Overview of the Higher-Order Design Environment (HOrDE)

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Sept. 17, 2019

Introduction

Vision: Enabling higher-order analysis of conceptual-level, conventional and unconventional aircraft concepts through design refinement.

- Motivation
  - Low-order analysis limits ability to accurately model unconventional configurations
  - Meaningful high-order analysis is limited to fully-developed designs
  - Lacking a capability for creating “higher order geometry” to complement higher order analysis
- General Approach
  - Leverage existing MDAO frameworks (OpenMDAO, ModelCenter)
  - Exploit Vehicle Sketch Pad (OpenVSP) as a common geometry interface
  - Develop “higher-order geometry” through automation and intelligent streamlining in a multi-fidelity design process
  - Build new design tools that integrate existing analysis methods tailored to early design stages

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HOrDE Software Organization

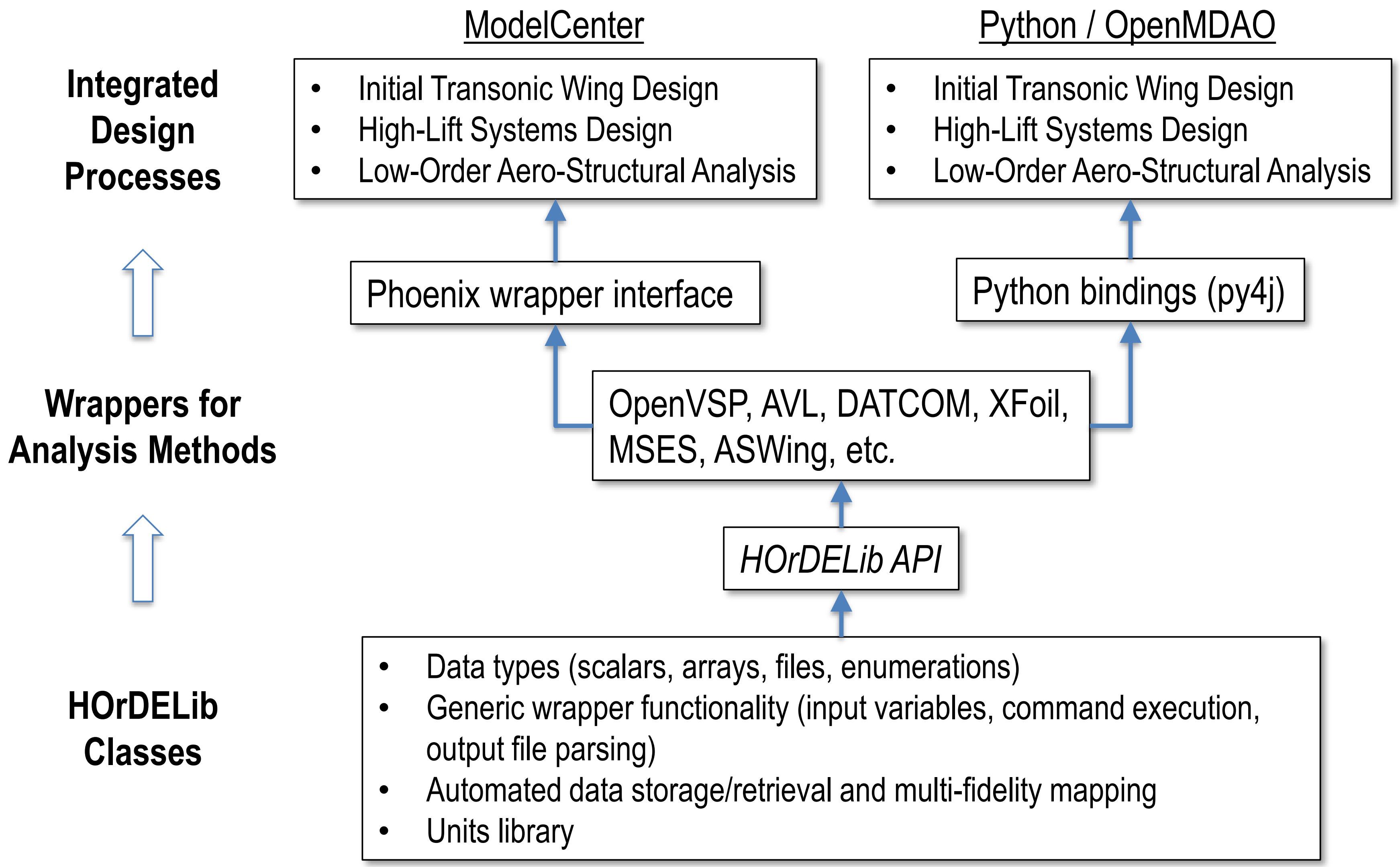
Introduction

HOrDELib Features

Wrapper Interfaces

Process Models

Documentation & Release



HOrDELib Features

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Degenerate Geometry

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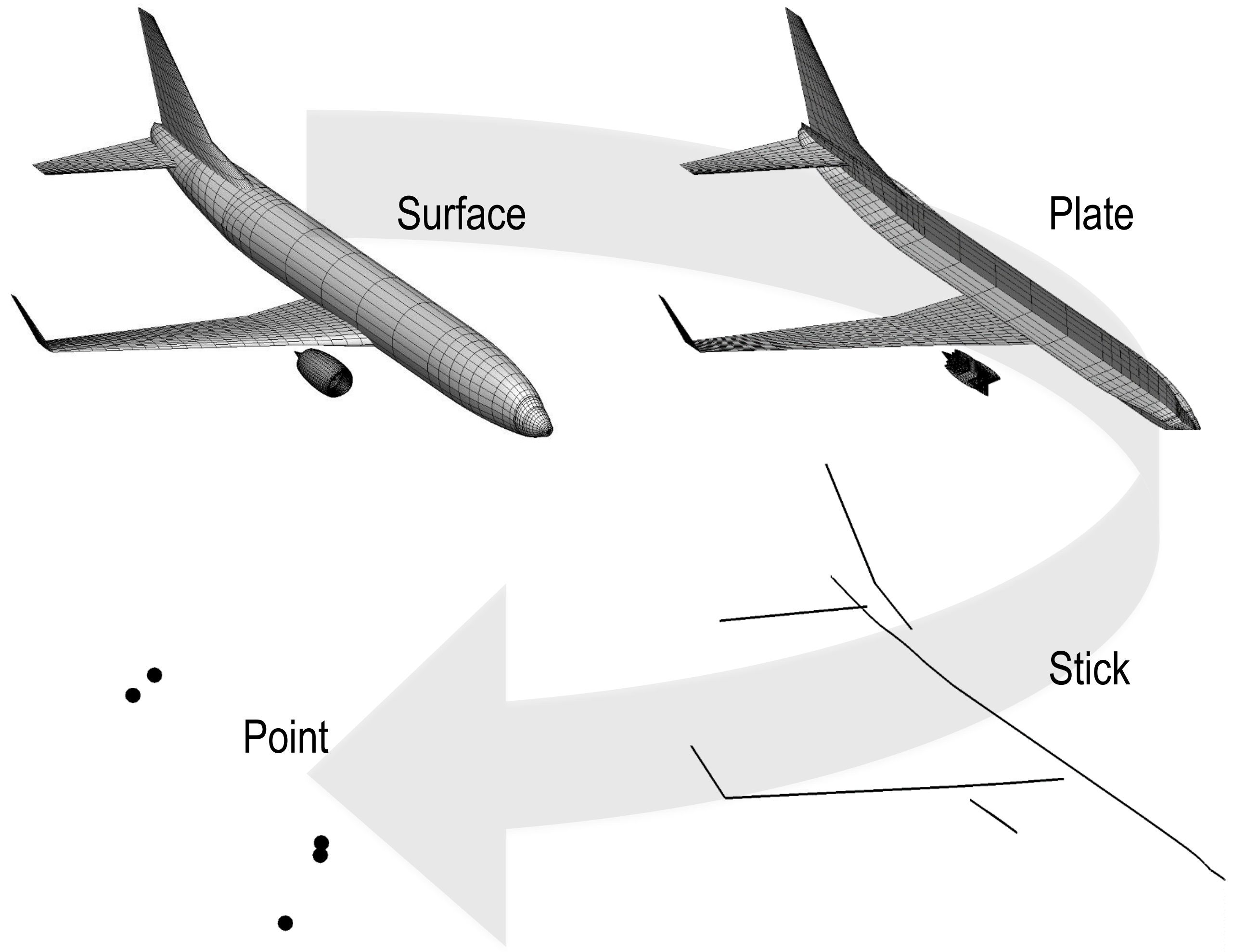

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Geometry Representation

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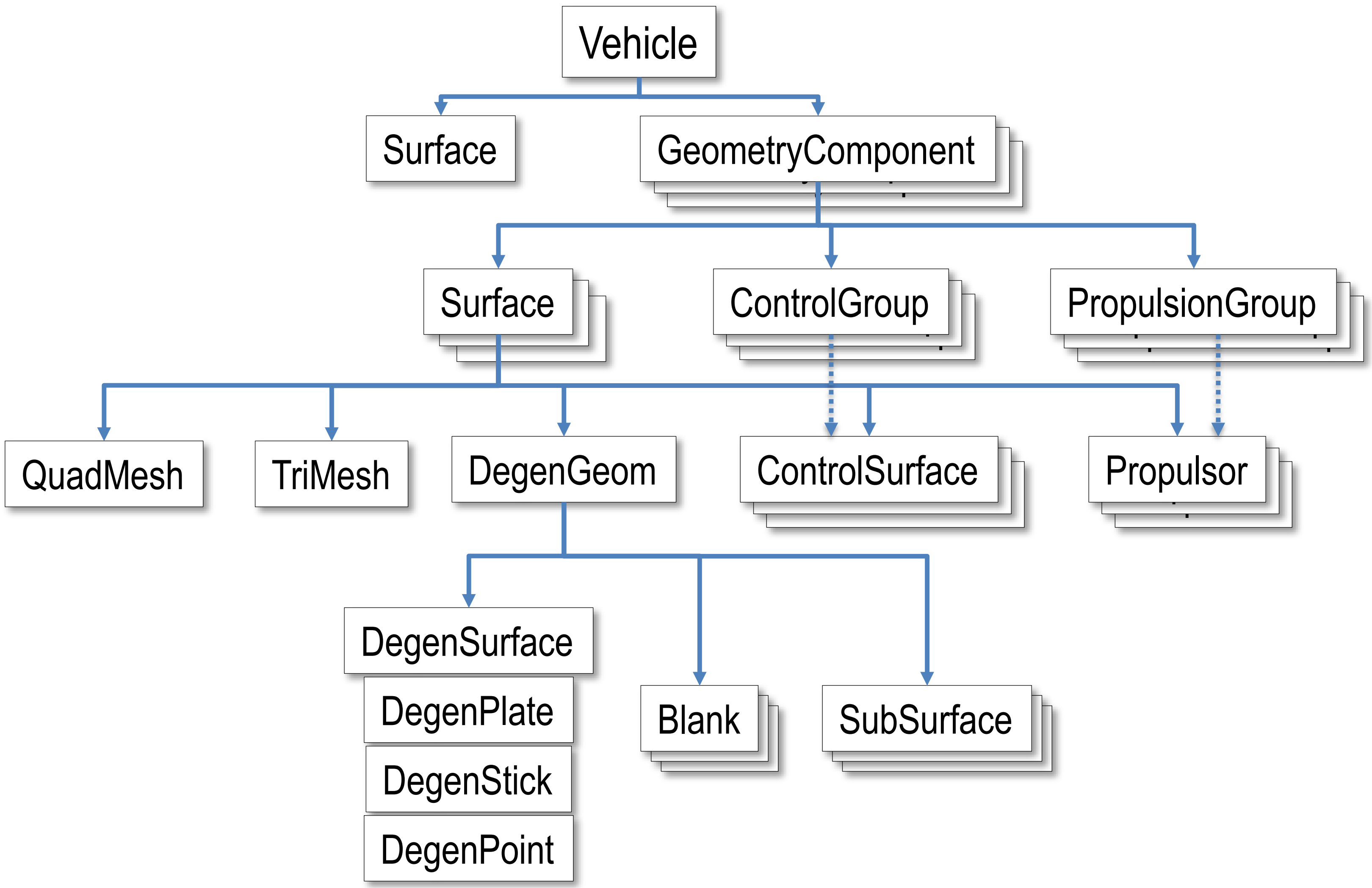

Multi-disciplinary, Multi-fidelity Mapping Process

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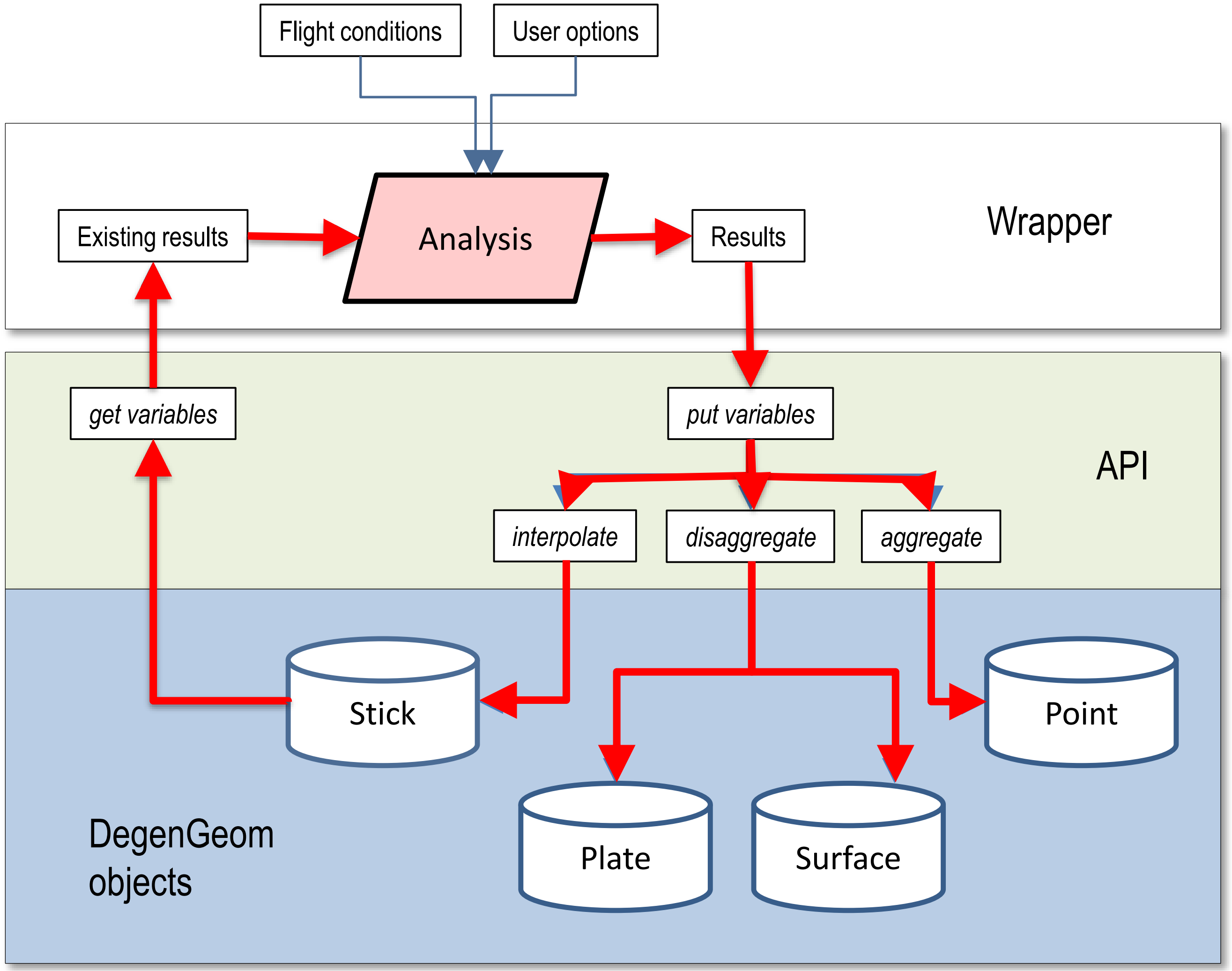

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Other Features

- Data Catalog
  - Hierarchical library of data keys (ex: *Aero_2D.Drag_Polar.cd*)
  - Compile-time data key lookup
  - Compile-time check on unit compatibility

- Units Framework
  - Implementation of Units of Measurement API v2.0
  - Units conversion
  - Convert units derived through combination of base units (e.g. Newton)
  - Wrappers accept inputs for length, mass, temperature, etc. units and maintain unit consistency of calculations throughout
  - Analysis data can be stored in one unit and retrieved in a different one.

Wrapper Interfaces

Python Bindings

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- HOrDEGateway
  - Dynamically access Java classes from Python using Py4j
  - Starts a Gateway Server prior to running Python scripts
- HOrDEWrapper
  - Lightweight Python-side interface to an individual Java wrapper
  - Get and set variable and array values as Python variables and lists
  - Run the Java wrapper
- HOrDEModel
  - Build a process model using one or more instances of HOrDEWrapper
  - Link inputs and outputs between wrappers
  - Scripted logic, iteration, intermediate calculations
  - Can be set up to work with OpenMDAO
- HOrDEServer
  - Initiated by the HOrDEModel at runtime
  - Provides interface between the HOrDEModel and the HOrDEGateway

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Local and Remote Computing in Python

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- HOrDELib Features
- **Wrapper Interfaces**
- Process Models
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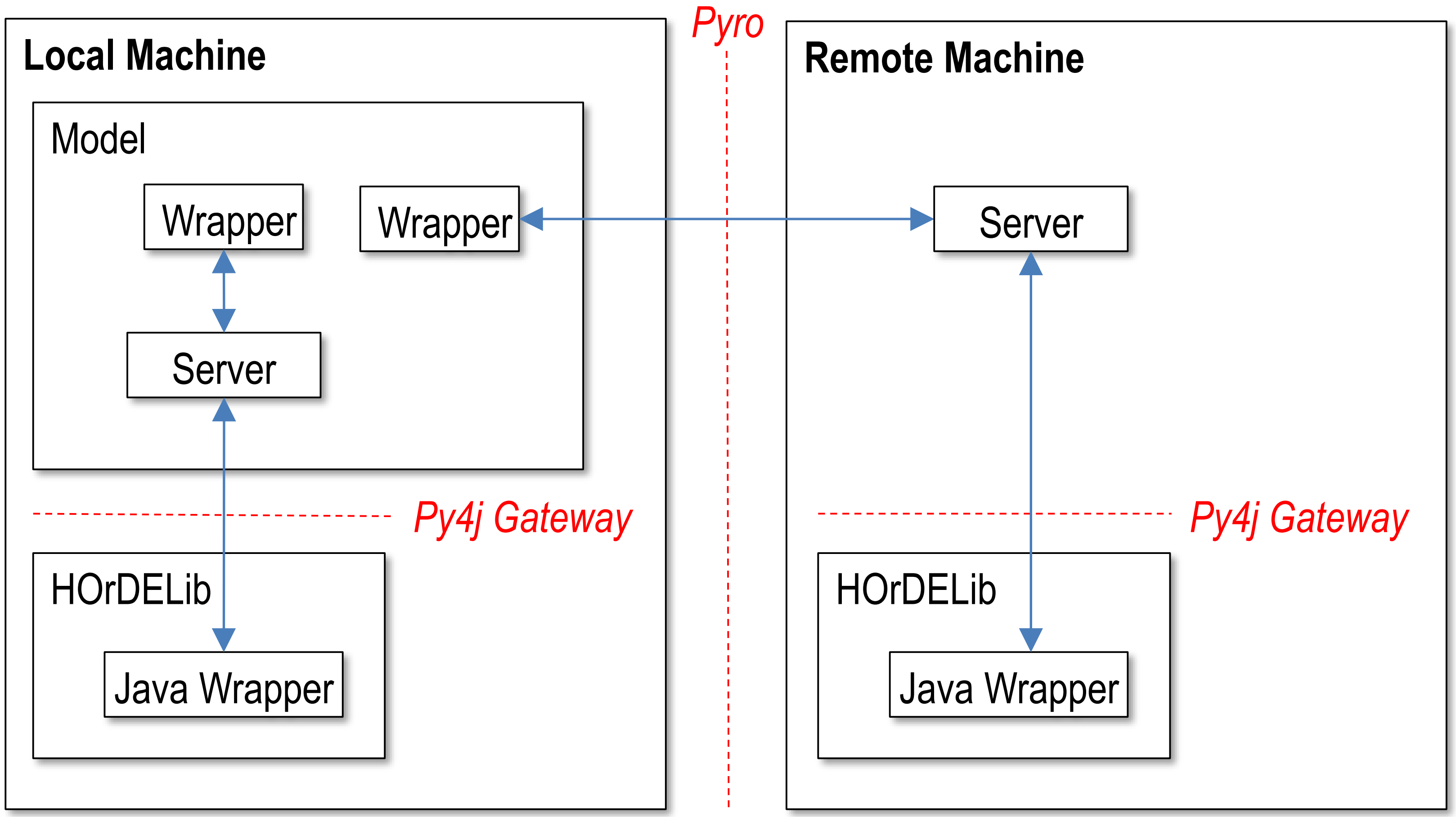
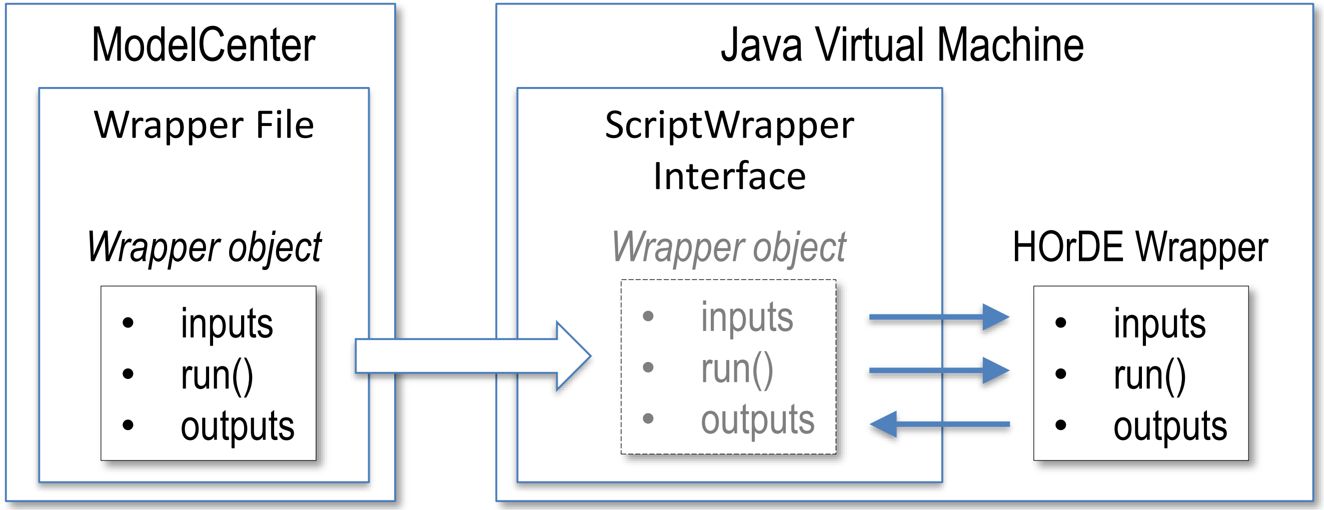


ModelCenter Interface

- Lightweight client-side wrapper files provide access to the Java wrapper
- ScriptWrapper Interface
  - Wrapper object passed to interface
  - Input and output variable values replicated using native classes on the server side
- Support for dynamic output variables



Process Models

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Library of Wrapped Codes

- Geometry Definition
  - OpenVSP
- Aerodynamic Analysis and Design
  - FRICTION – Zero-lift drag estimation
  - AVL – Vortex-lattice aerodynamic analysis
  - XFOIL – Two-dimensional panel code with coupled boundary layer
  - MSES – Two-dimensional Euler CFD with coupled boundary layer
- Aerostructural Analysis
  - ASWing –lifting-line aerodynamics and equivalent-beam structures

Utility Methods

- VSP2Geom – Create native geometry objects from OpenVSP export files
- DATCOM Airfoil – Empirical estimation of section lift and drag
- Empirical High-Lift Performance – Empirical estimation of high-lift system lift, drag, and moment
- Target Spanwise Lift Distribution – Generate target lift distributions for twist optimization
- Sonic-Plateau Pressure Distribution – Define target airfoil pressure-distribution for inverse design
- BSpline Airfoil – Fit fourth-order B-spline to smooth airfoil surface
- Kulfan Airfoils – Fit airfoils using Class-Shape Transformation
- Tecplot Data File Generation – Automatically generate Tecplot files from DegenGeom objects

Process Models Library

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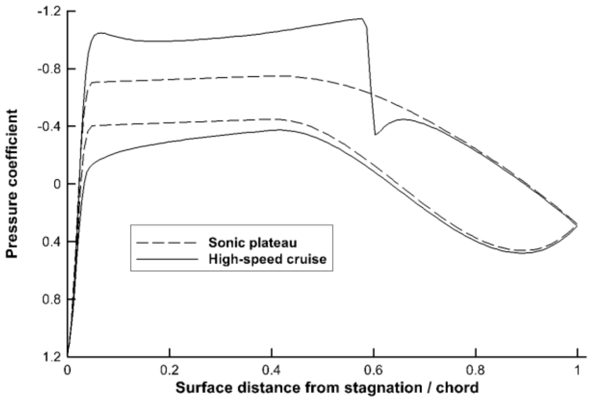
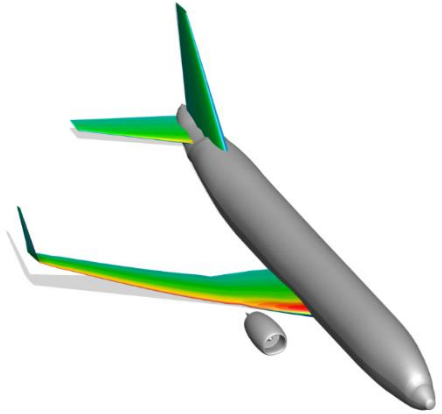
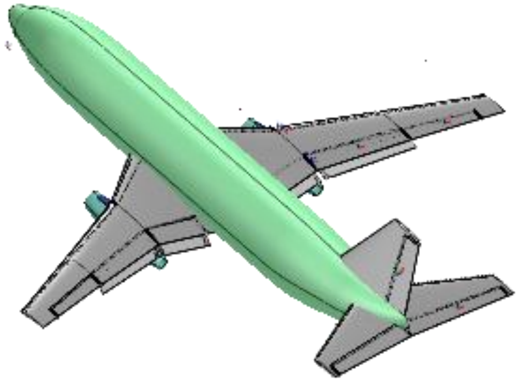
Initial Transonic Wing Design



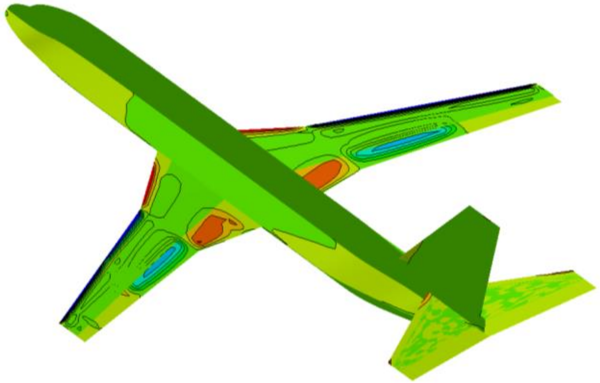
Low-Order AeroStructural Analysis



High-Lift Geometry Definition



Low-Order High-Lift Analysis



Documentation & Release

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Documentation & Release Status

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- Documentation
  - Java API documented using Javadoc
  - Python bindings documented using Sphinx
  - HOrDELib User's Guide
  - HOrDE Process Models Guide

- Release Status
  - Version 1.0 available from the NASA Software Catalog (https://software.nasa.gov/software/LAR-19572-1)
  - Approved for U.S. and foreign release

Related Publications

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- Olson and Henricks: Parametric Analysis of Aircraft Wing Weight Using Low-Order Physics-Based Analysis, AIAA 2018-4143.
- Olson: Multi-Disciplinary, Multi-Fidelity Discrete Data Transfer Using Degenerate Geometry Forms, AIAA 2016-3208.
- Olson and Albertson: Aircraft High-Lift Aerodynamic Analysis Using a Surface-Vorticity Solver, AIAA 2016-0779.
- Olson: Three-Dimensional Modeling of Aircraft High-Lift Components with Vehicle Sketch Pad, AIAA 2016-1274.
- Olson: Three-Dimensional Piecewise-Continuous Class-Shape Transformation of Wings, AIAA 2015-3238.
- Olson: Semi-Empirical Prediction of Aircraft Low-Speed Aerodynamic Characteristics, AIAA 2015-1679.

Acknowledgements

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- This work was conducted as part of the NASA Transformational Tools and Technologies Project, led by Dr. Michael Rogers, within the Multi-Disciplinary Design, Analysis and Optimization element, led by Patricia Glaab.

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