NASA 2016 SBIR PHASE I

Physics-Based Conceptual Design Flying Qualities Analysis using OpenVSP and VSPAOER

Geometry + Control Topology

Mass Properties

Dynamics Model

VSPAOER

Trim Solver

Tail Sizing GUI Tool

Parameter Sweep

Presented by:
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Agenda

• Introduction
  – Team Members
  – SBIR Topic
  – Proposal & Technical Objectives

• Task Overview & Status

• Conclusion

• Questions?
Intro – Team Members

ESAero Development Team
• Nick Brake – PI
• Ben Schiltgen
• Rob McDonald
• Bryan Schmidt
• Justin Gravett
• Andrew Gibson

NASA
• Erik Olson – TM
Intro – SBIR Topic

SBIR Topic: A1.05 Physics-Based Computational Tools - Stability and Control/High Lift Design Tools

[Excerpt]
For FY2016, specific capabilities are being sought in the following areas:
...

• Methods for **analysis of aircraft static and dynamic stability characteristics** suitable for unconventional aircraft.
  – **Physics-based sizing of tails and control surfaces** that is more sensitive to aircraft design parameters than traditional tail volume coefficients.
  – **Calculation of mass moments of inertia** for the complete aircraft system throughout the full mission.
  – Simulation of the dynamics of unconventional aircraft configurations with tight coupling of propulsion and aerodynamics characteristics, including evaluation of active control systems.
  – Definition of handling qualities for unmanned aerial systems.

The desired capabilities are **physics-based methods that are of higher order than traditional empirical methods**, but can be applied in the conceptual design phase with limited requirements on the availability of detailed design information.
Intro – Proposal & Tech. Objectives

Proposal:
Tool suite enhancements to enable rapid physics based handling qualities assessments through an efficient workflow

Tech. Objectives:
• Improved vehicle definition (Controls & Mass properties)

• Integrated tool suite for handling qualities with physics based models

• Simple kinematics engine
Task Overview

1. Improve Sub-Surface Based Control Surfaces
2. Mass Database
3. Mass Properties for Partially Filled Fuel Tanks
4. Interactive Tail Sizing
5. Trim Solver
6. Dynamic Model Synthesis
7. Tail Size Assessment Tool
8. OpenVSP Representation of Simple Kinematic Joints
Task 1 – Improved Sub-Surface Based Control Surfaces

Objective:
• Improve control surface definition for better representation of real surfaces

Status: IN PROGRESS
• Final integration with VSPAERO

Figure 4. Curved control surface leading edge

Figure 3. OpenVSP sub-surface GUI for control surface definition

Hinge Line Visualization

Improved curvature

Before After

Before After

Root & Tip angle
Task 2 – Mass Database Tool

Objective:
• Increase flexibility and accessibility of mass prop. info

Status: IN PROGRESS
• Override properties
• GUI layout
• Data export

Output similar to SAWE RP7 grouping

Figure 5. Example generic override

Figure 6. Example enhanced GUI display and table output
Task 3 – Mass Properties for Partially Filled Tanks

Objective:
• Calculate mass properties impact of fuel tanks

Status: IN PROGRESS
• GUI implementation
• API integration
Task 4 – Interactive Tail Sizing

Objective:
- Implement tail sizing with real-time visualization based on SAE 670370
- Used as “seed” size for Task 7

Status: IN PROGRESS
- GUI development & layout
- Algorithm implementation
  - SAE 670370 Fuselage Configuration Studies by J. Morris & D. M. Ashford of Douglas Aircraft

Example tail sizing implementation based on SAE 670370
Source: “Betterer_Tail_Volume_Coeff.xlsx”, Andy Hahn
Task 5 – Trim Solver

Objective:

• Calculate flight state and control deflection to satisfy simple user defined constraints

• Replicate AVL trim solver

Status: NOT STARTED

Pre-requisites:

• VSPAERO control derivatives
Task 6 – Dynamic Model Synthesis

Objective:
- Increase accessibility of aircraft dynamics characteristics

Status: NOT STARTED

Pre-requisites:
- VSPAERO control derivatives
- Task 5 – Trim solver

State Space Dynamics Model

\[ \dot{X} = [A] \times X + [B] \times U \]

\[ X = [u, w, q, \theta, v, p, r, \phi, x, y, z, \psi]^T \]

\[ A = [\text{system dynamic matrix}] \]

\[ B = [\text{control input matrix}] \]

\[ U = [\text{control vector}] \]

Table 1. Example additional flying qualities parameter output

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \phi/\beta ) effect</td>
<td>( \frac{\phi}{\beta} = \frac{</td>
<td>e_{\phi}</td>
</tr>
</tbody>
</table>
Task 7 – Tail Sizing Assessment Tool

Objective:
- Visualize impact of tail size parameters

Status: NOT STARTED

Pre-requisites:
- Task 5 – Trim Solver
- Task 6 – Dynamic Model Synthesis
Task 8 – Simple Kinematic Joints

Objective:

• Increase usability for modeling control surfaces, high lift devices, landing gear

Status: RELEASED v3.9.0

Figure 15. Symbolic representation of six lower order kinematic pairs.
Questions?
Contact Information

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