



CLV Upper Stage Common Bulkhead Sizing with HyperFEA

March 2007

**Collier Research
Corporation
Hampton, VA**

Spherical Common Bulkhead Geometry



- Three Load Cases:

- Internal (outward)

$P = 50 \text{ psi}$

$T = -293 \text{ F}$

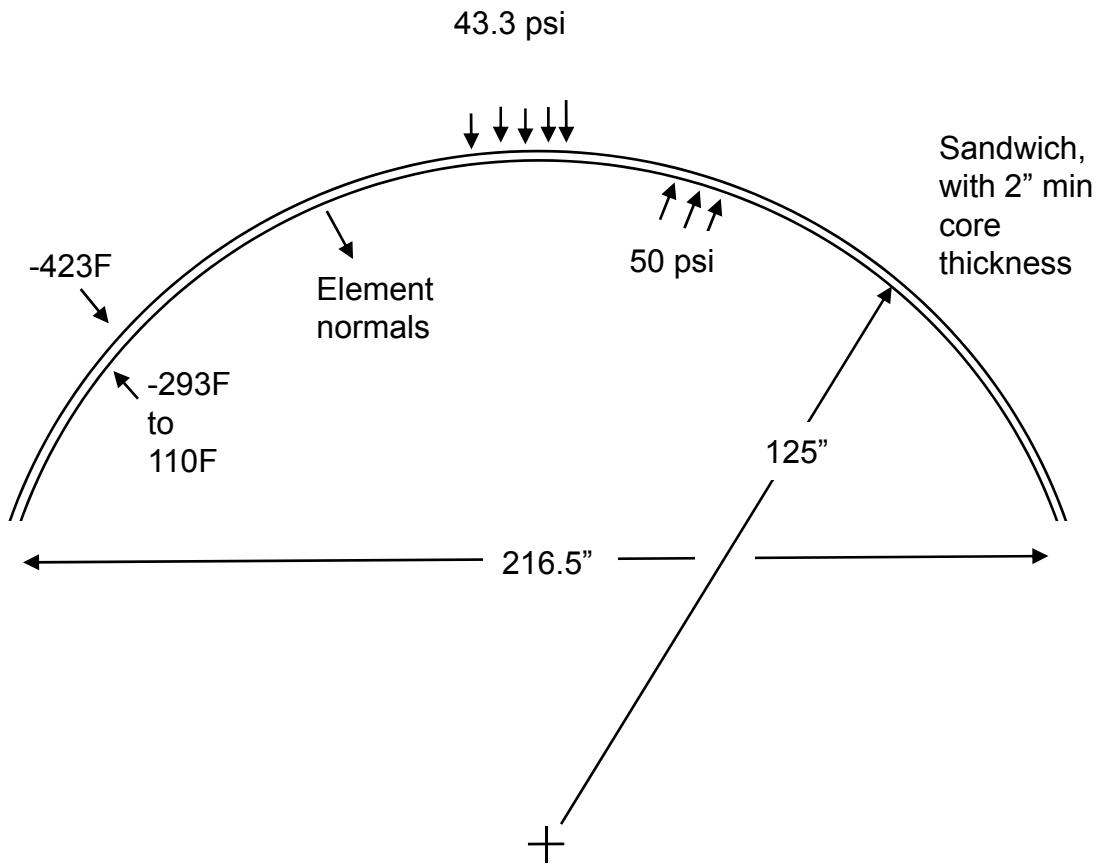
- External (crushing)

$P = 43.3 \text{ psi}$

$T = -423 \text{ F}$

- Combined

$\Delta G = -423 \text{ to } -293$



Assumptions

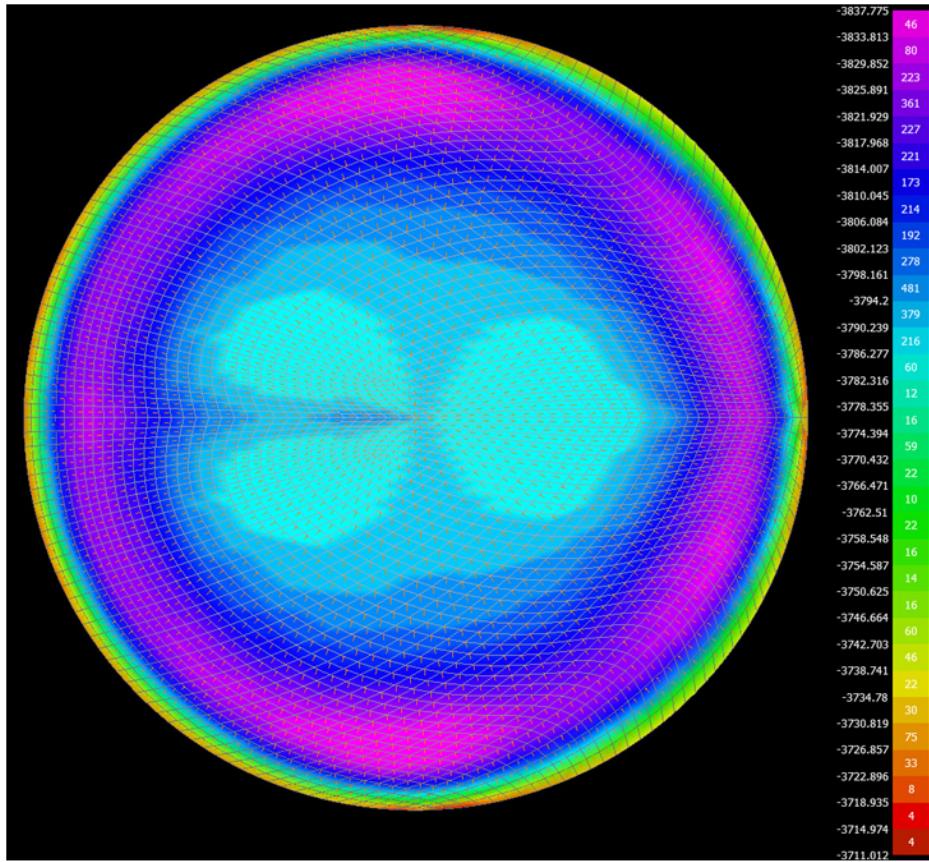


- Only using what is perceived to be the most severe load case: Hydrogen Crushing Pressure = 43.3 psi
- Temperature of wall assumed to be -423 F
- Boundaries of bulkhead are pinned ($u = v = w = 0$)
- Bulkhead is represented as a single large shell component where shell properties represent the entire sandwich (i.e. no solid elements)
- Reference plane is midplane of honeycomb panel
- Minimum gages of 2" Core and 0.04" facesheets not used for current sizing study

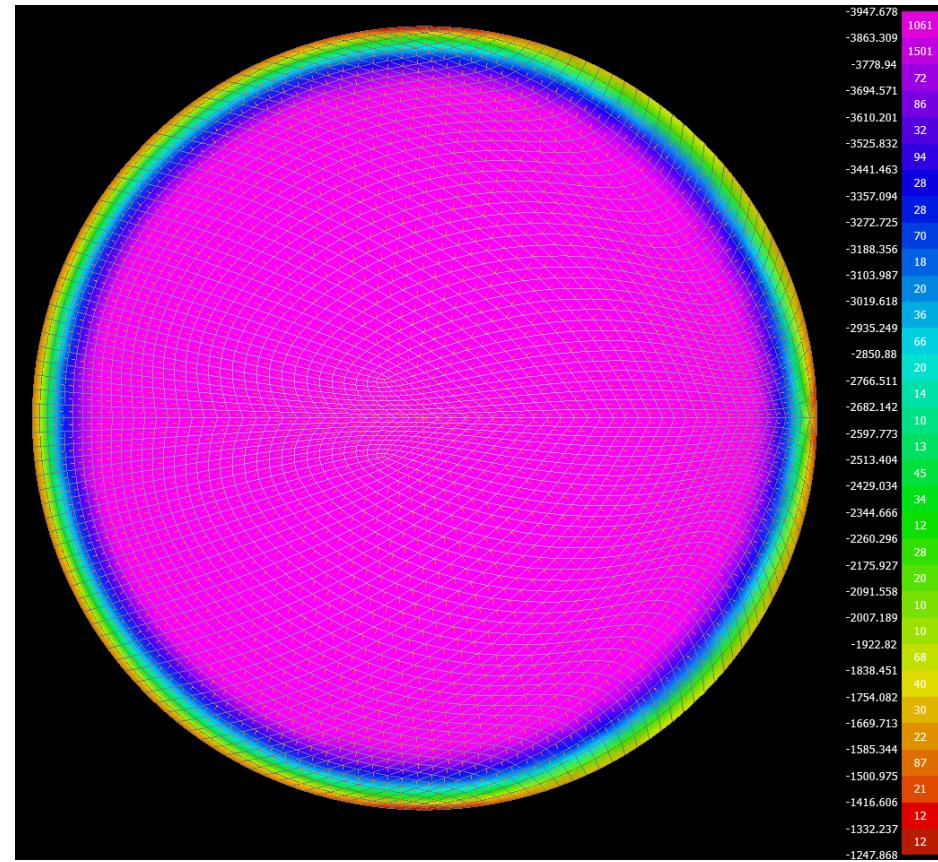
Nx and Ny Static Loads



Static Solution, Nx Contours



Static Solution, Ny Contours



Static Displacements and Buckling Modes (Nastran)



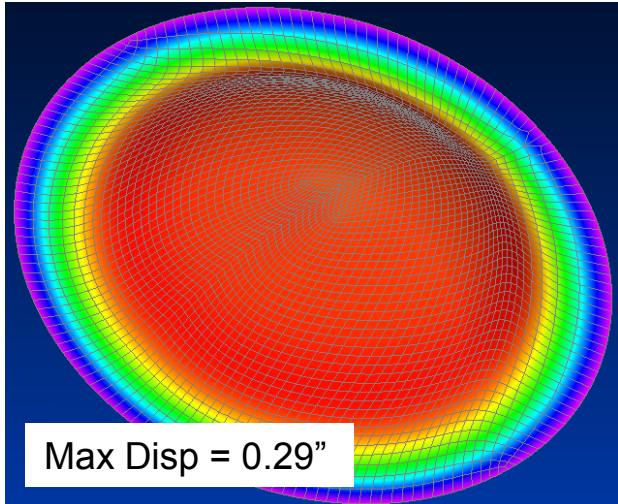
Facesheets:

Al 2219, $t = 0.06"$

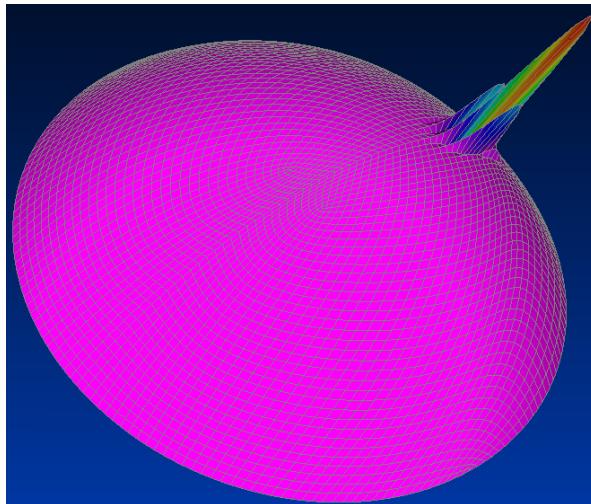
Core:

Hexcel HRH 10-1/8-4.0, $t=1"$

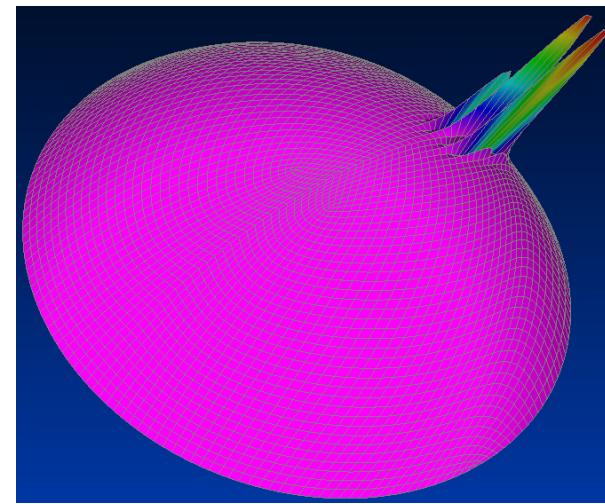
Static Solution (Displacement)



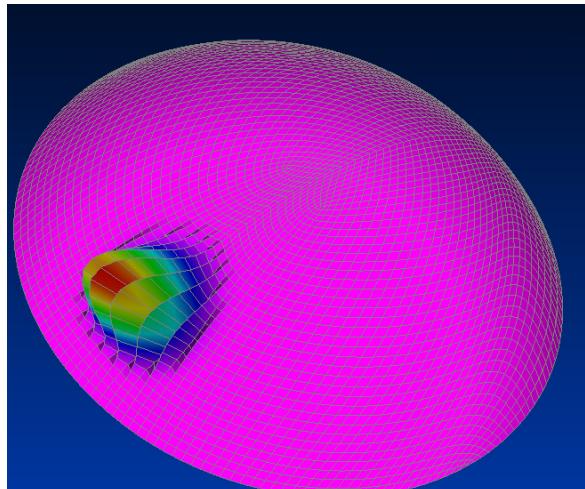
Mode 1



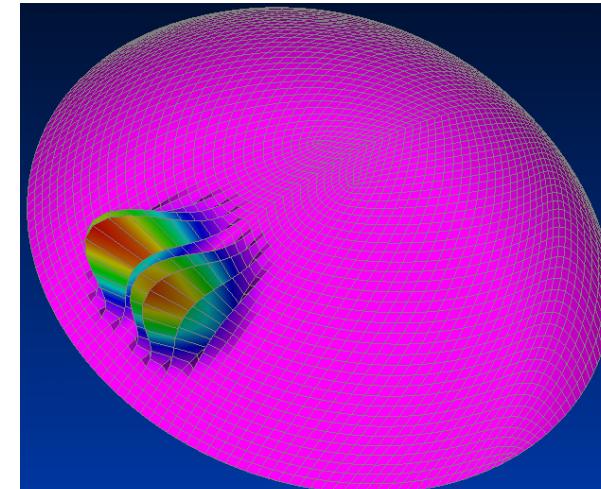
Mode 2



Mode 3



Mode 5

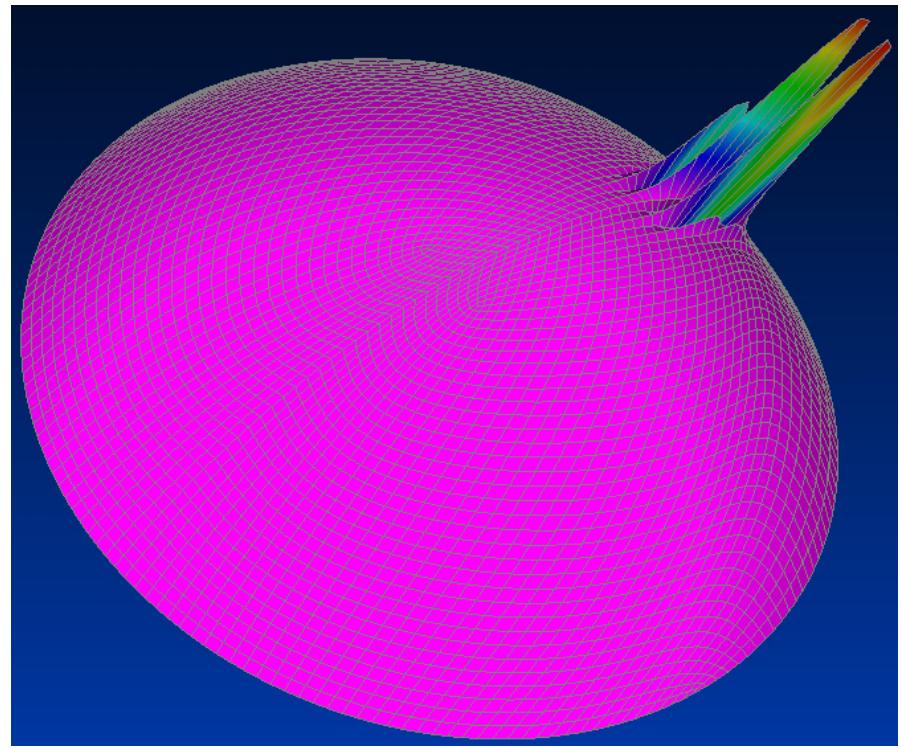
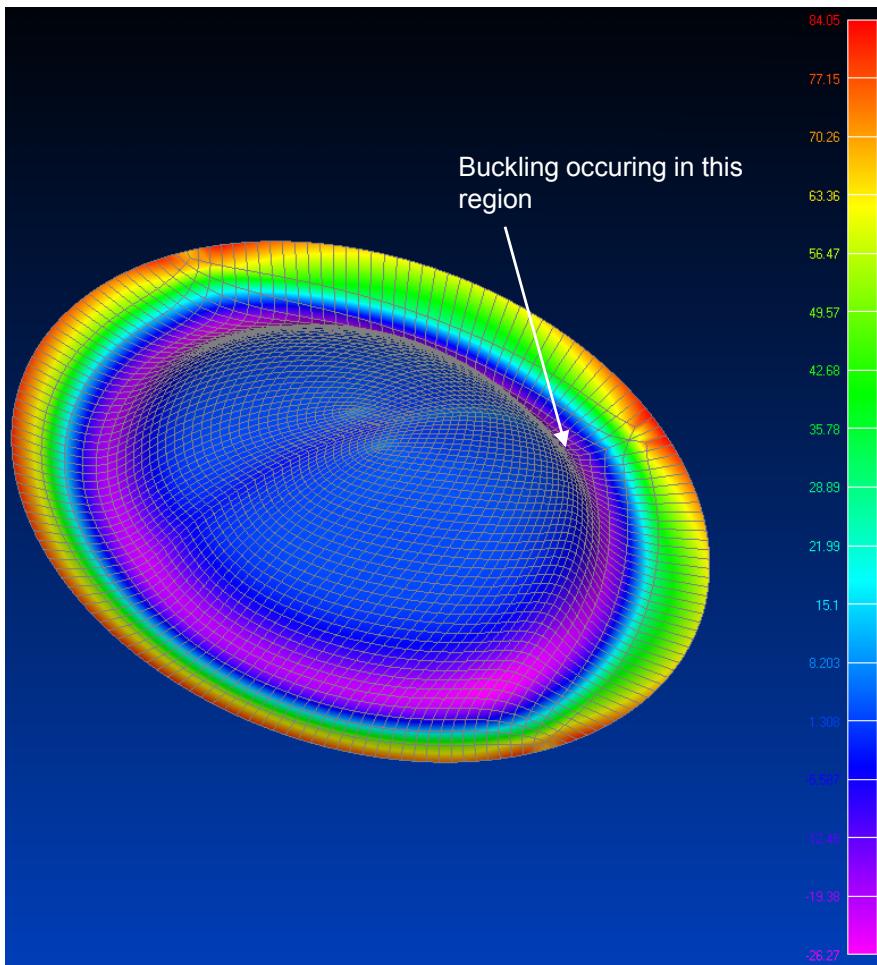


Buckling mode shapes show tendency for short wavelength buckling (i.e. crimping) in areas of high Q_x due to soft core material

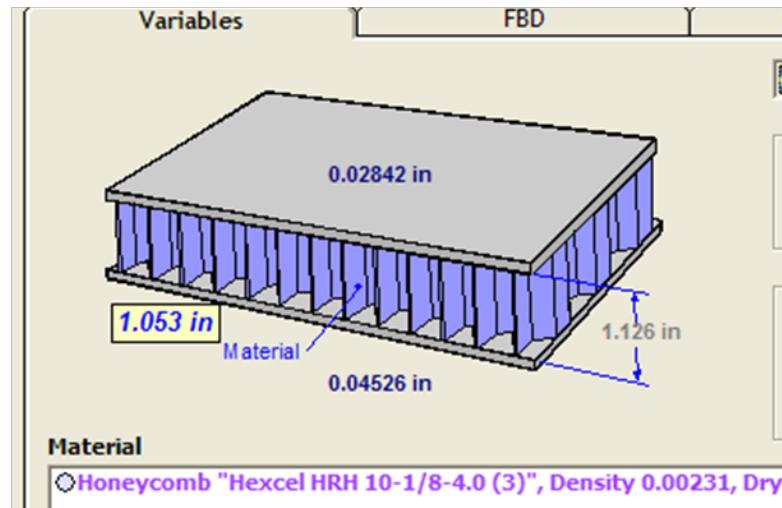
Short Wavelength Buckling in areas of high out-of-plane shear



Static Qx



Start with HyperSizer standard sizing



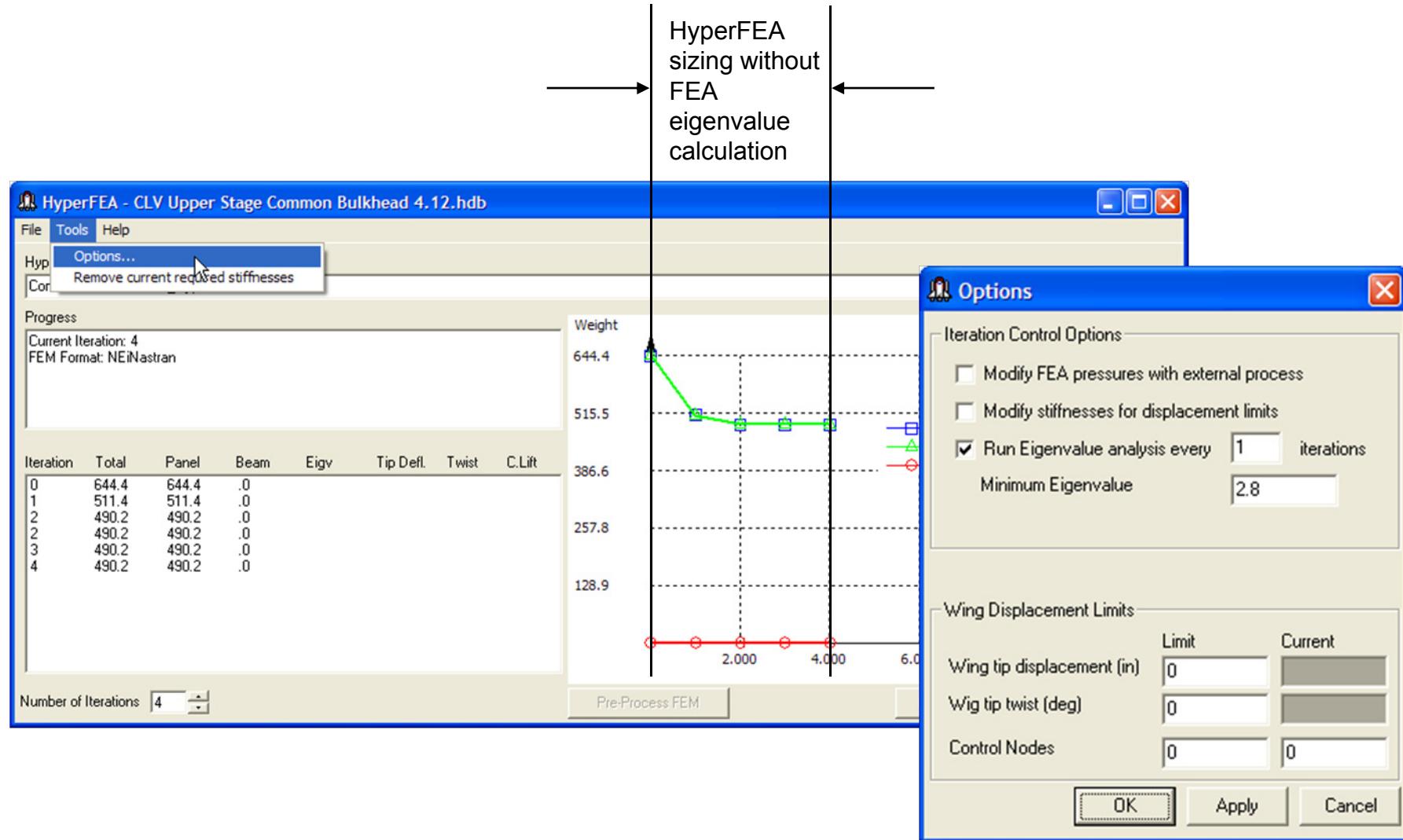
Setup

X Span	20
Y Span	20 (348.9926 max)
Panel Knockdown	0.5
Initial Imperfection	0
Local Knockdown	1
Panel is Curved	<input checked="" type="checkbox"/>

Available Failure Analyses			Location - Analysis Description
Limit MS	Ultimate MS	γ	
N/A	Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax		
N/A	Honeycomb Panel Buckling, Flat, Simple BC, Shear		
N/A	Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax		
N/A	Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax		
N/A	Honeycomb Panel Buckling, Flat, Simple BC, Shear w/TSF (1)		
N/A	Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax		
1.037 (0)	Honeycomb Panel Buckling, Curved or Flat, All BC		
0.4441 (0)	Honeycomb Panel Buckling, Curved or Flat, NASA SP-8007		
0.4107 (0)	Top Honeycomb Face Wrinkling, Eqn 1, Isotropic or Honeycomb		
26.46 (0)	Top Honeycomb Face Wrinkling, Eqn 2, Honeycomb Core,		
471.9 (0)	Top Honeycomb Face Intracell Dimpling, X, Y & Interaction		
0.3341 (0)	Honeycomb Core Crushing, Concentrated Load		
14.04 (0)	Honeycomb Core Crushing, Flexural Bending Load		
28.04 (0)	Honeycomb Core Crushing, Joint Support Load		
0.04822 (0)	Honeycomb Core Shear Crimping, X, Y & Interaction (Hexc)		
10.82 (0)	Honeycomb Core Shear Strength, X (Longitudinal) direction		
21.81 (0)	Honeycomb Core Shear Strength, Y (Transverse) direction		
0.2984 (0)	Honeycomb Core Shear Strength, Interaction		
0.5731 (0)	Bottom Honeycomb Face Wrinkling, Eqn 1, Isotropic or Honeycomb		
60.55 (0)	Bottom Honeycomb Face Wrinkling, Eqn 2, Honeycomb Core		
0.0202 (0)	Bottom Honeycomb Face Intracell Dimpling, X, Y & Interaction		
0.236 (0)			
47.36 (0)			

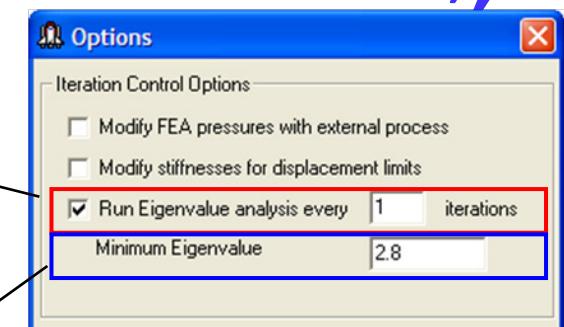
- Panel knockdown factor assumed to be 0.5 – solution also includes 1.4 ultimate factor
- Sizing controlled by facesheet wrinkling and Shear Crimping (i.e. short wavelength buckling)

After converging with standard HyperSizer HyperFEA sizing, activate eigenvalue sizing



HyperFEA Eigenvalue Sizing

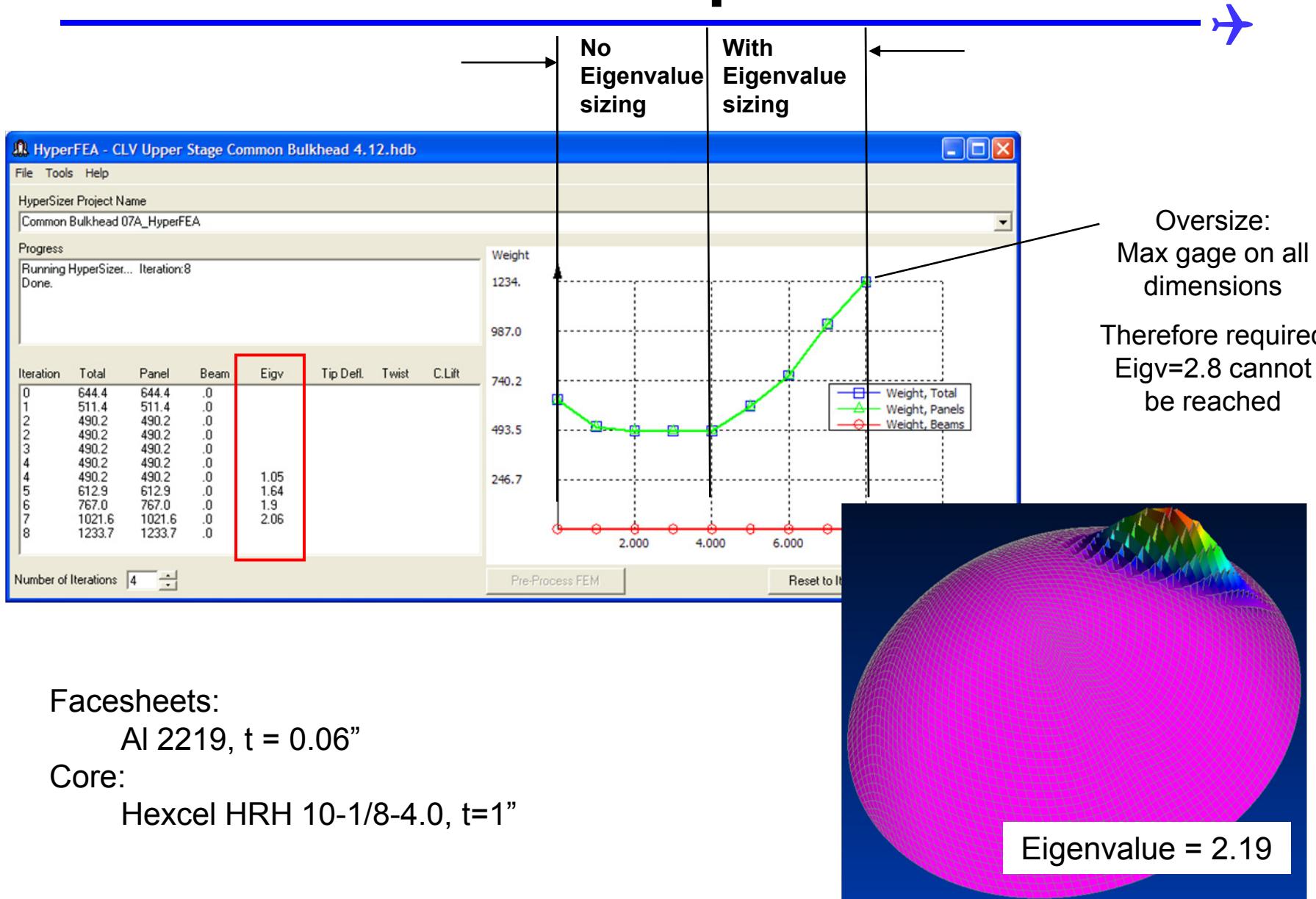
- Using HyperFEA, at user specified intervals, execute an FEA eigenvalue solution
- If minimum eigenvalue is below the required minimum, apply a required stiffness in HyperSizer



$$D_{ij, \text{reqd}} = D_{ij, \text{result}} * \text{Eigv}_{\text{reqd}} / \text{Eigv}_{\text{result}}$$

Optimization Requirements		
	Required Value	Computed Value
Symmetric Stiffness Terms		
A11		813711.5
A22		813711.5
A33		266021.1
D11	307157.2	329475.9
D22	307157.2	329475.9
D33	105339.2	112993.3

HyperFEA Sizing with Eigenvalue leads to oversize with soft nomex/phenolic core



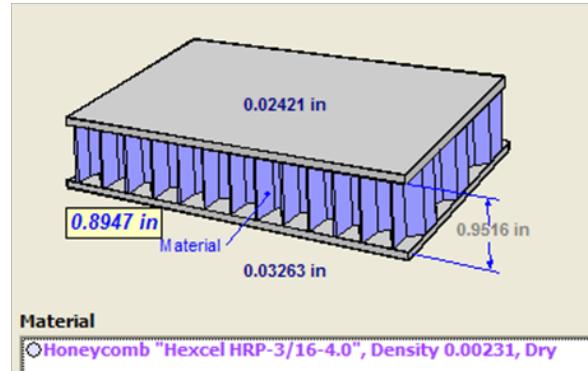
To prevent short wavelength buckling, use stiffer Aluminum Core Material



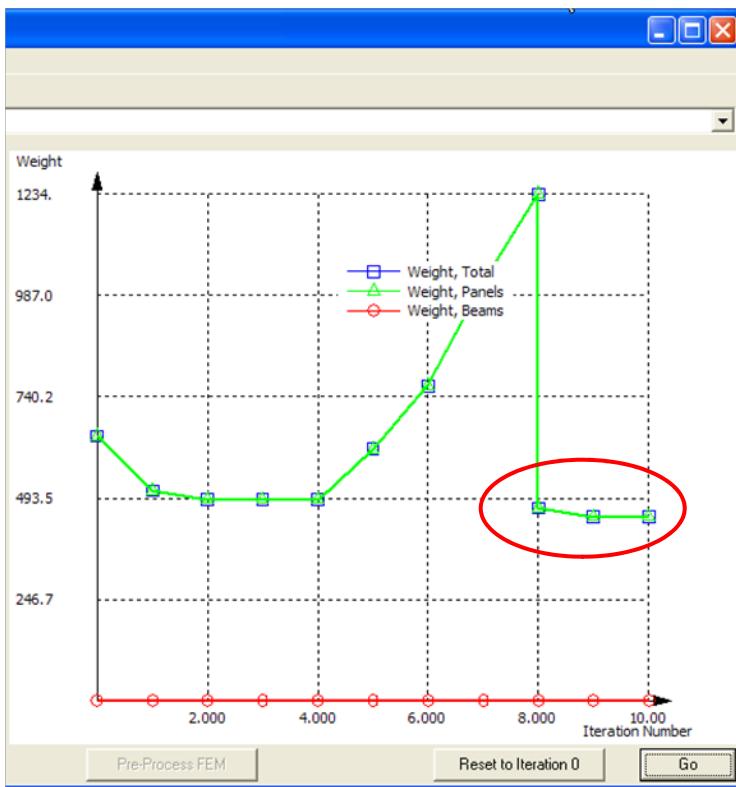
Hexcel HRH 10-1/8-4.0 Hexcel 1/8-5052-.0015

Material	Nomex/Phenolic	Al 5052
Density (pcf)	4	6.1
Et (ksi)	28	240
GW (ksi)	4.7	41
GL (ksi)	9.2	98
Ftu (ksi)	0.47	0.68
FsuW (ksi)	0.11	0.27
FsuL (ksi)	0.23	0.46

HyperSizer Sizing using stiffer core without eigenvalue analysis

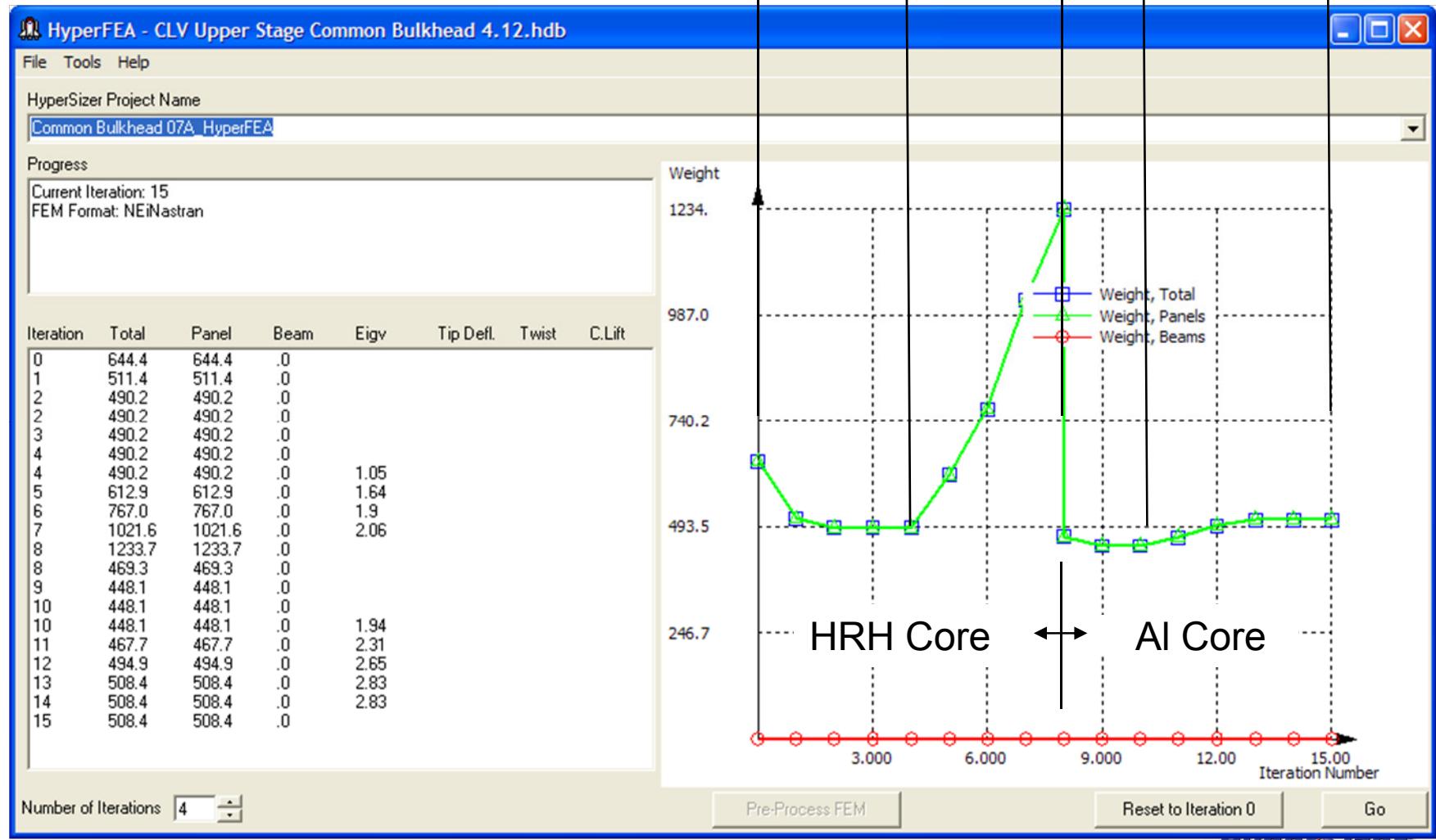


Available Failure Analyses		Location - Analysis Description	
Limit MS	Ultimate MS	γ	
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Shear
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Shear w/TSF (1)
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
0.07855 (0)			Honeycomb Panel Buckling, Curved or Flat, All BC
			Honeycomb Panel Buckling, Curved or Flat, NASA SP-8007
4.119 (0)	3.022 (0)		Top Honeycomb Face Wrinkling, Eqn 1, Isotropic or Honeycomb
2.972 (0)	2.121 (0)		Top Honeycomb Face Wrinkling, Eqn 2, Honeycomb Core,
22.25 (0)	17.27 (0)		Top Honeycomb Face Intracell Dimpling, X, Y & Interaction
Very High	710.4 (0)		Honeycomb Core Crushing, Concentrated Load
			Honeycomb Core Crushing, Flexural Bending Load
7.992 (0)	6.065 (0)		Honeycomb Core Crushing, Joint Support Load
11.64 (0)	8.928 (0)		Honeycomb Core Shear Crimping, X, Y & Interaction {Hexcell}
32.28 (0)	25.15 (0)		Honeycomb Core Shear Strength, X (Longitudinal) direction
			Honeycomb Core Shear Strength, Y (Transverse) direction
3.526 (0)	2.556 (0)		Honeycomb Core Shear Strength, Interaction
2.538 (0)	1.78 (0)		Bottom Honeycomb Face Wrinkling, Eqn 1, Isotropic or Honeycomb
24.48 (0)	19.02 (0)		Bottom Honeycomb Face Wrinkling, Eqn 2, Honeycomb Core
			Bottom Honeycomb Face Intracell Dimpling, X, Y & Interaction

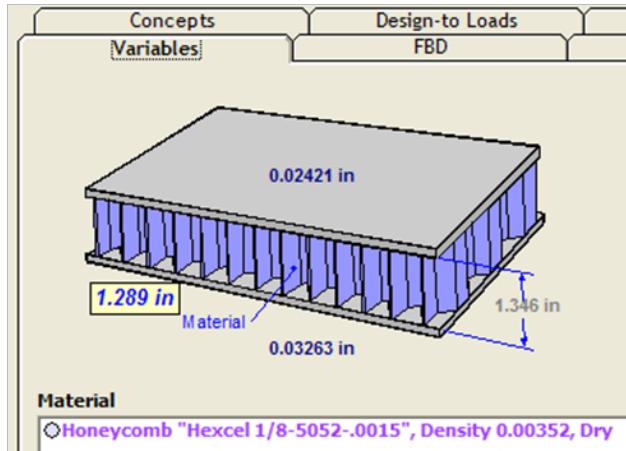


- Controlled by panel buckling
- Short wavelength phenomena (crimping, wrinkling) are no longer a factor

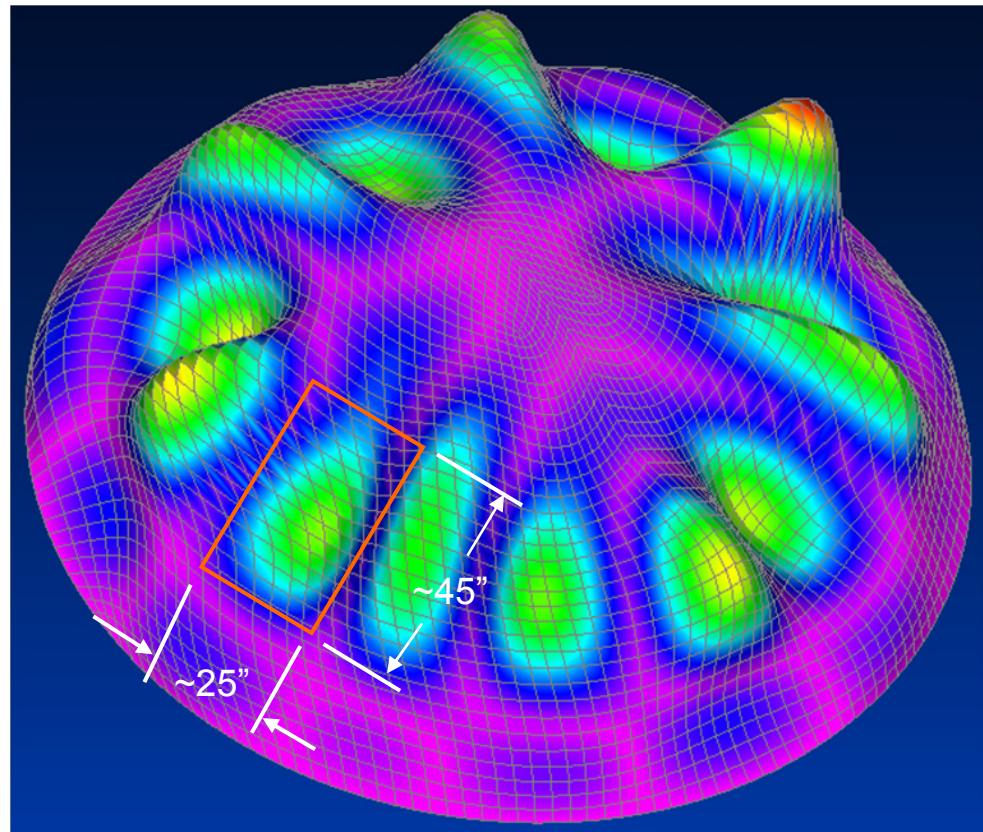
Activate Eigenvalue Sizing



HyperSizer buckling solution shows substantial positive margin, use FEA Eigv solution to determine more appropriate buckling lengths



Unit Weight = 1.50 psf
FEA Eigenvalue = 2.82



HyperSizer buckling solution shows substantial positive margin, use FEA Eigv solution to determine more appropriate buckling lengths



Original Buckling lengths

Setup

X Span	20	
Y Span	20	(348.9926 max)
Panel Knockdown	0.5	
Initial Imperfection	0	
Local Knockdown	1	
Panel is Curved	<input checked="" type="checkbox"/>	



Available Failure Analyses			
Limit MS	Ultimate MS	γ	Location - Analysis Description
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Shear
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Shear w/TSF (1
1.362 (0)			Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
3.63 (0)	2.637 (0)		Honeycomb Panel Buckling, Curved or Flat, All BC
1.666 (0)	1.094 (0)		Honeycomb Panel buckling, Curved or Flat, NASA SP-8007
14.42 (0)	11.12 (0)		Top Honeycomb Face Wrinkling, Eqn 1, Isotropic or Honey
Very High	647.9 (0)		Top Honeycomb Face Wrinkling, Eqn 2, Honeycomb Core,
			Top Honeycomb Face Intracell Dimpling, X, Y & Interaction
			Honeycomb Core Crushing, Concentrated Load
			Honeycomb Core Crushing, Flexural Bending Load
			Honeycomb Core Crushing, Joint Support Load
			Honeycomb Core Shear Crimping, X, Y & Interaction {Hex
			Honeycomb Core Shear Strength, X (Longitudinal) direction
			Honeycomb Core Shear Strength, Y (Transverse) direction
			Honeycomb Core Shear Strength, Interaction
			Bottom Honeycomb Face Wrinkling, Eqn 1, Isotropic or H
			Bottom Honeycomb Face Wrinkling, Eqn 2, Honeycomb C
			Bottom Honeycomb Face Intracell Dimpling, X, Y & Interact

Modified buckling lengths based on FEA solution

Setup

X Span	45	
Y Span	25	(348.9926 max)
Panel Knockdown	0.5	
Initial Imperfection	0	
Local Knockdown	1	
Panel is Curved	<input checked="" type="checkbox"/>	



Available Failure Analyses			
Limit MS	Ultimate MS	γ	Location - Analysis Description
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Shear
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
N/A			Honeycomb Panel Buckling, Flat, Simple BC, Shear w/TSF (1
0.007994 (0)			Honeycomb Panel Buckling, Flat, Simple BC, Uniaxial or Biax
3.63 (0)	2.637 (0)		Honeycomb Panel Buckling, Curved or Flat, All BC
1.666 (0)	1.094 (0)		Honeycomb Panel buckling, Curved or Flat, NASA SP-8007
14.42 (0)	11.12 (0)		Top Honeycomb Face Wrinkling, Eqn 1, Isotropic or Honey
Very High	647.9 (0)		Top Honeycomb Face Wrinkling, Eqn 2, Honeycomb Core,
			Top Honeycomb Face Intracell Dimpling, X, Y & Interaction
			Honeycomb Core Crushing, Concentrated Load
			Honeycomb Core Crushing, Flexural Bending Load
			Honeycomb Core Crushing, Joint Support Load
			Honeycomb Core Shear Crimping, X, Y & Interaction {Hex
			Honeycomb Core Shear Strength, X (Longitudinal) direction
			Honeycomb Core Shear Strength, Y (Transverse) direction
			Honeycomb Core Shear Strength, Interaction
			Bottom Honeycomb Face Wrinkling, Eqn 1, Isotropic or H
			Bottom Honeycomb Face Wrinkling, Eqn 2, Honeycomb C
			Bottom Honeycomb Face Intracell Dimpling, X, Y & Interact