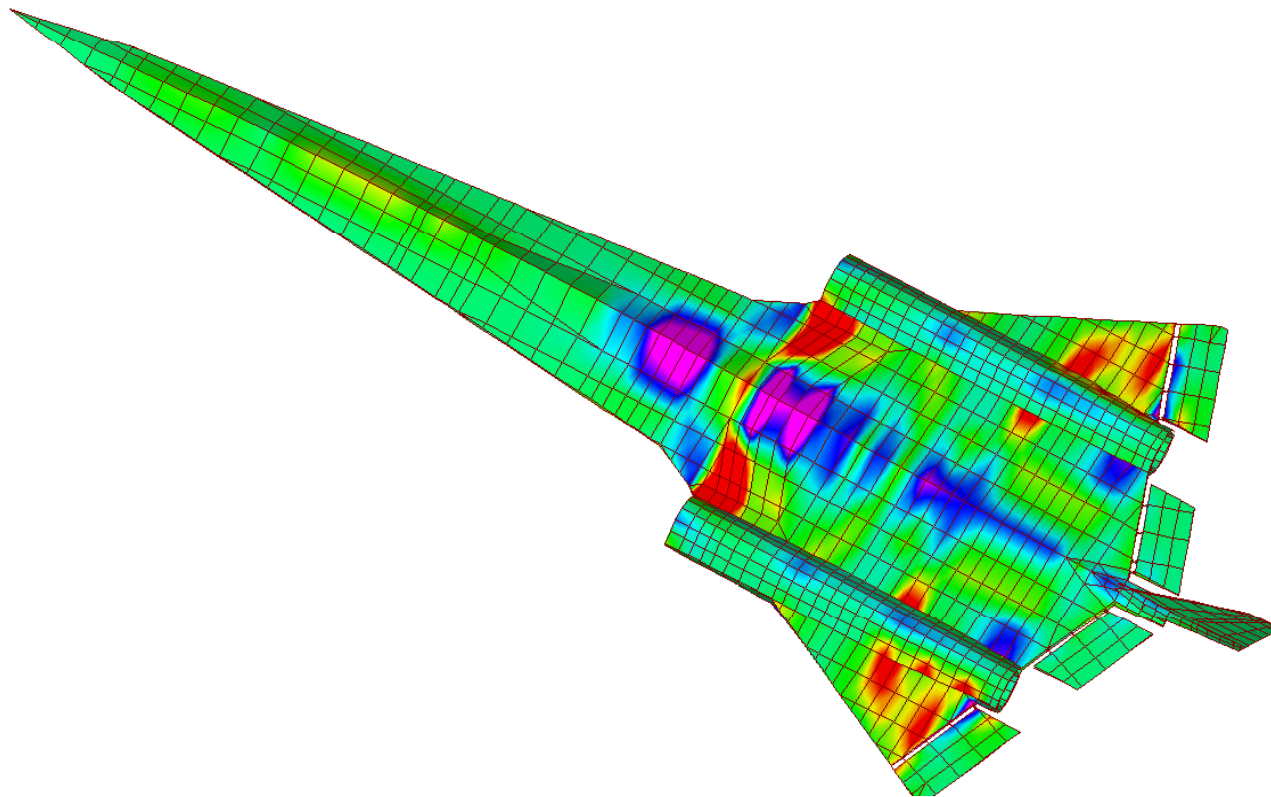




Optimization Approach



Optimization: Objective



Concurrently optimize panel and beam concepts, material choices, cross sectional dimensions, and layups. Handle complete vehicle systems modeled with many grids and elements. Ensure that optimum designs pass all structural integrity analyses. Provide accurate weight predictions and multiple equivalent weight designs which are manufacturable. Quickly display, to scale, optimum concept, shape, and size for user verification.

Optimization: Technical Approach



- 1. Directly optimize design by permutation of all continuous and discrete variables**
- 2. Generate a full factorial of design combinations**
- 3. Find optimum solution(s) without having to process the complete full factorial design matrix**

Directly Optimize by Permutation of Discrete Variables



Figure

Web - thickness (Isotropic, Hyper-Laminate, Hyper-Layup, Orthotropic Material)

Group Variable Bounds			Results
Minimum	Maximum	Permutations	Component Optimum Value
0.03	0.15	5	0.09

Advanced Group Optimization

Minimum	Maximum	Permutations	Requested Designs
			1

Statistical Optimization
 Link Variable Across Components
 Link Material Across Components

Material

- "Aluminum" Al 2024, Form: Sheet and Plate, Spec: QQ-A-250 4, Temp
- "Titanium" Gamma TiAl, Ti-46.5Al-4(Cr, Nb, Ta, B), Gamma Met, Form:
- "Titanium" Ti-6Al-4V, commonly used aerospace Titanium, Form: Shee
- "Heat-Resistant Alloys" Inconel 718, Form: Sheet, Spec: AMS 5596, T
- Graphite/Epoxy "IM7/8552 - Minotaur Boeing Grid Stiffened Optimiza
- Graphite/Epoxy "IM7/977-2_FiberDominated", Form: Tape, Spec: NO
- Graphite/Epoxy "IM7/977-2_LeakCriteria", Form: Tape, Spec: NONE,
- Graphite/BMI "IM7-5250-4_OpenHole&Filled", Form: Tape, Spec: NO
- Graphite/Polyimide "T650/PMR-15", Form: Tape, Spec: NONE, Basis:

Integrally Blade stiffened (Sandwich)
 "I" stiffened (Continuous, Sandwich)

Integrally "T" inverted stiffened
 "Z" stiffened

Variables include:

- Cross section dimensions
- Material selections
- Panel and beam concepts

Optimization



HyperSizer Direct Sizing Optimization



- **Optimize Everything**

- **Panel/beam concepts** optimum concept found from a library of commonly used designs: Z shape, mechanically fastened panel vs. blade shaped, integrally machined stiffened panel
- **Material selection** All isotropic, orthotropic, foams, and honeycomb cores are available as candidates
- **Design dimensions and thicknesses** facesheet, flange, and web sheet thicknesses and widths, heights, stiffener spacings
- **Layups** Thousands of pre-defined or user-defined layups are available as candidates for any panel or beam segment

Optimization Criteria



Available Failure Analyses

Limit MOS	Ult MOS	Location - Analysis Description
	13.82	Honeycomb Panel Buckling, Shear
	1.383	Honeycomb Panel Buckling, Symm Biaxial w/ Shear Interaction
	1.361	Honeycomb Panel Buckling, Unsymm Biaxial w/ Shear Interaction
	1.361	Honeycomb Panel Buckling, Symm Biaxial w/ TSF (transverse shear)
	1000	Honeycomb Panel Buckling, Unsymm Biaxial w/ TSF
	1.361	Honeycomb Panel Buckling, Shear w/ TSF
		Honeycomb Panel Buckling, Unsymm Biaxial w/ TSF&Shear Interact
		Honeycomb Stiffness Requirement, Membrane
		Honeycomb Stiffness Requirement, Bending
66.2	66.2	Top Honeycomb Face Wrinkling, X & Y directions {Hexcell method}
29.23	29.23	Top Honeycomb Face Intracell Dimpling, X & Y directions {Hexcell method}
	52.48	Top Honeycomb Face Composite Strength, Max Strain 1 Direction
	561.8	Top Honeycomb Face Composite Strength, Max Strain 2 Direction
	1.809	Top Honeycomb Face Composite Strength, Max Strain 12 Direction
	42.16	Top Honeycomb Face Composite Strength, Max Stress 1 Direction
	404.8	Top Honeycomb Face Composite Strength, Max Stress 2 Direction
	1.022	Top Honeycomb Face Composite Strength, Max Stress 12 Direction
	1.02	Top Honeycomb Face Composite Strength, Tsai-Hill Interaction
	1.009	Top Honeycomb Face Composite Strength, Tsai-Wu Interaction
	1.009	Top Honeycomb Face Composite Strength, Tsai-Hahn Interaction
	1.009	Top Honeycomb Face Composite Strength, Hoffman Interaction
1000	1000	Honeycomb Core Crushing {Hexcell method}
1000	1000	Honeycomb Core Shear Crimping, X & Y directions {Hexcell method}
82.37	82.37	Honeycomb Core Shear Strength, X & Y directions {Hexcell method}
66.23	66.23	Bottom Honeycomb Face Wrinkling, X & Y directions {Hexcell method}
29.24	29.24	Bottom Honeycomb Face Intracell Dimpling, X & Y directions {Hexcell method}
	51.06	Bottom Honeycomb Face Composite Strength, Max Strain 1 Direction
	546.9	Bottom Honeycomb Face Composite Strength, Max Strain 2 Direction
	155.9	Bottom Honeycomb Face Composite Strength, Max Strain 12 Direction

toggle toggle reset to default analyses set as default analyses

Any or all analyses can be selected as optimization criteria

Designer/analyst is not required to derive failure criteria as would be required for formal optimization packages

Optimization Requirements

	Required Value	Computed Value
Symmetric Terms		
A11	<input type="text"/>	5783200
A22	<input type="text"/>	5783200
A33	<input type="text"/>	1969000
D11	<input type="text"/>	15441.62
D22	<input type="text"/>	15441.62
D33	<input type="text"/>	5257.394
Minimum Natural Frequency		
Panel	11	11.0842
Local	<input type="text"/>	0
Deformation		
Strain X	<input type="text"/>	0
Strain Y	<input type="text"/>	0
Curvature X	<input type="text"/>	-2.157177E-03
Curvature Y	<input type="text"/>	-7.57413E-04
Center Deflection	1	0.9984004

Additional optimization criteria includes modal frequency, stiffness, deformation and midspan deflection limits

Optimization



Three Levels of Composite Material Optimization



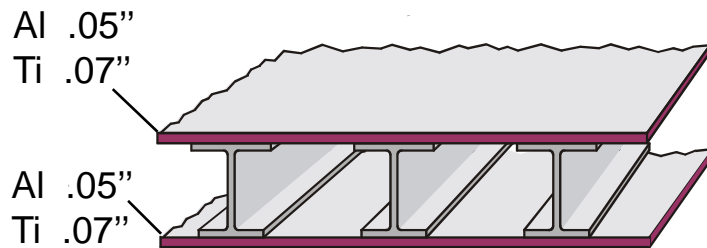
- Treat laminates as equivalent, homogenous orthotropic materials and optimize by varying their thickness in a continuous isotropic sheet metal manner. This allows quick computation of best ply percentage in each direction.
- Analyze laminates on a ply-by-ply basis and discretely optimize ply count and layup sequence using fabric or tape thickness.
- Specialize laminate optimization by analyzing any general arrangement of ply orientations such as 32.2 including any general hybrid material selection for the individual plies.
- Note: *Stock sizes* can be defined and used for isotropic material sheet thicknesses

Design Variable Linking

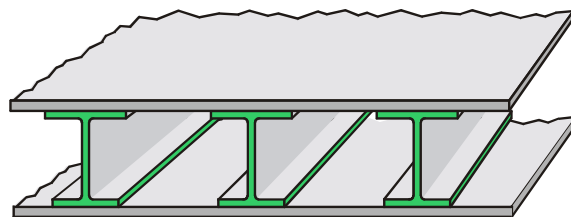


Linking Within Components

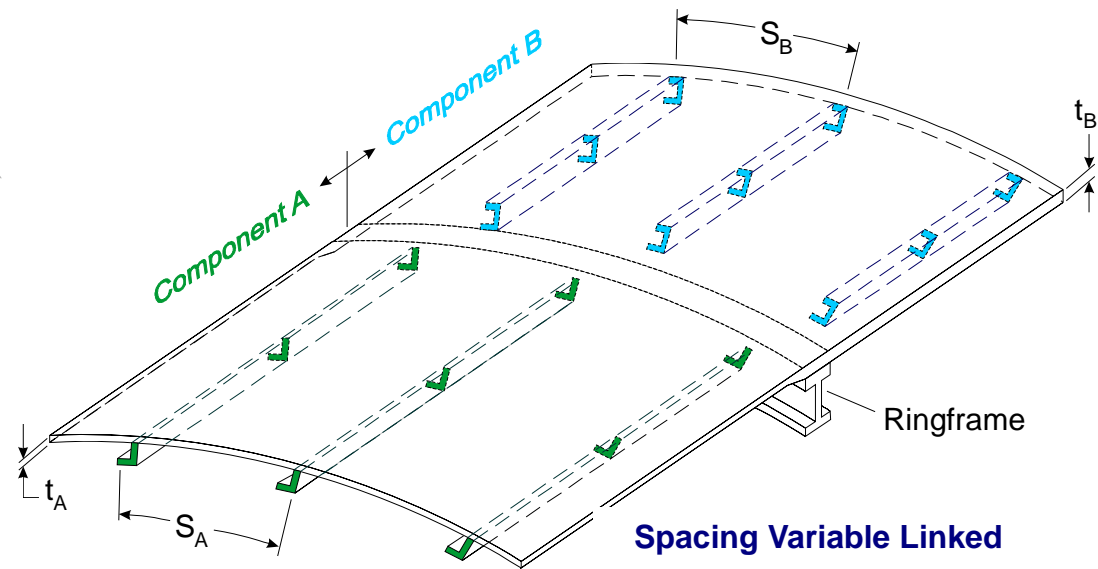
Linking Between Components



Link Facesheet materials and / or thicknesses



Link Flange and Web thicknesses



Spacing Variable Linked

$$S_A = S_B$$

Advanced Optimization



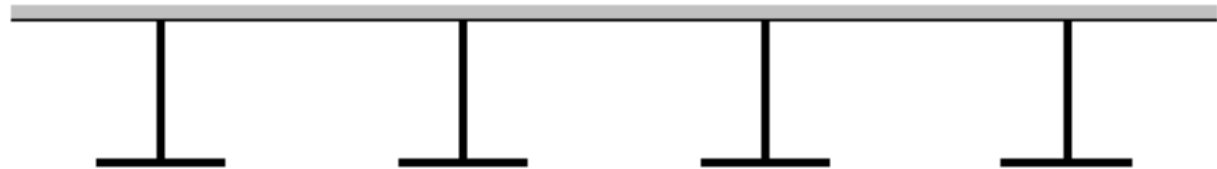
Multiple Workable Designs



Compression load causing panel buckling, local buckling, crippling...



1. Inverted "T"
S = 2.75", H = 1"
UW = [3.216](#) psf



2. Inverted "T"
S = 3.5", H = 1.75"
UW = [3.266](#) psf



3. "Z" stiffened panel
S = 3.5", H = 1"
UW = [3.268](#) psf

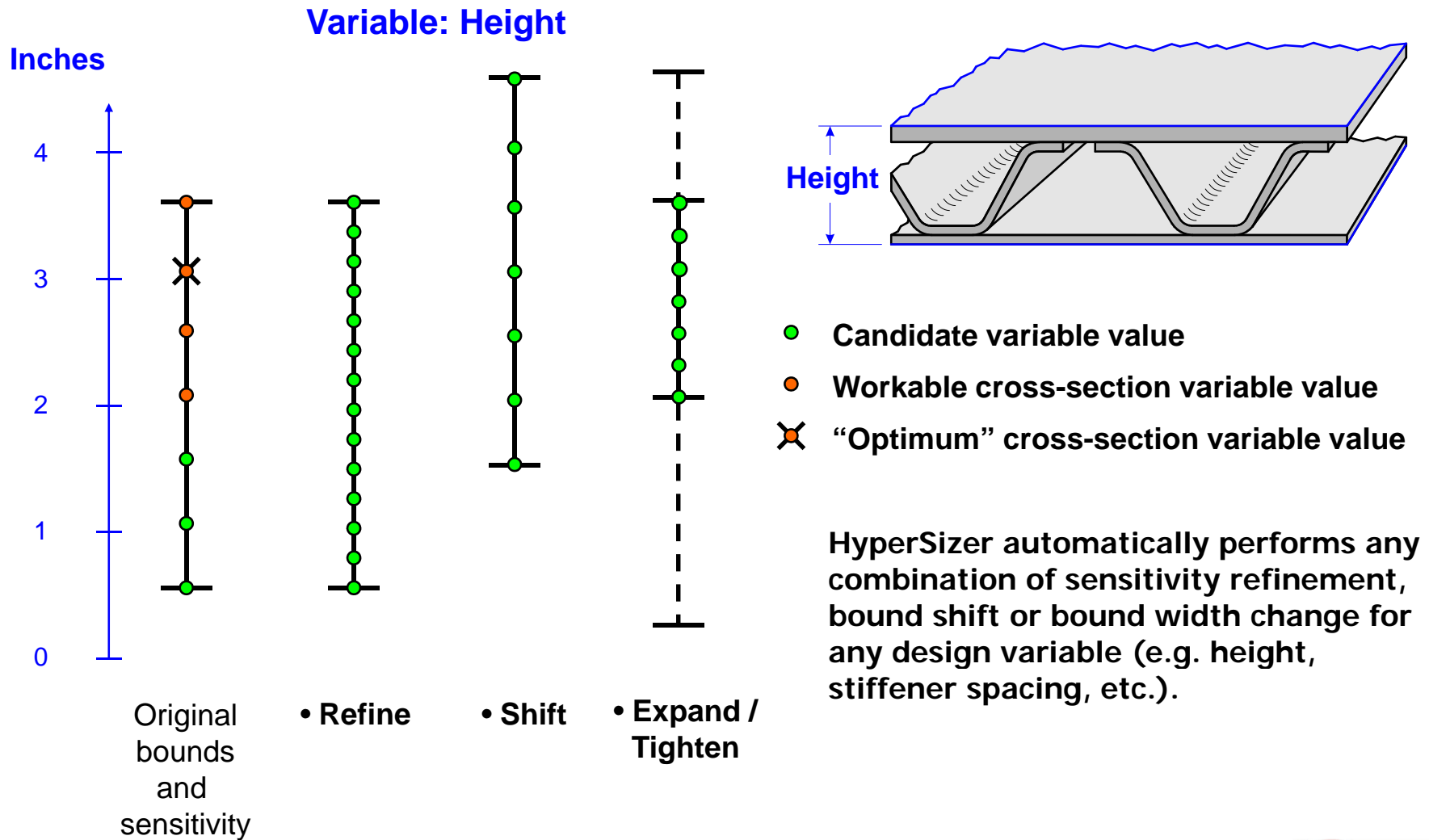


4. "I" stiffened panel
S = 3.5", H = 1"
UW = [3.268](#) psf

Optimize for multiple light weight solutions and provide manufacturing department with choices for best producibility



Statistical Optimization



Advanced Optimization



HyperSizer Optimization of the Previously Optimized RLV Intertank Design



Panel Concept	Unit Weight (psf)	Spacing	Height	Flange Top Width	Flange Bottom Width	Angle	Clear Span
Original Panel	1.093	5.90	1.7134	2.00	1.328	72.906	1.60
Optimized 1998	0.990	5.35	1.32	2.00	0.950	56.0	0.785
Optimized 2000 (Statistical)	0.890						

The as-fabricated, original facesheet was a 18 ply layup of [45/-45/90/0/90/0/90/45/-45]s

1998 optimum layup for the facesheet is a 16 ply layup of [45/-45/90/45/0/-45/0/0]s

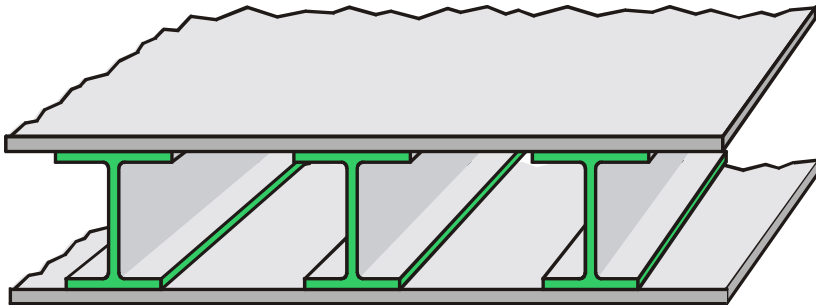
RLV HyperSizer Customers



Uniaxial Panel Optimization



How does HyperSizer determine candidate designs?



2	2	Top Face - Thickness (Isotropic, Laminate, Layup)
2	2	Web - Thickness (Isotropic, Hyper-Laminate, Hyp
2	2	Bottom Face - Thickness (Isotropic, Laminate, Lay
2		Panel - Height
2		Stiffener - Spacing
2		Bottom Flange - Width
		Web - Angle
2		Top Flange - Width
		Top Clear Span - Free Width (Dependent Variable)
2		Top Flange - Thickness
2		Bottom Flange - Thickness

Candidates

1. $2^{10} = 1024$

2. $2^8 = 256$

3. $2^8 + 2^{10} = 1024 + 256 = 1280$

4. $2^8 + 2^9 = 512 + 256 = 740$

5. $2^8 + 2^8 = 256 + 256 = 512$

Optimization Characteristics



- **Full factorial of design space, though HyperSizer does not need to compute entire space for finding an optimum**
- **Efficient; no limitation on problem size, optimize complete aircraft systems (1 million degree-of-freedom models have been easily handled)**
- **No occurrence of local or false optima for prescribed design space**
- **Integrate with formal optimization processes such as NASTRAN SOL 200 wing aeroelastic stiffness optimization**

Weight Predictions



- **Predict weights analytically - weight predictions are not interpolated from historical data**
- **Calculate weight based on**
 - material densities
 - adhesive bond weights
 - fastener weights and counts
 - user specified non-optimum penalties
- **Breakout weight based on several criteria:**
 - assemblies
 - groups
 - structural components
 - panels and beams
 - loadcases
 - controlling failure modes

Weight Prediction Summary



Setup	Load Sets	Load Cases	Options	Notes	Summary	Memory											
Run Time 00:00:01	Weight Total 16.01815	Summary information is for the most recent sizing only. For example, if the last sizing was for a single component, then this information applies to that component only. The summary tree contains weight information for the entire model															
Load Cases <ul style="list-style-type: none">Load Case #1 "Mechanical Load Set #101 (Run Deck #1) "Wing Pressure", Thermal None."Load Case #2 "Mechanical Load Set #101 (Run Deck #1) "Wing Pressure", Thermal Load Set #201 (Load Case #3 "Mechanical Load Set #102 (Run Deck #1) "Internal Tank Pressure", Thermal None."Load Case #4 "Mechanical Load Set #103 (Run Deck #1) "Fuselage Bending", Thermal None."Load Case #5 (0 lb) "Mechanical Load Set #104 (Run Deck #1) "Wing and Tank Pressure", ThermalLoad Case #6 (16.01815 lb) "Mechanical Load Set #105 (Run Deck #1) "Tank Press & Fuse BendingLoad Case #7 "Mechanical Load Set #106 (Run Deck #1) "All Mechanical", Thermal None." Structural Components <ul style="list-style-type: none">Assemblies				Beam Weights <table><tr><td>Unit Weight</td><td>0</td></tr><tr><td>Total Length</td><td>0</td></tr><tr><td>Total Weight</td><td>0</td></tr></table>	Unit Weight	0	Total Length	0	Total Weight	0	Panel Weights <table><tr><td>Unit Weight</td><td>1.140633</td></tr><tr><td>Total Area</td><td>14.04322</td></tr><tr><td>Total Weight</td><td>16.01815</td></tr></table>	Unit Weight	1.140633	Total Area	14.04322	Total Weight	16.01815
Unit Weight	0																
Total Length	0																
Total Weight	0																
Unit Weight	1.140633																
Total Area	14.04322																
Total Weight	16.01815																
				Failure Mode Weights <table><tr><td>Strength</td><td>16.01815</td><td>Min Opt Bound</td><td>0</td></tr><tr><td>Buckling</td><td>0</td><td>Max Opt Bound</td><td>0</td></tr><tr><td>Local Buckling</td><td>0</td><td></td><td></td></tr></table>	Strength	16.01815	Min Opt Bound	0	Buckling	0	Max Opt Bound	0	Local Buckling	0			
Strength	16.01815	Min Opt Bound	0														
Buckling	0	Max Opt Bound	0														
Local Buckling	0																

Weight Predictions

