



GRIFFIN



Executive Summary 2013 Penn State AHS Student Design Team



Configuration Selection

	Coaxial Push-Prop with wings	Tandem External Propulsion	Ducted Tilt Rotor	Quad Tilt Rotor	Tilt Rotor	Tilt Wing	Conventional
Range	1	2	3	4	5	5	1
Hover	1.2	1.2	0.8	1.2	0.8	1.2	2
Cruise Speed	2	3	3	5	5	5	1
Max Altitude	1	4	5	5	5	5	3
Cost	0.4	0.4	0.4	0.2	0.4	0.2	0.8
Complexity	0.8	1.2	0.8	0.4	0.8	0.4	2
Total	6.4	11.8	13	15.8	17	16.8	9.8

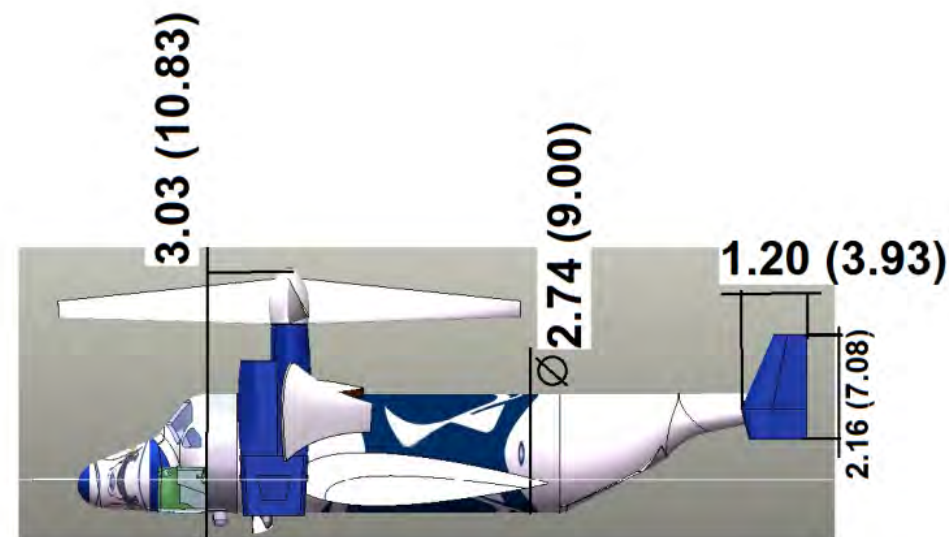
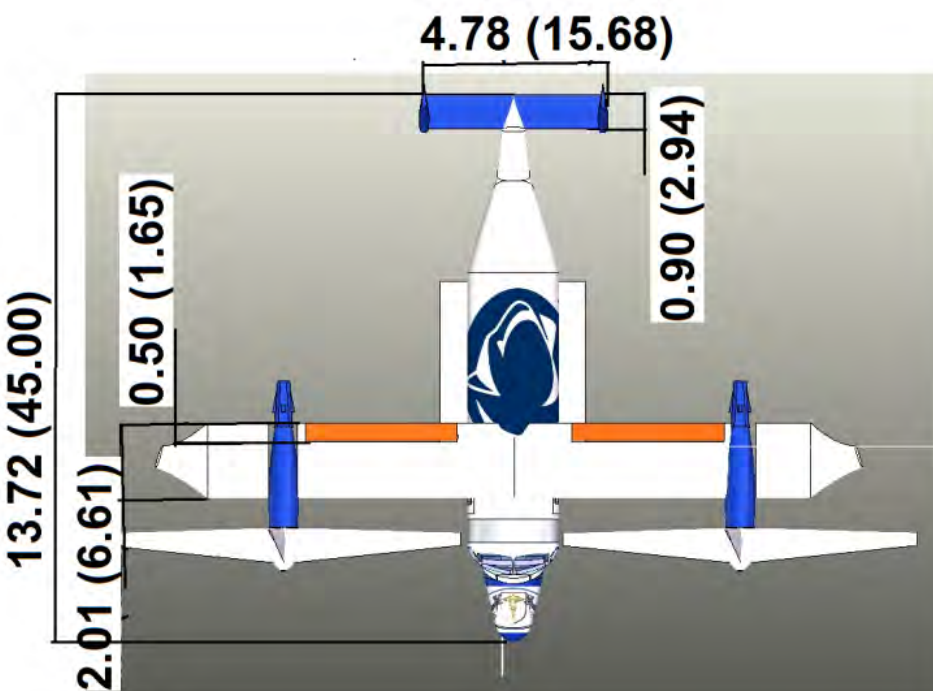
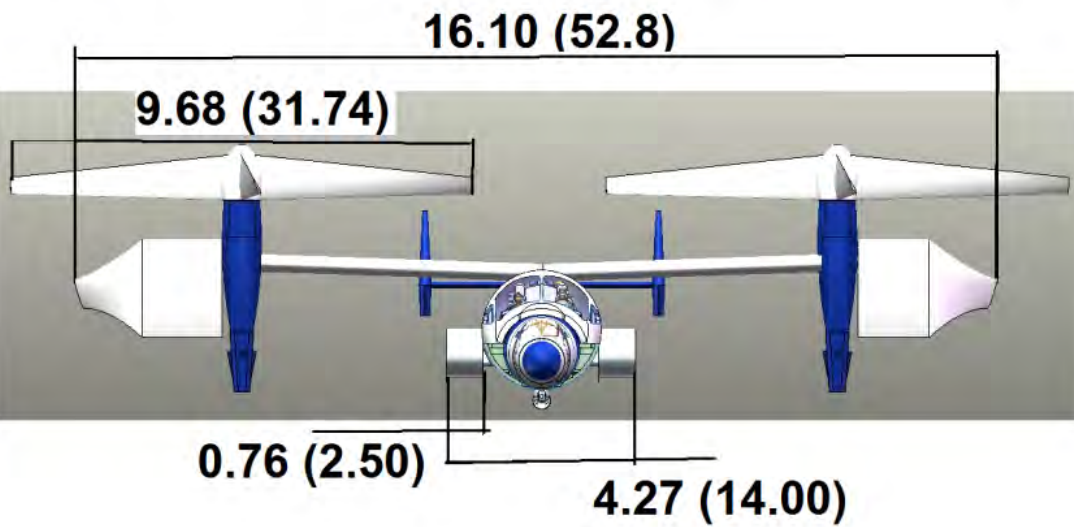
Weight Factor	Point Multiplier
Range	1
Hover	0.4
Cruise Speed 123.48 m/s (240 knots)	1
Altitude 6000 m (19,685ft)	1
Cost	0.2
Complexity	0.4

Vehicle Defining Challenges
240 knots Cruise Speed
6000 m Altitude
Maximizing Prop-Rotor Efficiency
Reduction of Wind Download
Maximizing Fuel Storage
Minimizing Weight

The Griffin, a symbol of strength and salvation, was determined to be the perfect representation of our team's mission to create the ultimate rescue aircraft. Capable of saving all life no matter the mission constraints.

A dual tilt-rotor design was chosen for Griffin

Aircraft Dimensions



Vehicle Data

Gross Weight	14,390 kg (31, 725 lbs)
Empty Weight	7,473 kg (16,475 lbs)

Engine Data

MCP (S.L)	(11,050 hp)
SFC at MCP (S.L.)	0.293 lb/(hp*hr)
Diameter	0.88 m (2.88 ft)
Length	2.04 m (6.68 ft)
Weight (Each)	270 kg (595 lb)

Propeller Data

Airfoil	NACA 64A 201
Chord	V-22 Chord Geometry
Number of Blades (Each Rotor)	4
Solidity (Each Rotor)	0.1236
Disk Loading (Each Rotor)	1,001 N/m ² (20.9 lbs/ft ²)
RPM	408

Empennage Data

Horizontal Stabilizer Airfoil	NACA 0012
Horizontal Stabilizer Area	4.28 m ² (46.1 ft ²)
Vertical Stabilizer Airfoil	NACA 0009
Vertical Stabilizer Area	5.17 m ² (55.67 ft ²)

Wing Data

Airfoil	NACA 23018
Chord	2.01 m (6.6 ft)
Span	16.09 m (52.8 ft)

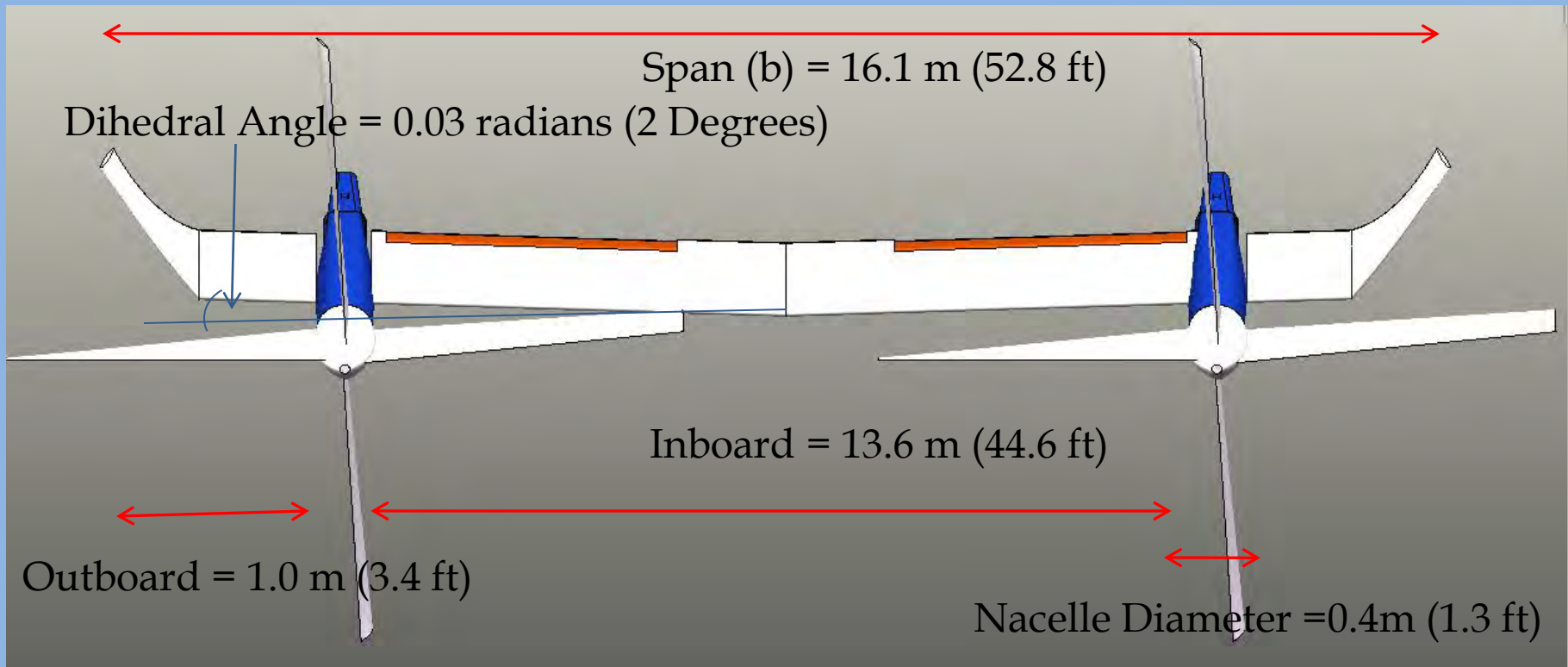
Basic Performance Data

Max Airspeed	153 m/s (298 knots)
Velocity at Best Range	107 m/s (208 knots)
Figure of Merit	0.63

Total Fuel Weight w/ 15% Extra

Mission 1	3,554 kg (7,836 lbs)
Mission 1 w/ Internal	6,503 kg (14,336 lbs)
Mission 2	2,748 kg (6,058 lbs)
Mission 3	2,404 kg (5,300 lbs)

Wing Design



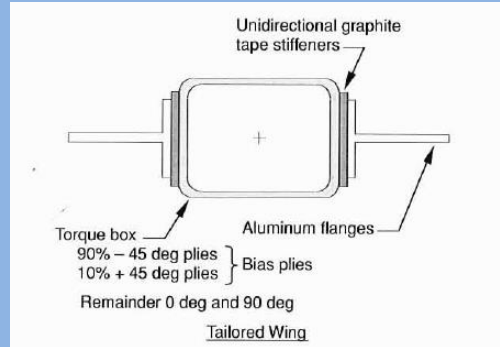
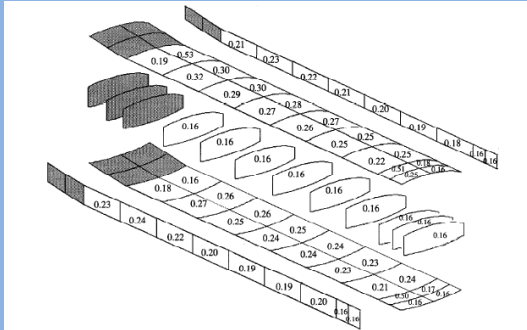
Unlike any of its kinds, Griffin wing introduces the next generation tilt rotor designs.

Utilizing the benefits of NACA 23018 Griffin wing is designed to:

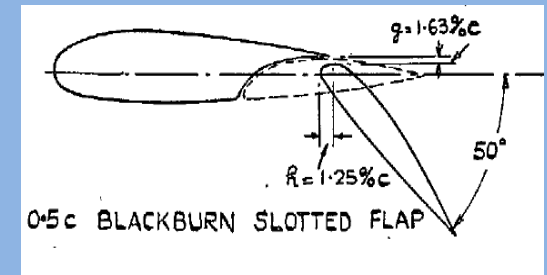
- Minimize wing weight
- Reduce whirl flutter
- Reduce Drag
- Provide sufficient lift during transition flight mode
- Reduce wing download during hover

Characteristics of Griffin Wing

Composite Lay-up of the wing:

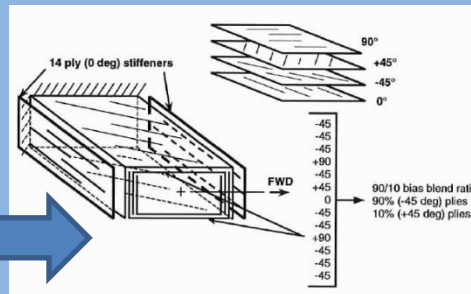


Blackburn slotted flaps:

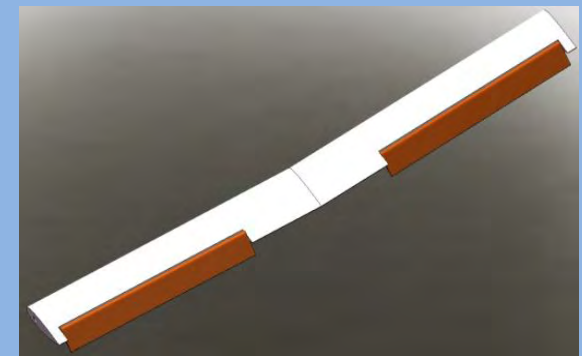


Clements, Rohani [1]

Corso, Popelka and Nixon [2]



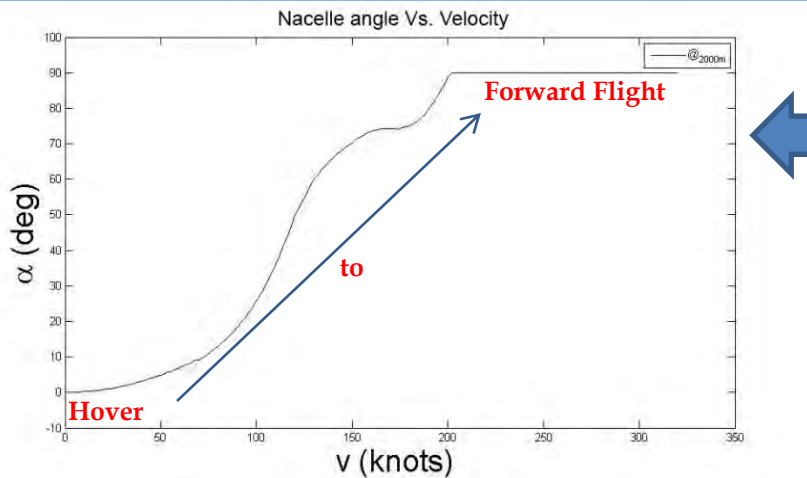
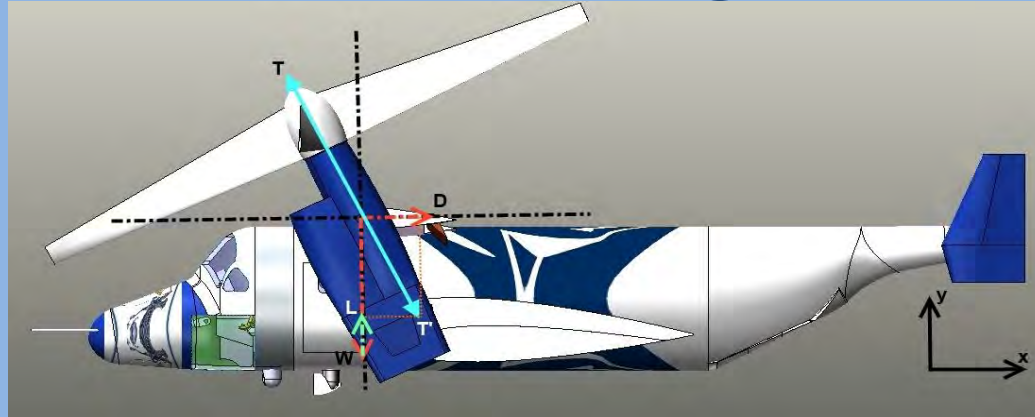
- Reduction of wing thickness from 23% to 18.02%
- Research done by Popelka and their colleagues on composite tailored wing “can improve stability boundaries and permit reduced wing thickness, increase in performance”. [2]



[1] Clements, Timothy, and Masoud Rohani. United State Of America.NASA. *Design Optimization of a Composite Tilt- Rotor Wing With Stability Approximations*. Fort Worth, TX: , Print.

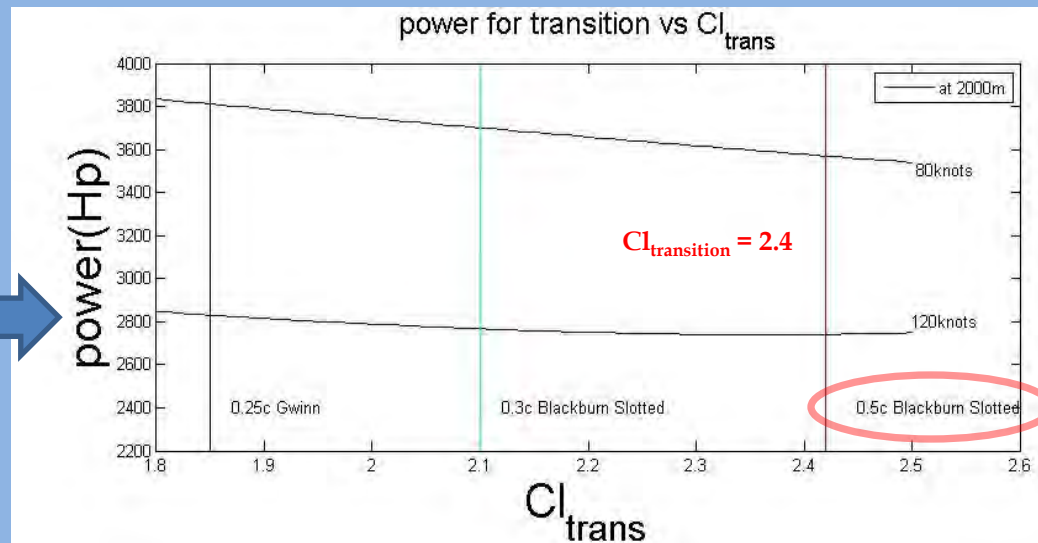
[2] Corso, Lawrence, David Popelka, and Mark Nixon. United State Of America.NASA. *Design, Analysis, and test of a composite tailored tilt rotor wing*. Fort Worth, TX: , Print.

Transition Flight

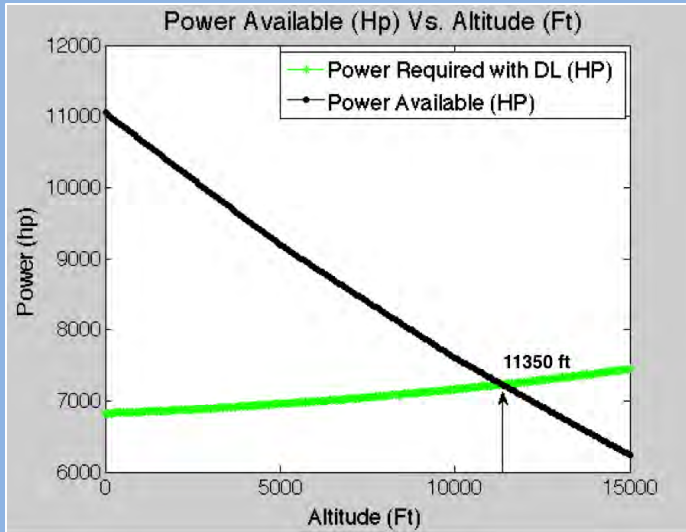


The nacelles tilt relative to the horizon according to required aircraft speed during missions

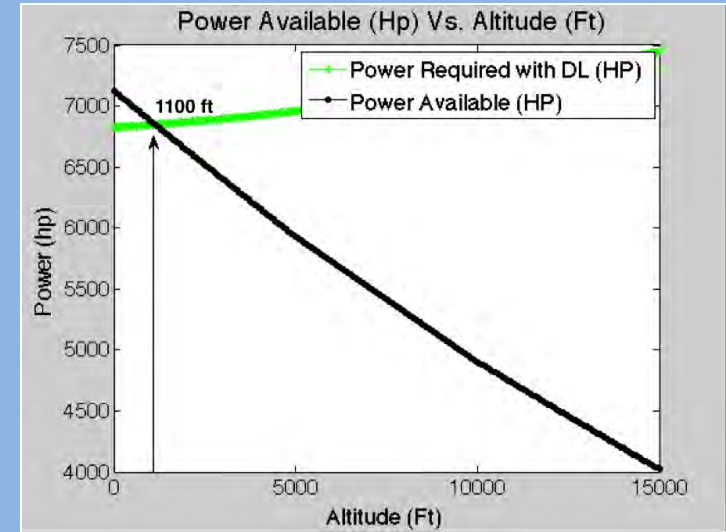
Wing lift is maximized to reduce power consumption by deploying flaps during transition flight.



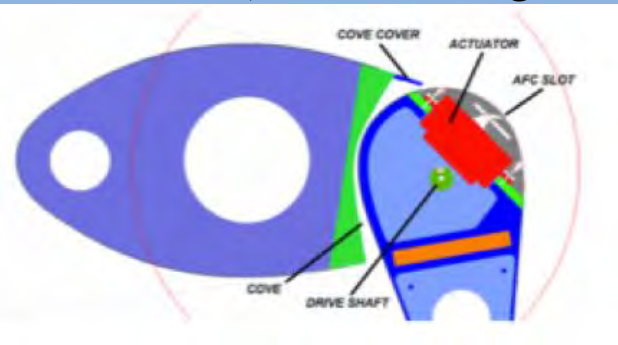
Hover



Hover ceiling at 11,350 ft
(with two engines)



Hover ceiling at 1100 ft
(with one engine out)

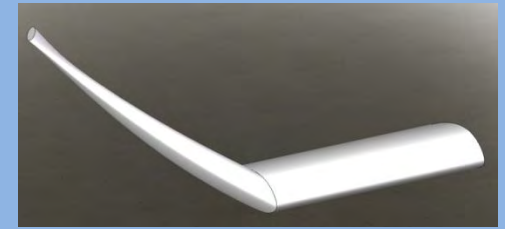


Reduction in wing download

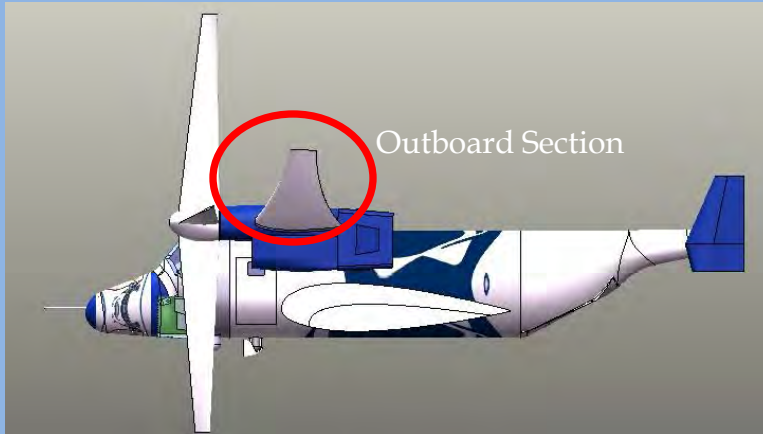


System	Penalty
Without Flaps	22,061.4 N (4959.6 lbs)
With Flaps	15,443.3 N (3471.8 lbs)
With Active Flow Control	13,281.1 N (2985.7 lbs)

Outboard Section



Forward Flight

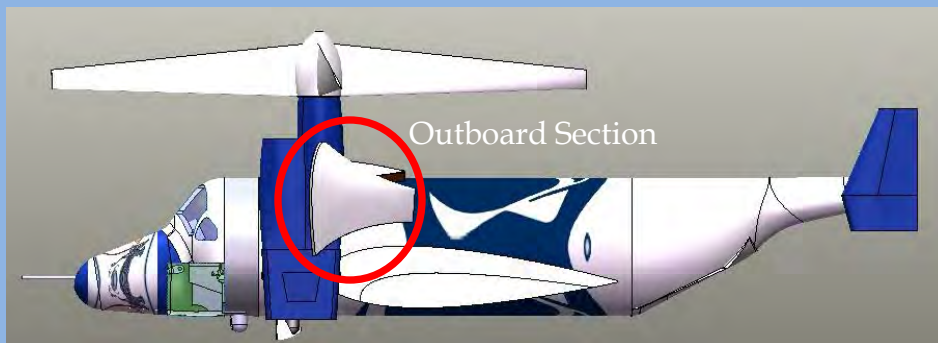


Transition Flight



Independently pilot controlled outboard wing sections with twisted wingtips allows aircraft roll control.

Hover



The outboard section is feathered along the incoming flow to reduce drag.

In this configuration the outboard section does not create any lift, so Griffin only creates lift with the Inboard section

The outboard section is tilted vertically during hover to reduce wing download.

Prop-rotor Design

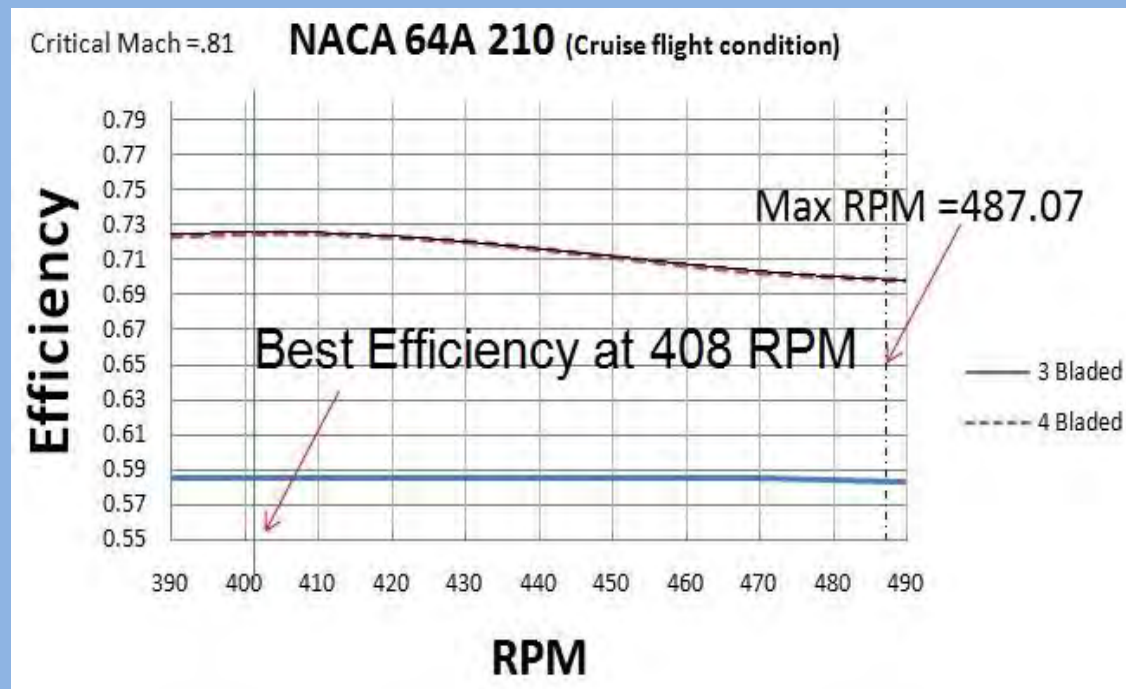


a)	Rotor Diameter	$D_{\text{rotor}} = 9.55 \text{ m (31.32 ft)}$ (Hover Requirement)
b)	Variable Chord	C_{rotor} (V-22 rotor blade geometry)
c)	Airfoil Selection	NACA ^A . 64A210
d)	Number of Blades	$N_b = 4$
e)	RPM	408
f)	Blade Twist	β_{tw} (V-22 rotor blade geometry)
g)	Thickness	t/c (V-22 rotor blade geometry)
h)	Altitude	$h = 6,000 \text{ meters (19,685 feet)}$
i)	Rotor hub diameter	$H_d = 30\%$ of Diameter (Rotor _d = 2.86 m (9.34 ft))

A prop-rotor analysis code developed at Penn State [1] was used to optimize the blade geometry for best prop-rotor efficiency.

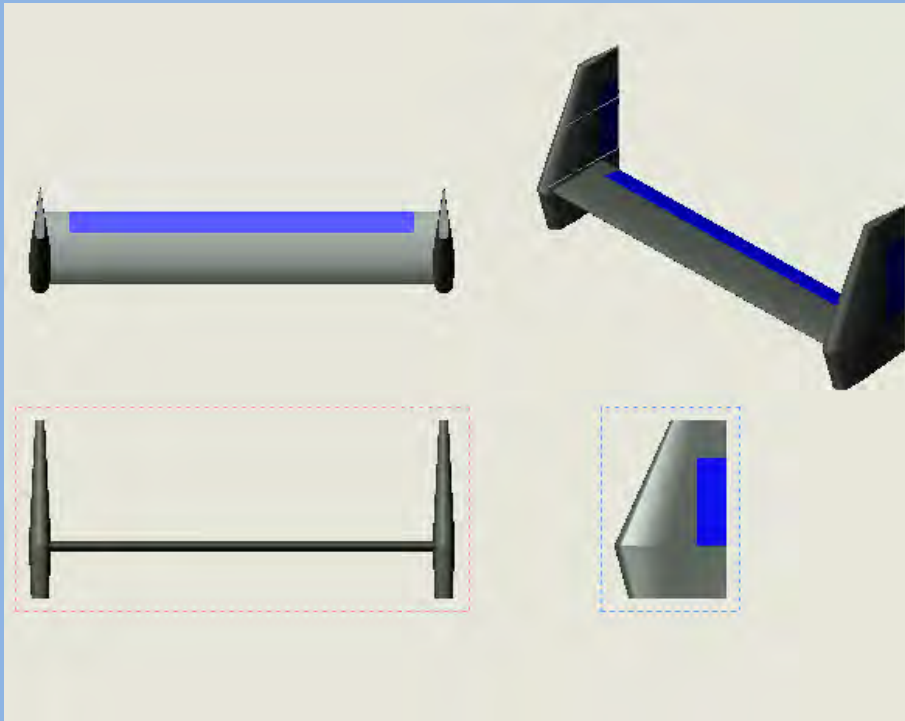
4 bladed prop-rotors provide higher efficiency compared to the 3 bladed.

The blades rotate slower than **Max RPM** (487.07) to avoid compressibility effects



[1] Thorson, Adam. "Propeller Desing for Clark-Y Airfoil." *Blade Element Vortex Theory Code*. State College: 2012.

Empennage



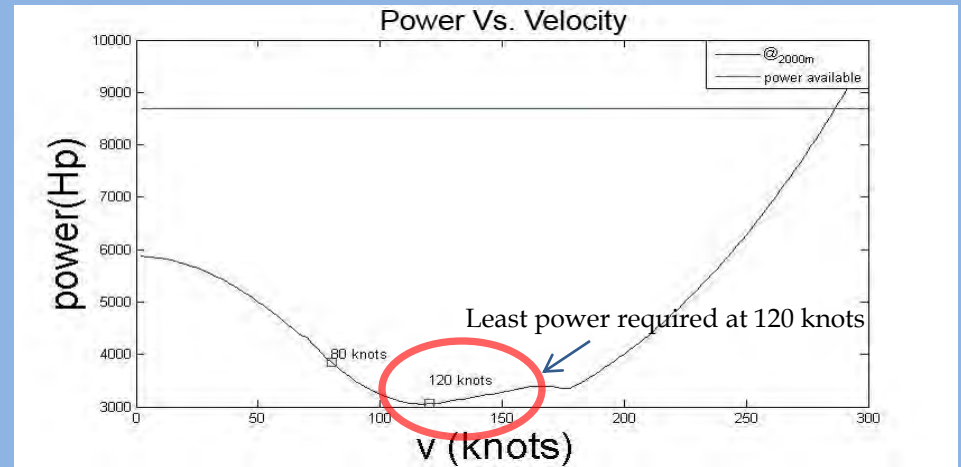
The Empennage was initially sized based on achieving a volume ratio similar to V-22 and AW-609.

- Elevator and rudder were sized based on minimum pitch and yaw control requirements, respectively
- Roll control is achieved through a combination of the Blackburn flaps and outboard section of the wing.

Airfoil NACA 0012	Vertical Stabilizer (one side)	Horizontal Stabilizer	Elevator	Rudder
Area	27.82 ft ²	46.10 ft ²	11.80 ft ²	4.12 ft ²
Chord	3.93 ft	2.94 ft	0.88 ft	1.18 ft
Span	7.08 ft	15.68 ft	13.38 ft	7.08 ft

Engine Selection

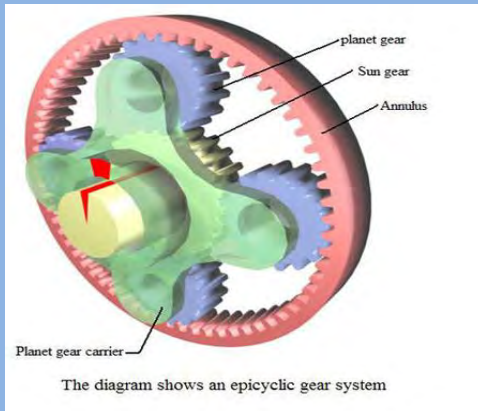
	Dimensions
Max Rated Power	13000 hp
Max Continuous Power	11050 hp
Engine Weight	595 lbs
Engine Diameter	34.9 in
Engine Length	80.1 in
Engine SFC	0.293



Power Required vs. Velocity at 2000 m (6562 ft)

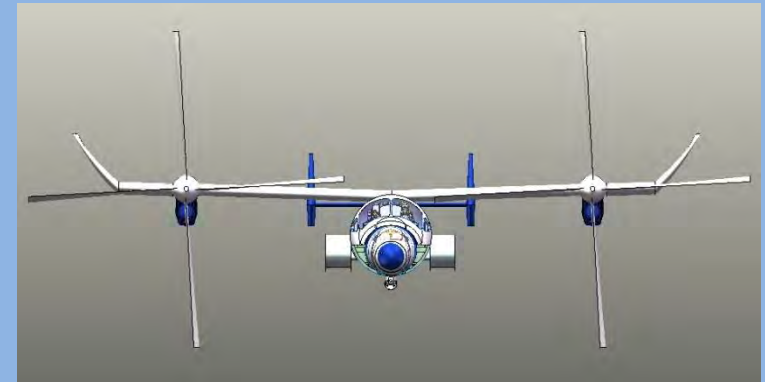


Transmission



Engine RPM = 17000

41.7 to 1
RPM Reduction



Rotor RPM = 408

Component	Design Dimension
Rotor Hub	1.1 m (3.61 ft)
Sun Gear	.11 m (4.32 in)
Planet Gear	.11 m (4.32 in)
Face Width	.088 m (3.46 in)
Number of Planets	4
Engine Rotational Speed	17000 RPM
Cross Shaft Rotational Speed	3400 RPM
Rotor Rotational Speed	408 RPM

Aircraft Systems



One Display for a Cockpit Interactive Solution (ODSCI)

Large Singular touch-screen display, reduces pilot work load, and provides more surface area for navigation information.



VMT-1220 HM Broadband Satcom

Use's ViaSat's worldwide broadband network for high speed communication worldwide.



Terrain and Traffic Collision Avoidance System (T³CAS)

Uses Thales industry leading traffic collision avoidance system, with aircraft climb performance based terrain awareness.



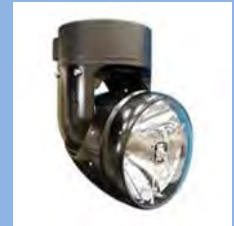
TOTEM 3000

Combo hybrid inertia navigation system and global navigation satellite system.

Allows the Griffin to save weight by incorporating navigation systems into one unit.

NightSun XP

A leading spotlights for current search and rescue helicopters. That Shines at an intensity of 40 million candlepower allowing it to light up an entire acre of land at once.



PS-AHD 1500 Loud Hailer

Effective for controlling large crowds in disaster relief areas resulting from natural disasters.



Star Safire HD

- HD FLIR imaging system with 120x zoom allows for searching for individuals in even the worst weather conditions.



Joint Precision Airdrop System

- GPS guided drop system currently in use by the U.S. Air force.
- Allows for pallets to be dropped into a land zone with a 45-68 meters (50-75 yards) of accuracy
- Capable of supporting loads significantly greater than the desired 1 ton pallets.



SNC Transport Telemedicine

Communicates critical patient injury information from Point of Injury to Medical Facility



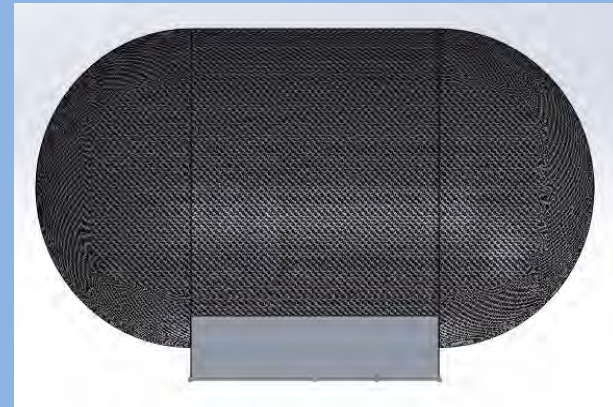
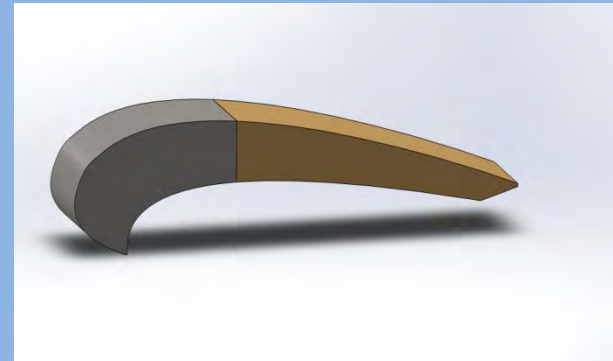
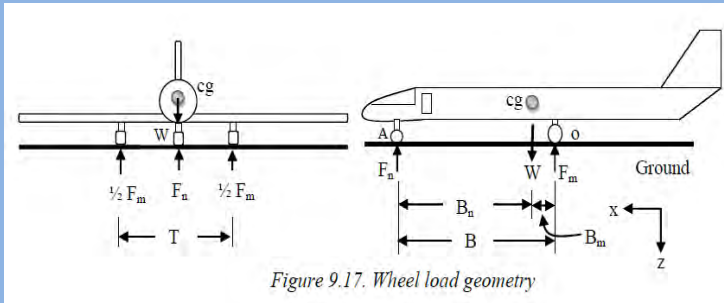
Fuel Storage & Landing Gear

6 Main Fuel Tanks

- AFT Sponson :1,250 lbs.
- FWD Sponson : 1,350 lbs.
- Internal Tanks in Wing: 1,500 lbs.

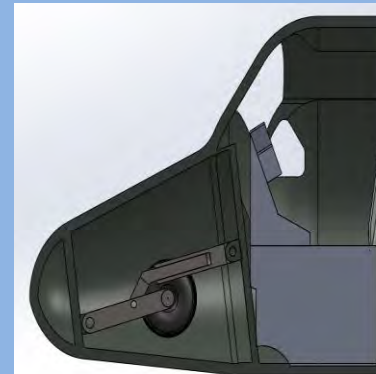
Additional Internal Auxiliary Tank option

- 6,500 lbs. additional fuel

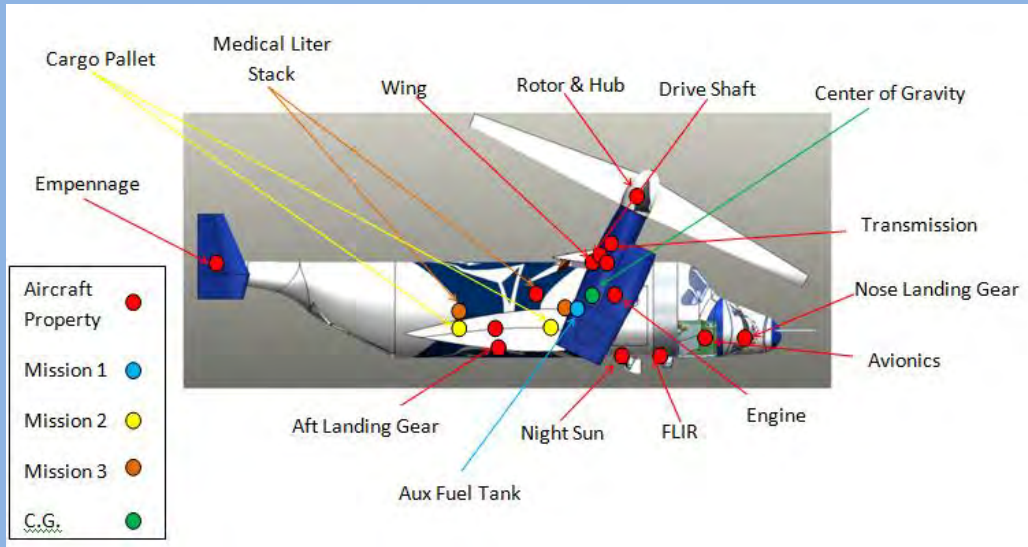


Nose Gear: **11567.54 lbs**
Main Gears: **21501.46 lbs,**
with **10750.73** per each gear.

Nose landing gear stowed

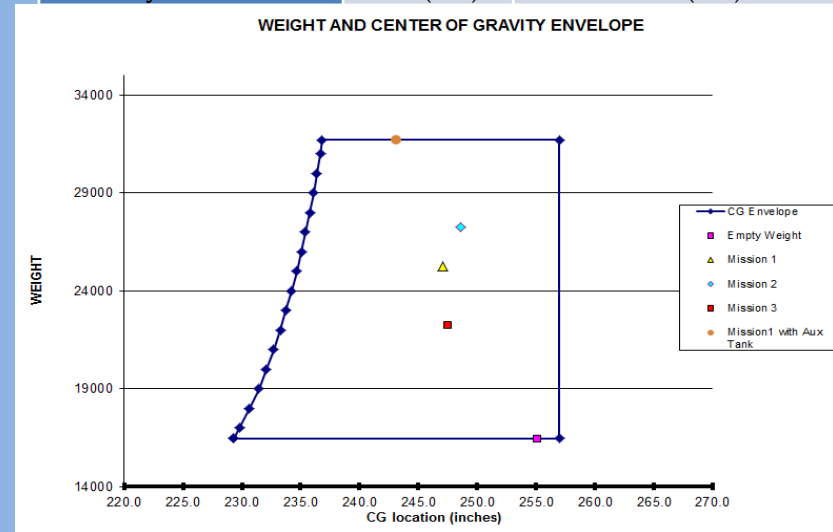


Weight and Center of Gravity



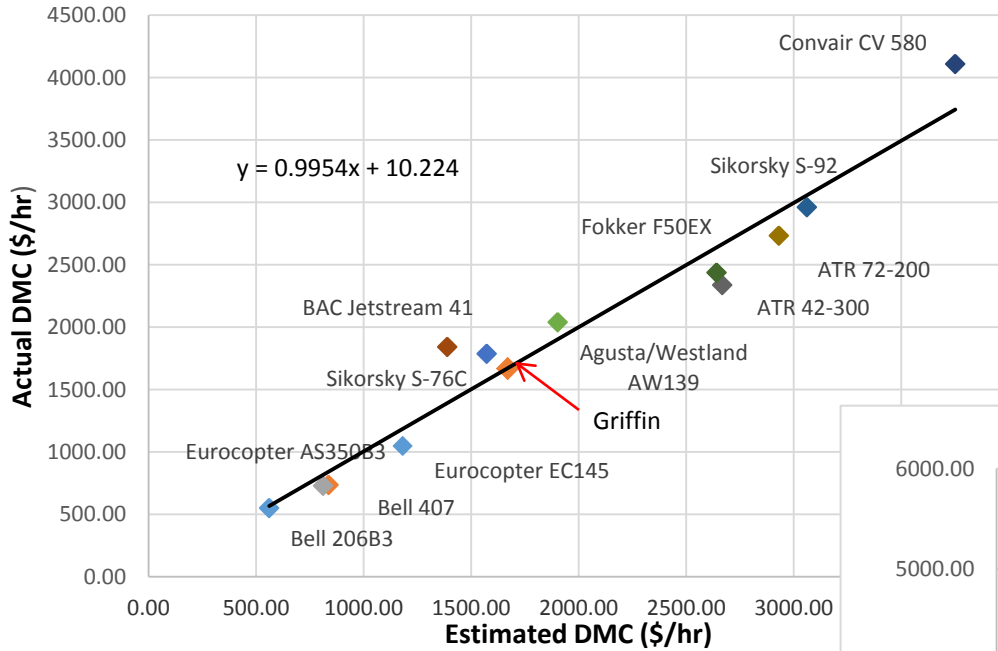
Aircraft Component	Weight kg (lbs)	STA forward Flight meters (in)	STA Hover meters (in)
Blades	544 (1,200)	5.03 (198)	6.10 (240)
Rotor	259 (571)	4.72 (186)	6.10 (240)
Anti-icing	181 (400)	4.83 (190)	6.10 (240)
Wing	1,485 (3,274)	6.10 (240)	
Avionics	454 (1,000)	3.66 (144)	
Fuel System	303 (668)	6.10 (240)	
Fuselage	2,127 (4,690)	6.6 (260)	
Empennage	342 (755)	13.72 (540)	
Engine	540 (1,190)	6.10 (240)	
Drive Shaft and Gear Boxes	749 (1,651)	6.10 (240)	
Nose Landing Gear	107 (236)	1.10 (43.2)	
Rear Landing Gear	214 (472)	8.53 (336)	
Hydraulics	154 (340)	5.59 (220)	

Mission Component	Weight kg (lbs)	STA forward Flight meters (in)	STA Hover meters (in)
Stretcher fwd	68 (150)	5.79 (228)	
Stretcher aft	68 (150)	8.43 (332)	
Pilots	181 (400)	2.62 (103.2)	
Crew	90.7 (200)	8.02 (315.6)	
Wounded fwd	272 (600)	5.80 (228)	
Wounded aft	272 (600)	8.43 (332)	
Airdrop Crate #1	998 (2,200)	5.72 (225)	
Airdrop Crate #2	998 (2,200)	8.60 (338.5)	
Fuel Wing Mission 1	1,361 (3,000)	6.02 (237)	
Fuel FWD Sponson 1	1,180 (2,600)	4.88 (192)	
Fuel AFT Sponson 1	1,180 (2,600)	7.62 (300)	
Fuel Aux Tank	2,926 (6,450)	5.79 (228)	



Cost

Actual DMC vs. Estimated DMC



Griffin Cost Equation

$$\text{Cost} = cW^n P^m$$

c = constant

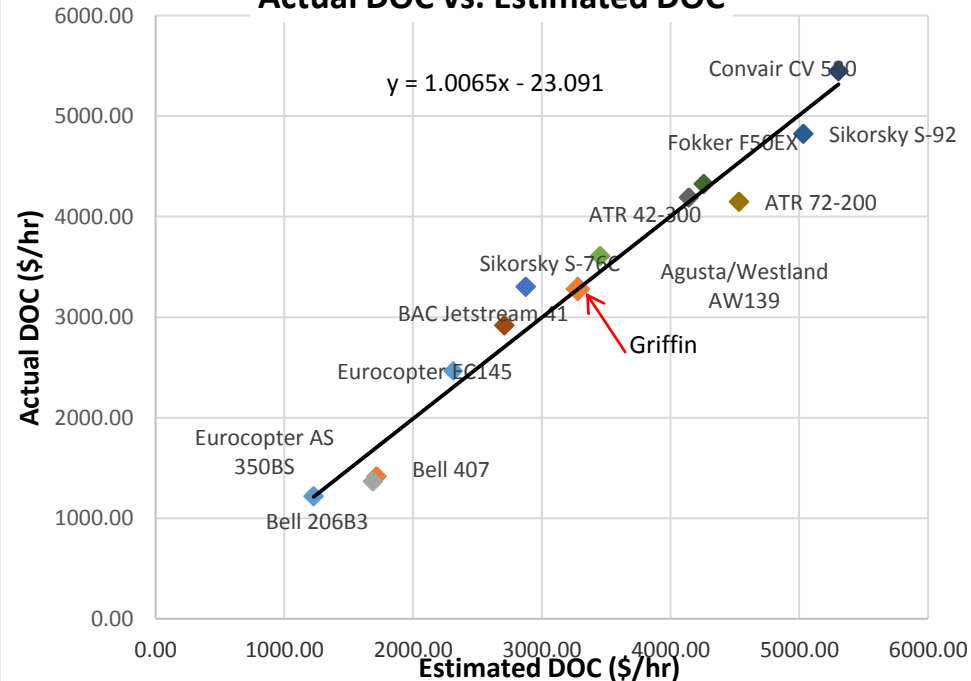
W = Weight

n = weight exponent

P = Power

m = Power exponent

Actual DOC vs. Estimated DOC



$\text{Cost} = cW^n P^m$	n	m	C
Helicopter DOC	0.4401	0.1987	10.4575
Helicopter DMC	0.6467	0.1369	1.3136
Turboprop DOC	1.1129	-0.6486	6.9231
Turboprop DMX	1.7446	-1.1754	0.433

Power law coefficient and exponents based on results from Conklin & de Decker's [1] database

[1] Aircraft Operating Costs & Aviation Services. Computer software. Aircraft Operating Costs & Aviation Services. Conklin and De Decker, n.d. Web. 12 Jan. 2013. <<https://www.conklindd.com/Default.aspx>>.

Mission Analysis

Mission 1: Fast Deployment and Rescue Coordination

3 Crew
Max take off weight: 15 tons
Useful Load: 6 tons



2) Approach:
Cruise at 240 Knots
Cruise at 6000m altitude
Distance 600 Km (included acceleration and climb)

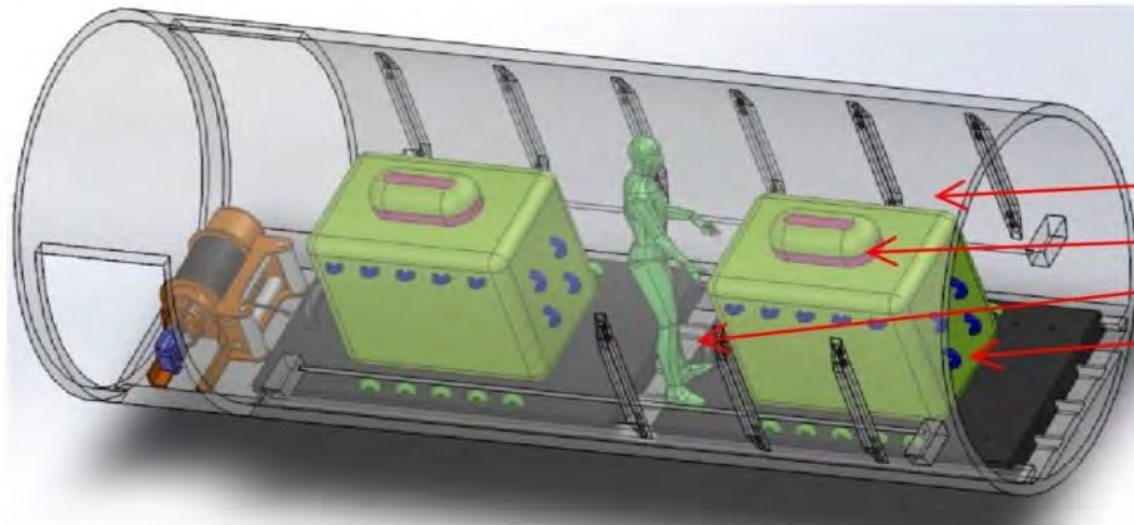
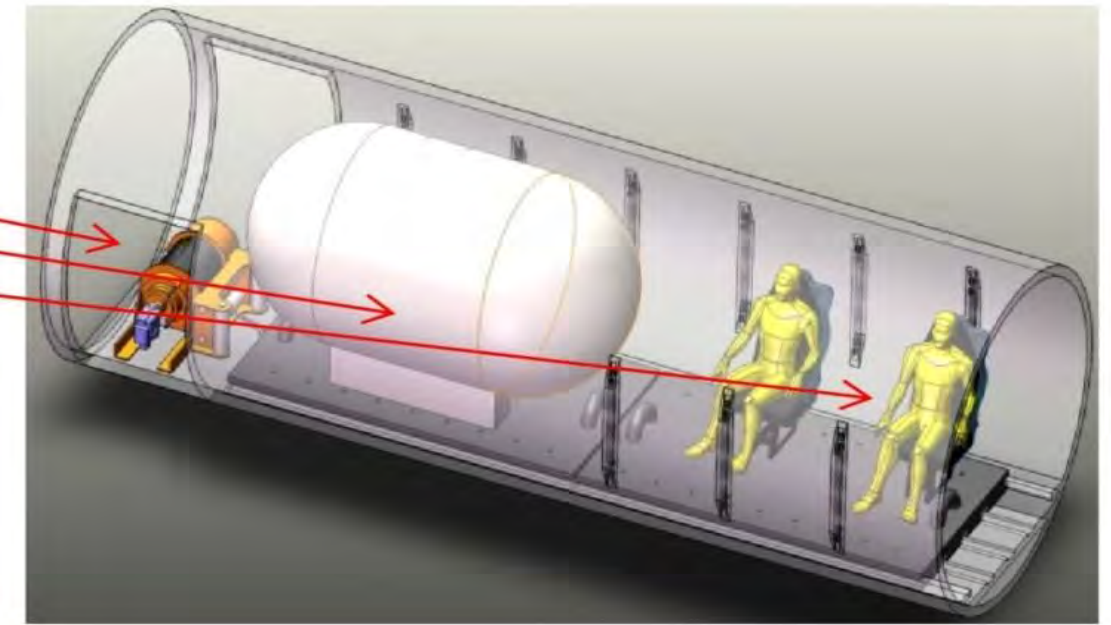
1) Take Off:
Warm-up: 15 mins
Climb up to 6000m
Rate of Climb 2000 ft/min

4) Return:
Cruise at 210 Knots
Cruise at 6000m altitude
Distance 600 Km

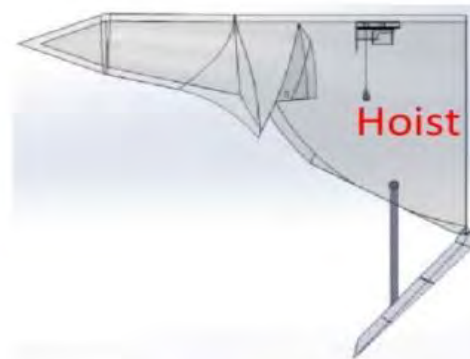
3) Fly Over:
Cruise at 120 Knots
Descent to 2000m altitude
Distance 600 Km
Time: 2.5 hrs



Mission 1 components:
Winch
Auxiliary Fuel Tank
Chair for Crew



Mission 2 components:
Pallets
Parachute system
Crew to facilitate cargo drop
Cable Strap hooks on pallets



Mission 2: AID Distribution

3 Crew
Max take off weight: 15 tons
Load/Unload: 1 hour & 2 tons



2) Approach:
Cruise at 240 Knots
Cruise at 6000m altitude
Distance 600 Km (included acceleration and climb)

1) Take Off:
Warm-up: 15 mins
Climb up to 6000m
Rate of Climb 2000 ft/min

4) Return:
Cruise at 210 Knots
Cruise at 6000m altitude
Distance 600 Km

3) Fly Over (Drop Off):
Cruise at 80 Knots
Descent to 2000m altitude
Distance 600 Km
Drop the load



Mission 3: Evacuation of Casualties

3 Crew
Max take off weight: 15 tons
6 Wounded



2) Approach:
Cruise at 240 Knots
Cruise at 6000m altitude
Distance 600 Km (included acceleration and climb)

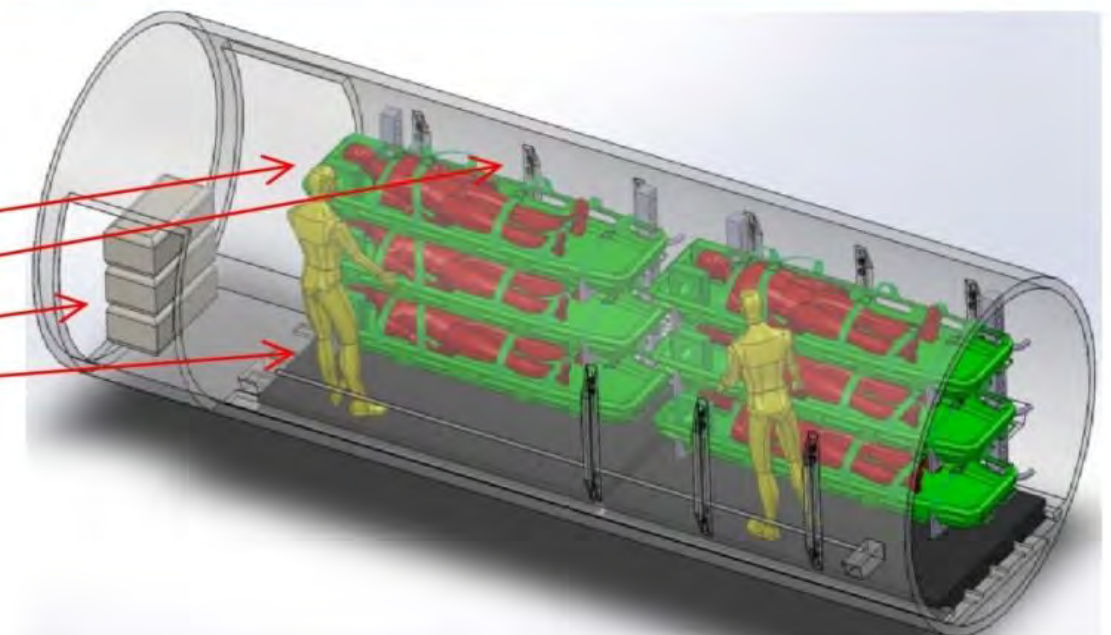
1) Take Off:
Warm-up: 15 mins
Climb up to 6000m
Rate of Climb 2000 ft/min

4) Return:
Cruise at 240 Knots
Cruise at 6000m altitude
Distance 600 Km

3) Landing:
Descent to Sea Level
Load/unload max time allowed:
30 min for 6 victims
Warm-up: 15 mins
Distance: 10 Km



Mission 3 components:
6 Stretchers for wounded
Stretcher Frame
Medical Equipment
Medics



Fuel Usage

During the Rescue Coordination mission the Griffin has an empty cabin. To make use of this space, an auxiliary fuel tank is loaded into the cabin that is capable of holding 6,500 lbs of extra fuel.

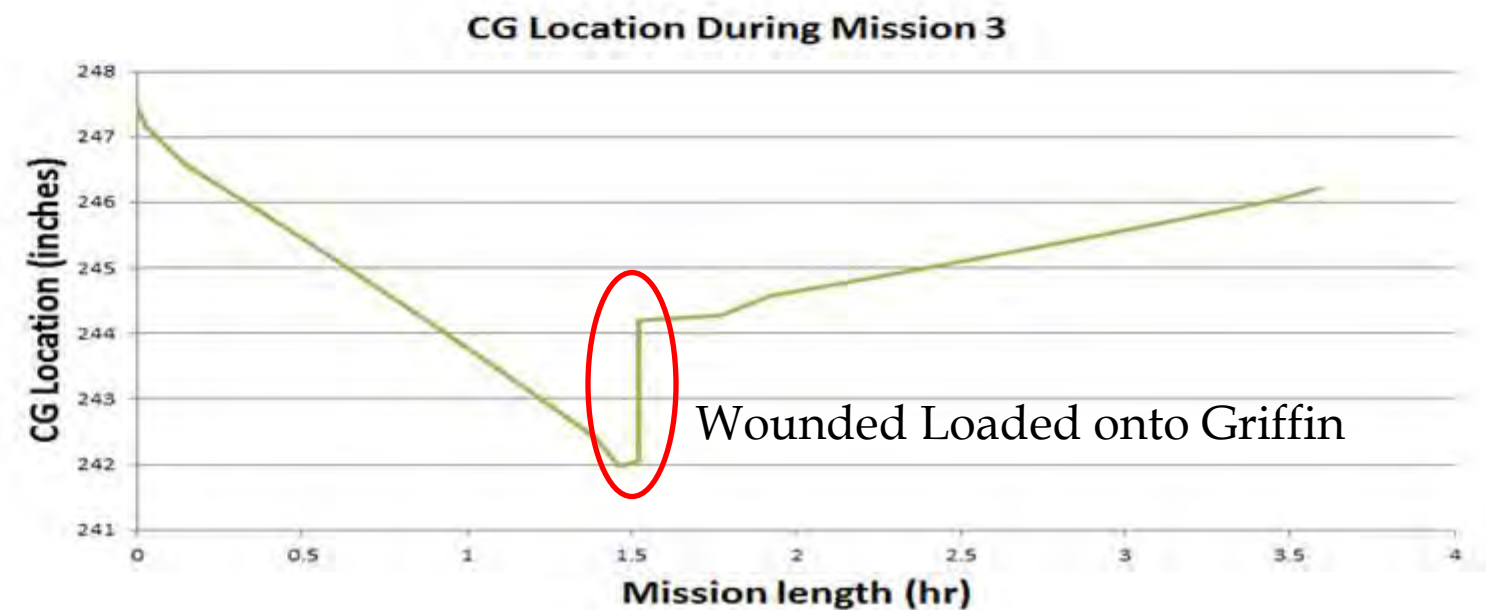
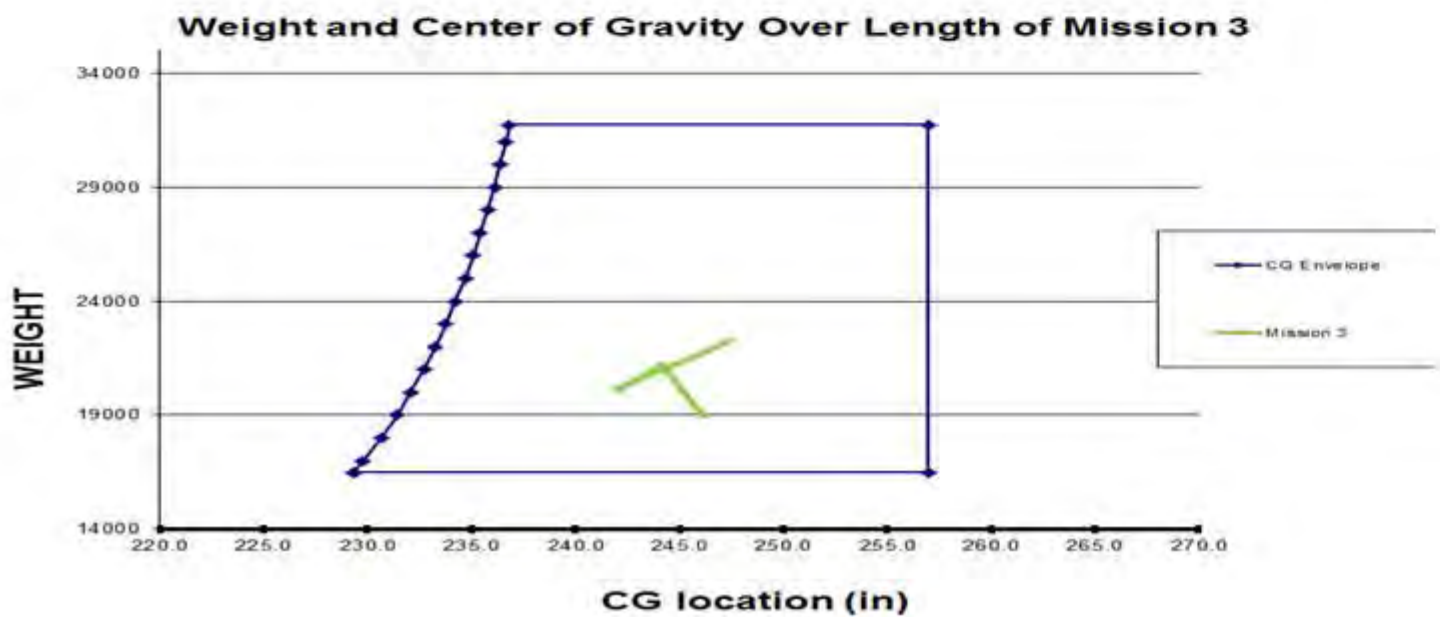
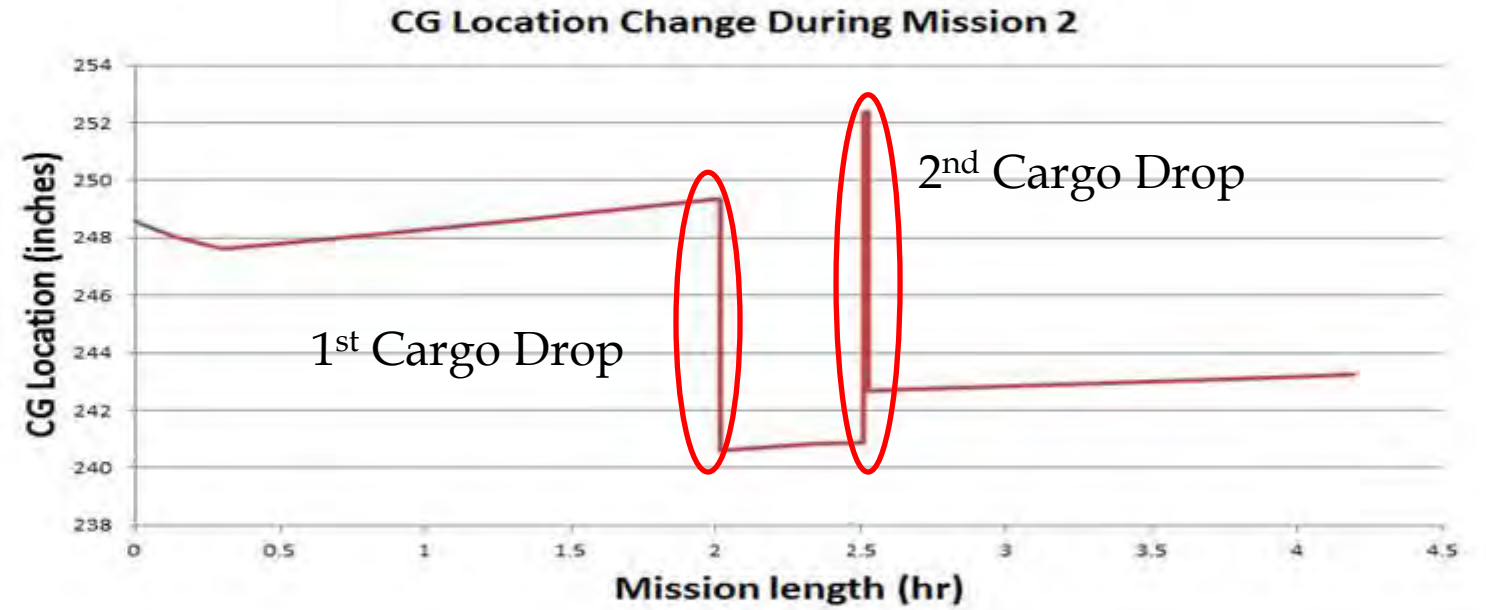
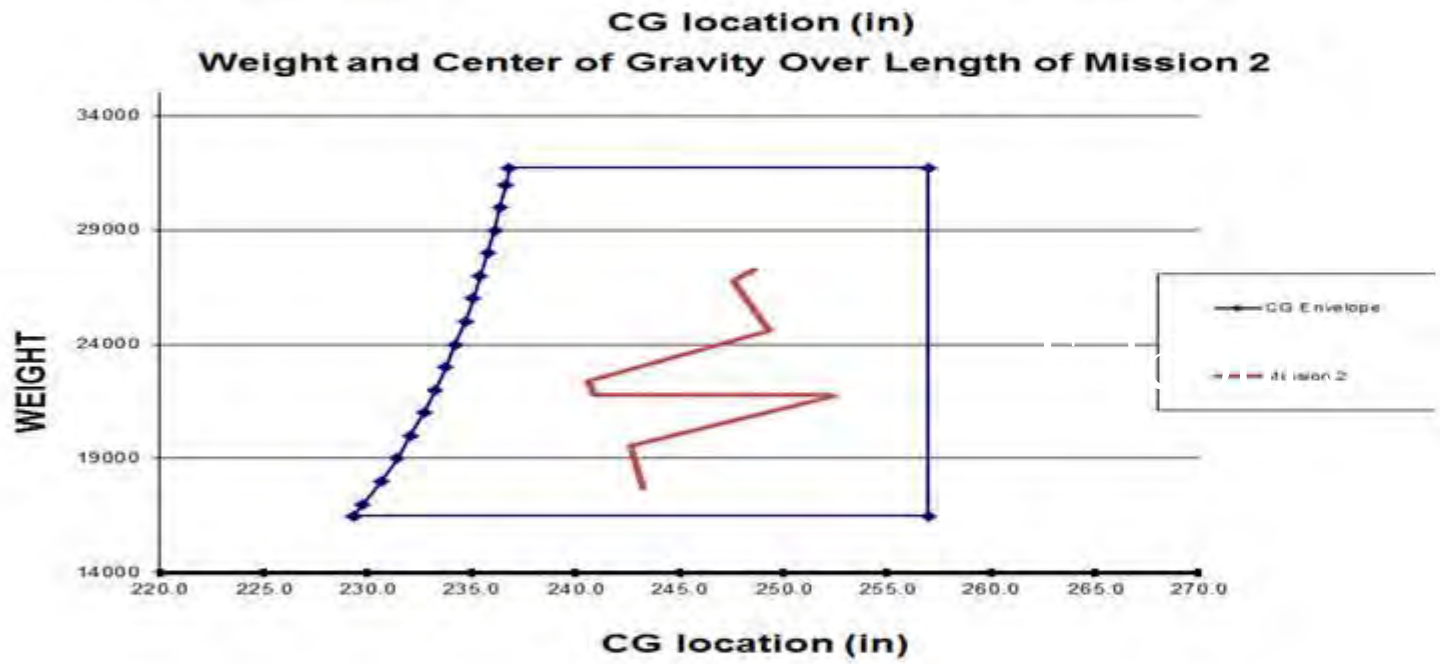
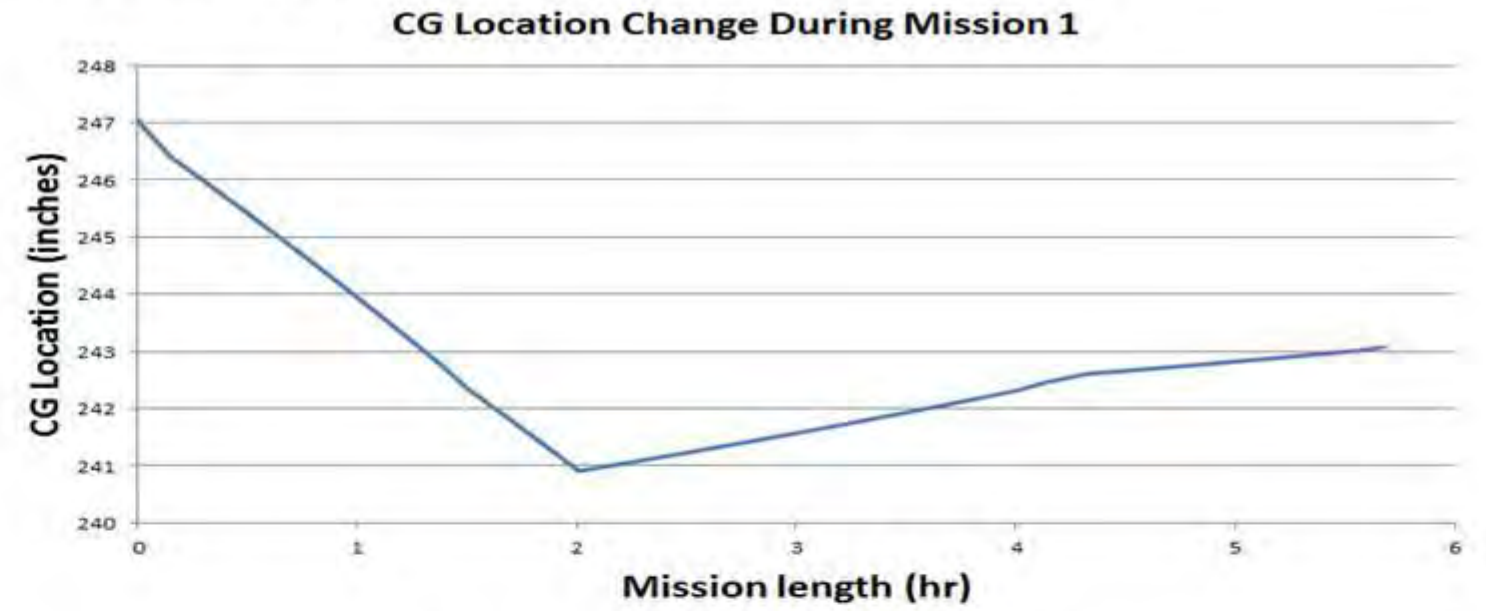
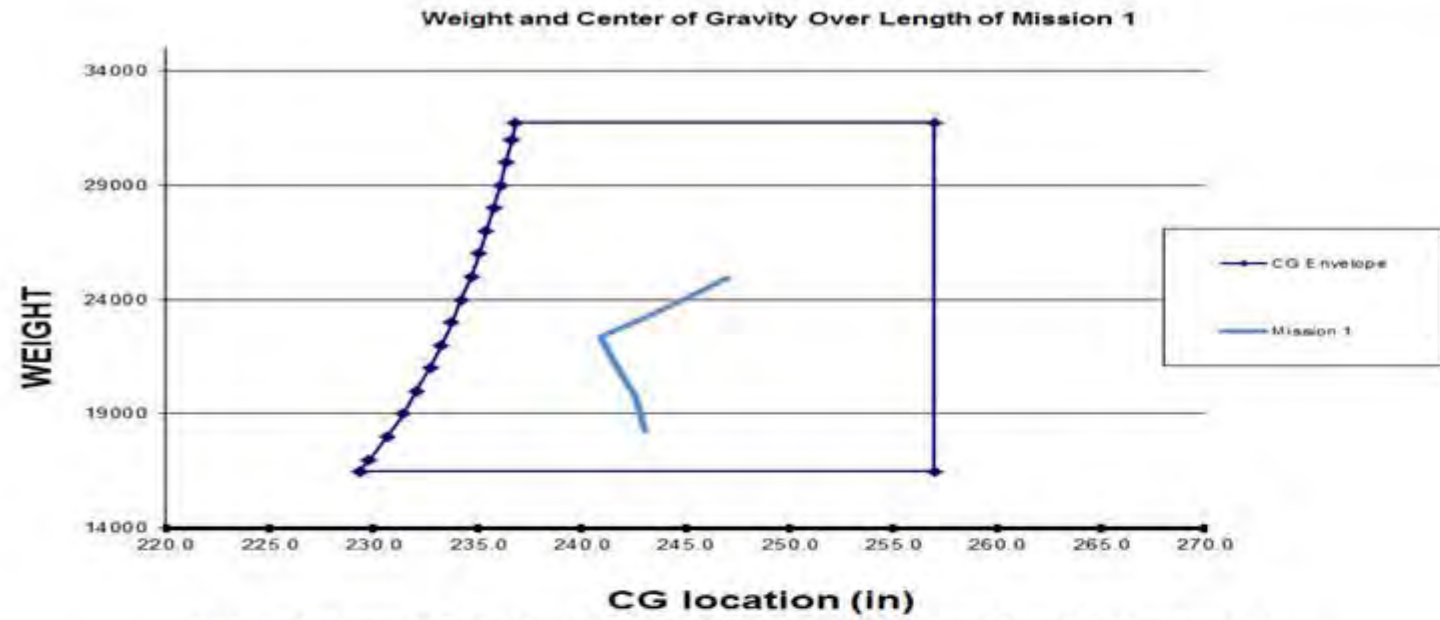
Mission 1: Rescue Coordination						
Mission section	Fuel usage(lbs)	Percentage	Time(hr)	Cl	Power	SFC
0. warm up	88.8	1.3%			277	1.28
1. Hover at 1500	59.1	0.9%	0.03		9700	0.244
2. Climb to 6000 meters	243.2	3.6%	0.12		7382	0.27
3. 240 knots for 600km @ 6000m	1581.3	23.2%	1.24	0.89	4926	0.258
4. Descend to 2000 meters	153.2	2.3%	0.11		4426	0.316
5. 120 knots for 600km @ 2000 meters	2756.0	40.5%	2.50	2.42	2765	0.399
6. Climb to 6000 meters	199.7	2.9%	0.13		6596	0.277
7. Return @210 knots for 600km @ 6000 meters	1535.2	22.6%	1.41	1.00	3591	0.298
8. Descend to 1500m	175.7	2.6%	0.12		4269	0.325
9. Landing	12.6	0.2%	0.01		4850	0.313
Total	6804.8	100.0%	5.68			
15% more	7825.5	115.0%				

Mission 3: Medical Evacuation						
Mission section	Fuel usage(lbs)	Percentage	Time(hr)	Cl	Power	SFC
0. warm up	89	1.9%			277	1.280
1. Hover at 1500m	59	1.3%	0.03		9700	0.244
2. Climb to 6000m	243	5.3%	0.12		7382	0.268
3. 240 knots for 600km @ 6000 meters	1581	34.3%	1.24	0.890	4926	0.258
4. Descend to 0m	262	5.7%	0.12		4892	0.326
5. Landing	13	0.3%	0.01		4850	0.327
6. Rescue for 15 mins	103	2.2%			321	1.281
7. Hover at 0m	61	1.3%	0.03		9700	0.251
8. Climb to 6000m	317	6.9%	0.12		7054	0.274
9. Return @240 knots for 600km @ 6000 meters	1694	36.8%	1.54	0.846	4779	0.263
10. Descend to 1500m	174	3.8%	0.12		4387	0.322
11. Landing	13	0.3%	0.01		4850	0.313
Total	4608	100.0%	3.34			
15% more	5300	115.0%				

Mission 2: Aid Distribution						
Mission section	Fuel usage(lbs)	Percentage	Time(hr)	Cl	Power	SFC
0. warm up	89	1.7%			277	1.28
1. Hover at 1500m	59	1.1%	0.03		9700	0.24
2. Climb to 6000 meters	243	4.6%	0.12		7382	0.27
3. 240 knots for 600km @ 6000 meters	1581	30.0%	1.24	0.89	4926	0.26
4. Descend to 2000 meters	153	2.9%	0.11		4426	0.32
5. 80 knots for 200km @ 2000 meters	1307	24.8%	1.06	2.42	3615	0.34
6. Climb to 6000 meters	193	3.7%	0.11		6181	0.29
7. Return @210 knots for 600km @ 6000 meters	1460	27.7%	1.43	0.89	3344	0.30
8. Descend to 1500m	171	3.2%	0.12		4205	0.33
9. Landing	13	0.2%	0.01		4850	0.32
Total	5268	100.0%	4.23			
15% more	6058	115.0%				

Mission	Extra Fuel (lbs)	Amount of Total fuel (%)	Extra Range (km)	ΔPI	Time (hr)	Cl	Power (hp)	SFC (lbs/hr/hp)	
Rescue Coordination	6880	47%	2596	1.45	6.7	0.90	3366	0.304	(210knots)
Aid Distribution	2142	26%	851.6	0.61	2.2	0.80	3165	0.309	(210knots)
Evacuation of Casualties	2900	35%	1054	0.87	2.4	0.76	4523	0.2704	(240knots)

CG Sensitivity Breakdown for Each Mission



Performance Index (PI) calculation

$$PI = PI_{weight} + PI_{range} + PI_{speed} + PI_{DOC} + PI_{DMC} = 11.14$$

$$PI_{weight} = \frac{15000 \text{ kg}}{\text{weight}_{take-off}} = \frac{15000 \text{ kg}}{14390 \text{ kg}} = 1.04$$

$$PI_{range} = \frac{\text{range}_a}{1800 \text{ km}} + \frac{\text{range}_b}{1400 \text{ km}} + \frac{\text{range}_c}{1210 \text{ km}} = \frac{4396 \text{ km}}{1800 \text{ km}} + \frac{2252 \text{ km}}{1400 \text{ km}} + \frac{2264 \text{ km}}{1210 \text{ km}} = 5.92$$

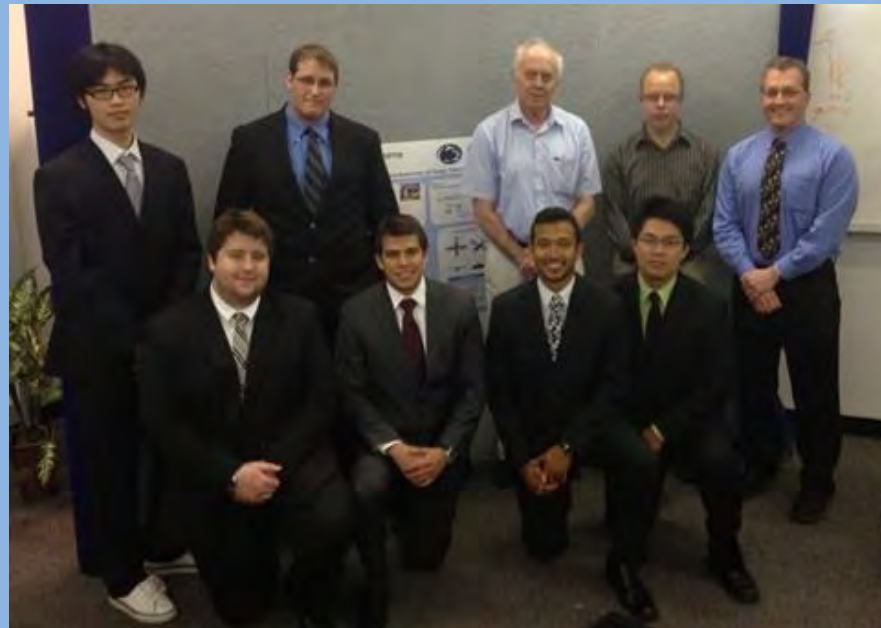
$$PI_{speed} = \frac{\text{speed}_{max}}{240 \text{ knots}} = \frac{298 \text{ knots}}{240 \text{ knots}} = 1.61$$

$$PI_{DOC} = \frac{1.25 \text{ DOC}_{Black Hawk}}{\text{DOC}_{Griffin}} = \frac{5739.28 \frac{\text{dollar}}{\text{hr}}}{4143.87 \frac{\text{dollar}}{\text{hr}}} = 1.39$$

$$PI_{DMC} = \frac{1.25 \text{ DMC}_{Black Hawk}}{\text{DMC}_{Griffin}} = \frac{3496.27 \frac{\text{dollar}}{\text{hr}}}{2253.06 \frac{\text{dollar}}{\text{hr}}} = 1.55$$

The team worked to optimize Griffin, keeping in mind to increase PI

Griffin PI = 11.14 **Standard PI = 7** **4.14** Extra (optimization) Points



2013 Penn State AHS Student Design Team