CAD-BASED WORKFLOWS

VSP Workshop 2017
RESEARCH IN FLIGHT COMPANY

- Established 2012
- Primary functions are the development, marketing and support of FlightStream and the development of aerodynamic solutions
- Website: [https://researchinflight.com](https://researchinflight.com)

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FlightStream® is a highly efficient subsonic, inviscid, surface-vorticity flow solver

Capabilities:
- High Fidelity Inviscid Load Calculations for Airplanes of a wide variety of configurations including blended bodies, canard configurations, and nearly any nonconventional geometry.
- Generates accurate results in seconds.
- Industry validated across a range of geometries and applications.
- CAD-based geometry import and surface meshing.
- Highly intuitive and scriptable UI & High Quality native graphical post processing.
- Gas Turbine engine integration through NPSS, inlet definition, and exhaust modeling.
INTRODUCTION

FLIGHTSTREAM PHILOSOPHY

Conceptual Design  Preliminary/Detailed  Specialty

Highly Resolved Flow Physics
Flow Features Resolved
to Small scales
Accurate Estimate of Loads
for Attached Flows
Inviscid Load Estimates
Simple Geometry
Lift for Simple Geometry

Order of the Method

Relative Required Computation Time

Euler Codes
RANS solvers
LES
DNS
AEROSPACE APPLICATIONS

STEADY-STATE
- Lift/Drag & Moments
- Sweep toolbox
- Example: D8.5

PROPELLER & WING
- Propeller actuators
- Time-dependent solver
- Example: X-57

TAKE-OFF / LANDING
- High-lift devices
- Max CL

ENGINE ANALYSIS
- Inlets & exhaust jets
- NPSS toolbox

OPTIMIZE
- VSP toolbox
- GA Optimizer toolbox
INDUSTRIAL APPLICATIONS

INLET ANALYSIS
- Velocity inlets
- Off-body streamlines
- Safran using this capability extensively

BOUNDARY-LAYER INGESTION
- Aero-propulsive effect
- Vortex shedding
- Vortex tracking

MARINE PROPELLER
- Propeller actuator discs
- Time-dependent solver
- Flow separation

SOLID ROCKET MOTOR
- Modeling time-dependent flow inside a rocket motor
- Potential collaboration with ULA
FLIGHTSTREAM CORE AREAS

- CAD / GEOMETRY
- PHYSICS & SOLVER
- POST PROCESSING
- VALIDATION
FLIGHTSTREAM CORE AREAS

- CAD / GEOMETRY
- PHYSICS & SOLVER
- POST PROCESSING
- VALIDATION
CAD IMPORT

- **IGES**
  - All IGES standard entities are supported
  - Simultaneous NURBS and analytical entities
    - No forced translations
  - “Free” or floating surfaces converted to trimmed surfaces (Type 144) internally

- Parasolid Transmit file import to be released soon

- **CAD repair capabilities**
  - Fix holes, cracks and “missing” patches
  - Extrude curves into surfaces
  - Split patches and edit patch curves
  - Translate between parametric and physical representations as preferred

- **CAD export**
  - IGES file export
VEHICLE SKETCH PAD

Integration with FlightStream®

- Vehicle Sketch Pad software is directly integrated into FlightStream®
- The generation of the wetted surface of the geometry from VSP is used as an input into FlightStream®
- Imported files are in multi-solid STL or TRI file format
- Users can also use the VSP CAD export to import an IGES file into FlightStream® and follow established CAD workflow
- This solver-ready mesh is then immediately solved in the FlightStream® solver

VSP Toolbox

- FlightStream® has a VSP toolbox that integrates design variables in the geometry with VSP to conduct rapid turnaround of different test cases
CAD WORKFLOW

- Workflow Focus
- Meshing Pipeline
- Advantages & Opportunities
- CAD-Based Physics
WORKFLOW FOCUS

INTRODUCTION

GEOMETRY

CAD

SURFACE MESH

BOUNDARY PHYSICS

SOLVER

SIMULATION ANALYSIS

RESEARCH IN FLIGHT
WORKFLOW FOCUS: OPENVSP

INTRODUCTION

CAD

SURFACE MESH

BOUNDARY PHYSICS

SOLVER

SIMULATION ANALYSIS

New!
CAD Export

CompGeom

CFD Mesh

Research In Flight
ADVANTAGES

**CAD**
- High geometric fidelity.
  1. Adjoint mesh refinement.
  2. High-quality anisotropic quads and unstructured isotropic triangles.
  3. CAD-based physics.
  4. Streamlined solver setup.
  5. Reduced setup time.

**COMPGEOM**
- Anisotropic meshes.
  - Mesh-size efficiency.
  - Simple one-click operation.
  - Fast.

**CFD-MESH**
- Isotropic meshes.
  - Good quality unstructured surface meshes.
  - Integrated with VSP: good geometric fidelity of meshes.
CAD
- Higher one-time setup time (including physics).
- May need to use CAD repair on some models after import.
- Complex setup, if using FlightStream Adjoint methods.

COMPGEOM
- Pipeline rigidity.
- User needs to return to VSP to make mesh changes.
- No CAD availability; restricts discrete mesh refinement quality.
- No CAD-based physics.
- Needle-like triangles in stitched areas between components: need cleanup in solver.

CFD-MESH
- Pipeline rigidity.
- User needs to return to VSP to make mesh changes.
- No CAD-based physics.
- Slow.
FlightStream® allows you to mesh your OpenVSP CAD models in seconds.

These meshing tools are integrated within FlightStream®'s in-house CAD-library, and work directly on the CAD surfaces and curves, thereby preserving the geometrical fidelity at all times, whether you are coarsening the mesh or refining it.

Surface meshers:
- Unstructured triangles or quadrilaterals (completely automated)
- Anisotropic, curvature aligned quadrilaterals
- Patch-fillers
FlightStream® has tools designed to allow you to take full advantage of the swept surfaces on your geometry:

- Wings & propellers
- Stabilizers & fins
- Nacelles
- Pylons
- Cylindrical fuselage sections

Anisotropic surface meshing allows you to specify the refinement in the directions that are useful, while keeping the mesh coarse in directions that do not benefit from the refinement. This keeps your mesh sizes small, your solver runs fast, and accuracy at its highest.

Precise application of anisotropic meshing allows you to often generate meshes that are a fraction of the typical isotropic meshes in terms of face count, and yet more true to the physical surface.
CAD-BASED MESHING: CURVATURE

• FlightStream® allows users to refine their meshes using local surface curvature.

• Note that this works automatically with the unstructured triangulated mesher; and can be invoked for the anisotropic mesher.
• Control surfaces need additional local refinement, given their proximity to other surfaces.

• This is accomplished using the volumetric mesh controls in FlightStream®.

• Volume mesh controls can be added at the model level, and applied selectively to specific components as needed.

• Can be defined in local coordinate systems and rotated with the control surfaces.
OPENVSP CAD WORKFLOW

- Workflow Focus
- Meshing Pipeline
- Advantages & Opportunities
- Cad-Based Physics
CAD-BASED PHYSICS

• Context: currently, user applies boundary physics directly on the mesh in FlightStream®.
  • This is a manual process that must be repeated every time the mesh refinements change.
  • Increases workload!
  • Decreases workflow efficiency!

• CAD-Based Physics (CBP) allows users to set up their boundary physics directly on the CAD surfaces.
  • Trailing edges
  • Inlets

• Post-CBP meshing borrows the physics setup directly from the CAD and transfers it directly to solver.

• Advantages:
  • Allows FlightStream® users to import a CAD model, apply boundary physics one time, and let subsequent meshing operations be free from boundary settings.
  • One-time setup that eliminates continuous user interaction with the setup.
  • Maximizes efficiency of workflow.
  • Script-able.
  • Reduces setup time to a fraction of original workflow!
CAD-BASED PHYSICS

INTRODUCTION

GEOMETRY

CAD
BOUNDARY PHYSICS
SURFACE MESHING
SOLVER
SIMULATION ANALYSIS

RESEARCH IN FLIGHT
CAD ADVANTAGE: ADJOINT REFINEMENT

- **Context:** currently, user refines mesh using either the CAD-based meshing route, or in VSP and then importing into FlightStream®.
  - This is a manual process

- Adjoint mesh optimization can be performed directly on the unstructured surface mesh in FlightStream®.

- CAD allows mesh projection on to the analytical surfaces to retain geometric fidelity.

- Unstructured surface mesh allows localized refinements as needed.
  - Similar to automated curvature and volume control refinement in FlightStream®
  - Similar to CFD mesh source-term-driven refinement

- Automated mesh refinement for the user!
FLIGHTSTREAM® CORE AREAS

- CAD / GEOMETRY
- PHYSICS & SOLVER
- POST PROCESSING
- VALIDATION
BOUNDARY PHYSICS

• Shedding vorticity for generating aerodynamic loads
• Slip wall boundaries for all geometry surfaces
• Compressible-flow modeling and transonic flow corrections up to free-stream Mach 0.85

• **Modeling jet engines**
  • Velocity inlets for engine intakes
  • NPSS toolbox for engine performance and boundary conditions
  • 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
PROPELLERS: STEADY-STATE

- Created using local coordinate systems in FlightStream®
- Need only radius, RPM, thrust and power coefficients as user inputs.
- Extremely high computational efficiencies.
- Can be used to model large number of propellers on the same geometry.
PROPELLERS: TIME-DEPENDENT SOLVER

- Surfaces can be coupled with motion definitions (rotation, translation etc.)
- Time-dependent solver allows surface motion and time-dependent wake propagation
- Aerodynamics loads as a function of propeller motion
INLETS & EXHAUST JETS

- Surfaces can be marked as velocity or mass-flow inlets
- Can be coupled with NPSS to create integrated engine simulations
- Created using local coordinate systems
- Need only radius, exhaust velocity and fluid parameters as user inputs
- Can be cascaded to model concentric jets
SURFACE PRESSURE

- Evaluated as a byproduct of the vorticity solution
- No computational penalties
FINITE ELEMENT ANALYSIS

- Integration with Abaqus, NASTRAN file formats
- Import FEA models and map solutions & forces on FEA meshes
MOVING REFERENCE FRAME

- Rotating reference frames for marine propellers, wind turbines & aircraft propellers
- Steady-state performance analysis
- Wake contraction models
FLIGHTSTREAM® CORE AREAS

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- VALIDATION
DPW-4 CRM

- AIAA Drag Prediction Workshop 4 “Common Research Model”
- Highly compressible flow (Mach 0.85) & localized supersonic flows
- Integrated shock correction using potential theory

![Diagram of aircraft with CL vs CD plot]
DPW-1 DLR-F4

- AIAA Drag Prediction Workshop 1
- Highly compressible flow (Mach 0.6)
- Advanced surface pressure corrections model
PIPER PA-24 (POWERED)

- Propeller actuators for steady-state powered conditions
- Asymmetric flow conditions
- Lateral & longitudinal characteristics verified

![Graphs showing CL, CD, and CM plots for different angles of attack and Tc values.](image)
HLPW-2 DLR-F11

- 2\textsuperscript{ND} AIAA High Lift Prediction Workshop (HLPW-2) DLR-F11 model
- High-lift devices: flaps, slats and wing slots
- Near-incompressible flow
LATERAL CHARACTERISTICS

• Wing-body model validated for lateral characteristics
• Incompressible flow
ROBIN HELICOPTER

- NASA Rotor-Body Interaction (ROBIN) helicopter
- Steady-state validation (rotor actuators)
- Time-dependent validations (with rotor blades)
- Current tests: radially loaded rotor actuators versus constant loading actuators
FLIGHTSTREAM® CORE AREAS

- CAD / GEOMETRY
- PHYSICS & SOLVER
- POST PROCESSING
- VALIDATION
POST-PROCESSING

- Streamlines
  - Surface streamlines
  - 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
FlightStream® scripting is text-file based
- Simply create the script in text format and use it in the command line call to FlightStream®!

Extensive API library

Highly suited for integration into an optimization pipeline such as one created in Modelcenter.