Creation and Analysis of High-Lift Components in OpenVSP

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Sept. 17, 2019

Motivation

- VSPAero, AVL can model high-lift surfaces using tilting of the normal vectors. This is an appropriate level of complexity for lower-order aerodynamic analysis methods.
- For higher-order analysis methods (panel and Euler codes), actual three-dimensional surfaces must be modeled, particularly for slats and slotted flaps.
- Need a method for creating higher-order geometry definition of control surfaces and flaps, and for controlling complex flap and slat motions parametrically and intuitively.

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Goal

- Establish a method for modeling high-lift components in OpenVSP at a level of complexity suitable for higher-order analysis methods.
  - Flaps and slats modeled as separate three-dimensional surfaces
  - Controlling motion using simple parameters in the local frame of reference

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High-Lift Components

Introduction

High-lift Components

Attaching Components

Sample Analysis

Concluding Remarks

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Modeling High-Lift Components

- Components of the high-lift configuration (main wing, slat, vane and flap) modeled as separate “wings”.
- Planform layout for components identical to the complete wing (same span, tip chord, root chord, sweep, dihedral and twist).
- Component airfoil coordinates use fractional chord but normalized by the chord of the full wing section.
- Transition segments allow for nearly-discontinuous change in cross section.
- Flap and slat surfaces can be assigned to separate sets to visualize and export independently.

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Fractional Airfoil Coordinates

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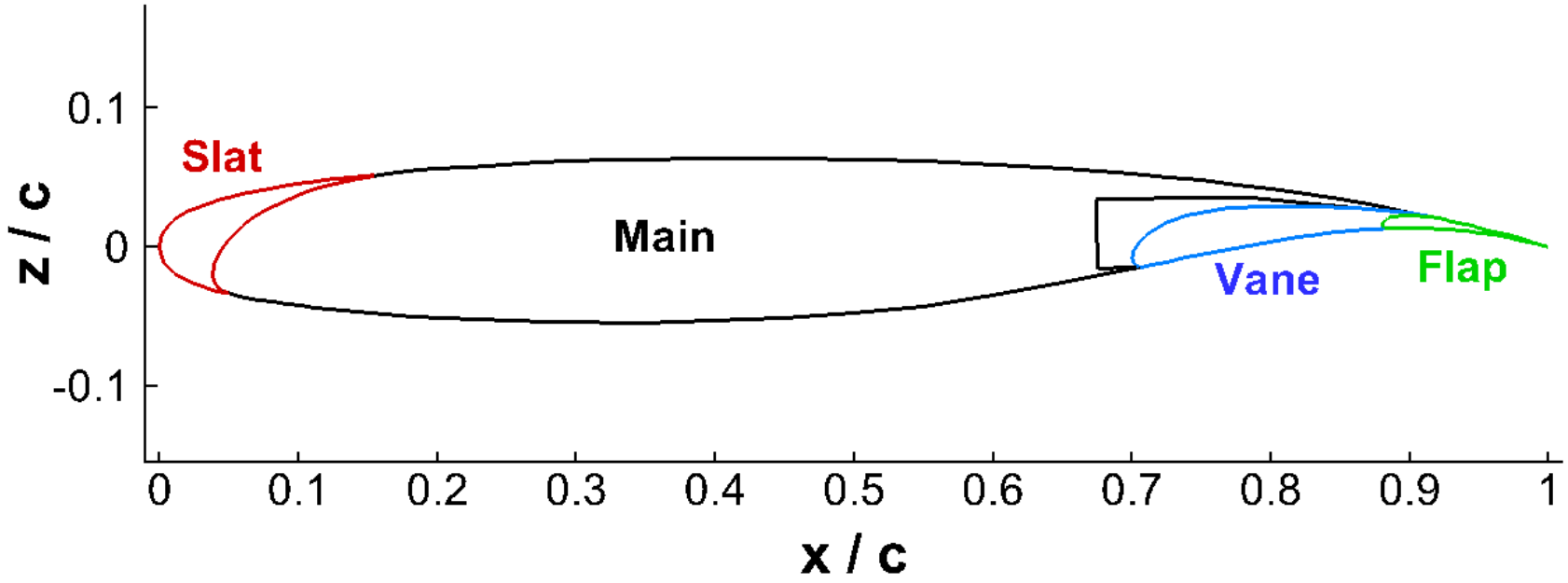

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Parametric Generation of High-Lift Components

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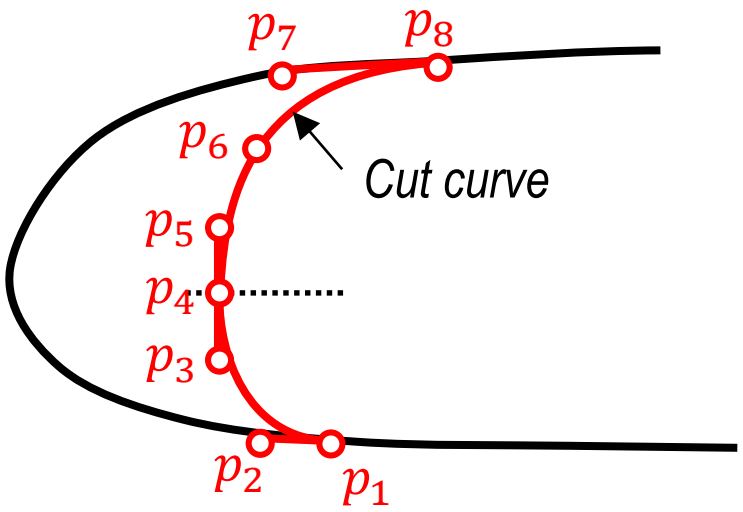
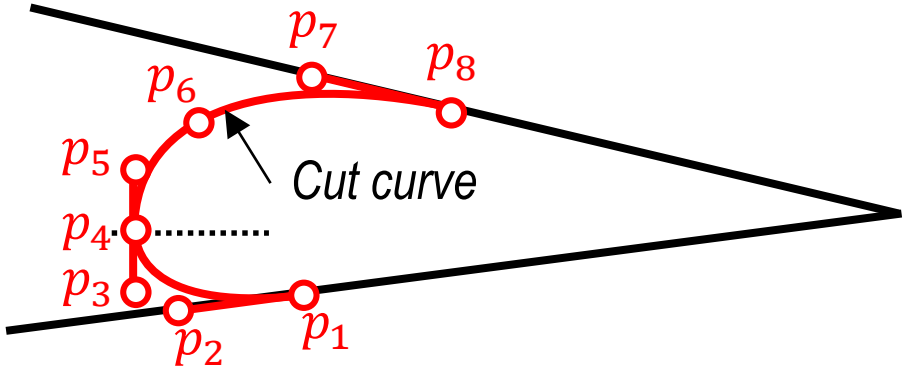
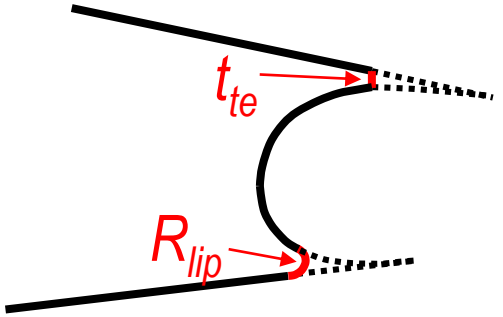
Leading-edge flap/slat



Trailing-edge flap



Upper and lower Bézier curves
Tangent to upper and lower airfoil surfaces (p_1, p_8)
Curvature continuity at nose point (p_4)
Entire curve specified by 9 parameters
Forward component truncated to finite thickness TEs



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Transition Segments

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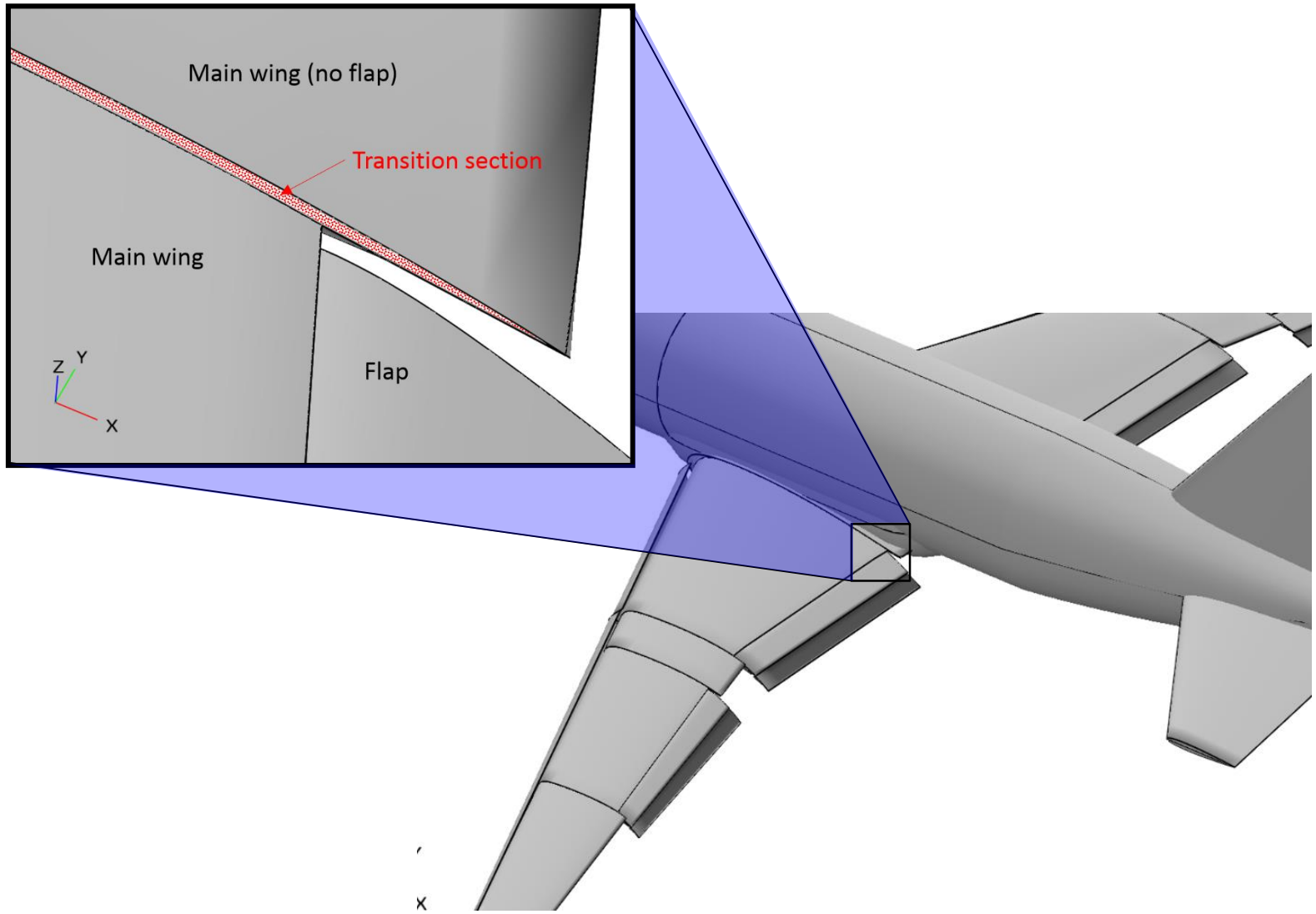

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Attaching Components

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Attaching High-Lift Components to the Model

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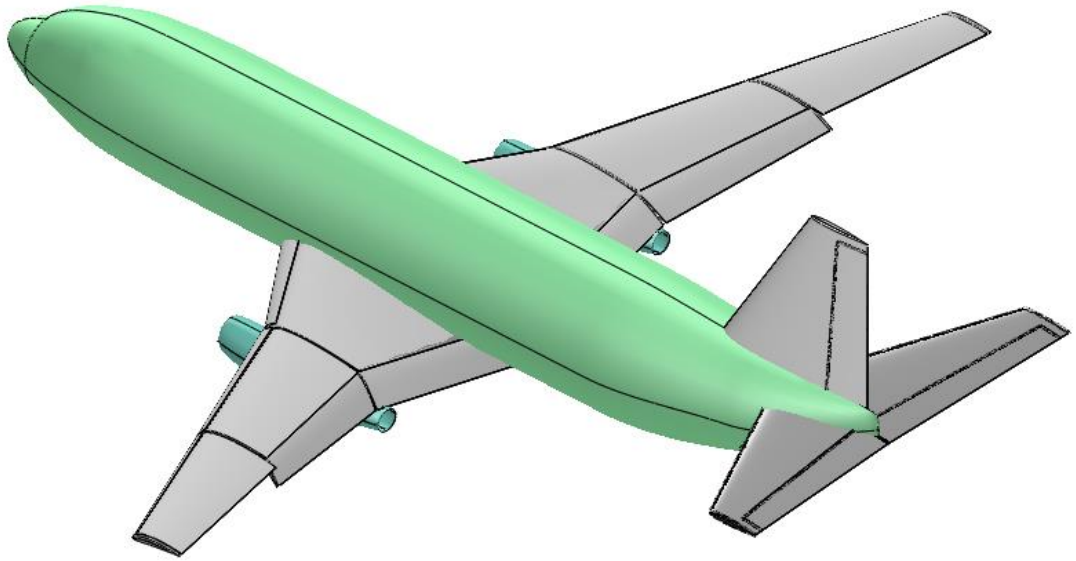

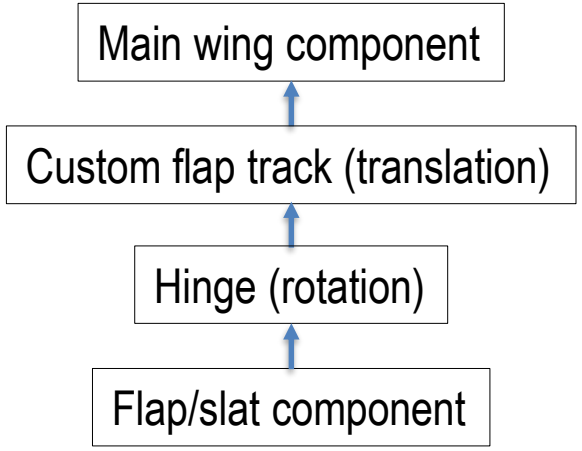

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CutOutControlSurfaces Method

- Part of Higher-Order Design Environment (HOrDE) software
- Accomplished through OpenVSP script
- Uses existing control surface SubSurfs from the original OpenVSP model
- Adds new high-lift components to the model and saves new OpenVSP file
- Flap track and hinge parameters automatically calculated
- Requires FlapTrack.vsppart custom component

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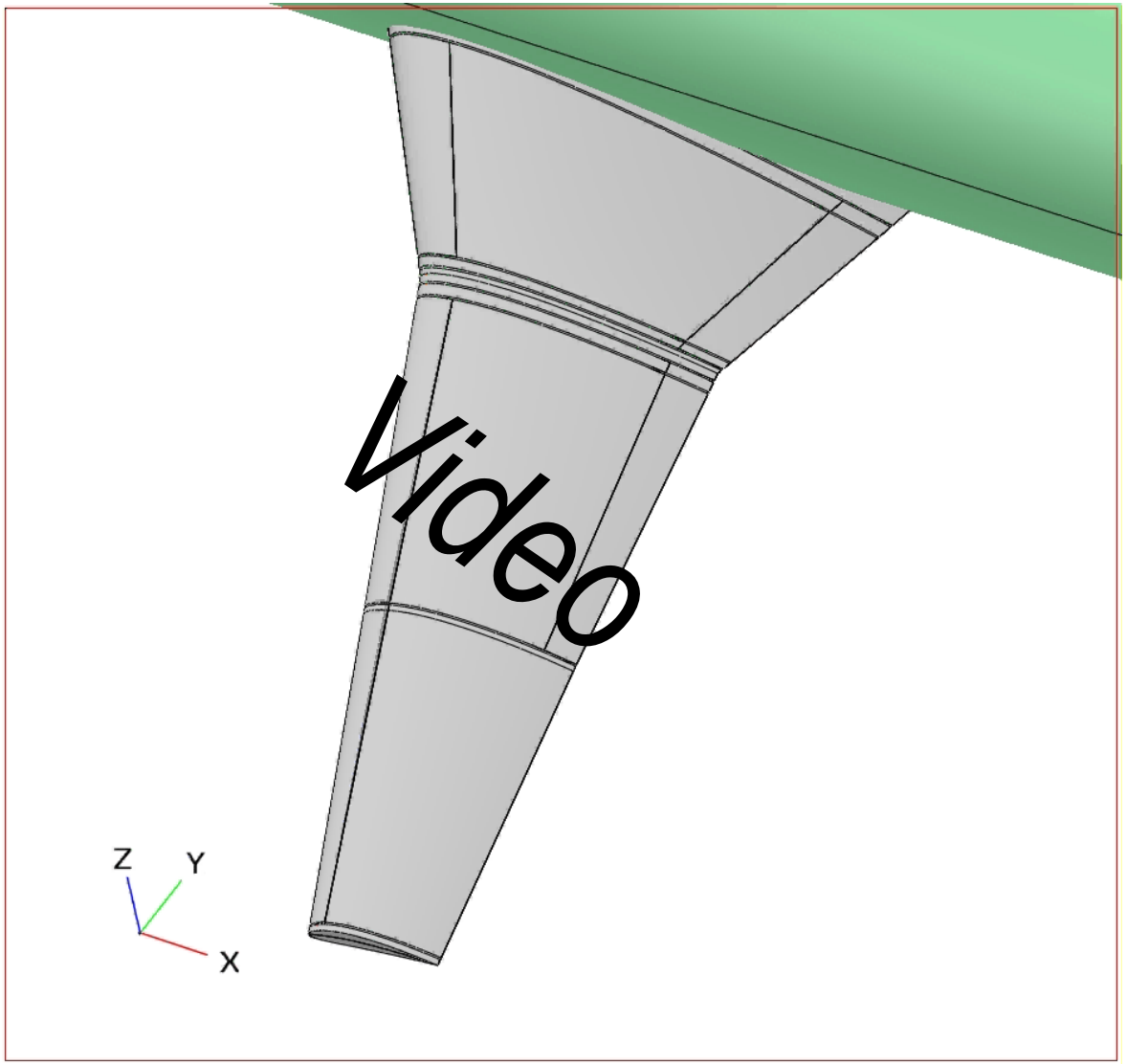
Advanced Flap Motion

- Introduction
- High-lift Components
- **Attaching Components**
- Sample Analysis
- Concluding Remarks

Flap lever moved from 0 -- 40



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Sample Analysis

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FlightStream Analysis

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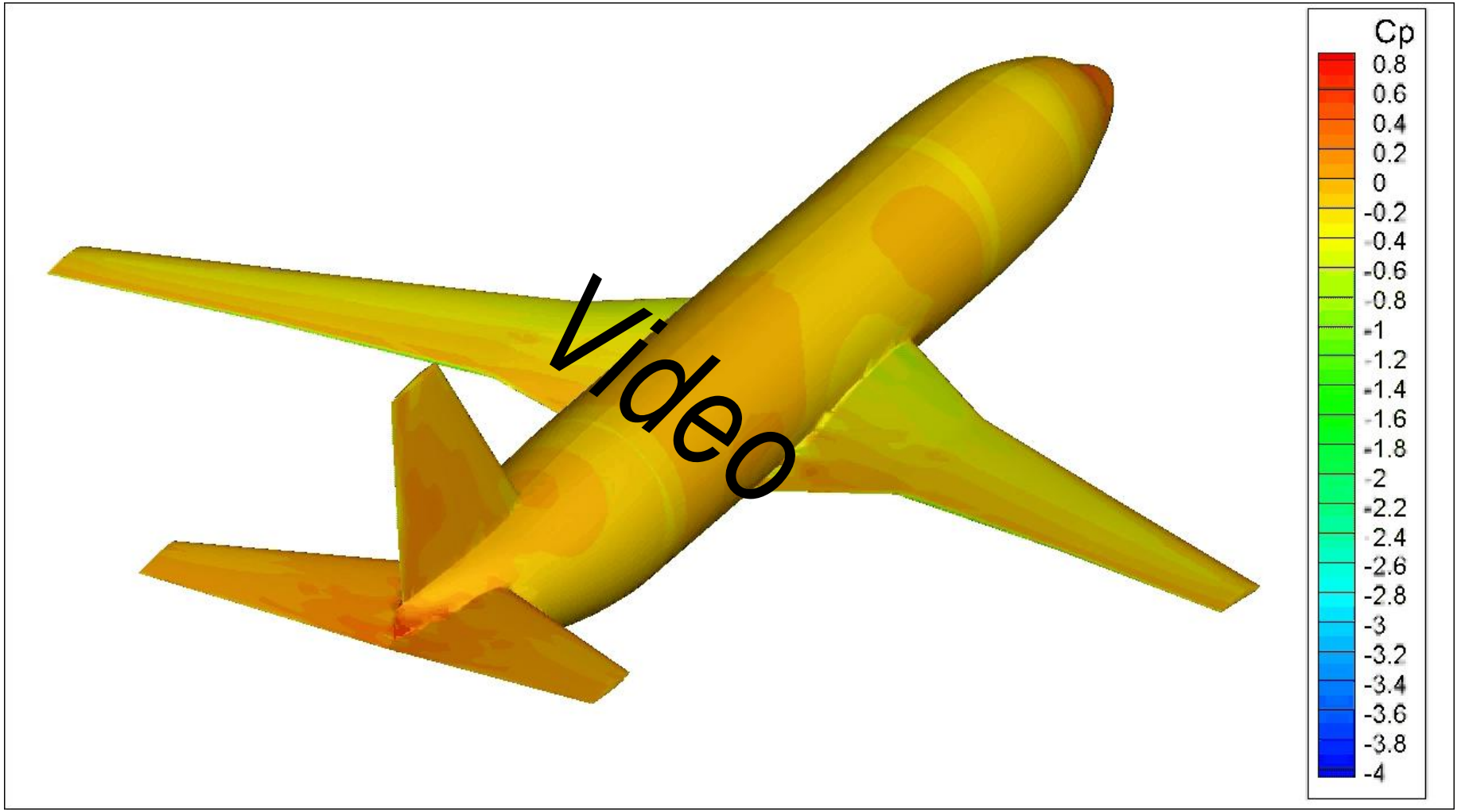
Pressure contours at $\alpha = 0$, no slat



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Lift Curves

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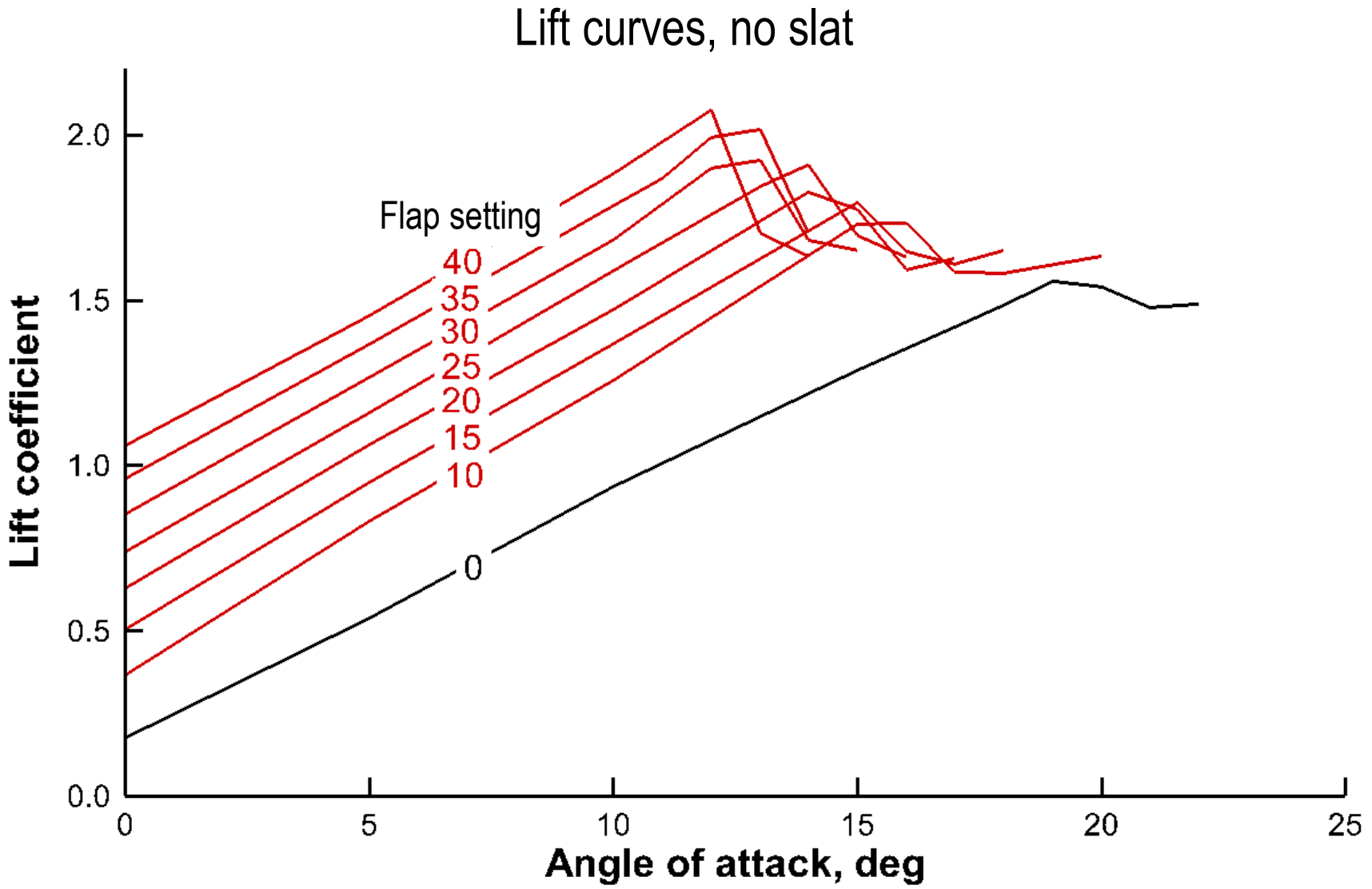

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Drag Polars

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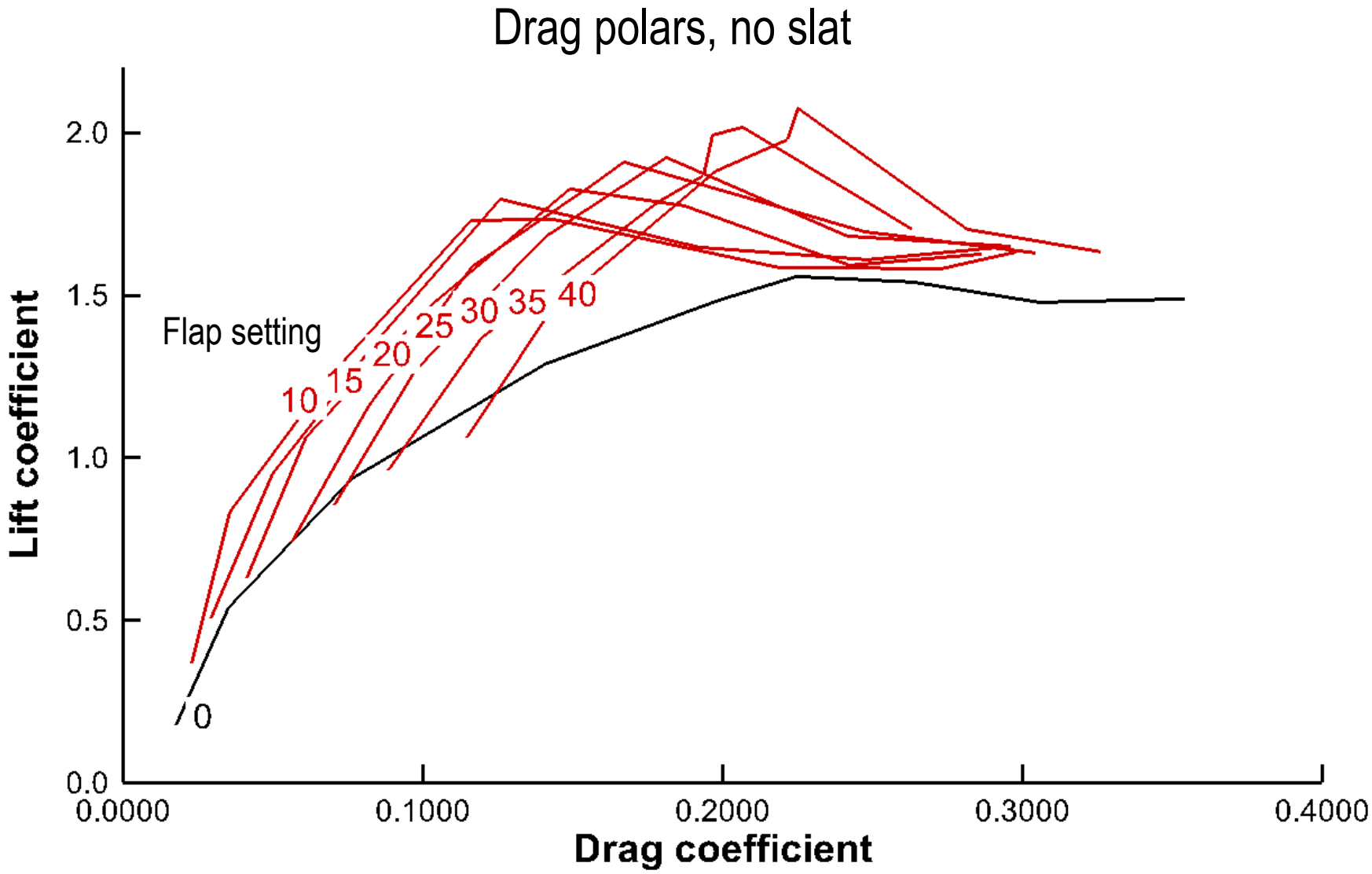

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Effect of Slat

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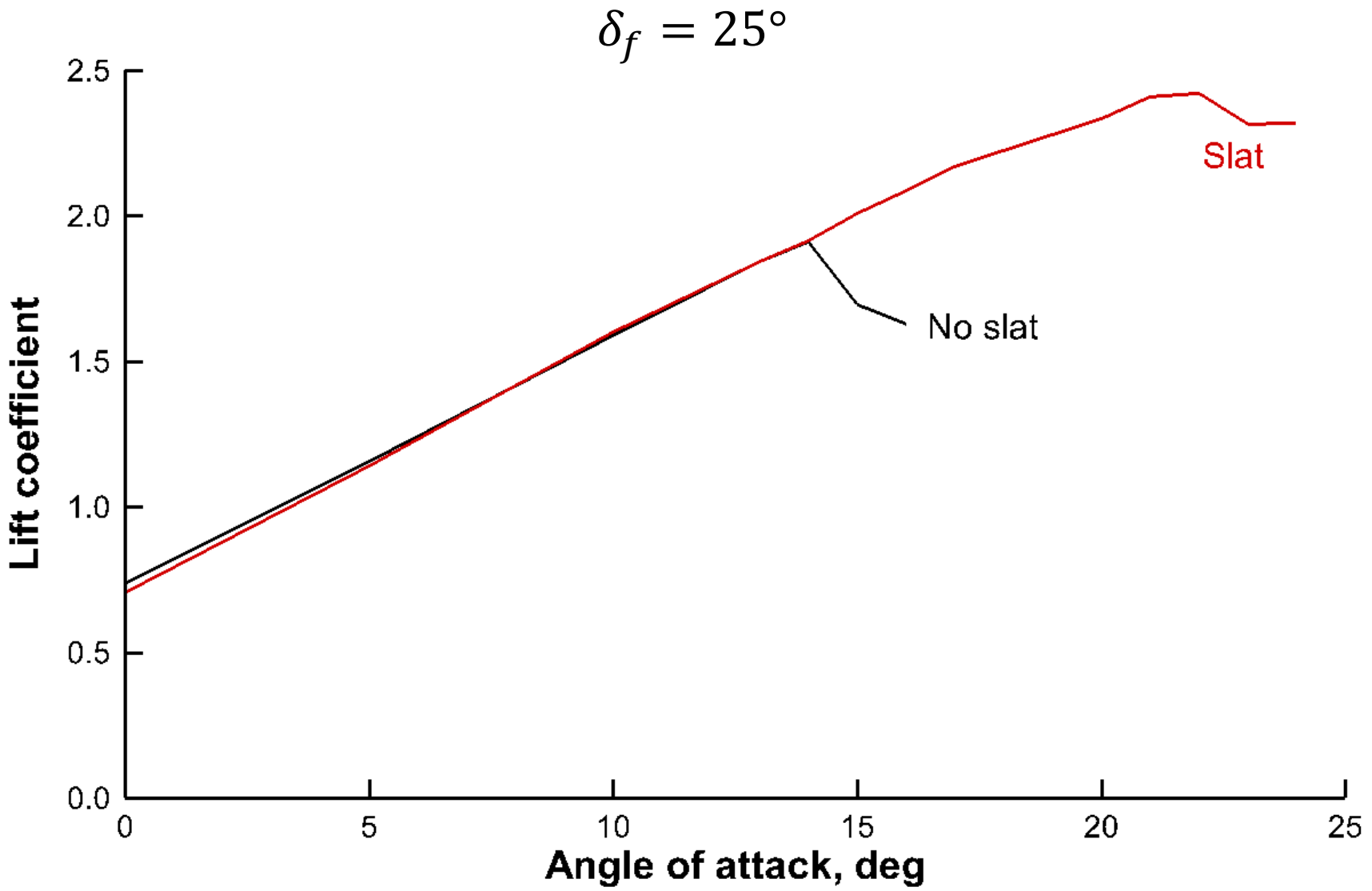

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Concluding Remarks

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Concluding Remarks

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- Devised a method for creating higher-order geometry definition of control surfaces, flaps, and slats using parametric cut curves
- Parametric and intuitive process for controlling complex flap and slat motions using Hinge and FlapTrack
- Process available as a OpenVSP scripted process in HOrDE
- Preliminary three-dimensional analysis of generated high-lift configuration in FlightStream

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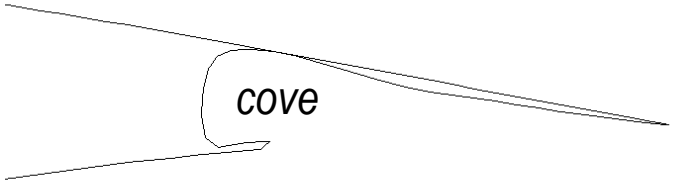
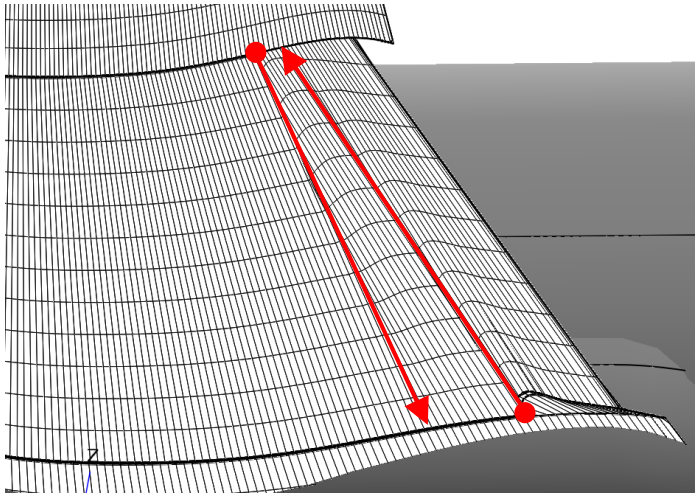
Current Shortcomings

- Discontinuous airfoils in cove region
  - VSP w-lofting (chordwise) is always continuous.



- Spanwise lofting of discontinuities
  - When “discontinuities” are at different arc lengths, u-lofting does not connect them to each other.



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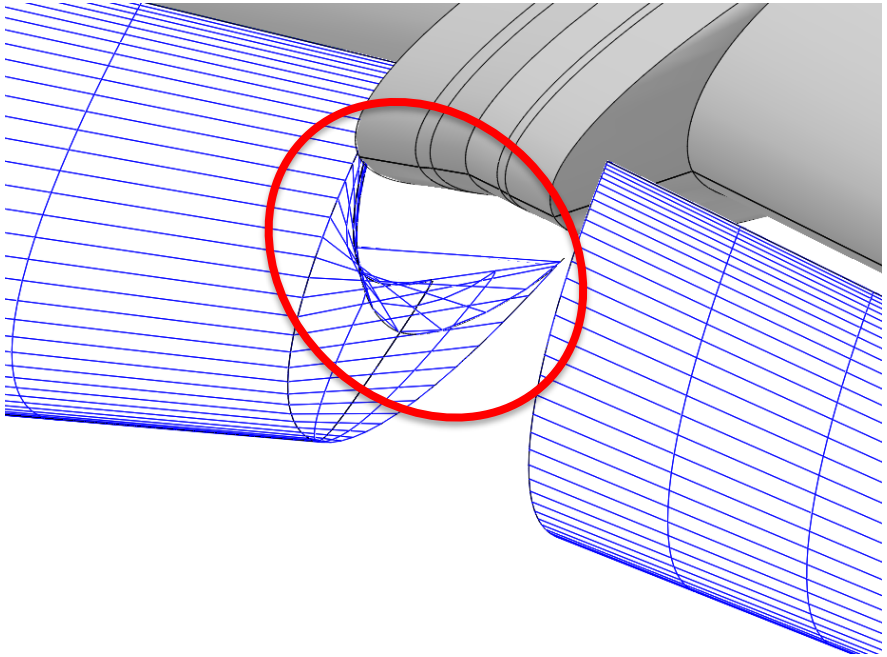
Current Shortcomings (cont.)

- Self-intersecting elements in slat caps



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Recommendations

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1. Add a method for introducing discontinuities to airfoils (repeated point?).
2. Automatically connect discontinuities during spanwise lofting (in conjunction with #1).

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Acknowledgements

- 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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