HyperXpert's Role in Trade Studies on BWB Aircraft

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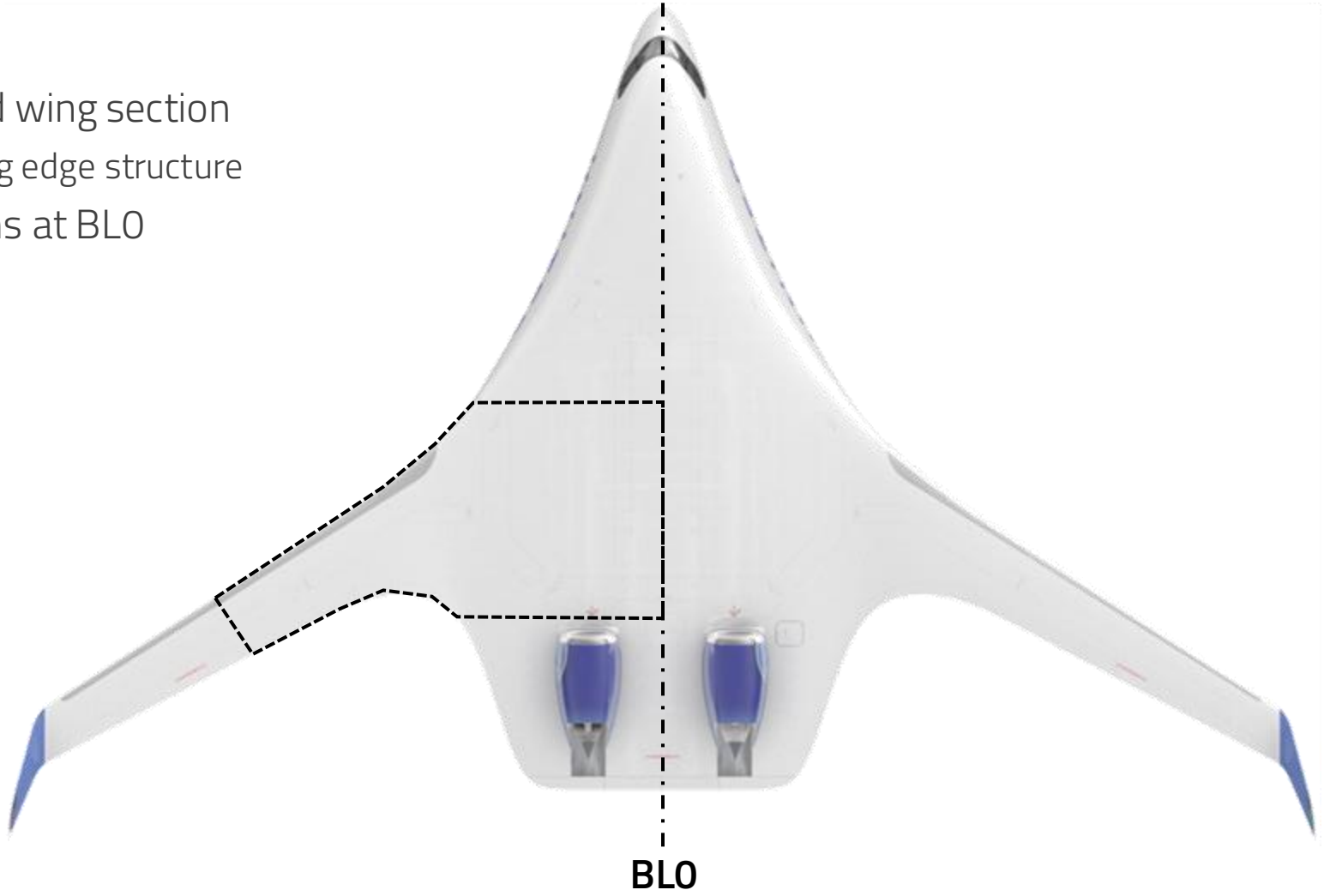
Trade Study Overview

- Objective
  - Determine weight efficient wing-to-center body load path that satisfies producibility and manufacturing requirements.

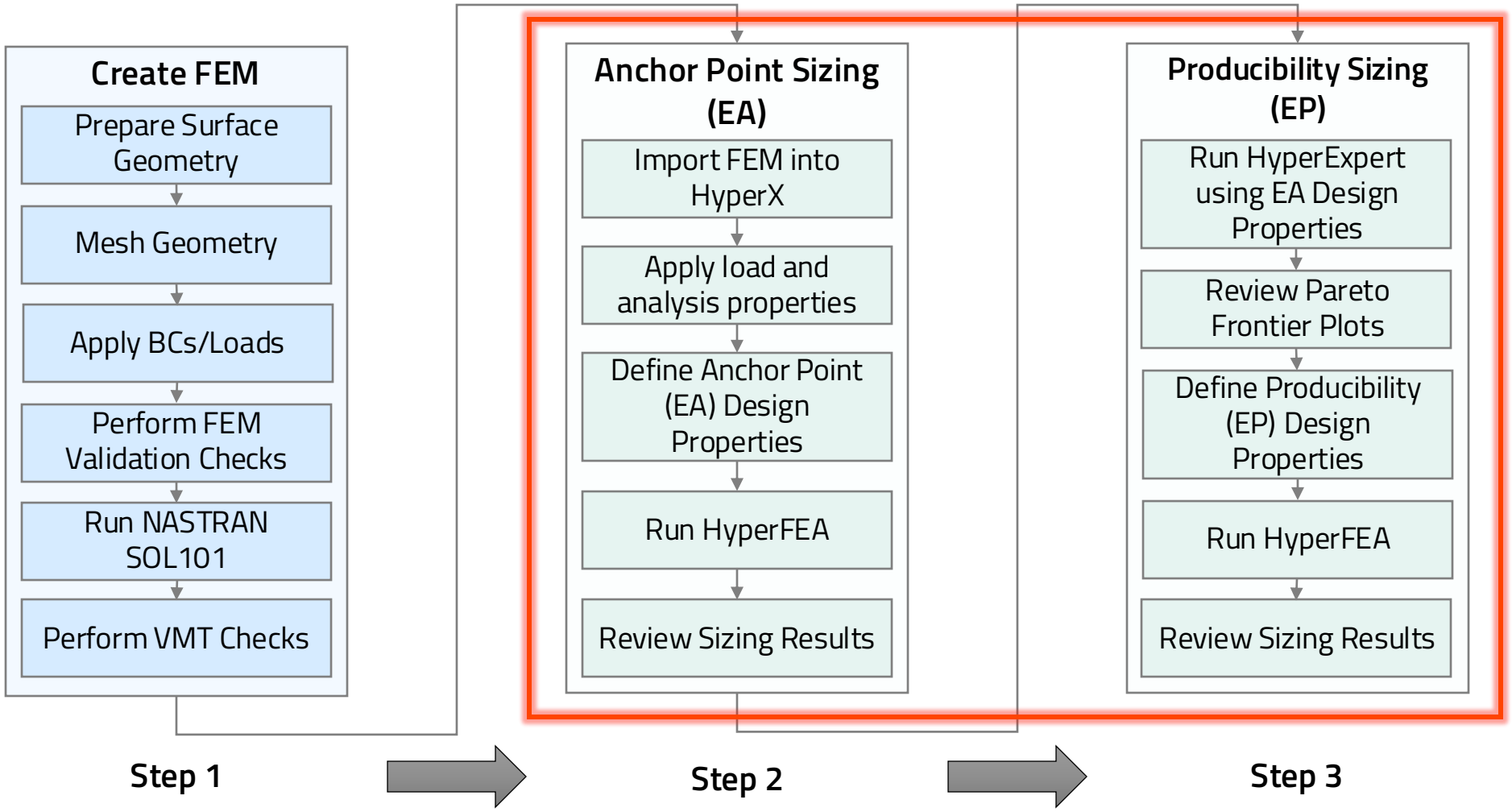
- Two Configurations
  1. Load Path 1
  2. Load Path 2

Trade Study Scope

- FEM Model
  - Portion of LHS center body and wing section
    - Includes leading edge and trailing edge structure
  - Symmetric Boundary Conditions at BL0
  - Model Statistics
    - # Elements > 95k
    - # Nodes > 80k
- Loads
  - Flight + Cabin Pressure Loads
  - Design Load Cases = ~2k



Trade Study Sizing Workflow



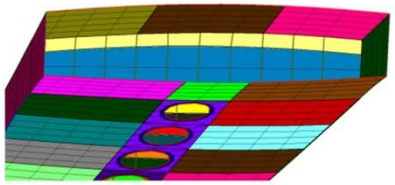
FEM Pre/Post Processor

HyperX

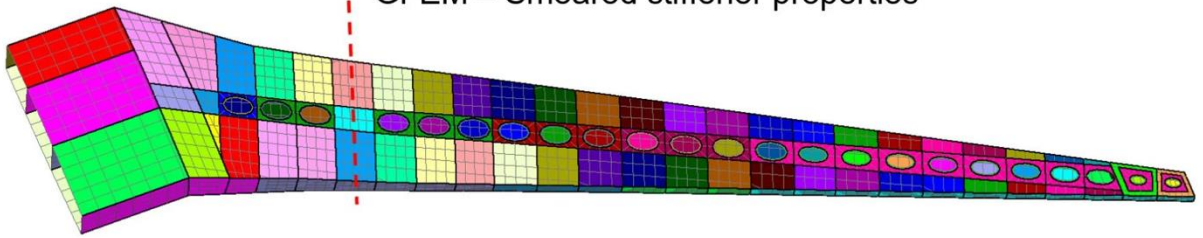
HyperX Analysis Technique

Analysis & Sizing Uses *Smeared Mesh* Approach

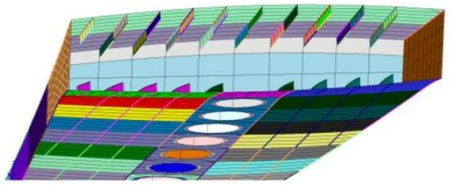
FEM with Stiffeners Modelled as a *Smeared Mesh*



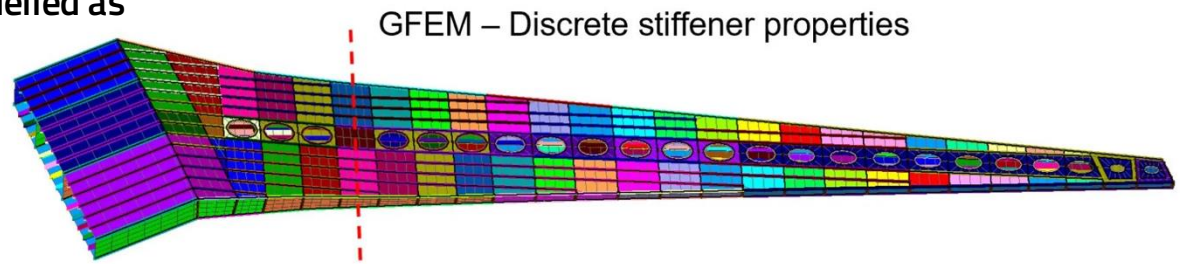
GFEM – Smeared stiffener properties

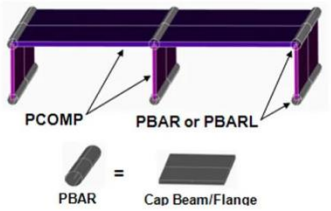


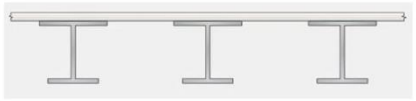
FEM with Stiffeners Modelled as a *Discrete Mesh*



GFEM – Discrete stiffener properties





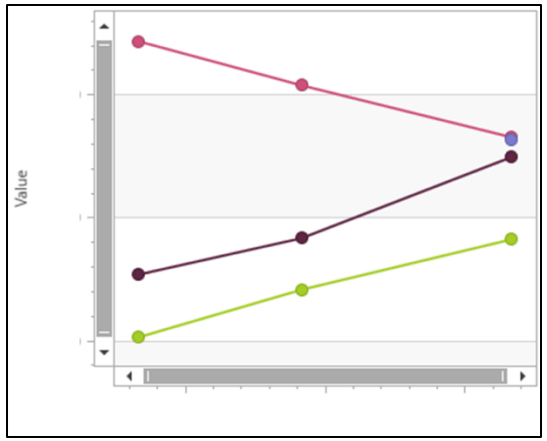


Both FEMs are "I" stiffened panels

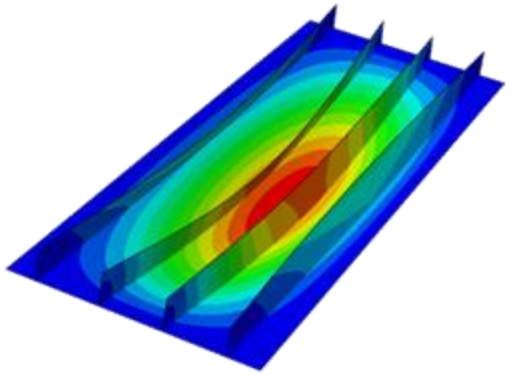
HyperX Failure Modes

Jetzero

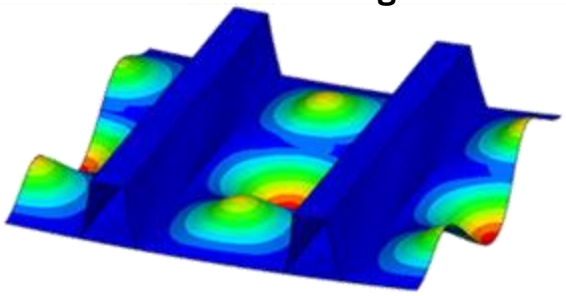
Laminate Strength



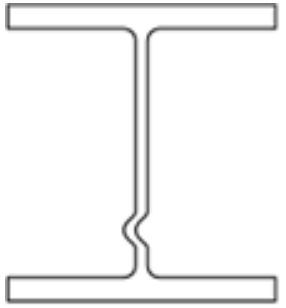
Panel Buckling



Local Buckling



Web Crippling

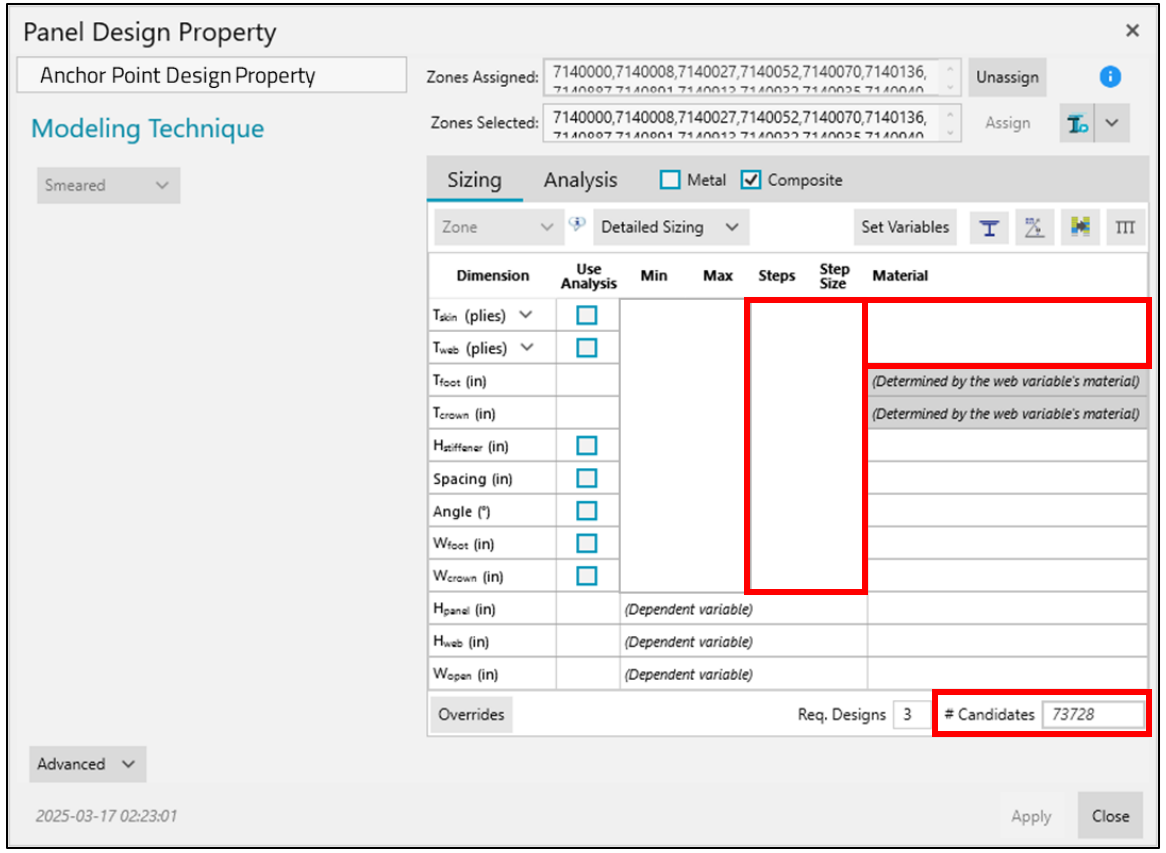


Web Buckling

Anchor Point Sizing

- Anchor Point Sizing
  - Unique "optimum" design for *every zone*
    - Lightest Weight
    - + Margins of Safety
    - *Least Producible*

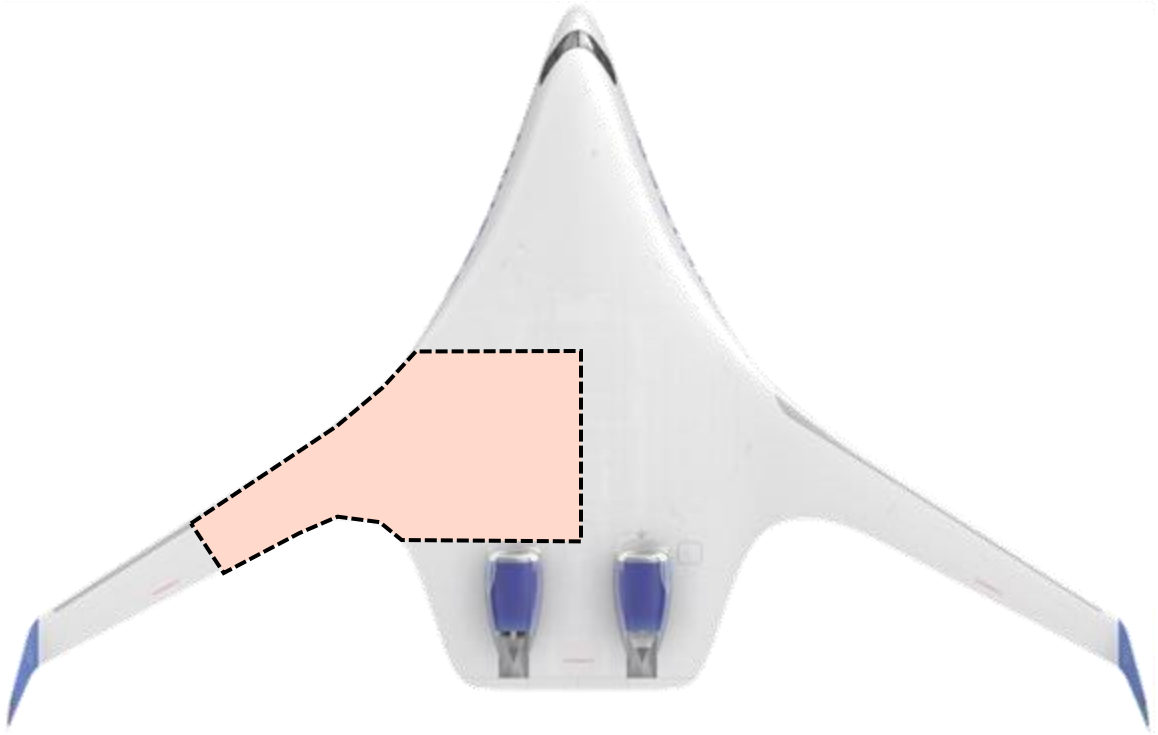
- Anchor Point Design Properties
  - When?
    - Preliminary design phase when trading numerous variables
  - What?
    - Coarse Step Sizes
    - Effective Laminates
    - Large Number of Candidate Designs
    - Runtime vs # Design Variables
  - Why?
    - Obtains new FEA starting point with updated stiffness for *producibility sizing* with HyperXpert (Step 3)



Example Anchor Point Design Property

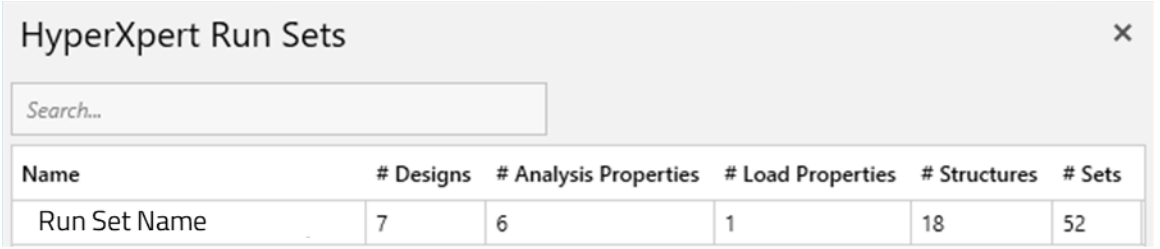
Producibility (EP) Sizing

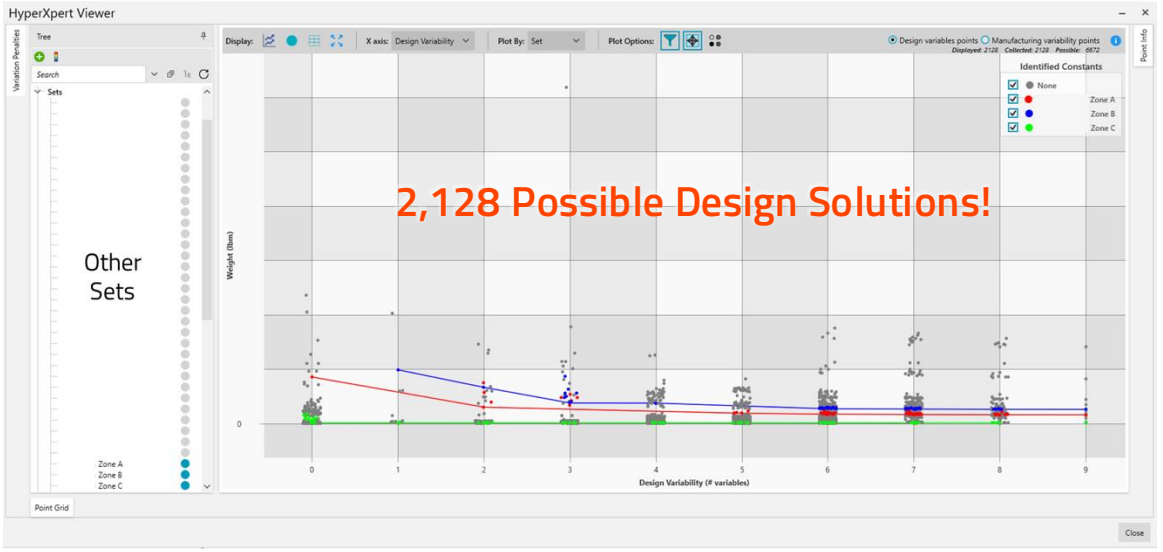
- Wing Skins
  - Split into three (3) zones for producibility
    - Zone A (FWD)
    - Zone B (MID)
    - Zone C (AFT)
  - Producibility Assumptions
    - Stringer Stiffened Wing Skins
    - All zones have same stringer tooling mandrel shape
      - $H_{stiffener}$ = Constant
    - All zones may have different stiffener spacings
      - Spacing ≠ Constant



Producibility Sizing

- HyperXpert
  - What?
    - Runs full-factorial DOE solution based on input design property variables
  - Why?
    - Determine most weight efficient and more producible combination of design variables across any number of sets or structures
  - When?
    - Optimum design variables that yield a producible design are unknown
  - How?
    - Run using anchor point design properties on HyperX model using updated stiffness properties and internal loads from anchor point sizing results

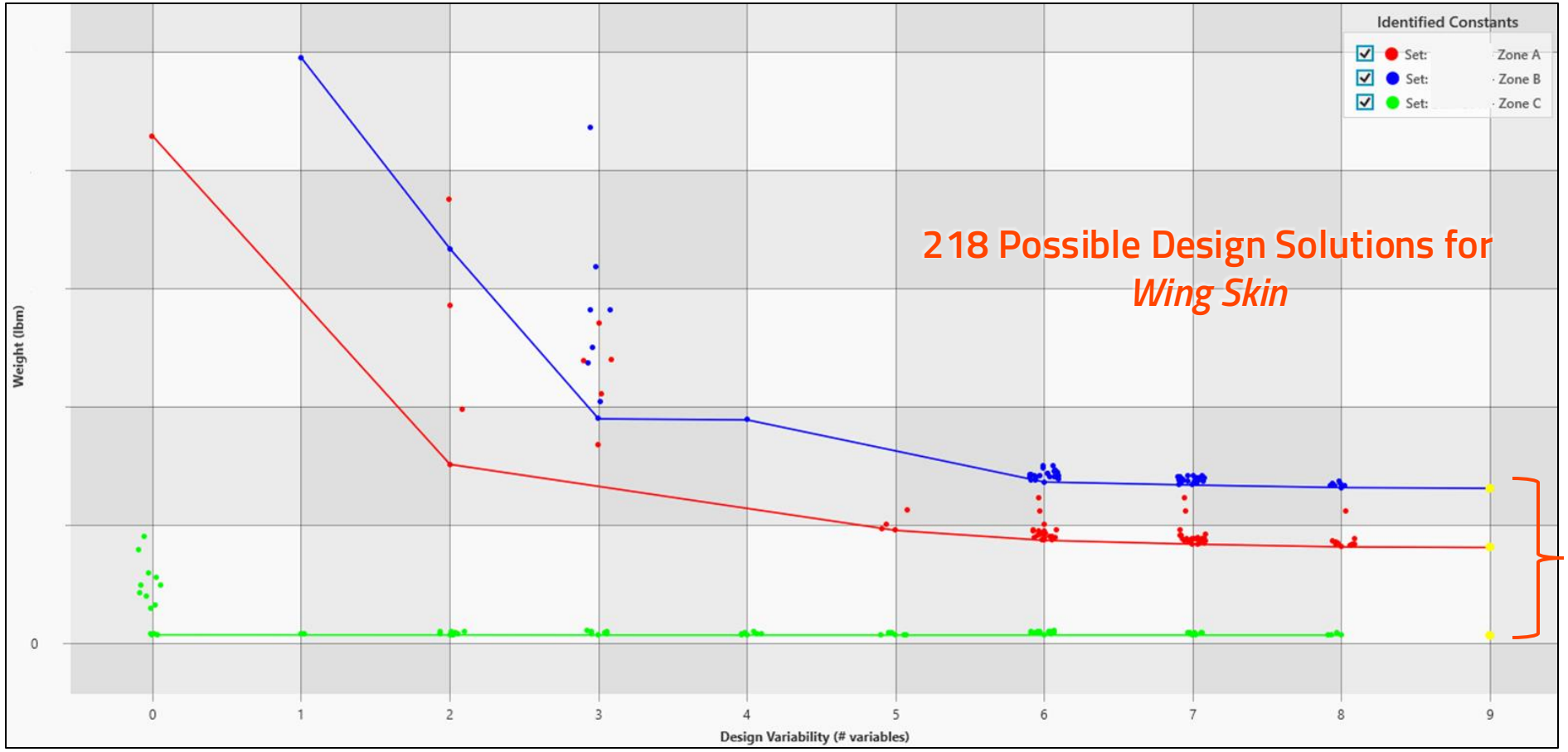




HyperXpert Viewer of Effective Laminate Producibility Results

Producibility Sizing

HyperXpert Pareto Frontier Plot for Wing Skin Sets



Anchor Point Sizing Results

More Producible

Less Producible

Producibility Sizing

Jetzero

- Panel
  - Stiffener
    - Spacing(in)
      - Spacing A
      - Spacing B
      - Spacing C
      - Spacing D
    - $H_{stiffener}$(in)
      - Height A
      - Height B
      - Height C
    - Angle(°)
      - Angle A
    - W_{crown}(in)
      - Width A
      - Width B
      - Width C
    - W_{foot}(in)
      - Width A
    - T_{skin}(in)
    - T_{web}(in)
    - T_{foot}(in)
    - T_{crown}(in)

Wing Skin Set – Sorted by *Spacing*

Lower Spacing **Higher Spacing**

Producibility Sizing

Jetzero

Wing Skin Set – Sorted by $H_{Stiffener}$

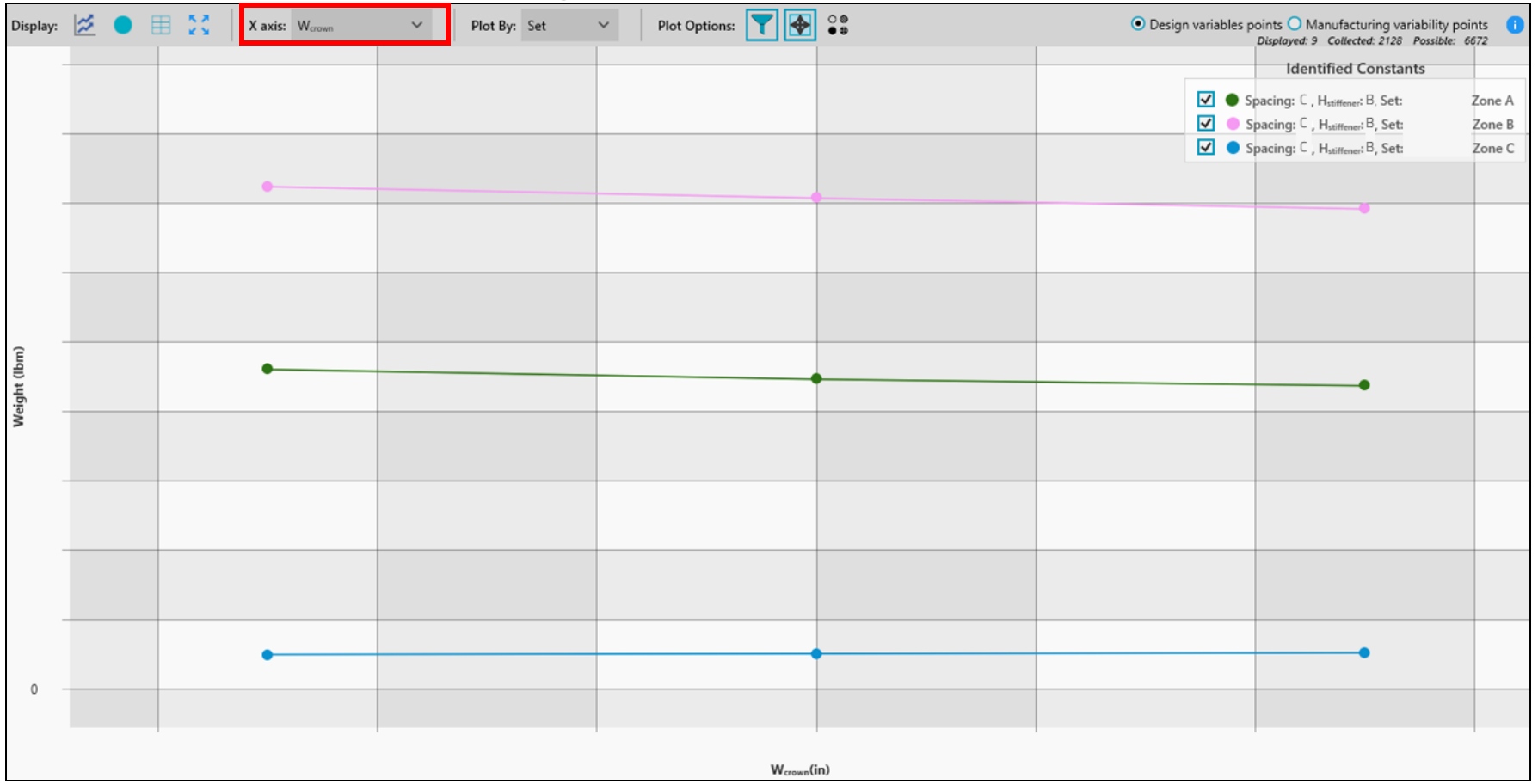
Lower $H_{Stiffener}$

Higher $H_{Stiffener}$

Producibility Sizing

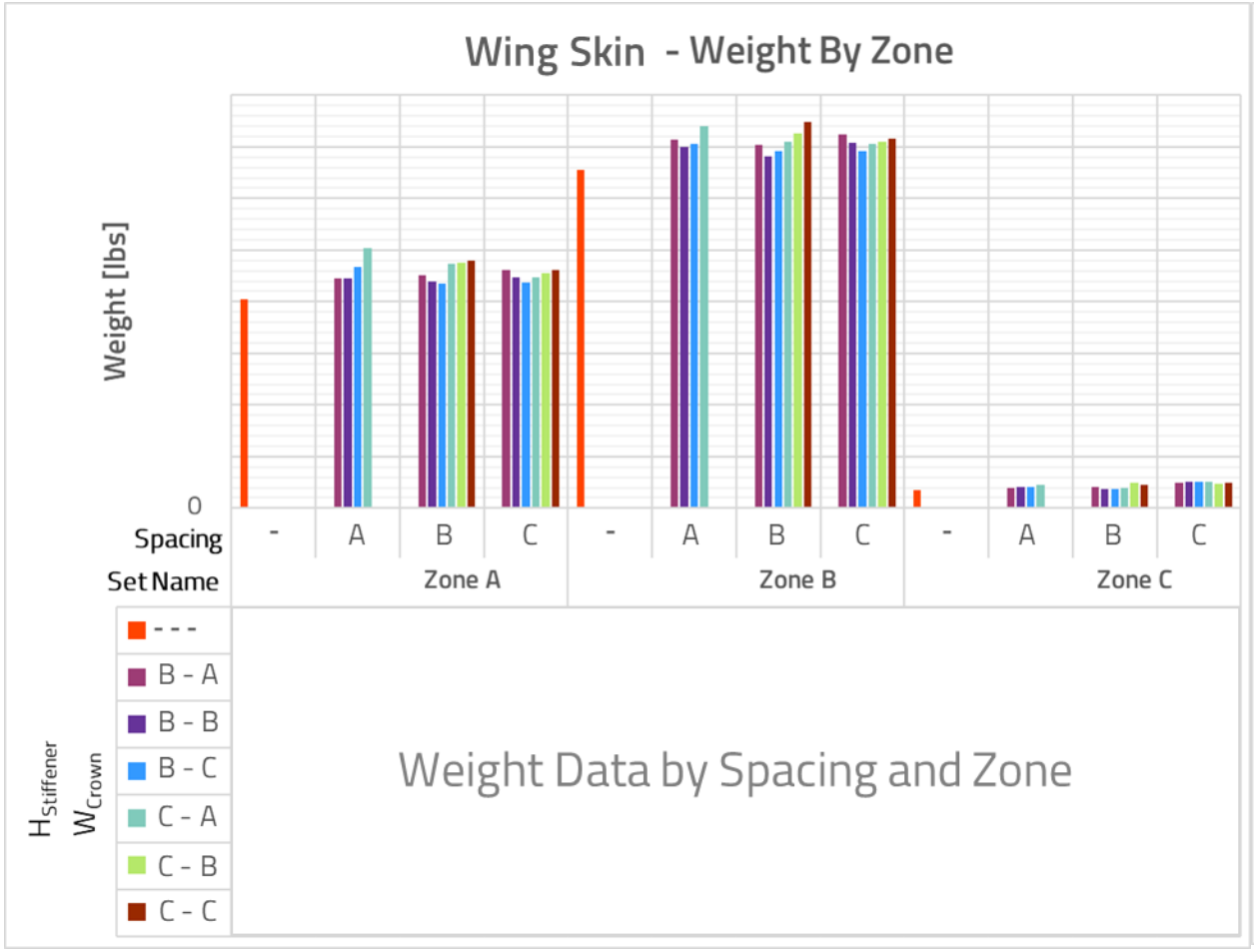
Jetzero

Wing Skin Set – Sorted by W_{Crown}



Lower W_{Crown} **Higher W_{Crown}**

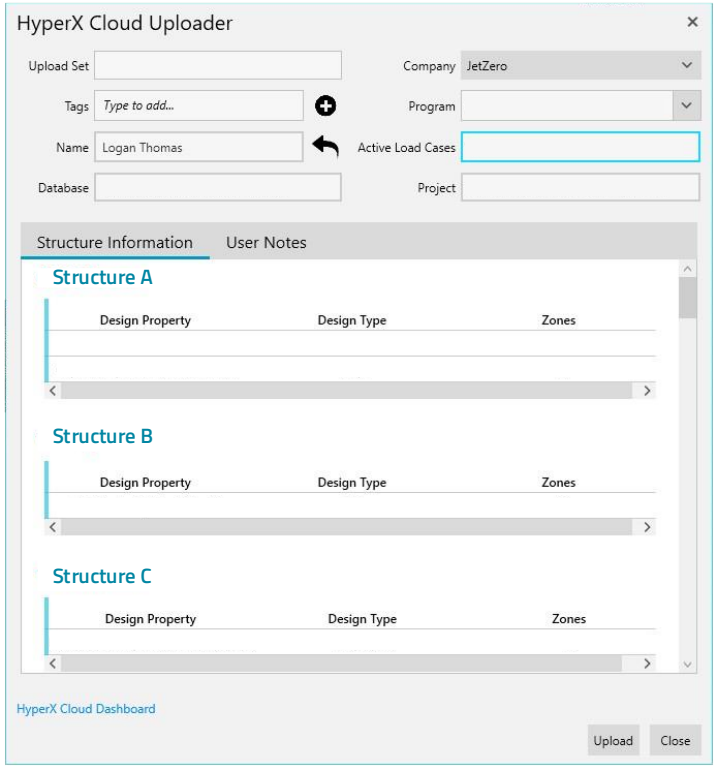
Producibility Sizing



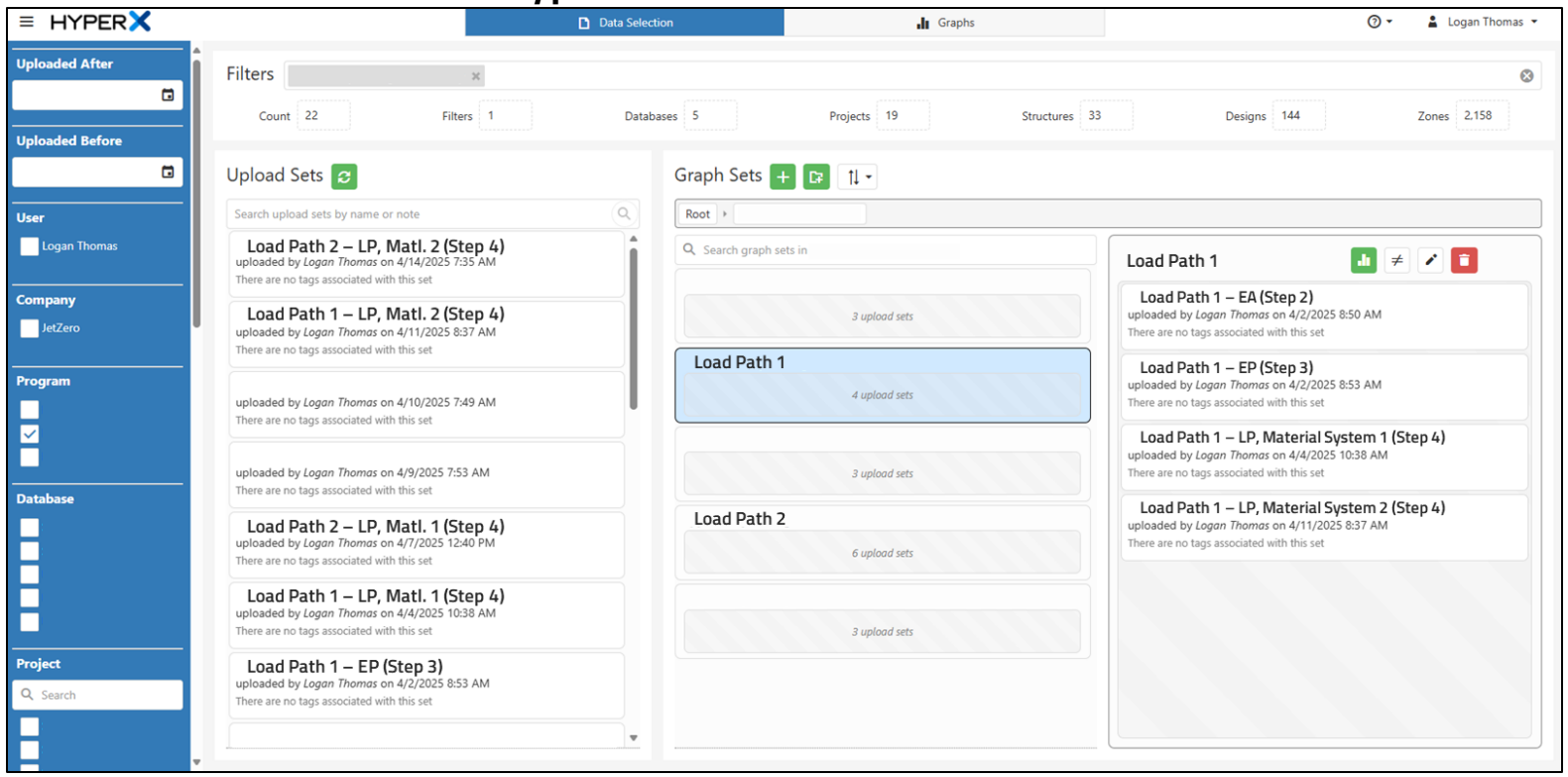
Anchor Point Weight Δ = +5.5%

Compare Trade Study Results via HyperX Dashboard

HyperX Dashboard Upload

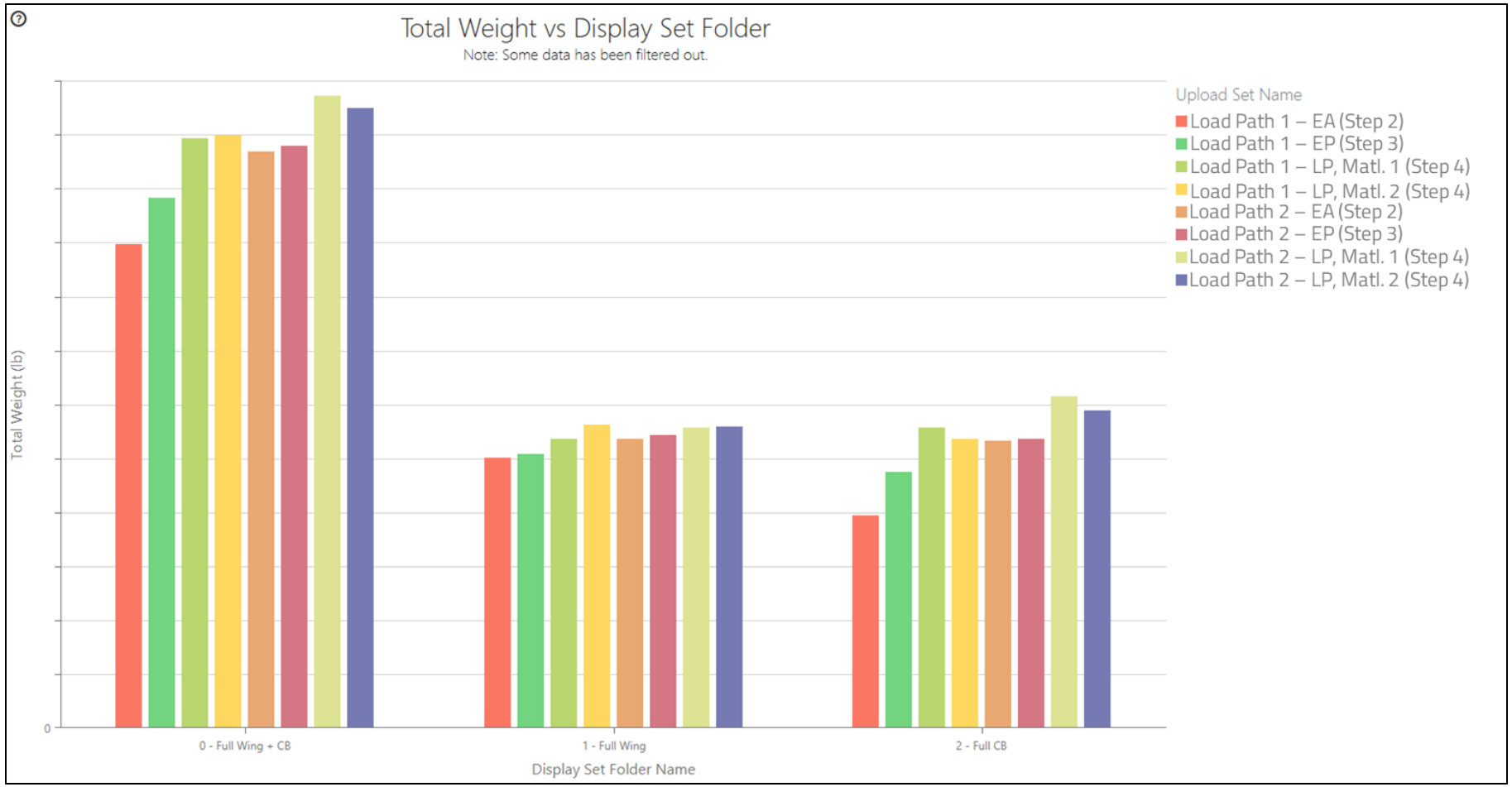


HyperX Dashboard Database



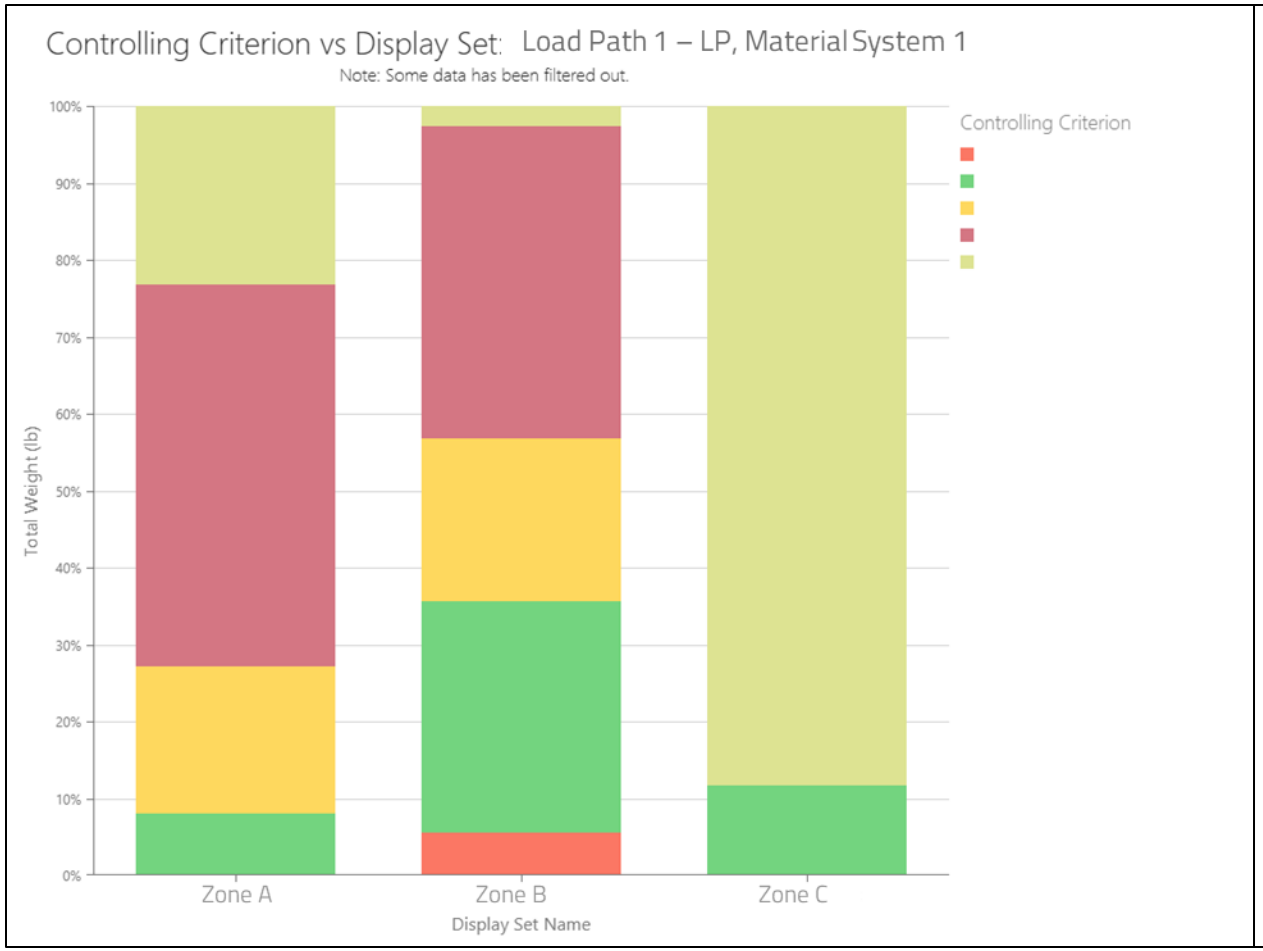
Quickly Graph HyperX Sizing Results for Comparisons

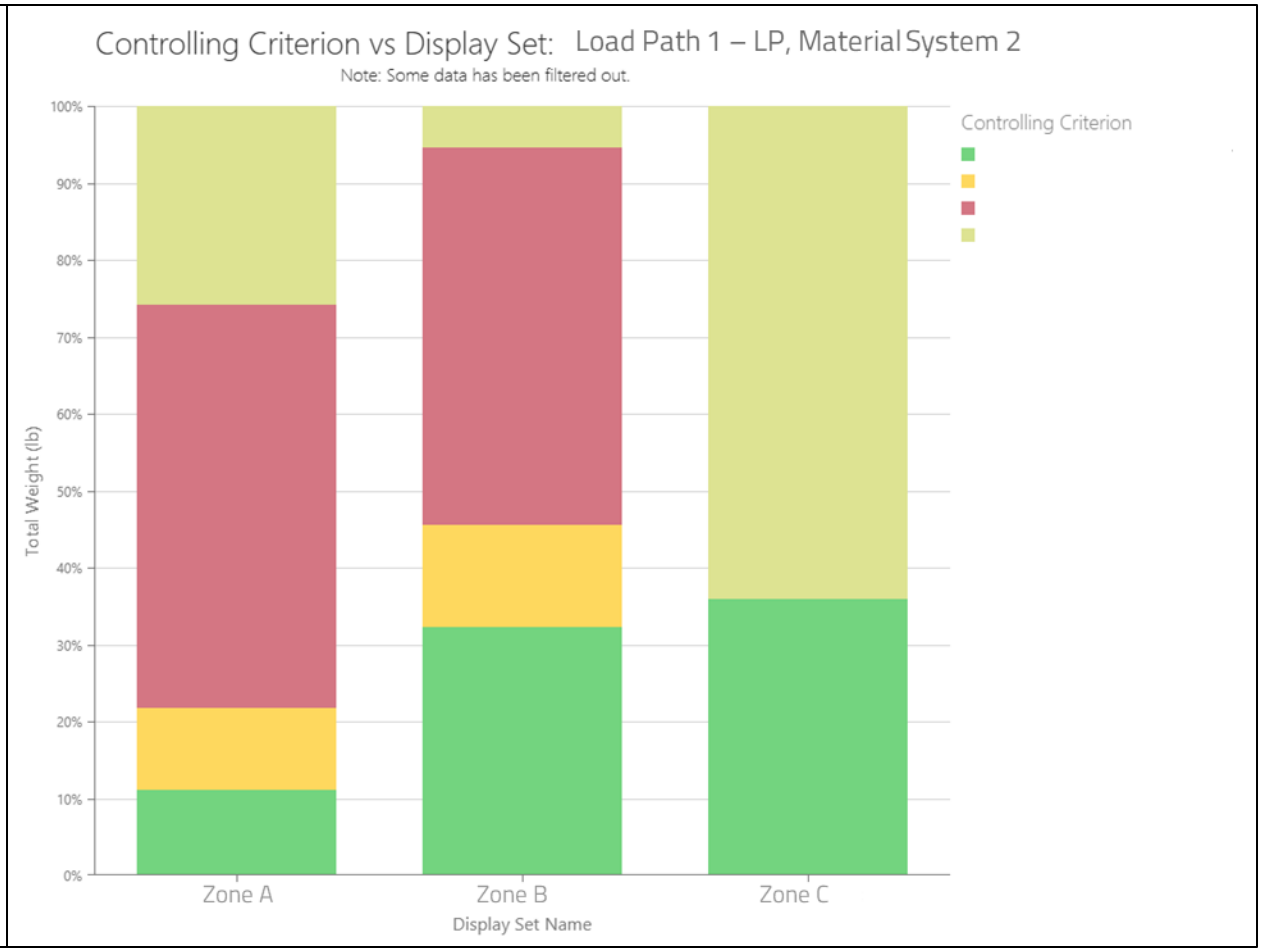
Compare Trade Study Results via HyperX Dashboard



Compare Total Weight between Trade Study Configurations

Compare Trade Study Results via HyperX Dashboard

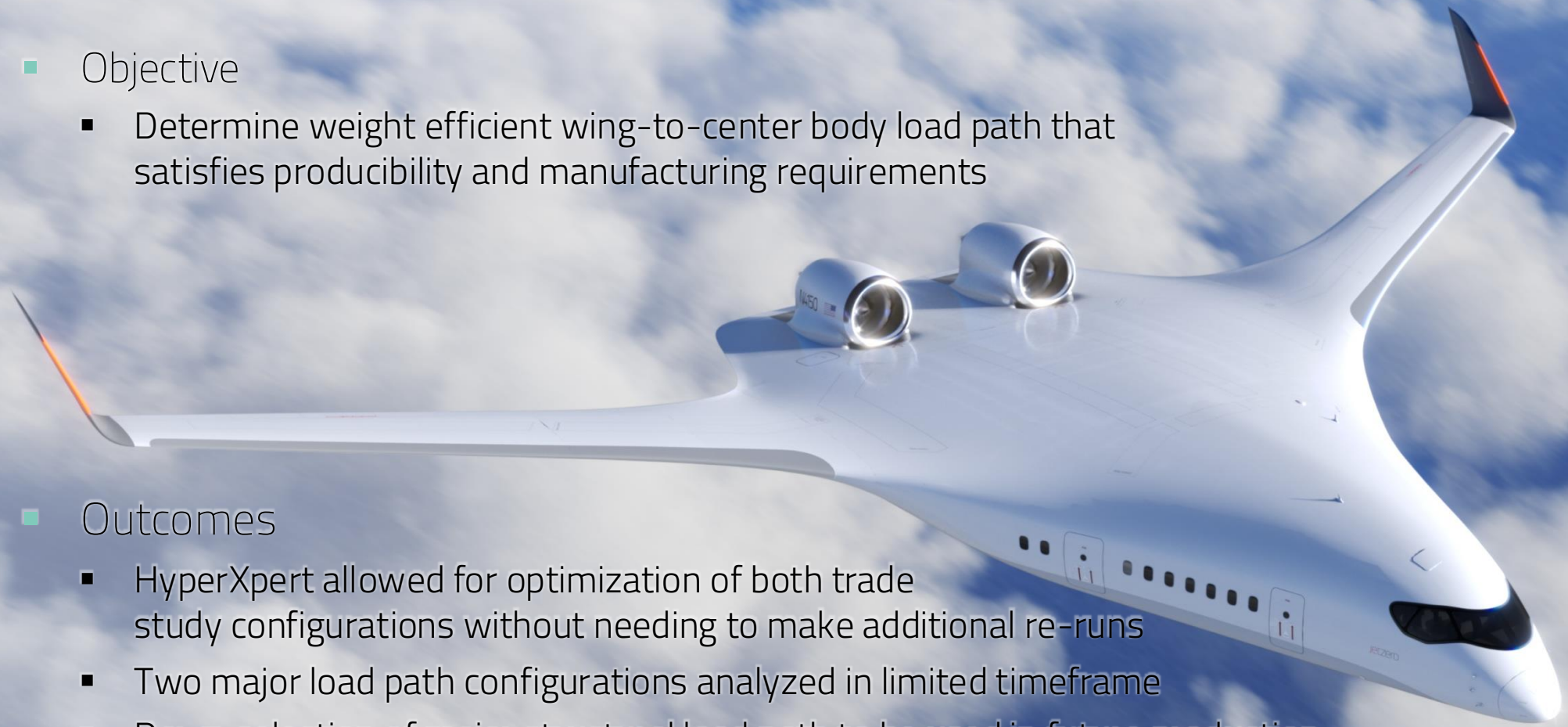




Compare % Controlling Criterion between Different Material Systems

Key Takeaways

- Objective
  - Determine weight efficient wing-to-center body load path that satisfies producibility and manufacturing requirements



- Outcomes
  - HyperXpert allowed for optimization of both trade study configurations without needing to make additional re-runs
  - Two major load path configurations analyzed in limited timeframe
  - Down selection of major structural load path to be used in future production activities