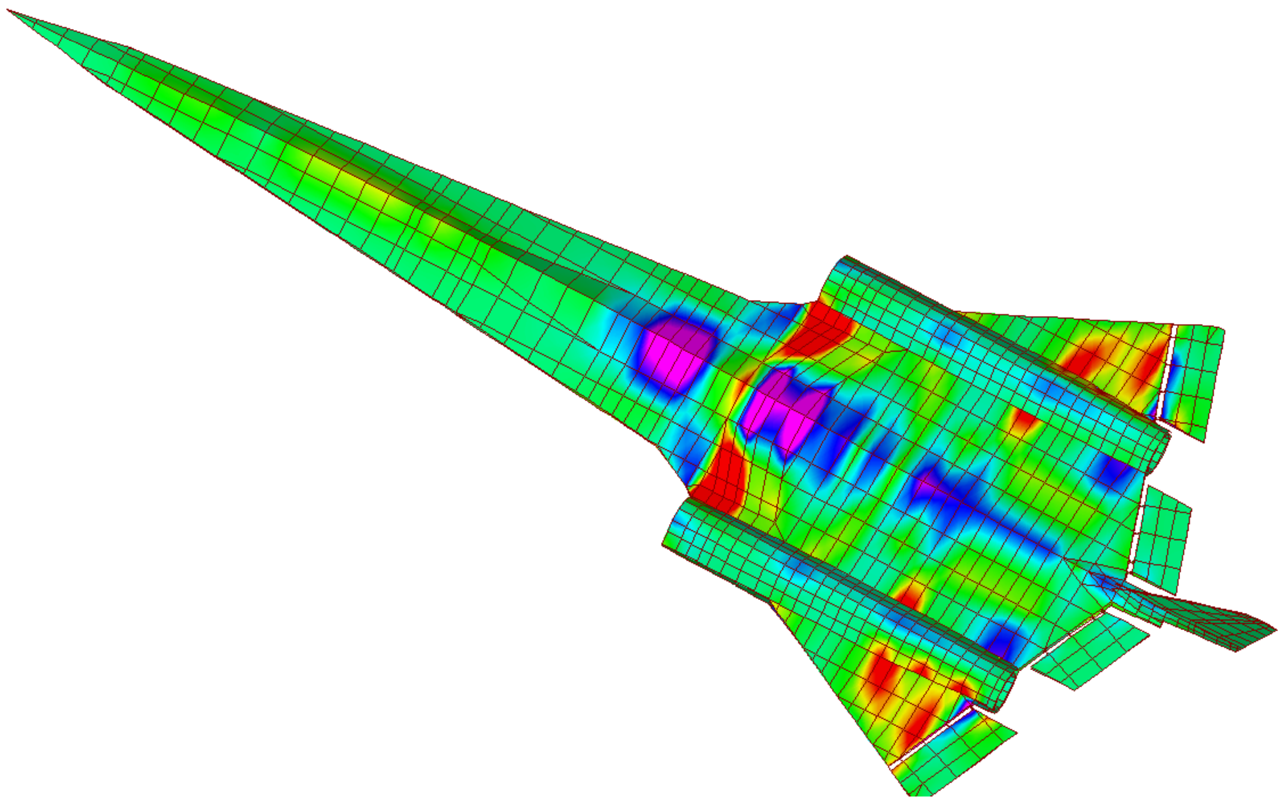
HyperSizer®

Optimization Approach



Collier Research Corporation

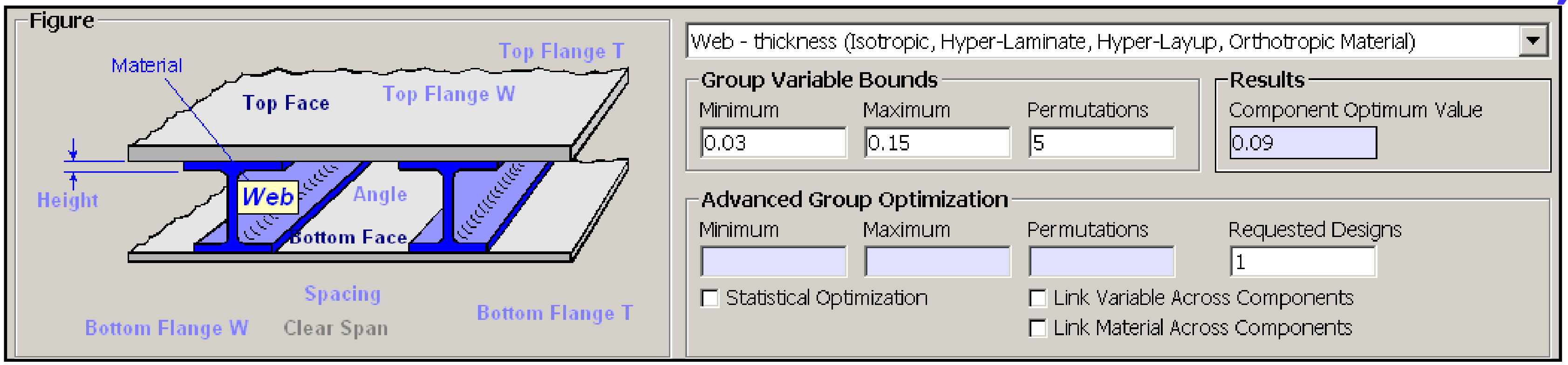
Optimization:
Objective

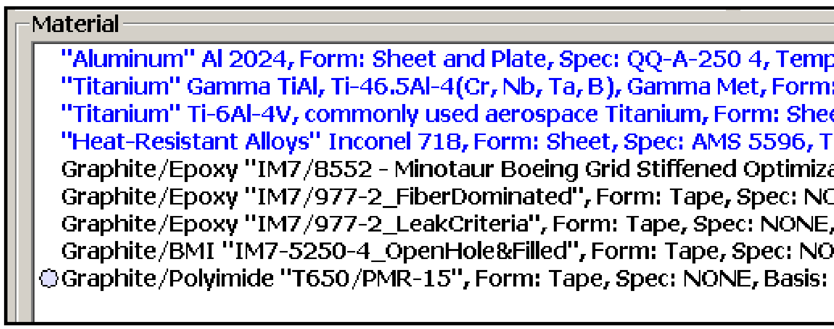
Concurrently optimize panel and beam concepts, material choices, cross sectional dimensions, and layups. Handle complete vehicle systems modeled with many grids and elements. Ensure that optimum designs pass all structural integrity analyses. Provide accurate weight predictions and multiple equivalent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

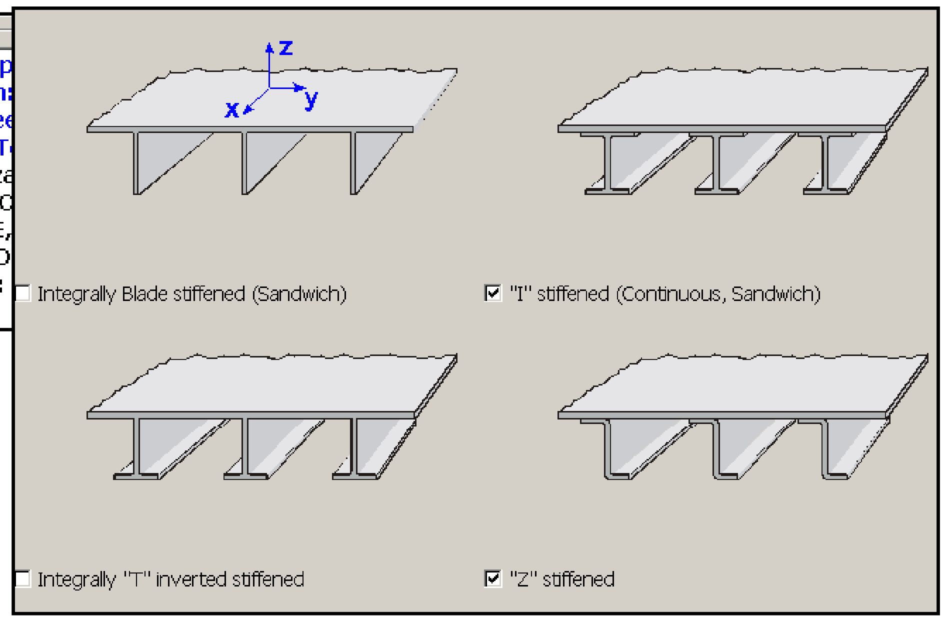
Optimization:
Technical Approach

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







Variables include:

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

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
		Honeycomb Panel Buckling, Symm Biaxial w/ Shear Interaction
	1.383	**Honeycomb** Panel Buckling, Unsymm Biaxial w/ Shear Interaction
		Honeycomb Panel Buckling, Symm Biaxial w/ TSF (transverse shear
	1.361	**Honeycomb** Panel Buckling, Unsymm Biaxial w/ TSF
	1000	**Honeycomb** Panel Buckling, Shear w/ TSF
	1.361	**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 i
	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 Directior
	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 meth
29.24	29.24	**Bottom Honeycomb Face** Intracell Dimpling, X & Y directions {Hexc
	51.06	**Bottom Honeycomb Face** Composite Strength, Max Strain 1 Directi
	546.9	**Bottom Honeycomb Face** Composite Strength, Max Strain 2 Directi
	155.9	**Bottom Honeycomb Face** Composite Strength, Max Strain 12 Direct

toggle | toggle | reset to default analyses | set as default analyses

Optimization Requirements

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

Any or all analyses can be selected as optimization criteria

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

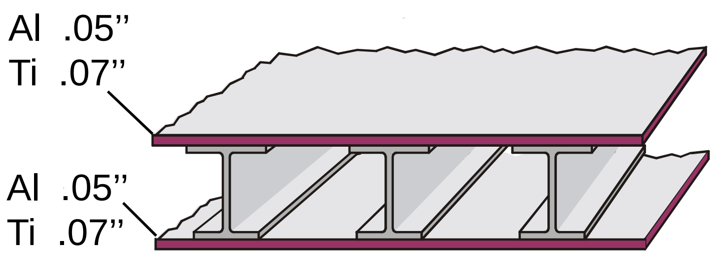
Designer / analyst is not required to derive failure criteria as would be required for formal optimization packages

Three Levels of Composite Material Optimization

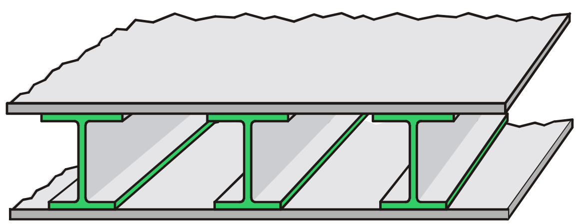
- **Treat laminates as <u>equivalent, homogenous orthotropic</u> materials and optimize by varying their thickness in a continuous isotropic sheet metal manner. This allows quick computation of best ply percentage in each direction.**
- **Analyze laminates on a <u>ply-by-ply basis</u> and discretely optimize ply count and layup sequence using fabric or tape thickness.**
- **Specialize laminate optimization by analyzing <u>any general arrangement of ply orientations</u> 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

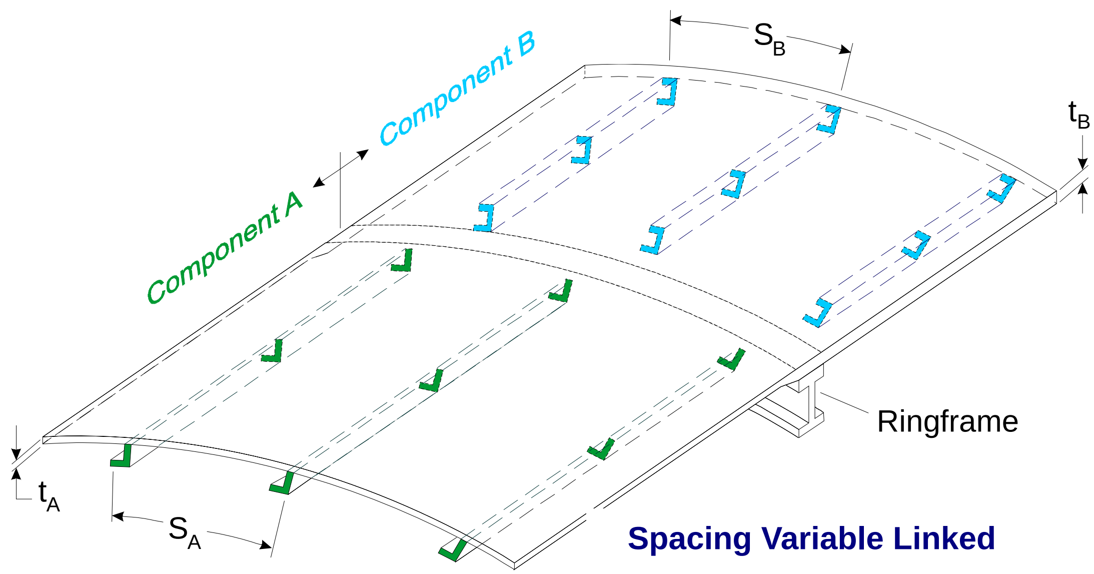


Link Facesheet materials and / or thicknesses



Link Flange and Web thicknesses

Linking Between Components

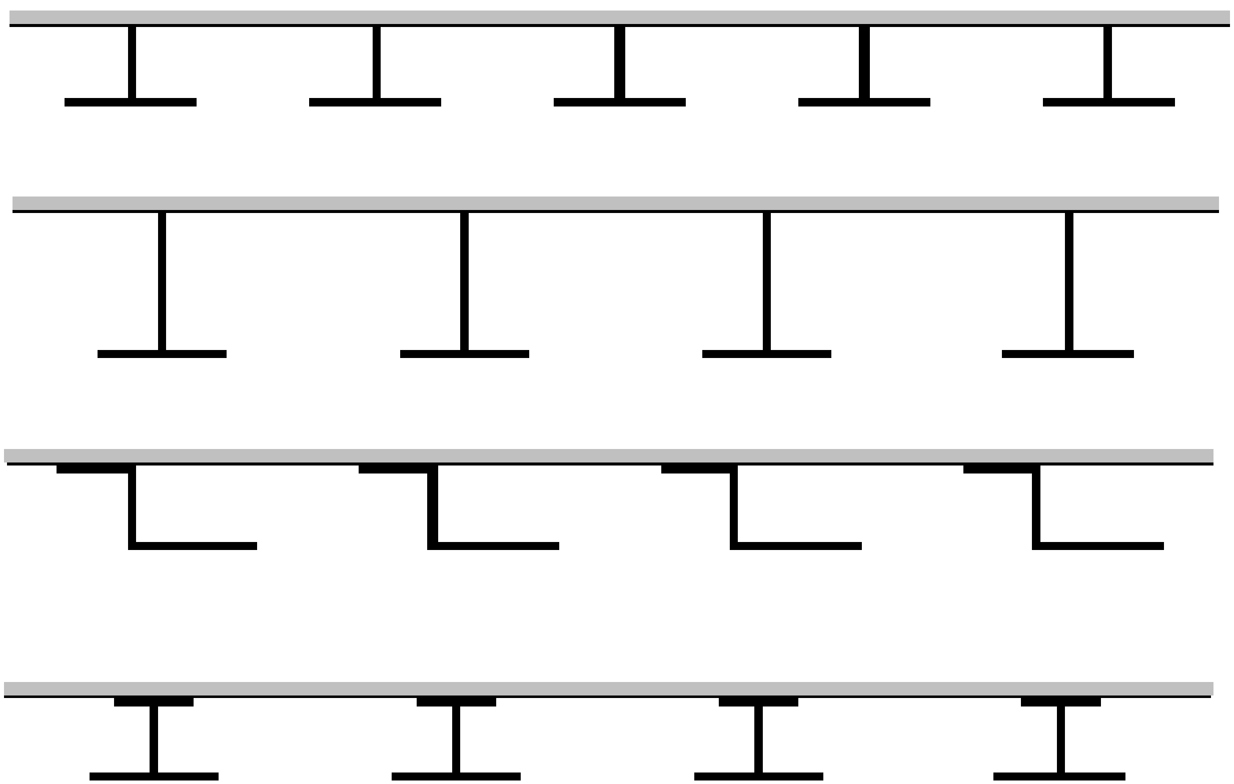


Spacing Variable Linked

$S_A = S_B$

Multiple Workable Designs

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



1. Inverted "T"
S = 2.75", H = 1"
UW = 3.216 psf

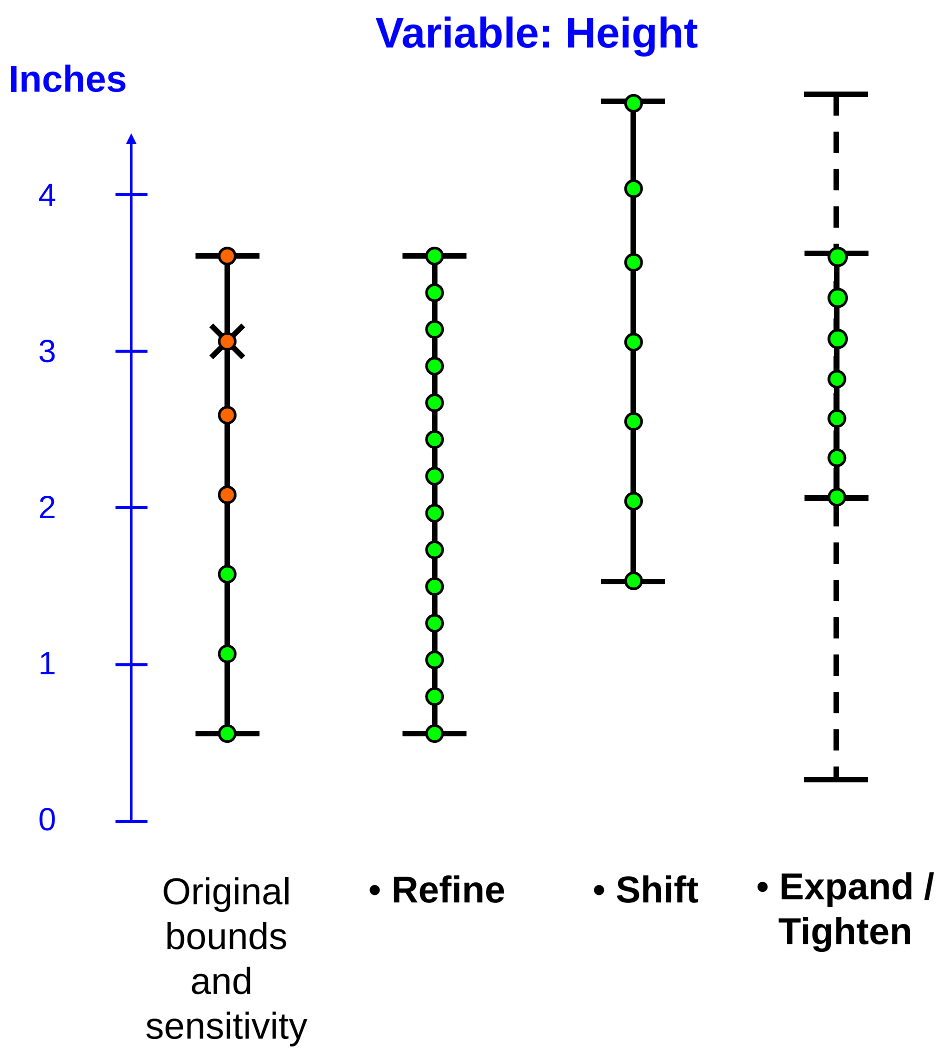
2. Inverted "T"
S = 3.5", H = 1.75"
UW = 3.266 psf

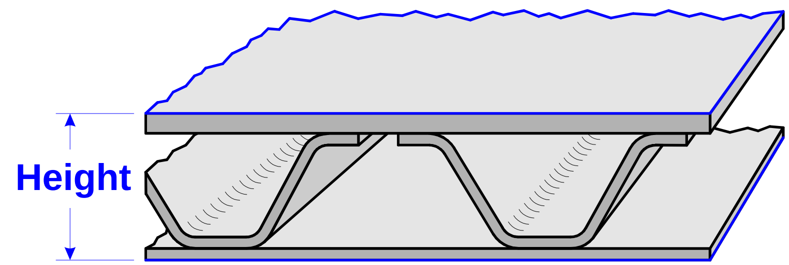
3. "Z" stiffened panel
S = 3.5", H = 1"
UW = 3.268 psf

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





- Candidate variable value
- Workable cross-section variable value
- "Optimum" cross-section variable value

HyperSizer automatically performs any combination of sensitivity refinement, bound shift or bound width change for any design variable (e.g. height, stiffener spacing, etc.).

HyperSizer Optimization of the Previously Optimized RLV Intertank Design

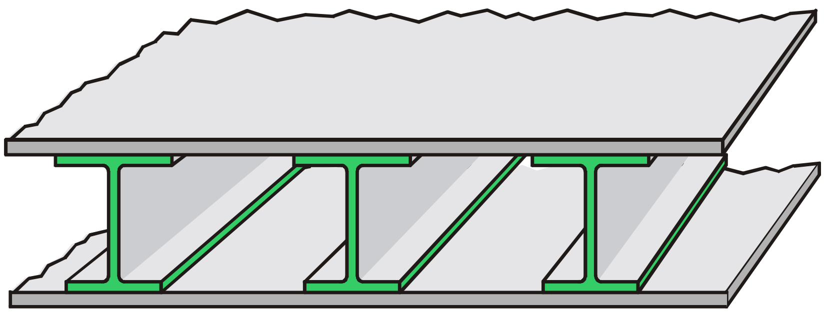
Panel Concept	Unit Weight (psf)	Spacing	Height	Flange Top Width	Flange Bottom Width	Angle	Clear Span
Original Panel	1.093	5.90	1.7134	2.00	1.328	72.906	1.60
Optimized 1998	0.990	5.35	1.32	2.00	0.950	56.0	0.785
Optimized 2000 (Statistical)	0.890						

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

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, La
	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