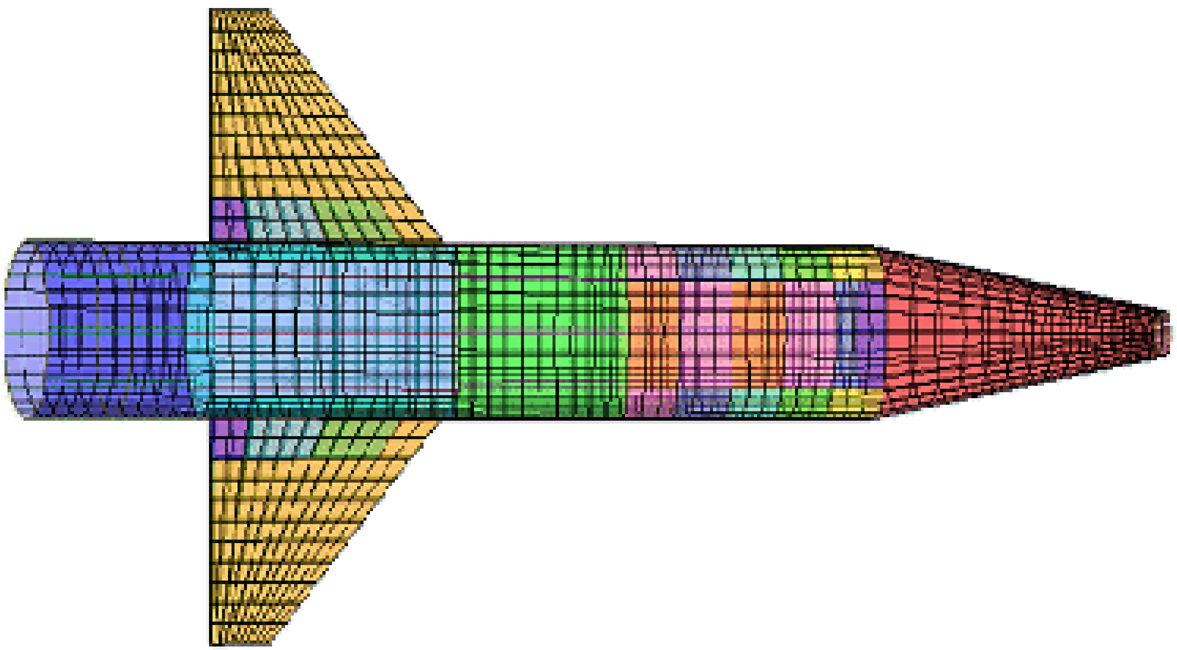
HyperSizer®

Analysis Approach



Collier Research Corporation

Thermoelastic Formulations: Objective

Compute very accurate stress/strain fields throughout a panel or beam depth for general mechanical or thermal loading conditions. The loadings may be either user-defined or from finite element solutions. Handle any general panel concept, shape, and composite layup very rapidly. Include coupling effects of panel stiffeners.

Thermoelastic Formulations: Technical Approach

1. **Formulate the full membrane, bending, and membrane-bending coupling terms in a general way for any panel concept**
2. **Supplement the general formulation with additional panel or beam concept specific formulations**
3. **Use the formulations to permit general loadings and general boundary conditions on panel edges. Permit uniform pressures and through-the-thickness temperature gradients on the panel surface.**
4. **<u>The general loadings can be user specified or come from FEA</u>**

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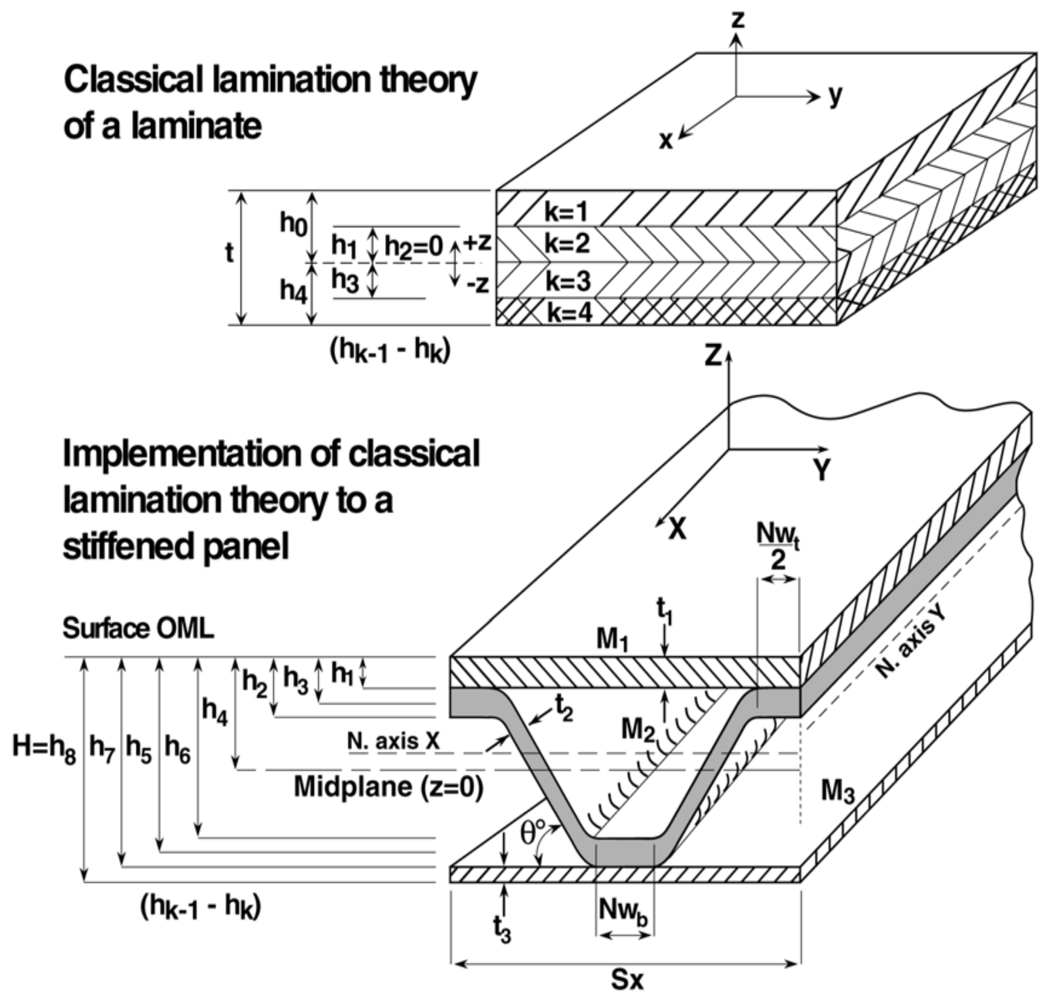
Thermoelastic Stiffened Panel Formulation (General Behaviors)

- **Classical Lamination Theory is Extended to a represent any stiffened cross sectional shape**
- **General panel behaviors, are quantified with:**
  - **Stiffeness terms [A], [B], [D]**
  - **Thermal coefficients [A$^{\alpha}$], [B$^{\alpha}$], [D$^{\alpha}$]**



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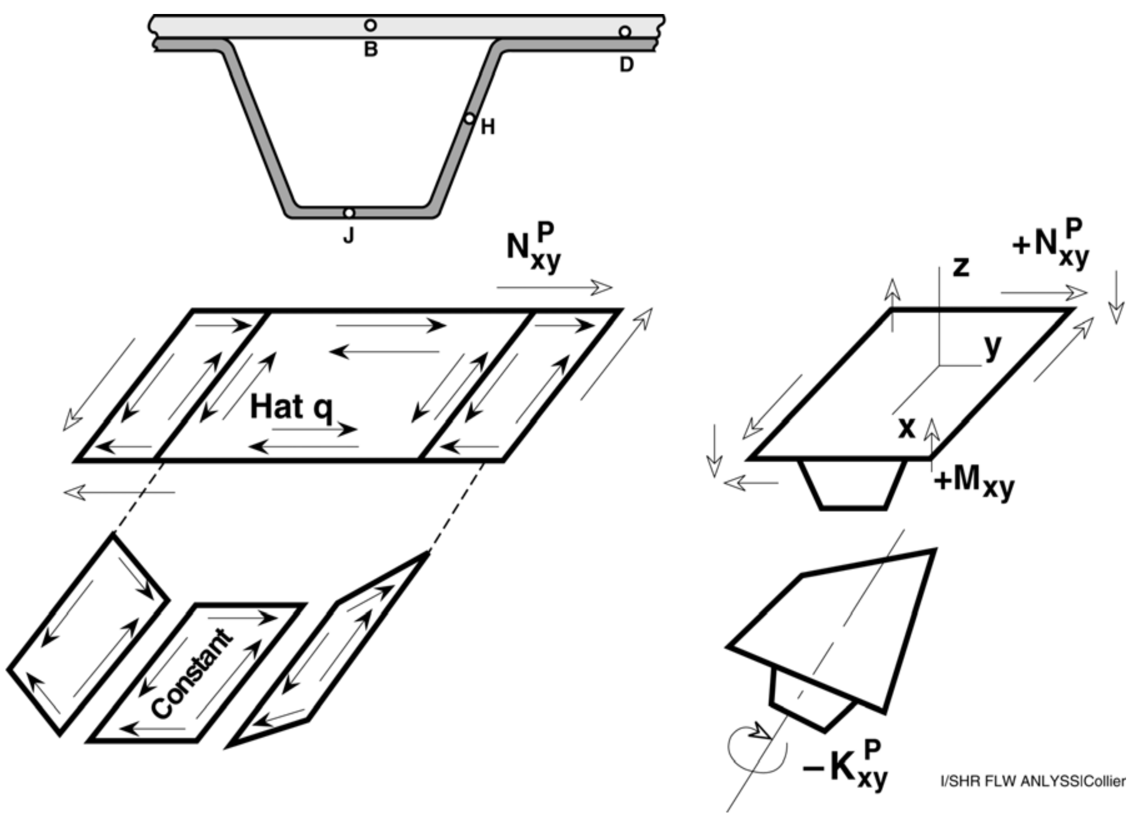
Thermoelastic Stiffened Panel Formulation (Unique Behaviors)

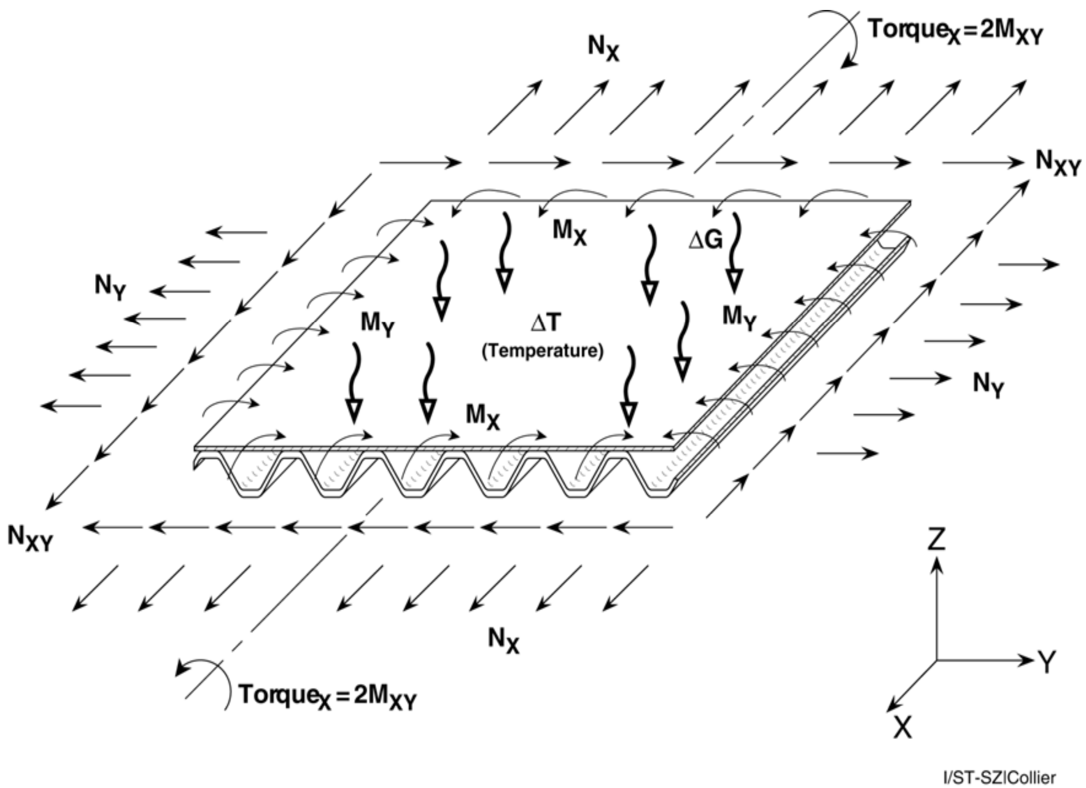
- Each panel concept has additional unique characteristics to quantify
- For example, hat stiffened panels have shear flow in the closed section to account
- The closed section adds considerable bending-twisting stiffness which increases panel stability
- Unique behaviors are quantified without classical lamination theory

Shear Flow Analysis Locations



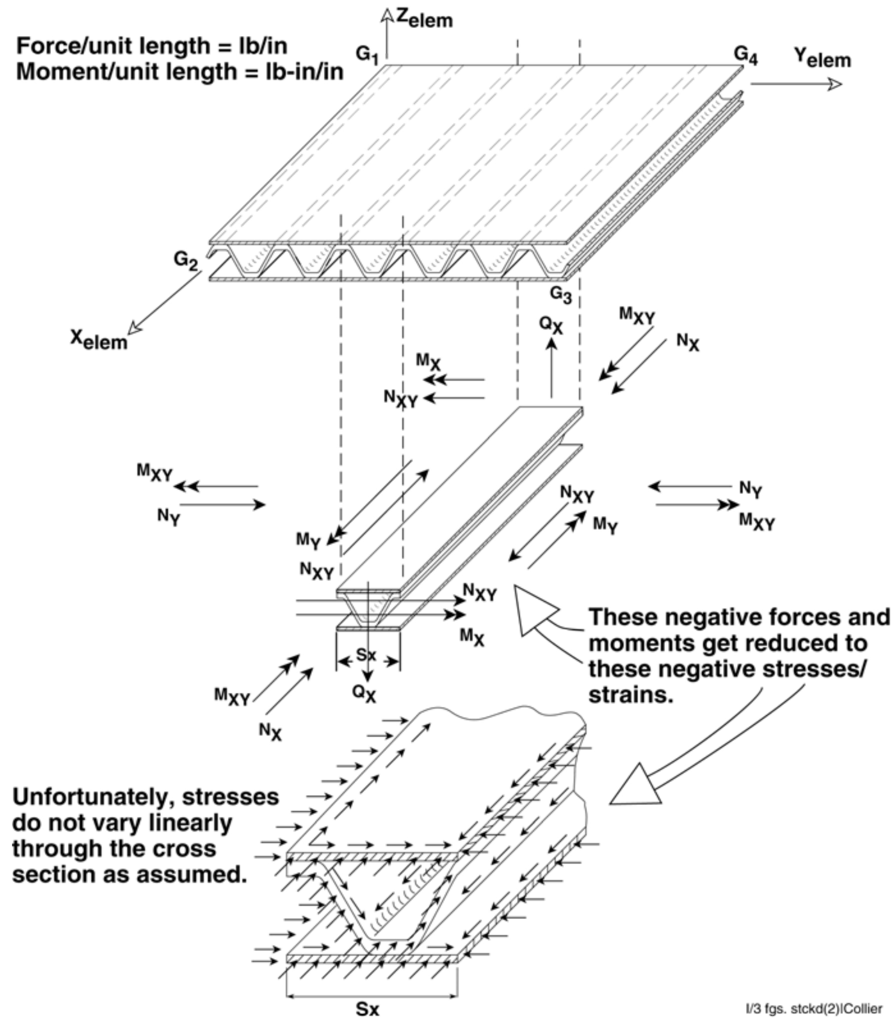
Balanced Free Body Diagram (FBD) Approach

- **All solutions reduce to a balanced free body diagram approach, regardless if the loading and/or boundary conditions come from:**
  - **FEA**
  - **user defined input**
- **Consistently applied thermoelastic formulations guarantee**
  - **equilibrium of forces**



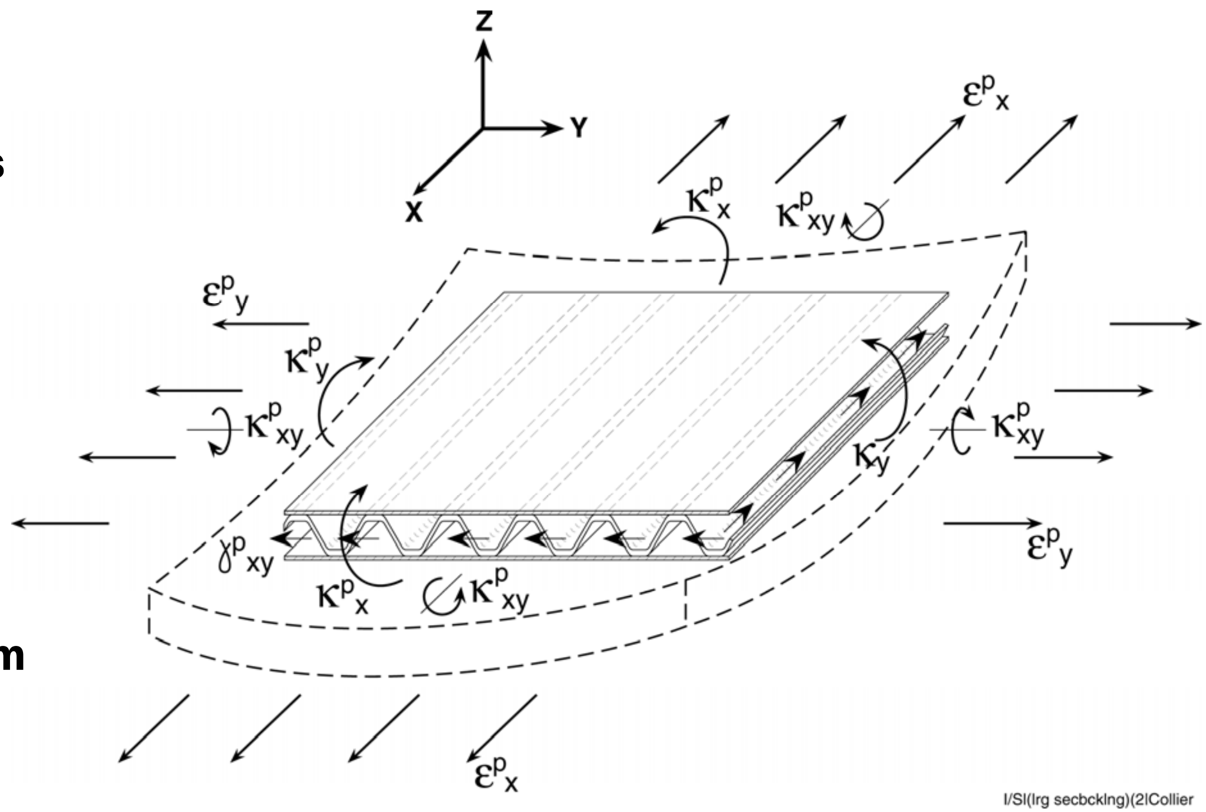
HyperSizer overcomes traditional analytical approach shortcomings

- **Depicted in the figure is a wide strip approach with forces applied to obtain stresses directly**
- **Traditional approaches mistakenly assume stresses vary linearly through the depth**
- **Only strains vary linearly through the panel depth**

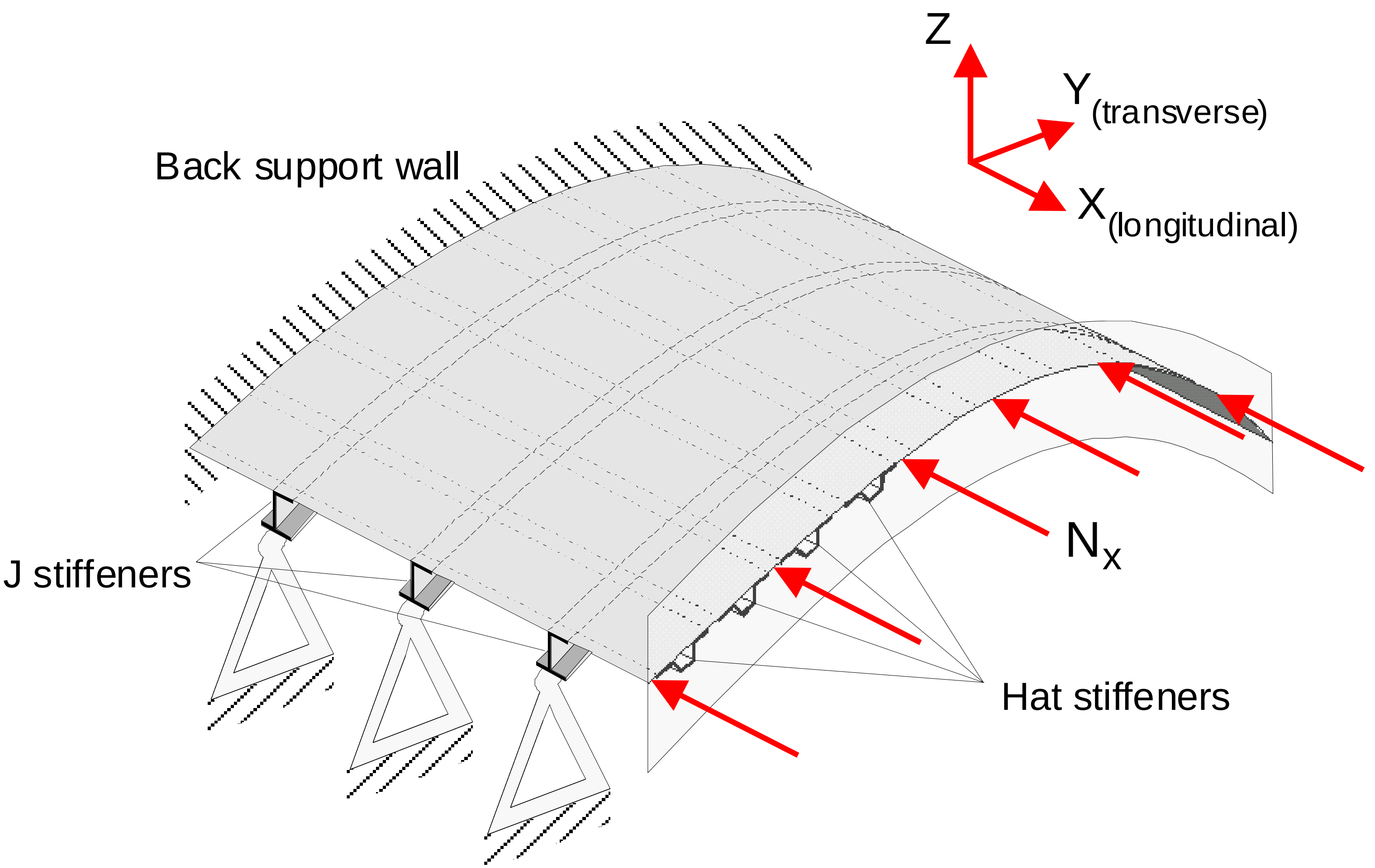


Panel Reference Plane Strains and Curvatures Are Computed from FBD Forces

- **Matrix math approach is used, which includes all panel response couplings**
- **Consistently applied thermoelastic formulations guarantee**
  - **strain compatibility**
- **Ply strains, throughout the panel depth, are accurately computed from the panel response**
- **ply stresses are calculated from ply strains**



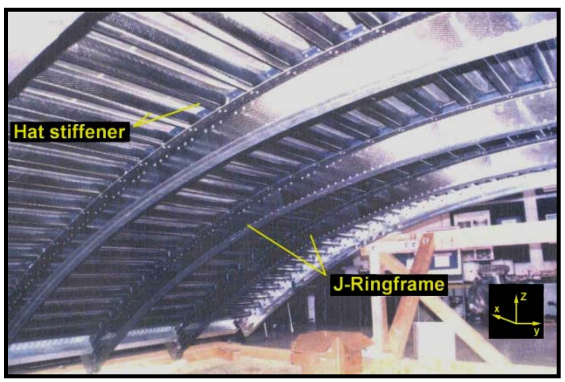
<u>Without FEA;</u> Uniform Compression Load and Enforced Displacement-Hat Panel

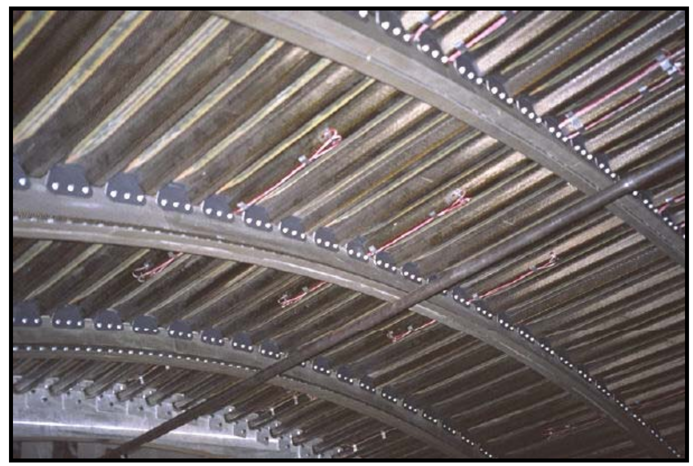


1st Use: Accurate Analysis of Many Potential Failure Modes

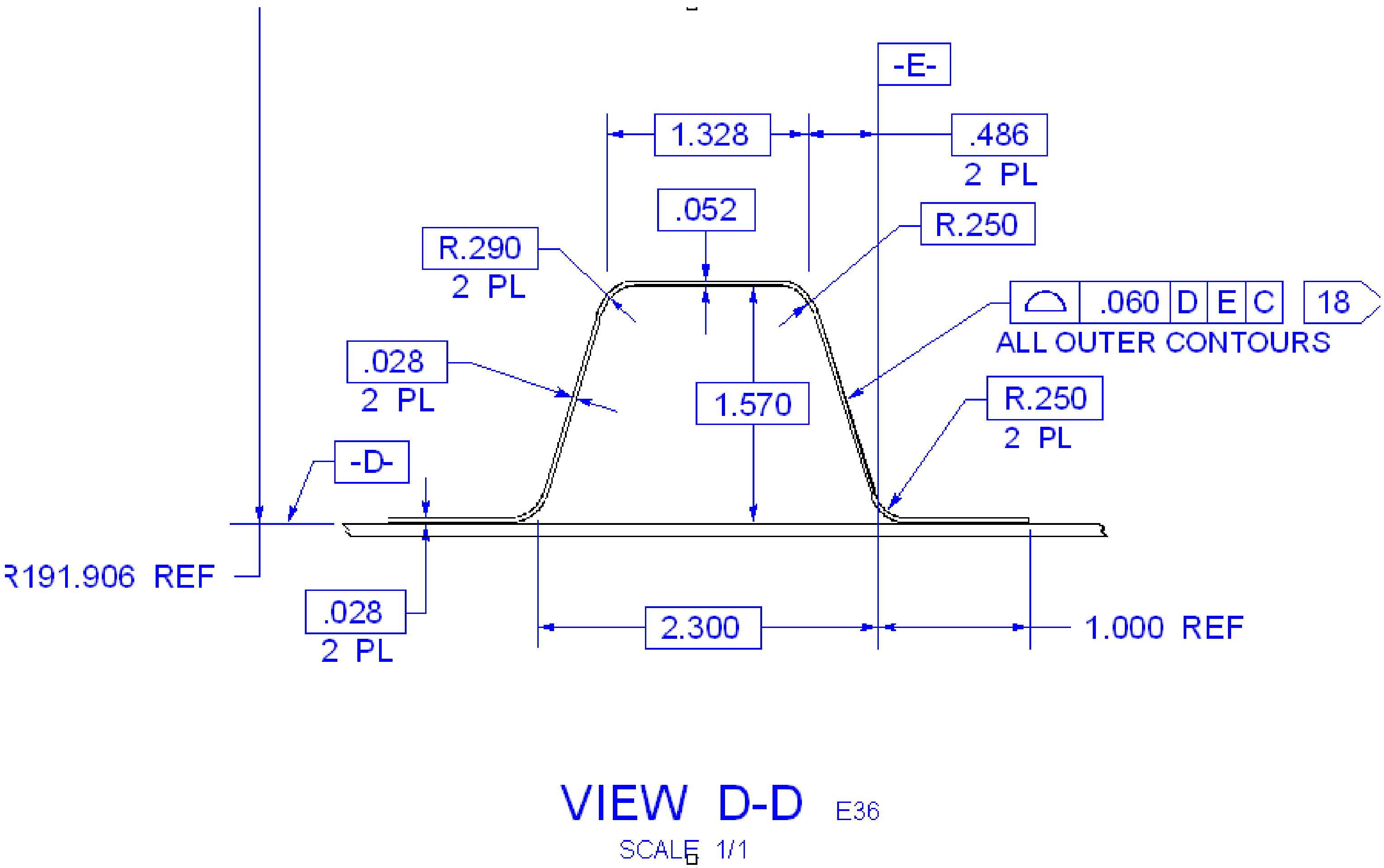
RLV Intertank Failure Load Prediction for a NASA Langley Test

Analyze a structural panels and beams in *detail*



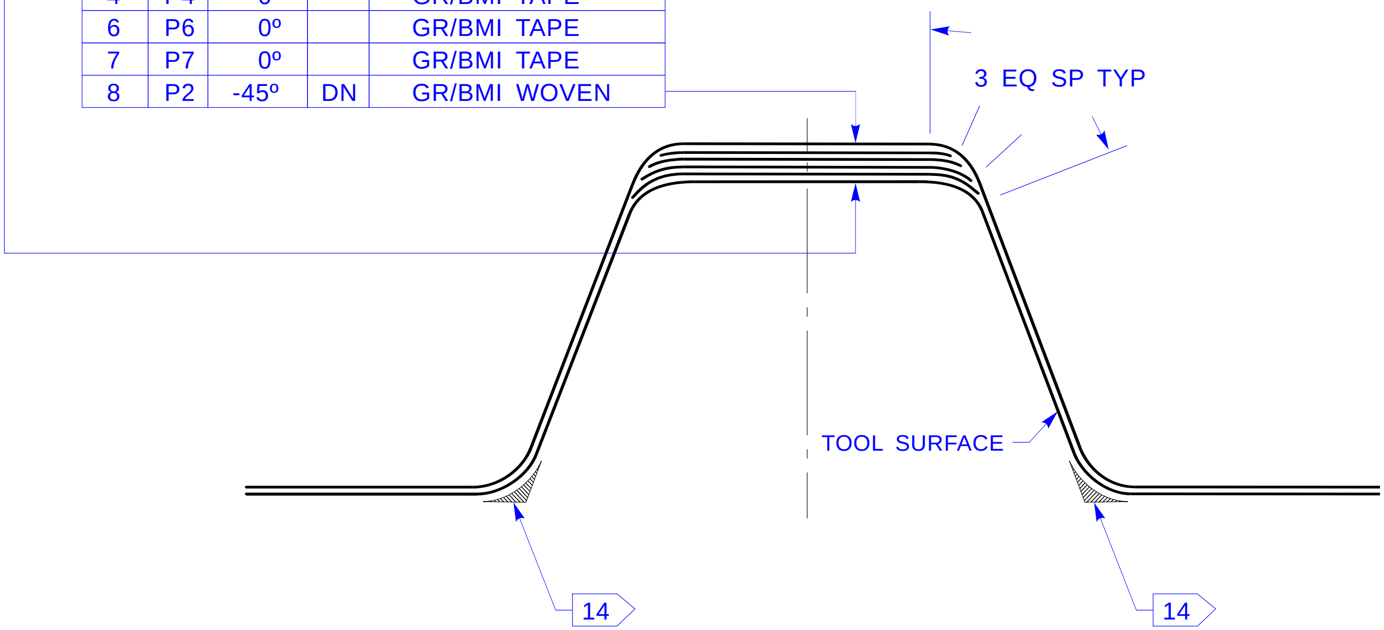


Cross Section Dimensions



Coresheet Layup Schedule, Hybrid Woven and Tape Forms, Ply drop-offs in the Crown

PLY LAYUP TABLE: -005				
PLY SEQ NUMBER	DETAIL PLY NO.	PLY OREN. WARP/FILL (+)/(-)	WARP DIRECT	MAKE FROM
2	P2	+45º	UP	GR/BMI WOVEN
3	P3	0º		GR/BMI TAPE
4	P4	0º		GR/BMI TAPE
6	P6	0º		GR/BMI TAPE
7	P7	0º		GR/BMI TAPE
8	P2	-45º	DN	GR/BMI WOVEN



SECTION R-R E36

PLY SCHEMATIC FOR -005

NO SCALE

Formulation Accuracy Checks

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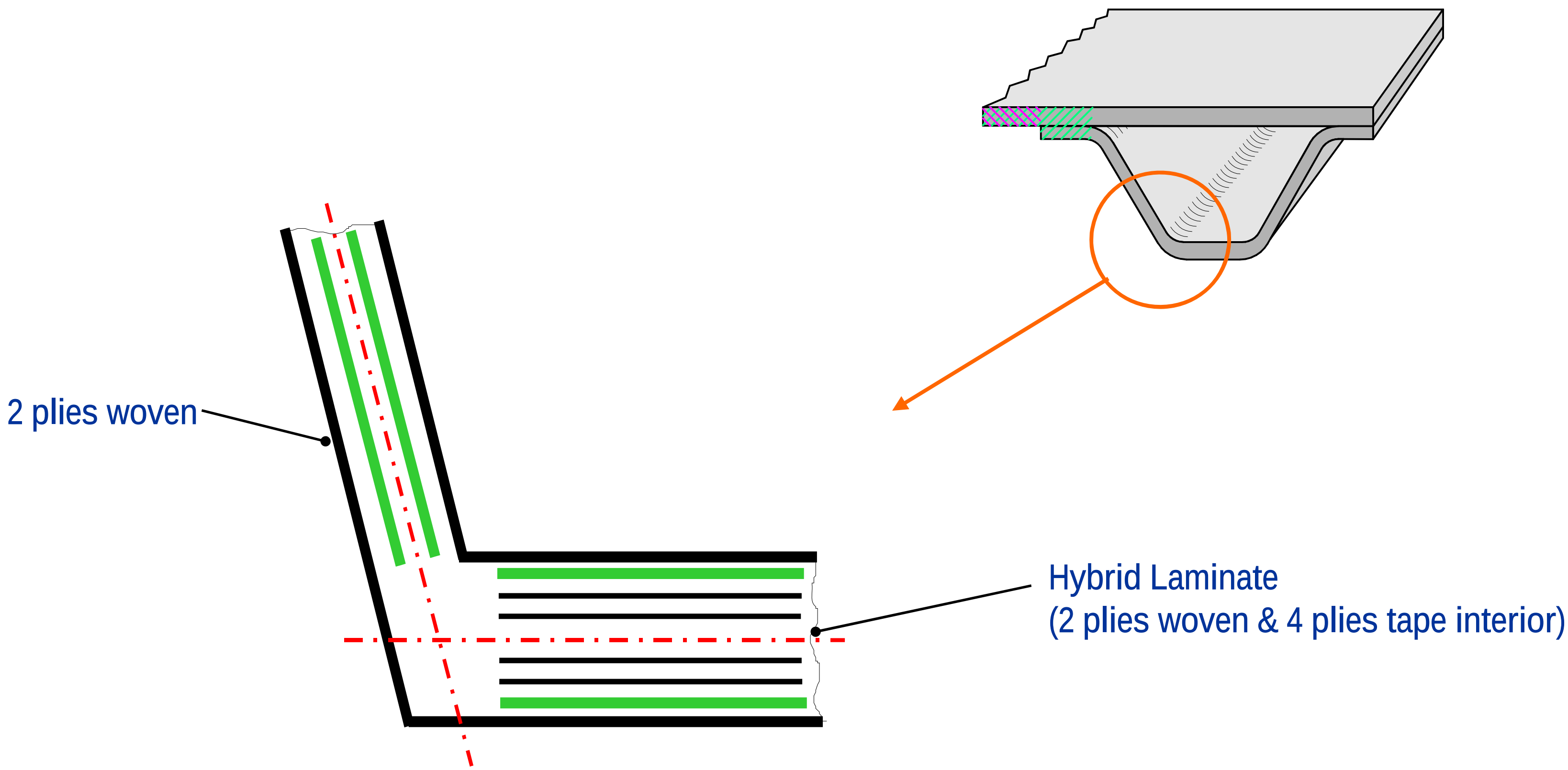
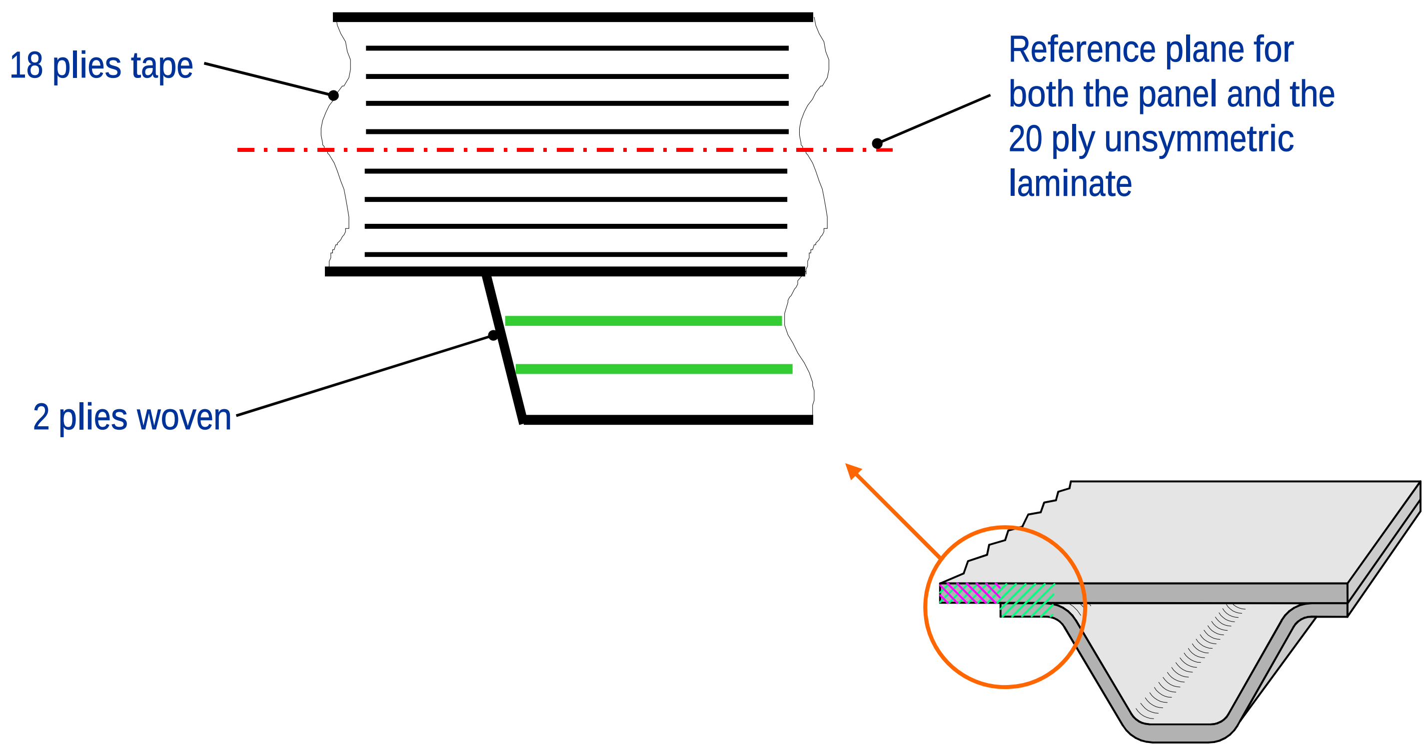
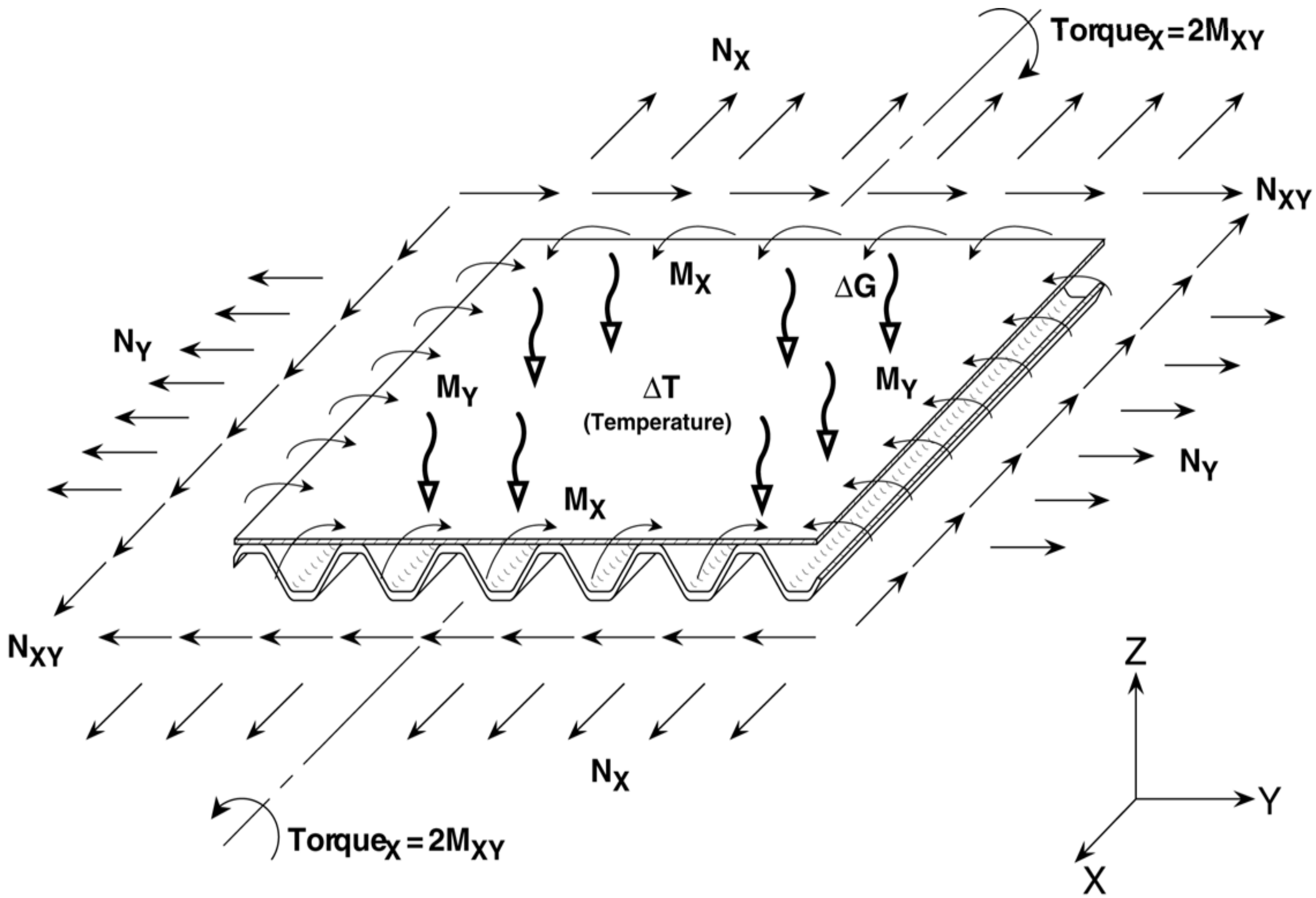
Hybrid Laminate of the Hat Crown



Skin - Stiffener Bonded Laminate



Balanced Free Body Diagram (FBD) & Strain Compatibility Approach



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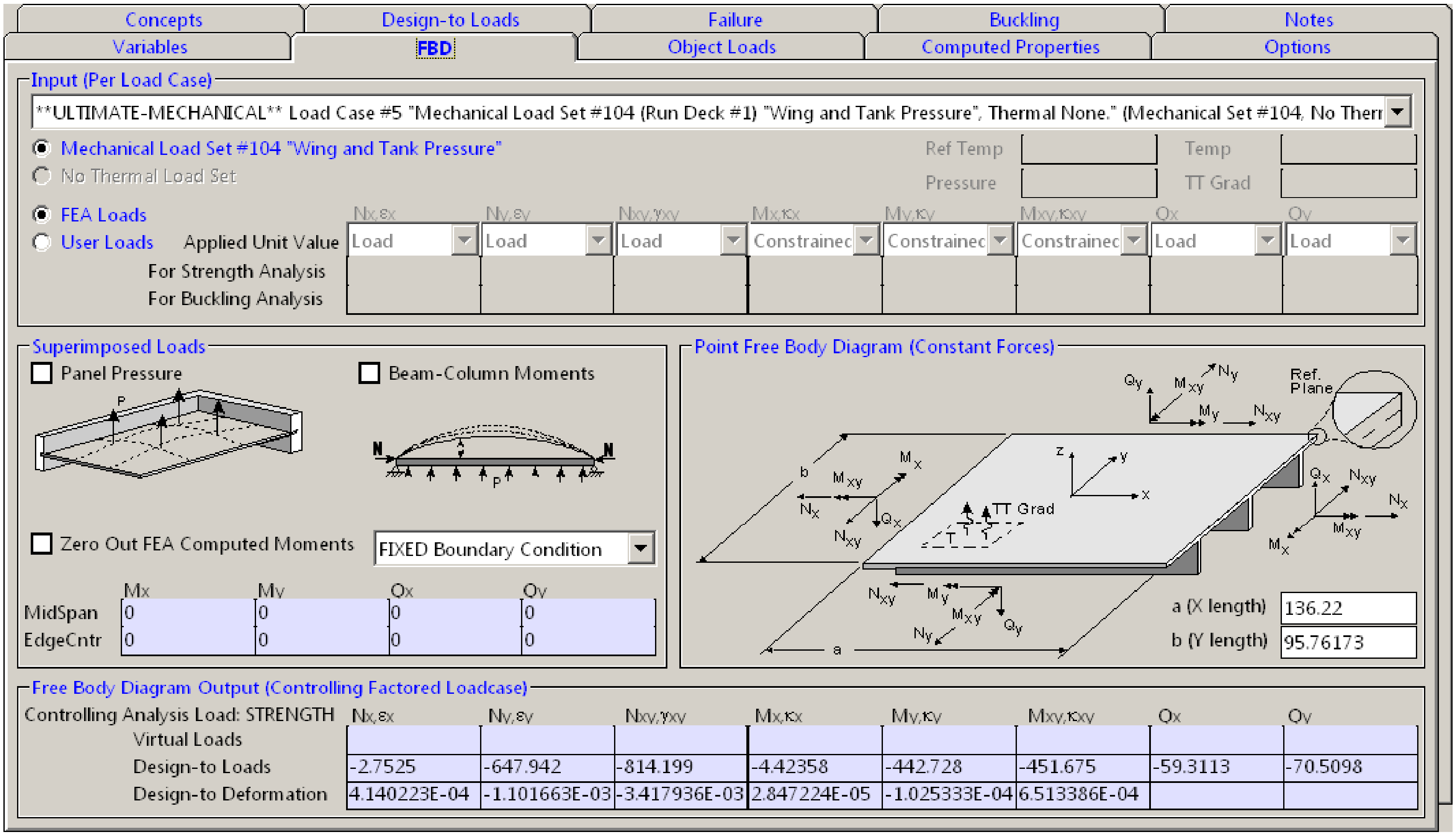
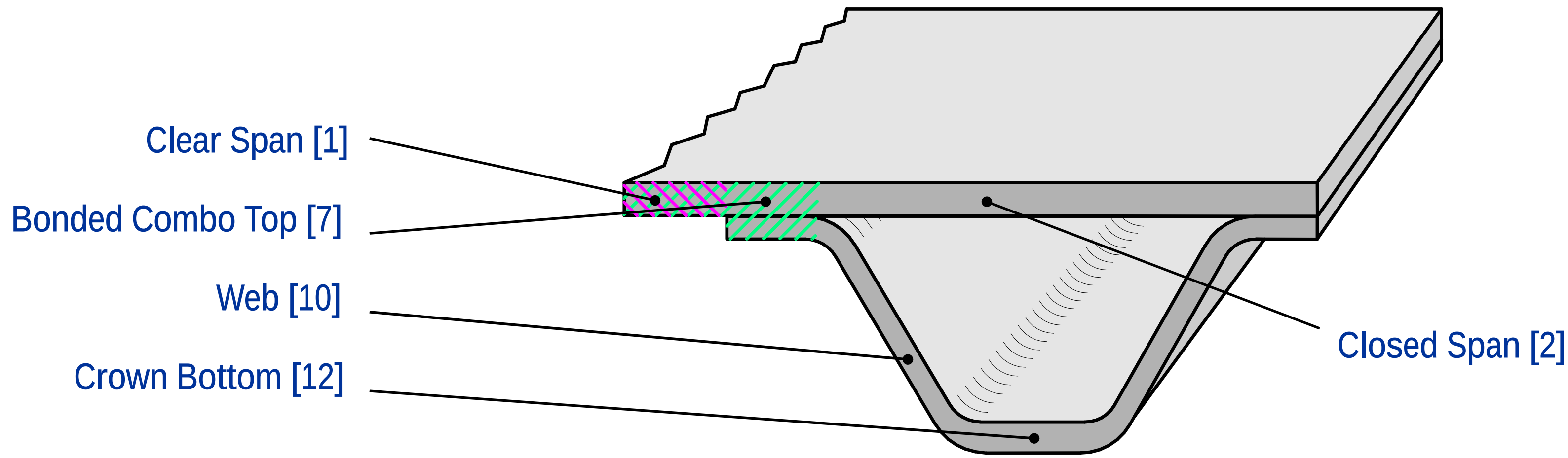
Balanced FBD Implementation of General Edge Loadings and Boundary Conditions



Object Loads

Load Results

Object	Nx	Ny	Nxy	Mx	My	Mxy
Clear Span [1]	-1534.22	-567.892	16.8327	-1.15463E-14	-1.11022E-14	8.88178E-16
Closed Span [2]	-1534.22	-567.892	13.2117	-1.68754E-14	-1.02141E-14	4.44089E-16
Bonded Combo Top [7]	-1925	-567.892	16.8327	-23.9166	-18.0217	0.343983
Web [10]	-169.591	1.84627E-13	3.62103	0	0	2.6177E-15
Crown Bottom [12]	-1058.52	1.77636E-13	3.62103	-3.33067E-15	-7.49401E-16	5.99867E-15



Summation Verification of the Object Membrane Forces

Load Results

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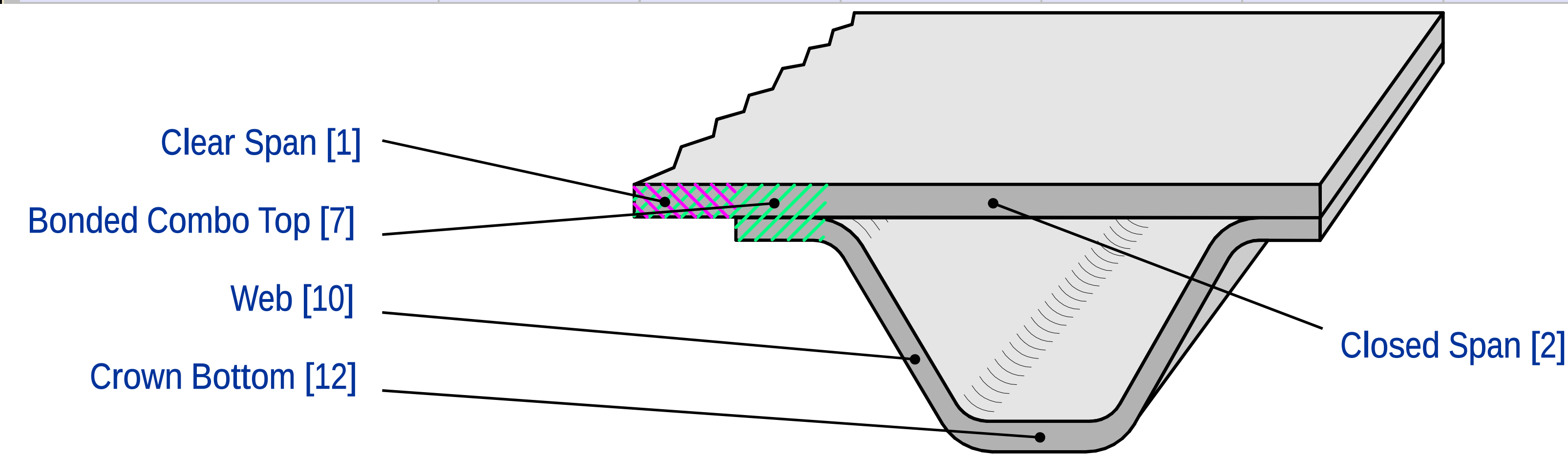


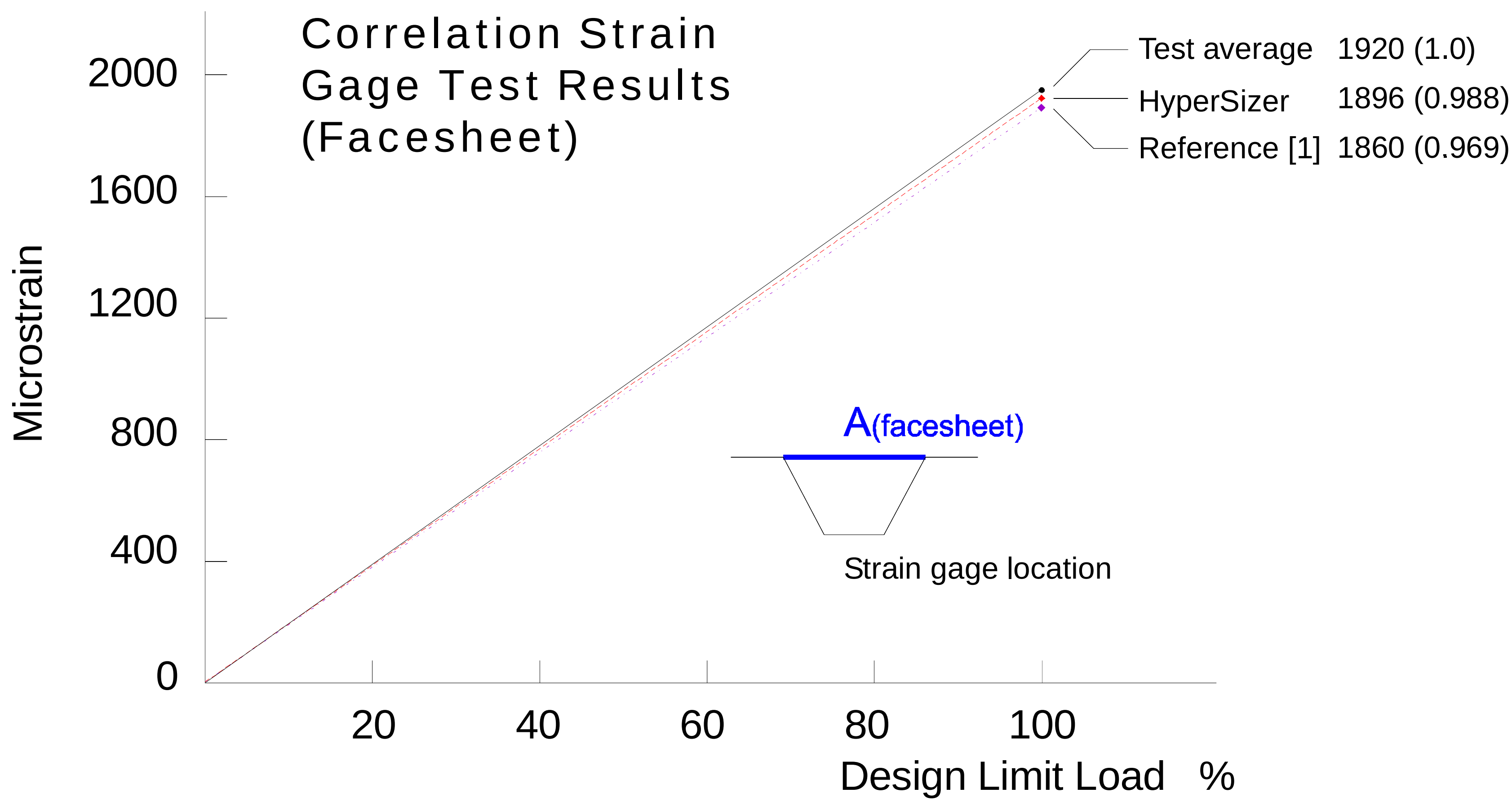
Ply integrated stresses = object loads ; Summation of object loads = applied loadings

FBD balance and strain compatibility maintained for each individual object and for the entire panel

Failure Analyses

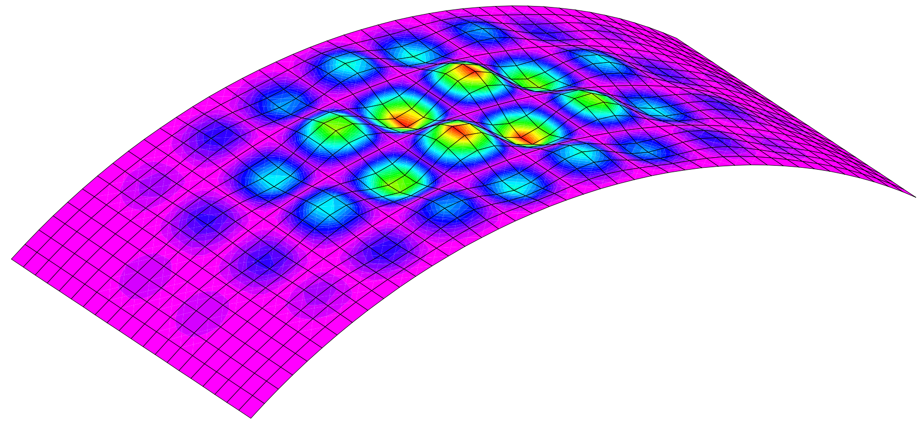
- **Material strength, panel buckling, local buckling, crippling, deformation, stiffness, and natural frequency**
- **Each failure analysis is summarized with a margin-of-safety (MoS) for limit and ultimate loads**
- **Each failure analysis can be turned on or off independently for specific components or entire projects**
- **Company administrator can change product default analyses, users can change project defaults**

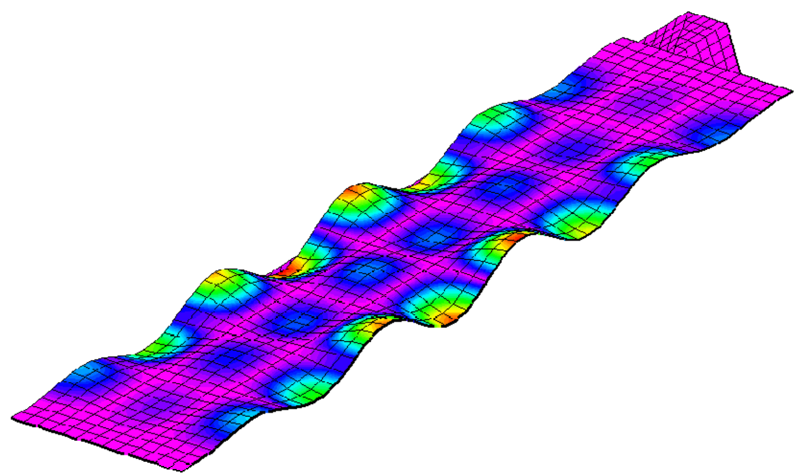
Pretest Prediction to Uniform Compression Load – Hat Stiffened Panel Structural Certification



Global to Local Analyses are Performed Automatically, All the Time

- **HyperSizer performs panel buckling every time---->**
- **HyperSizer performs local buckling every time---->**
- **HyperSizer performs all analyses every time**





Important Observations About the Test Correlation Process

The aerospace industry builds many FEMs to capture different responses of the structure

- a model for system buckling
- a model for panel buckling
- a model for local buckling
- a model for detailed stresses and material strength

For this test, at least four non-HyperSizer models were made

HyperSizer needs just one coarse planar FEM