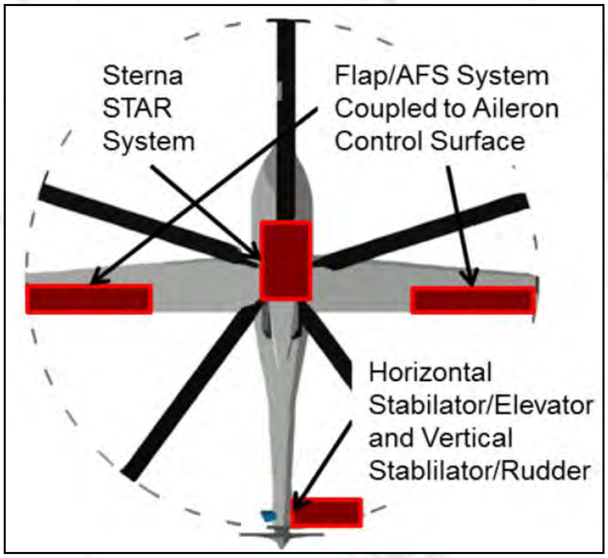




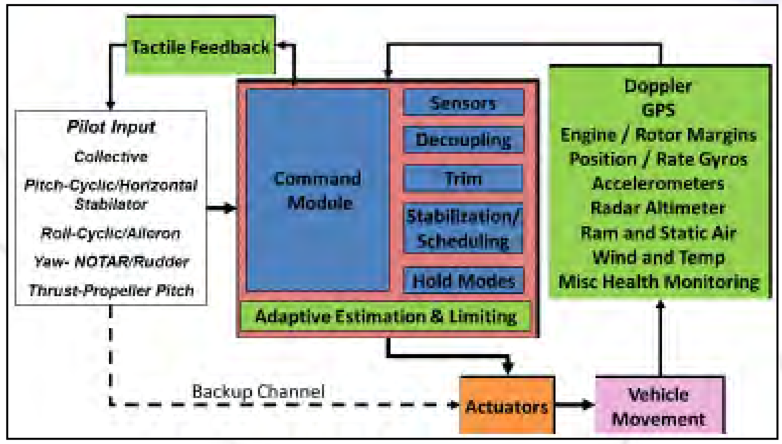




Flight Controls: Technologies incorporated

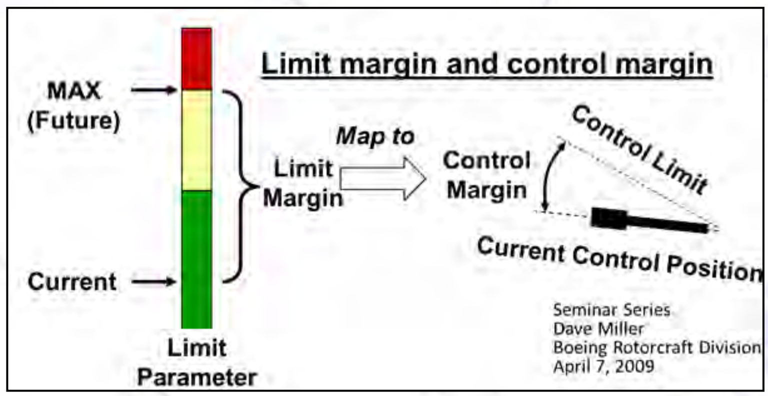


Sterna Controls

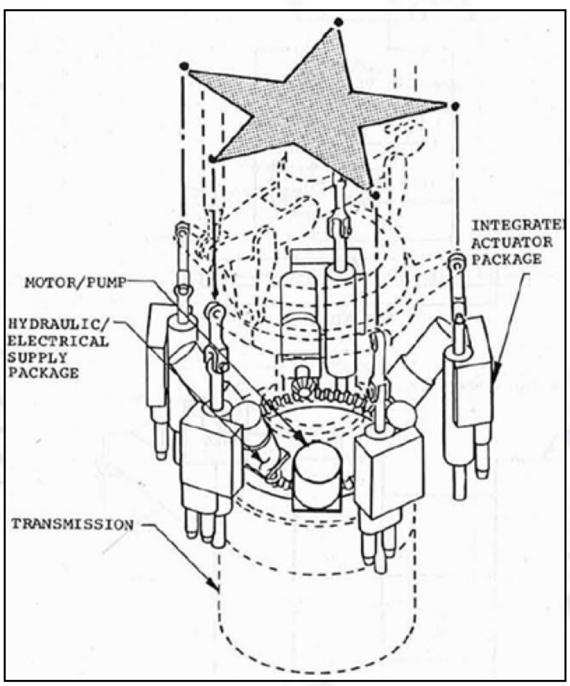


Automatic/Adaptive Flight Control System (AAFCS)

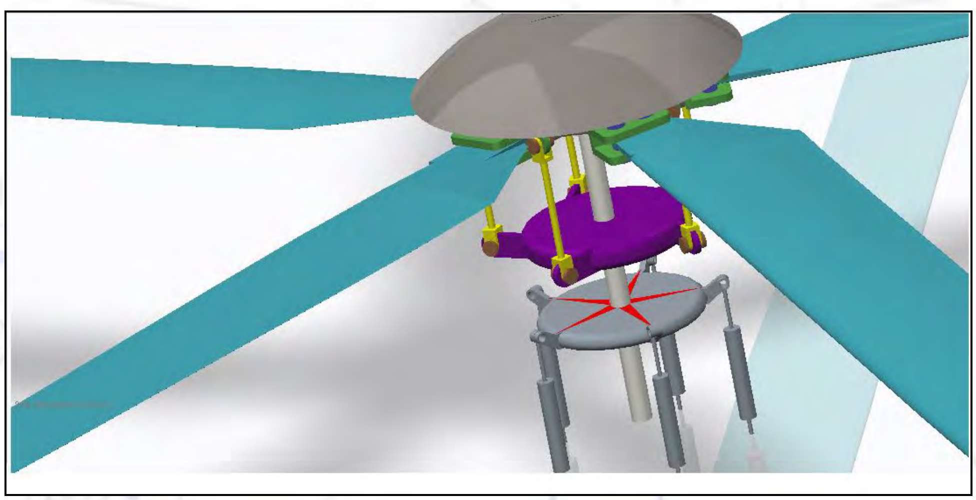
The control system is a fly by light and "power by wire" system which links the pilot control input to integrated actuator packages (IAP) located at the wing, rudder, horizontal stabilator, NOTAR nozzle, and a five point swash plate (Bell STAR).



Dynamic Limit Margin Protection

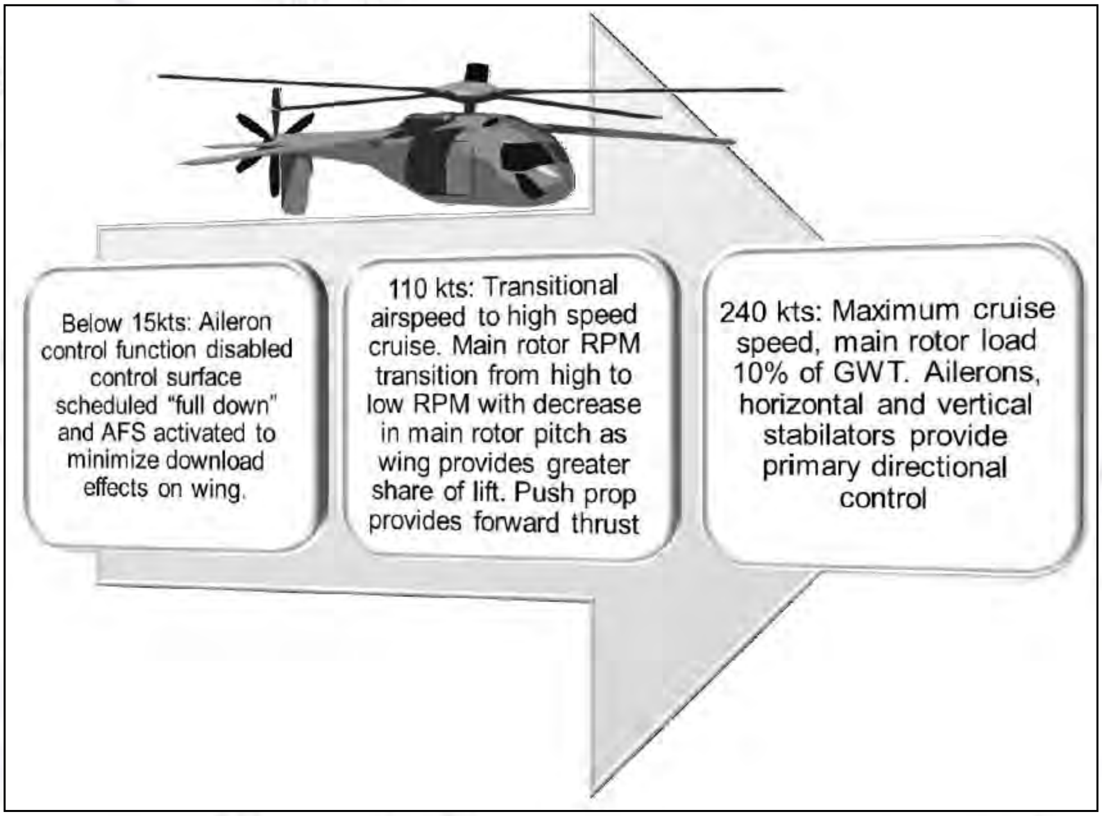


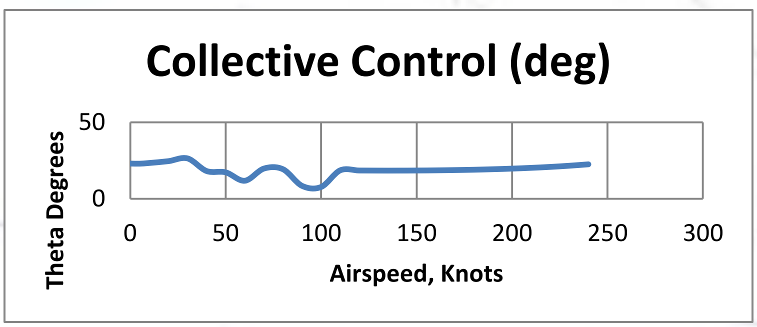
Bell STAR flight control system

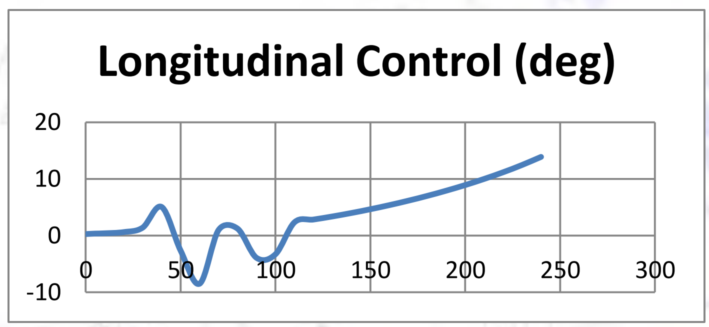


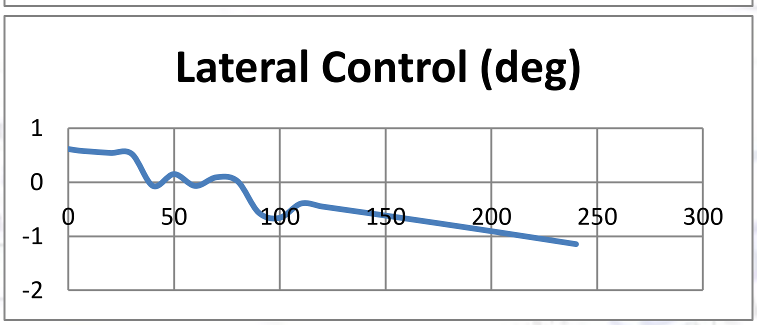
Bell STAR inspired control system for the Sterna

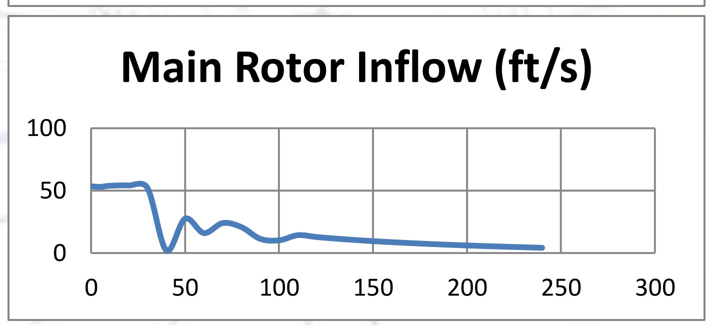
Control Transition and Handling

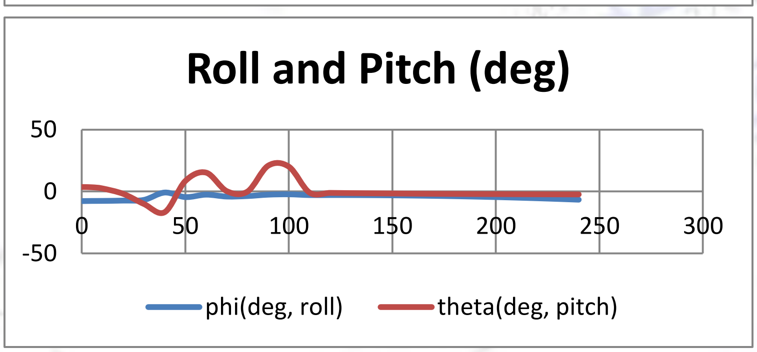


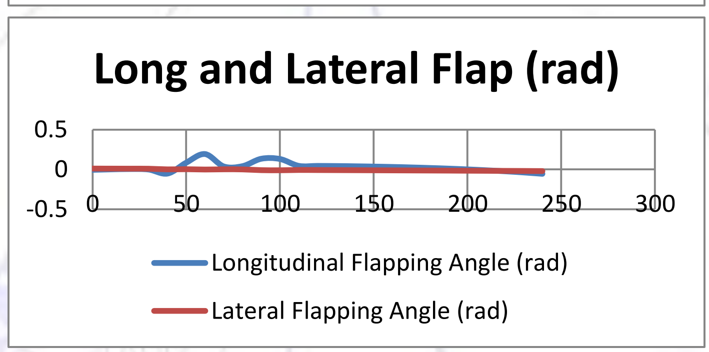






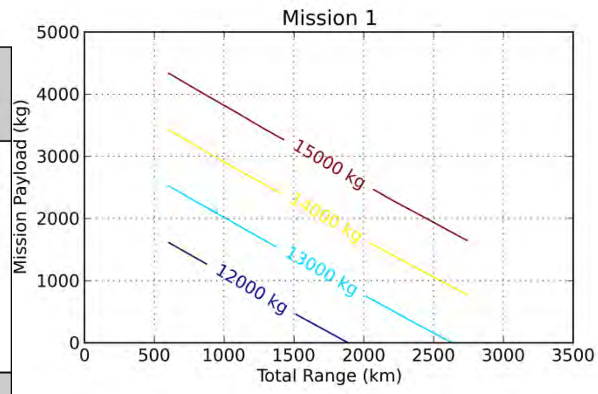


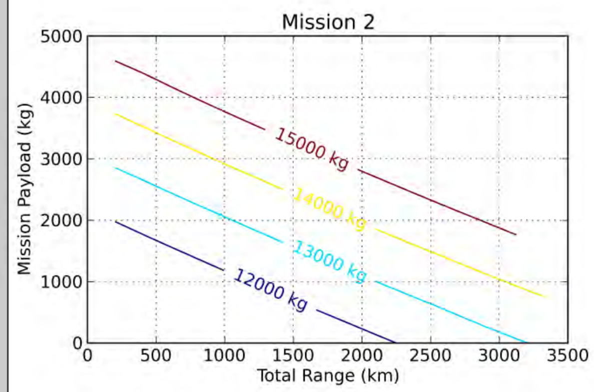


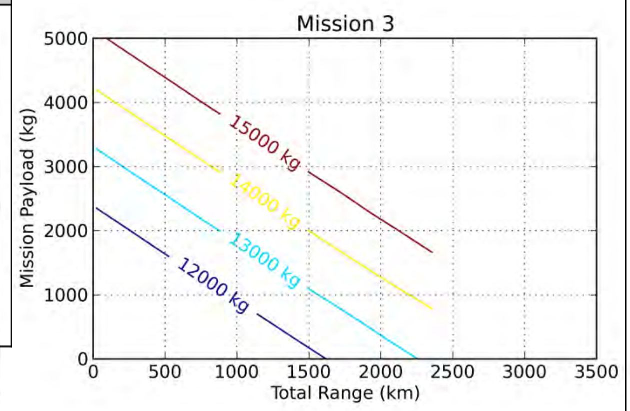


Payload

Mission Payload	Surveillance, Command and Control	Aid Distribution	SAR, Medical Evacuation
Design Requirement	Configurable surveillance payload. Communications architecture supporting over the horizon data transmission.	2 metric ton payload of aid deliverable by parachute. Load/unload maximum time allowed of one hour for two metric tons of material.	Transport 3 crewmembers and 6 wounded on litters. Load/unload maximum time allowed of 30 minutes for 6 litter patients.
Sterna Enablers	Dual side loading (payload can be developed to orient out either door and used while in orbit over objective.) Wing above cargo doors preventing interference during loading and unloading of personnel or payload. Over the horizon communications standard in baseline avionics configuration. Payload "piggybacks" off existing data bus.	Dual side loading Wing above cargo doors preventing interference during loading and unloading of or payload.	Dual side loading. Wings above cargo doors preventing interference during loading and unloading of or payload while facilitating quick hoist operations. Medical equipment attached to litter carrier can access vehicle electrical bus.
Required Third Party Specifications for Payload Development.	Must be detachable and releasable in flight during emergency situations where weight reduction is critical to continued survival of the occupants	Must be immediately releasable in flight during emergency situations where weight reduction is critical to continued survival of the occupants	Litter carrier must be capable of enduring a minimum of 10 G vertical impact without compromising living space between litters. This allows for the deployment of the emergency parachute recovery system without risk to recovered personnel.







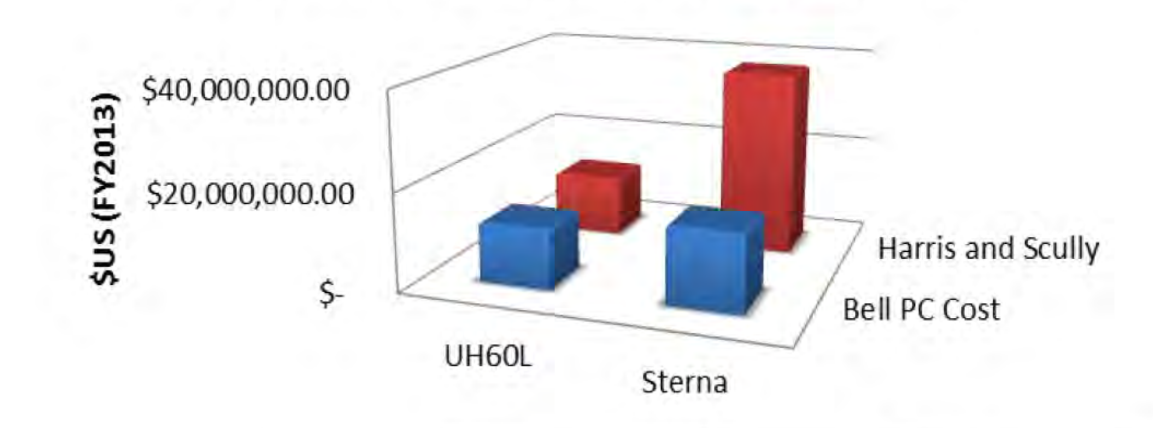
Payload Considerations and Payload range diagrams for the three missions

The Sterna is designed to incorporate a modular payload system in order to meet the surveillance, cargo, and medical evacuation requirements without the need to modify the vehicle.

The vehicle is designed with a rapid installation and removal interface with incorporated climate control, pressurization, and ample electrical power available to operate the necessary surveillance, para-drop, and medical equipment that may be employed.

Economics

Unit Price Estimation by Model



	UH60L	Sterna
Bell PC Cost	$12,296,427.00	$15,743,724.00
Harris and Scully	$12,642,977.45	$38,034,622.81

Unit cost was estimated using two different cost models.

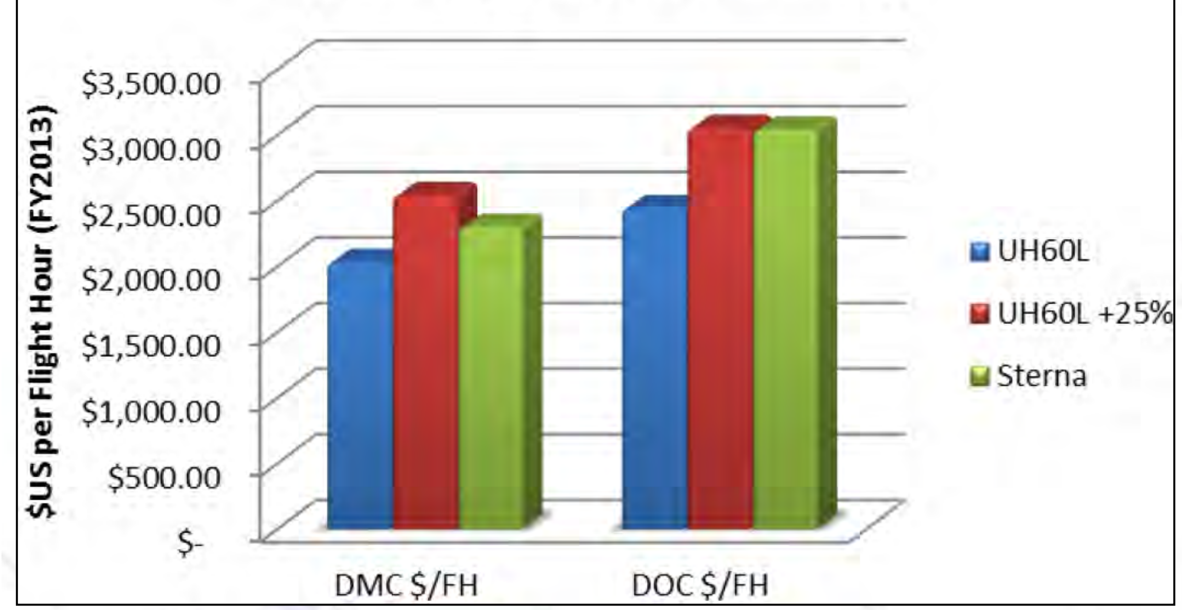
The Sterna meets the Direct Operating Cost requirement and exceeds the Direct Maintenance Cost requirement.

Maintenance Man Hours per Flight Hour is lesser than that of the UH-60.

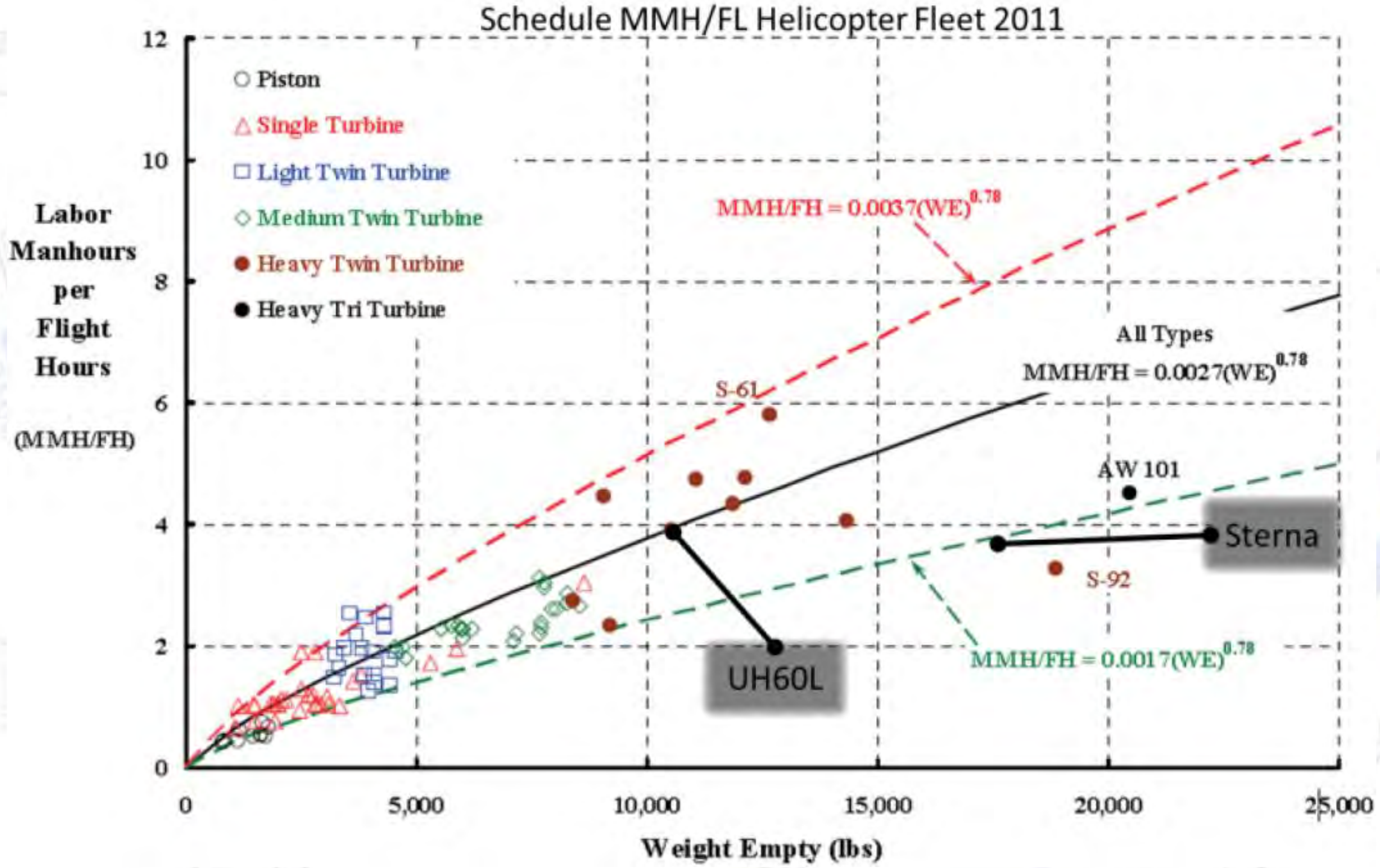
Average hourly fuel consumption of the Sterna was set to the industry standard, giving a slight edge to the UH-60.

Availability is a critical element for a rescue and disaster relief vehicle. For the Sterna, it is 0.7315 as compared to the UH-60's 0.6764.

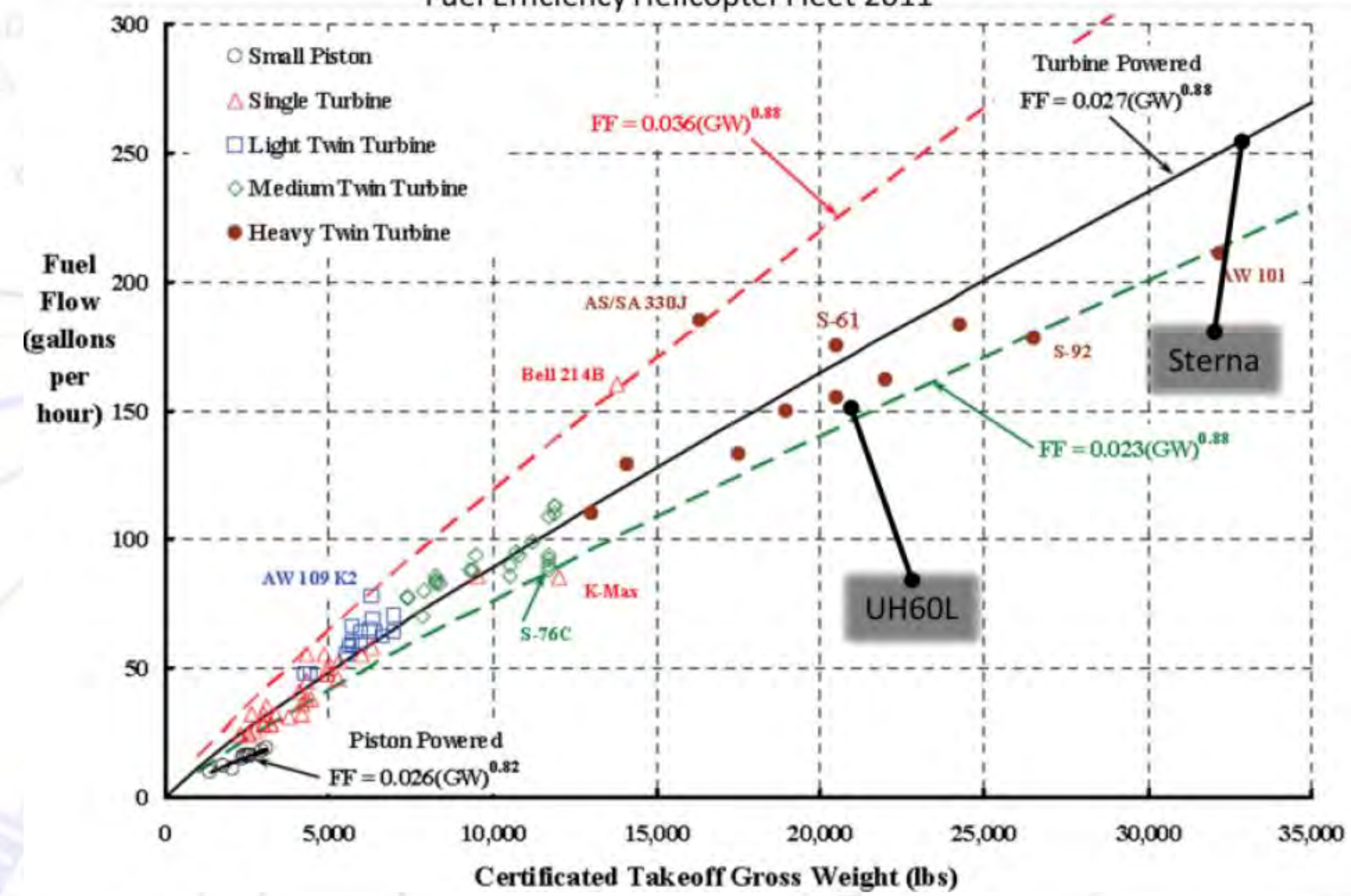
Operating Cost Summary



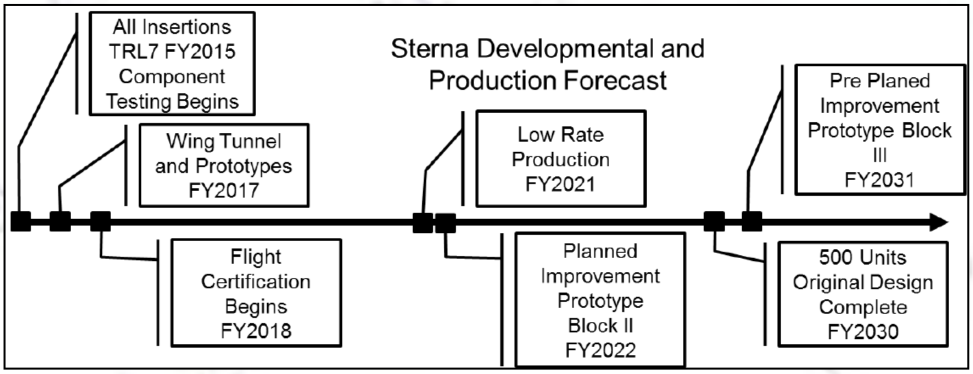
Schedule MMH/FL Helicopter Fleet 2011



Fuel Efficiency Helicopter Fleet 2011



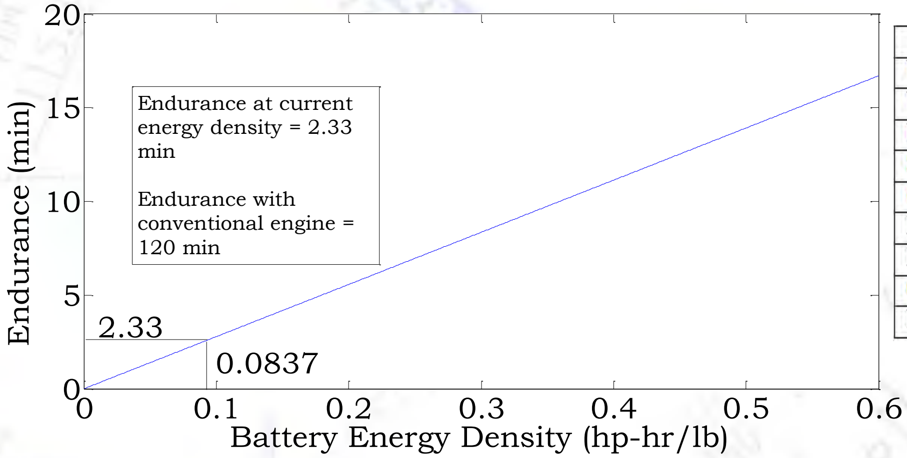
Development Timeline and Future



The following technologies may be incorporated in the future:

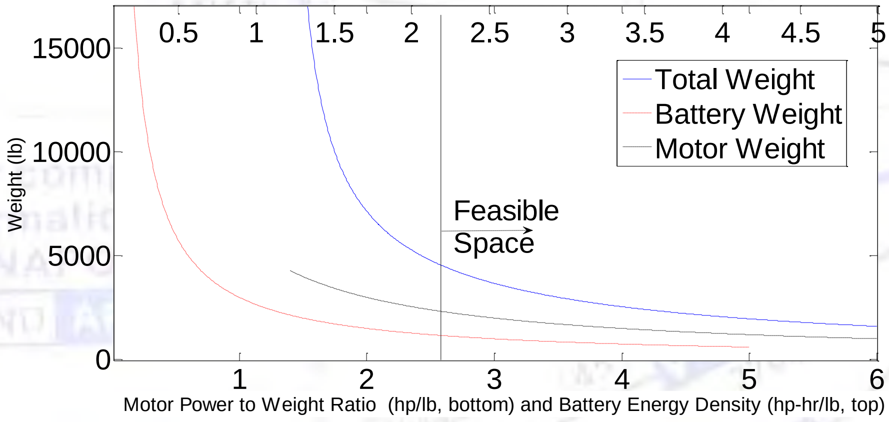
- Transparent Composites
- Smart Materials Activated Rotor Technology
- Hybrid Engine Technologies
- Electric Motor Technologies
- NOTAR to Auxiliary Propulsion Conversion in Forward Flight

Future development: Feasibility of a full electric propulsion



	Conventional	Motor	Batteries
Weight (lbs)	1084	1499.63	2784.22
Volume (in^3)	51820	25000	46153.84
Number of Units	2	1	1
SFC (lb/shp-hr)	0.452	0	0
Gear box Wt. (lbs)	2000	0	0
Fuel Weight	1200	0	0
P/wt (hp/lb)or En. den(hp-hr/lb)	5.53	4.001	VARIED
Current Value	5.53	1.4	0.0837
Power to Volume (hp/in^3)	0.11	0.24	0.13

Endurance penalty for the same propulsion system group weight

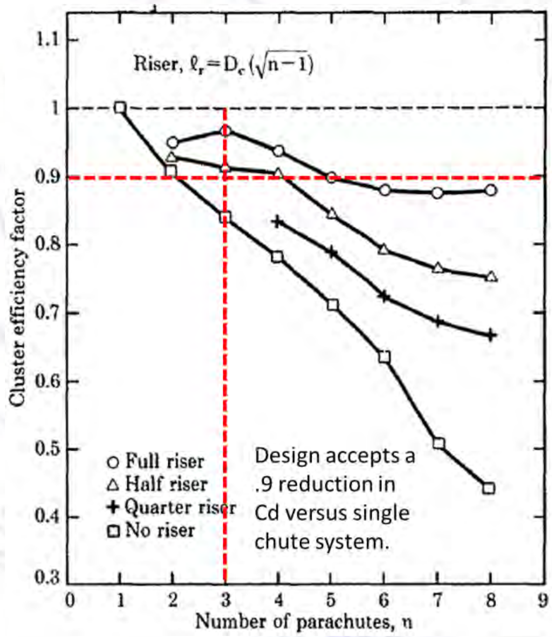


	Conventional	Motor	Batteries
Weight (lbs)	1084	DEPENDENT	DEPENDENT
Power per unit	6000	6000	6000
Number of Units	2	1	1
SFC (lb/shp-hr)	0.452	0	0
Gear box Wt. (lbs)	2000	0	0
Fuel Weight	1200	0	0
P/wt (hp/lb)or En. den(hp-hr/lb)	5.53	VARIED	VARIED
Current Value	5.53	1.4	0.0837

Weight sensitivity to motor power to weight ratio and battery energy

Conclusion: Full electric concepts would be feasible only with breakthroughs in specific energy and power density of electrical devices. Initially, they may be incorporated for smaller aircraft, with low performance requirements. Once proven, they may be found fit for demanding applications like the current one.

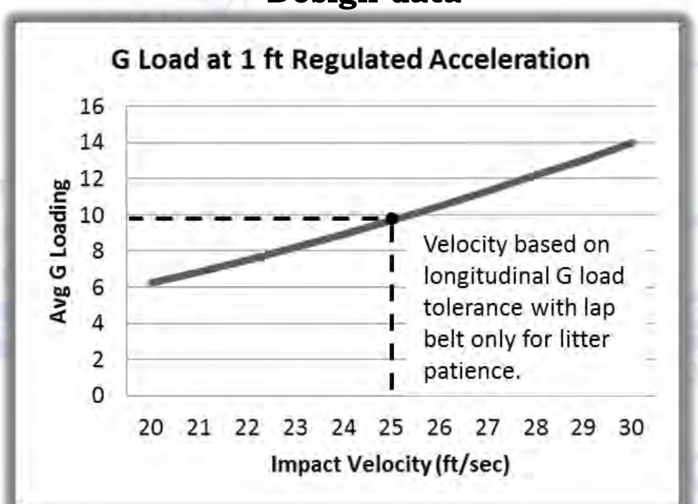
Safety



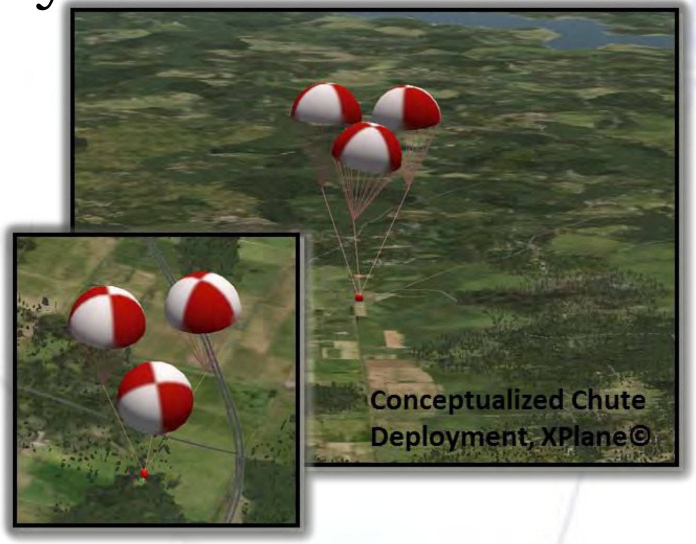
Selecting the number of parachutes

	Canopy Data
Decent Vel (MSL)	7.62 m/s (25 ft/sec)
Drag Coef	.9
Number of Chutes	3
Adj. Drag Coef	.81
Dc/Do	.97
Constructed Diameter	22.86 m (75 ft)

Design data



G load study



Concept demonstration in X-plane

The Sterna's operational environment places the vehicle in rugged terrain or areas subject to extensive debris fields associated with large scale manmade or natural disasters. This severely restricts the vehicles ability to maneuver under reduced power or auto-rotate to a suitable landing area in case of emergency.

Therefore, an Emergency Parachute Recovery System (EPRS) that would allow the passengers to egress the aircraft in distress is proposed.

The EPRS draws inspiration from the F-111 "Aardvark" cockpit capsule egress system and the Ballistic Recovery Systems (BRS) complete plane ballistic parachute system now in service on general aviation aircraft, in particular the Cirrus and Cessna models.

Type	Constructed Shape Dc/Do	Inflated Shape (Dp/Do)	Cd0	Average angle of oscillation	General Application
Ringslot/Solid Canopy	0.97	0.65 to 0.68	0.85 to 0.95	±18° to ±22°	Deceleration /Descent

Selected parachute configuration

Saviour In the Sky

No matter when or where mother nature expresses her fury, the Sterna will always be available at the service of mankind.

Great performance achieved through incorporation of technologies: Low fuel consumption, better handling and controllability, low drag, high cruise speed and service ceiling. All this at an affordable price so that we may save something priceless: life.