Tranair Multi-Point Optimization

Why Use Tranair?

Rapid Analysis

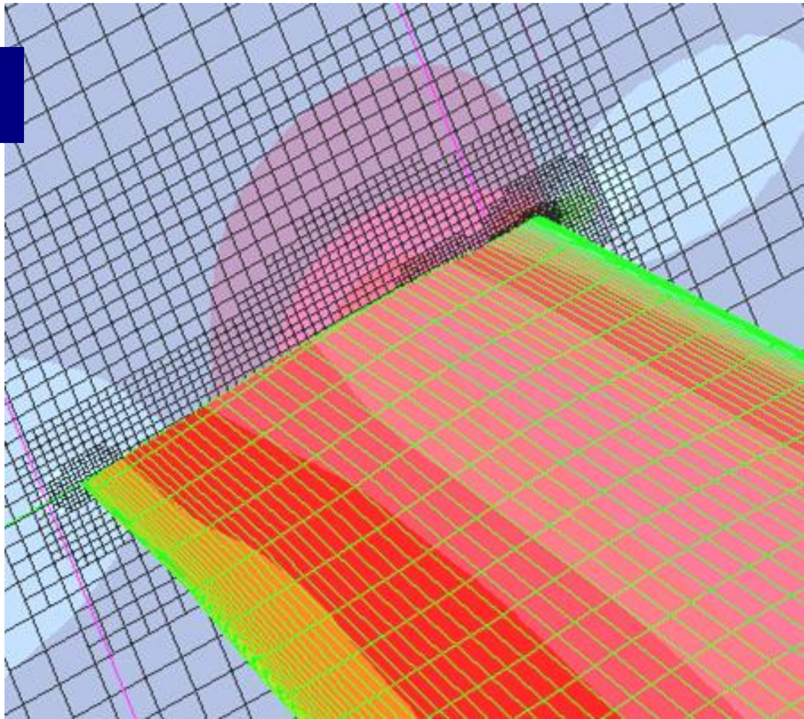
- Automation prepares grids & inputs in < 10 min from arbitrary CAD surfaces
- Execution is typically 1 CPU-hr per case
- Solutions may be trimmed automatically
- Sensitivity to alpha & beta are automatically determined

MDO/MPT Optimization

- Direct optimization with pre- and user-defined constraints and design modes
- Target pressure distribution is not required
- Multi-point optimization allows best design for a range of conditions

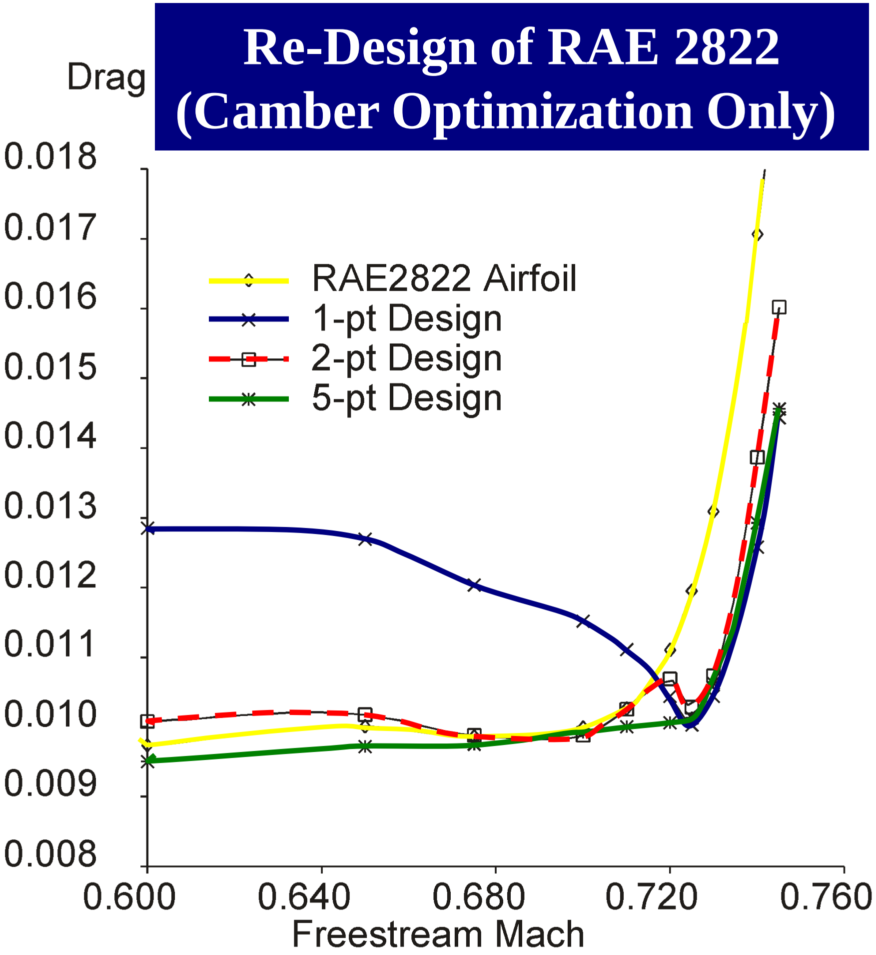
Solver Features

- Solution adaptive field grid captures shock and leading edge areas effectively
- Full potential solver with coupled boundary layer provides consistent results for attached or mildly separated flows.
- Steady & Unsteady time harmonic solvers
- Static & Dynamic S&C Derivatives



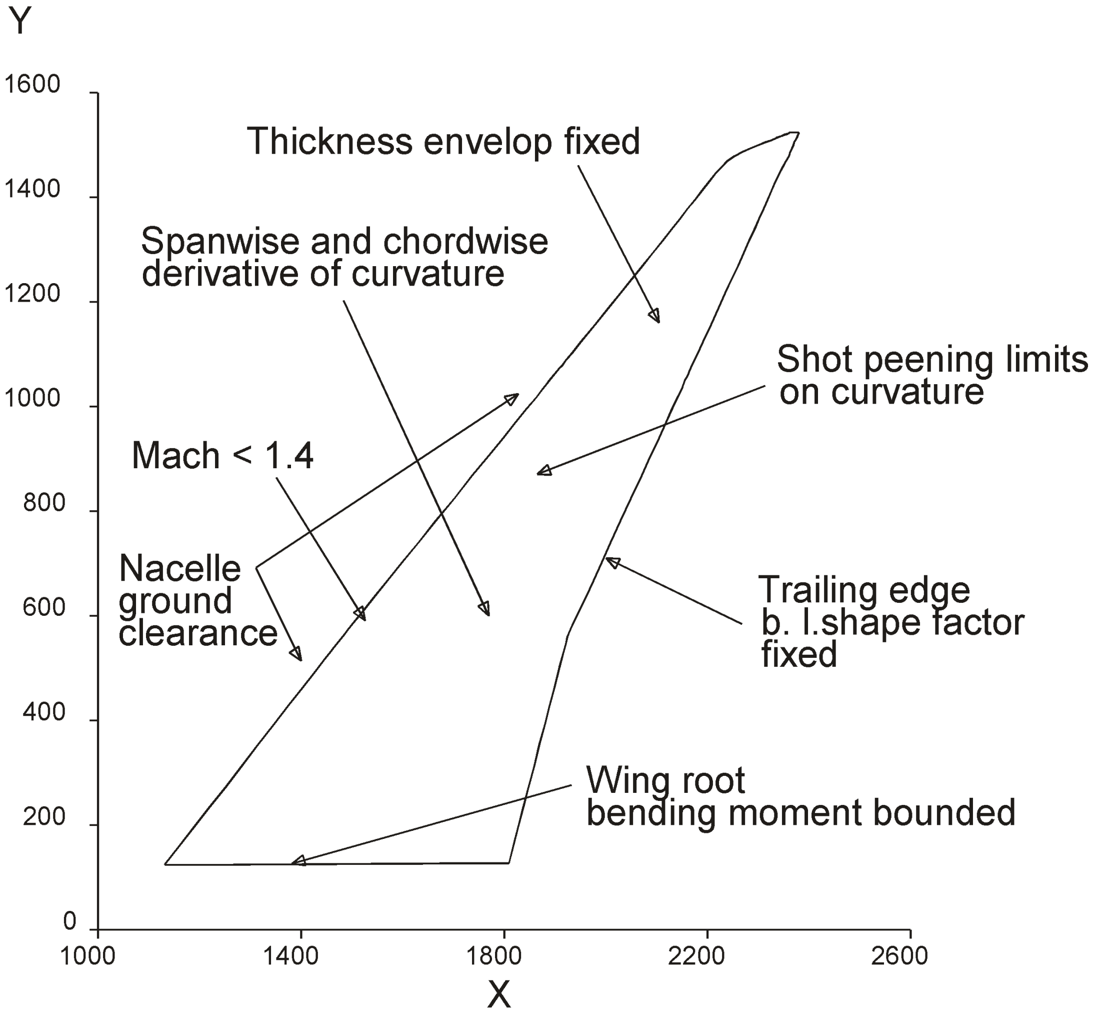
Why Use Multi-Point Design?

- Eliminates adverse drag rise of single point optimization (Blue Line)
- Multi-point drag at single-point optimization condition (Mach 0.725) is nearly identical to single-point optimization.
- 5 Multi-point conditions results in monotonic drag rise.
- Multi-Points may include:
  - Mach Number
  - CL or Alpha
  - Reynolds number



From: D.Young, IMA Workshop, 2003

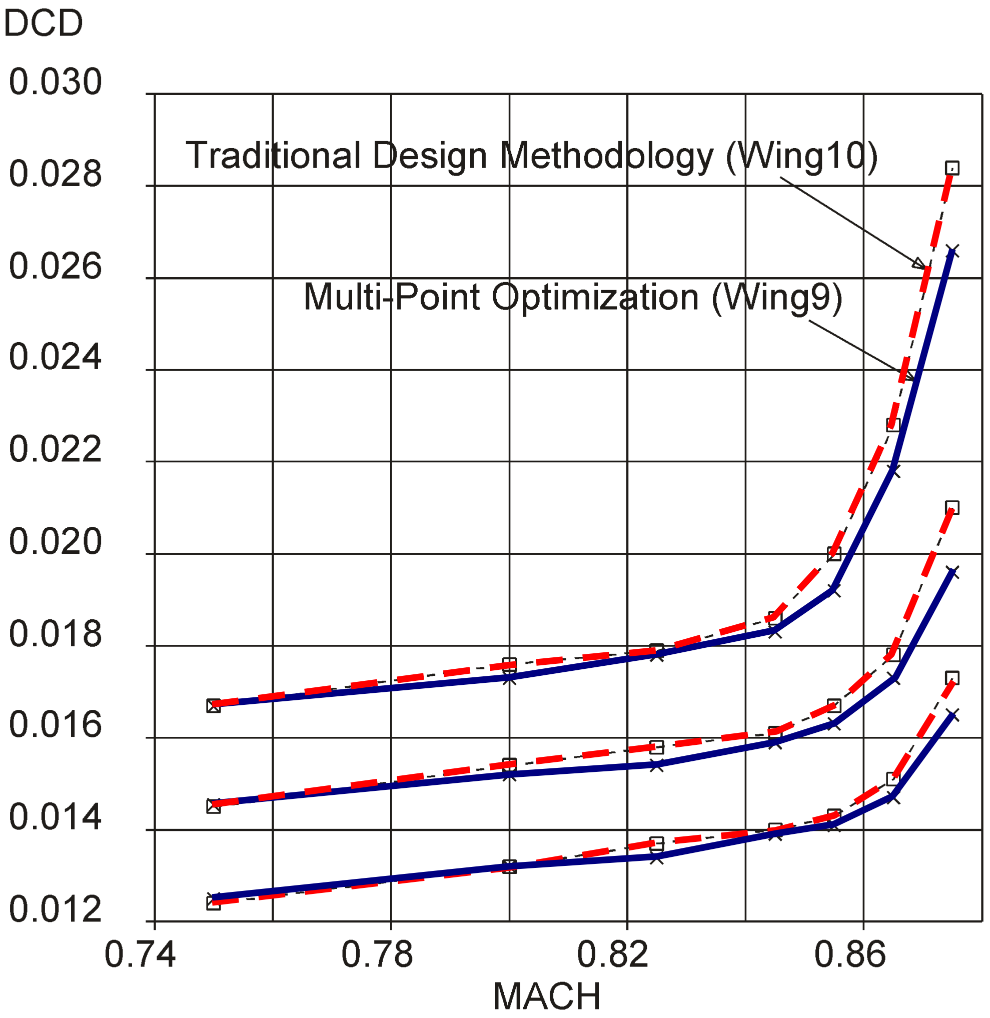
Typical Constraints for Wing Design



From: D.Young, IMA Workshop, 2003

Wind Tunnel Drag Rises For Conventional and Optimized Wing

- Tranair Multi-Point Optimization benefit is proven in wind tunnel experiments
- Results from Young (Boeing) show improvement relative to pre-multi-point optimization



From: D.Young, IMA Workshop, 2003

Productivity Through Automation

Geometry Preparation

Cut-n-Loft Tools transform arbitrary CAD surfaces into manageable lofts

Grid Generation

Automatic grid generation for consistent topologies

Input Deck Preparation

Tranair Input Decks prepared automatically including grid adaptation controls and boundary layer.

Cut-N-Loft Process

Input:

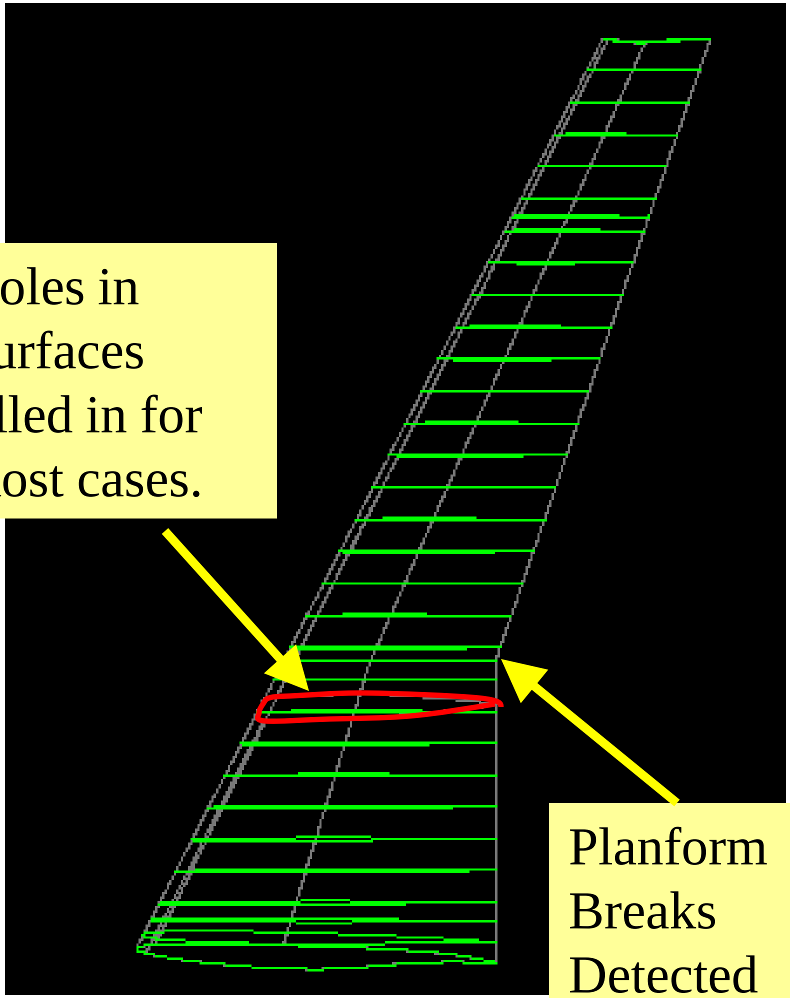
- **Collection of Surfaces**
  - **Wing, Body or Nacelle**

Process:

- **A series of cuts are made**
- **Cuts are made normal to the surface**
- **Resulting curves are sorted and combined after discretization.**
- **Inboard cut angle is fanned out.**

Output:

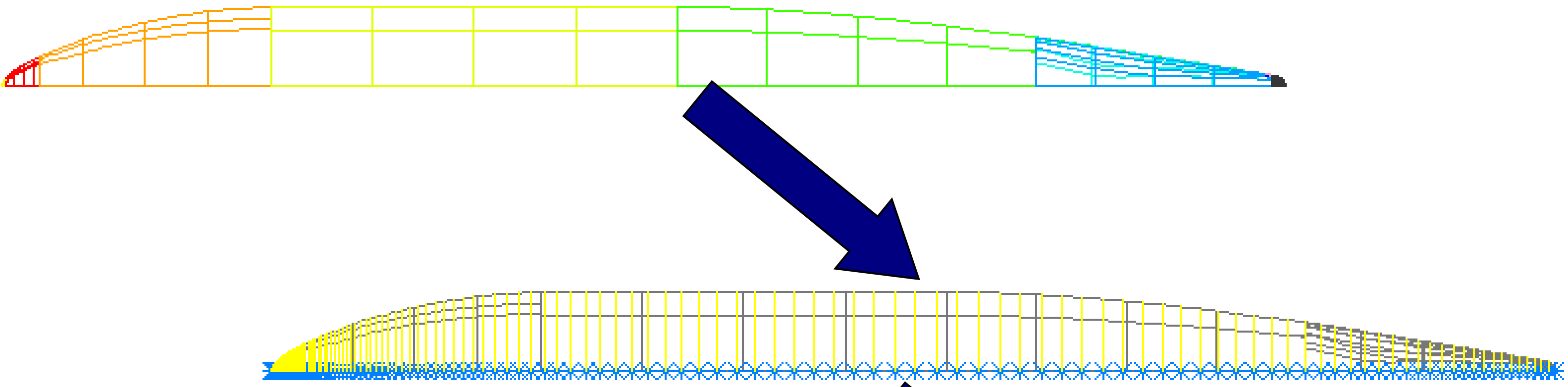
- **Clean Loft of single wing surface**

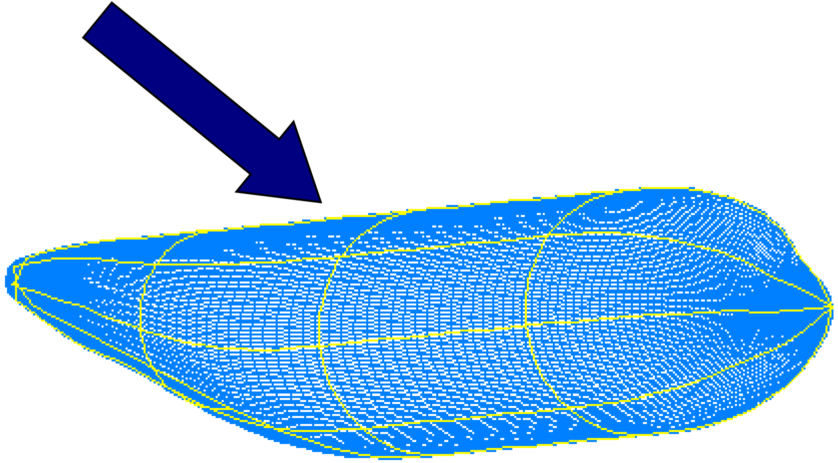


Holes in Surfaces filled in for most cases.

Planform Breaks Detected Automatically

Body Cut-n-Loft





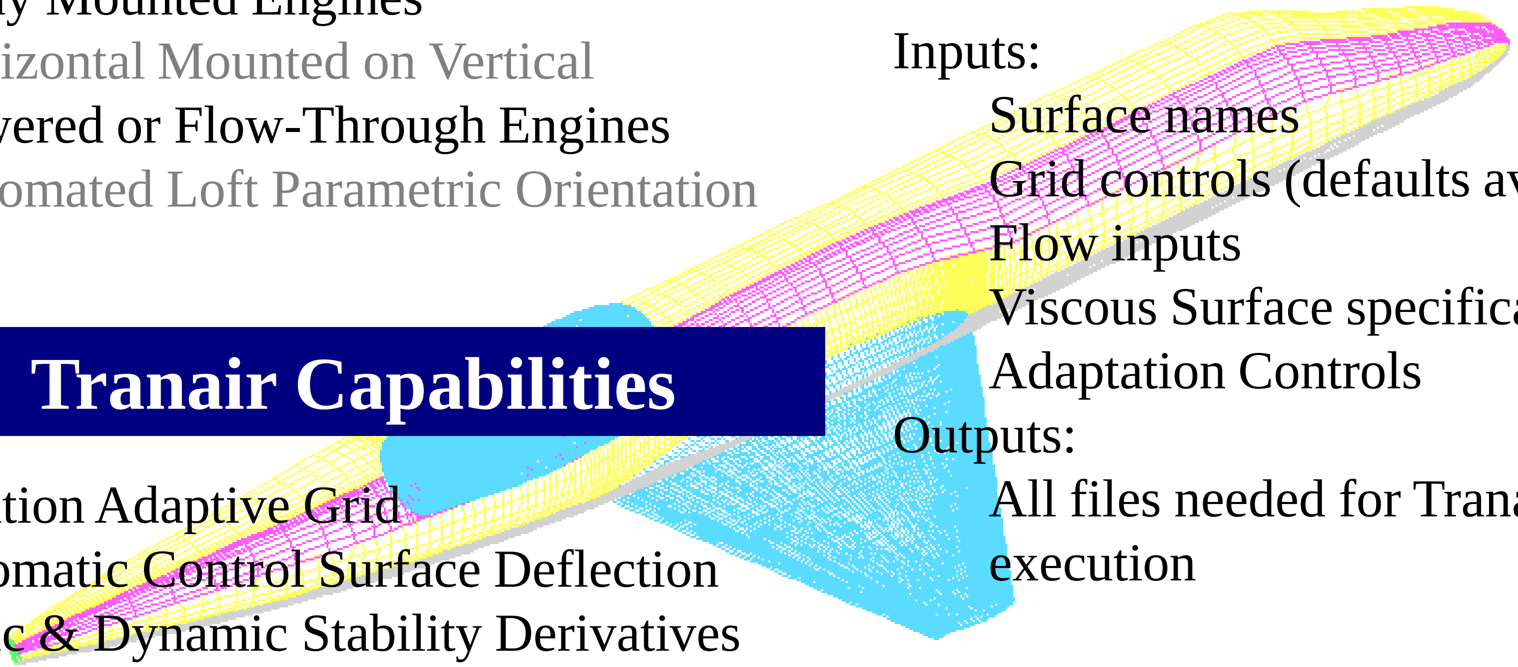
Input:
- **Collection of Surfaces**

Process:
- **A series of cuts are made at constant X-coordinate**

Output:
- **Clean loft of single body surface**

Note: Holes are not currently filled and curvature breaks are not yet automatically detected

Tranair Business Jet Package



Geometry Features

Arbitrary Number of Wing-like surfaces
Body Mounted Engines
Horizontal Mounted on Vertical
Powered or Flow-Through Engines
Automated Loft Parametric Orientation

Tranair Capabilities

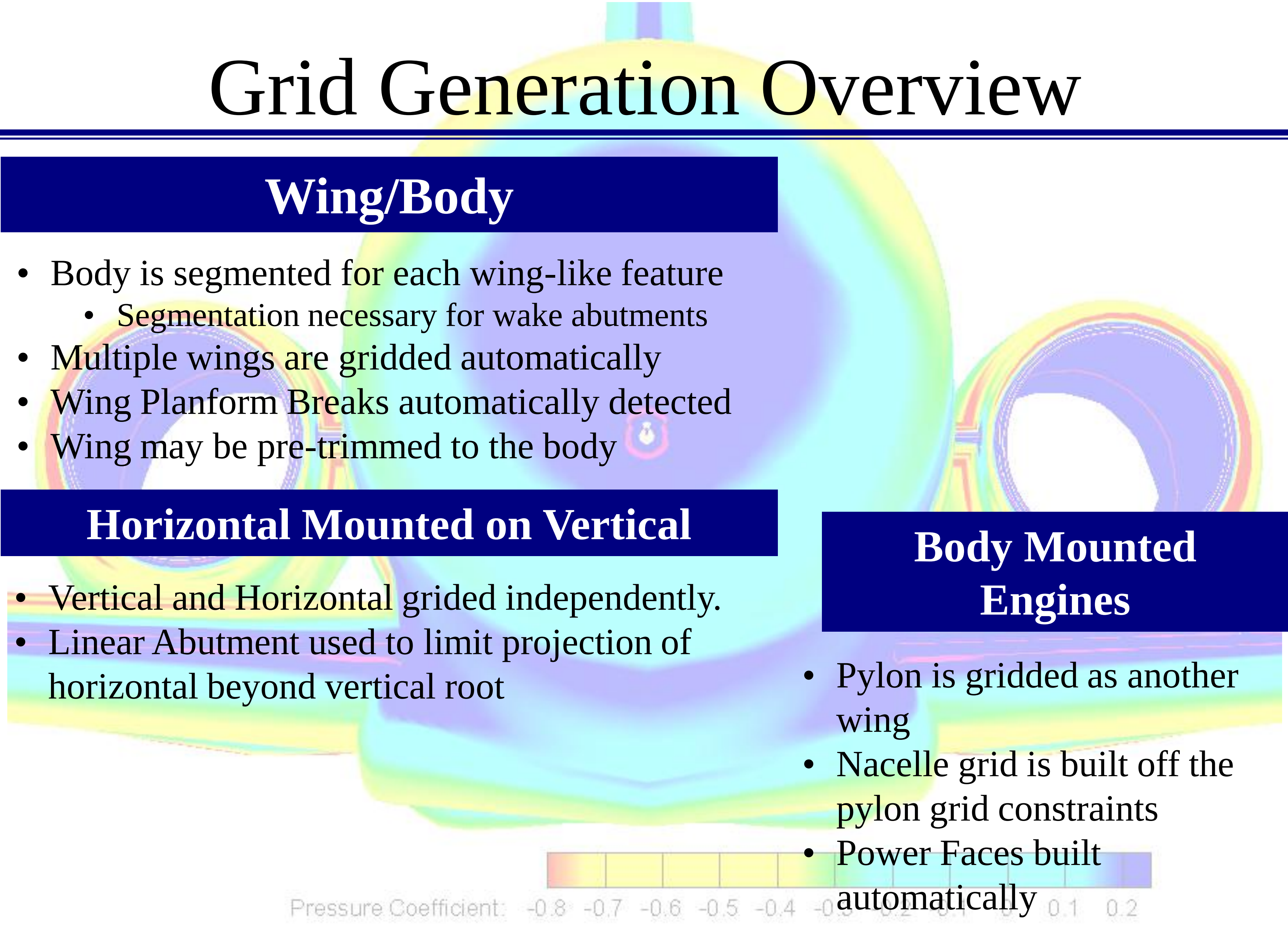
Solution Adaptive Grid
Automatic Control Surface Deflection
Static & Dynamic Stability Derivatives
Multi-Point Constrained Design

Automation

Inputs:
- Surface names
- Grid controls (defaults available)
- Flow inputs
- Viscous Surface specification
- Adaptation Controls

Outputs:
- All files needed for Tranair execution

Grid Generation Overview



Wing/Body

- Body is segmented for each wing-like feature
  - Segmentation necessary for wake abutments
- Multiple wings are gridded automatically
- Wing Planform Breaks automatically detected
- Wing may be pre-trimmed to the body

Horizontal Mounted on Vertical

- Vertical and Horizontal grided independently.
- Linear Abutment used to limit projection of horizontal beyond vertical root

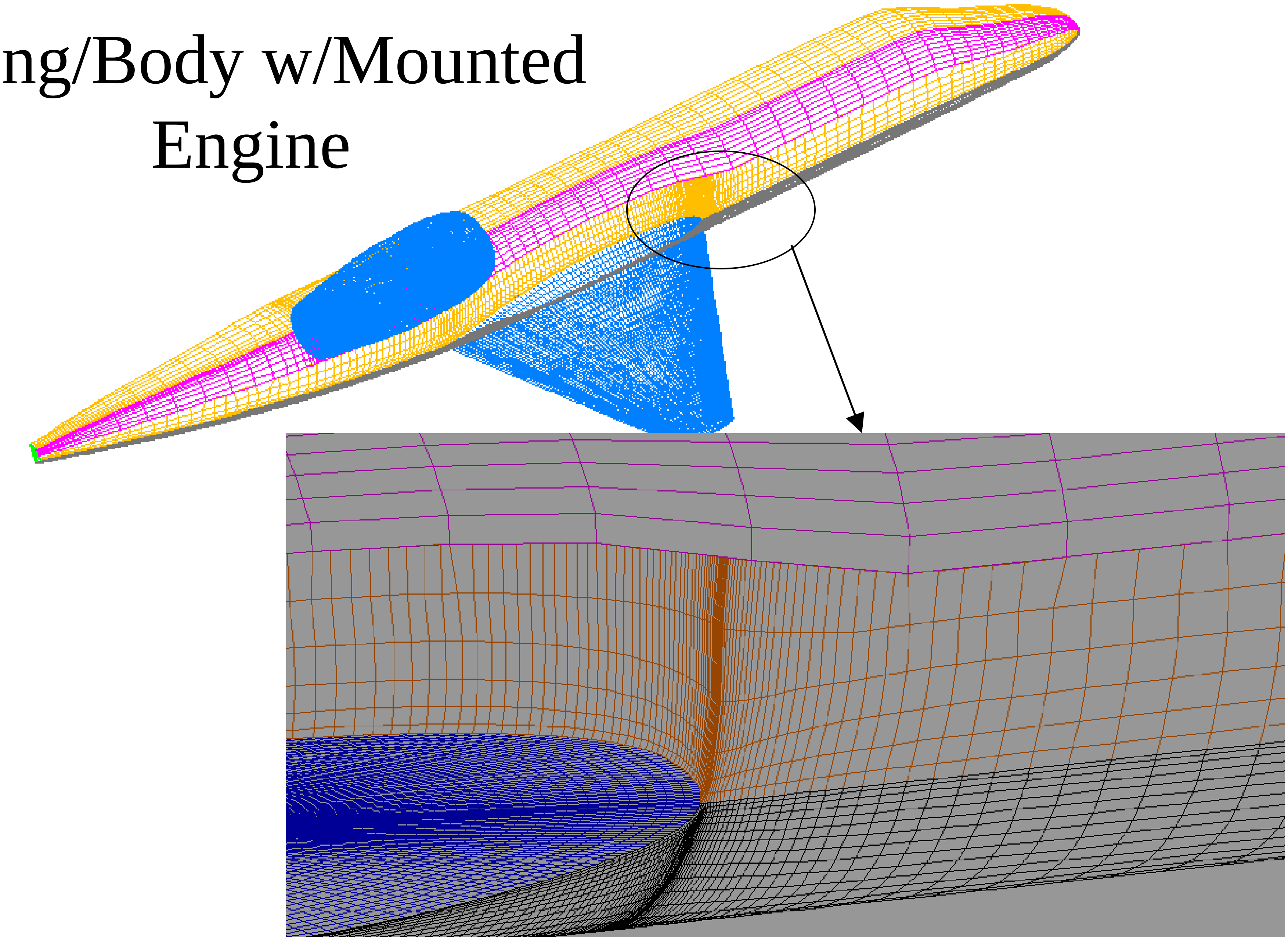
Body Mounted Engines

- Pylon is gridded as another wing
- Nacelle grid is built off the pylon grid constraints
- Power Faces built automatically

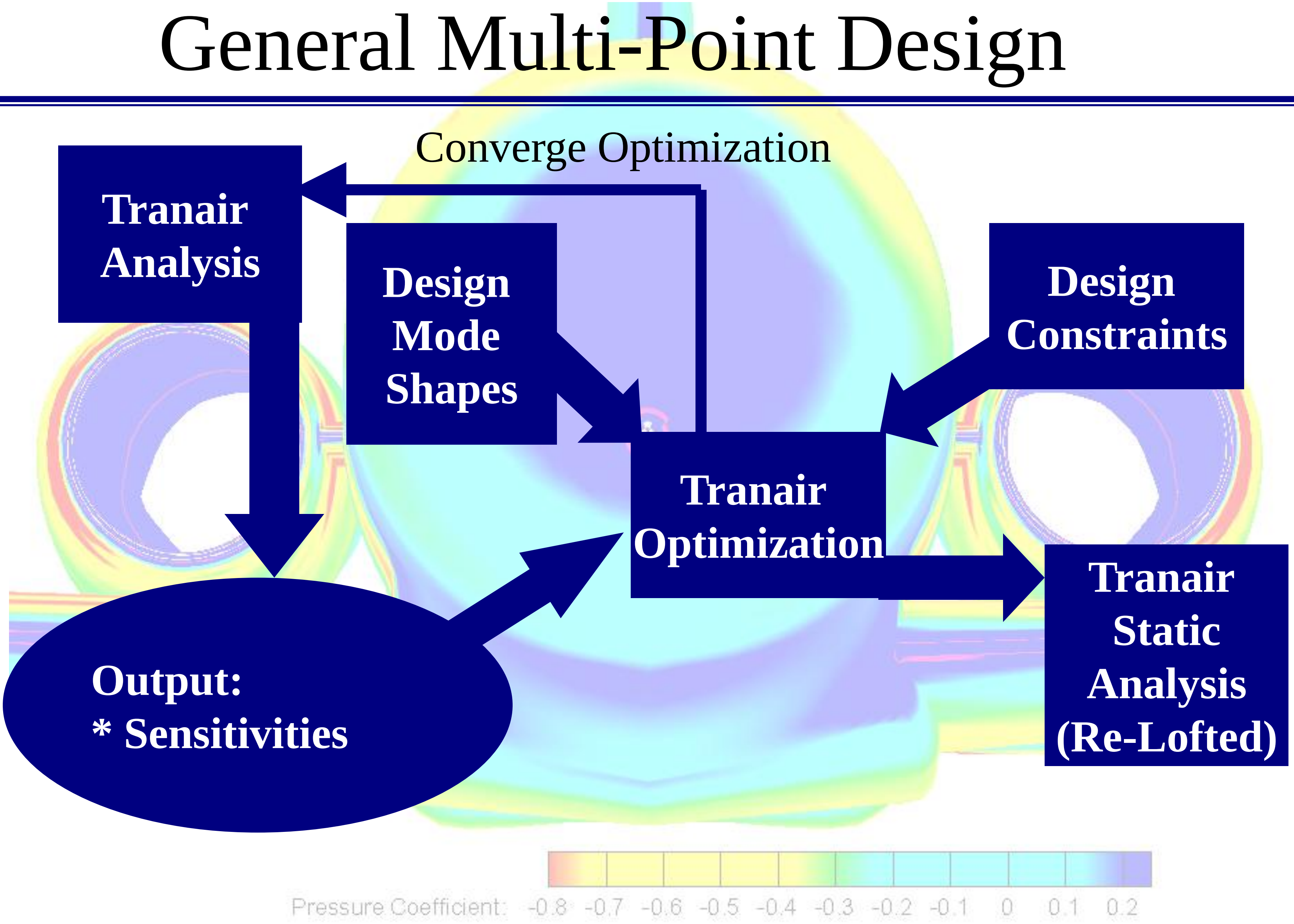
Grid Gen. Input Deck

```
Basic Grid Controls:
!    These controls set the basic grid density for the configuration.
!    Input terms are defined at the bottom of this file
!
*Components  Chord-Grid   Span-Grid  FwdGrid    AftGrid  UpGrid    LowGrid
  IBWing          101           25           35          25       25          15
  OBWing           81           21          N/A         N/A      N/A         N/A
  Pylon            61            6           75          15       15          15
  Vertical         61           25          120           7       11         N/A
  Nacelle         N/A           81           35          11      N/A         N/A
  Horizontal       81           21           25          11      N/A         N/A
!
!________________________________________________________________________
Flow Conditions:
     MachNumber      0.70
     ReynoldsNumber  20e6        !  (per Cref) The Reynolds number per unit length will be this value divided by Cref
     Alpha           1.0
     Beta            0.0         ! (Optional Input) Default is 0.
     Temperature     293 degK     ! (Optional input)Freestream temperature (specify degK or degR for Kelvin or Rankine)
!________________________________________________________________________
Reference Parameters:  (Semi-Optional)
!    Units should be consistent with lofts
!    Values will be calculated from geometry if not input.
!       -> It is highly recommended that these be input if they are already defined
!
     RefArea    4605            ! For a 1/2 model, RefArea is for a tip-tip wing
     RefSpan    1263            !  Bref & Dref
     RefMAC      258            !  Cref  (Mean Aero. Chord)
     Xref       1240            !  X coordinate of moment center
     Yref          0            !  Y coordinate of moment center
     Zref        210            !  Z coordinate of moment center
```

Tranair Grid: Wing/Body w/Mounted Engine



General Multi-Point Design



Converge Optimization

Tranair Analysis

Design Mode Shapes

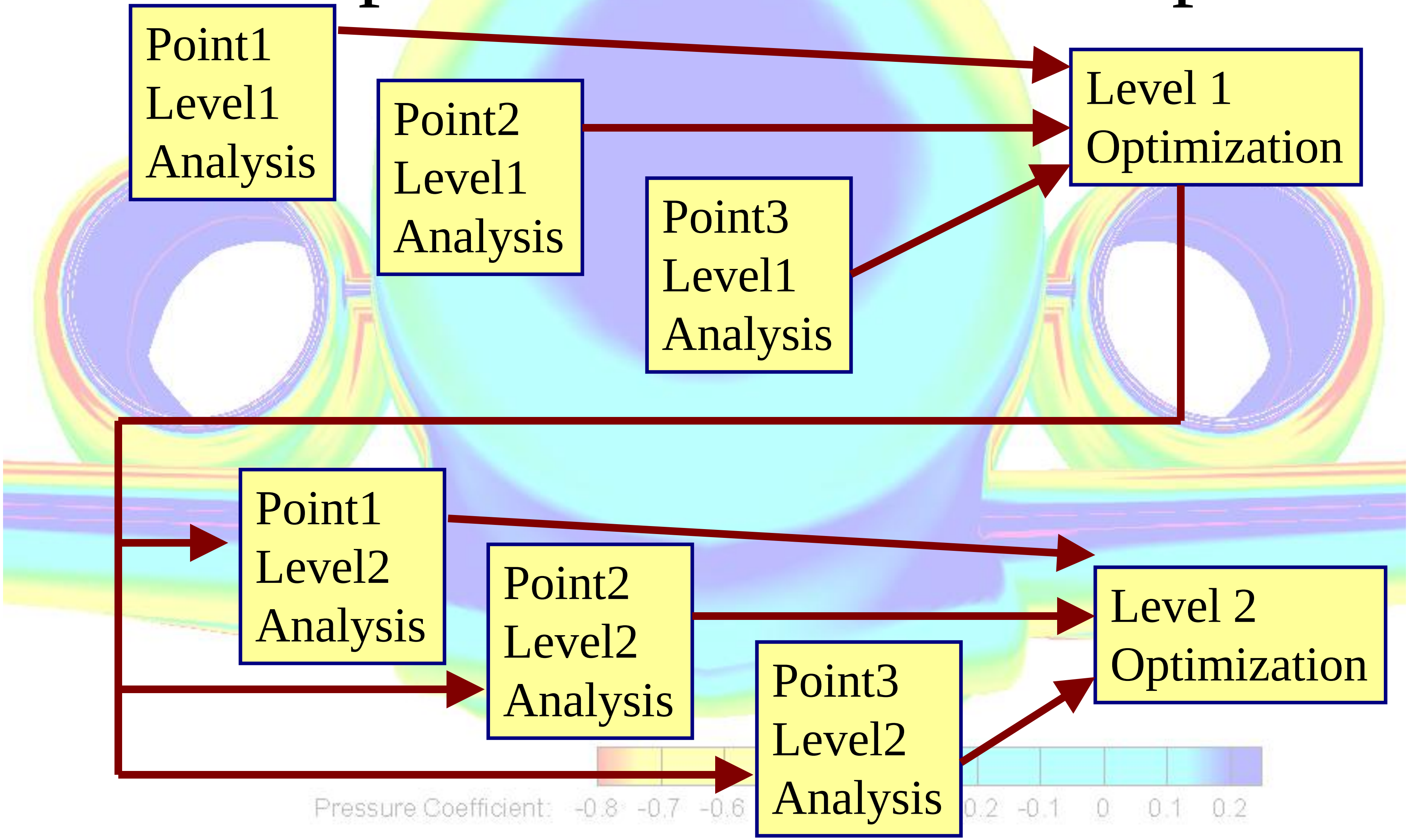
Design Constraints

Tranair Optimization

Tranair Static Analysis (Re-Lofted)

Output:
*** Sensitivities**

Multi-Point Directory Structure Set Up with Automated Scripts



Point1 Level1 Analysis

Point2 Level1 Analysis

Point3 Level1 Analysis

Level 1 Optimization

Point1 Level2 Analysis

Point2 Level2 Analysis

Point3 Level2 Analysis

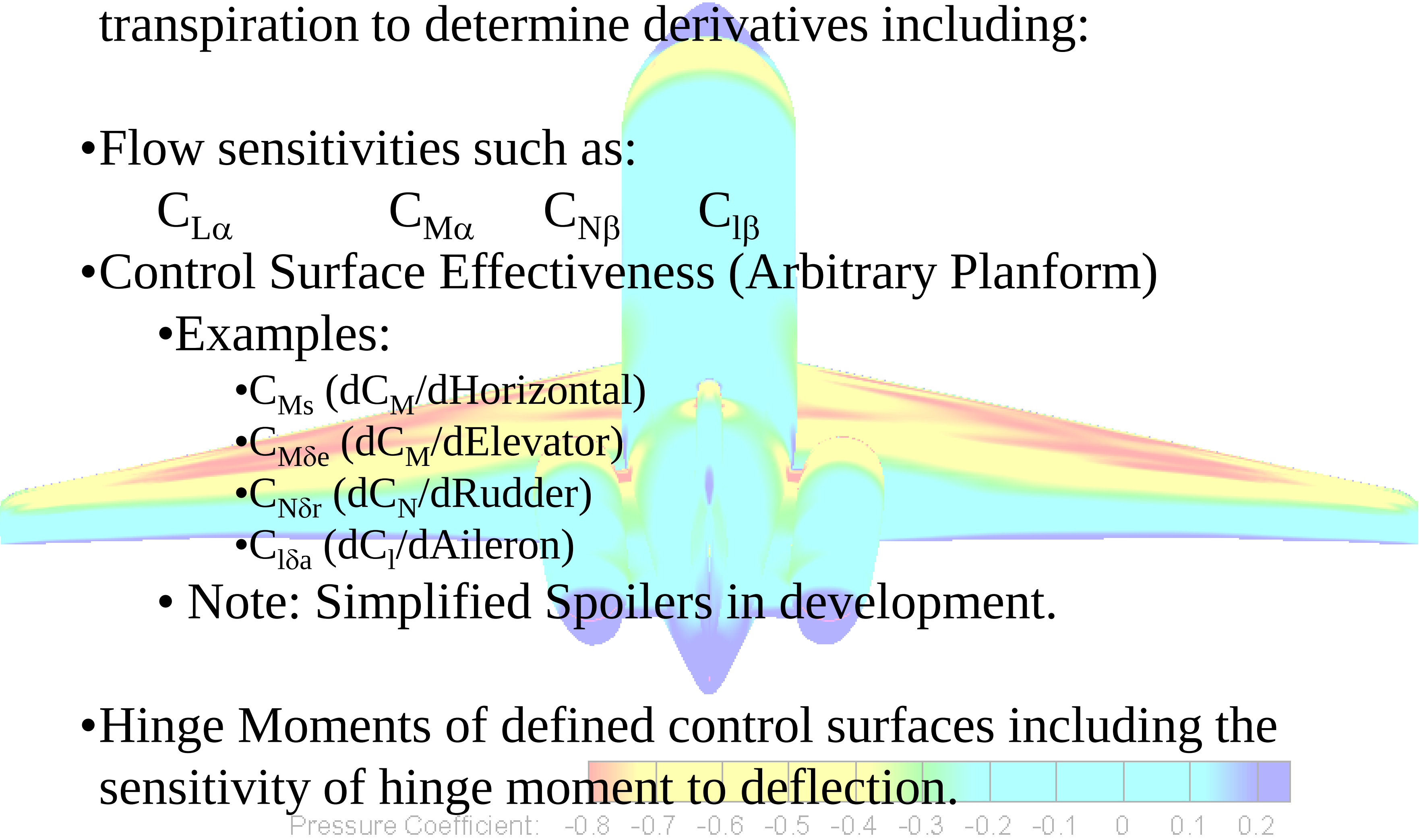
Level 2 Optimization

Tranair Stability & Control Package

The Stability & Control package utilizes second order transpiration to determine derivatives including:

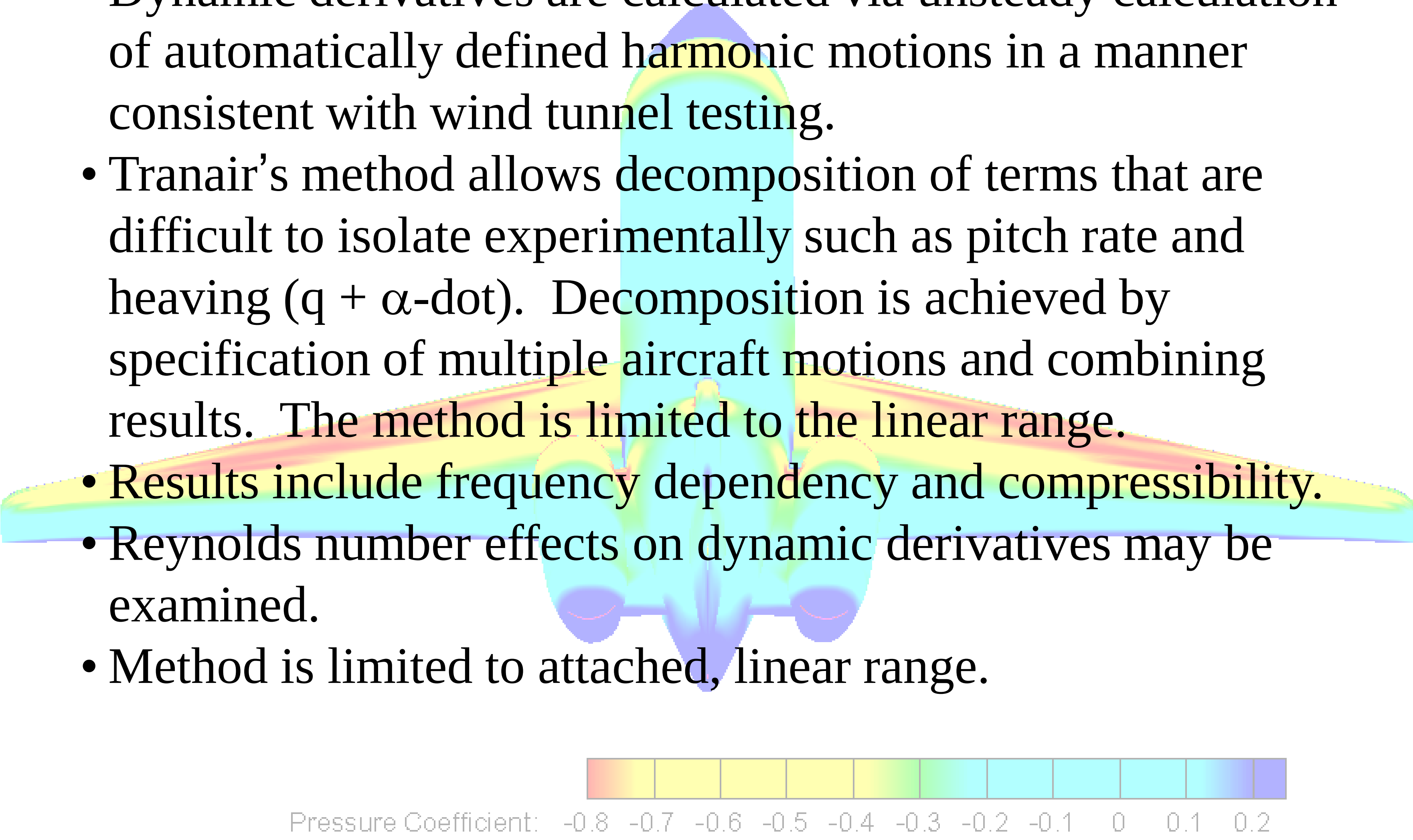
- Flow sensitivities such as:
  $C_{L\alpha}$ $C_{M\alpha}$ $C_{N\beta}$ $C_{l\beta}$
- Control Surface Effectiveness (Arbitrary Planform)
  - Examples:
    - C_{Ms} (dC_M/dHorizontal)
    - $C_{M\delta e}$ (dC_M/dElevator)
    - $C_{N\delta r}$ (dC_N/dRudder)
    - $C_{l\delta a}$ (dC_l/dAileron)
  - Note: Simplified Spoilers in development.

- Hinge Moments of defined control surfaces including the sensitivity of hinge moment to deflection.

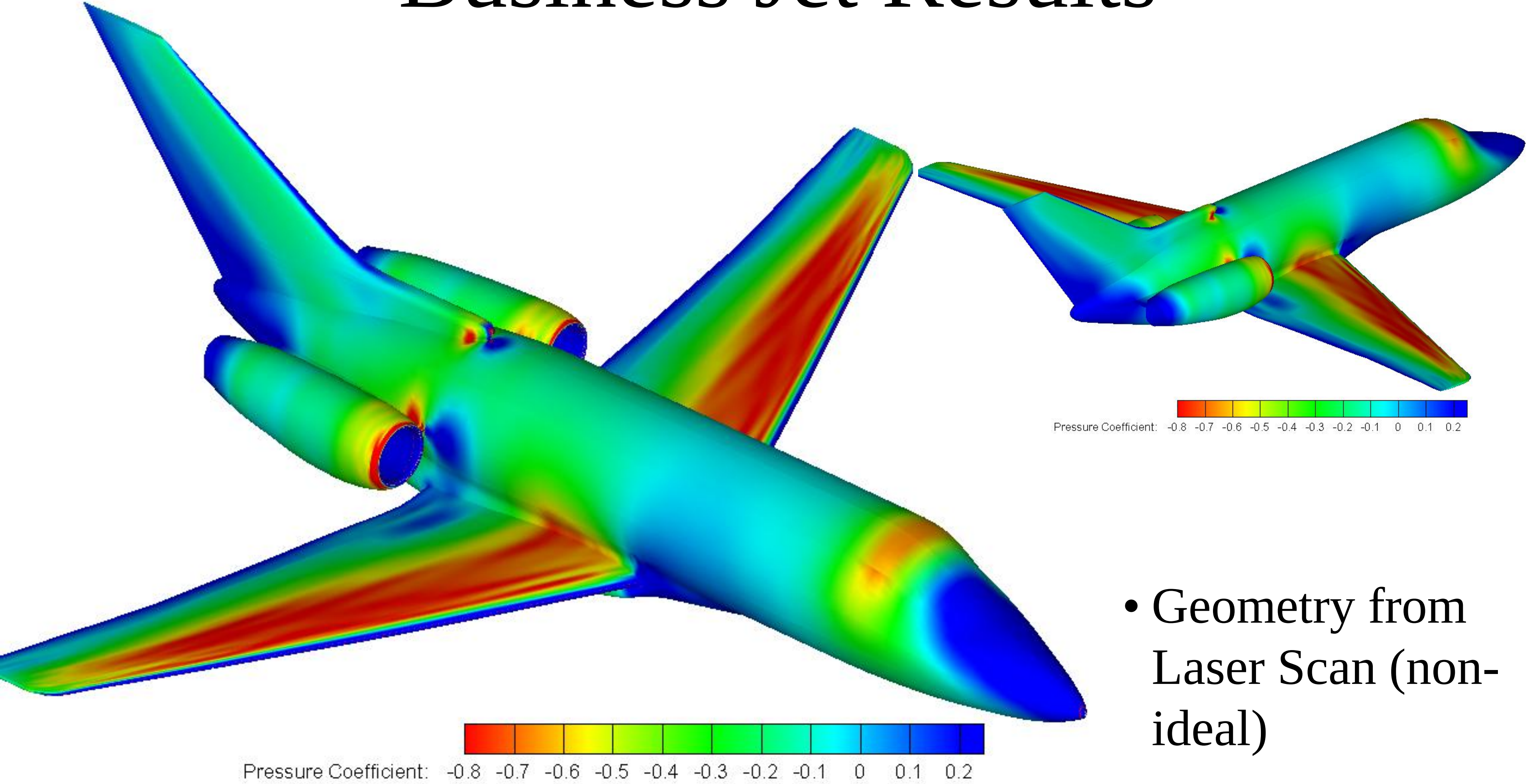


Dynamic Derivatives

- Dynamic derivatives are calculated via unsteady calculation of automatically defined harmonic motions in a manner consistent with wind tunnel testing.
- Tranair’s method allows decomposition of terms that are difficult to isolate experimentally such as pitch rate and heaving (q + α-dot). Decomposition is achieved by specification of multiple aircraft motions and combining results. The method is limited to the linear range.
- Results include frequency dependency and compressibility.
- Reynolds number effects on dynamic derivatives may be examined.
- Method is limited to attached, linear range.



Business Jet Results



- Geometry from Laser Scan (non-ideal)

Why Use Tranair++ ?

It’s Fast

- Grid generation is typically in minutes
- Solutions require ~1cpu-hr

It’s Consistent

- Grid adaptation and consistent grid rules help obtain consistent results

Multi-Point Optimization

- Field-proven on Boeing aircraft
- Significant benefits over single-point optimization

Stability and Control Package

- Enables evaluation of all stability and control terms.