Problem Definition

In recent years, climate change has increased the frequency of disaster events of all kinds, and floods and forest fires represent some of the most pressing threats - floods represent 40 percent of all disasters, and forest fires burn twice as much annually than they did only 20 years ago. Accordingly, it is important to implement a system that can provide relief to people affected by these disasters.

The Humanitarian Response Airplane Fleet project aims to design a globally distributed fleet of aircraft capable of rapidly delivering essential supplies—such as medical kits, fresh water, and nonperishable food—to areas affected by natural disasters including floods, fires, earthquakes, and tornadoes. Leveraging existing municipal and rural airfields near disaster-prone regions, the fleet will utilize a twin-engine aircraft with short takeoff and landing (STOL) capabilities to operate efficiently in constrained environments. Each aircraft will be crewed by a captain, first officer, and load master, and designed to carry 1,500 lbs of palletized cargo along with onboard loading equipment for autonomous operations. With a mission radius of 800 miles, cruising altitudes between 10,000–15,000 ft, and an operational ceiling of 30,000 ft, the aircraft must also reserve fuel for loitering and return flights. This fleet will serve as a vital logistical backbone for first responders, ensuring timely and reliable delivery of life-saving resources to isolated or displaced communities.

ENAE482 Capstone: Humanitarian Response Airplane Fleet

Team 9

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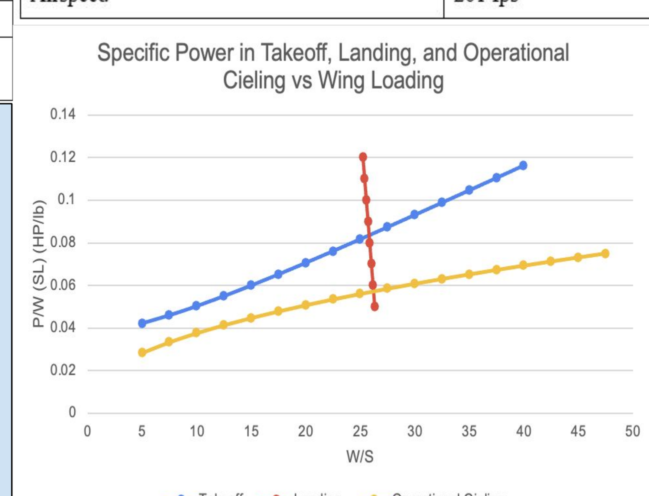
Conceptual Design Process Overview

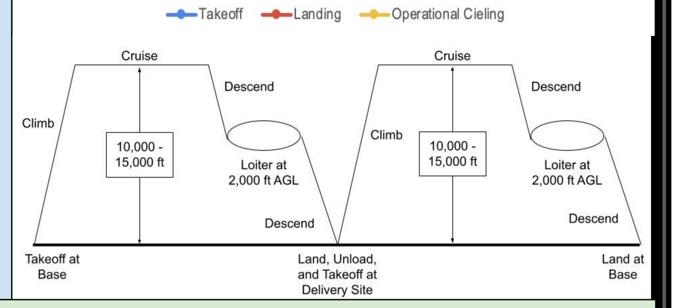
Table of Parameters

Parameter	Value	Range and/or Source
Clean Maximum Lift Coefficient	1.4	Acceptable range: 1.2 - 1.4 (Ch. 7 Appendix D)
Flap ΔCL_{Max} (Takeoff)	0.42	Typical for single-slotted flaps (Ch. 7 Appendix D)
Flap ΔCD_0 (Takeoff)	0.01	Typical for single-slotted flaps (Ch. 7 Appendix D)
Landing Gear ΔCD_0	0.02	0.0135 - 0.0218 (Ch. 7 Appendix D); 0.02 suggested starting point
Flap ΔCL_{Max} (Landing)	0.90	Typical for single-slotted flaps (Ch. 7 Appendix D)
Flap ΔCD_0 (Landing)	0.08	Typical for single-slotted flaps (Ch. 7 Appendix D)
Round-out Load Factor	1.2	1.2 is most common (Ch. 9 pg 2)
Propeller Efficiency	0.75	Reasonable assumption (Ch. 7 Appendix D)
Coefficient of Braking Friction	0.5	Typically 0.4 - 0.5 on dry pavement (Ch. 9 pg 4)
Landing Approach Stall Margin (fraction)	0.3	FAA regulation
Landing Approach Flight Path Angle (degrees)	-3	FAA regulation
Takeoff Distance (Xto)	2250 ft	Based on the project specification
Takeoff and Landing Altitude	0 to 5000 ft	Use 0 ft for fuel fraction; 5000 ft for P/W and T/W calculations
Oswald Efficiency (e)	0.8	0.70 - 0.86 (Ch. 7 pg 4); 0.8 is a good starting point for twin-engine prop
Aspect Ratio (AR)	12.3	8.6 - 12.3 (Ch. 7 Appendix D); High AR preferred for better aerodynamics
Clean Zero Lift Drag Coefficient (CD_0)	0.0218	0.0218 - 0.0323 (Ch. 7 Appendix D); chose the lower end of the range
Critical Altitude	10,000 ft	Notes
Payload Weight	2447 lbs	1500(cargo) + 690(crew + luggage) + 257(cargo handling equipment)

Conceptual Design Results

Parameter	Value
Takeoff Gross Weight	9451 lb
Empty Weight	5390 lb
Fuel Weight	1621 lb
Wing Span	68.2 ft
Chord Length	5.54 ft
Wing Area	378.04 ft^2
Wing Loading	25 lb/ft^2
Specific Power Required	0.0817-0.094 Hp/lb
Flight Time	12 hr 20 min
Growth Factor	3.873
Risk Assessment	Moderate
Engine Name	Allison 250-B17
Specific Fuel Consumption	0.657
Rated Power	400 HP
Airspeed	201 fps

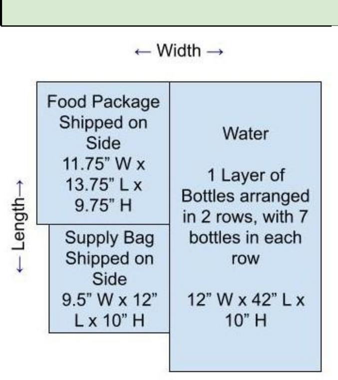




The first step in our process was to come up with a conceptual design of our airplane, and to define the mission more carefully. The tables above and images at right show the results of our conceptual design.

This phase of the project led us to choose a high-wing regional turboprop aircraft to design in full.

Palletized Cargo Breakdown



We chose to include commercially available water jugs, emergency food cases, and supply bags, grouped in packages providing 14 person-days of support per package, based on researched figures for the relative quantities needed of each type of supply. These packages are packed onto pallets by stacking the packages. 10 of these packages fit within the allotted cargo weight, on 2 pallets; 13 additional jugs of water can be stocked separately without exceeding the designed cargo weight. A pallet jack is included to facilitate loading and unloading.

Step 1: Wing Design (NACA 2415)

Enter values in all yellow shaded cells.

Wing Design Spreadsheet

Input parameters:			Flight Condition				
Wing Area (sq ft):	378.04	ft^2	Altiude =	15000			
Aspect Ratio:	12.30		Airspeed=	201	fps	←Select units here =	201 fps
Taper Ratio (**see Taper sheet**):	0.500		Std. Temp	465.18	5.51 °F		
Quarter chord sweep:	0.00	degrees	Ambient Temp (°F)		5.51 °F		
Wing Span	68.19	ft	Density	0.001496319	slug/cu. Ft		
Root Chord	7.39	ft	Sonic velocity	1057.314113	fps		
Tip Chord	3.70	ft	viscosity	3.43E-07	slug/ft/sec		
Leading edge sweep:	1.55	°	kinematic viscosity	0.000229229			
MAC:	5.75	ft	Reynolds no/ft=	8.769E+05	per ft		
Distance from root to MAC:	15.15	ft	Mach No. =	0.190			
Distance from vertex to AC:	1.85	ft					
Tip Rn =	3.241E+06						
Root Rn =	6.482E+06						
$(cl_{max})_{tip}$ = (from **Clmax sheet**)	1.635						
$(cl_{max})_{root}$ = (from **CLmaxsheet**)	1.700						
$(CL_{max})_{wing}$ =	1.467						
Airplane CL_{max} =	1.334						
Aileron Design							
Aileron area/Wing area (**see SaS sheet**)	0.06						
Semispan fraction at outboard end of aileron	1.0000	34.10	ft from wing center				
Fractional chord at hinge line	0.75						
Semispan fraction at inboard end of aileron	0.689	23.475	ft from wing center				

Step 2: Fuselage Design

Our fuselage is designed to include sufficient room in the cockpit for the 3 crewmembers, and a large enough cargo bay to accommodate the two pallets and store the pallet jack.

The fuselage design includes a cargo ramp for easy loading and unloading of the plane.

Step 3: High Lift Device (Flap)

Wing Aspect Ratio=	12.3		tan(Sweep at 50% chord) =	-0.0271
Wing Taper ratio =	0.5		k (used in CLα calculation)=	0.9666041
Quarter chord sweep (degrees) =	0		Wing CL_alpha (per rad)=	5.1917421
Enrter airfoil cl_alpha (per degree):	0.106		Kb(out)-Kb(in)=	0.56
Flap chord ratio =	0.2	←Select	Enter $(\alpha_\delta)_{C_L}/(\alpha_\delta)_{c_l}$ (Fig 11 & 12):	1.04
Semi-span fraction inboard =	0.2		Enter K' (Interpolate Figures 10a, b, c)	1.3
Semi-span fraction outboard =	0.689			
Enter Kb at inbard end (Figure 9)	0.25			
Enter Kb at outboard end(Figure 9):	0.81			
Flap deflection angle (degrees)=	20			
Flapped area ratio =	0.507093			
K_gamma=	0.92			

Single Slotted Flap

K=	0.97
Enter fractional chord translation:	0.05
Enter alpha_delta (Figure 8):	0.42
Δcl =	0.9349
Δcl_{max} =	0.9069
Wing ΔCL_{max} =	0.4231
cdf=	0.00615
ΔCLf=	0.46546
ΔCD_o =	0.0107

Step 4: Wing-Fuselage Integration

Step 6: Propulsion System Integration

Step 7: Landing Gear & Wheel Design

$FS_x = 17.338$ | $l_m = 1.108\ in$ | $V_{TO} = 113.16\ mph$

$WL_x = 3.6916$ | $l_n = 6.3156\ in$ | $V_L = 80.93\ mph$

$w_{TD} = 9.8387$ | $P_m = 4020.201\ lb$ | $s_{t,m} = 2.075\ inches$

$\theta_{TD} = 15.09°$ | $P_n = 247.411\ lb$ | $s_{t,n} = 1.95\ inches$

$e_s = 6.012$ | $P_{n_{dym}} = 4543.08\ lb$ | $(s_s)_{main} = 8\ inches$

$h_{cg} = 5.4678$ | $P_{m_{strut}} = 5025.25\ lb$ | $(s_s)_{nose} = 2\ inches$

$\delta = 37.303°$ | $P_{n_{strut}} = 5678.85\ lb$ | $d_{s,main} = 2.627\ inches$

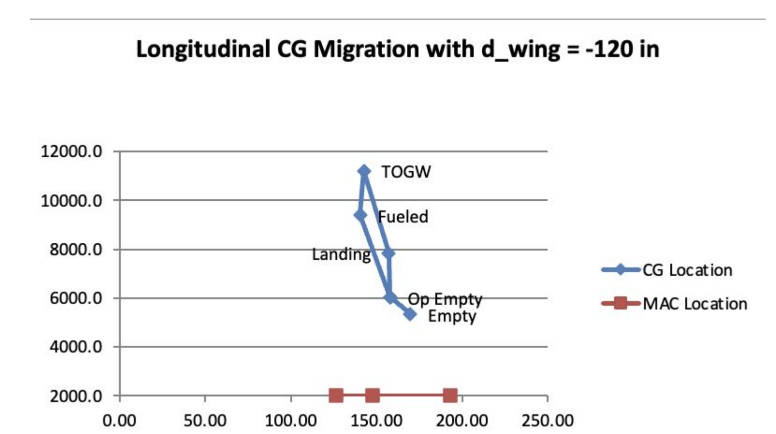
$track = 11.312\ ft$ | $d_{s,nose} = 2.52\ inches$

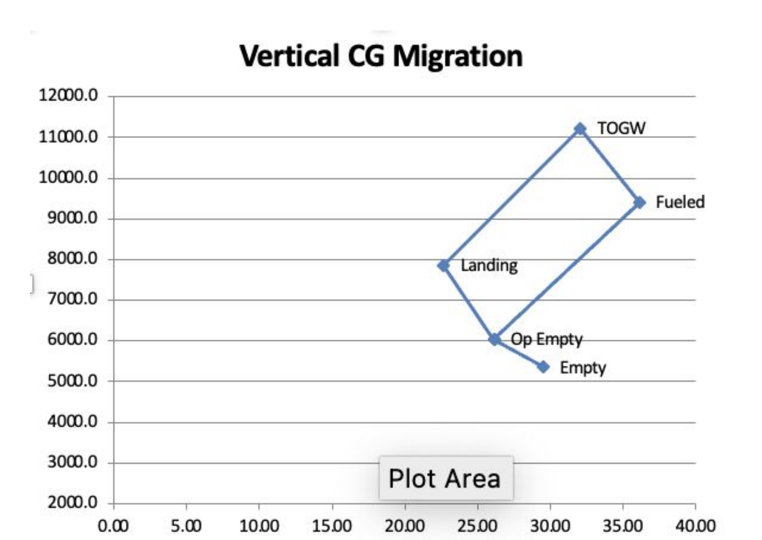
Since the loads are all less than 10,000 pounds, we can use table 26.4 to find the maximum inflation pressures. For tarmac with poor foundation, the maximum allowable tire pressure is 50-70 PSI.

Nose Gear: 7 - 6 Main Gear: 6.5 - 10 Tire Type: III

The nose gear and main gear are set such that there is little to no safety factor, but the plane will still function as planned. The main gear is behind the cg and the nose gear was placed in the proper range to allow take off and landing. The gear track we designed for places the wheels directly under the engine bays to allow us to retract them with no interference to the fuselage.

Step 8: Mass Properties





In order to center the CG over the 32% MAC location as well as achieve a CG excursion percentage in the typical range of Regional Turboprops, the Wing was moved forward by 10 ft, and the fuel tank was reduced in size and moved back aft of the wing.

Step 5: Empennage Design (NACA 0012)

Vertical Tail

Empennage Design Spreadsheet

Enter H for horizontal or V for vertical tails:	V		
Input parameters:			
Enter Tail Volume: (see sheet 2)	0.09		
Enter L_V/Wing span:	0.287		Initial estimate
Wing Area (sq ft):	378.0	ft^2	
Tail Area (sq ft):	118.5	ft^2	
Aspect Ratio:	1.50		See Sheet 4 for vertical or sheet 5 for horizontal typical values
Taper Ratio:	0.740		
Quarter chord sweep:	35.00	°	
Span	13.34	ft	
Root Chord	10.22	ft	
Tip Chord	7.56	ft	
Leading edge sweep:	36.87	°	
MAC:	8.96	ft	
Distance from root to MAC:	6.34	ft	
Distance from vertex to AC:	6.99	ft	
Actual L_V/Wing span and volume:	0.281	0.088	After integrating the tail with your GAD update th
Rudder Design			
Rudder area/vertical tail area:(see sheet 6)	0.3		
Semispan fraction at outboard end of rudder	1	13.34	ft from root
Semispan fraction at inboard end of rudder	0.100	1.33	ft from root
Hinge Line percent chord:	66.16		

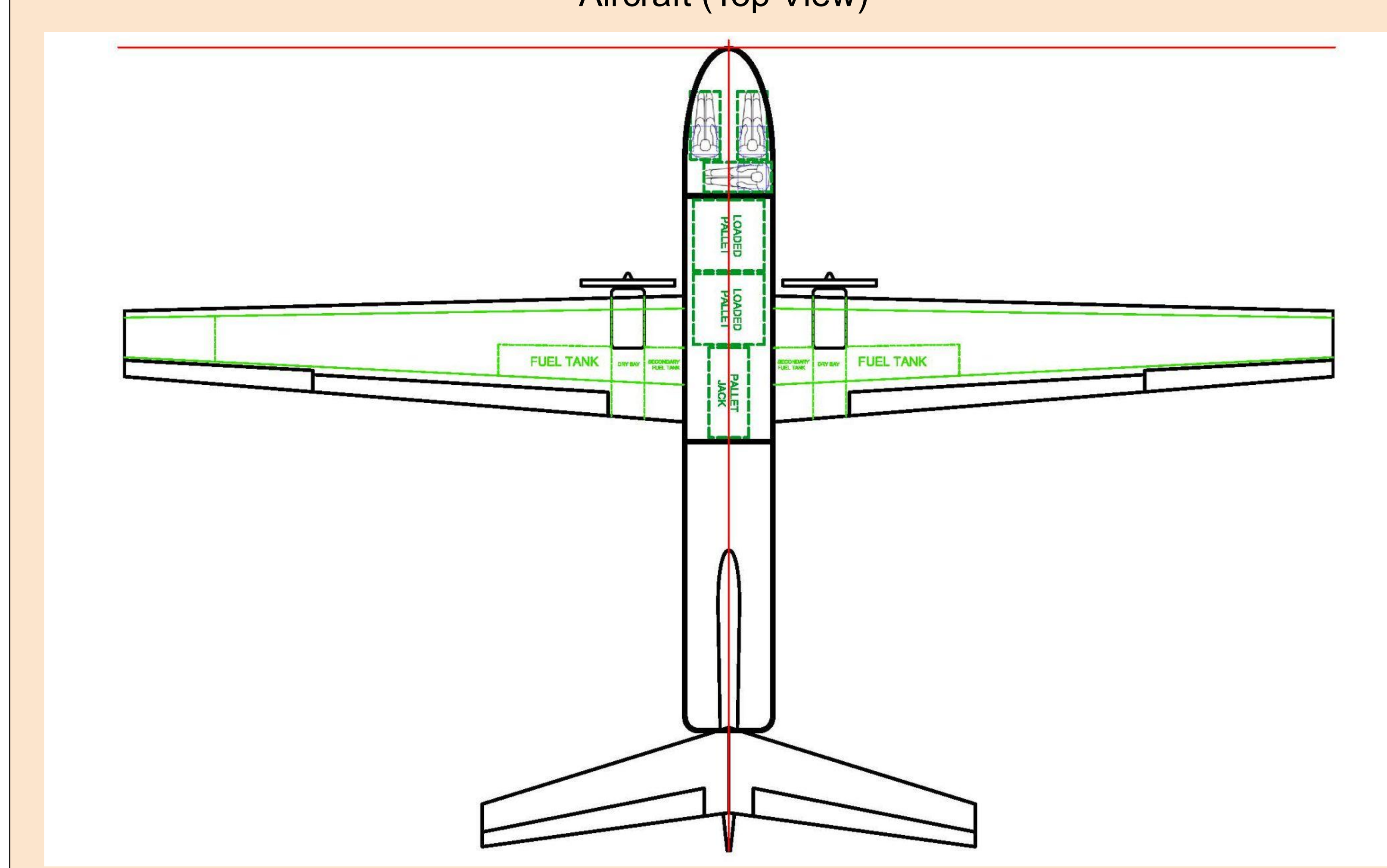
Horizontal Tail

Empennage Design Spreadsheet

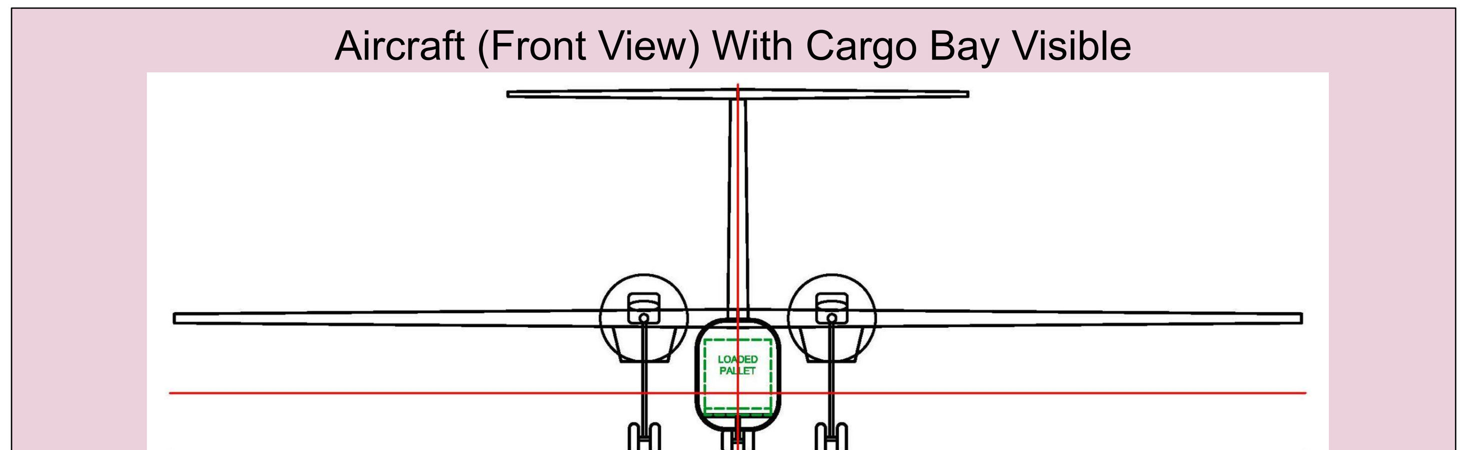
Enter H for horizontal or V for vertical tails:	H		
Input parameters:			
Enter Tail Volume: (see sheet 3)	1.2		
Enter L_H/Wing MAC:	4.514		Initial estimate
Wing Area (sq ft):	378.0	ft^2	
Tail Area (sq ft):	100.5	ft^2	
Aspect Ratio:	7.70		See Sheet 4 for vertical or sheet 5 for horizontal typical values
Taper Ratio:	0.500		
Quarter chord sweep:	15.00	°	
Span	27.82	ft	
Root Chord	4.82	ft	
Tip Chord	2.41	ft	
Leading edge sweep:	17.29	°	
MAC:	3.75	ft	
Distance from root to MAC:	6.18	ft	
Distance from vertex to AC:	2.86	ft	
Actual L_H/Wing MAC:	4.354	1.157	After integrating the tail with your GAD update th
Elevator Design			
Elavator area/horizontal stab area: (see sheet 7)	0.3		
Semispan fraction at outboard end of elevator	1	13.91	ft from root
Semispan fraction at inboard end of elevator	0.100	1.39	ft from root
Hinge Line percent chord:	65.52		

Final Aircraft Drawings

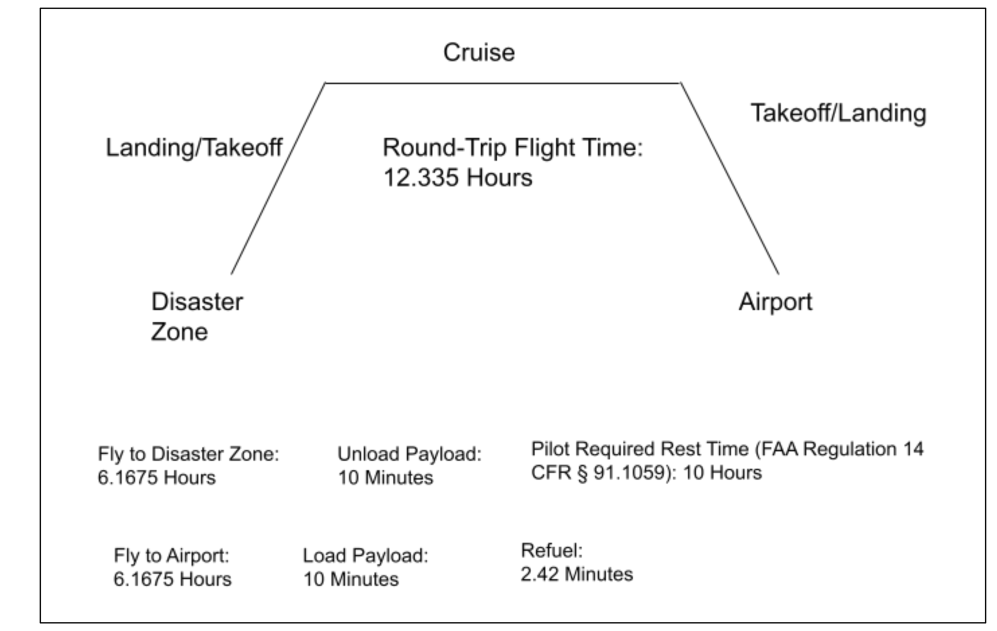
Aircraft (Top View)



Aircraft (Front View) With Cargo Bay Visible



Simulated Deployment

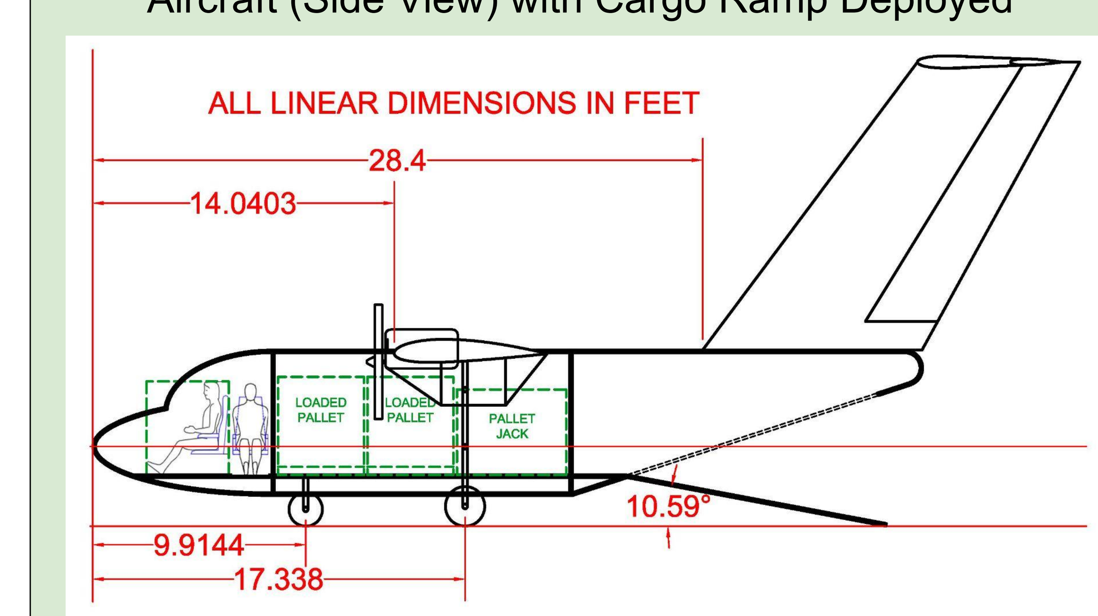


To validate the functionality of this fleet of aircraft for fulfilling the mission, we built a schedule for response to a hypothetical disaster. We set the goal of landing a flight at the disaster zone once every 30 minutes.

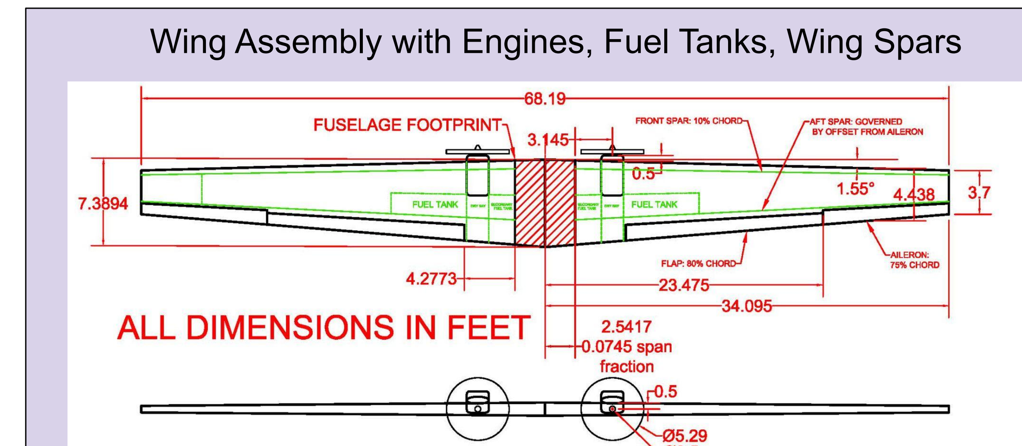
To do this, we used the times listed in the figure above, and assumed the worst-case scenario of a disaster at the maximum range from our base. We also assumed that refueling and reloading could be conducted at the same time. Using these, we built a full schedule chart.

With this schedule, we determined that a fleet of **44 aircraft is sufficient to meet this worst-case scenario**. Additionally, to comply with FAA regulations regarding crew flight and rest time, we determined that **66 3-member crews are required to operate the aircraft continuously in this scenario.**

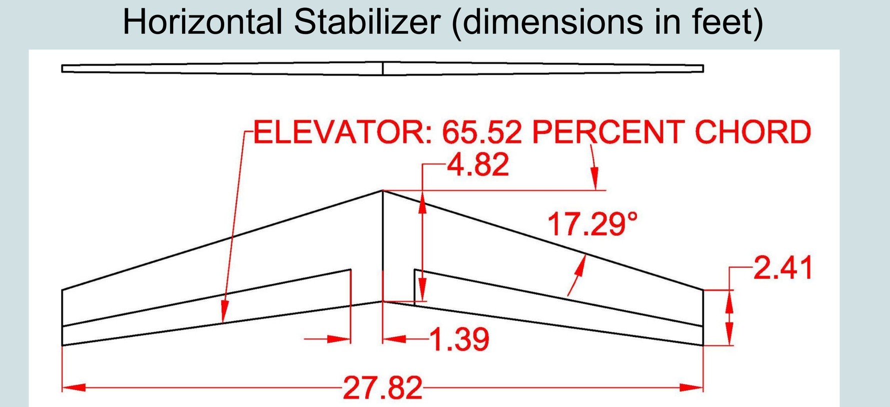
Aircraft (Side View) with Cargo Ramp Deployed



Wing Assembly with Engines, Fuel Tanks, Wing Spars



Horizontal Stabilizer (dimensions in feet)



Vertical Stabilizer