

ACTE Wing Loads Analysis



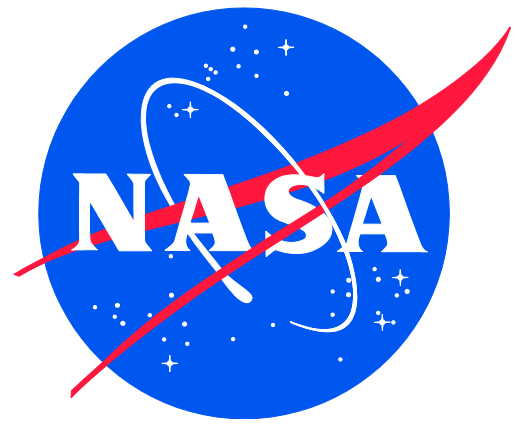
Nicholas Horn

Armstrong Flight Research Center

8/4/2015



About Me



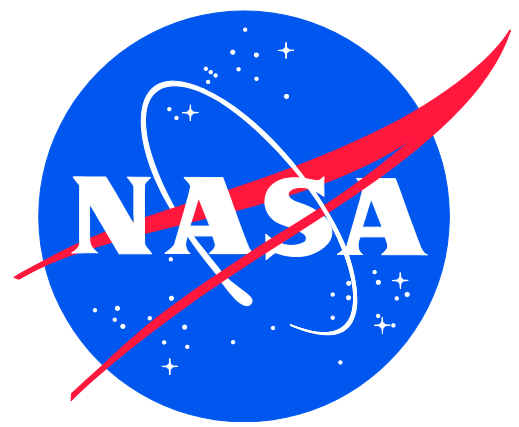
- The Ohio State University, Columbus, OH
- 3rd year student
- Double Major: Aerospace Engineering & Aviation

- AERO Institute
- Code RS: Aerostructures
- Mentor: Josué Cruz



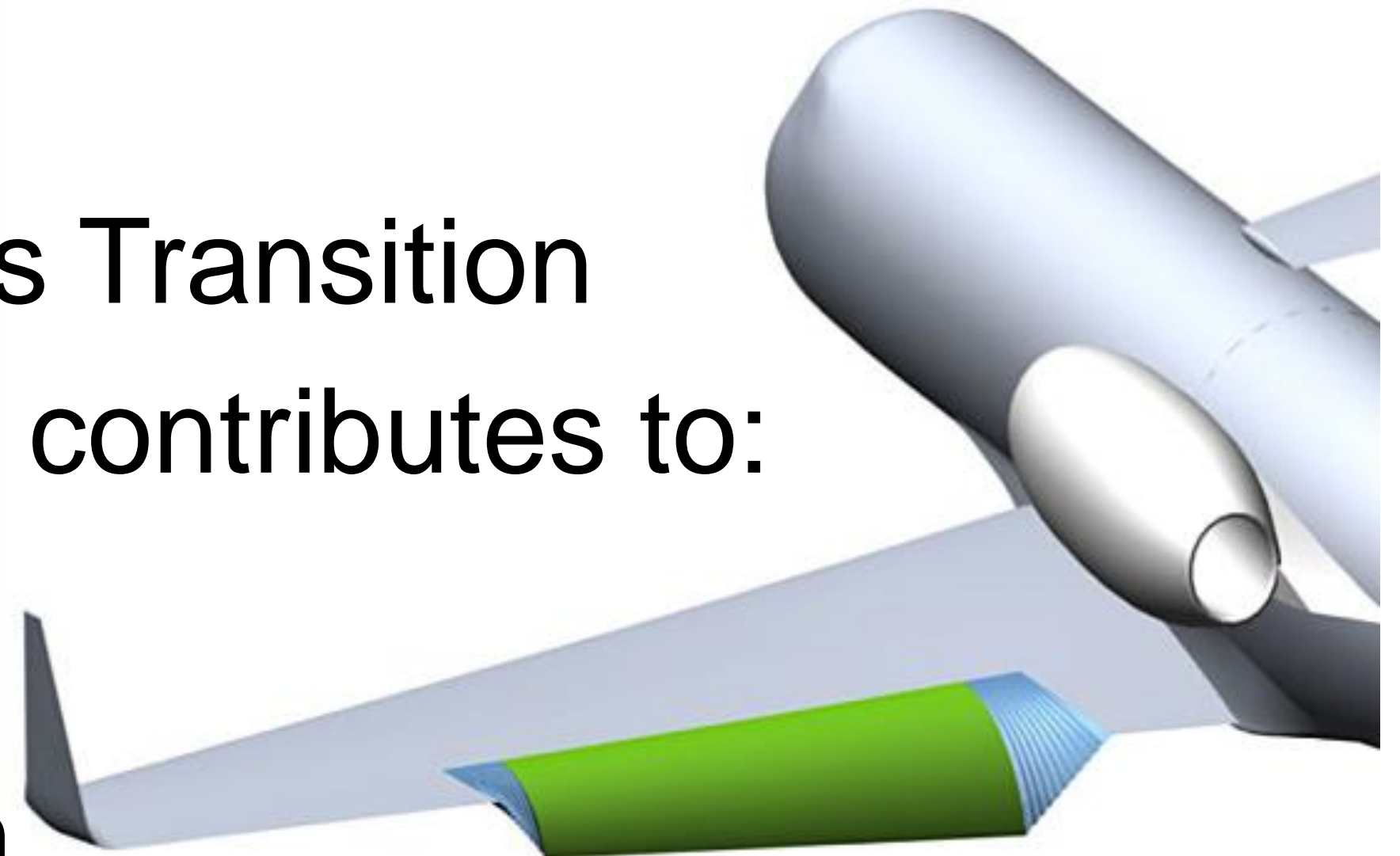
THE OHIO STATE
UNIVERSITY





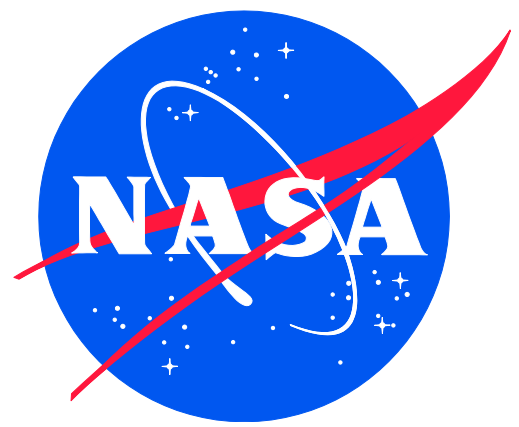
Background

- ACTE – Adaptive Compliant Trailing Edge
- Joint project between NASA, AFRL, FlexSys
- Modified GIII
- Flexible Flap – Seamless Transition
- Multifunctional Structure contributes to:
 - Noise Reduction
 - Wing Load Alleviation
 - Cruise Drag Optimization
- ACTE Project Goal: Prove full scale flap structure could be manufactured and flown in a relevant flight environment

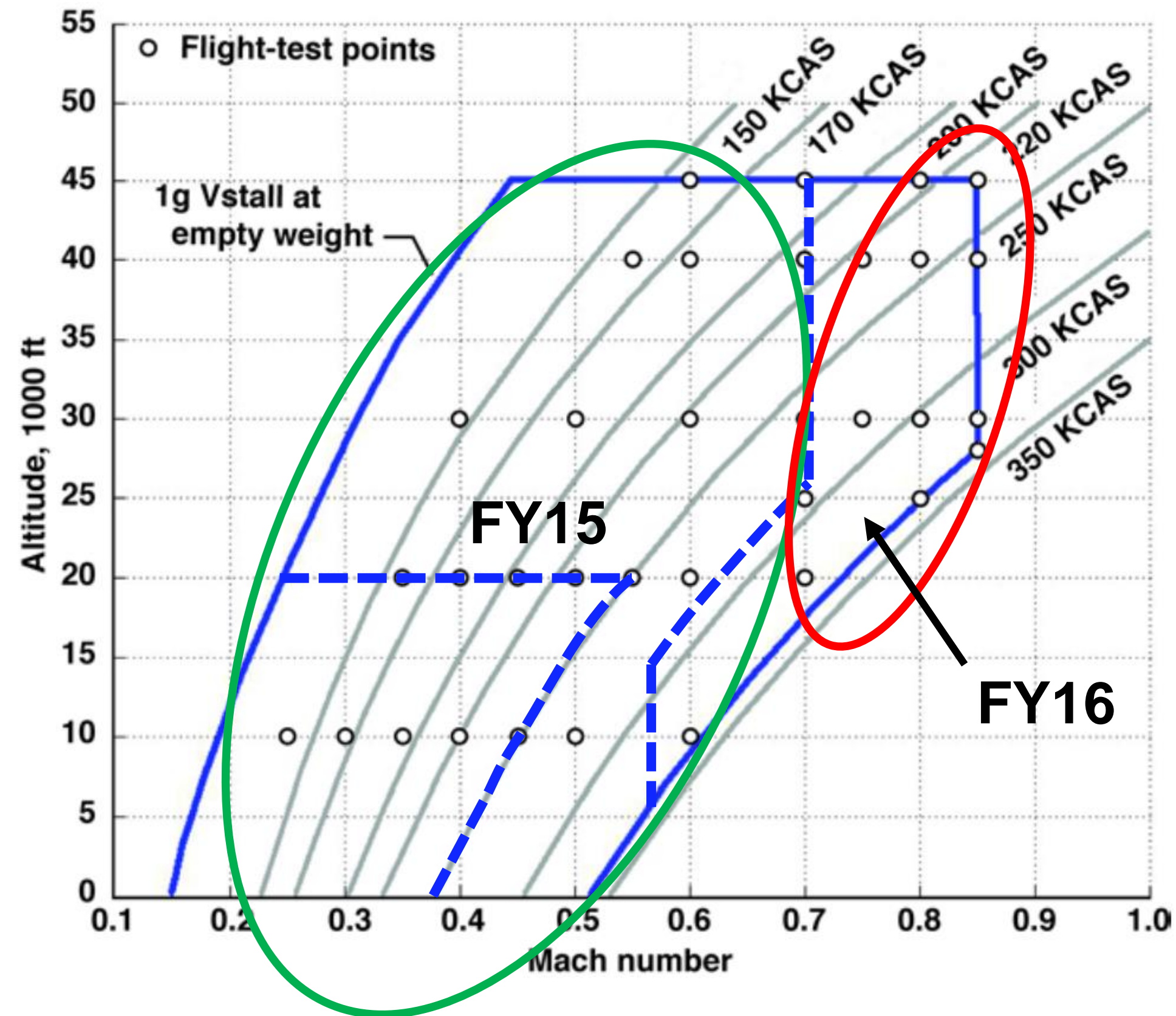




Background

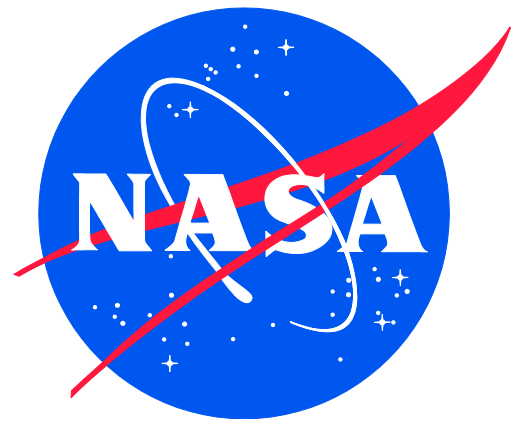


- Wing Loads Analysis needed with new modification
- Includes CFD analysis and flight tests
- Important load characteristics include: shear force, bending and torsion moments

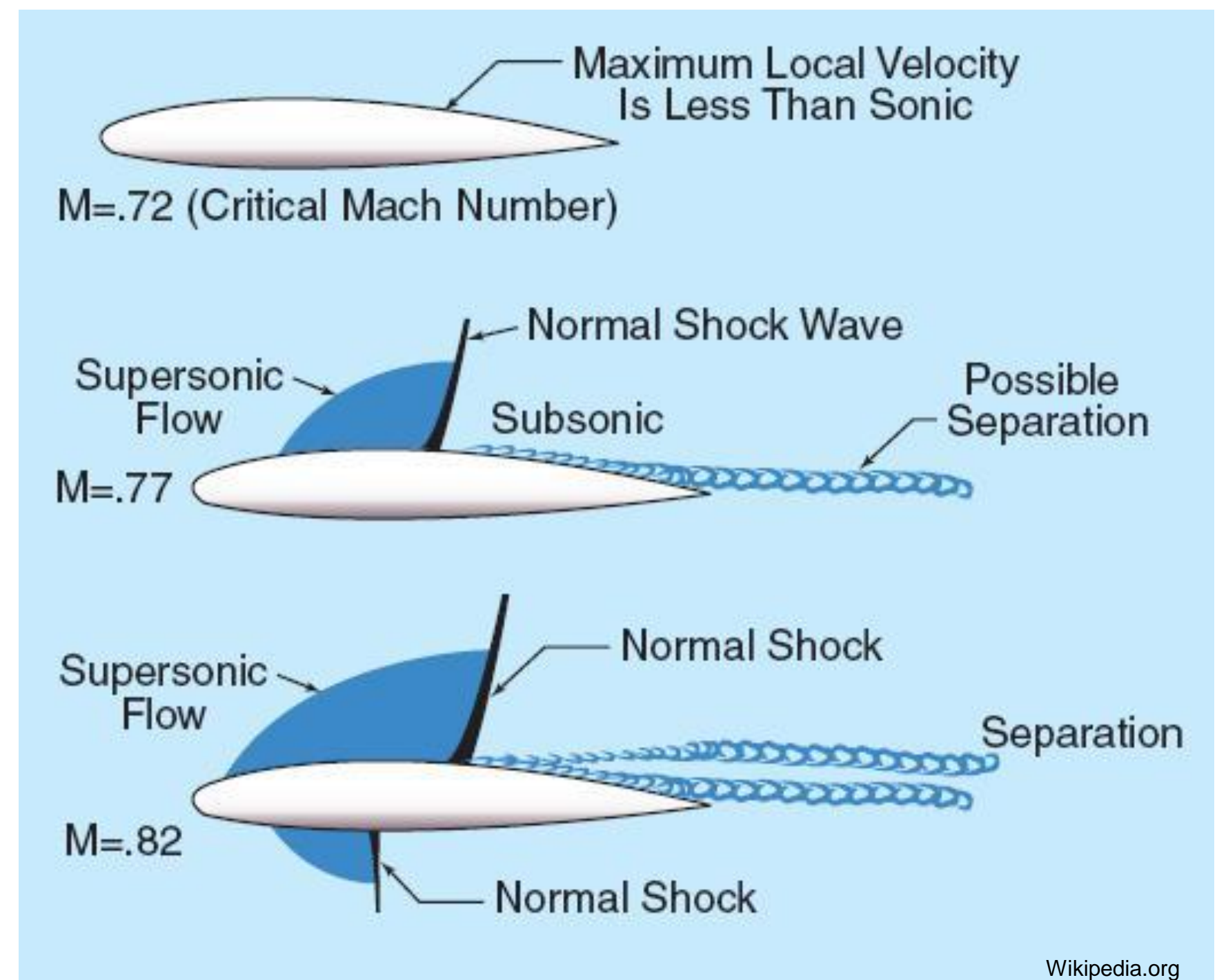




Background

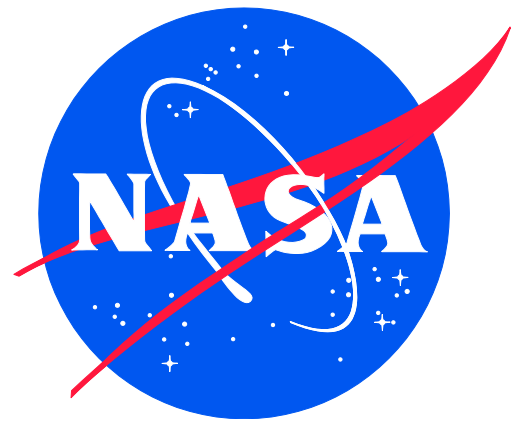


- Previously TRANAIR used as CFD software
- Worked well for initial testing at lower Mach numbers
- Higher fidelity code required for testing at higher Mach numbers (near transition region)
- Star-CCM+ chosen for further testing
- Outputs TECPLOT format

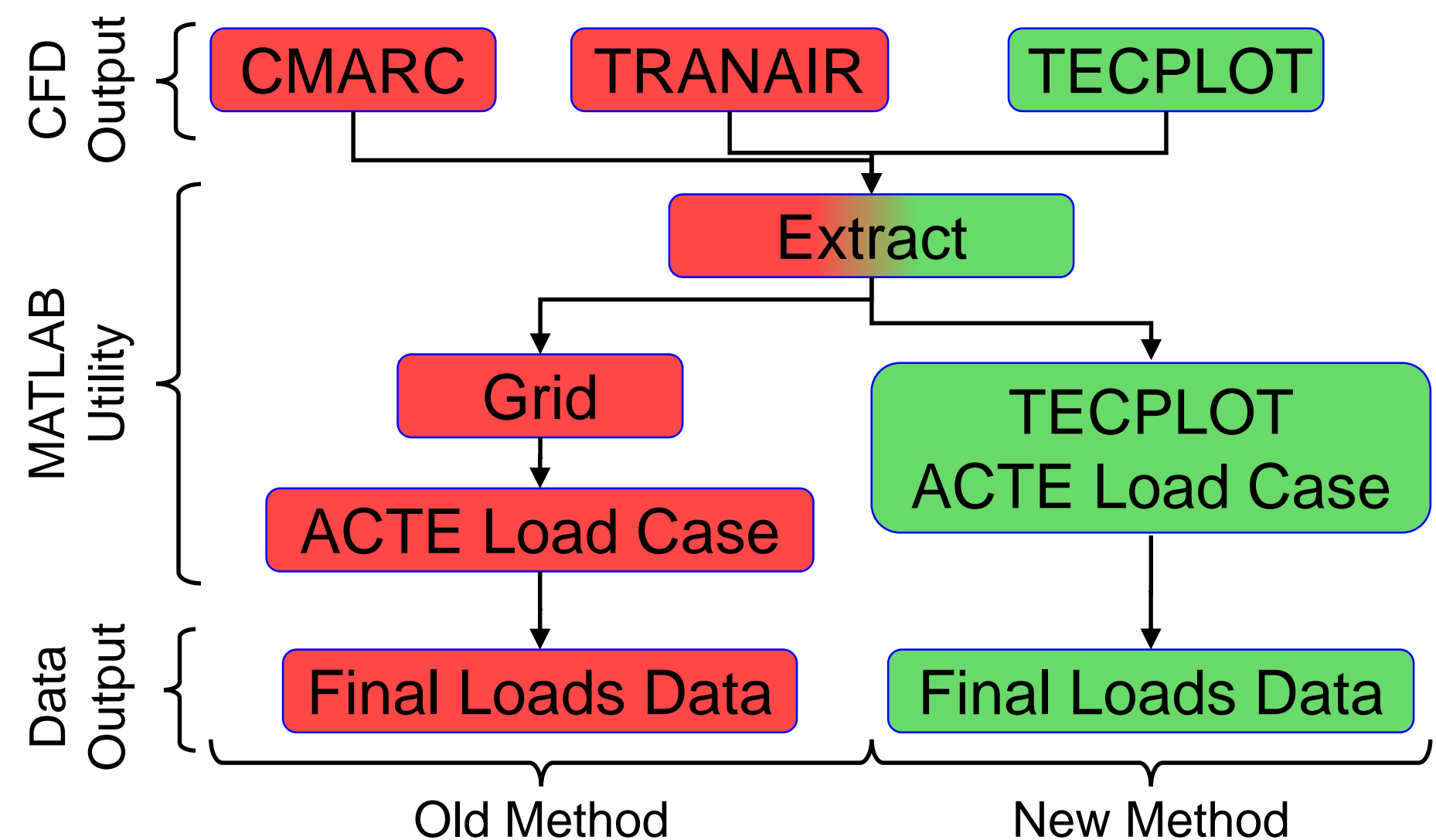




Objective

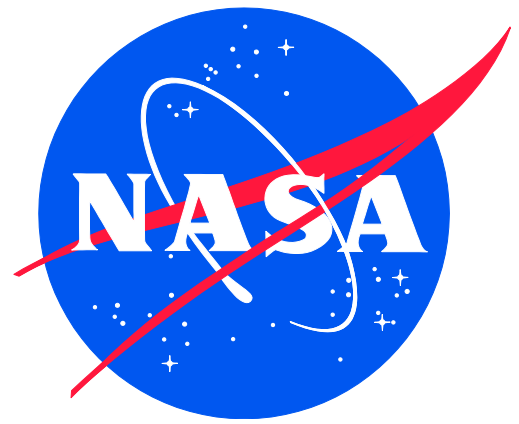


- CFD output is ran through MATLAB utility
- Calculates wing loads from aerodynamic and inertial data
- Needed updating/ replacement to work with TECPLOT format before further flight testing could be conducted

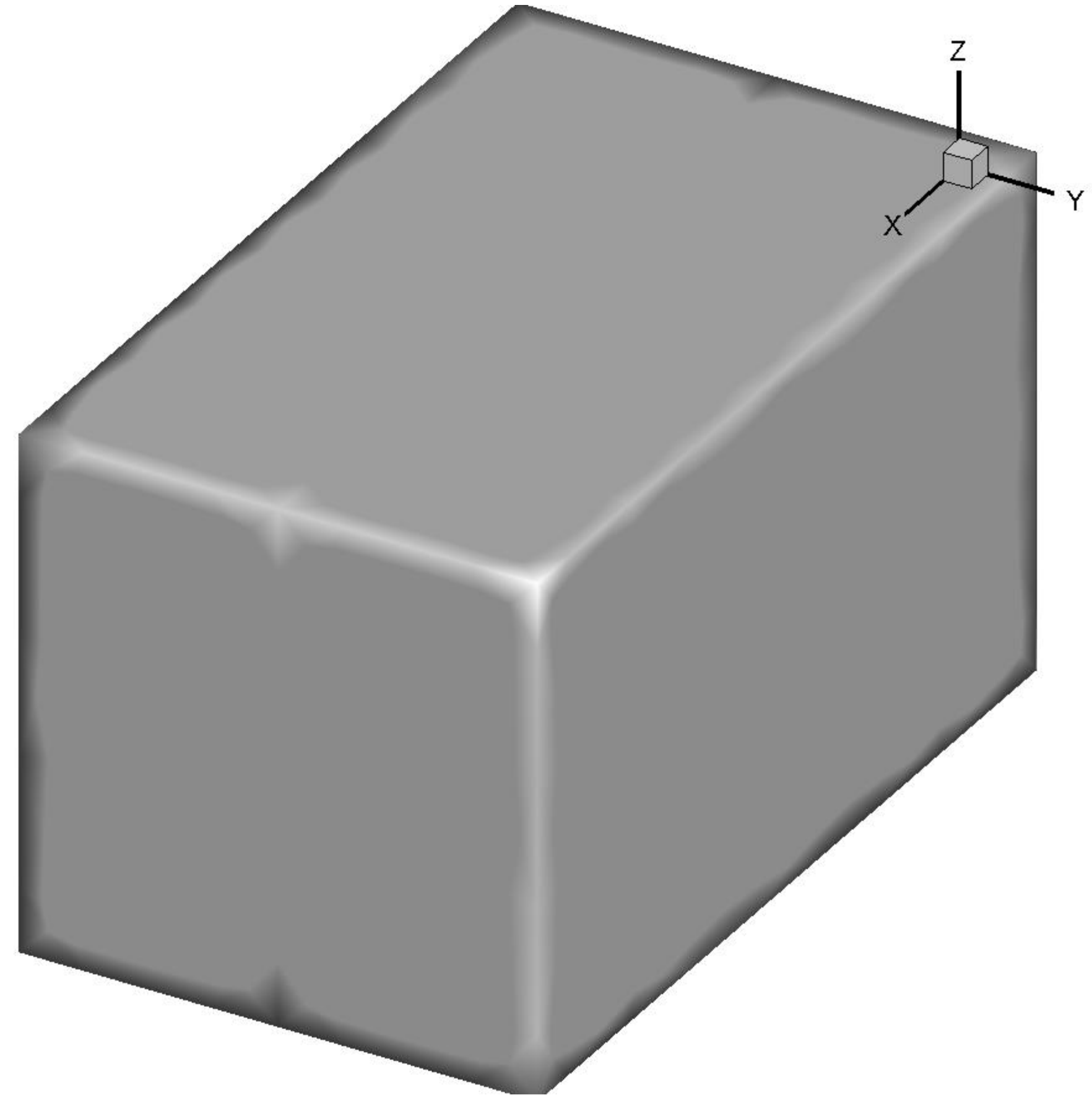




Star-CCM+ Output

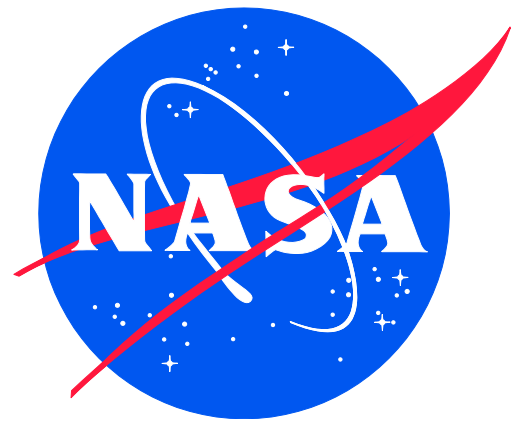


- Outputs data file in TECPLOT format
- Post-processing tool
- Many CFD programs output in this format
- Contains data for free-stream and aircraft
- Surrounding air is unnecessary – only need GII surface data

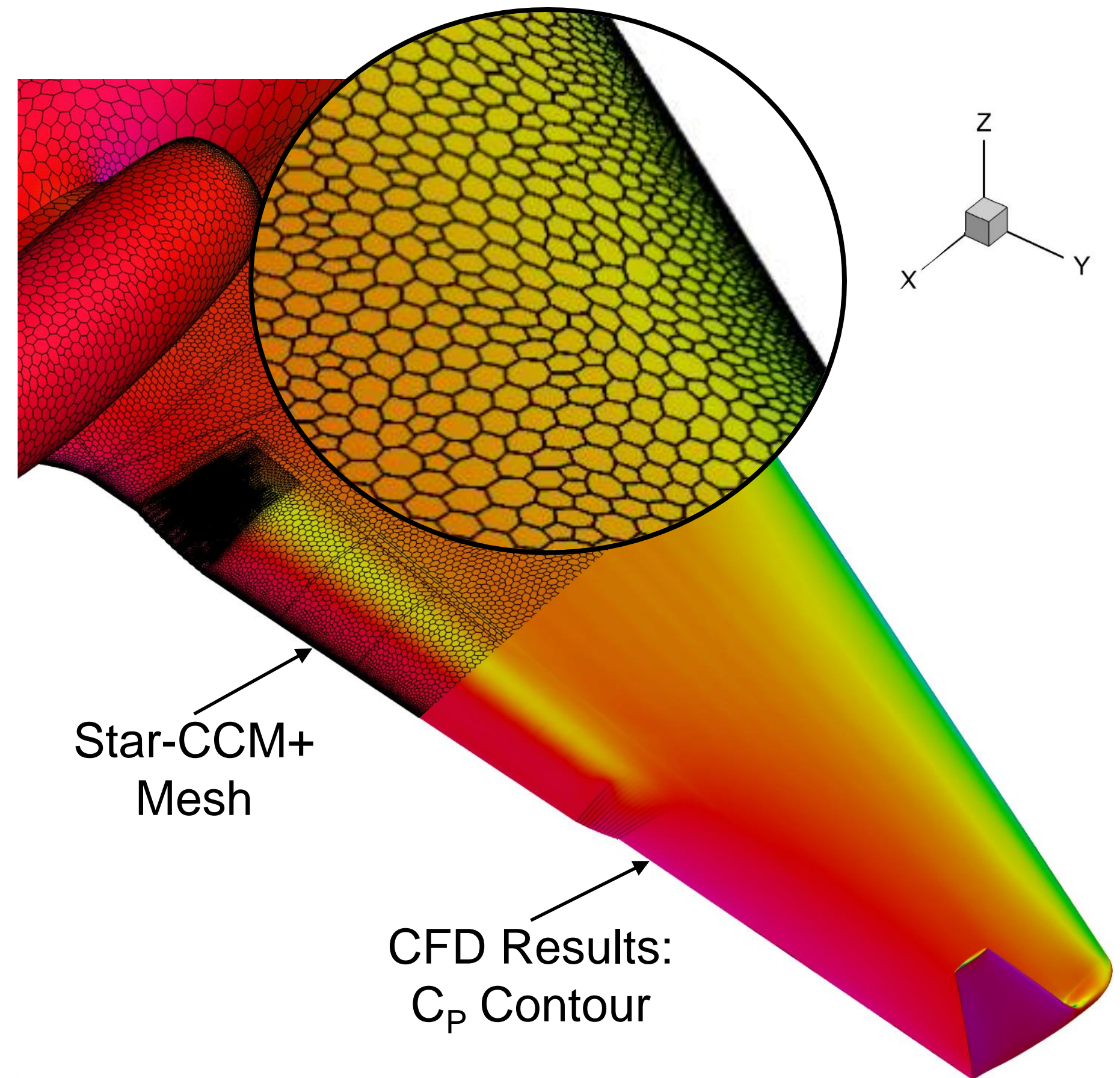




TECPLOT

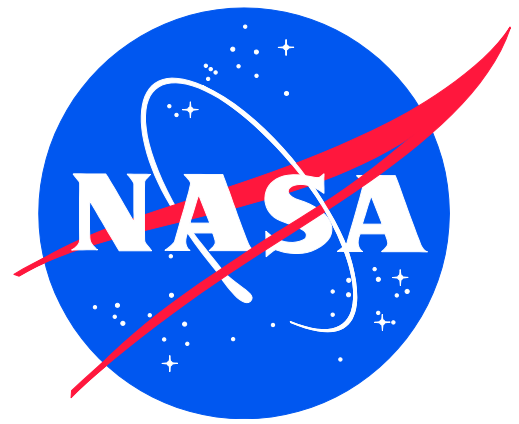


- Original file only contains node and C_p data
- TECPLOT used to calculate other important variables
- Saved as ASCII format
- New file contains all variables





TECPLOT Output



File Header

```

TITLE = "ACTE_20degflap_M0.30H10kft_4.0AoA0.0AoS"
VARIABLES = "X"
"Y"
"Z"
"Pressure Coefficient"
"Cell Volume"
"X Grid K Unit Normal"
"Y Grid K Unit Normal"
"Z Grid K Unit Normal"
"X_center"
"Y_center"
"Z_center"

```

Zone Header

```

ZONE T="Region 1:wing"
STRANDID=3, SOLUTIONTIME=0
Nodes=692661, Faces=1047496, Elements=354834, ZONETYPE=FEPolygon
DATAPACKING=BLOCK
VARLOCATION=( [4-11]=CELLCENTERED )
NumConnectedBoundaryFaces=0, TotalNumBoundaryConnections=0
DT=(DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE )

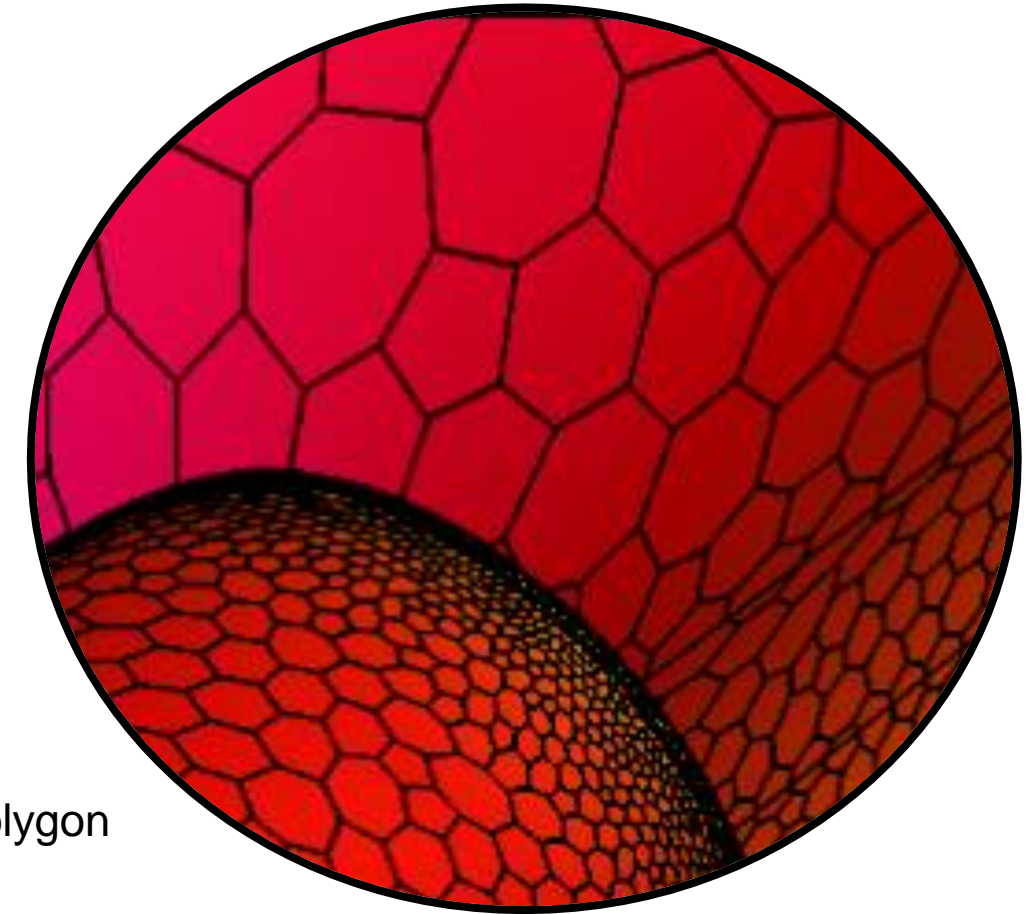
```

Zone Data

```

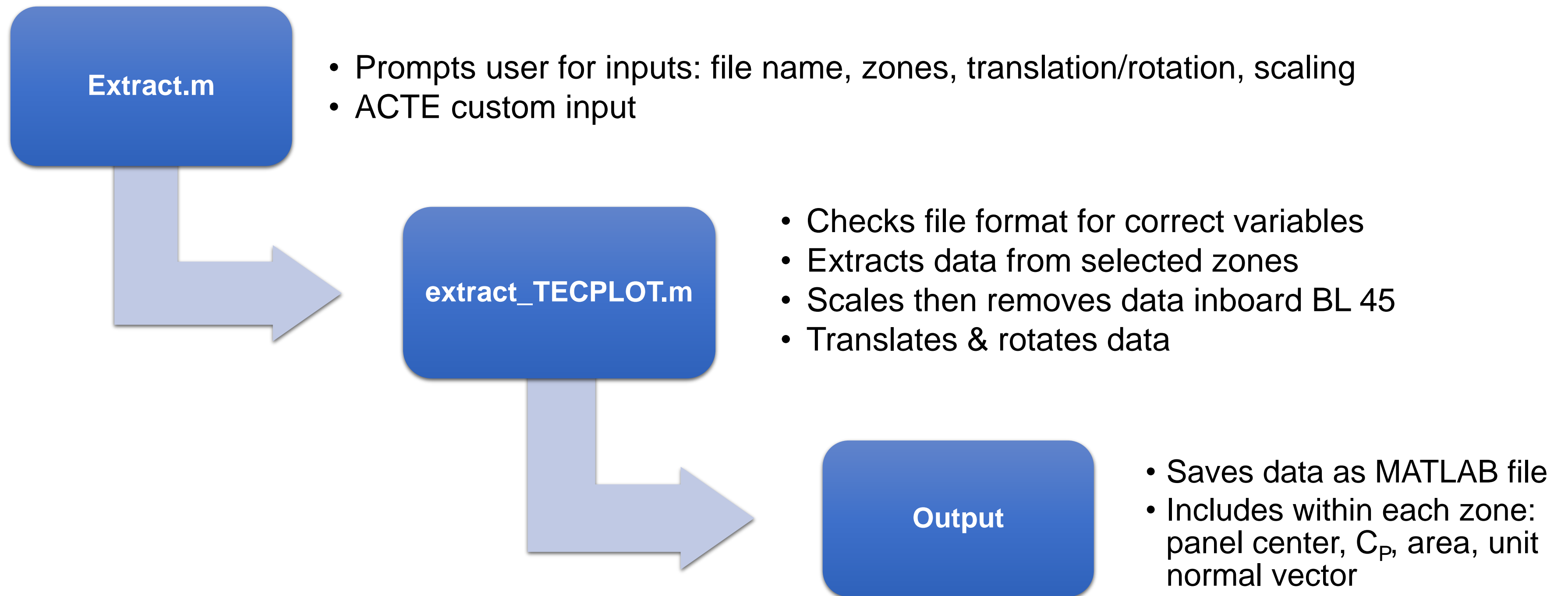
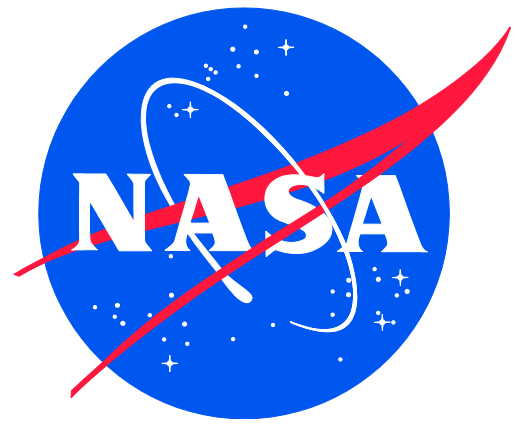
1.309661787E+001 1.309656766E+001 1.309531916E+001 1.309375143E+001 1.309303646E+001
1.309403980E+001 1.309535404E+001 1.309578638E+001 1.309330879E+001 1.309449942E+001
1.309827356E+001 1.309878812E+001 1.309752041E+001 1.309578186E+001 1.309789396E+001
1.309889237E+001 1.309677409E+001 1.309892959E+001 1.309889874E+001 1.309696464E+001
1.309503726E+001 1.309498318E+001 1.309357208E+001 1.309716251E+001 1.309570962E+001
1.309407097E+001 1.309629902E+001 1.309528563E+001 1.309377327E+001 1.309291962E+001
1.309630228E+001 1.309548382E+001 1.309405978E+001 1.309287135E+001 1.310179459E+001
1.310143392E+001 1.309609816E+001 1.309675545E+001 1.310034621E+001 1.310327025E+001
1.310316434E+001 1.310087883E+001 1.310093249E+001 1.310169554E+001 1.310025089E+001
1.309802742E+001 1.309472228E+001 1.309325384E+001 1.309665941E+001 1.309612846E+001
1.309753282E+001 1.309704733E+001 1.309834718E+001 1.310042634E+001 1.310186334E+001
1.310223578E+001 1.309977391E+001 1.310069604E+001 1.310106978E+001 1.309909711E+001
1.309930575E+001 1.309792568E+001 1.309776139E+001 1.309872672E+001 1.309862095E+001
1.309796273E+001 1.310096247E+001 1.310101160E+001 1.310025726E+001 1.310771202E+001
1.310487740E+001 1.310725745E+001 1.311247704E+001 1.311192579E+001 1.310799924E+001
1.310507603E+001 1.310065120E+001 1.310595965E+001 1.310575741E+001 1.310361101E+001
1.310098249E+001 1.310424269E+001 1.310796986E+001 1.310461847E+001 1.310889502E+001
1.311014570E+001 1.310432472E+001 1.310304547E+001 1.310834198E+001 1.310834734E+001
1.310659294E+001 1.312362694E+001 1.312089807E+001 1.311960537E+001 1.312125180E+001
1.312374310E+001 1.312529521E+001 1.311848754E+001 1.311536953E+001 1.311343005E+001
1.311406975E+001 1.311640057E+001 1.311829852E+001 1.311714953E+001 1.311338876E+001

```



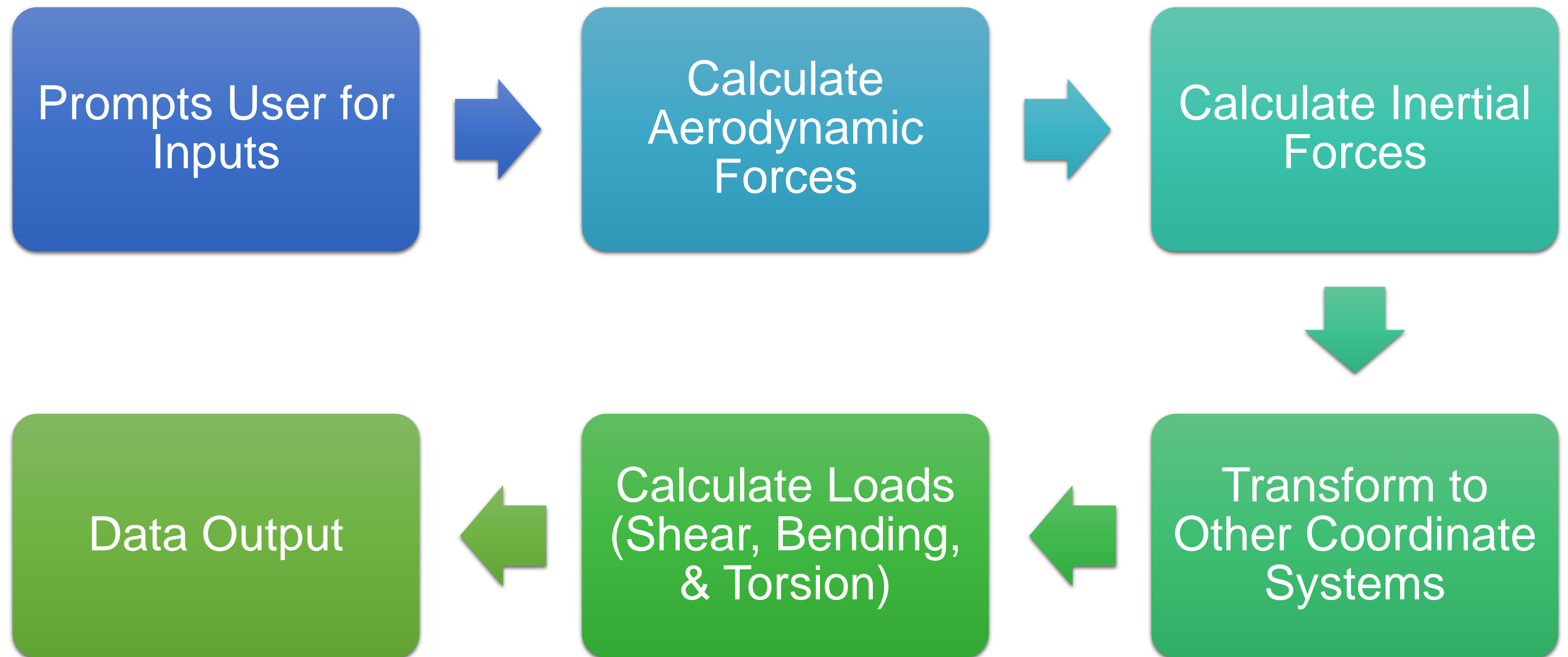
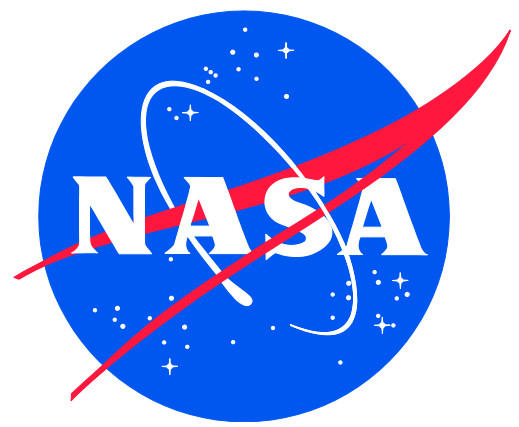


Extract.m



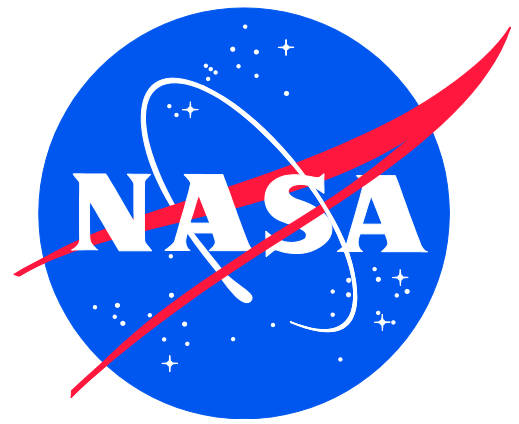


ACTE_Load_Case_M_TECPLOT.m

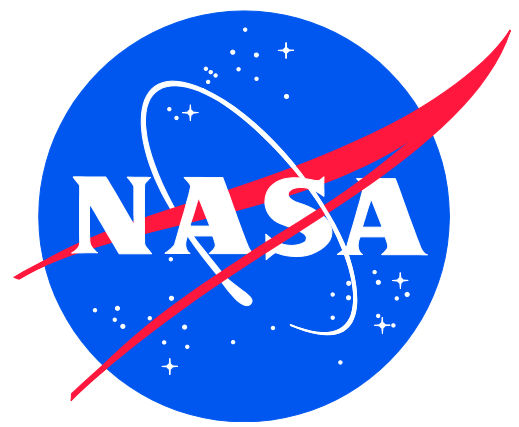




Load Case: Inputs

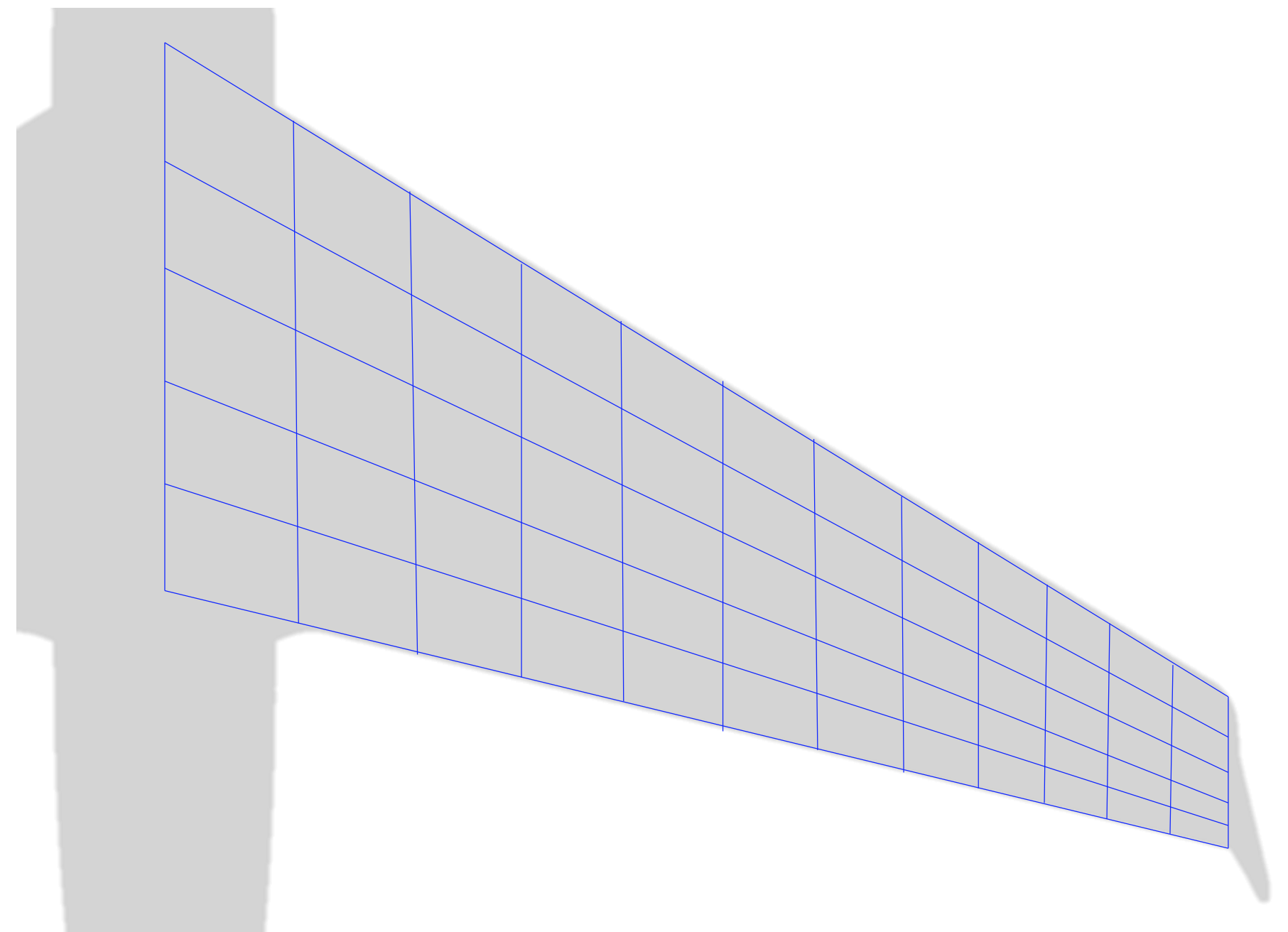


- Old program required manual input (physically changing script each time)
- New program: Just hit “run”
- Prompts User:
 - File from Extract.m output
 - Wing Weights File(s)
 - Flight Conditions:
 - Dynamic Pressure (q)
 - Maneuvering Load (N_z)
 - CG & Roll Rate/Acceleration (only for rolling maneuvers)
 - Wing Stations for Load Analysis



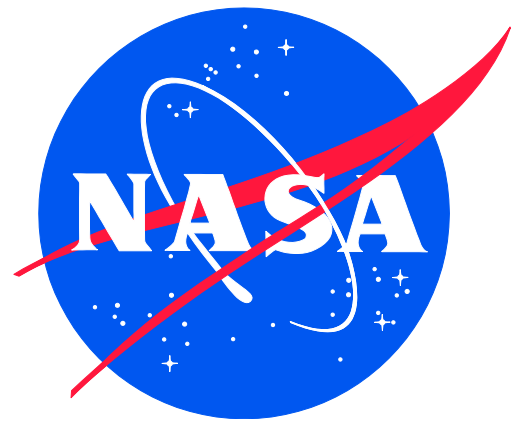
Load Case: Forces

- Aerodynamic Force:
 - $F = C_p \times q \times \text{Area} \times \text{Unit Norm}$
- Inertial Force:
 - $F = ma$
 - No Roll:
 - $F = \rho \times \text{Area} \times Nz$
 - With Roll:
 - Lots more math...

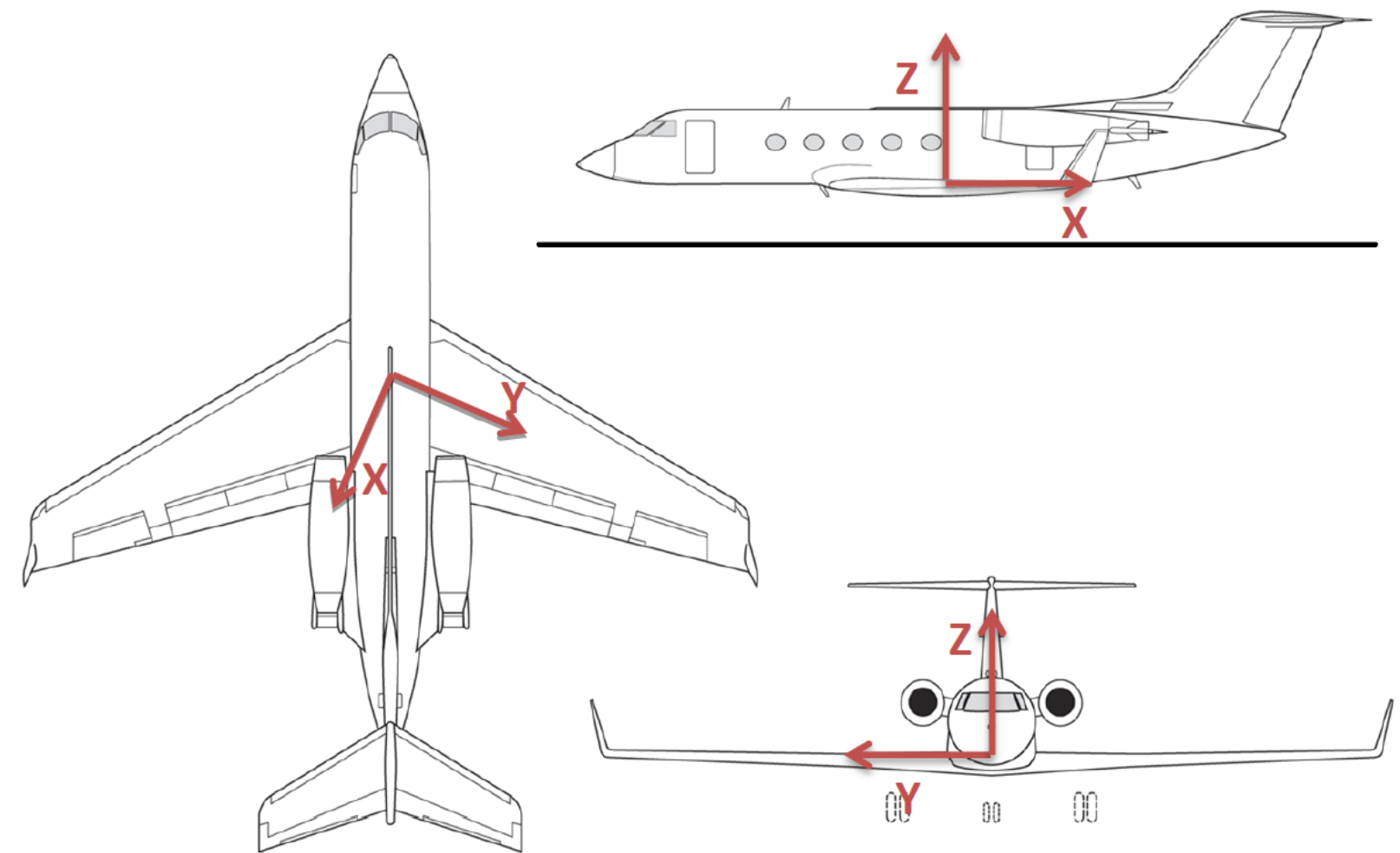




Load Case: Coordinate Sys

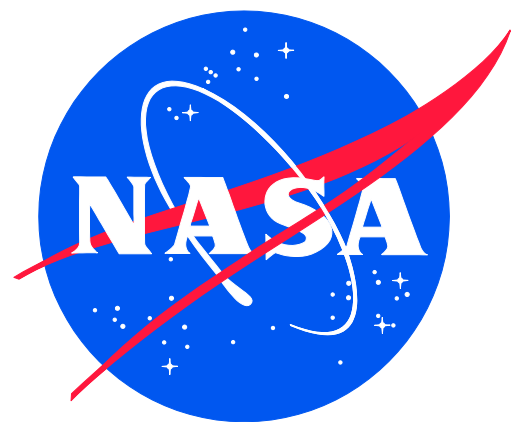


- Points/Forces need to be transformed to new coordinate system
- GIII reference frame is located at nose
 - Useless for wing loads
- New reference systems created to give loads with reasonable values
 - Un-swept
 - Swept
 - ACTE

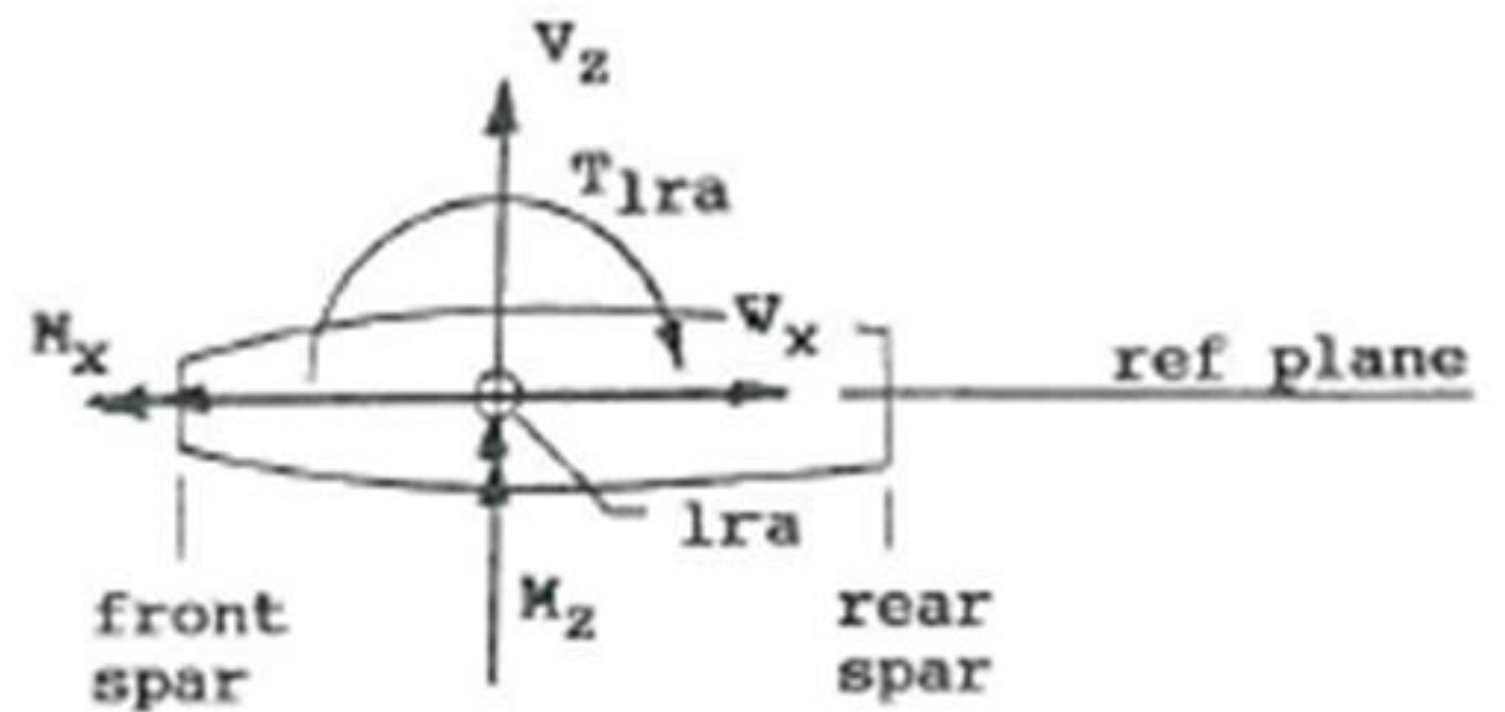
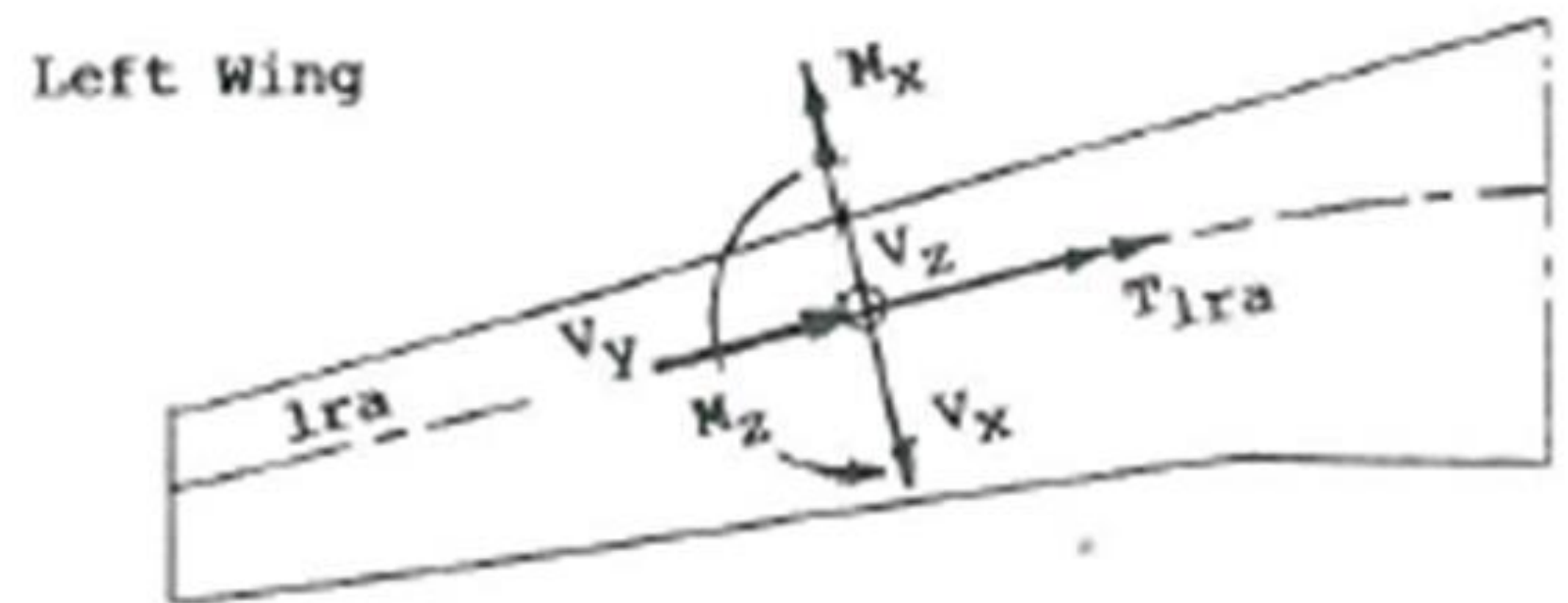




Load Case: Calculate Loads

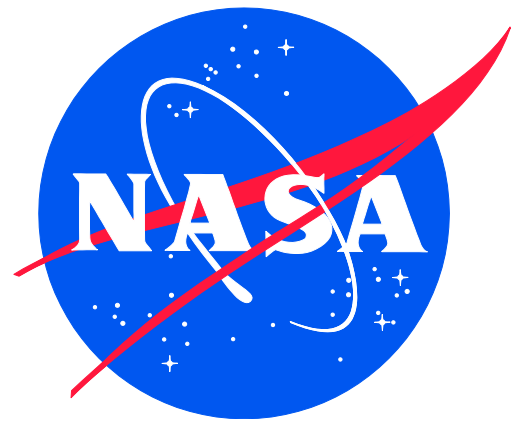


- Sum forces/moments created by each panel
- Shear = $\sum F_z$
- Bending = $\sum [(F_z \times Y) - (F_y \times Z)]$
- Torsion = $\sum [(F_x \times Z) - (F_z \times X)]$

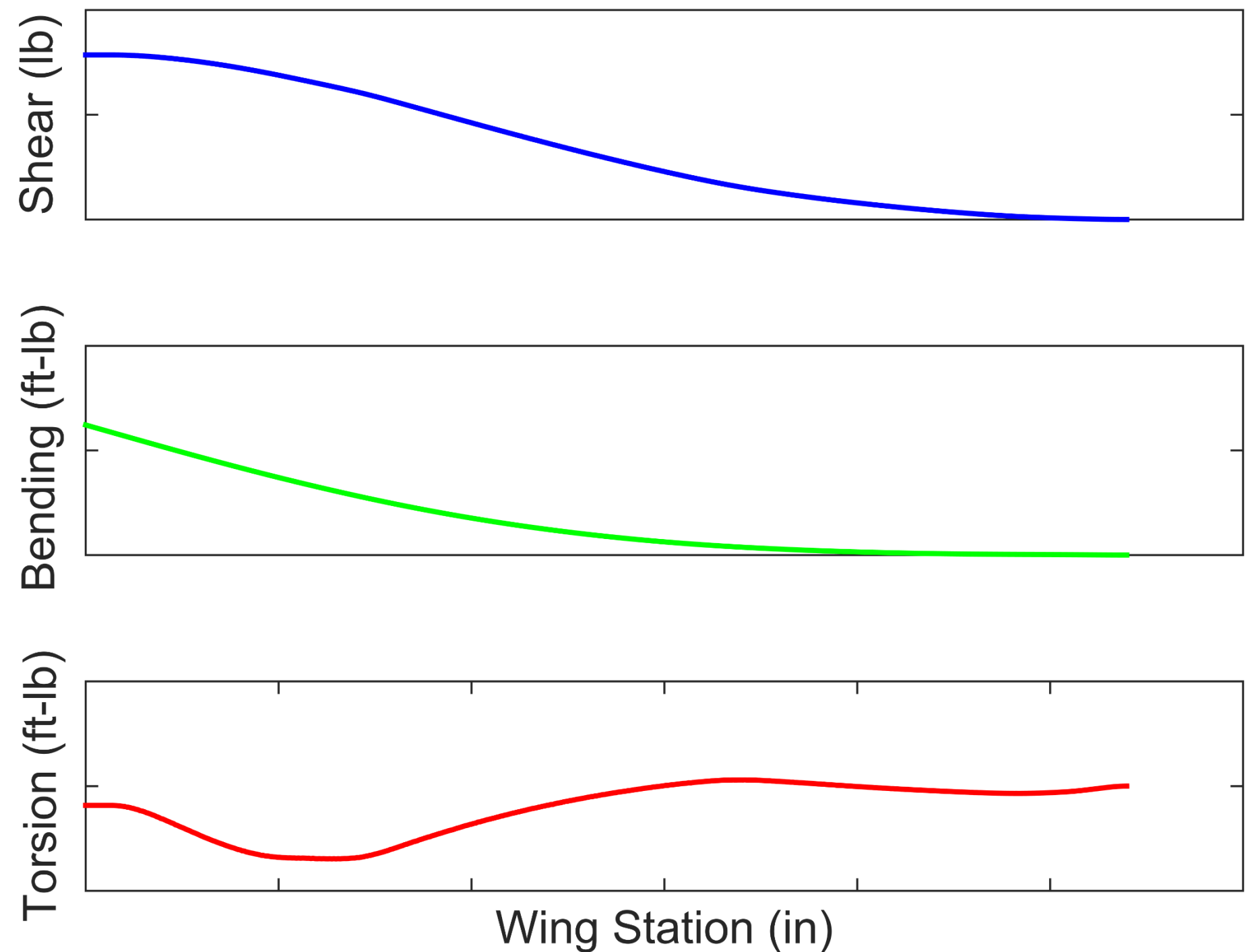




Data Output

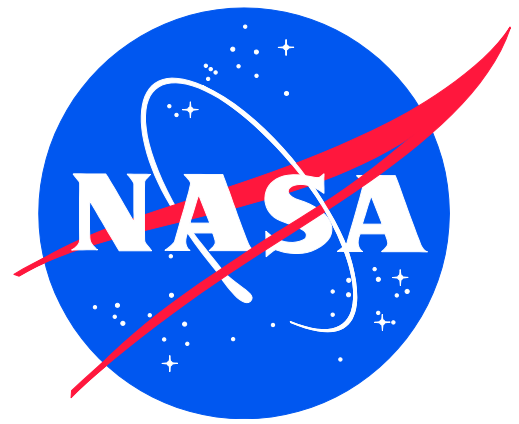


- Displays total wing loads as well as loads for specific stations
- Graphs shear, bending, and torsion in un-swept, swept, and ACTE reference frames
- Saves load data as MATLAB file
- Saves graphs as .png





Acknowledgements



- Josué Cruz
- Eric Miller
- Aerostructures Branch
- Becky Flick
- NASA Armstrong
- Aero Institute



Questions?

