An Advanced Extensible Parametric Geometry Engine for Multi-Fidelity and Multi-Physics Analysis in Conceptual Design

Rob McDonald

NASA Ames
July 23, 2016

AEROSPACE ENGINEERING
CAL POLY • SAN LUIS OBISPO

Team Members

Cal Poly

- Rob McDonald
- David Marshall
- Alex Gary
- Pat Meyers
- Joel Belben
- Mitch Lane
- Brandon Clark

J.R. Gloudemans

Phoenix Integration

- Andy Ko
- Yue Han
- Hongman Kim
- Mike Haisma
- Peter Menegay
- Scott Ragon

Motivation

2.2 Robust Aircraft Conceptual Design Geometric Modeling

Objective

The objective of this topic is to enhance the ability to employ higher-order, physics-based analysis during conceptual design through robust, easy to create geometry

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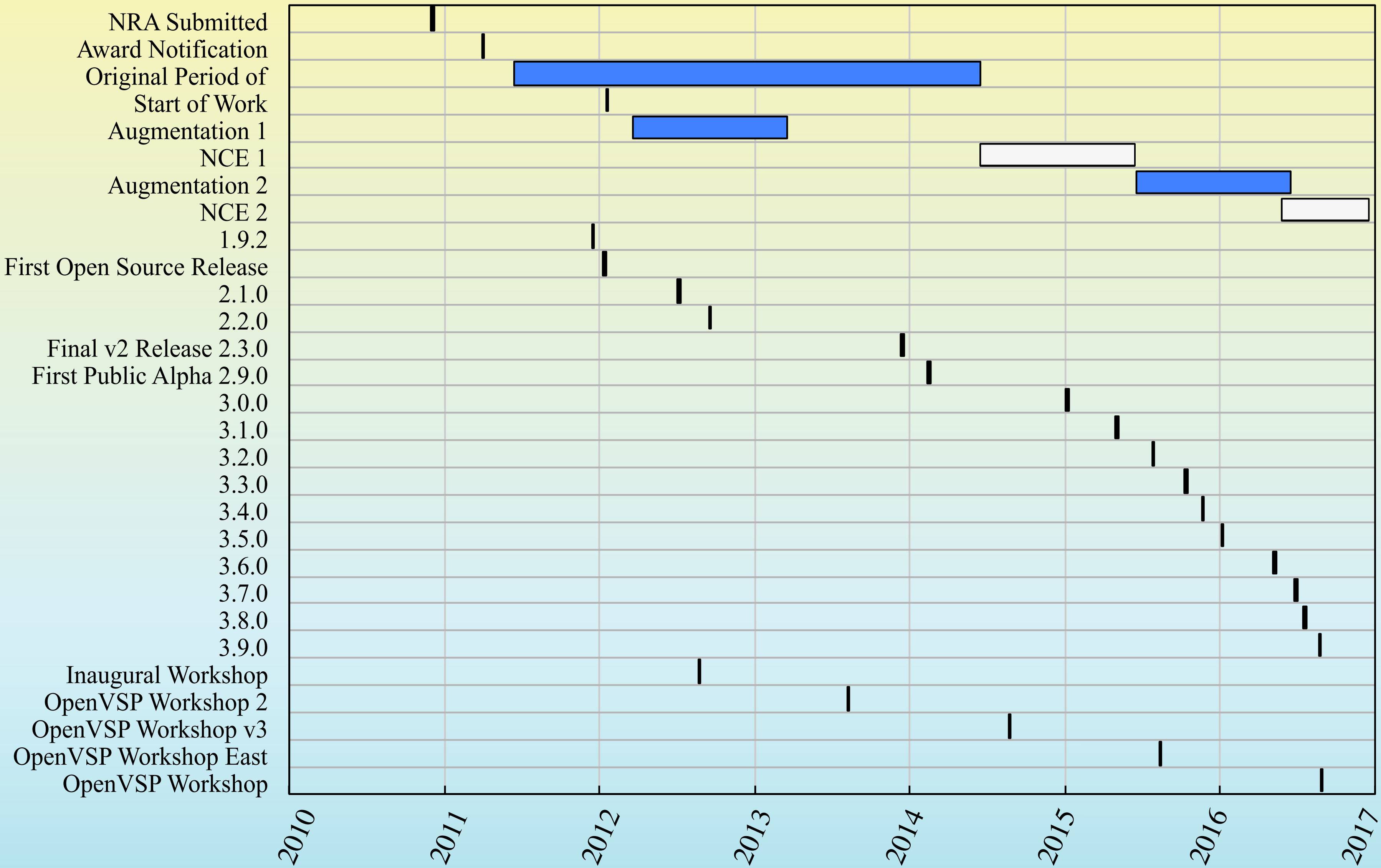
Objective

The objective of this topic is to enhance the ability to employ higher-order, physics-based analysis during conceptual design through robust, easy to create geometry models. The research goal is to automate the rigorous steps required for intelligent conversion of a conceptual level parametric geometry model into the detailed representation necessary for higher-order analysis. Conceptual design is the starting point for a new engine or aircraft development. A successful design is highly dependent on accurate geometric representations, since they are used throughout the computational engineering process. Over the past several decades computational capability has drastically improved as has the understanding of human-computer interfaces. These advances have enabled less experienced users to perform far more sophisticated tasks without the requirement of extensive training time. More accurate geometry representations will advance the state-of-art in conceptual design by enabling more routine use of higher-order analysis tools.

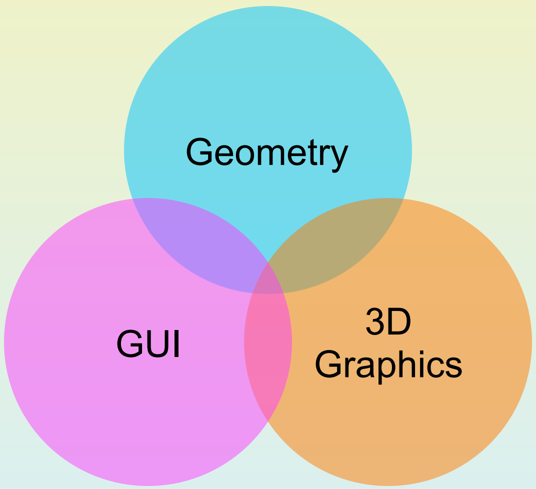
analysis. This typically involves modification of the geometry through meshing to meet specific needs. Currently these intermediate steps are very time consuming – and transitioning between tools loses necessary parametric definitions that could provide valuable sensitivity analyses. Being able to accomplish these steps in more intelligent ways, with less labor would provide timely access to more sophisticated tools. Such capability is not merely about attaching geometry interfaces to the most powerful CFD (computational fluid dynamics) or FEA (finite element analysis) tools– it is about bringing all levels of analysis capability to the designer in an easier and more rapid fashion, with less data loss from geometric translations.

Project Timeline

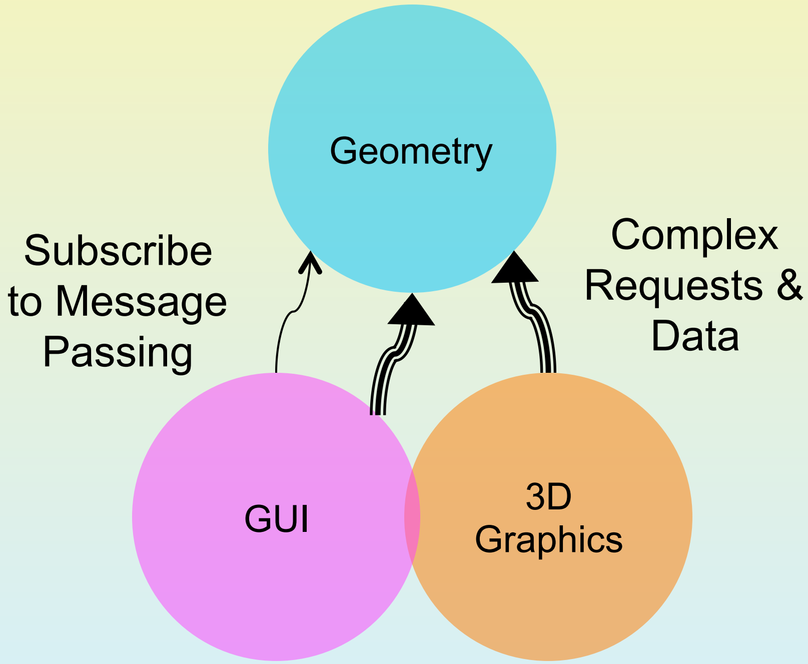


Redesign & Refactor

~1992 to OpenVSP 2.X



OpenVSP 3.X



- ‘Headless’ batch/script mode
- ‘Headless’ API access
- HPC Installation

Yr 5 Augmentation Task List

CST/Kulfan airfoils
Flat Blunt Airfoil TE modeling
Flat Blunt TE mesh
Negative volumes
VSPAERO & CBAERO Integration
OpenVSP Training & Promotion
Rounded Blunt Airfoil LE &TE modeling
CFDMesh Symmetry Plane Improvements
Tessellation spacing
Simplified Fuse Skinning
Actuator disk
Propeller component
End Caps
Fit Model Save/Restore
Fit Model Merge
Parameter Drag-N-Drop
Improve Search UW
Projected Areas

Yr 5 Augmentation Task List

CST/Kulfan airfoils	v3.4.0 on 11/18/15
Flat Blunt Airfoil TE modeling	v3.2.0 on 7/24/15
Flat Blunt TE mesh	v3.2.0 on 7/24/15
Negative volumes	v3.2.0 on 7/24/15
VSPAERO & CBAERO Integration	v3.1.0 on 4/29 & v3.2.0 on 7/24/15
OpenVSP Training & Promotion	OpenVSP Workshop August 2015 & 2016
Rounded Blunt Airfoil LE &TE modeling	v3.6.0 on 5/6/16
CFDMesh Symmetry Plane Improvements	v3.2.0 on 7/24/15
Tessellation spacing	v3.5.1 on 1/23/16
Simplified Fuse Skinning	v3.2.3 on 9/20/15
Actuator disk	v3.2.0 on 7/24/15
Propeller component	v3.8.1 on 8/1/16
End Caps	v3.6.0 on 5/6/16
Fit Model Save/Restore	v3.2.0 on 7/24/15
Fit Model Merge	v3.2.0 on 7/24/15
Parameter Drag-N-Drop	v3.2.0 on 7/24/15
Improve Search UW	v3.2.3 on 9/20/15
Projected Areas	v3.6.1 on 5/29/16

Agenda

	8/23 Tuesday		8/24 Wednesday		8/25 Thursday	
8:00 8:30	Welcome & Overview	Rob McDonald	Automated FEM	Wu Li	Wave Drag	Rob/Michael
8:30 9:00	Intro to OpenVSP	Brandon Litherland	Structural Modeling and OpenVSP	Trevor Laughlin	Drag buildup	Bryan Schmidt
9:00 9:30	Basic modeling	Brandon Litherland	TOW Steered Wing Structure Design	Mike Hensen	Aerodatabases with GoCart & Cart3D	Aerion
9:30 10:00	Tour of main components	Brandon Litherland	OpenVSP Inertia Calculation	Mark McMillin	Aerodatabases with GoCart & Cart3D	Aerion
10:00 10:30	Break		Break		Break	
10:30 11:00	Cal Poly NRA Final Review	Rob McDonald	RapidFEM & PBWeight	Tyler Winter	Projected Area	Rob McDonald
11:00 11:30	XSecs in detail	Brandon Litherland	VSPAERO Background	Dave Kinney	NDARC Integration	Travis Perry
11:30 12:00	USAF SBIR Report	Ben Schiltgen	VSPAERO GUI VLM Basics	Nick Brake	Aircraft design framework	Alessandro Silva
12:00 12:30						
12:30 13:00	Lunch		Lunch		Lunch	
13:00 13:30	NASA SBIR Report	Nick Brake	VSPAERO GUI VLM Advanced	Nick Brake	CompGeom and Meshing tutorial	Rob McDonald
13:30 14:00	Attach, symmetry, sets, subsurfaces	Rob McDonald	VSPAERO GUI Panel Method	Nick Brake	Flightstream	Roy Hartfield
14:00 14:30	Skinning explained	Rob McDonald	VSPAERO Test and Verification	Dave Kinney	Flightstream	Roy Hartfield
14:30 15:00	Break		Break		Break	
15:00 15:30	Advanced Wing Modeling	Rob McDonald	VSPAERO Next Steps	Dave Kinney	Design vars & xddm, API, Scripting	Rob McDonald
15:30 16:00	Conformal Components	J.R. Gloudemans	VSPAERO SUGAR braced wing aero	Doug Wells	Automation	Rob McDonald
16:00 16:30	Saved Parameter Settings	Bryan Schmidt	Advanced Parameter Linking	Rob McDonald	Fit Model Presentation	Rob McDonald
16:30 17:00	Modeling Demo	Rob McDonald	Leveraging DegenGeom	Erik Olson	Fit Model Interactive	Rob McDonald
17:00 17:30	Modeling Demo	Rob McDonald	Custom Components	Rob McDonald	Feedback session	
17:30 18:00						
18:00 18:30	BBQ social					

Major NRA Contributions

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Publications & MS Theses

MS Theses Completed

Belben, Joel. Reduced Fidelity Geometry for Conceptual Design in VSP. MS Thesis, California Polytechnic State University, San Luis Obispo, CA, April 2013.

Papers Presented

McDonald, R., “Advanced Modeling in OpenVSP:, AIAA Aviation AIAA-2016-3282.

McDonald, R., Gloudemans, J.R., “User Defined Components in the OpenVSP Parametric Geometry Tool”, AIAA Aviation, AIAA-2015-2547.

Gary, A., McDonald, R., “Parametric Identification of Surface Regions in OpenVSP for Improved Engineering Analysis”, 53rd AIAA Aerospace Sciences Meeting, AIAA 2015-1016.

McDonald, R., “Interactive Reconstruction of 3D Models in the OpenVSP Parametric Geometry Tool”, 53rd AIAA Aerospace Sciences Meeting, AIAA 2015-1014.

Gary, A., McDonald, R., “Aerodynamic Shape Optimization of Propulsion Airframe Integration While Matching Lift Distribution”, 52nd AIAA Aerospace Sciences Meeting, AIAA-2014-0533

Marshall, D., “Creating Exact Bezier Representations of CST Shapes”, 21st AIAA Computational Fluid Dynamics Conference, AIAA-2013-3077.

Belben, J., McDonald, R., “Enabling Rapid Conceptual Design Using Geometry-Based Multi-Fidelity Models in VSP”, 51st AIAA Aerospace Sciences Meeting, AIAA 2013-0328.

ASM Oral Presentations

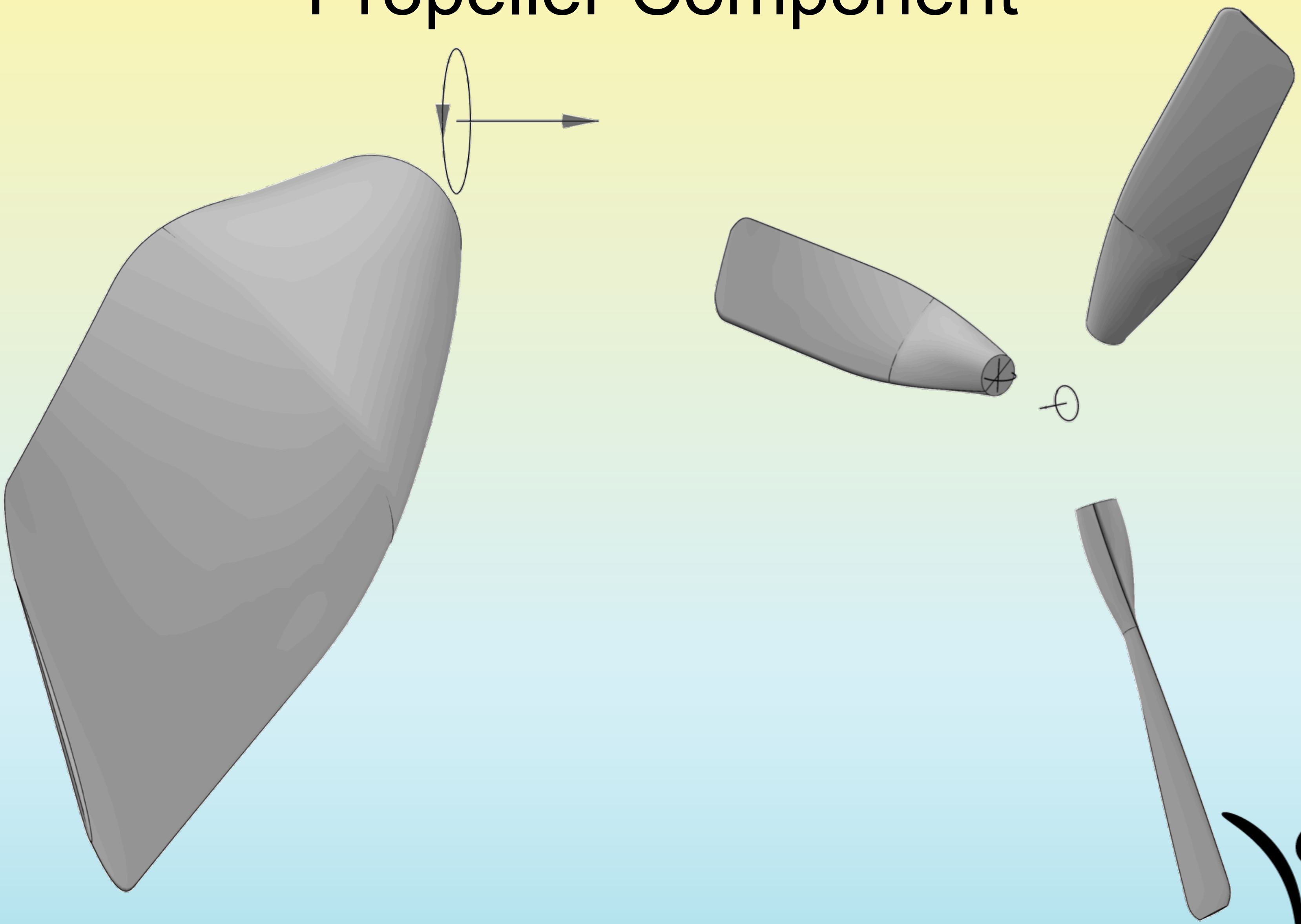
Gary, A., McDonald, R., “Demonstration of OpenVSP Community Website”, 51st AIAA Aerospace Sciences Meeting, 2013.

McDonald, R., “Curvature Based Surface Meshing in VSP and Validation of VSP Geometry Representation for CFD”, 51st AIAA Aerospace Sciences Meeting, 2013.

McDonald, R., “Geometry Requirements for High-Fidelity CAE”, 50th AIAA Aerospace Sciences Meeting, 2012.

McDonald, R., “VSP Directions; Advancing Vehicle Sketch Pad Multi-Fidelity and Multi-Physics Analysis in Conceptual Design.” 50th AIAA Aerospace Sciences Meeting, 2012.

Propeller Component



Prop Design

Diameter

Number of Blades

Rotate & Reverse

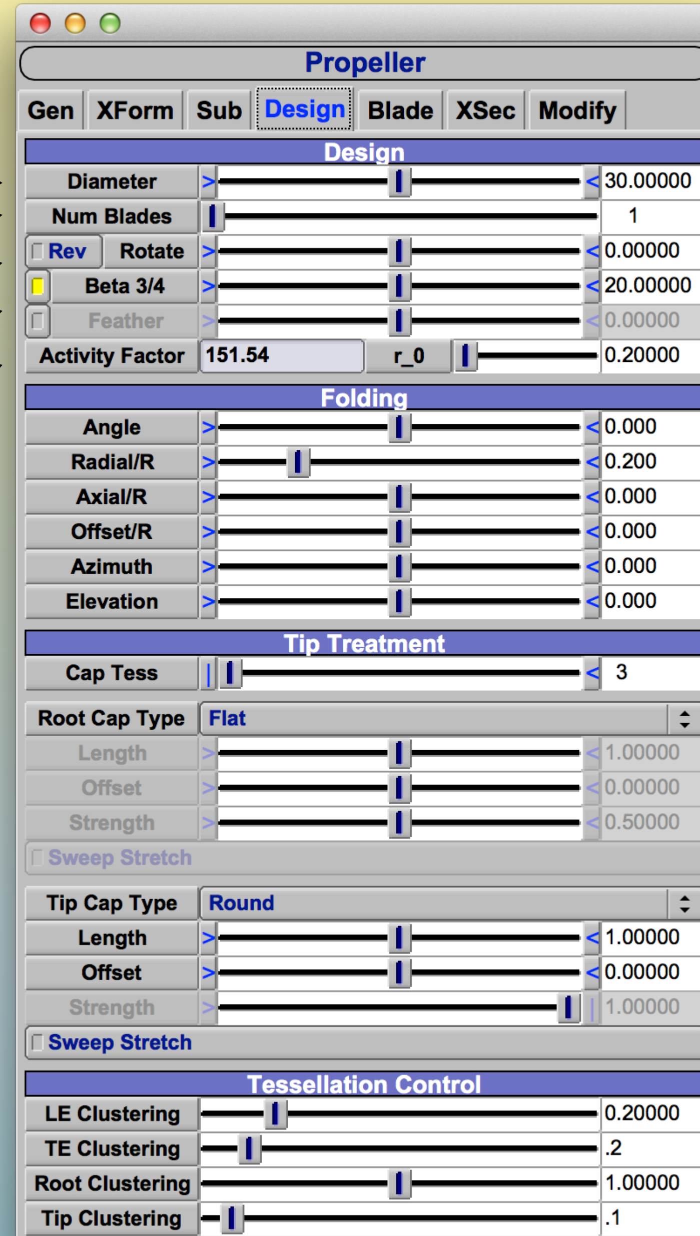
Beta 75% Control

Activity Factor

Folding Control

Root/Tip Cap Treatment

Tessellation Clustering



Chord Distribution

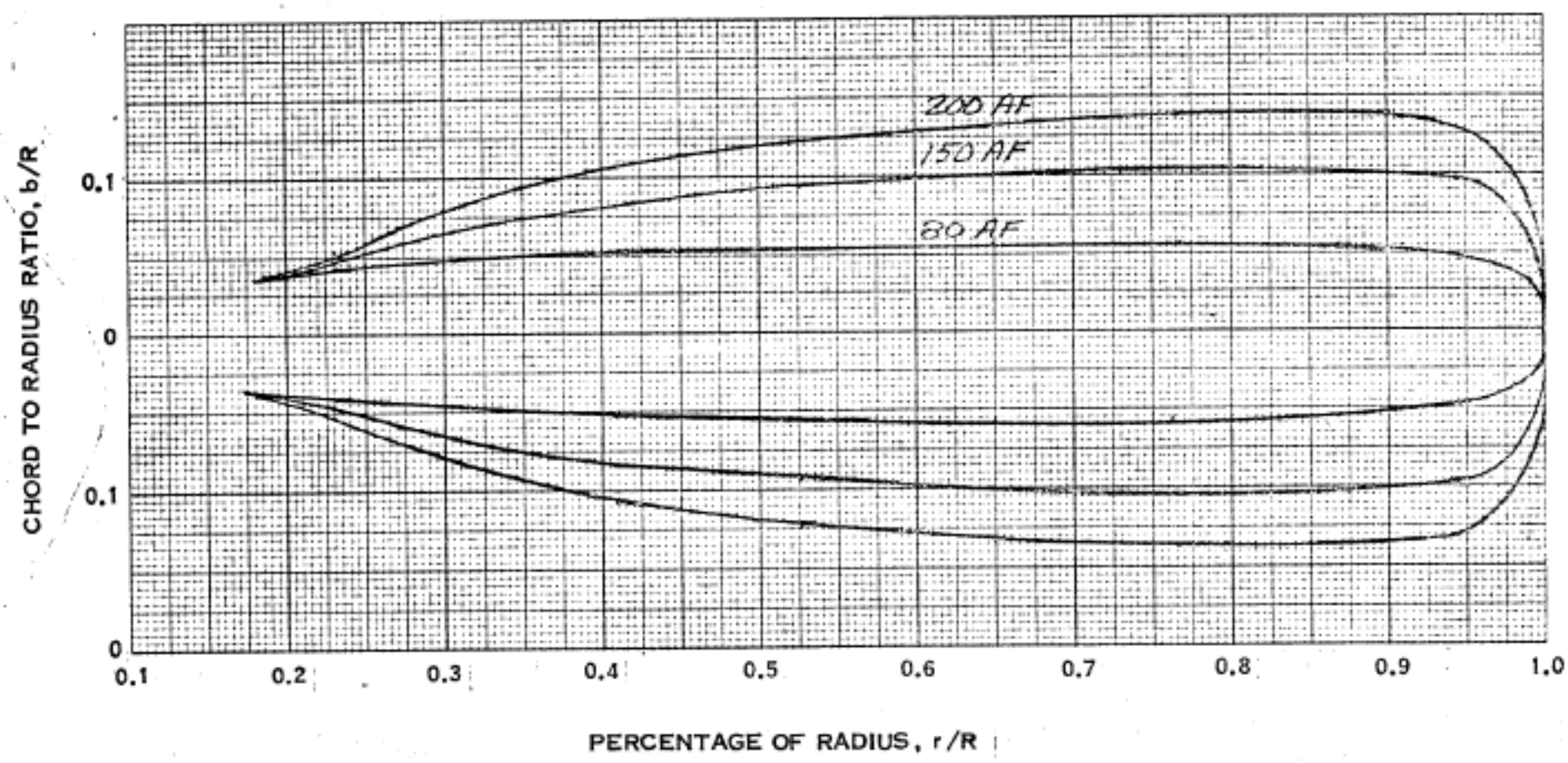
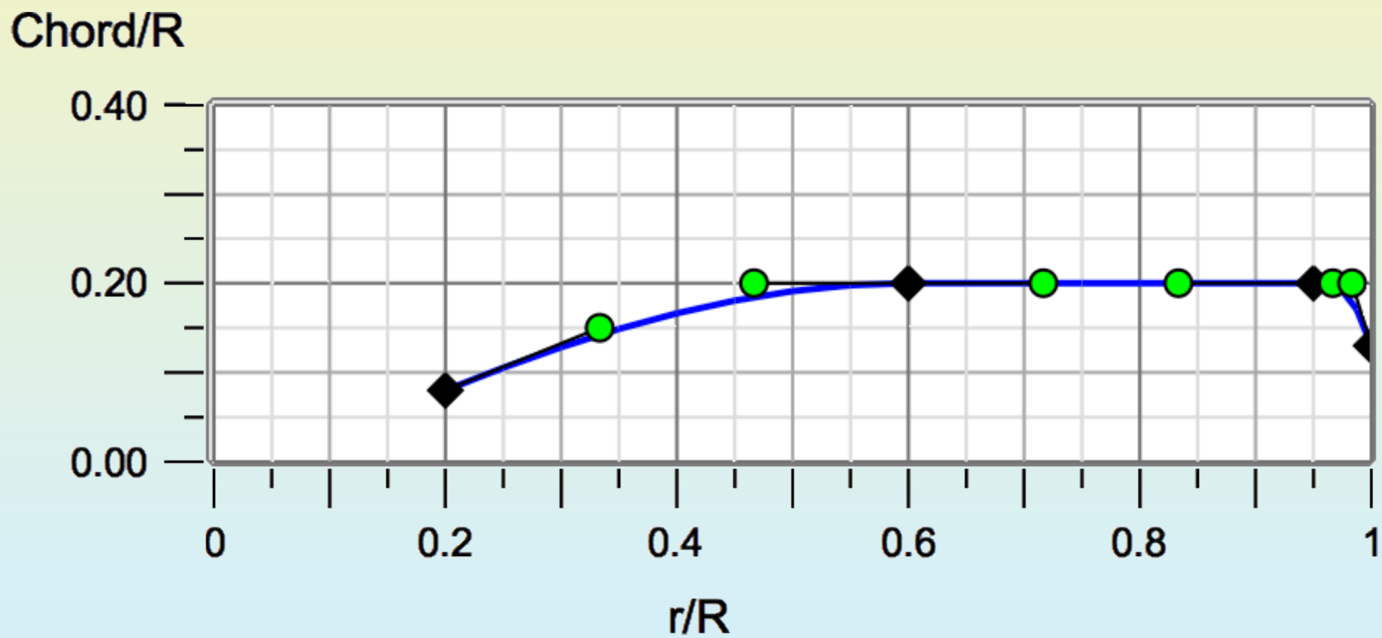


FIGURE 1. BLADE PLANFORM DISTRIBUTION

Hamilton Standard, 'Advanced General Aviation Propeller Study', 1971, NASA CR 114289.

Chord Distribution



Chord Curve Editor

Curve Selector

Curve Type
& Convert

Interactive Plot

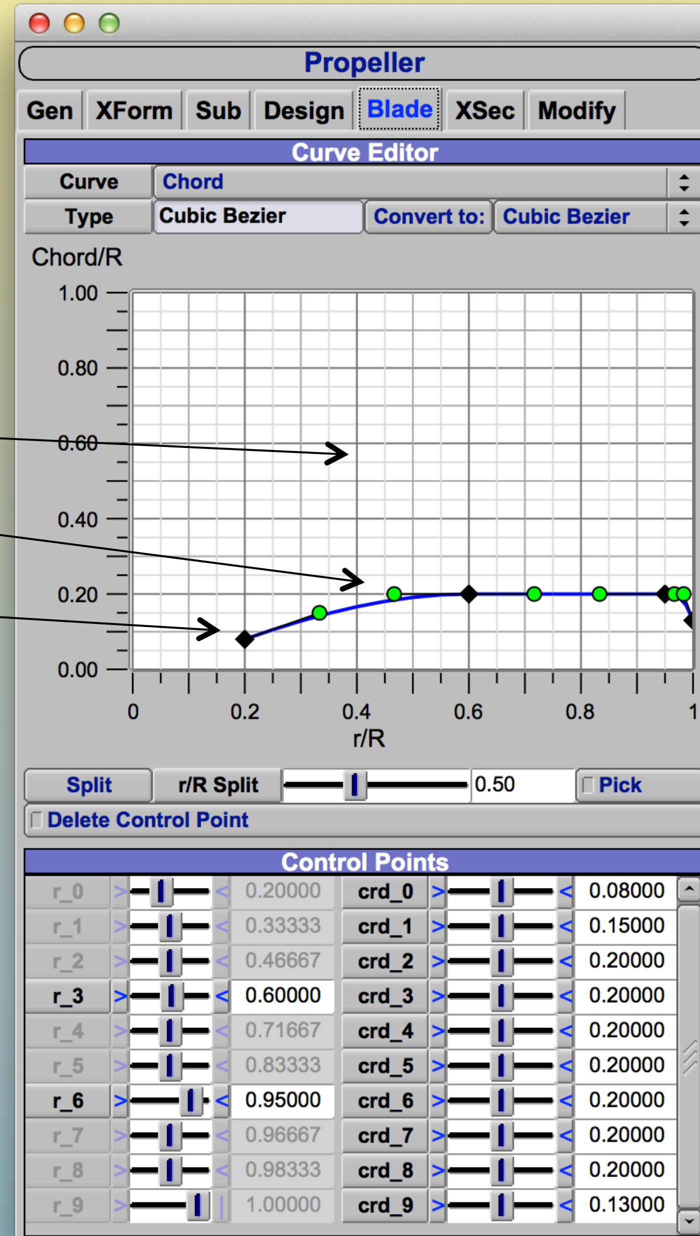
Tangency Control

Position Control

Split Curve
(Add Control Point)

Delete Control Point
(Pick)

Control Points



Chord Distribution

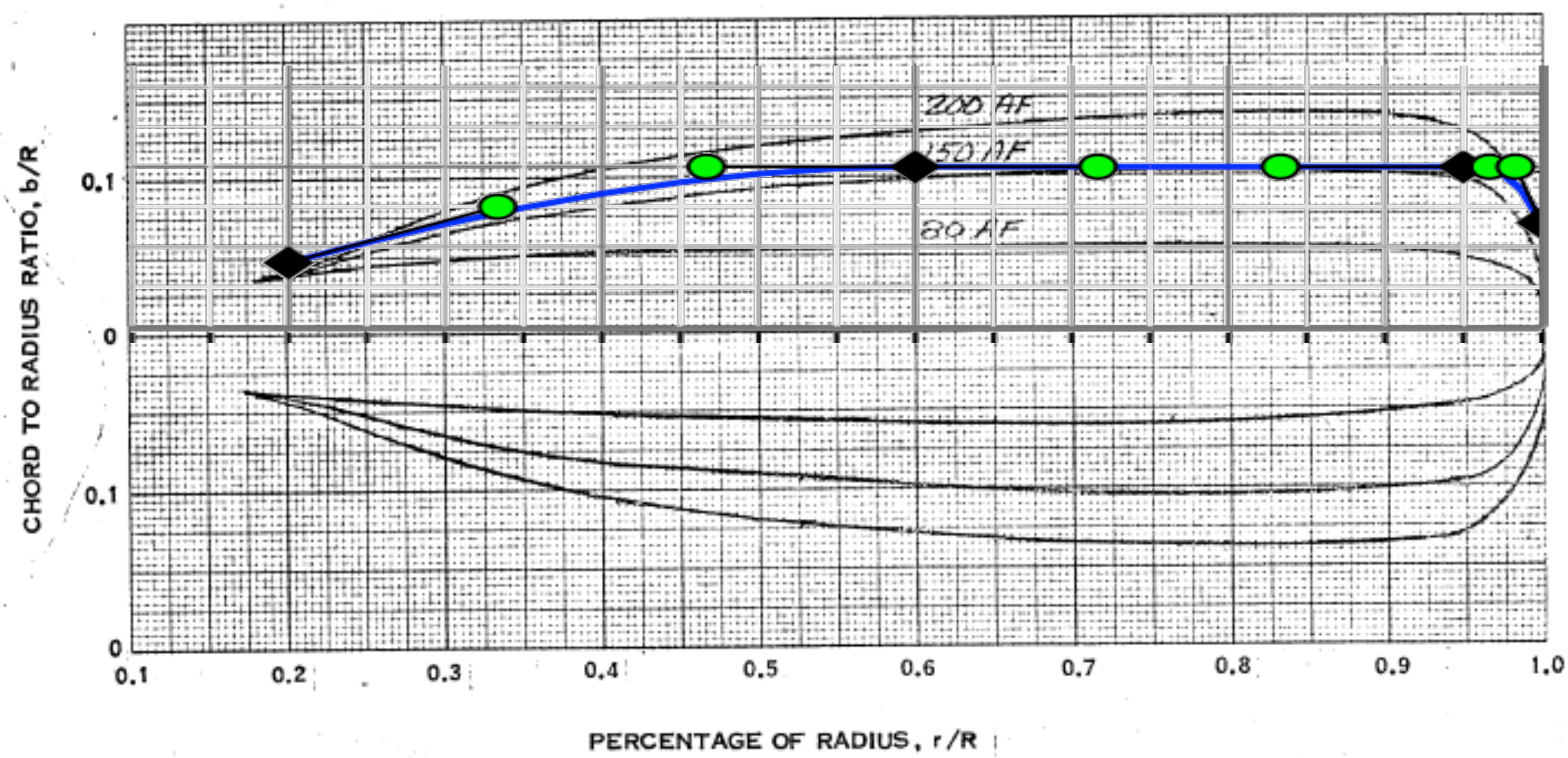


FIGURE 1. BLADE PLANFORM DISTRIBUTION

Hamilton Standard, 'Advanced General Aviation Propeller Study', 1971, NASA CR 114289.

Twist Distribution

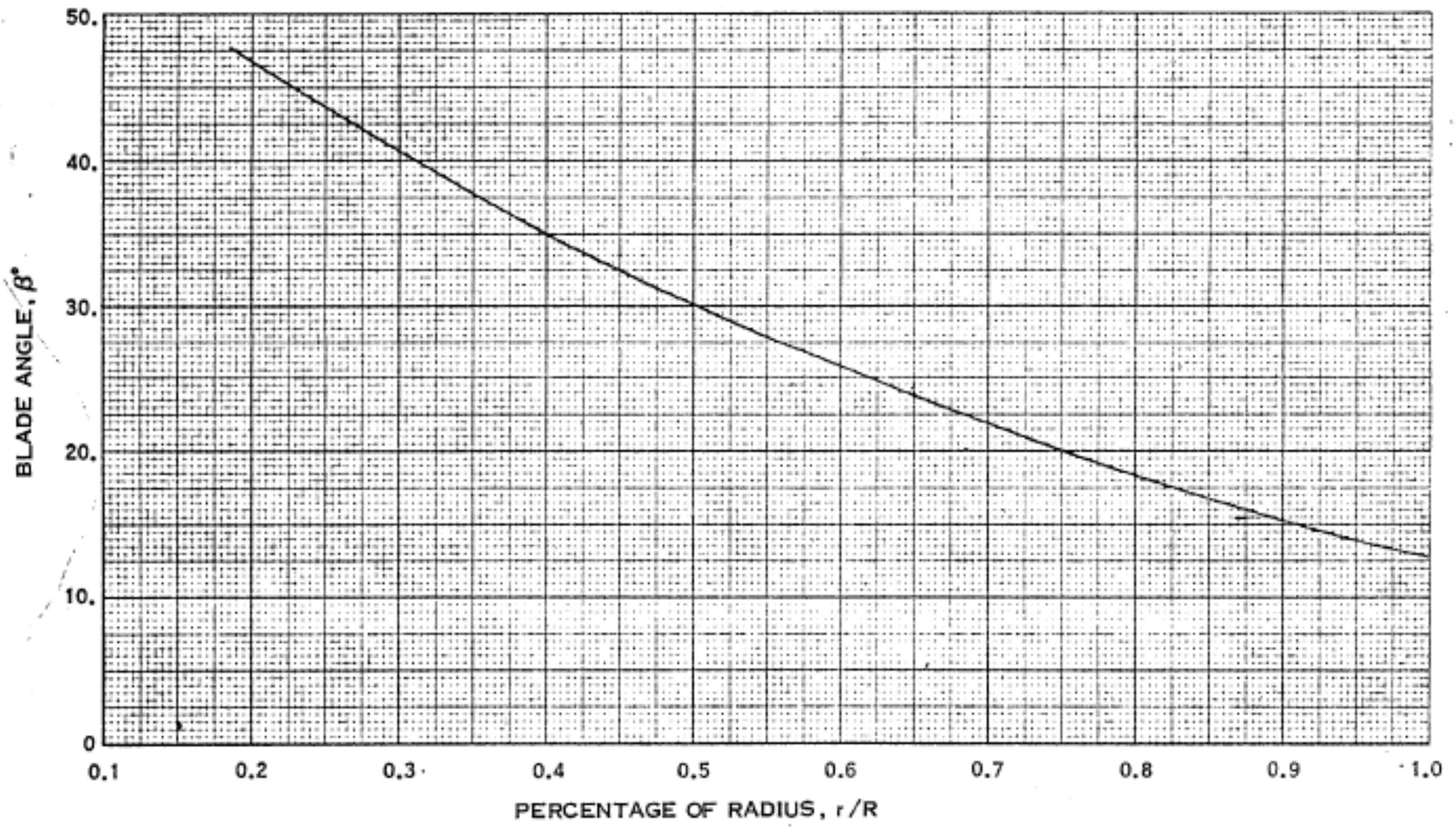
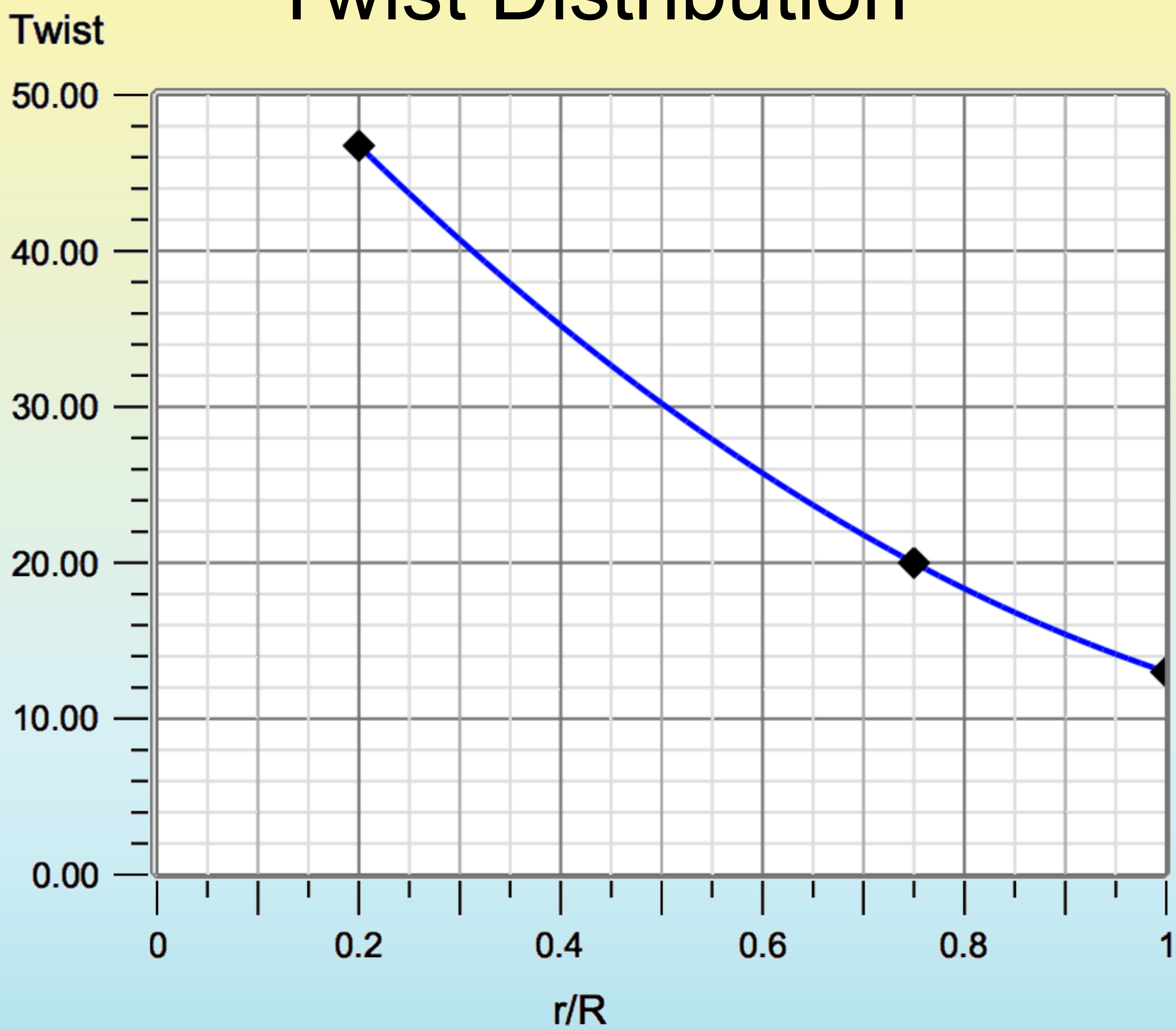


FIGURE 3. BLADE PITCH DISTRIBUTION

Hamilton Standard, 'Advanced General Aviation Propeller Study', 1971, NASA CR 114289.

Twist Distribution



Twist Distribution

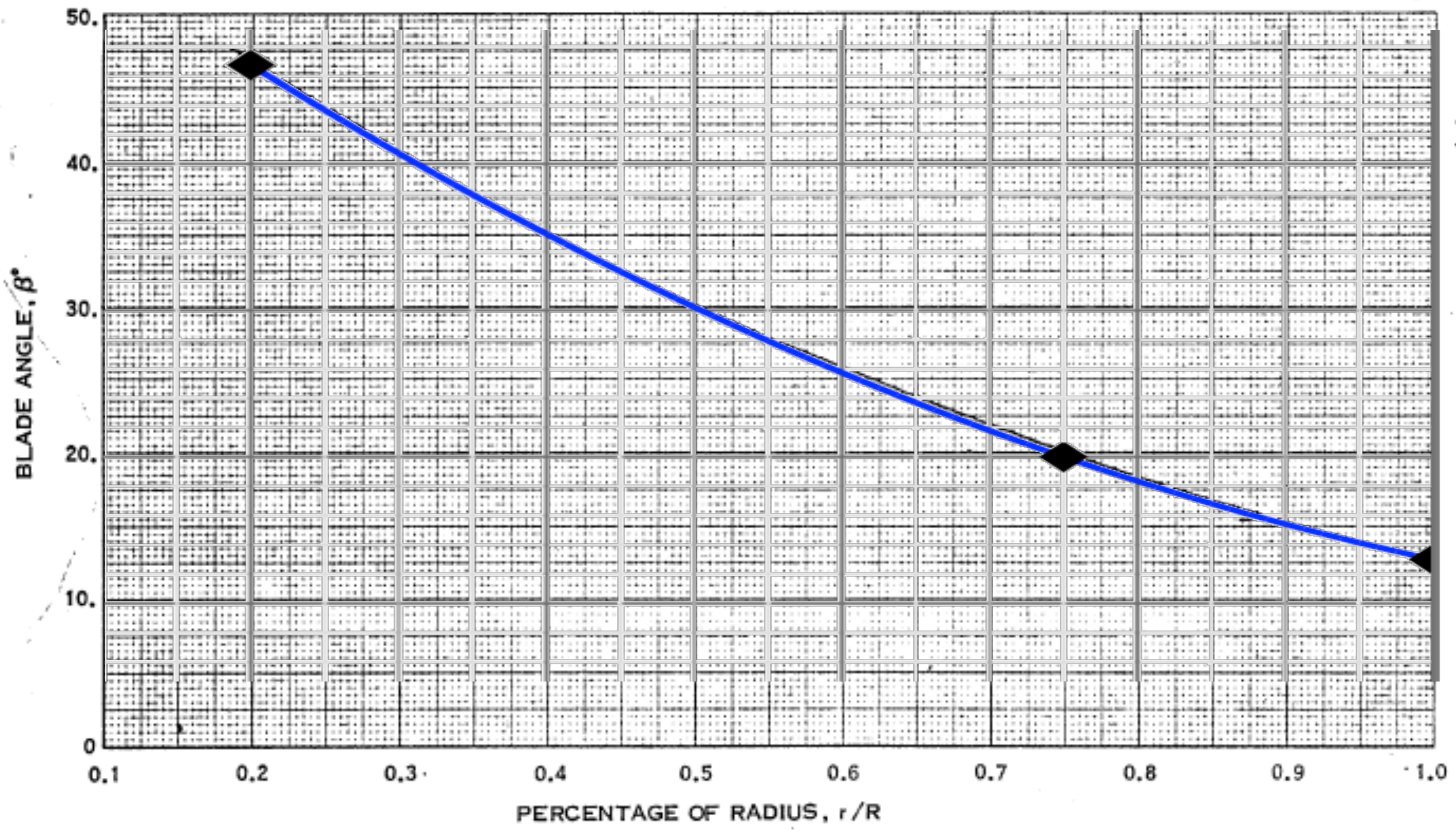


FIGURE 3. BLADE PITCH DISTRIBUTION

Hamilton Standard, 'Advanced General Aviation Propeller Study', 1971, NASA CR 114289.

Blade Element Import/Export

```
...BEM Propeller...
Num_Sections: 12
Num_Blade: 3
Diameter: 30.00000000
Beta 3/4 (deg): 20.00000000
Feather (deg): 0.00000000
Center: 0.00000000, 0.00000000, 0.00000000
Normal: -1.00000000, 0.00000000, 0.00000000

Radius/R, Chord/R, Twist (deg), Rake/R, Skew/R
0.20000000, 0.08000000, 46.75000000, 0.00000000, 0.00000000
0.27272727, 0.11601803, 42.31743050, 0.00000000, 0.00000000
0.34545455, 0.14698723, 38.15773854, 0.00000000, 0.00000000
0.41818182, 0.17182569, 34.27092412, 0.00000000, 0.00000000
0.49090909, 0.18945154, 30.65698723, 0.00000000, 0.00000000
0.56363636, 0.19878287, 27.31592787, 0.00000000, 0.00000000
0.63636364, 0.20000000, 24.24774606, 0.00000000, 0.00000000
0.70909091, 0.20000000, 21.45244177, 0.00000000, 0.00000000
0.78181818, 0.20000000, 18.93001503, 0.00000000, 0.00000000
0.85454545, 0.20000000, 16.68046582, 0.00000000, 0.00000000
0.92727273, 0.20000000, 14.70379414, 0.00000000, 0.00000000
1.00000000, 0.13000000, 13.00000000, 0.00000000, 0.00000000
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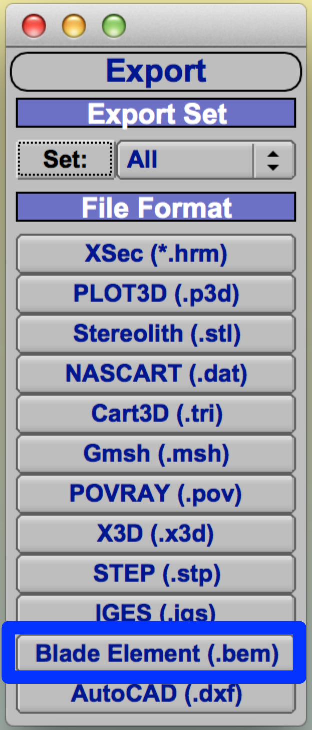

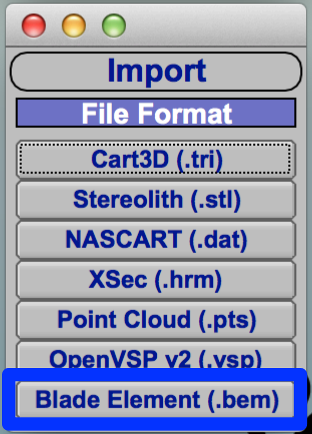

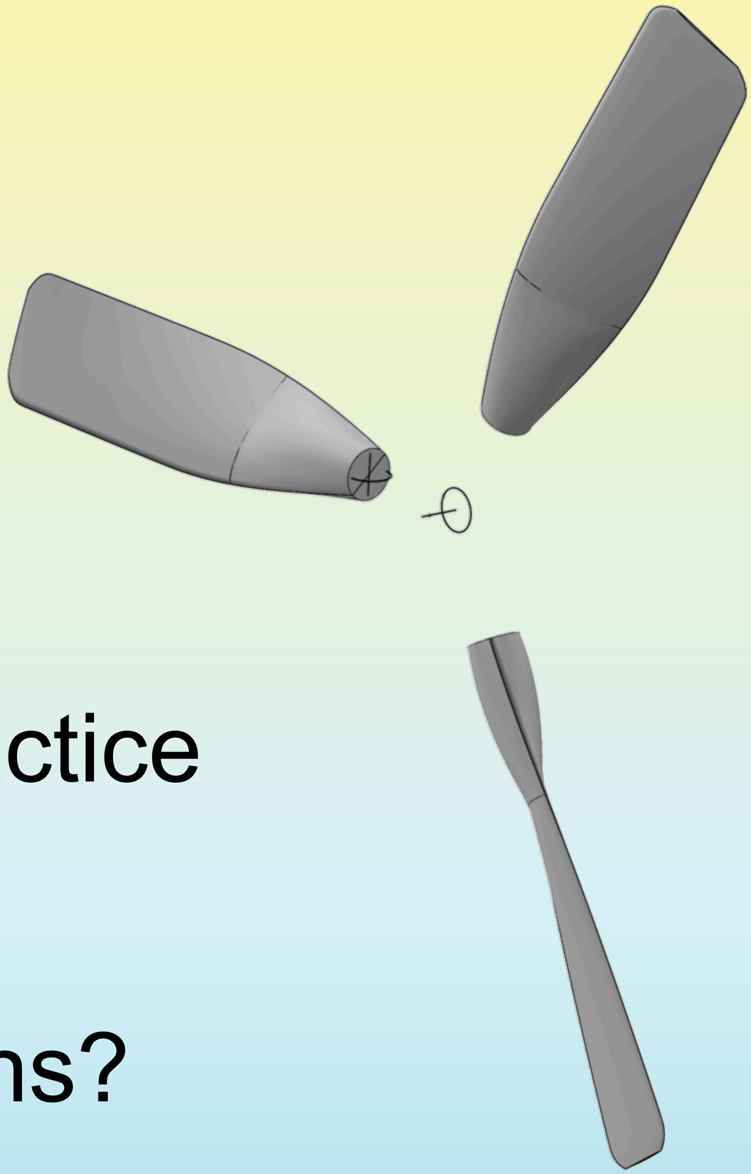

Demo/Practice

Questions?

Rob McDonald