UCI Cargo Plane - Structural Optimization

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Executive Summary

UCI Cargo Plane is a senior design project aiming to develop a lightweight RC aircraft capable of taking off, maneuvering, and landing with the heaviest payload possible to compete in the International SAE Aero Design competition. Our MAE151 project acts as an auxiliary unit to the team by providing additional analysis of the two major load-bearing structures in the aircraft: the cargo bay fuselage beam and the primary spar structures for next year's aircraft. Our goal is to provide mathematically driven design of the cargo bay fuselage beam and the primary spar through hand calculations, FEA analysis and static testing.

Dimensions

Table 1: Dimensions of Cargo Bay Fuselage Beam and Primary Spar

Cargo Bay Fuselage Beam		Primary Spar		
		Section 1 (inboard)	Section 2	Section 3 (outboard)
Length (in)	46.5	29	48	30
Spar Cap Width (in)	3.75	1.33	1.08	0.83
Shear Web Height (in)	4.1	3.42	2.67	2.05
Shear web Thickness (in)	0.25	1/8	1/8	1/8
Top Spar Cap Thickness (in)		0.375	0.25	0.25
Bottom Spar Cap Thickness (in)		0.375	0.375	0.25

Material Research

Table 2: Material Research for Common Aircraft Woods and Aluminum Alloys

		Wood						Aluminum			
Properties		Balsa	Sitka Spruce	Douglas Fir	Basswood	Birch	Ash	6063-T6	6063-T4	6061-T6	6061-T4
Density (kg/m^3)		160	400	500	320	550	550	2700	2700	2700	2700
Young's Modulus E (MPa)	Longitudinal	3400	11880	13860	7200	13900	12000	68900	68900	68900	68900
	Tangential	51	510.84	693	390	740	1391				
	Radial	156.4	926.64	942.48	673	1403	1908				
Shear Modulus G (MPa)	G_LR	183.6	760.32	887.04	403.2	1028.6	1308	25800	25800	25800	25800
	G_LT	125.8	724.68	1081.08	331.2	945.2	924				
	G_RT	17	35.64	97.02	X	236.3	X				
Ultimate Tensile Strength F_tu (MPa)	Longitudinal	73.0	38.6	49.0	41.0	56.0	51	172	241	310.3	241
	Tangential	1.00	1.59	6.00	1.9	3.0	4.1				
Ultimate Shear Strength (MPa)		1.10	5.38	6.34	4.1	7.7	9.3	110	152	207	165
Poisson's Ratio μ_stressdirection,straindirection	μ_LR	0.229	0.372	0.292	0.364	0.426	0.371	0.33	0.33	0.33	0.33
	μ_LT	0.488	0.467	0.449	0.406	0.451	0.44				
	μ_RT	0.665	0.435	0.39	0.912	0.697	0.684				
	μ_TR	0.231	0.245	0.374	0.346	0.426	0.36				
	μ_RL	0.018	0.04	0.036	0.034	0.043	0.059				
	μ_TL	0.009	0.025	0.029	0.022	0.024	0.051				
Minimum Thickness (inch)		1/64	1/32	1/16	1/16	1/8	3/4	1/16	1/8	0.035	0.032

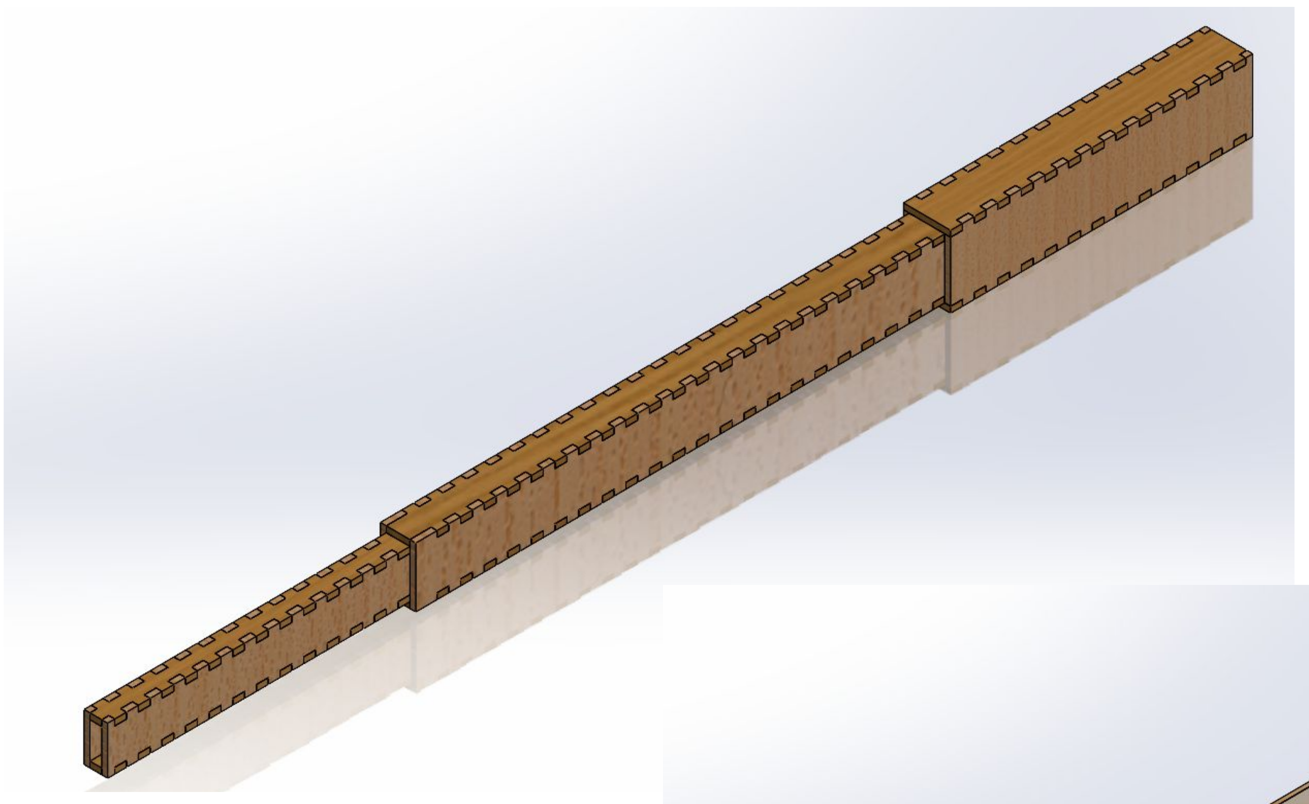


Figure 1: CAD model of primary spar

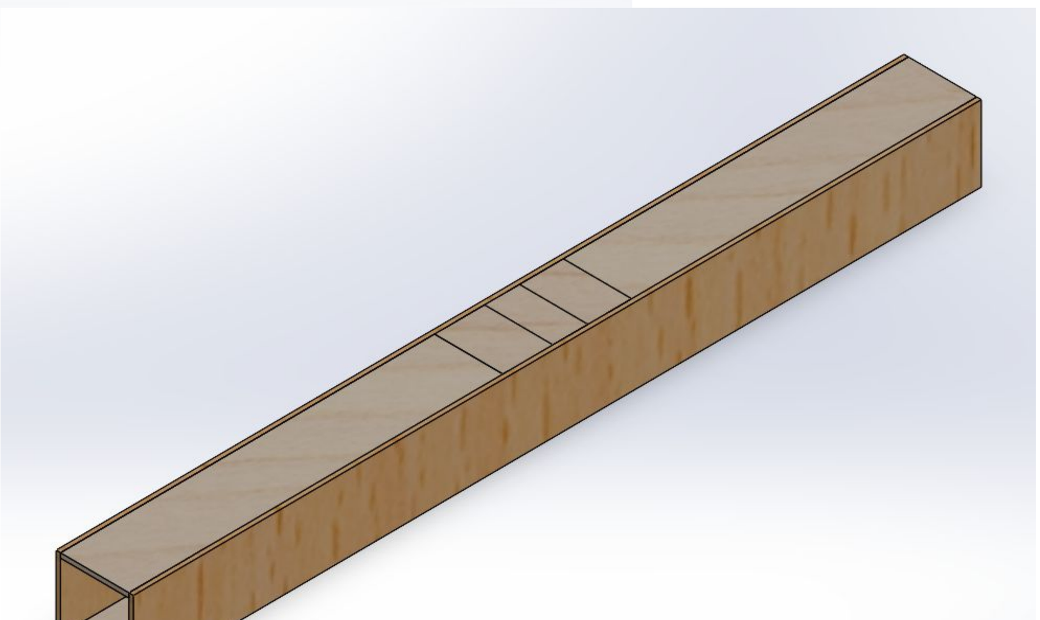


Figure 2: CAD model of cargo bay fuselage beam

Cargo Bay Fuselage FEA Analysis

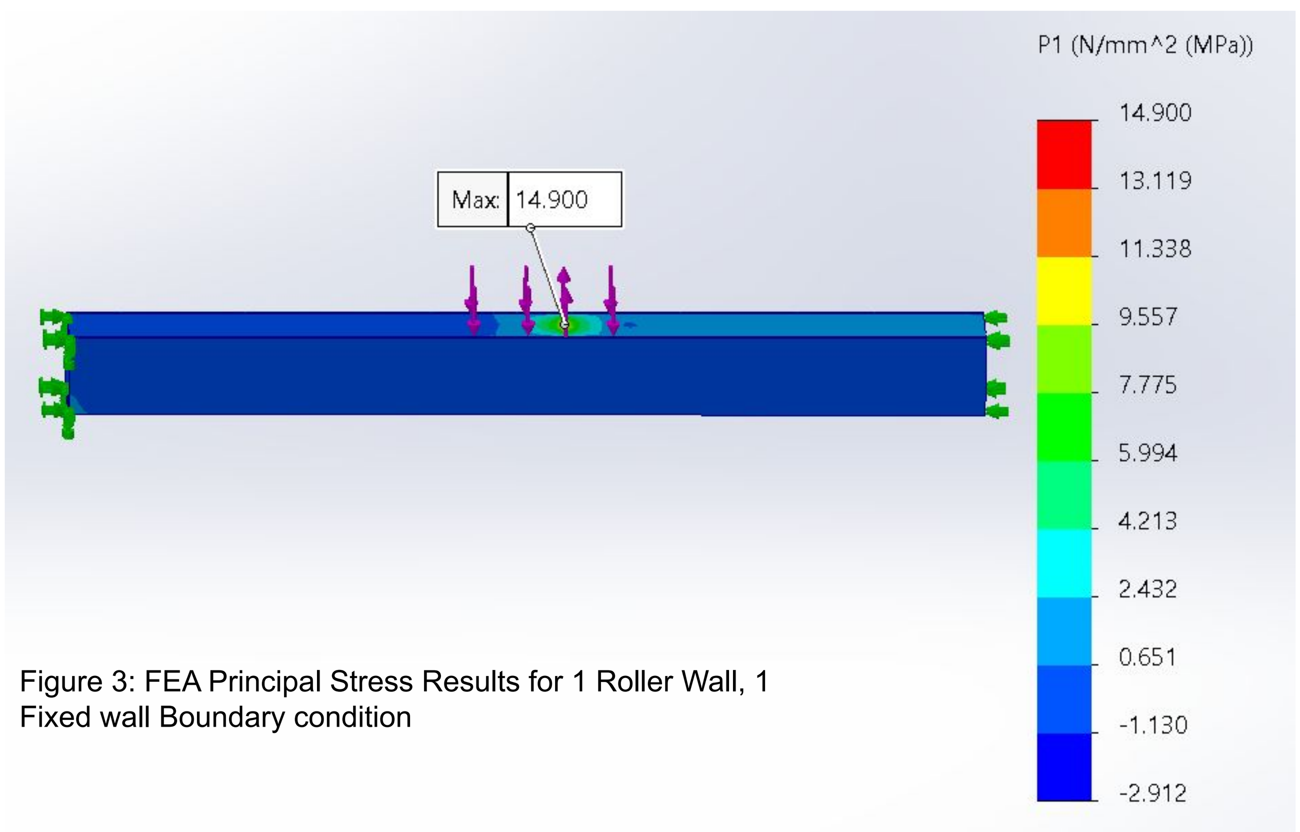


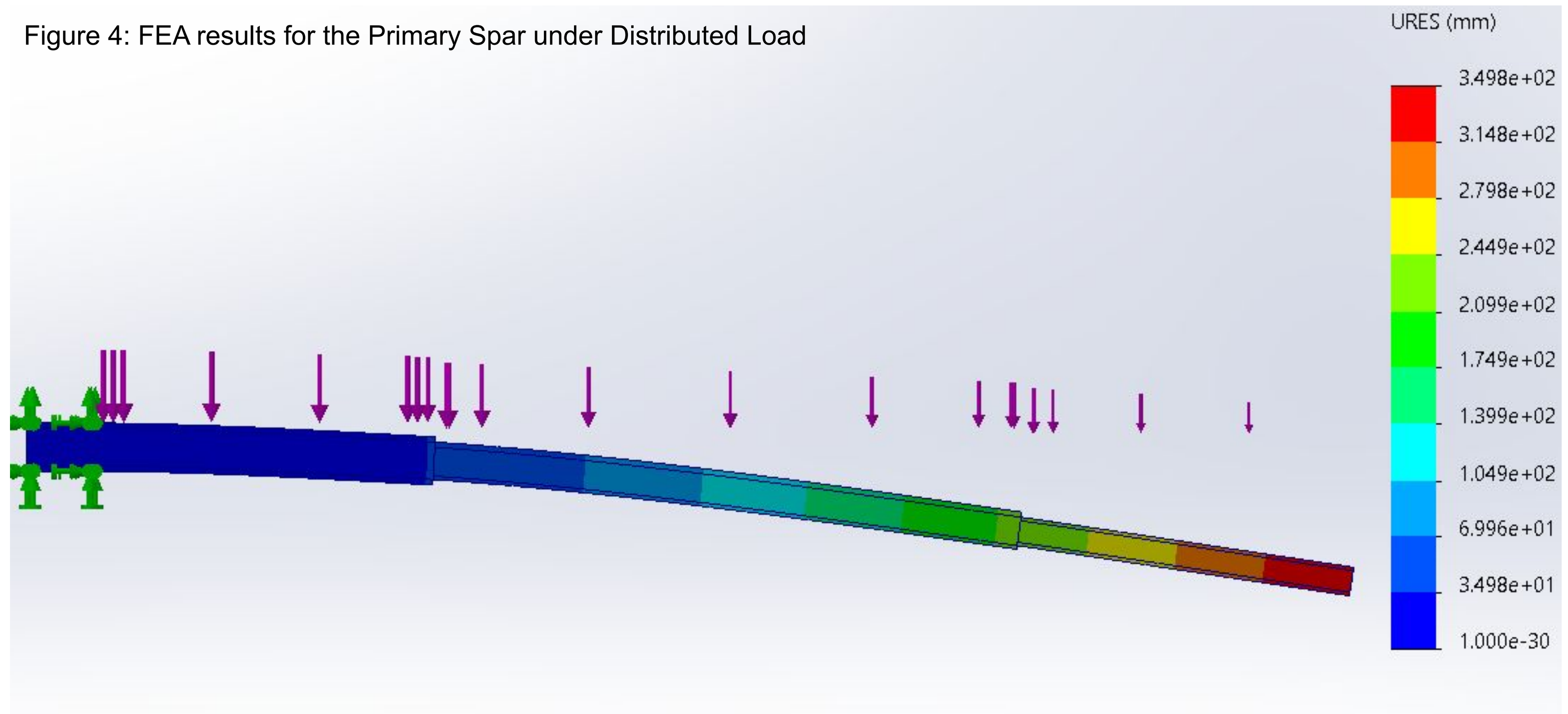
Figure 3: FEA Principal Stress Results for 1 Roller Wall, 1 Fixed wall Boundary condition

Boundary Conditions	F_tu Spruce (MPa)	Max Principal Stress (MPa)	< F_tu of Spruce Caps?	Max Displ. (in)	Location of Max Displacement
2 Fixed Walls	38.6	**14.729**	YES	**0.013**	Around lift force
1 Fixed Wall, 1 Roller Wall	38.6	**14.589**	YES	**0.030**	Shear web of most aft section
1 Roller Wall, 1 Fixed Wall	38.6	**14.900**	YES	**0.040**	Shear web of most forward section

Table 3: Principal Stress Results for Boundary Conditions on Cargo Bay Fuselage Beam In Flight

Primary Spar FEA Analysis

Figure 4: FEA results for the Primary Spar under Distributed Load



Primary Spar Static Testing

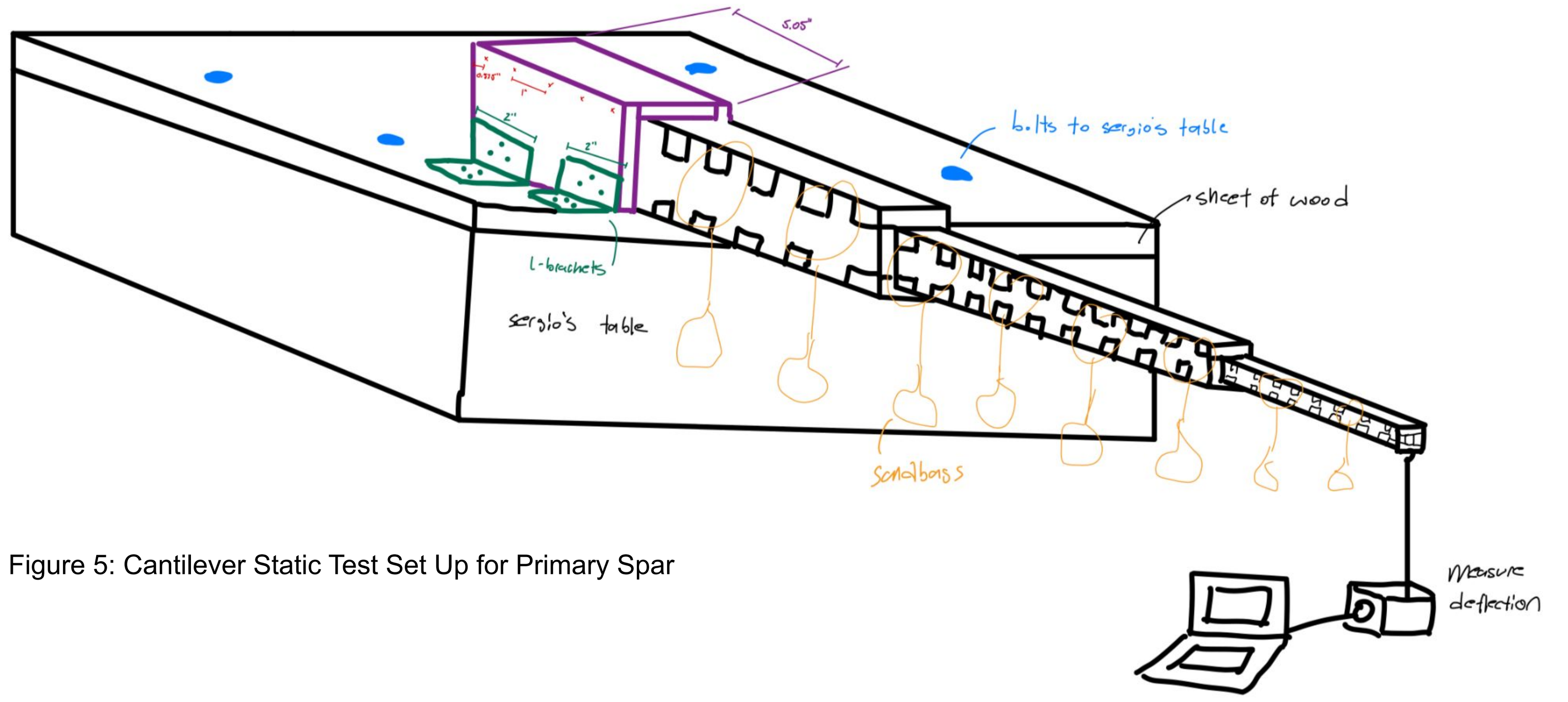


Figure 5: Cantilever Static Test Set Up for Primary Spar

Conclusion

Based on our analysis, **the structures will withstand the appropriate loading**. In addition, considerations about shipping times for specialized aircraft woods should be made earlier into the project. Lastly, for the most accurate analysis, an entire wing should be manufactured and tested to truly validate the structures selection.