

Simplified Applied Loads of a Transonic Truss-Braced Wing Derived from Computational Fluid Dynamics

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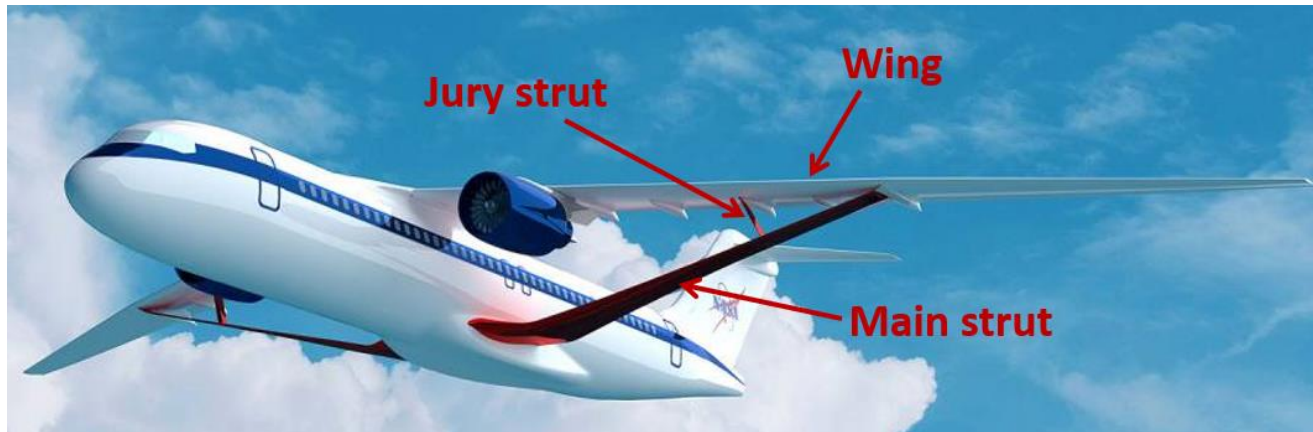
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Transonic Truss-Braced Wing (TTBW)

- TTBW: A transport aircraft concept under consideration by the NASA Advanced Air Transport Technology (AATT) project to help meet goals of ***reduced fuel burn, noise, and emissions*** for next generation subsonic fixed-wing aircraft

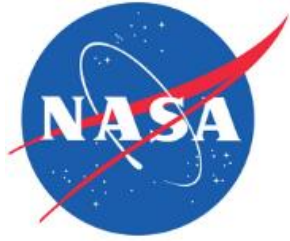


Transonic Truss-Braced Wing
(Subsonic Ultra-Green Aircraft Research, SUGAR)

SUGAR design:

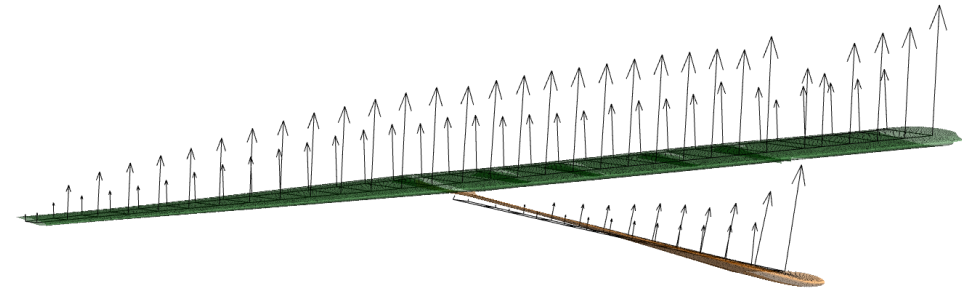
- Aspect ratio of 19.56
- Wing sweep 22.5°
- Projected 7% to 9% per seat reduction in fuel
- Mach 0.8

Evaluating the TTBW Concept

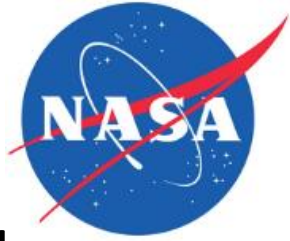


- Prior TTBW Research
 - Wind tunnel testing
 - Analysis of low-fidelity structural models
- Current research needs
 - Detailed structural analysis
 - Efficient, low-weight structural designs
 - Explicitly modeled joints
 - Testing
 - Static and dynamic loads

Required input:
Accurate set of
simplified
aerodynamic loads

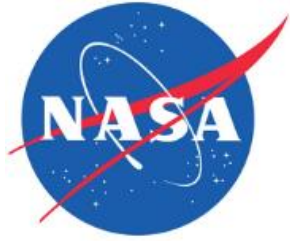


Overview



- Describing an approach for determining distributed load vectors along the wing and strut of the TTBW
- Given the unique architecture and aerodynamics of the TTBW
 - Used surface data from computational fluid dynamics (CFD)
- Employed a data transfer tool
- Assessed various mapping approaches
 - CFD surfaces (wing and strut)
 - Finite element (FE) load vectors (number and arrangement)
- Ensured suitable arrangement of load vectors for analysis and testing
- Conclusions

Data Transfer (Aero data to structural inputs)



- Discrete Data Transfer Between Dissimilar Meshes (DDTBDM) tool
 - Conservation of forces and moments
 - Integrate surface pressures and skin friction over source mesh
 - Map resulting load vectors into the target mesh

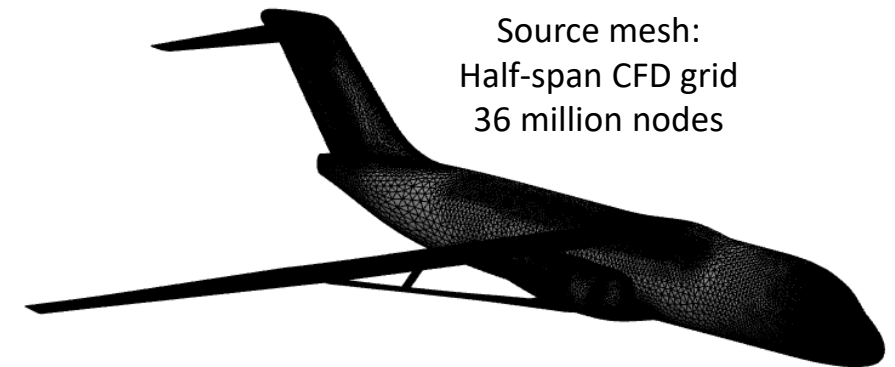
- Input:

SOURCE (fine mesh):
CFD grid



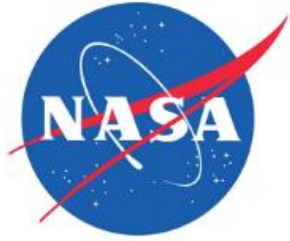
TARGET (course mesh):
Simplified FE mesh with grid
points only at the location of
desired load application points

- Output: Point forces and point moments on target mesh
 - Resulting point moments are larger when
 - Insufficient number of target points are chosen
 - Mismatch between the source and target surfaces
 - Large point moments are undesirable
 - Analysis: Produce unrealistic local rotations
 - Testing: Difficult to simulate

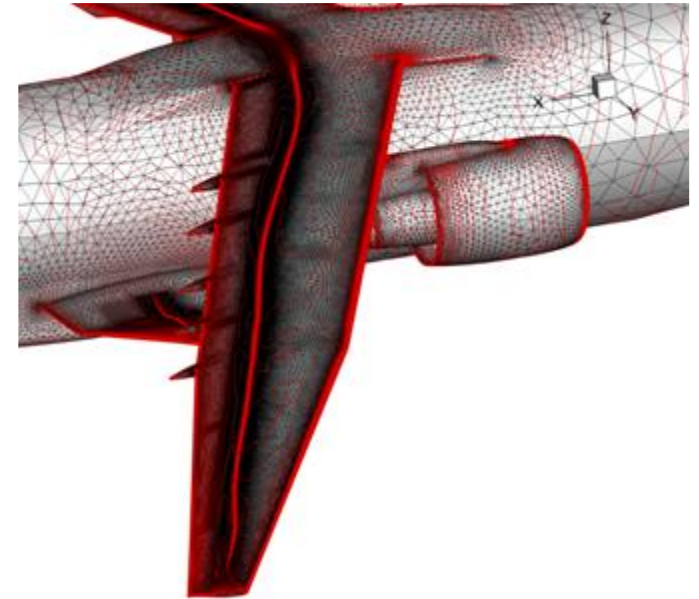


Source mesh:
Half-span CFD grid
36 million nodes

CFD

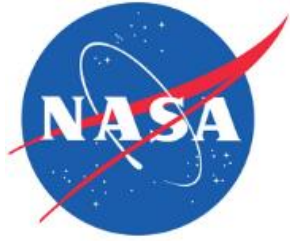


- DDTBDM tool required data
 - Grid coordinates and connectivity
 - Coefficients of pressure and coefficients of friction
- Model (321 surfaces over half-span)
- Analysis
 - NASA Langley Research Center CFD code FUN3D
 - 2.5g positive limit maneuvering load condition
 - Sea level
 - Mach 0.40
 - 9.0° angle of attack

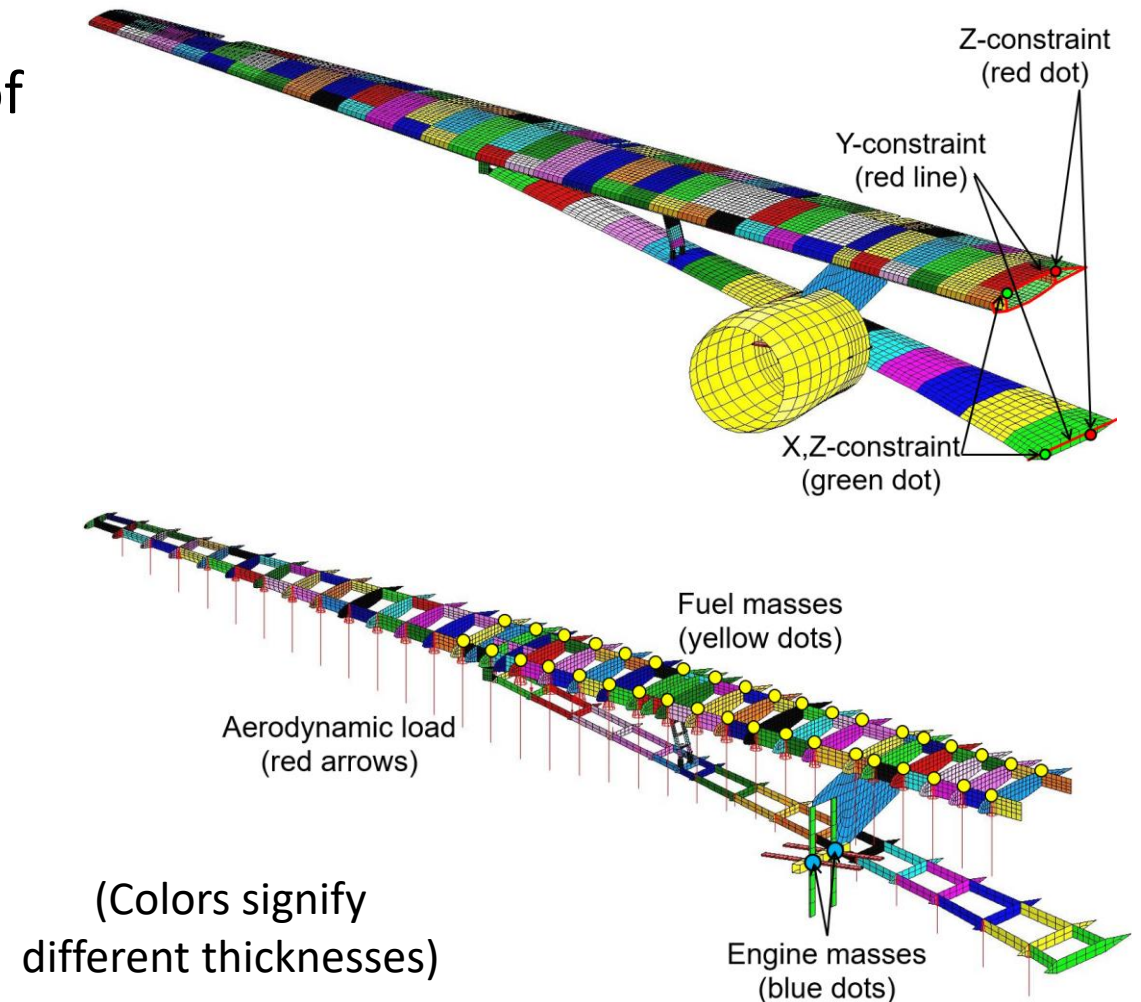


Surface and mesh contours of pressure coefficient

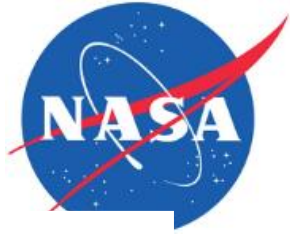
Structural Model



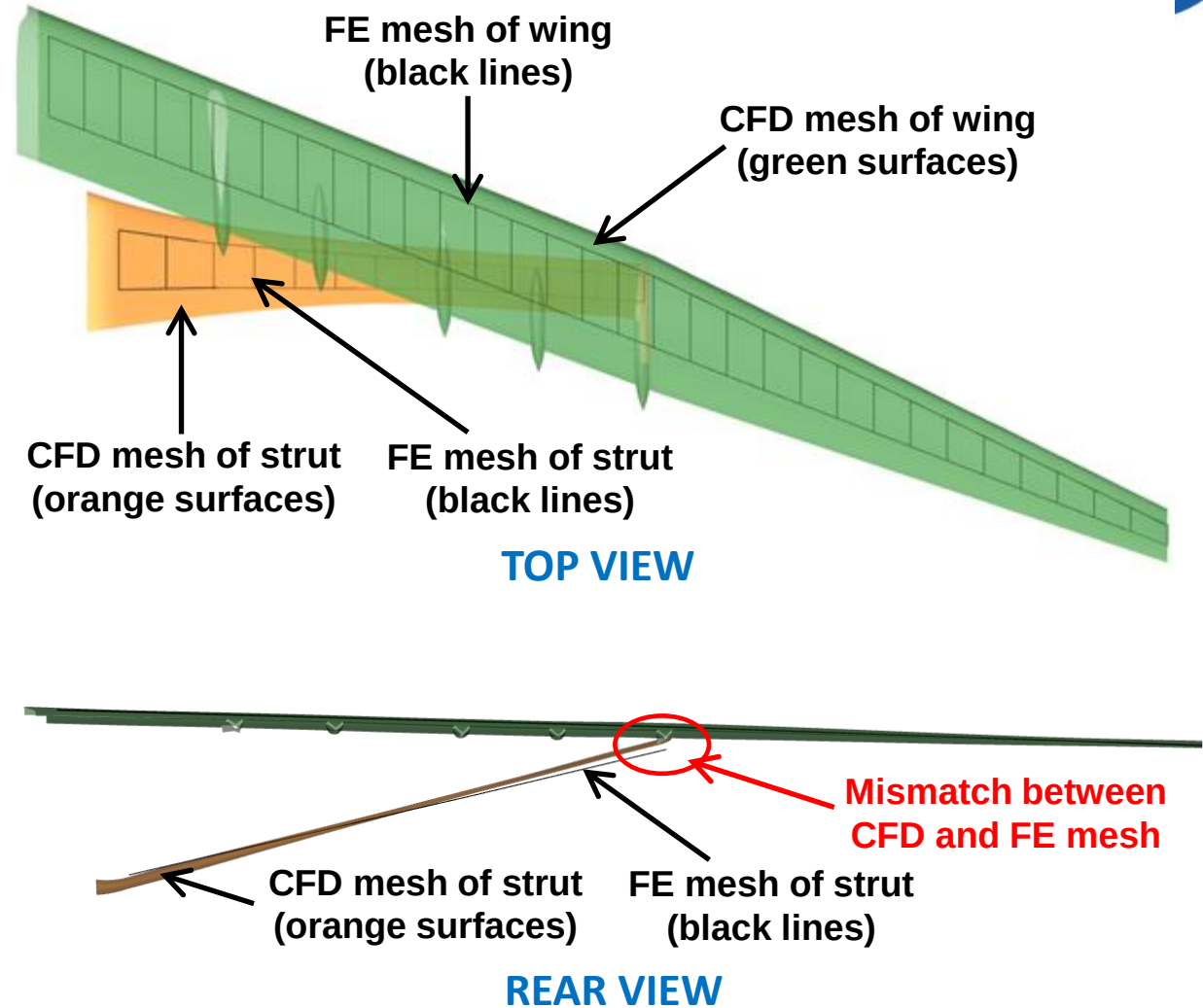
- DDTBDM tool required data
 - Grid coordinates and connectivity of load application nodes (next slide)
- Global FE Model
 - 31,459 shell elements
 - 29,972 nodes
 - 1353 beam elements
 - 47 point masses



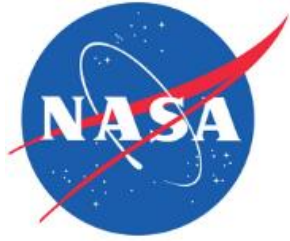
DDTBDM Tool Inputs



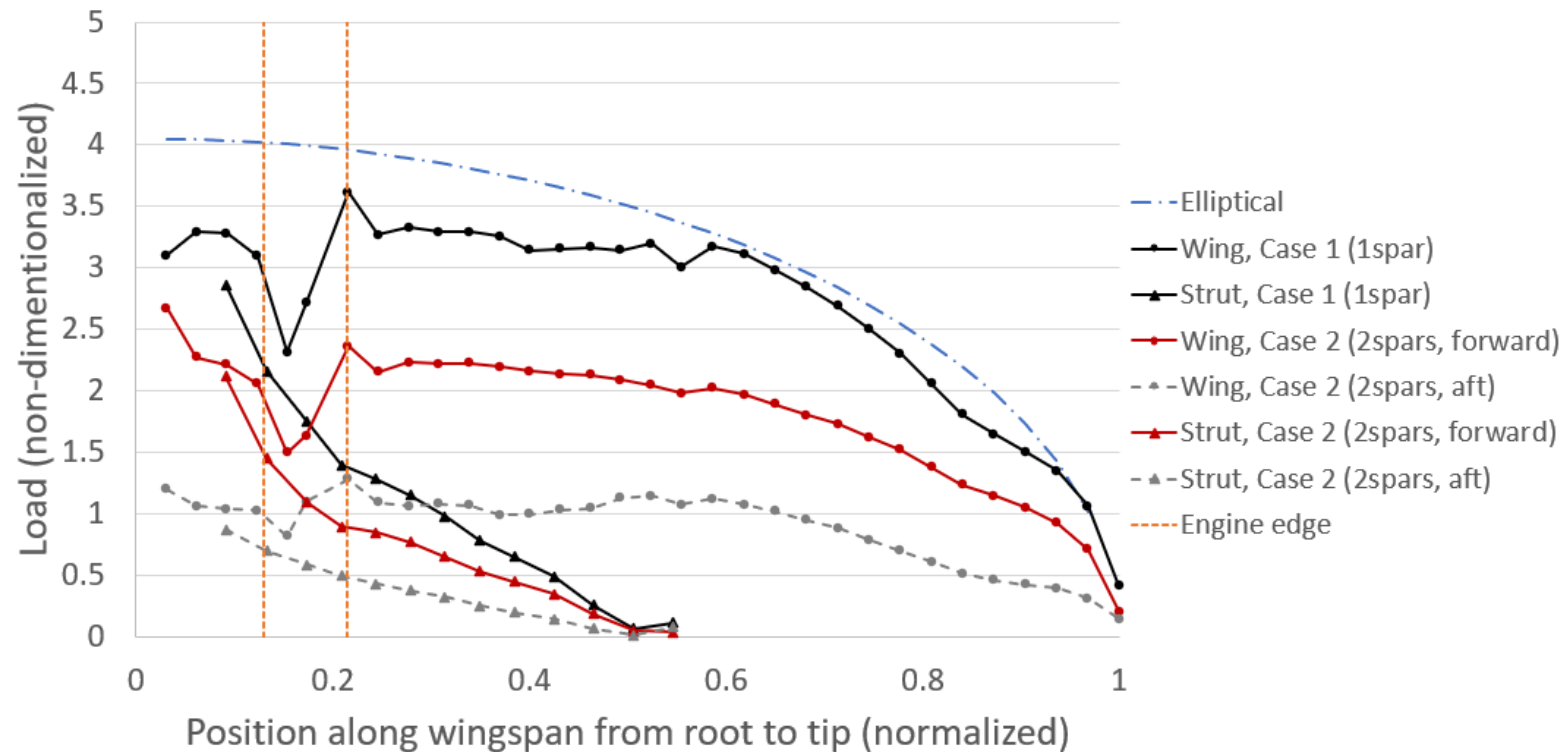
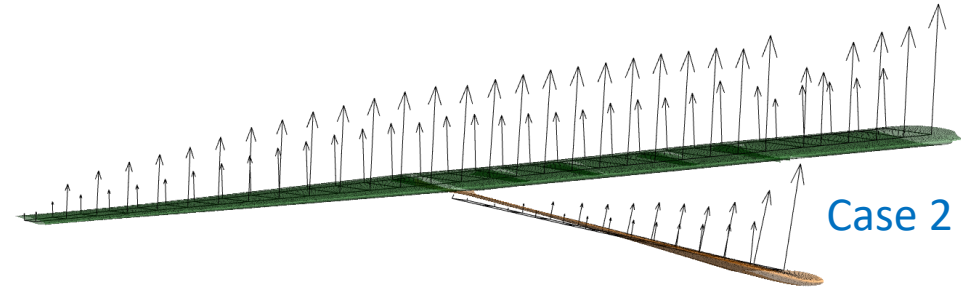
- Simplified FE Mesh
 - Based on global model
 - Used nodes at skin, spar, and rib intersections (hardpoints)
 - Connected with 2-node beam elements
- Considerations with TTBW
 - Proximity of wing and strut surfaces near main joint
 - Ran DDTBDM tool twice
 - Once for wing only
(green surfaces to wing mesh)
 - Once for strut only
(orange surfaces to strut mesh)



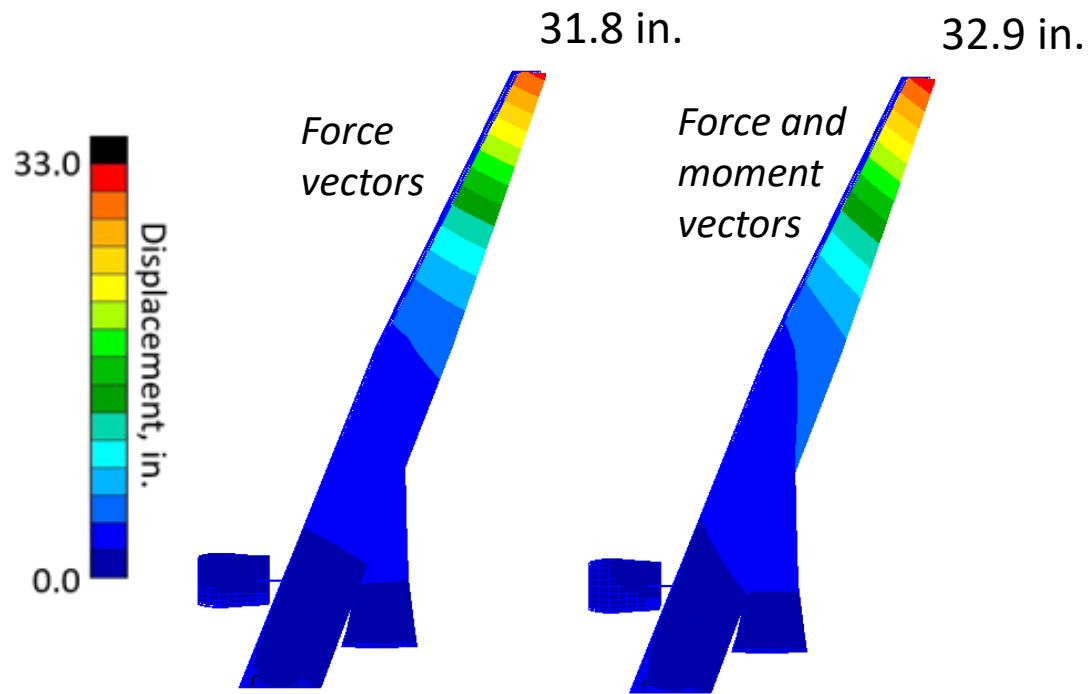
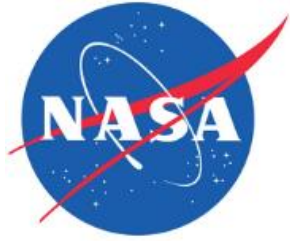
DDTBDM Tool Outputs: Discrete Load Vectors



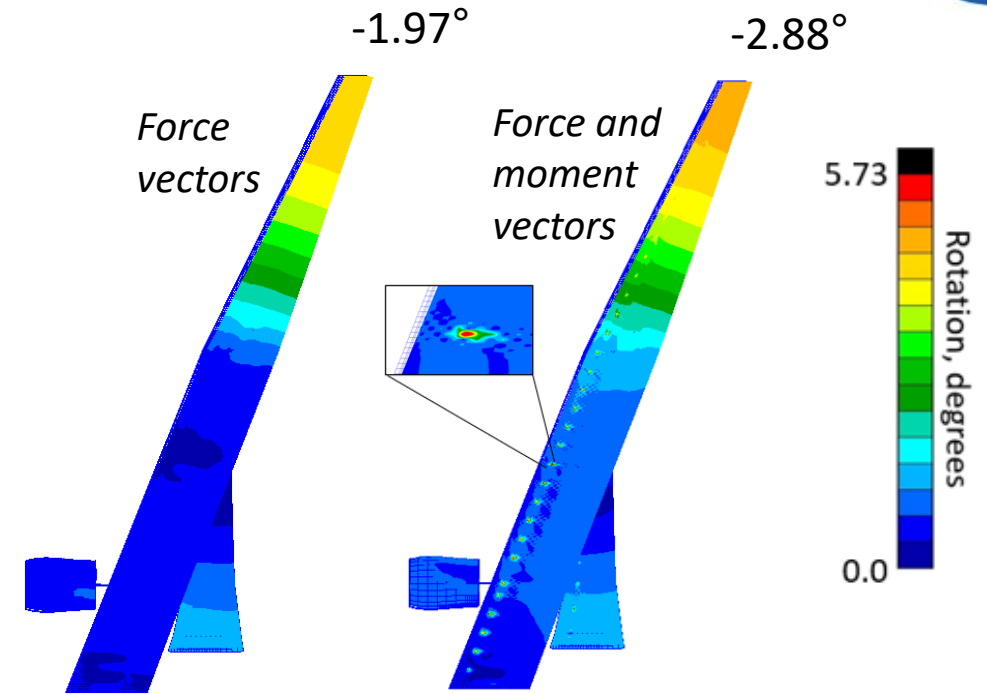
- Used Two Simplified FE Meshes
 - Case 1: Along forward spars only
 - Case 2: Along both spars



Results: Loads on Forward Spars only



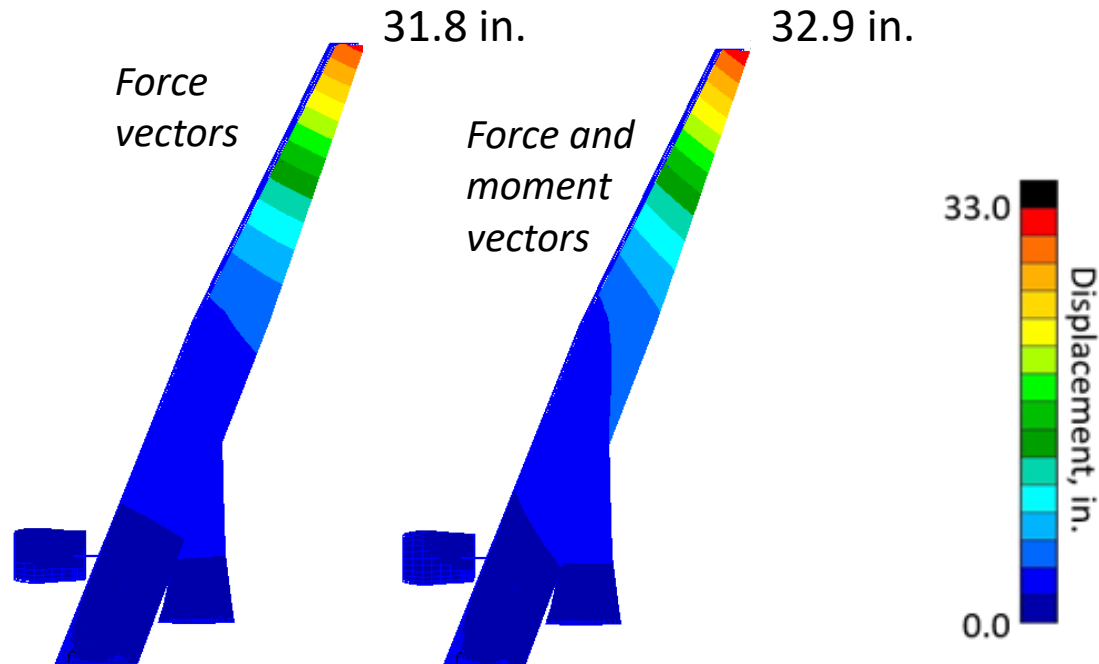
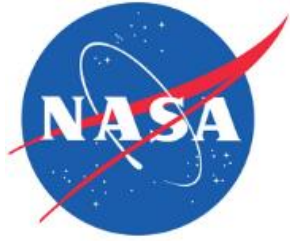
Case 1: Translations
Difference: 1.1 in. (3.3%)



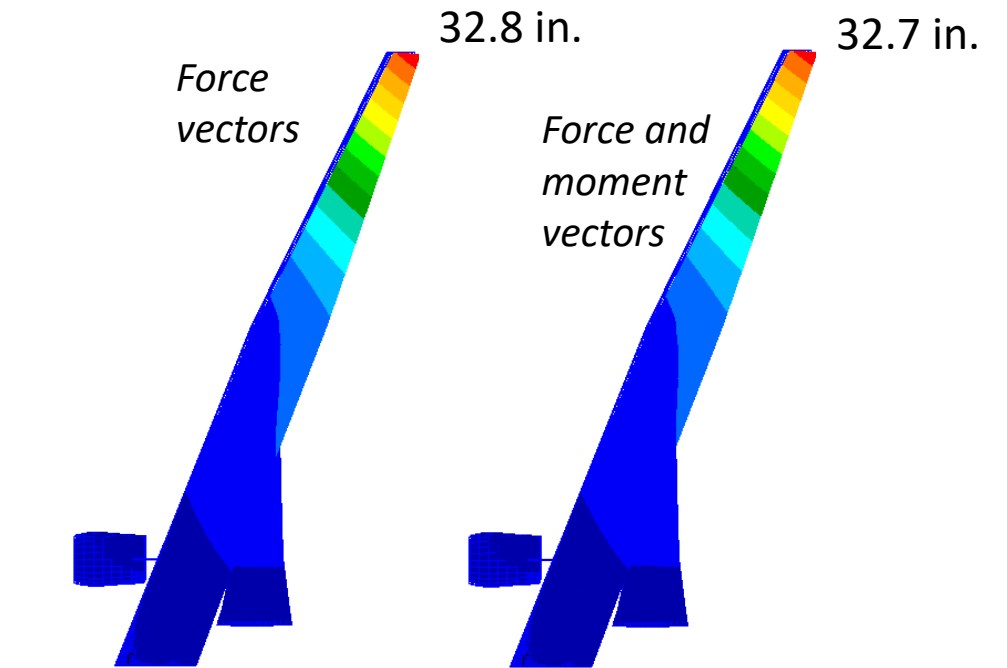
Case 1: Rotations
Difference : -0.91° (31.6%)

NASTRAN v2022.2 FE, linear static analysis solver (Solution 101)

Results: Translation



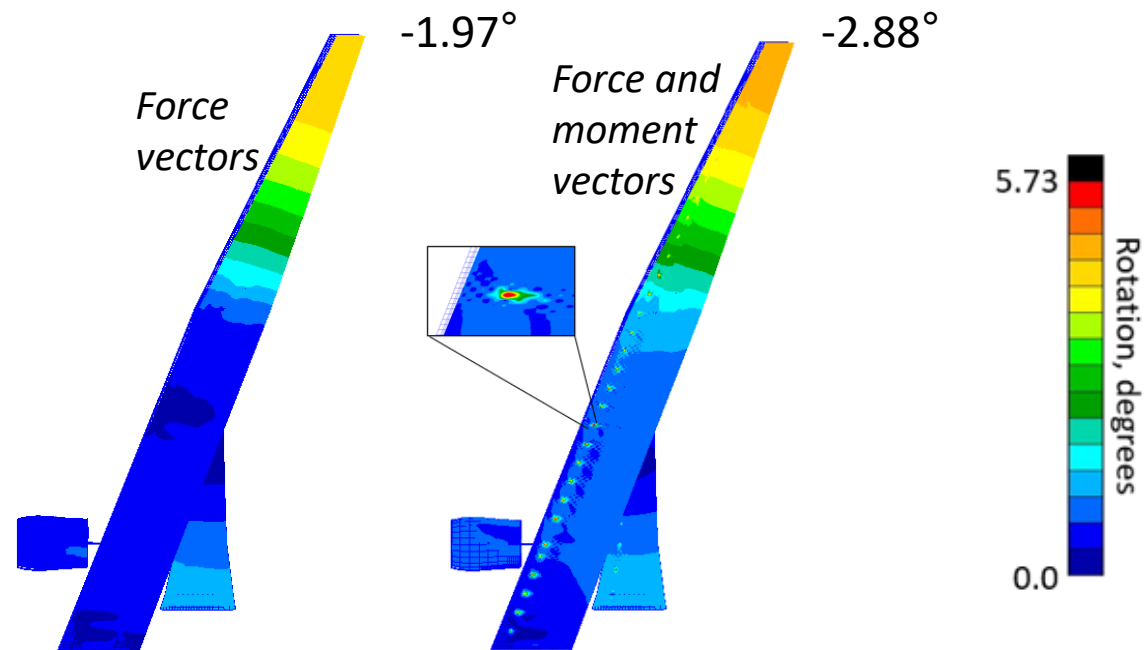
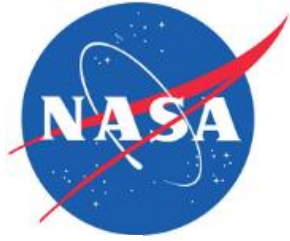
Case 1: Loads on **Forward Spars Only**
Difference: **1.1 in. (3.3%)**



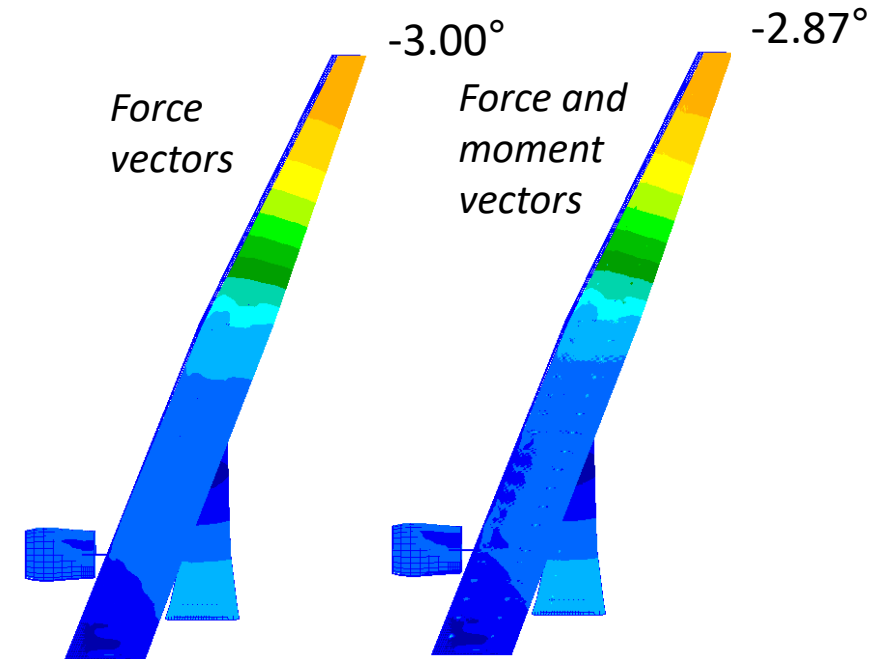
Case 2: Loads on **Forward and Aft Spars**
Difference: **-0.1 in. (-0.3%)**

NASTRAN v2022.2 FE, linear static analysis solver (Solution 101)

Results: Rotation



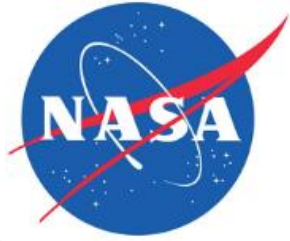
Case 1: Loads on **Forward Spars Only**
Difference: **-0.91° (31.6%)**



Case 2: Loads on **Forward and Aft Spars**
Difference: **0.13° (-4.5%)**

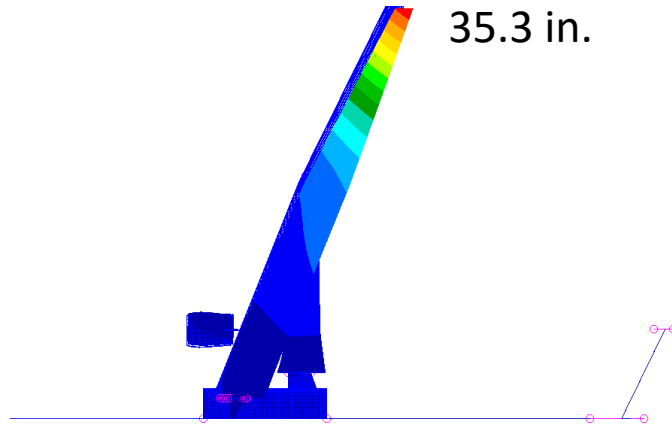
NASTRAN v2022.2 FE, linear static analysis solver (Solution 101)

Comparison to Aeroelastic Results

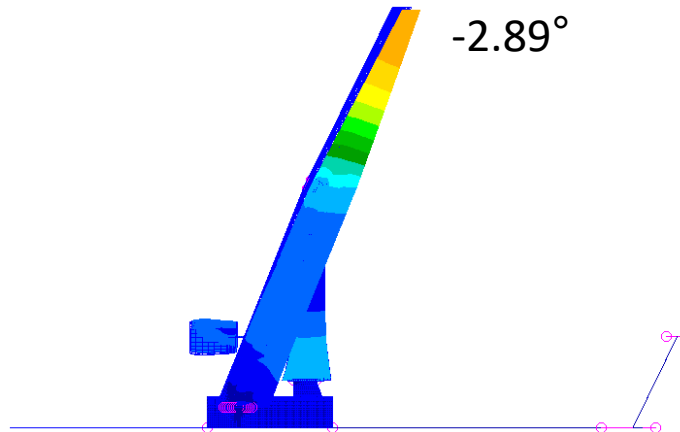


Translations

Point Forces on Forward and Aft Spars

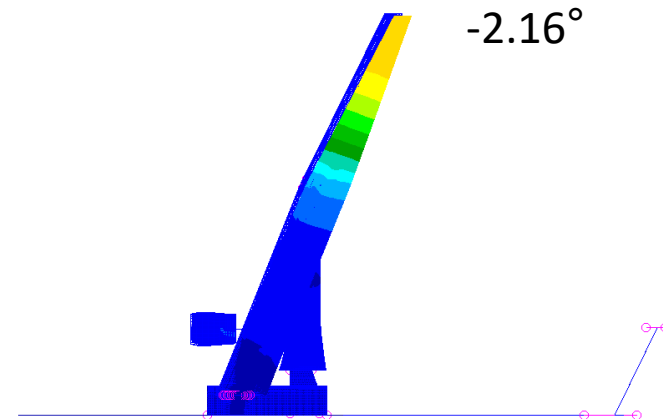
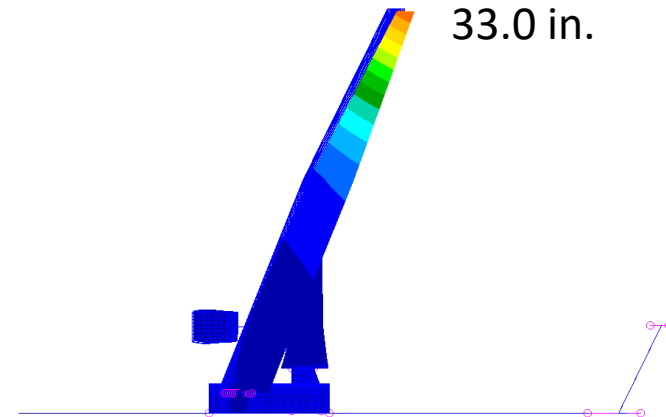


Rotations

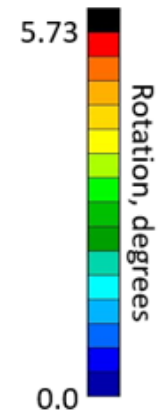
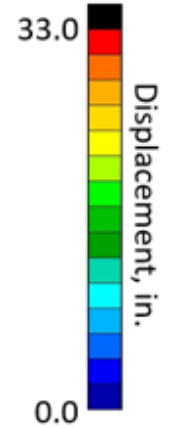


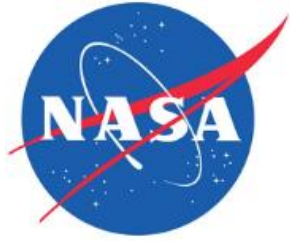
Linear Static Analysis
(Solution 101)

Aero Load at Same Flight Condition



Linear Static Aeroelastic Results
(Solution 144)





Comparison to Aeroelastic Results

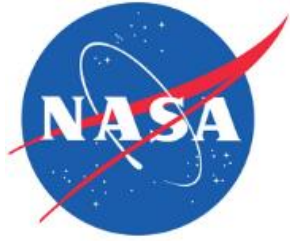
- Static aeroelastic results (same flight condition)
 - Aft swept wing naturally twists under load
 - Coupled nature of the linear static aeroelastic solver (Solution 144) effectively lessens the load on the outboard portion of the wing
 - Less displacement and less rotation
 - Similar angle of attack

FE Analysis Predictions	Solution 101	Solution 144	Difference
Wingtip Displacement	35.3 in.	33.0 in.	-2.3 in.
Wingtip Rotation	-2.89°	-2.16°	0.73°
Angle of Attack	9.0° used in CFD	9.53°	0.53°

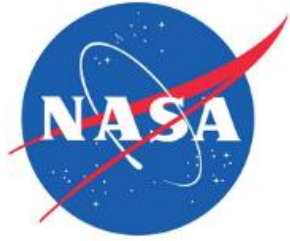
- General consistency between Solution 101 and Solution 144
 - The accuracy of the linear aerodynamic solvers in Solution 144 is decreased with large angle of attack; prefer using the CFD-derived loads for design/testing

NASTRAN v2022.2 FE, linear static aeroelastic analysis solver (Solution 144)

Conclusions



- Summary
 - Application of DDTBDM tool to resolve aerodynamic pressures from CFD into single load vectors at hardpoints on both the wing and strut of the TTBW
 - For more accurate load transfer, separated CFD wing surfaces from CFD strut surfaces
 - Evaluated two different arrangements of load vectors over wing and strut
- Results
 - Distributing load vectors along **only the forward spars**
 - Global response sensitive to the use of point moments
 - Including point moments improved response, but caused unrealistic local rotations
 - Distributing load vectors along the **forward and aft spars**
 - Global response much less sensitive to the use of point moments
 - Point forces alone are sufficient input for structural design work and testing
 - Point forces (with no point moments) provide a more continuous loading profile
 - Global response was consistent with linear static aeroelastic predictions
 - Determined **distributed forces on forward and aft spars** met research requirements



Questions?