ANALYSIS & GFEM MANAGEMENT WITH HYPERX ENTERPRISE

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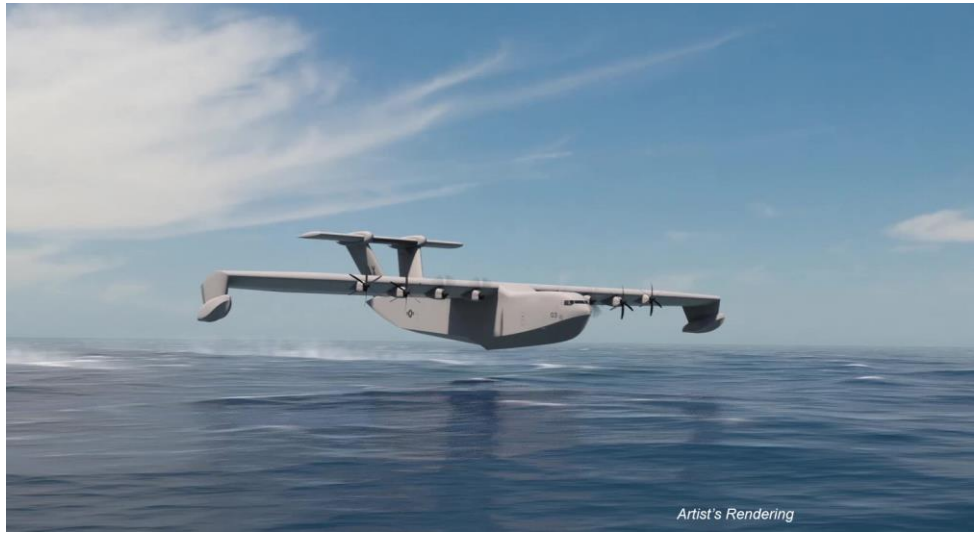
OVERVIEW

- Present HyperX capabilities for managing Global Finite Element Model (GFEM) architecture with relation to program requirements
- Outline examples from use-case from stress work done at Aurora Flight Sciences on DARPA's Liberty Lifter program
- Show effective guiderails for flowing information up and down for design and stress analysis while developing a prototype aircraft



"The Liberty Lifter program is currently designing and will build, float, and fly an affordable and innovative seaplane that can potentially transform fast logistics missions for the DOD and commerce…"

- Operating efficiently for long distances flying low over the ocean surface in a wide range of conditions
- Sustaining flight altitudes up to 10,000 feet mean sea level with a compromise on range
- Efficiently transporting large payloads at speeds far exceeding existing sea lift platforms"

Ref: https://www.darpa.mil/research/programs/liberty-lifter

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AIRCRAFT STRUCTURAL SIZING REQUIREMENTS

Operational Requirements
CFR, MIL-HDBK, JSSG, ETC

Manufacturing Requirements
Materials, Tooling, Assembly

Flight Physics | Ground Loads | Environments | Fatigue/DaDT

Aeroelasticity | Subsystems | Testing

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Artist's Concept

SIZING AND ANALYSIS WITHOUT ENTERPRISE

- Reference Document
- Database on a shared drive
- Public datasheets

Material Allowables

Design Space

- Design Criteria Document
- Individual Contributor experience
- Industry Standards

Loads

Stress Analyst

Analysis Methods

- Database from External Loads
- Miscellaneous Interface Documents
- Loads Criteria Database

- Stress Criteria Document
- Individual Contributor experience and a tool set that is mix of company and individual created
- Various FEA packages

SIZING & ANALYSIS

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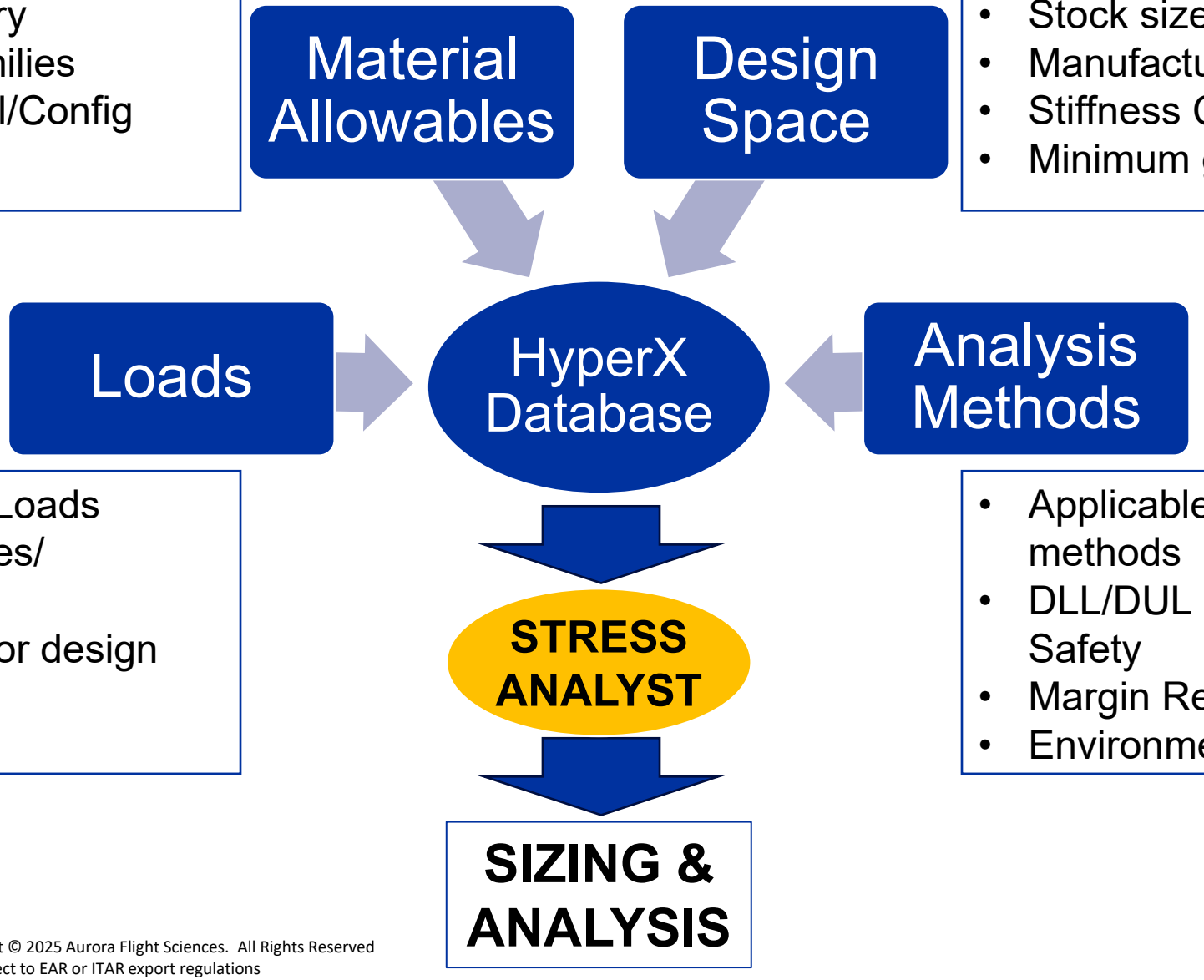
SIZING AND ANALYSIS WITH ENTERPRISE

- Material Library
- Laminate Families
- Environmental/Config Knockdowns



- Stock sizes
- Manufacturing limits
- Stiffness Criteria
- Minimum gauge

- FEM Internal Loads
- Local pressures/ temperatures
- Load factors for design cases
- Loads filtering

- Applicable handbooks/ methods
- DLL/DUL Factors of Safety
- Margin Requirements
- Environmental cases

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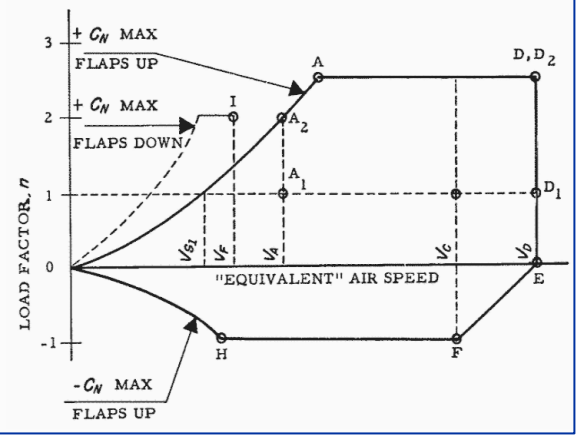
HYPERX DATABASE MANAGEMENT: LOADS

§ 25.333 Flight maneuvering envelope.

(a) *General.* The strength requirements must be met at each combination of airspeed and load factor on and within the boundaries of the representative maneuvering envelope (*V-n* diagram) of paragraph (b) of this section. This envelope must also be used in determining the airplane structural operating limitations as specified in § 25.1501.

(b) *Maneuvering envelope.*



§ 25.527 Hull and main float load factors.

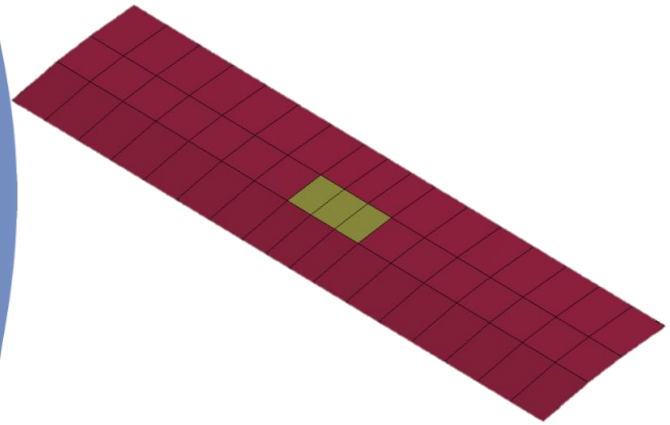
(a) Water reaction load factors n_W must be computed in the following manner:

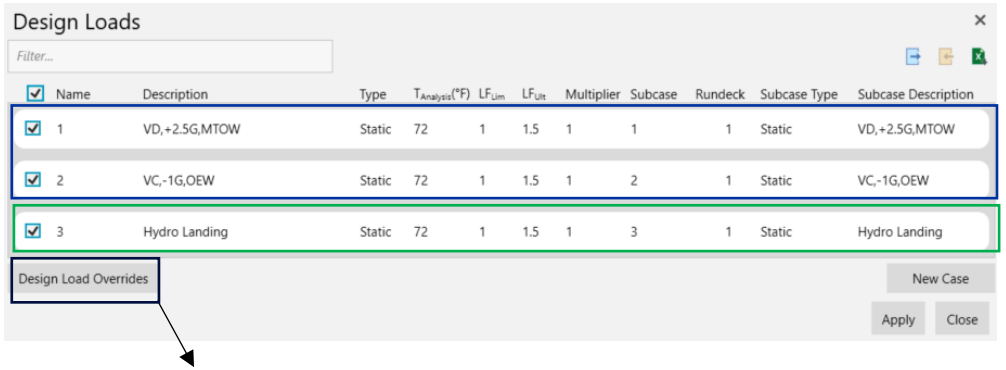
(1) For the step landing case

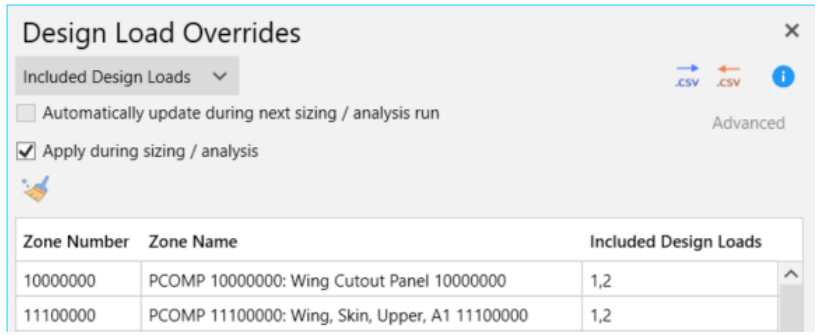
$$n_w = \frac{C_1 V_{S0^2}}{\left(\mathrm{Tan}^{\frac{2}{3}}\beta\right) W^{\frac{1}{3}}}$$

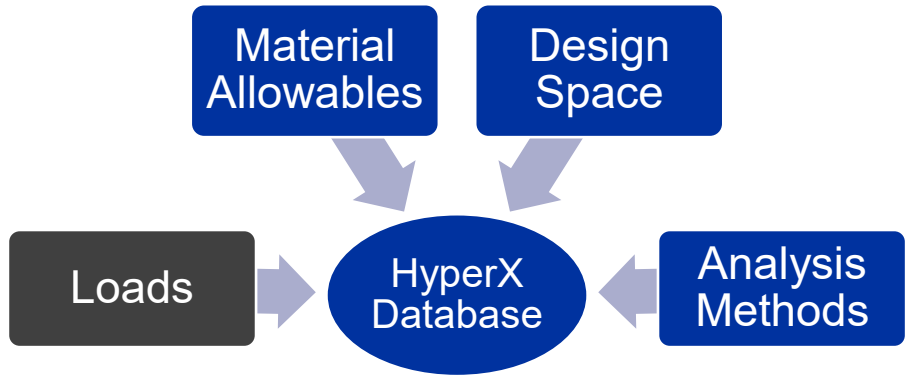
(2) For the bow and stern landing cases

$$n_w = \frac{C_1 V_{S0^2}}{\left(\mathrm{Tan}^{\frac{2}{3}}\beta\right) W^{\frac{1}{3}}} \times \frac{K_1}{\left(1+r_x{}^2\right)^{\frac{2}{3}}}$$









- Design Loads flow down from parent database to child databases
- Load filter parameters can be set at a global level for all sizing efforts
- Design Load Overrides can be used to set load cases from external load downselection information (i.e. VMTs, potato plots, etc.)

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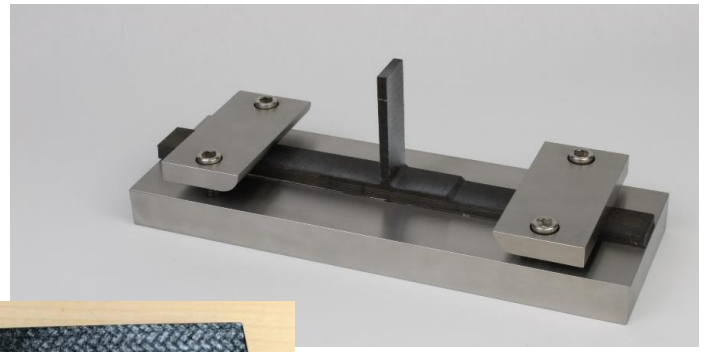
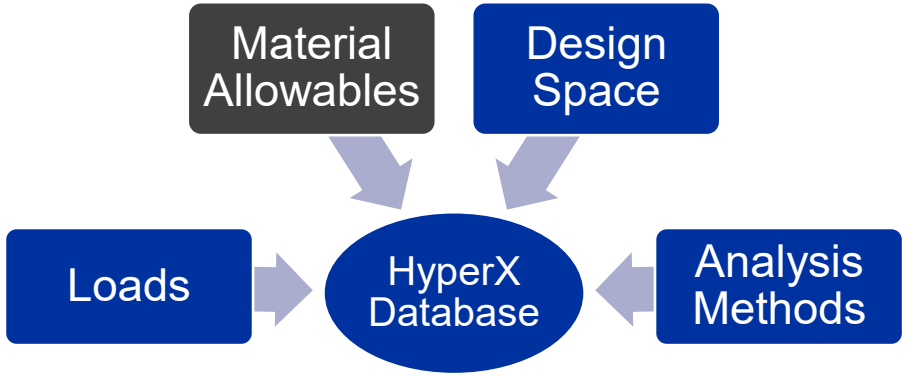
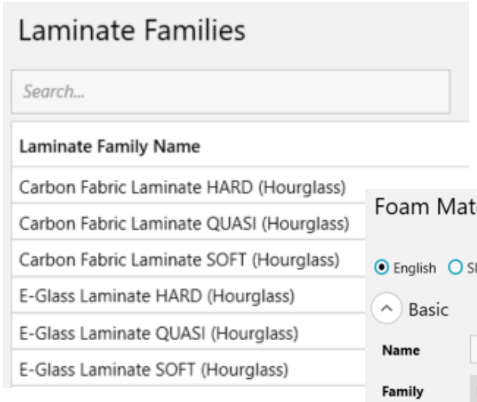
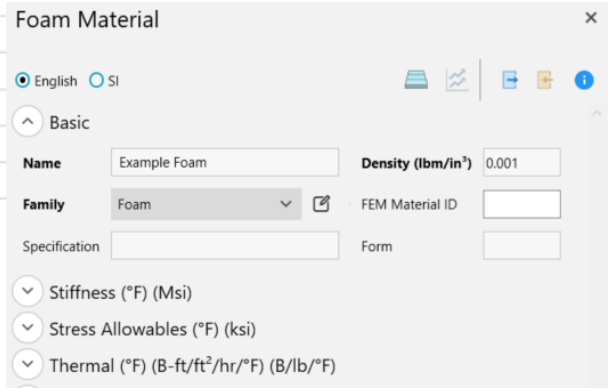
HYPERX DATABASE MANAGEMENT: ALLOWABLES





- Allowables managed at global level
- Stock sizes and laminate families can be consistent across vehicle to fit manufacturability and stress requirements
  - Laminate properties meet boundaries for analysis methods
  - Environmental effects established to meet program requirements





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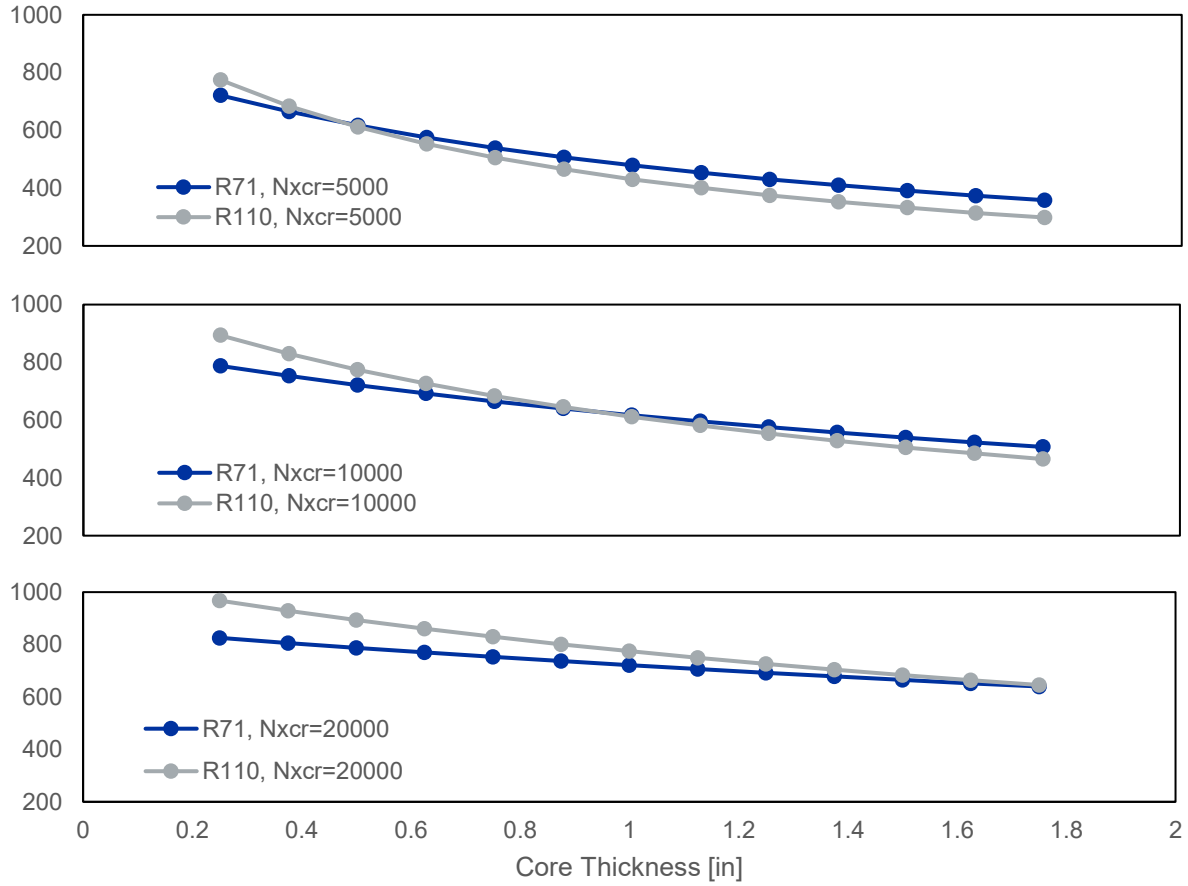
MATERIAL TRADE STUDY IMPACT

Ref: EVONIK ROHACELL_HERO_2022_April_EN_243522.pdf

- Initial sandwich material established for sizing was R71 core, set in Enterprise Database
- Individual contributor showed that using higher R110 core could save weight with due to increased transverse shear capability from shear modulus
  - Critical buckling load, Nxcr, is a function of C_{TSF}, D matrix, and panel geometry
- Updated material properties rolled back up into global database and integrated into sizing for other sections of the aircraft

				BASELINED	ADDED
Property	Test Method*	Unit	ROHACELL® 51 HERO	ROHACELL® 71 HERO	ROHACELL® 110 HERO
Density	ISO 845 ASTM D 1622	kg/m^3 lbs/ft^3	52 3.25	75 4.68	110 6.87
Shear Modulus	DIN 53294 ASTM C 273	MPa psi	22 3,190	28 4,060	50 7,250

NX_{TSF} per Core Area Density



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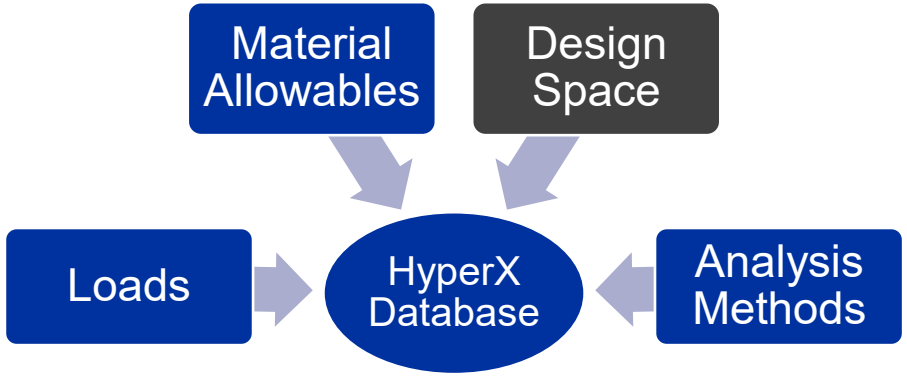
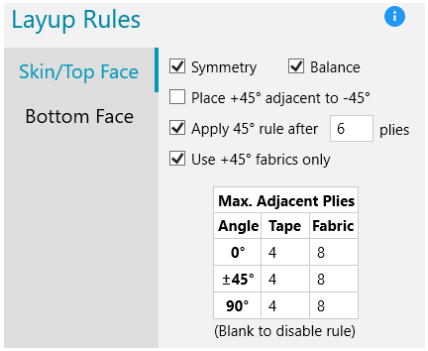
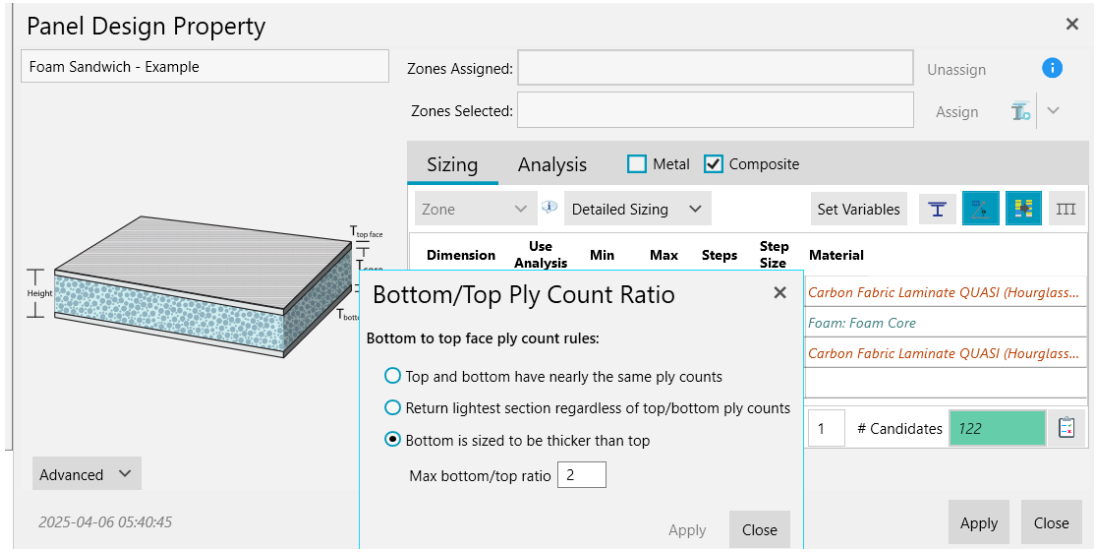
HYPERX DATABASE MANAGEMENT: DESIGN SPACE

Laminates Rules and Minimum Gauge

- Preset design properties can be established with construction rules established from requirements from:
  - Manufacturing
  - Damage Tolerance
  - Material Allowable Limits
  - Stress Criteria
- Additional design properties can be created at individual contributor level but gets flagged upon reintegration with parent database







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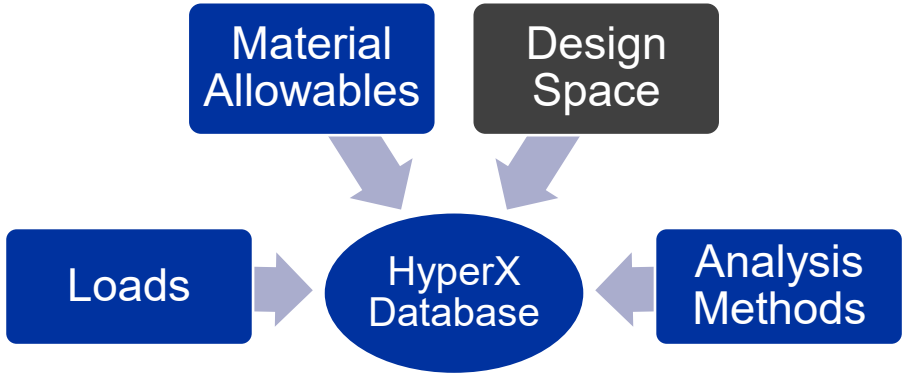
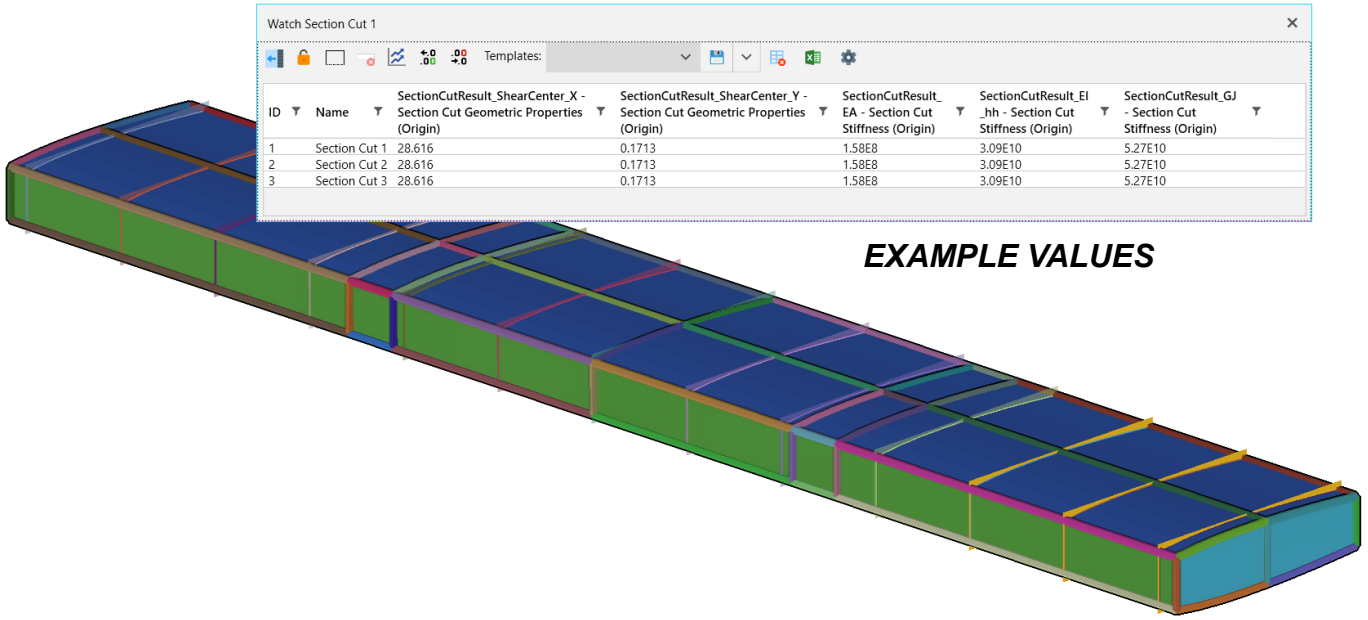
HYPERX DATABASE MANAGEMENT: DESIGN SPACE

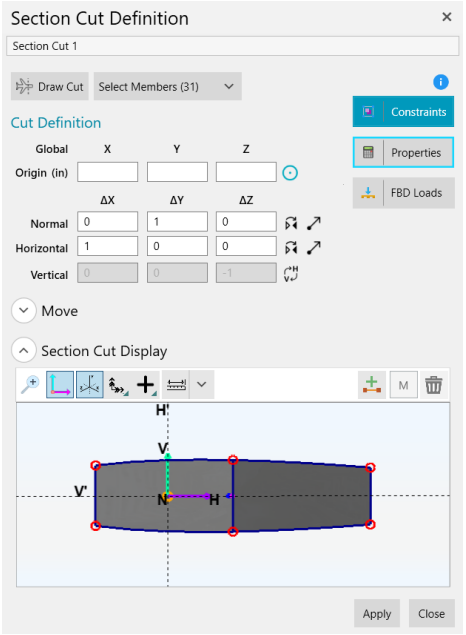
Stiffness Requirements

- Sectional Stiffness constraints can be defined on sections to ensure structure does not become too compliant (i.e. flutter constraints)





EXAMPLE VALUES



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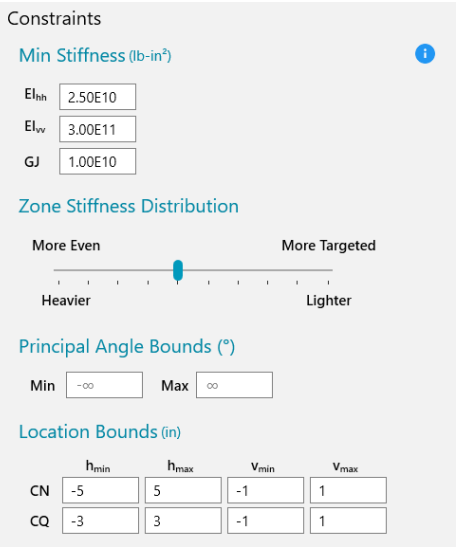

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HYPERX DATABASE MANAGEMENT: ANALYSIS

- Ensure that all failure modes and project settings that are being used to analyze structure are captured in stress criteria
  - HyperX Analysis IDs, Plug-Ins, and Scripts are all being documented and captured
- Established margin requirements for different analysis phases depending on maturity of loads, allowables, test plans, configuration, etc.

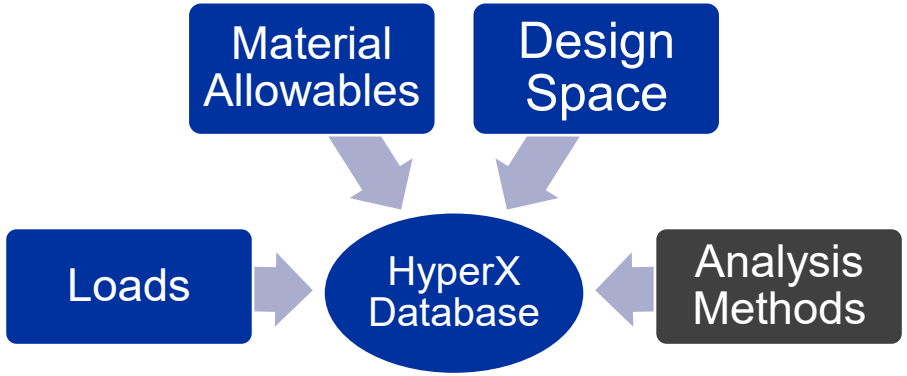


TABLE I. Minimum Design and Test Factors for Metallic Structures

Verification Approach	Ultimate Design Factor	Yield Design Factor	Qualification Test Factor	Acceptance or Proof Test Factor
Prototype	1.4	1.0*	1.4	NA or 1.05**
Protoflight	1.4	1.25	NA	1.2

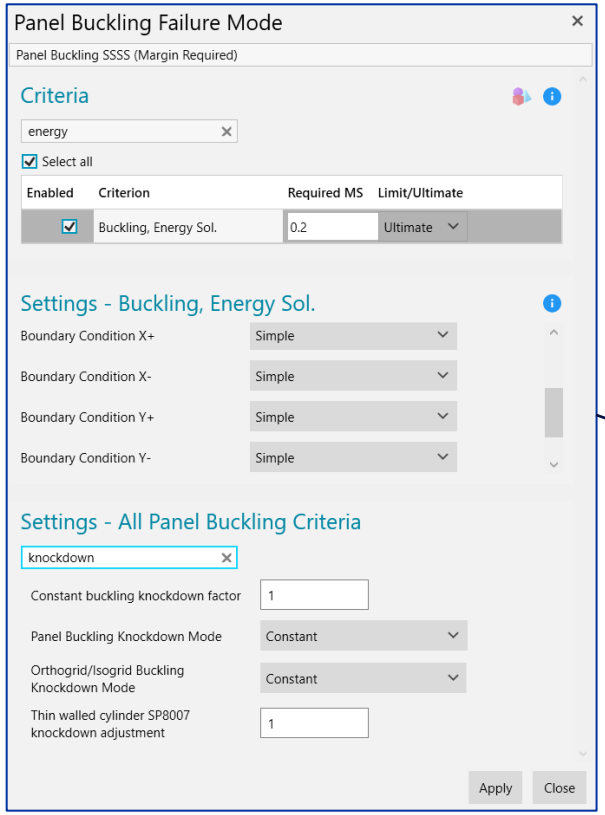
NOTES:
* Structure must be assessed to prevent detrimental yielding during flight, acceptance, or proof testing.
** Propellant tanks and solid rocket motor cases only.

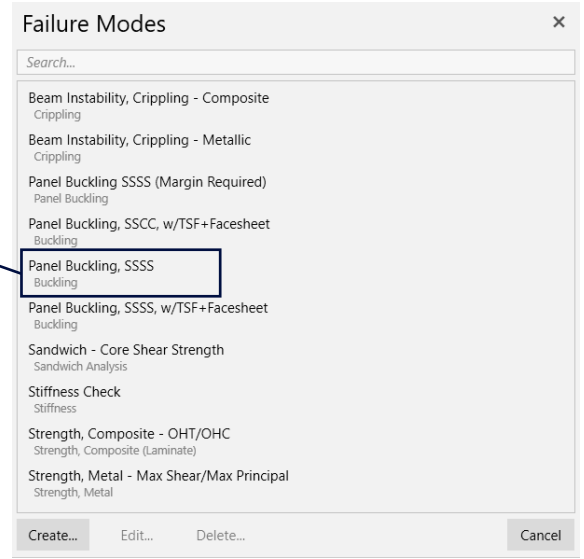
TABLE III. Minimum Design and Test Factors for Composite/Bonded Structures

Verification Approach	Geometry of Structure	Ultimate Design Factor	Qualification Test Factor	Acceptance or Proof Test Factor
Prototype	Discontinuities	2.0*	1.4	1.05
	Uniform Material	1.4	1.4	1.05
Protoflight	Discontinuities	2.0*	NA	1.2
	Uniform Material	1.5	NA	1.2

NOTE:
* Factor applies to concentrated stresses. For non-safety critical applications, this factor may be reduced to 1.4 for prototype structures and 1.5 for protoflight structures.

Ref: NASA-STD-5001





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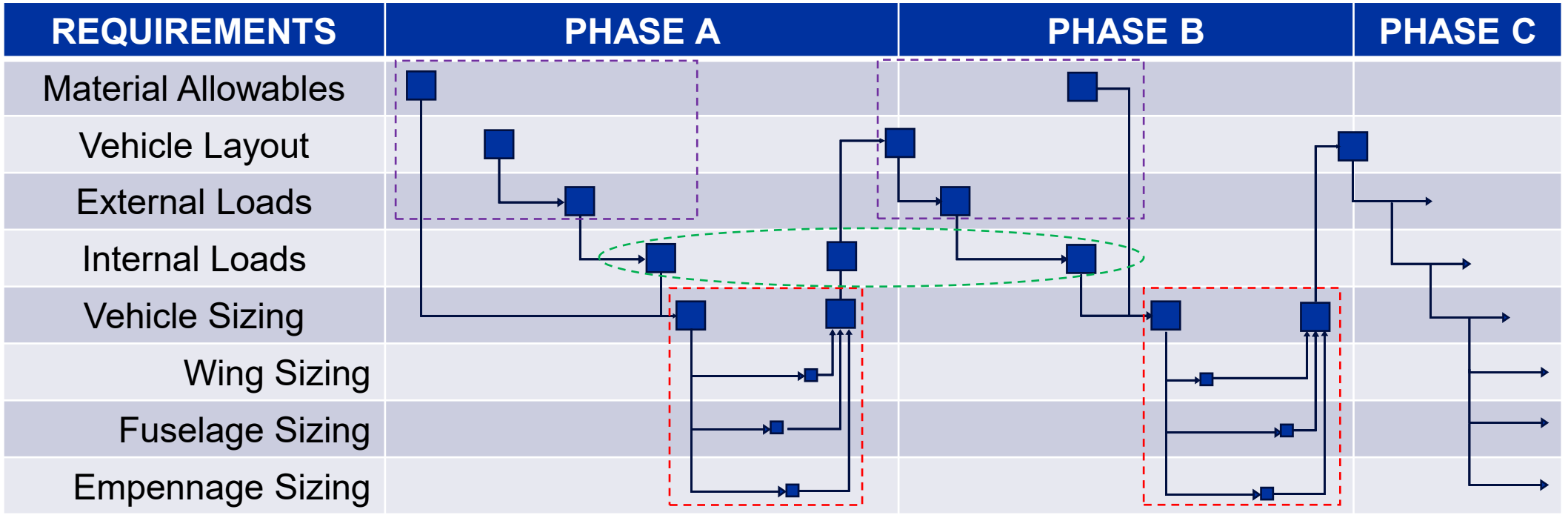
EXAMPLE VEHICLE SIZING FLOW



PROGRAM DRIVEN SIZING INPUTS

SUBSECTION SIZING EFFORTS

Internal loads change as sizing/stiffness is updated in design maturation. Having each section work break off from same parent database allows for control of established internal loads model throughout process

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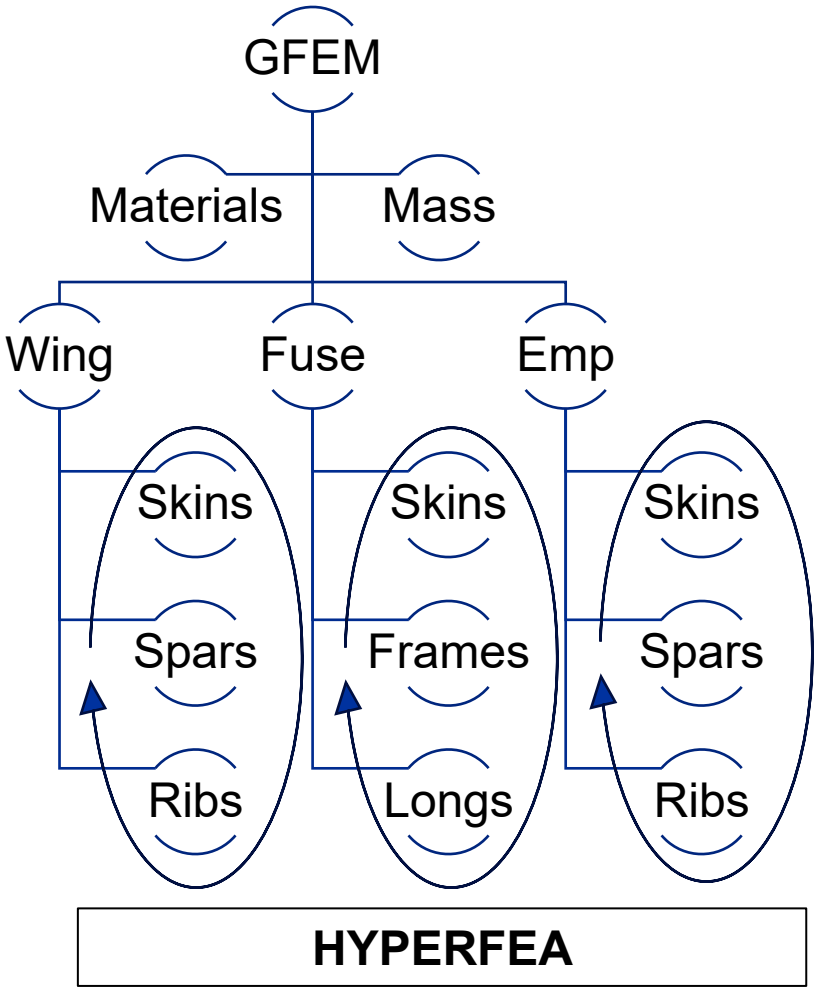
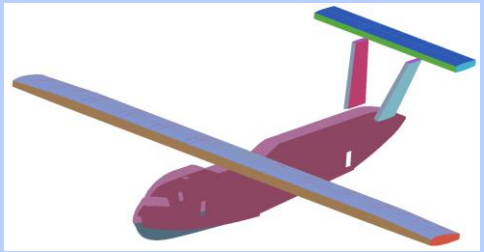
GFEM MANAGEMENT



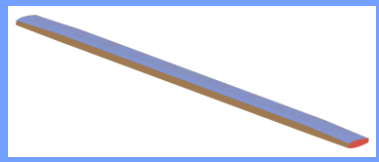
GFEM INTEGRATOR

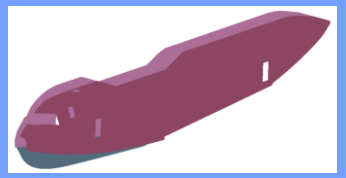
- Manages internal loads model
- Sets boundaries for subsections
- Defines global settings/allowables
- Collects final sizing to integrate back into GFEM each iteration



SUBSECTION LEAD

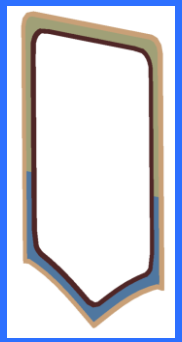
- Sets standards for methods and parameters
- Defines local sizing requirements
- Integrates design results from part level into final subsection sizing

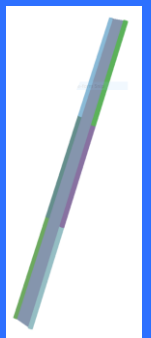




ANALYSIS INDIVIDUAL CONTRIBUTOR

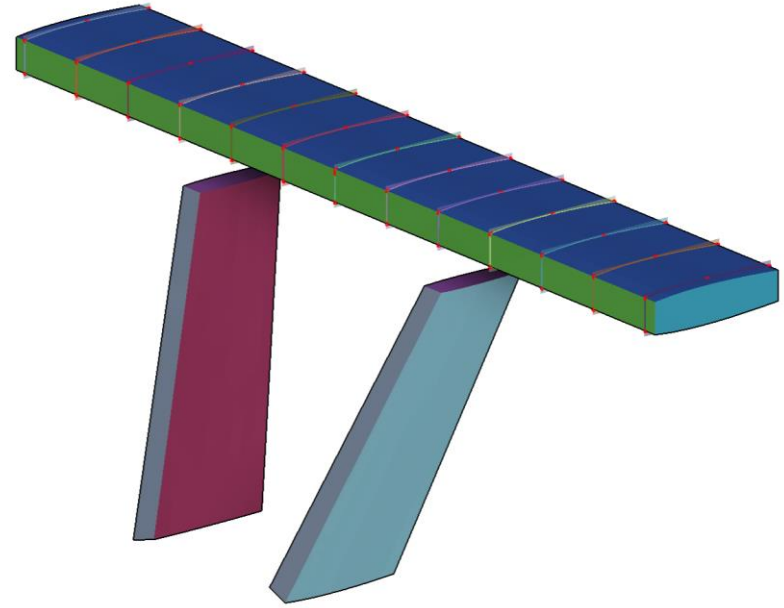
- Performs sizing/analysis on component level
- Produces stress reports
- Details structural layout

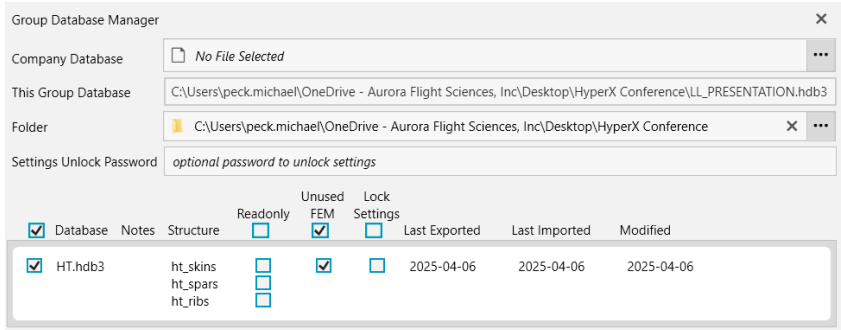


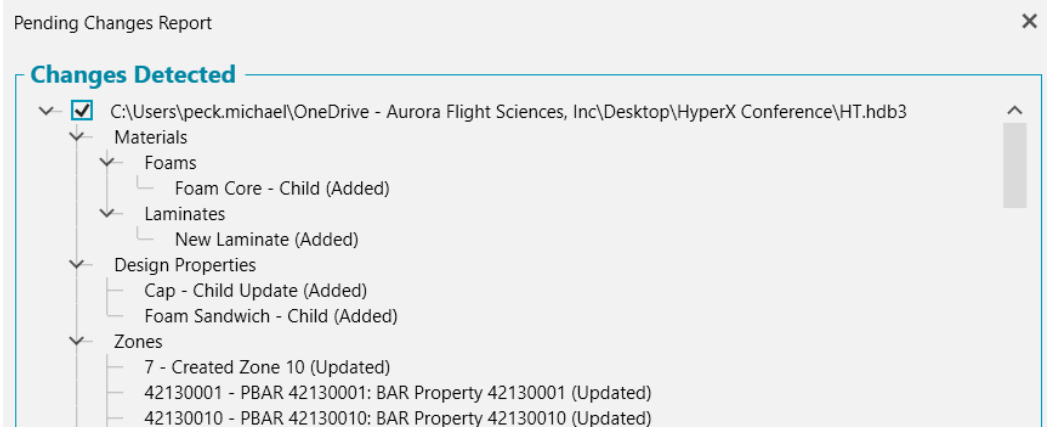


GUIDERAILS VS CONSTRAINTS

- Stress leads, GFEM integrator, and subsection leads are responsible for setting boundaries to start sizing **BUT** individual contributors may need to push those limits when necessary
- Changes are flagged upon reintegration with parent database and can be approved or rejected before being incorporated into final sizing
- While much of these controls are implemented in the template forms, the enterprise database allows for more control flowing up and down







Questions to Consider

- What stage is the project being worked on?
- How are the teams split up?
- What is common between sections? What is unique?
- How big are my FEM files?

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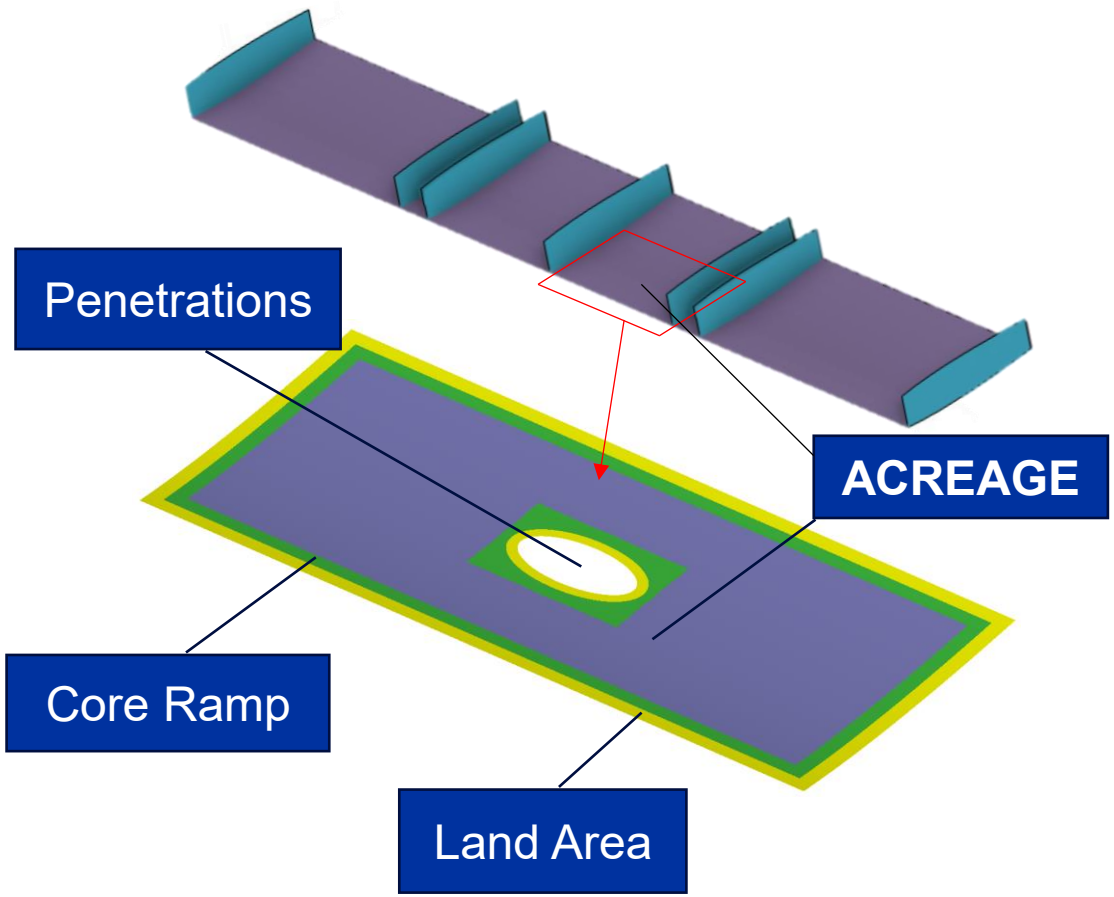
AREAS FOR GROWTH OF ENTERPRISE TOOL

- Structure that requires sub- modeling for higher resolution and detailed analysis can still tie into GFEM
  - Automate Zone ID compatibility for gross acreage represented in GFEM can flow up and down the process
  - Maintain analysis methods, properties, and design limits all still controlled at a program level, Management of joint entities with excel tables
- Additional support for monitor points and grid point force load processing
- More documentation on project settings for control across databases
- New design cases and project change settings being flagged on child import into parent

BREAKOUT MODELING CONNECTION TO GFEM



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