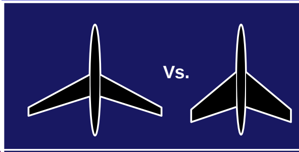
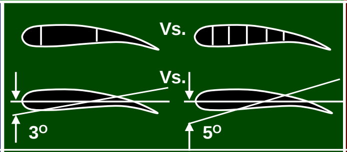
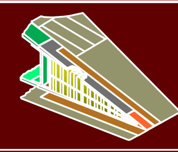
AFRL SBIR PHASE II

OpenVSP Smart Conceptual Design Tool Improvements, Including Inboard Profile Visualization

	Phase I Conceptual Design	Phase II Preliminary Design	Phase III Detail Design
			
Known	• Basic Mission Requirements • Range, Altitude, Speed • Basic Material Properties σ/ρ E/ρ $.lb	• Aeroelastic Requirements • Fatigue Requirements • Flutter Requirements • Overall Strength Requirements	• Local Strength Requirements • Producibility • Functional Requirements
Results	**Geometry**: Air Foil Type, R, t/c, λ, Δ **Design Objectives**: Drag Level, Weight Goals, Cost Goals	• Basic Internal Arrangement • Complete External Configuration – *Camber, Twist Distributions* – *Local Flow Problems Solved* • Major Loads, Stresses, Deflections	• Detail Design – *Mechanisms* – *Joints, Fittings & Attachments* • Design Refinements as Results of Test
Output	Feasible Design	Mature Design	Shop Drawings
TRL	2-3	4-5	6-7

Leland Nicolai, Fundamentals of Aircraft and Airship Design, AIAA, 2010.

Presented by:
Empirical Systems Aerospace, Inc.

For:
OpenVSP Workshop 2016

Project Objectives

- Build on the successes of the Phase I effort and take large steps to increase OpenVSP's utility as a conceptual and preliminary design tool.
- This work will greatly reduce the time required to notionally design aircraft's external shape and inboard layout while adding tremendous analysis capability.
- Higher-fidelity analysis can be performed during the conceptual design phase, enabling appropriately accurate and rapid trade studies of novel configurations.

Task 1 – Master Aerodynamic Analysis Tool (Aero Manager)

- Interact with internal modules and external codes in order to gather the necessary information to properly analyze a configuration’s aerodynamics.
- Acts as a liaison between OpenVSP, VSPAero, and the modules developed in Task 2 of this proposal.
- Provides quick analysis of lift and drag, enabling geometric sensitivity trades and polar generation.

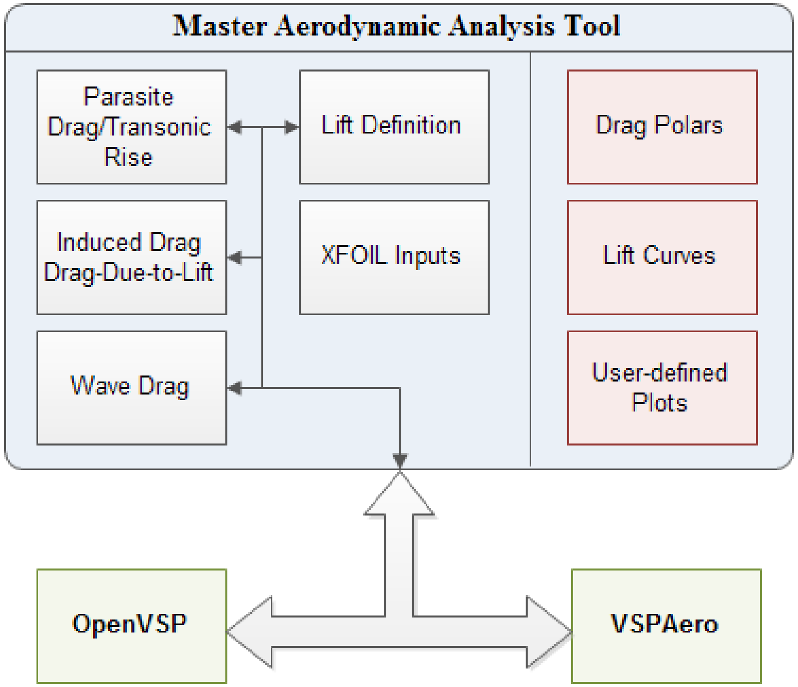
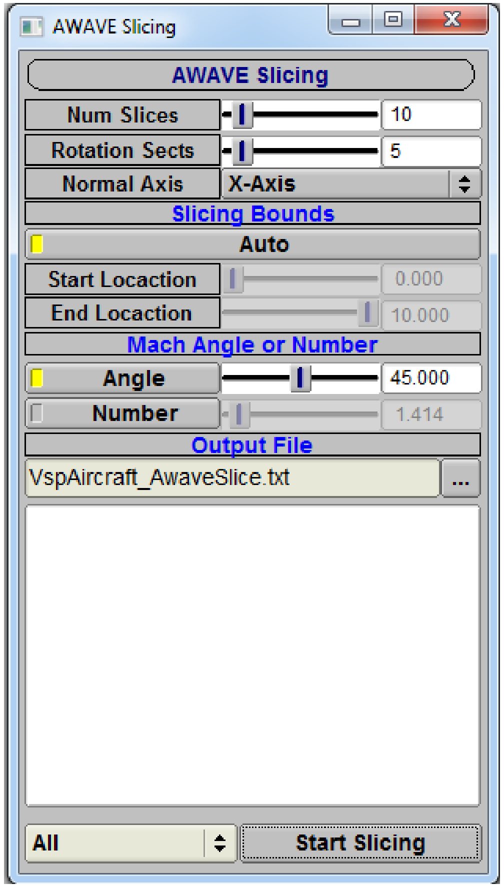


Figure: Preliminary Aero Manager Flow Path

Task 2 – Sub-Aero Tool Development and Modification

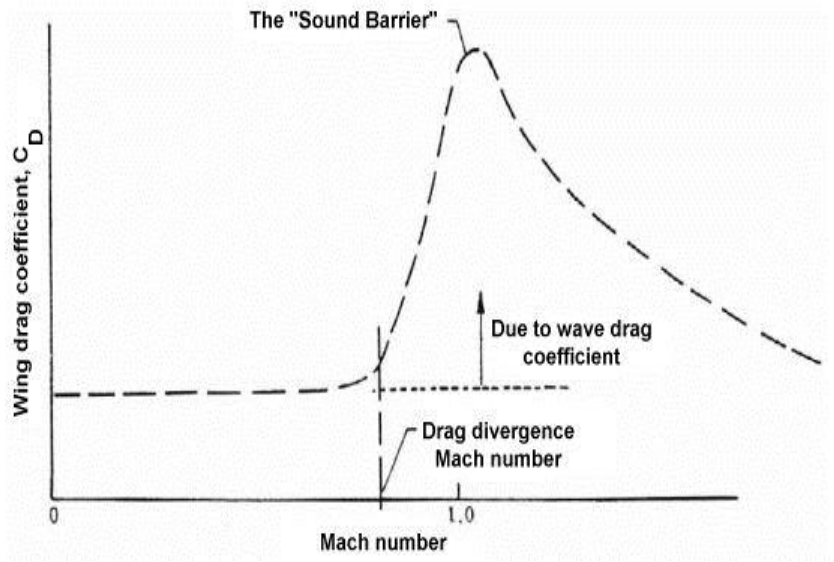
- The quick exchange of geometry constructed in OpenVSP into the drag tool enables rapid analysis and sensitivities integral to concept development.
- In concert with aerodynamic analysis improvements, this task builds upon previous efforts to improve the parasite drag fidelity by adding transonic drag rise, induced drag, and wave drag.



Slicing Interface

Task 2 – Sub-Aero Tool Development and Modification [Transonic Drag Rise Module]

- Implement an agreed upon transonic drag rise model into the parasite drag buildup tool.
- Appropriate geometry will already be within the uploaded degenerate geometry (Degen Geom) file making geometric information transfer straight forward.
- Adds much needed fidelity in the analysis of high sub-sonic and supersonic aircraft configurations.



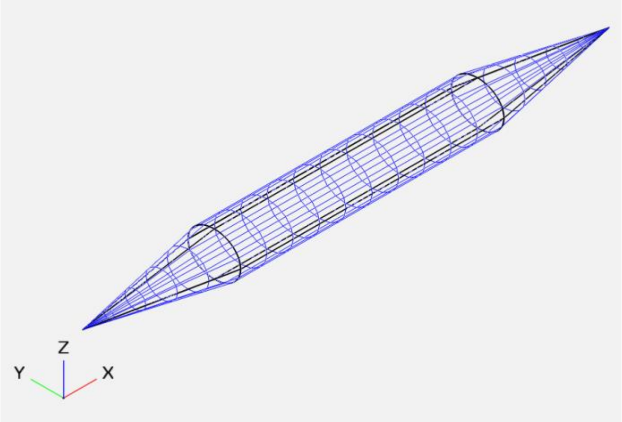
Typical Drag Rise Model

Task 2 – Sub-Aero Tool Development and Modification [Wave Drag Module]

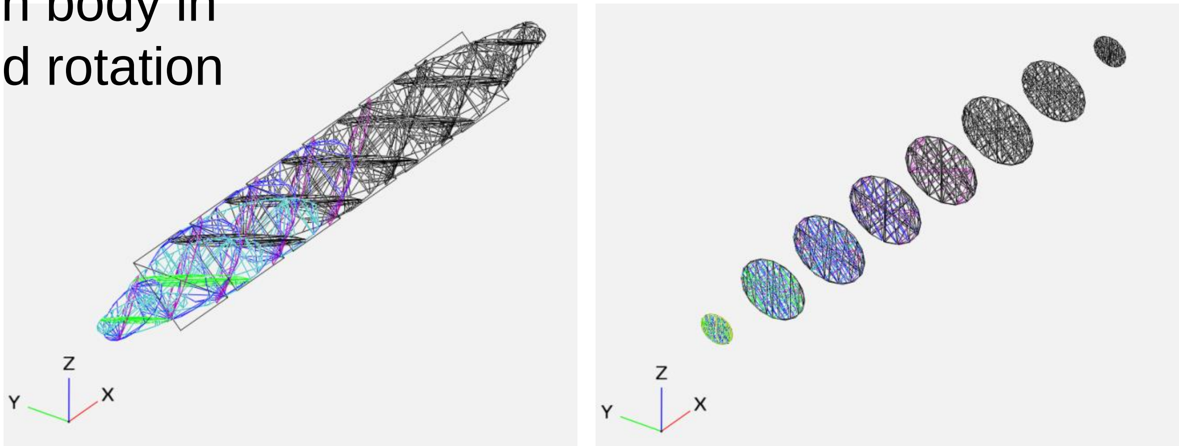
- Reducing wave drag over a body can be accomplished by minimizing the following integral:

$$I = -\frac{1}{2\pi}\int_0^1 \int_0^1 S''(x)S''(y)log|x-y|dxdy$$

- The Slicing tool computes the cross-sectional areas of the given body in user-specified intervals and rotation sections.



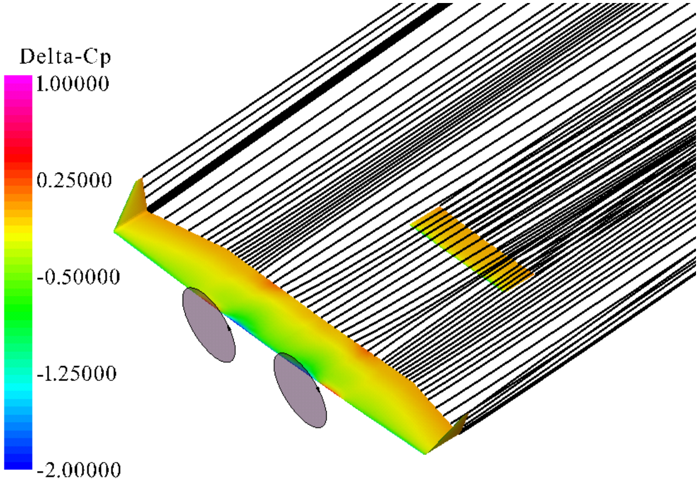
Basic Tube Model



Various Slicing Examples

Task 2 – Sub-Aero Tool Development and Modification [Induced Drag Module Through VSPAero]

- VSPAero is a vortex lattice analysis tool, with integrated actuator disks, built for rapid aero-propulsive analysis.
- The master tool developed in Task 1 will control and call upon VSPAero for the calculation of induced drag.
- This task will ensure cross-compatibility between OpenVSP, VSPAero, and the master aerodynamic tool.
  - Required modifications to VSPAero that enable robust, easy-to-implement induced drag calculation will be conducted under this task.
  - Allow for any master aerodynamic tool tweaks that interfere with the overarching goal of developing a cohesive unit.



Tecnam P206T modeled in VSPAero

Task 3 – Basic Static Stability Analysis

- Enable VSPAero to calculate basic static stability derivatives such as C_{L_α}, C_{M_α}, C_{N_β}, etc. Adding sub-surfaces to the degenerate geometry tool will be included in this work.

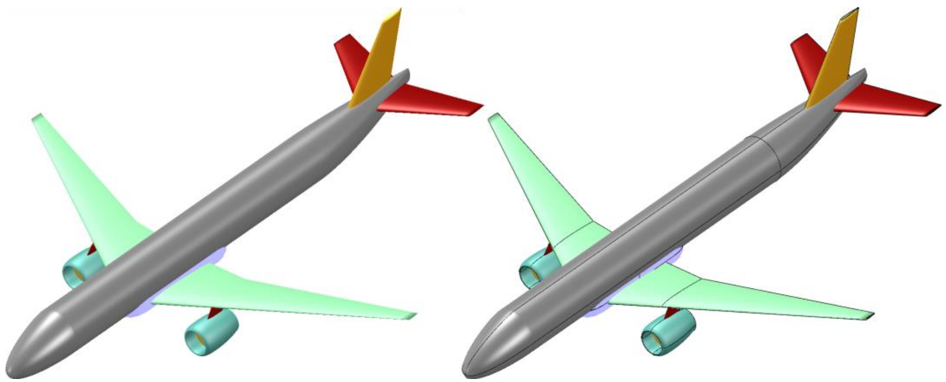
- OpenVSP will be modified to support control surfaces and stability qualities such as elevator effectiveness, $C_{M_{\delta_e}}$.

Task 4 – Radar Cross Section (RCS) Analysis Using Xpatch®

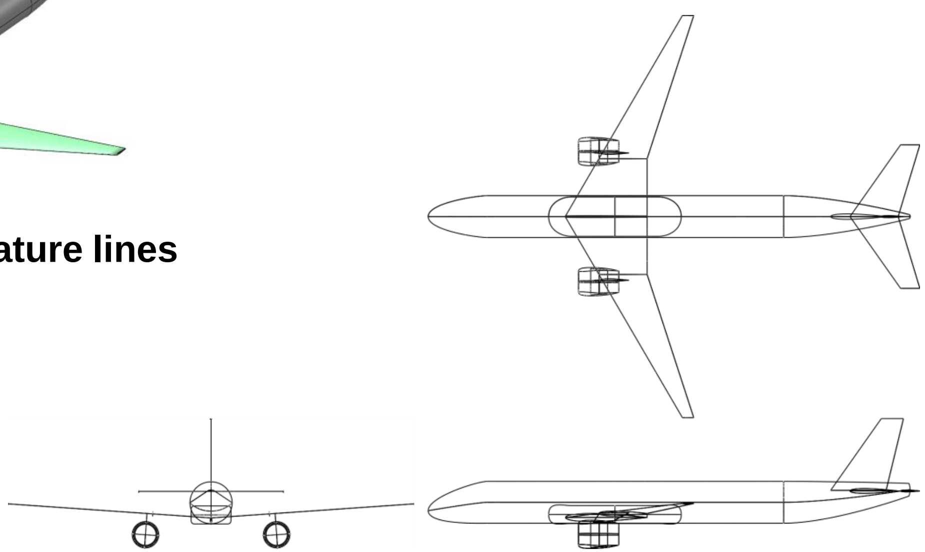
- Xpatch® (Xpatch) is an industry standard tool for predicting radar signatures of 3D models.
  - Can interpret 3D models in two forms, as a subset of entities from IGES CAD interchange files, or as a discretized triangulated surface facet file.
- OpenVSP will be modified to write out Xpatch facet files for both the CompGeom and CFDMesh approaches to discretizing a surface.
- OpenVSP's subsurface modeling capability will be implemented in the Xpatch facet file format to the extent allowed by the facet files.
- The subsurface modeling capability allows regions of surfaces to be separately identified and assigned particular properties.
- A tutorial on using OpenVSP with Xpatch (targeting an experienced Xpatch user) will be developed and provided to the USAF.

Task 5 – 2D Drawing Exportability

- OpenVSP will be extended to output the feature lines as AutoCAD Drawing Exchange Format (DXF) files.
  - The DXF format has become an industry standard CAD interchange format for 2D and 3D line drawings.



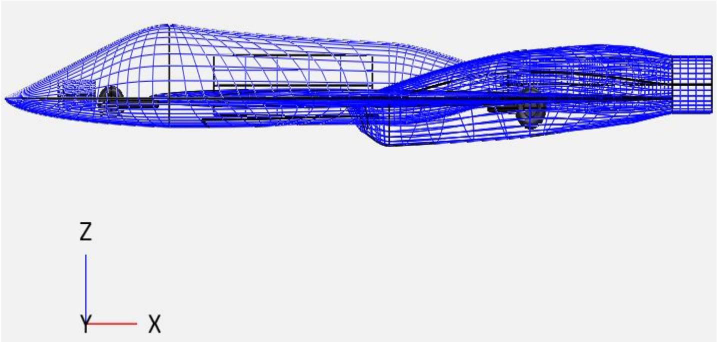
Shaded aircraft view depicting addition of feature lines

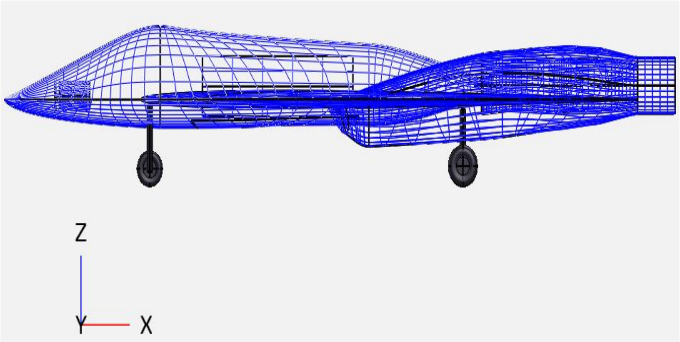


Simulated DXF export from OpenVSP

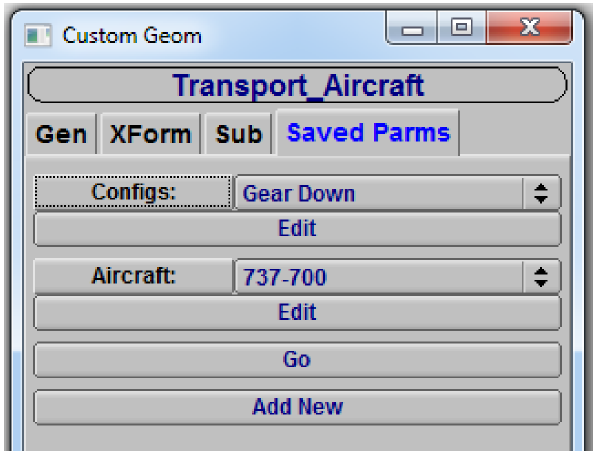
Task 6 – Saved Parameter Settings

- Adds the ability to save parameter sets in OpenVSP's geometry tool





Different Model Conditions Made Available by a Saved Parameters Option



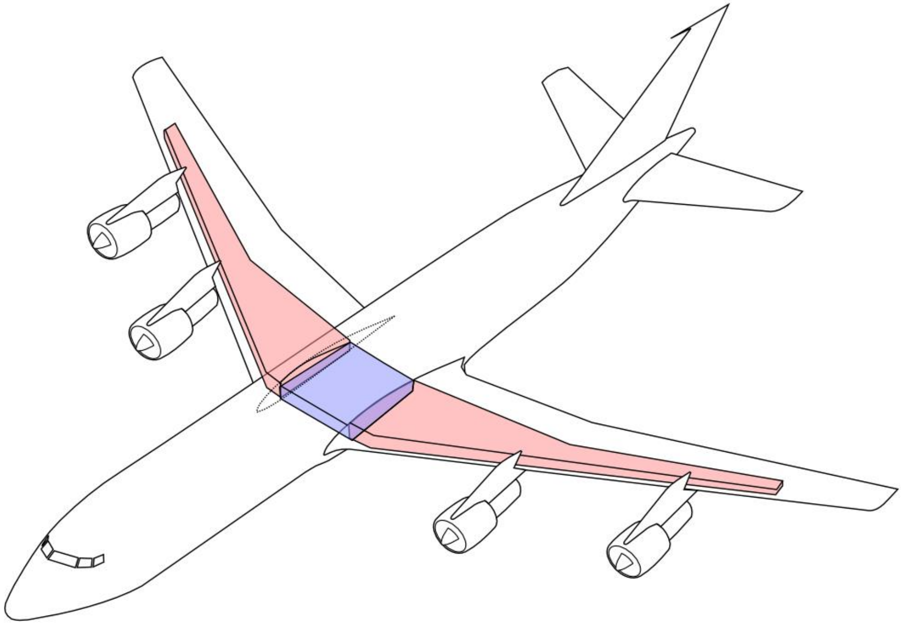
Simulated Saved Parameters GUI Showing Saved Landing Gear Configurations and Saved Sets of Aircraft Dimensions.

Task 7 – Addition of Structure Modeling Capability

- OpenVSP v3 will be extended to:
  - Support modeling representative aerospace structures for all component types
  - Use the sub-surface modeling and attribute capability as a fully integrated aspect of modeling structures
  - Support modeling no-depth structures as FEA beam elements
    - Beam elements will allow direct modeling of spar caps, ring frames, stringers and other skin stiffeners
  - Support modeling of key points in the FEA mesh
    - These key nodes may be used to connect separate structures (say wing to fuselage), model structures otherwise omitted (engine mount or landing gear details), or to apply point loads or masses.

Task 8 – Conformal Feature

- OpenVSP will be extended to support conformal components.
  - Conformal components will derive their shape from another component.
  - For example, a fuel tank may be constructed through specification of start/end percent span and percent chord of a wing.
- Currently, OpenVSP components have predominantly independent shape.
  - This is appropriate for many roles, like placing a satellite dish inside a fuselage.
  - However, other internal components like a fuel tank may need to derive their shape from another component.



Task 9 – Blendable Wings

- OpenVSP's built-in wing component will be extended to support such blended lofting between airfoil sections.
  - OpenVSP currently has limited potential to model exotic wings or blended wing-body concepts, like NASA's BWB concept shown below.

NASA Blended Wing Body Concept

Task 10 – Addition of a *.VSP to *.VSP3 Converter

- OpenVSP v3 will be modified to import existing files from v2.
- At present, OpenVSP v3 cannot open or import v2 files.
  - This means that established OpenVSP users must re-make their existing models in v3 and the established library of models available in the OpenVSP hangar are unavailable to users of the latest versions of OpenVSP.
- The converter will open existing *.vsp files and will interpret the parameters in terms of the new v3 components.

Task 11 – Fighter Aircraft Library

- A library of major fighter aircraft models will be created.
- Publically available data on several fighter aircraft will be collected and used to model the aircraft in OpenVSP using major components.
- From these models, components may be used as building blocks for future aircraft models.

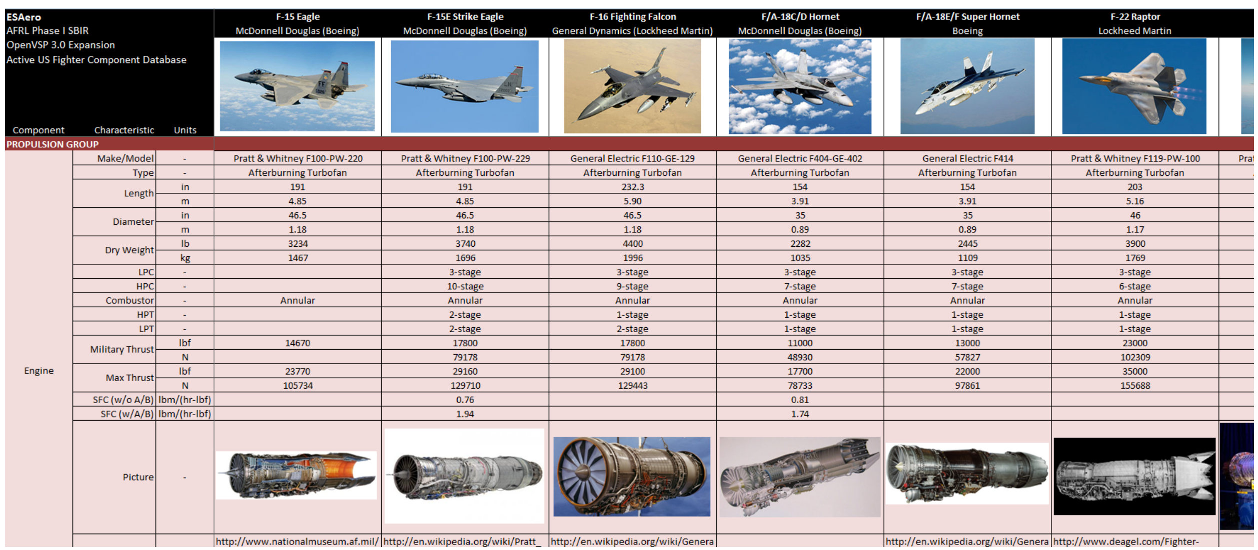
Representative Fighter Models from VSP2 Hangar

Task 12 – Continuation of Component Database and Advanced Parameter Link Library

- Create a library of conceptual and preliminary level advanced parameter links in OpenVSP.

Table 1. Components and Systems Considered for Fighter Component Database

Engines	Landing Gear	Various Missiles
Gearboxes/Accessory Drives	Nosewheel Tires	Other Bombs/Weapons
Ejection Seats	Mainwheel Tires	Guns
Human Anthropometrics	Radars	External Fuel (Drop) Tanks

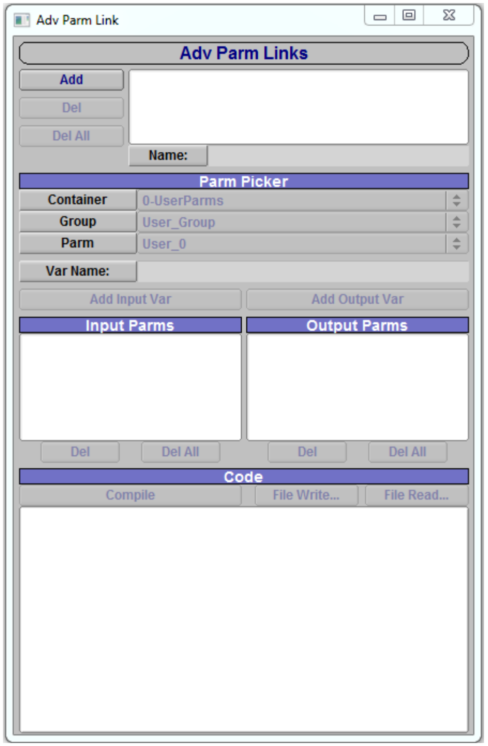


ESAero AFRL Phase I SBIR OpenVSP 3.0 Expansion Active US Fighter Component Database			F-15 Eagle McDonnell Douglas (Boeing)	F-15E Strike Eagle McDonnell Douglas (Boeing)	F-16 Fighting Falcon General Dynamics (Lockheed Martin)	F/A-18C/D Hornet McDonnell Douglas (Boeing)	F/A-18E/F Super Hornet Boeing	F-22 Raptor Lockheed Martin	
Component	Characteristic	Units							
PROPULSION GROUP									
Engine	Make/Model	-	Pratt & Whitney F100-PW-220	Pratt & Whitney F100-PW-229	General Electric F110-GE-129	General Electric F404-GE-402	General Electric F414	Pratt & Whitney F119-PW-100	Pra
	Type	-	Afterburning Turbofan	Afterburning Turbofan	Afterburning Turbofan	Afterburning Turbofan	Afterburning Turbofan	Afterburning Turbofan	
	Length	in	191	191	232.3	154	154	203	
		m	4.85	4.85	5.90	3.91	3.91	5.16	
	Diameter	in	46.5	46.5	46.5	35	35	46	
		m	1.18	1.18	1.18	0.89	0.89	1.17	
	Dry Weight	lb	3234	3740	4400	2282	2445	3900	
		kg	1467	1696	1996	1035	1109	1769	
	LPC	-		3-stage	3-stage	3-stage	3-stage	3-stage	
	HPC	-		10-stage	9-stage	7-stage	7-stage	6-stage	
	Combustor	-	Annular	Annular	Annular	Annular	Annular	Annular	
	HPT	-		2-stage	1-stage	1-stage	1-stage	1-stage	
	LPT	-		2-stage	2-stage	1-stage	1-stage	1-stage	
	Military Thrust	lbf	14670	17800	17800	11000	13000	23000	
		N		79178	79178	48930	57827	102309	
	Max Thrust	lbf	23770	29160	29100	17700	22000	35000	
		N	105734	129710	129443	78733	97861	155688	
	SFC (w/o A/B)	lbm/(hr-lbf)		0.76		0.81			
	SFC (w/A/B)	lbm/(hr-lbf)		1.94		1.74			
	Picture	-							
			http://www.nationalmuseum.af.mil/	http://en.wikipedia.org/wiki/Pratt_	http://en.wikipedia.org/wiki/Genera		http://en.wikipedia.org/wiki/Genera	http://www.deagel.com/Fighter-	

Portion of Fighter Component Database Created in Phase I

Task 12 – Continuation of Component Database and Advanced Parameter Link Library

- An advanced parameter link GUI provides the user with all necessary interaction to create, modify, and delete links.
- Any number of equations and/or additional variables may be created and used in conjunction with the parameters specified in the Input/Output Parms.



Advanced Parameter Link GUI