X-59 Quiet SuperSonic Technology Aircraft (QueSST)
Nose Structural Analysis and Certification Testing

Collier Aerospace HyperX Users Conference
June 17th to June 18th , 2025
NASA Langley, VA

Mahesh Patel (Ex-Swift) & Dr. Bill Giannetti (Ex-Swift)
Structural Analysis Group
Swift Engineering Inc., San Clemente, CA

Credits:
Gene Folsom, Jason Adair, Scott Zink
Skunkworks, Palmdale, CA
Lockheed Martin Aeronautics Co.

Contents:

Swift's JOURNEY

35+ Year Pedigree in Advanced Vehicles

Swift Engineering Inc.

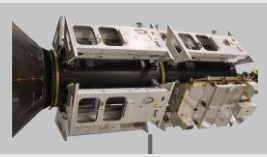
Swift Race Cars was created with DB-1 Championship Formula Race Car

Swift Race Cars was Purchased and Converted to Swift Engineering

Eclipse Aviation Single Engine Business Jet Design & Build

Northrop Grumman Fire Scout UAS Nosecone

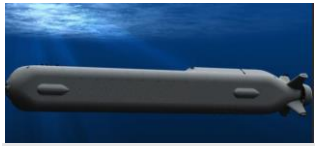
Boeing Product Development Echo Voyager Submarine XLUUV



Space X Iridium Satellite Dispenser

Sikorsky/Boeing Product Development SB-1 JMR Defiant Helicopter

NASA Low-Boom Flight Demonstrator (LBFD)



Boeing/HII ORCA SS 1-6

Lockheed Martin Product Development Raider X/FARA

1983 1991 2000 2007 2009 2013 2015 2016 2019 2020 2025

Killer Bee KB-1 Runway Independent UAS

Bat, Runway Independent UAS, 4 UAS configurations, Sold to Northrop Grumman

Northrop Grumman Global Hawk

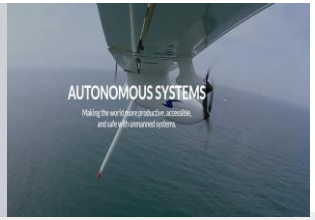
Swift Products and Technologies

Swift020 VTOL UAS Featuring X-Blade Technology™

HIRO Telepresence Robotic Operation

Swift High Altitude Long Endurance UAS

Swift021 All Electric VTOL Transitional UAS



Autonomous Systems

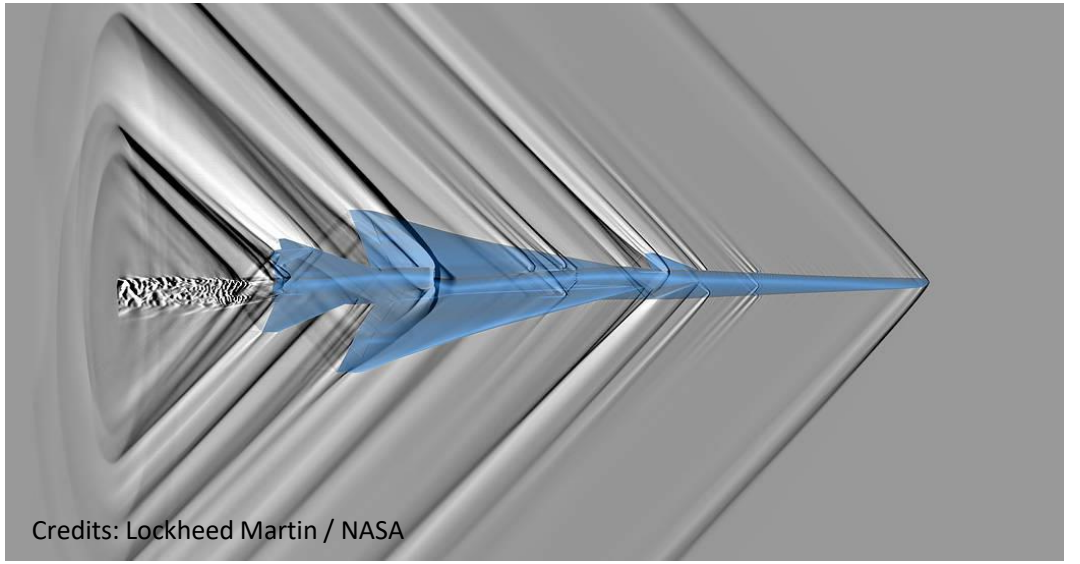
2014 2016 2018 2020 2021

1. Project Overview

- X-59 designed to demonstrate reduction in Sonic Boom signature.
- Nose structure helps divert air flow while providing controlled aerodynamic pressure distribution.
- **Design, Substantiate and Manufacture the Nose Structure**
- **Critical to maintain dimensional stability.**
- **Use FEM analysis and physical testing for certification.**

X-59 CONFIGURATION	
Max Design Gross Weight	25,000 lbs
Empty Weight	14,990 lbs
Fuel	8,700 lbs
Payload	600 lbs
Design Mach	1.4
Loudness	<75 PLdB
Engine	1xF414-GE-100
Landing Gear	F-16 Blk25 NLG
	F-16 Blk25 MLG

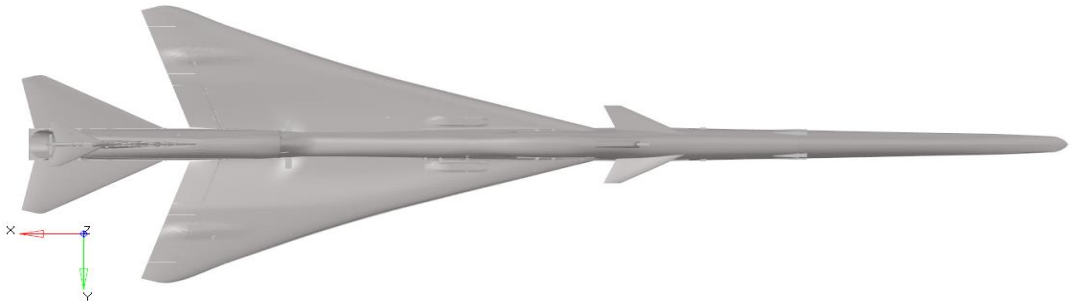
Credits: Lockheed Martin / NASA



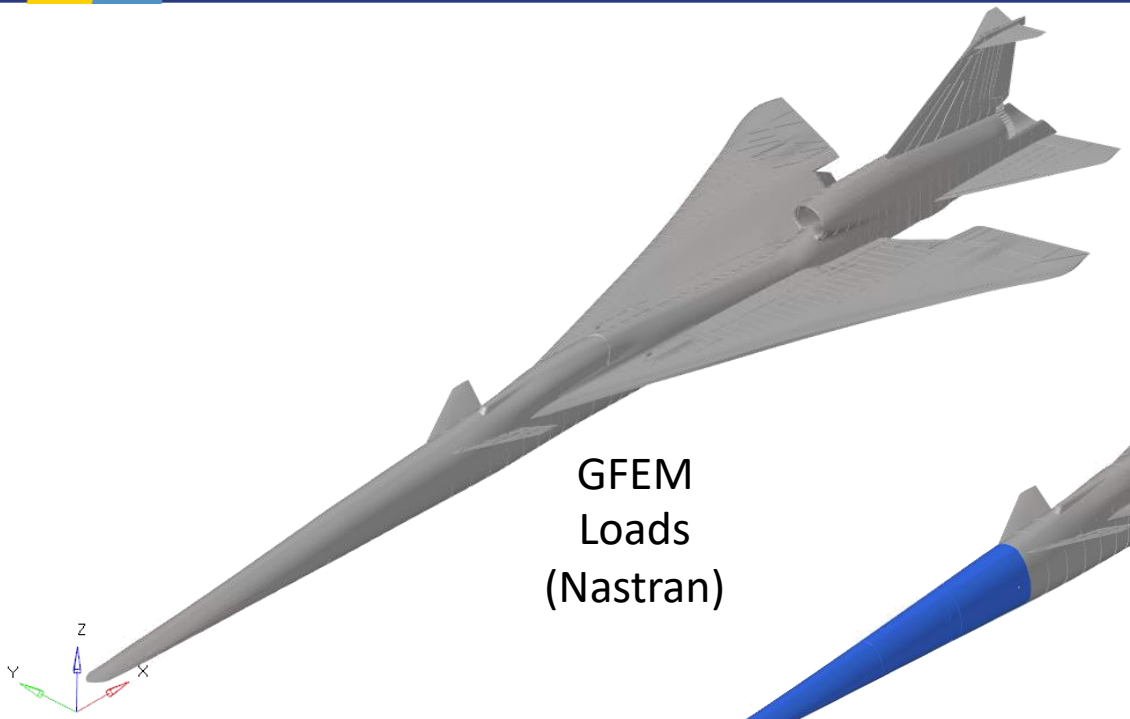
Credits: Lockheed Martin / NASA

2. Design Criteria

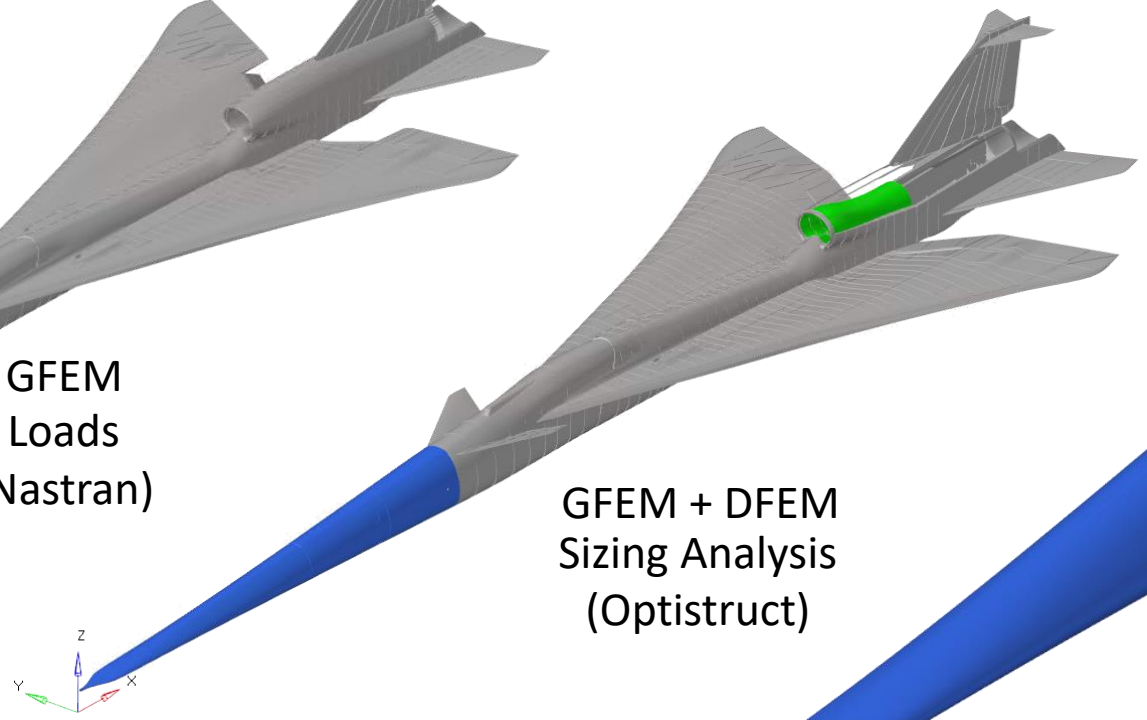
- Pressure Capability
- Pressure Dimensional Stability
- Impact Pressure Capability Requirements
- Temperature Capability Requirements
- Mass Properties
- Center of Mass
- Useful Life
- Operational Service Life



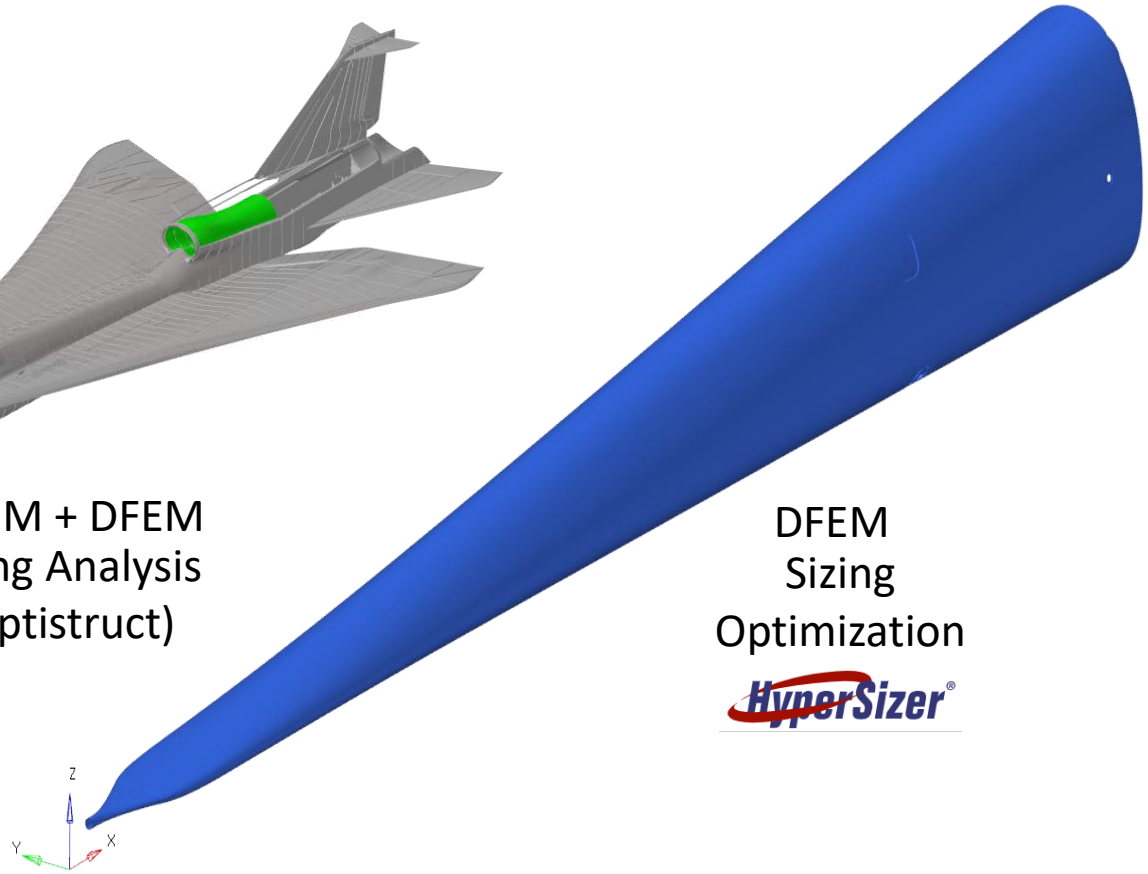
3. Loads and FEM Models



GFEM
Loads
(Nastran)



GFEM + DFEM
Sizing Analysis
(Optistruct)



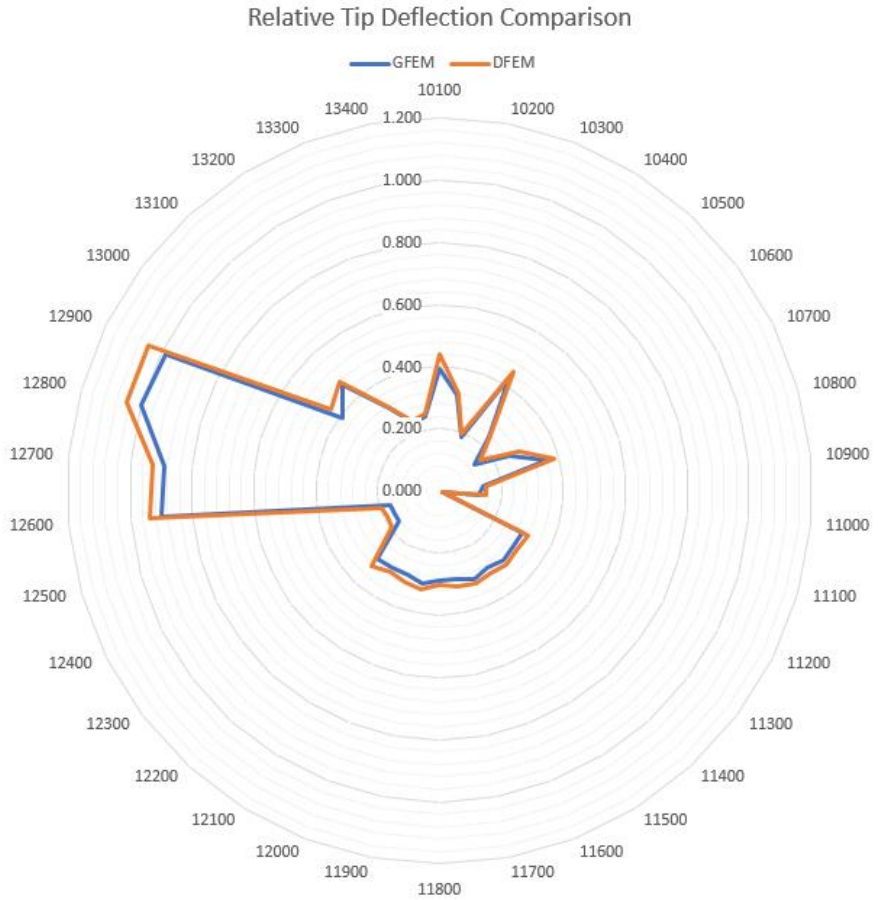
DFEM
Sizing
Optimization

HyperSizer®

- Global finite element model (GFEM) developed by LMA.
- A detailed finite element model (DFEM) was developed by Swift for sizing using HyperSizer.
- DFEM consists of Cored Composite Panels, Metallics, Composite Bulkheads, Fasteners and Adhesive Bonds

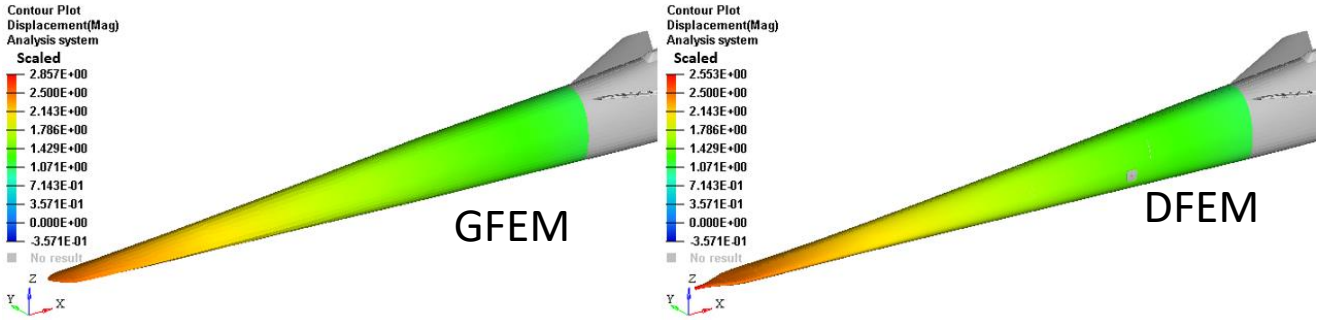
3. Loads and FEM Models

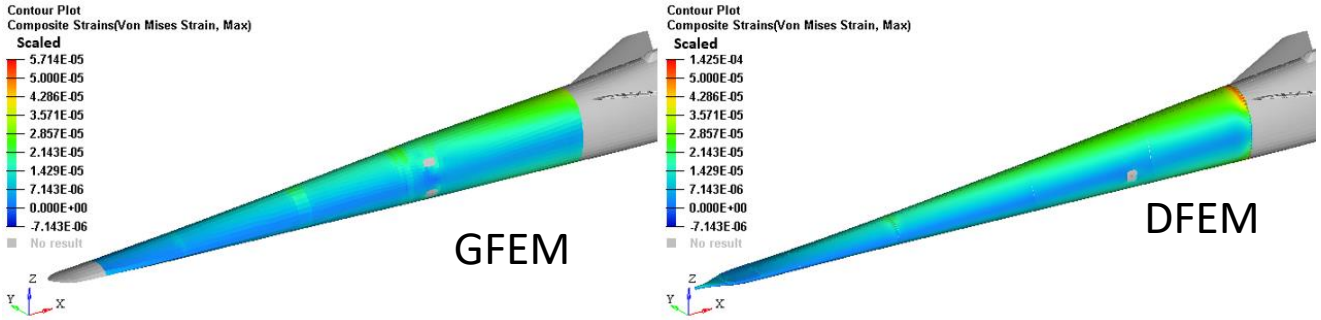
- Loads mapping correlation:



Select Loadcases

Displacement



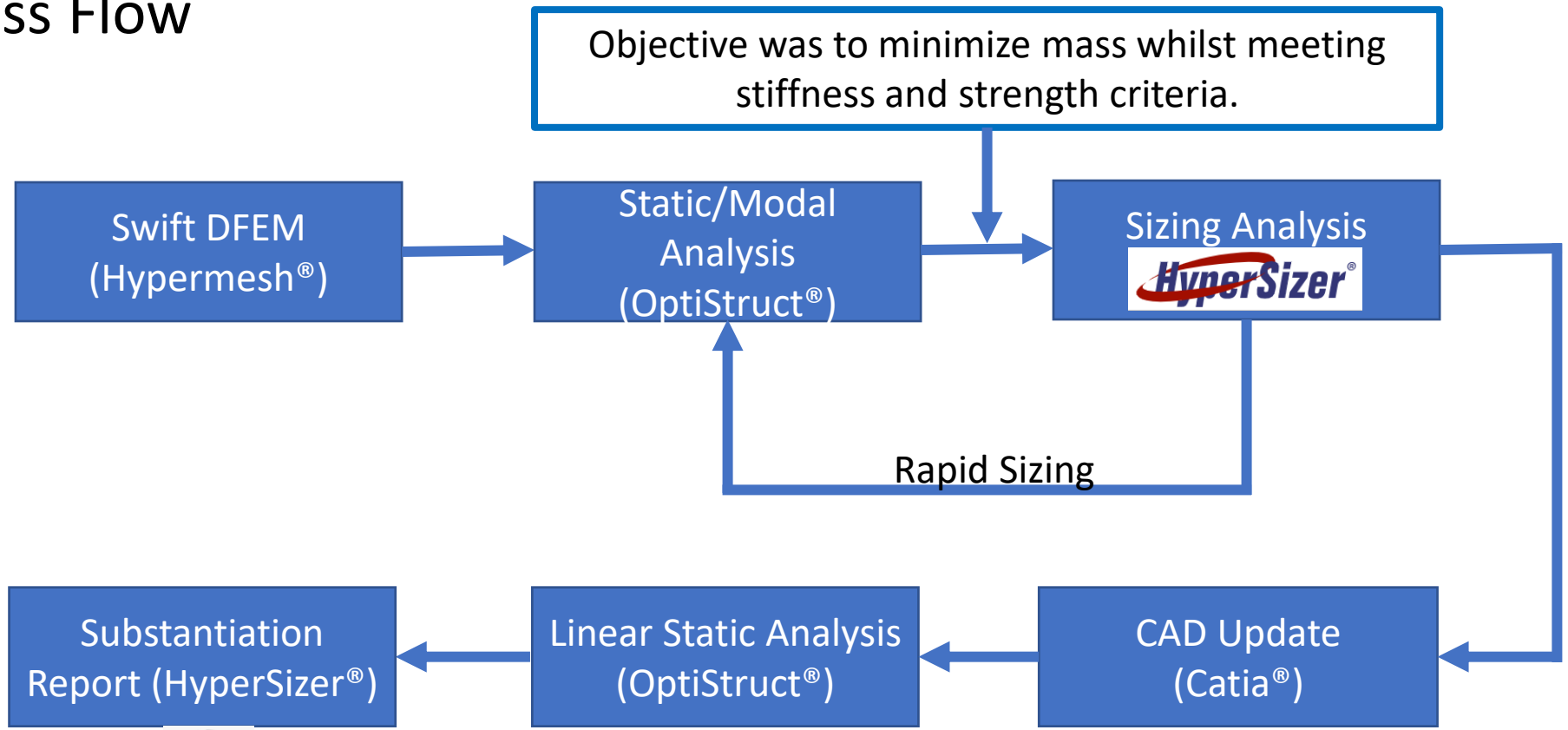


Strain

LMA GFEM v. Swift DFEM

4. Analysis and Sizing

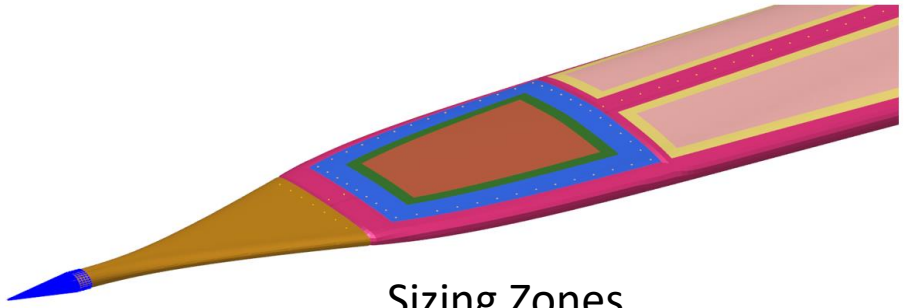
- Process Flow



147 page MS Word substantiation report

4. Analysis and Sizing

- Sizing Analysis (HyperSizer®)



Sizing Zones

Metallic Failure Criteria
Isotropic Strength, Ultimare, Von Mises-Hill Criterion
Isotropic Strength, Fatigue, Tension
Metalic Bearing - Discrete
Fastener Metallic Shear Out
Fastener Matellic Pull-Through
Fastener Metallic Net Section
Crippling

Composite Failure Criteria
Composite Strength, Laminate, Compression, Open Hole (OHC)
Composite Strength, Laminate, Tension, Filled Hole (OHT)
Composite Strength, Hoffman Interaction
Composite Strenght, Interlaminar Shear
Composite Strength, Interlaminar Tension
Wrinkling, Eqn 1, Isotropic or Honeycomb Core, X, Y & Interaction
Intercell Dimpling, X, Y & Interaction
Shear Crimpling, Min X, Y (Hexcel)
Ramp Core Shear
Ramp ILT + ILS Interaction Check 2
Ramp ILS
Joint, Bolted, Single Hole, Bearing, Composite Laminate Allowable
Composite Bearing-Bypass - Discrete
Fastener Laminate Shear Out
Fastener Laminate Pull-Through
Fastener Laminate Net Section
Crippling

1. Assemblies, parts and features organized into individual optimization sizing variables/zones (spreadsheet).
2. Effective laminates are used initially to determine overall ply percentages and laminate thicknesses.
3. Discrete laminates used for margin calculations and ply orientations.
4. Designs iterated until all margins are positive for each ply and metallic.

4. Analysis and Sizing

Lowest Margin of Safety for Each Analysis by Component						
Component	Concept / Object	MS	Load Case	Lim/Ult	AID	Analysis
80000101	Top Stack	2.25	14380	Ultimate	144	Composite Strength, Hoffman Interaction
		0.65	10904	Ultimate	203	Composite Strength, Interlaminar Shear
		465	500001	Ultimate	204	Composite Strength, Interlaminar Tension
		1.65	500001	Ultimate	223	Composite Strength, Laminate, Compression, Open Hole (OHC)
		2.2	14416	Ultimate	229	Composite Strength, Laminate, Tension, Filled Hole (FHT)
80000102	Top Stack	2.15	14380	Ultimate	144	Composite Strength, Hoffman Interaction
		0.34	14380	Ultimate	203	Composite Strength, Interlaminar Shear
		155	500000	Ultimate	204	Composite Strength, Interlaminar Tension
		1.15	14380	Ultimate	223	Composite Strength, Laminate, Compression, Open Hole (OHC)
		2.5	14344	Ultimate	229	Composite Strength, Laminate, Tension, Filled Hole (FHT)
80000103	Top Face	3.95	14380	Ultimate	90	Wrinkling, Eqn 1, Isotropic or Honeycomb Core, X, Y & Interaction
		22.5	10776	Ultimate	94	Intracell Dimpling, X, Y & Interaction
		1.45	500001	Ultimate	223	Composite Strength, Laminate, Compression, Open Hole (OHC)
		3.75	14452	Ultimate	229	Composite Strength, Laminate, Tension, Filled Hole (FHT)
	Core	1.15	14380	Ultimate	105	Shear Crimping, Min X, Y {Hexcel}
	Bottom Face	3.4	14380	Ultimate	90	Wrinkling, Eqn 1, Isotropic or Honeycomb Core, X, Y & Interaction
		115	14380	Ultimate	94	Intracell Dimpling, X, Y & Interaction
		1.8	14380	Ultimate	223	Composite Strength, Laminate, Compression, Open Hole (OHC)
		4.75	14380	Ultimate	229	Composite Strength, Laminate, Tension, Filled Hole (FHT)

Example of HyperSizer Sizing Spreadsheet Output Report:

Sandwich Panel, Core Ramp Shear

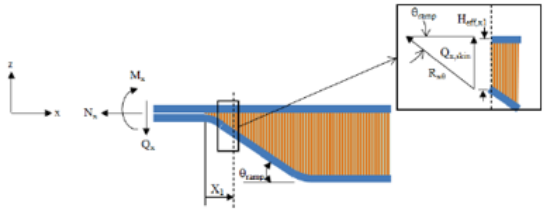


Figure 9-6, Core Shear Interaction (Configuration 1 Shown)

Margin of safety written against the core shear strength at the ramp:

$$M.S. = \frac{1}{\sqrt{\left(\frac{\tau_{xz,x1}}{F_{su,13}}\right)^2 + \left(\frac{\tau_{yz}}{F_{su,23}}\right)^2}} - 1 \quad (39)$$

Transverse shear stresses at location x_1:

$$\tau_{xz,x1} = \frac{Q_{x,total}}{H_{eff,x1}} \quad (40)$$

$$\tau_{yz} = \frac{Q_y}{H_{eff,x1}} \quad (41)$$

Effective height at location x_1 (user input):

$$H_{eff,x1} = x_1 tan\theta_{ramp} + \frac{t_{OML} + t_{IML}}{2} \quad (42)$$

Table 9-10 lists the user constants required by the analysis plugin to compute the margin of safety for core shear interaction.

Table 9-10, Core Shear Interaction User Constants

Variable	Variable Description	Default Value
t_{IML}	Inner mold-line facesheet thickness (in)	0.066
t_{OML}	Outer mold-line facesheet thickness (in)	0.066
θ_{ramp}	Ramp Taper Angle (degrees)	0
$\alpha_{ramp,dir}$	Ramp Direction (between 0 and 90 degrees)	0
n	Nx Load Ratio	0.5
F_{su13}	Core 1,3 Shear Stress Allowable (ksi)	258
F_{su23}	Core 2,3 Shear Stress Allowable (ksi)	168
x1	Distance from End of Ramp (in)	0.5
Nx thermal	Additional thermal loads, Nx (lb/in)	0
Ny thermal	Additional thermal loads, Ny (lb/in)	0
Configuration	Changes how the free body loads are computed	1

HyperSizer Core Ramp Analysis:

4. Analysis and Sizing

Example of Automated MS Word Sizing Report:

Analysis ID = 223 = Composite Strength, Laminate, Compression, Open Hole (OHC)

Assembly	**FS333.0**
Component ID:	**80000119**
Load Case:	**14308**
Element ID:	**80198237**
Object ID:	**Top Stack**

Panel Loads

	N_x (lb/in)	N_y (lb/in)	N_{xy} (lb/in)	M_x (lb in/in)	M_y (lb in/in)	M_{xy} (lb in/in)	Q_x (lb/in)	Q_y (lb/in)
Strength Loads	-117.0	-1519.	48.82	3.8557	-5.3504	0.09593	35.79	-1.4363

Object Loads:

	N_x (lb/in)	N_y (lb/in)	N_{xy} (lb/in)	M_x (lb in/in)	M_y (lb in/in)	M_{xy} (lb in/in)	T (°F)	TT Grad (°F/in)
Strength Loads	-117.0	-1519.	48.82	3.8557	-5.3504	0.09593	200.0	0.

Laminate Base Percentages of Plies and Strains in the X direction

The strains at the laminate mid-plane and bottom and top fibers are:

Variable	Midplane	Bottom Outer Fiber	Top Outer Fiber
ε_1	992.5 µin/in	1704. µin/in	281.2 µin/in
ε_2	-2839. µin/in	-3642. µin/in	-2036. µin/in
ε_{12}	189.3 µin/in	208.2 µin/in	170.5 µin/in

Note: The outer fiber strains include a bending correction factor of 1.3.

Strains and Laminate Allowables in -45° Analysis Direction

The percentages of plies in this analysis direction are:

0° Plies: 30.0
45° Plies: 40.0
90° Plies: 30.0

The stress allowable, interpolated from the "Laminate Based Strain Allowables" plots is:

Material: LMA :IM7_MTM45_FAB_200W (#B Basis Fabric, From Lwr Bound Interpolation File)
Method: %45s
Value for this Analysis Direction: 40.0
Strain Allowable, ε_{OHC}: 4195. µin/in

The applied strains transformed into analysis direction as:

$\{\varepsilon_1, \varepsilon_2, \varepsilon_{12}\}$ = {-1173., -864.8, 5345.} µin/in @ Bottom Outer Fiber

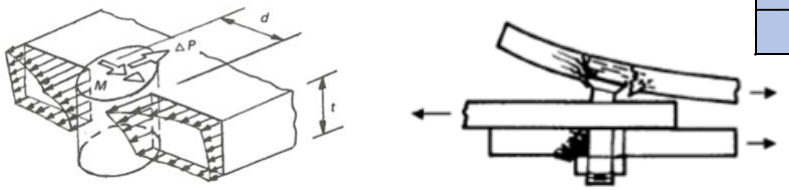
The Margin-of-Safety is,

Variable	Allowable Strain	Applied Strain	MS
ε_{OHC}	4195. µin/in	-1173. µin/in	**3.9096**

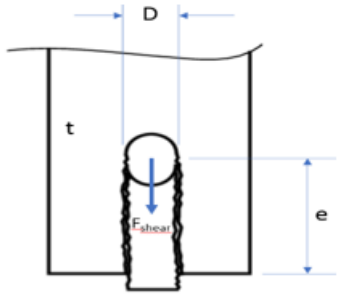
4. Analysis and Sizing

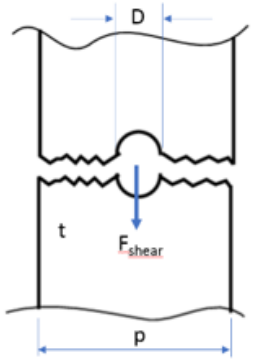
- Joint Analysis

Joint Failure Criteria



Credits: Collier HyperSizer®





Bulkhead Margin Summary					
Analysis	MS	Load Case	Lim/Ult	Comp.	Object
Joint, Bolted, Single Hole, Bearing, Composite Laminate Allowable	15.0	10776	Ultimate	80001346	Top Stack
Composite Bearing-Bypass - Discrete	15.0	15141	Ultimate	80001039	Top Stack
Fastener Laminate Shear Out	12.2	10764	Ultimate	80000122 Fastener80309018	Top Stack
Fastener Laminate Pull-Through	High	10768	Ultimate	80000122 Fastener80309010	Top Stack
Fastener Laminate Net Section	84.4	10764	Ultimate	80000122 Fastener80309018	Top Stack

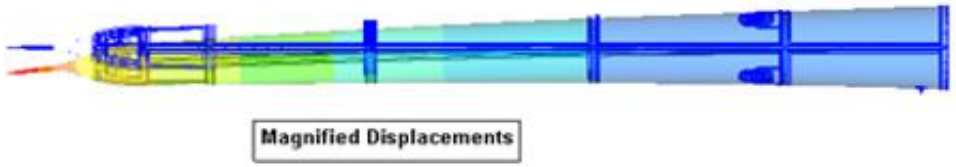
Example of Joint Analysis Results from HyperSizer®

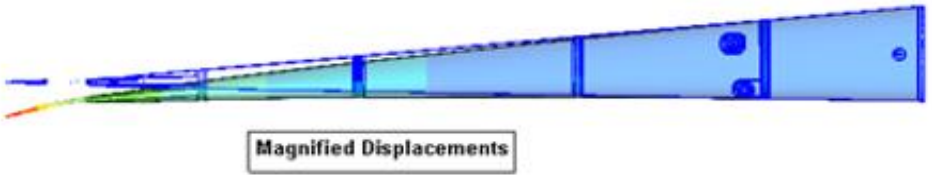
DEM Model	LOADCASE ID	Bolt ID	Axial F	Shear1	Shear2	Bolt Size	Fastener Head Diameter d	Bolt Allowable Tension	Bolt Allowable Single Shear	Shear Resultant F	Tension MS	Shear MS	Rt=Pt/Ptu (min Axial assigned to +15 lbs to aid Solver)	Rs	Fastener Combined MOS ((x^2*Rt^2+x^3*Rs^3)-1=0) using numerical solver
SEI DFEM	14380	80305079	-92	-1001	202	3/16	0.2578	1400	2300	1021	Compression	1.25	0.0107	0.4440	1.25
Boom Long Probe	FTB001 Aero	80312015	188	1039	-8	3/16	0.2578	1400	2300	1039	6.43	1.21	0.1345	0.4516	1.15
Boom Short Probe	FTB001 Aero	80312015	188	1042	-8	3/16	0.2578	1400	2300	1042	6.44	1.21	0.1344	0.4530	**1.14**

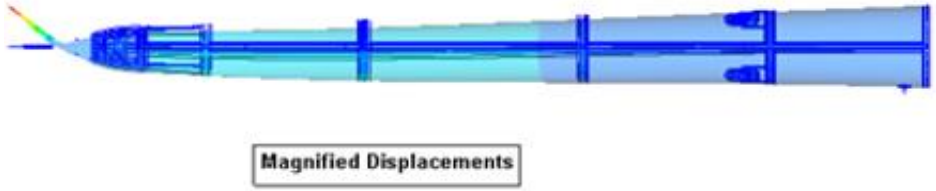
Example of Fastener Analysis Results

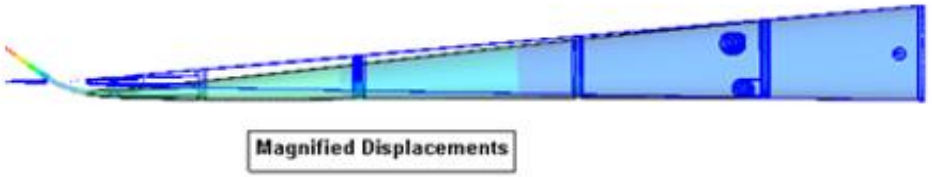
4. Analysis and Sizing

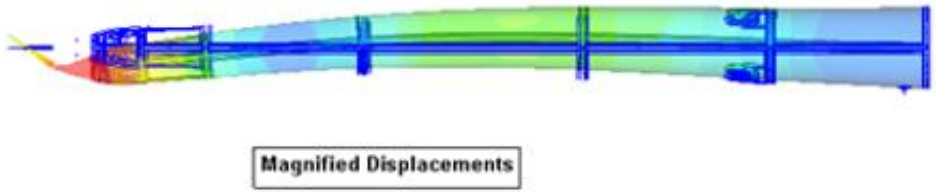
- Modal, Buckling and Crippling

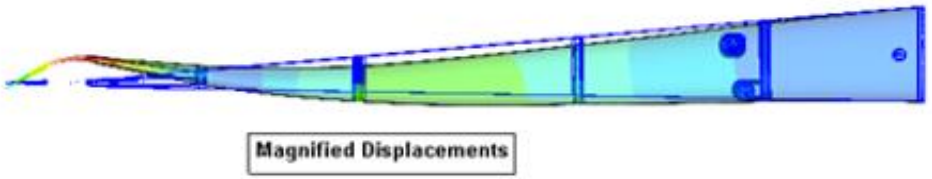








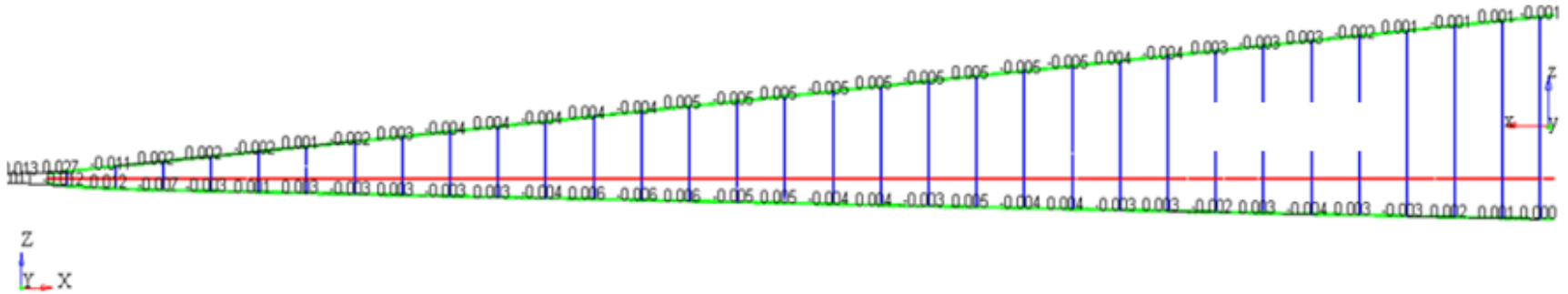




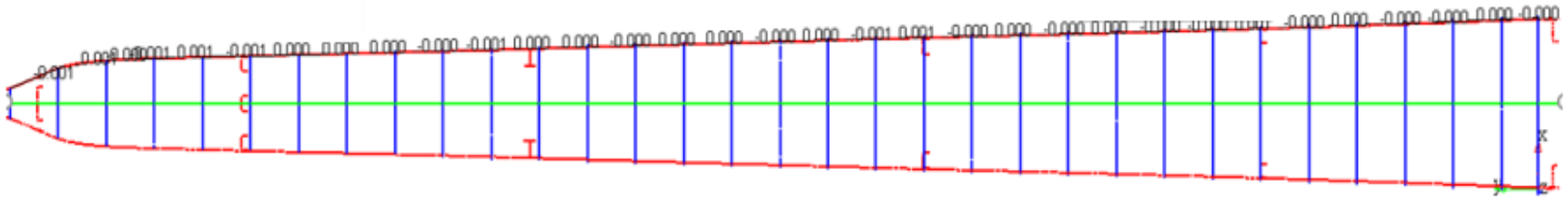
- Linear Buckling analysis performed on Nose assembly for each loadcase
- Crippling check performed on each assembly and part.

4. Analysis and Sizing

- Dimensional Stability



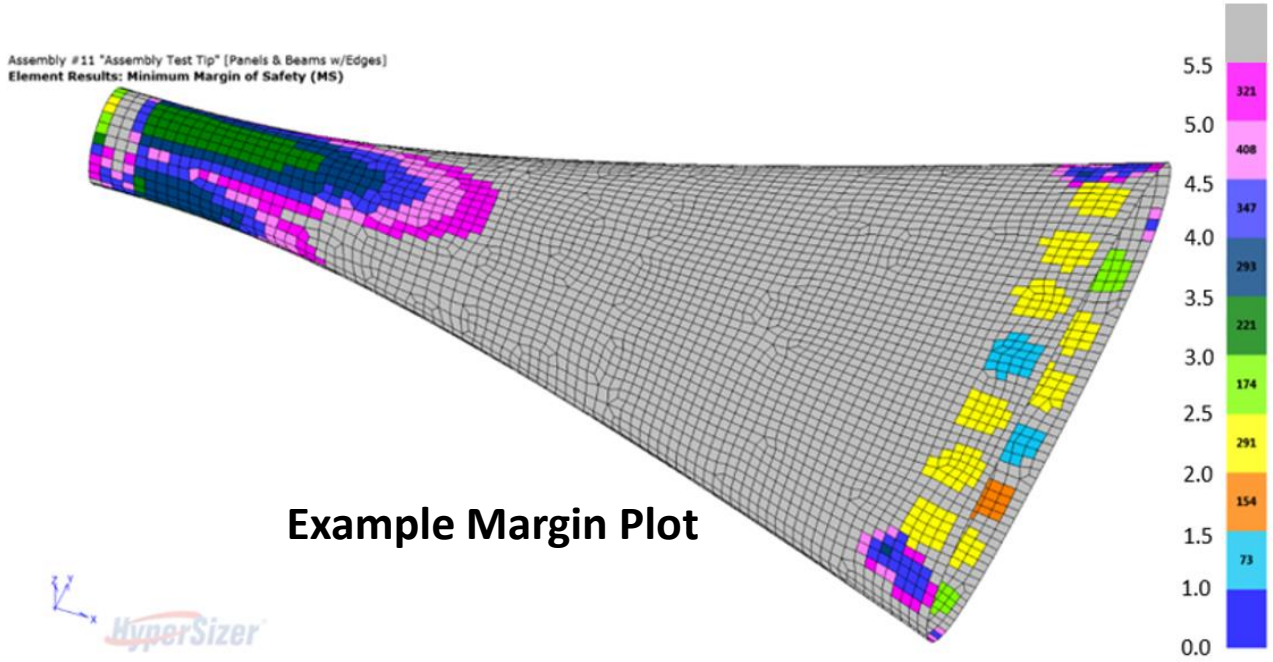
Example



Dimensional stability measurement locations (Cruise Level Flight Loadcase)

4. Analysis and Sizing

- Margin of Safety



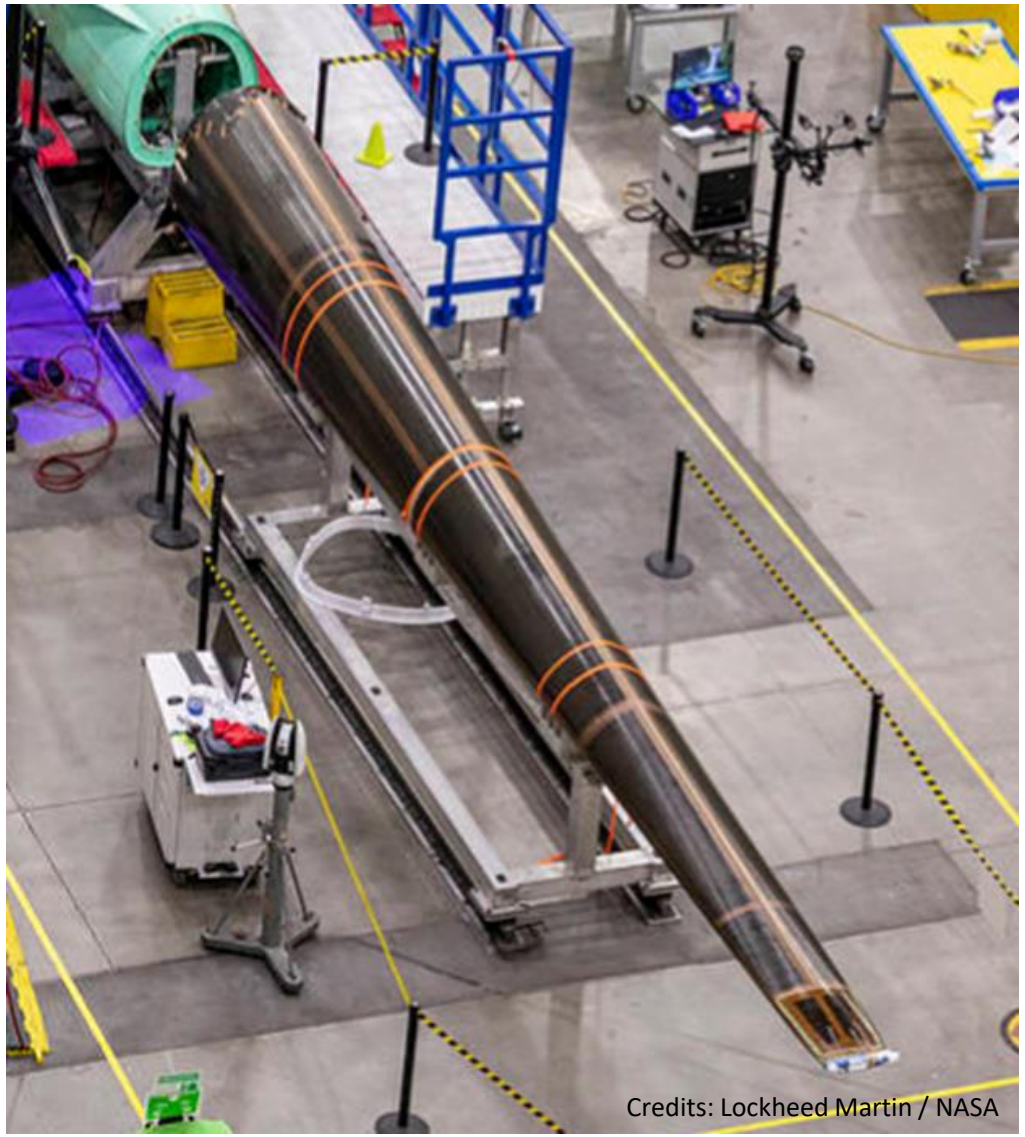
Example Margin Plot

Composite Failure Criteria	Scaled MS	Load Case	Lim/Ult	Comp.	Object
Composite Strength, Laminate, Compression, (OHC)	1.28	10960	Ultimate	80001591	Top Stack
Composite Strength, Laminate, Tension, (OHT)	4.20	10764	Ultimate	80000140	Top Stack
Composite Strength, Hoffman Interaction	3.80	10960	Ultimate	80001591	Top Stack
Composite Strenght, Interlaminar Shear	1.24	14380	Ultimate	80000102	Top Stack
Composite Strength, Interlaminar Tension	100.00	10904	Ultimate	80000140	Top Stack
Wrinkling, Eqn 1Honeycomb Core, X, Y & Interaction	12.80	14380	Ultimate	80000103	Btm Face
Intercell Dimpling, X, Y & Interaction	45.00	10778	Ultimate	80000103	Top Face
Shear Crimpling, Min X, Y (Hexcel)	4.60	14380	Ultimate	80000103	Core
Ramp Core Shear	0.90	10764	Ultimate	80000129	Top Stack
Ramp ILT + ILS Interaction Check 2	0.40	14452	Ultimate	80000129	Top Stack
Ramp ILS	7.20	500000	Ultimate	80000130	Top Stack
Joint, Bolted, Single Hole, Bearing, Composite Laminate Allowable	0.55	10904	Ultimate	80001450	Top Stack
Composite Bearing-Bypass - Discrete	0.26	10904	Ultimate	80001450	Top Stack
Fastener Laminate Shear Out	15.67	14752	Ultimate	80000101 Fstnr. 80306025	Top Stack
Fastener Laminate Pull-Through	0.16	14380	Ultimate	8000101 Fstnr 80305079	Top Stack
Fastener Laminate Net Section	3.23	14380	Ultimate	80000102 Fstnr 80311525	Top Stack
Crippling	1.65	14380	Ultimate	80000101 Fstnr 80311524	Top Stack

Example of HyperSizer® Sizing Results

- Single margin plot shows lowest margins of any selected failure criteria for each laminate, honeycomb, metallic or joint.
- Sized for Stiffness and Strength with

5. Test and Calibration



5. Test and Calibration

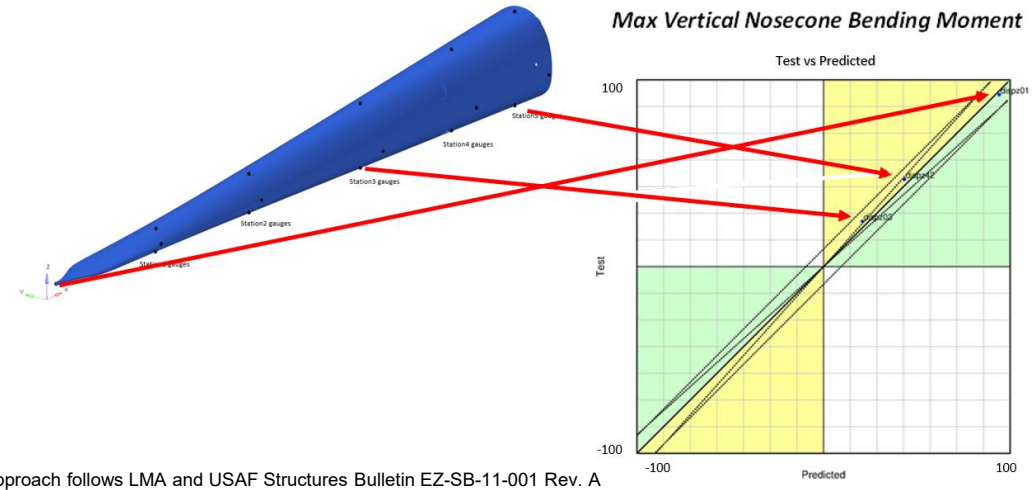
- Static Test

1. Full airframe proof test with only forward fuselage jacks engaged to match integrated forces and moments.
2. Series of strain gauges (uni-axial and rosettes) placed along the length of the Nose positioned at top, side and bottom outer surface of the Nose.
3. Nosecone tested to four independent proof loadcases.

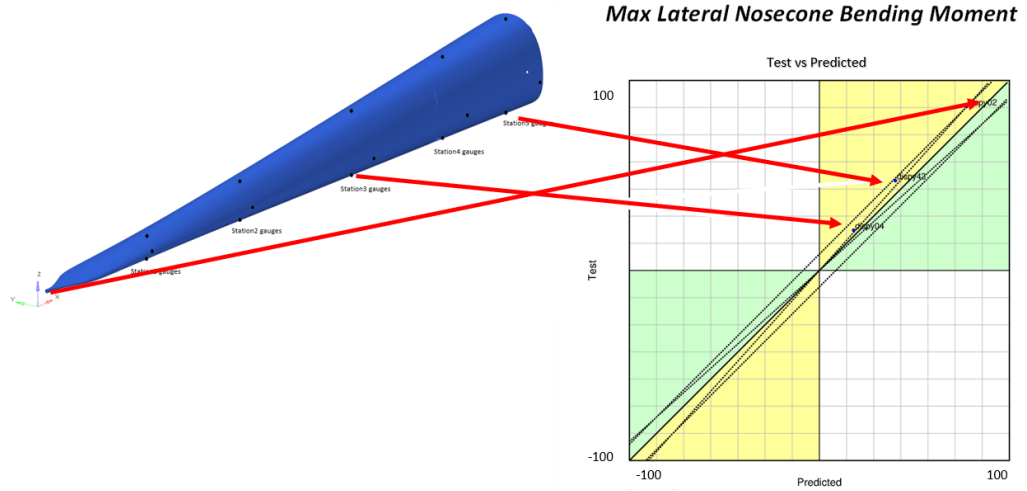
Credits: Lockheed Martin / NASA

5. Test and Correlation

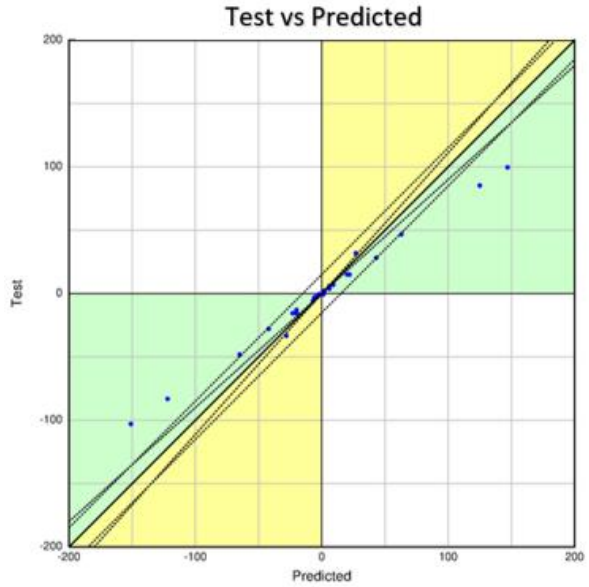
- Test Transducer Deflection and Strain Data Calibration



Approach follows LMA and USAF Structures Bulletin EZ-SB-11-001 Rev. A



Test Strain Data and Calibration



Station 1 Gauges

1. GFEM overpredicted strains and deflections and is therefore conservative.
2. All of the measured deflections are below the max allowable and strains are below the max allowable proof strain.
3. Tests show acceptable correlation to GFEM with minor updates to account for NLG lateral constraint.

6. Conclusions

- Composite Sizing using HyperSizer enabled a mass optimum design.
- Manufactured Nose assembly and delivered to LMA **on time** with full structural substantiation report.
- GFEM+DFEM Strain and deflection predictions were conservative compared with static proof tests.
- FEA models were calibrated and path to flight certification established.

Credits: Lockheed Martin / NASA