The Research in Flight Company

- Established 2012
- Primary functions are the development, marketing and service of FlightStream and the development of aerodynamic solutions
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NASA SBIRs and other activities

- Evaluation of the D8.5 configuration

- Development of engine integration capability (SBIR 2015-I NNX15CL92P)

- Maximum Lift Estimation

- An advanced solution to vortex shedding for high lift modeling (SBIR 2016-I NNX16CL39P)
FlightStream Characteristics

FlightStream is a highly efficient subsonic inviscid solver

Capabilities:

- Flow Field parameters with approximately the fidelity of a well implemented Euler solver except that FlightStream offers time resolved solutions, preservation of trailing vorticity, and solutions with close proximity aerodynamic lifting surfaces.

- High Fidelity Inviscid Load Calculations for Airplanes of a wide variety of configurations including blended bodies, canard configurations, and nearly any nonconventional geometry.

- FlightStream is fully integrated with a range of geometry inputs.

- Viscous drag estimates are provided via a Reynolds analogy based approach.
FlightStream Characteristics

- Vortex Lattice, Planar Potential Methods
- Lifting Line
- Empirical Methods
- Euler Codes, Cart 3D
- RANS solvers
- LES
- DNS

Order of the Method

Fidelity
- Highly Resolved Flow Physics
- Flow Features Resolved to Small Scales
- Accurate Estimate of Loads for Attached Flows
- Accurate Load Estimates Simple Geometry
- Lift for Simple Geometry

Relative Required Computation Time

Preliminary Design
Detailed Design
Specialty
FlightStream Capabilities Overview

- All primary aerodynamic loads are calculated using a proprietary inviscid surface based method.

- Field variables are available on demand through efficient post processing.

- Surface pressures are available with appropriate solver settings

- Seamless geometry input:
  - Fully integrated with NASA’s OpenVSP
  - Commercial surface mesh generators such as Pointwise
  - For missiles, missile lab and other stl or key geometry inputs are usable
  - Limited CAD interface capability

- Highly intuitive UI & High Quality native graphical post processing

- Built in Optimization using OpenVSP for geometry and a Real coded GA

- Propeller analysis using direct blade analysis or actuator disk models.

- Gas Turbine based engine integration through NPSS, inlet definition, and exhaust modeling
FlightStream Geometry Pre-processing: Overview

IGES / IGS files
(Step/stp in near future)

CAD Import

Mesh
(STL, TRI, PLY, INP files)

Post-processing
(Streamlines, section planes, probes)

Solver

OpenVSP
Pointwise
ABAQUS

tecplot
ParaView

Research In Flight
Geometry Pre-processing: VSP
Geometry processing from CAD
Geometry Pre-processing: Pointwise® Meshes

- FlightStream is compatible with Pointwise® meshes
- Pointwise® can generate aligned structured and unstructured surface meshes
  - Both of these have been tested with FlightStream successfully
Engine Integration Modeling

- Modeling jet engines:
  - Velocity inlets for engine intakes
  - Actuator discs for engine exhaust flows

- Modeling propellers:
  - Actuator discs for propeller models in steady flow
  - Unsteady solver for time-dependent studies with full fidelity propeller modeling
Engine Integration Modeling: Velocity Inlets
Engine Integration Modeling: Jet Exhausts

- **Turbofan Example:**
  - Two actuator exhausts. One for the fan and the other for core; Concentric cascading.
  - Free-stream velocity set to 1 m/sec.

Jet spreading rate: 0.1000
Condition for high velocity gradient in the exhaust plane

Jet spreading rate: 0.0375
Condition for uniform exhaust velocity distribution
Engine Integration Modeling: Jet Exhausts (Contd.)
Engine Integration Modeling: Combined Inlets + Exhausts
Modeling Propellers: Vehicle Sketch Pad Geometries
Modeling Propellers: Actuator discs for steady-flow

- Created using local coordinate systems in FlightStream.
- Need only radius, RPM, thrust and power coefficients as user inputs.
- Works within the FlightStream steady-state solver.
- Is used as a preliminary approach to modeling propeller effects on aircraft geometry.
- Extremely high computational efficiencies.
- Can be used to model large number of propellers on the same geometry.
Modeling Propellers: Time-Dependent Solver
Surface Pressure Computations

- Evaluated as a byproduct of the vorticity solution
- No computational penalties
Parallel Solver Scalability

- FlightStream flow solver is completely parallel-scalable
Special Applications: In-Flight Refueling Modeling

- Multi-aircraft simulations
- Geometry modeled using VSP
Special Applications: Proximity to surroundings

- Carrier landings
- Wind-Tunnel flow with modeled ducts
Validation cases: Boeing F-18A
Validation cases: DLR-F4

- Angle of Attack (Deg)
- Flightstream (M 0.75)
- Experiments

CL vs. Angle of Attack

- CL vs. CD
- Flightstream (M 0.75)
- Experiments
Validation cases: Cessna 210
Validation cases: Tecnam P2006T
Validation cases: HLPW-2 (With Slats & Flaps)
Modeling Separation

- $Cl_{\text{max}}$ computations for each spanwise section
- Formulation based on the Valarezo and Chin Pressure Difference rule
- Reformulated into vorticity

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Output of CL-max computations in the Analysis tab

Status of individual elements
Validation cases: Flow Separation

- EET AR-12 Cruise
- FlightStream
- CLmax

Cessna 210 NLF(1)-0414F Airfoil Mod / WT data

CLmax

Angle of attack (Deg)
Validation cases: High-lift Prediction Workshop

- HLPW 2012 Experiment Data
- FlightStream CL
- Wing Clmax from FlightStream
- Clmax from FlightStream
- Linear (FlightStream CL)

Angle of attack (Deg) vs. CL

0.00 5.00 10.00 15.00 20.00 25.00
FlightStream Toolboxes

- AOA and Mach sweeps
- VSP
- N.P.S.S. Turbofan/Turbojet model
- Aero-propulsive optimizer
Toolbox: AOA and Mach Sweeps

- Automated solver runs to generate sweep data
- Export per-surface component loads
- Plot data directly in FlightStream

L/D plots

Export full analysis spreadsheets for each data point!

Loads per component and overall geometry
Toolbox: VSP

- Import VSP design parameters into FlightStream
- Integrate with the aero-propulsive optimizer
- Change parameters and automate import and solver setup

Specify VSP location and model file

Import .des files and execute from within FlightStream

Change any design parameter here
Toolbox: N.P.S.S. Turbofan / Turbojet modeling

- Connect to velocity inlet and exhaust boundaries on the mesh
- Generate design and off-design performance and boundary conditions
- User needs N.P.S.S. software to use this toolbox!

![Turbofan tree diagram]

- NPSS installation
- Turbofan tree
- Engine performance output
Post-processing enhancements

- Off-body streamlines
  - Stream tubes
  - Stream line distributions
  - 3D modeling of streamlines
  - Growing streamlines from probe points
  - Upstream/Downstream growth
  - Flow contours along streamlines

- Probe points
  - User-specified probing locations in 3D-space
  - Import/Export spreadsheet of probe point clouds

- Probe surfaces
  - Generate a cloud of probe points from individual components

- Sectional planes
  - Pressure and Mach number contours
Post-processing: Streamlines

- Stream tubes
- Stream line distributions
- 3D modeling of streamlines
- Growing streamlines from probe points
- Upstream/Downstream growth
- Flow contours along streamlines
- Import / Export streamlines
Post-processing: Probe Points & Surfaces

- User-specified probing locations in 3D-space
  - Import/Export spreadsheet of probe point clouds
  - Off-body specifications

- Probe surfaces
  - Generate a cloud of probe points from components
Post-processing: Sectional Planes

- Pressure and Mach number contours
- Sections in any arbitrary location and orientation
- Post-processing step only; No computational penalties for solver
Post-processing: Sectional Planes (Contd.)

Sectional plane example:

- Vorticity-derived Surface pressure fields
- Engine Inlet Boundary effect
- Actuator Jet Exhaust effect
FlightStream Takeaways

- FlightStream offers the aircraft designer the opportunity to move high fidelity load calculations up into the preliminary design process with very high efficiency.

- Integrates seamlessly with outer mold line tools such as VSP.

- Engine integration capability at the conceptual and preliminary design level.

- Time dependent solutions at this level.

- High lift and maximum lift configuration analysis is possible at the preliminary design level.

- Designs leaving the preliminary phase are much more mature, saving on development time.