



AFRL Morph X

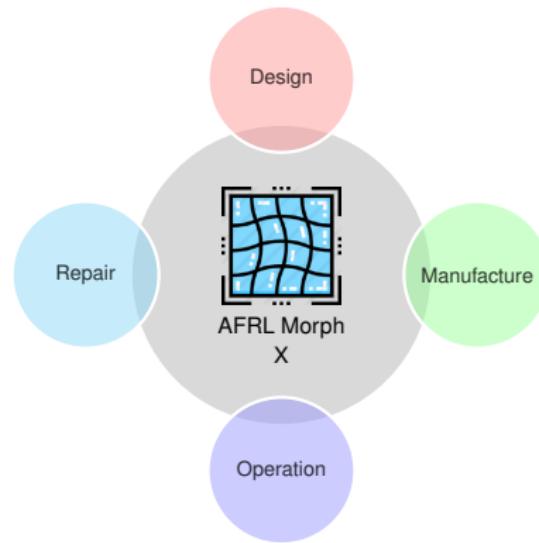
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ALEX KASZYNSKI**

**ENGINE INTEGRITY BRANCH
TURBINE ENGINE DIVISION
AEROSPACE SYSTEMS DIRECTORATE
26 FEB 2021**

AFRL Morph X

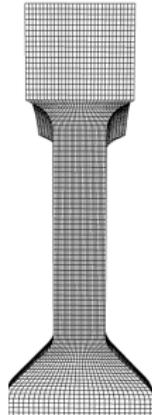
3D Mesh Morphing Software

- Move 3D FEM and CFD meshes to point cloud and surface data
- Save design time by removing mesh generation bottlenecks
- Rapidly assess impacts of as-manufactured geometry on design intent
- Learn the effects of operational damage on continued operation
- Design and validate the suitability of component repair
- And more...



Design with AFRL Morph X

Update FEM to Parametrically Variable CAD Surface

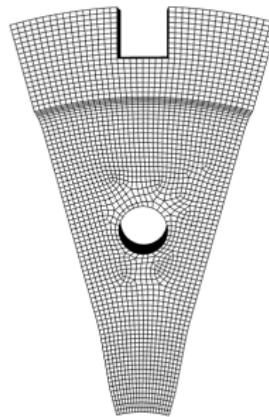


FEM



Target CAD

Side View



FEM



Target CAD

Front View

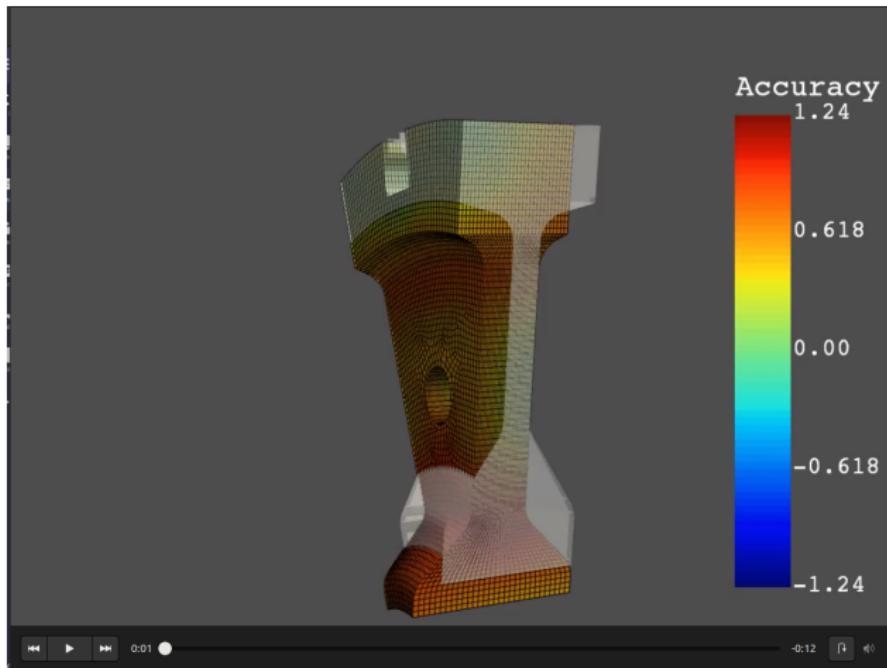
Models plotted in same reference frame. FEM grows radially.
Fourteen variable geometry parameters.

Design with AFRL Morph X

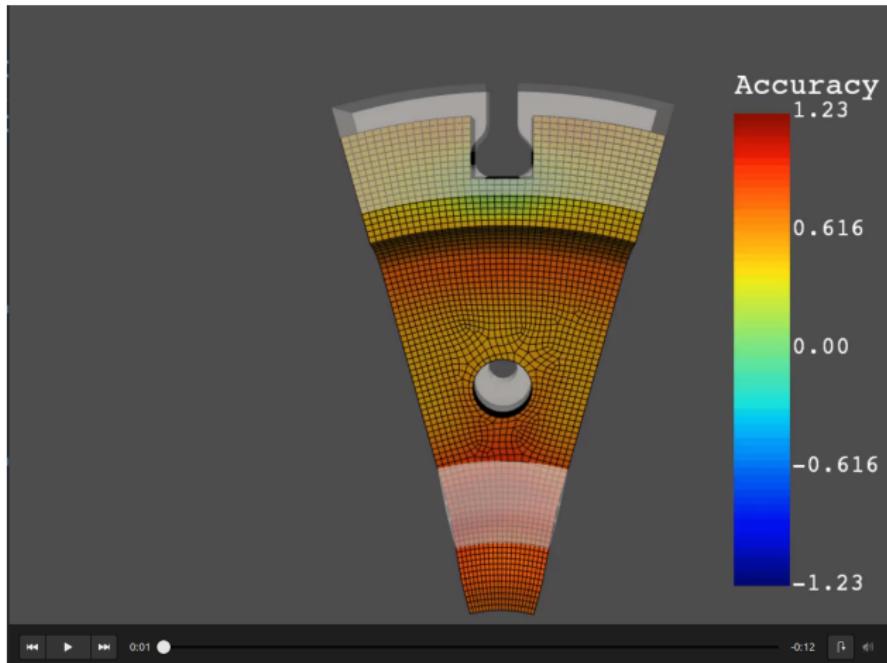
Update FEM to Parametrically Variable CAD Surface



Animation - Click image to Play

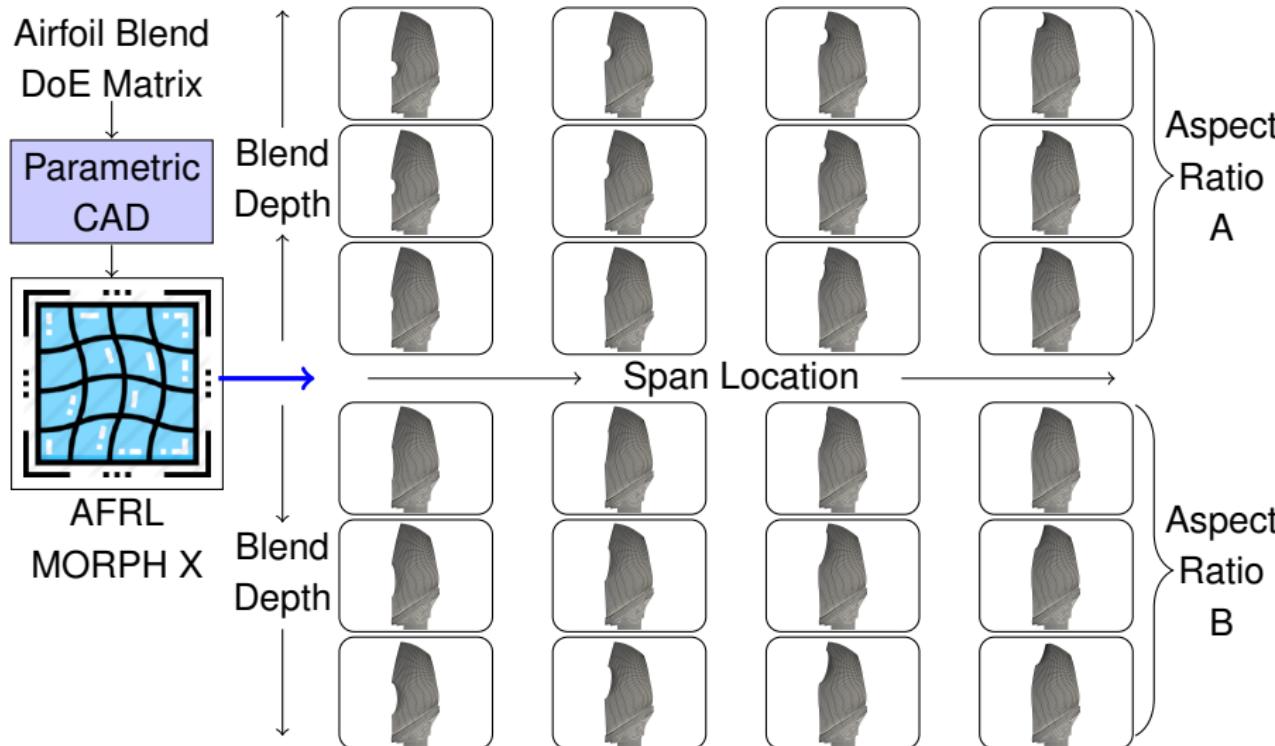


Animation - Click image to Play



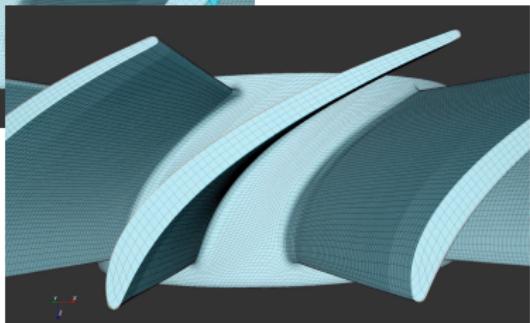
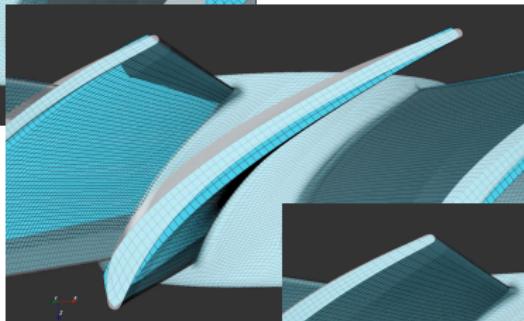
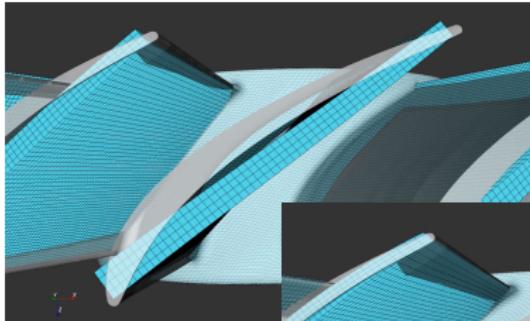
Design with AFRL Morph X

Sample Large Design Spaces Without Remeshing Challenges

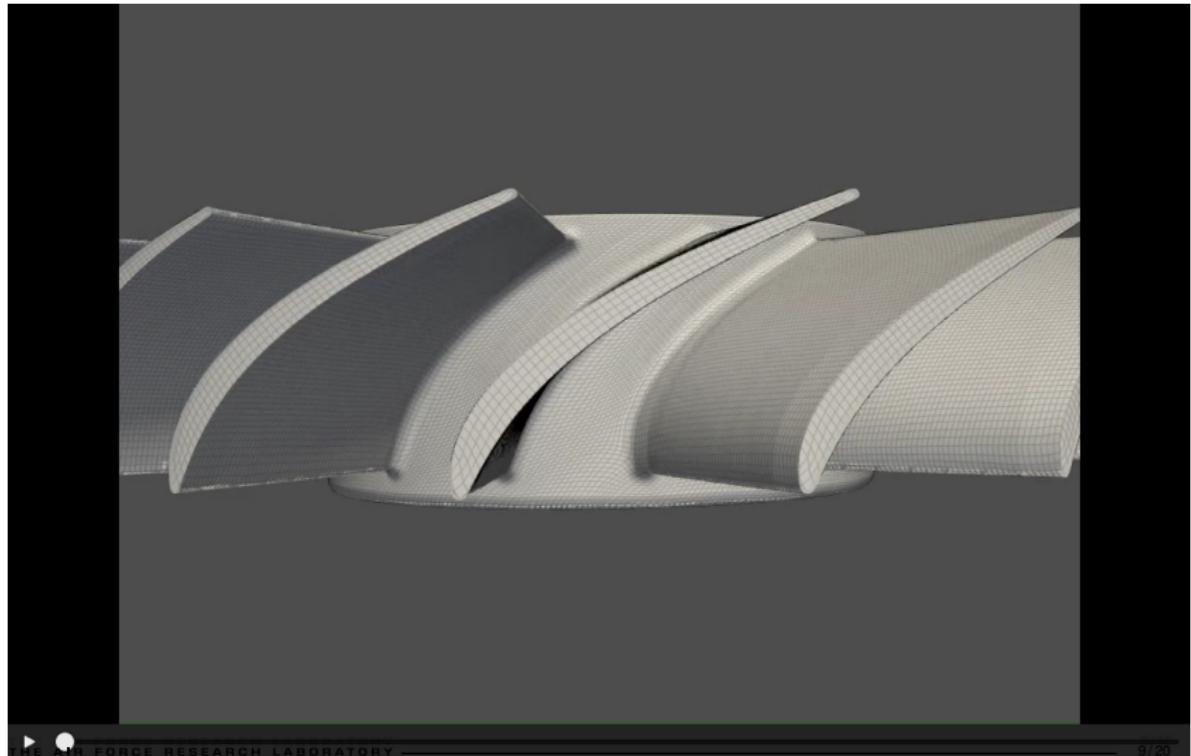


Design with AFRL Morph X

Simplify Hex Mesh Generation - Morph defeatured FEM to Complex Surface



Animation - Click image to Play

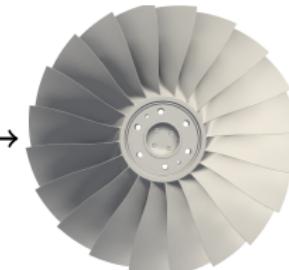


Manufacturing with AFRL Morph X

It starts with measuring variation of a real part and comparing to Design Intent

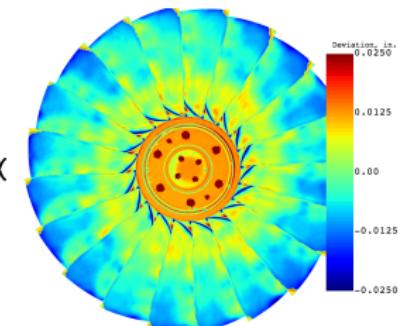


Geometry Measurement

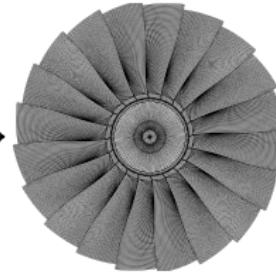


STL Surface

Manufacturing Deviations



FEM Software



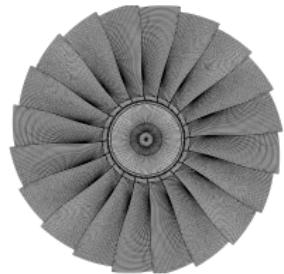
Design FEM

Manufacturing with AFRL Morph X

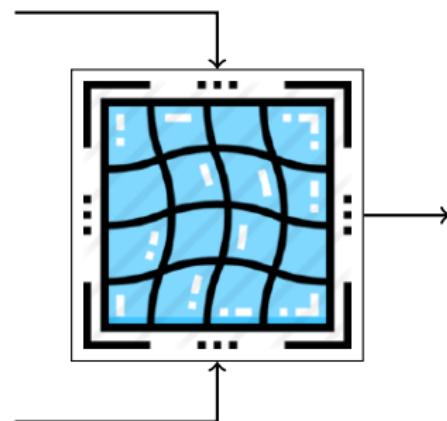
AFRL Morph X updates the Design FEM to match the STL surface within 0.001"



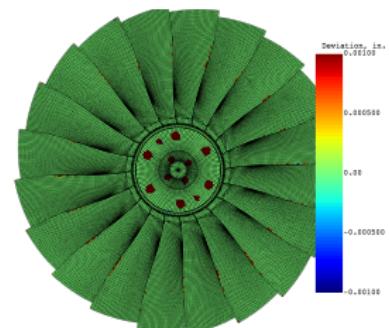
STL Surface



Design FEM

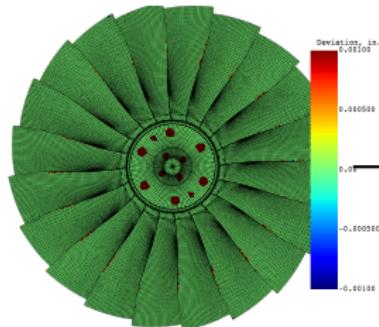


Morphed FEM
Deviations from STL



Manufacturing with AFRL Morph X

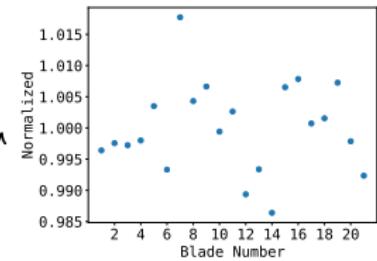
Morphed FEM is a Computational Replica of Physical Part



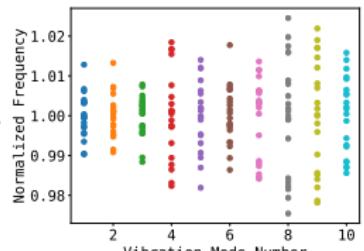
Morphed FEM
Computational Replica

Ansys

FEM Software

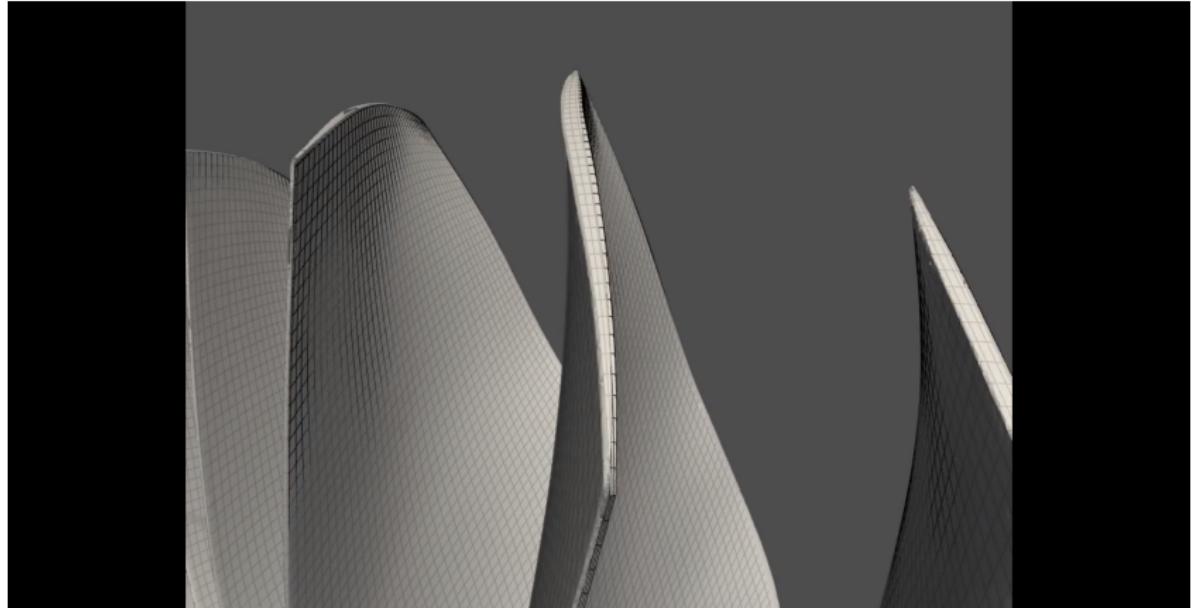


Blade to Blade
Variation



Rotor to Rotor
Variation

Animation - Click image to Play

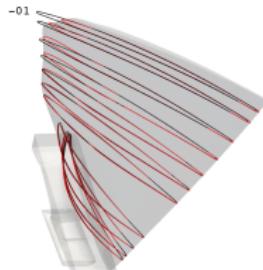


Operations with AFRL Morph X

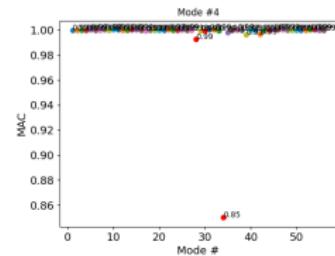
Integrating with Maintenance, Repair, and Operations with Morph X



Airfoil Leading Edge Blend Repair

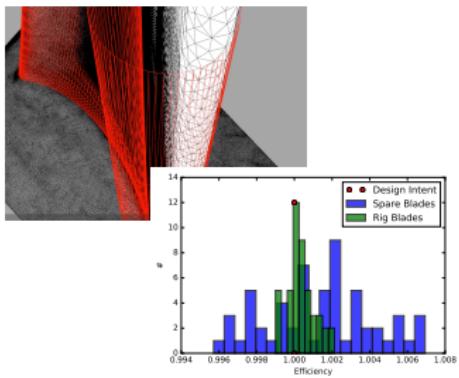


Assess Damage

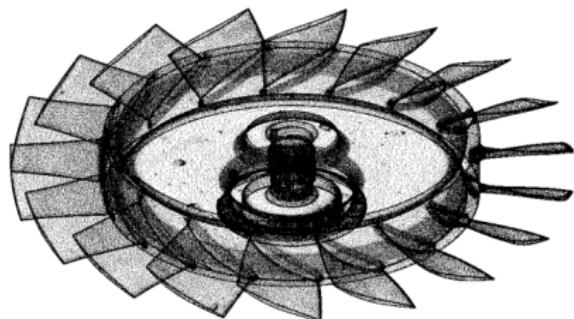


Safety Review Board

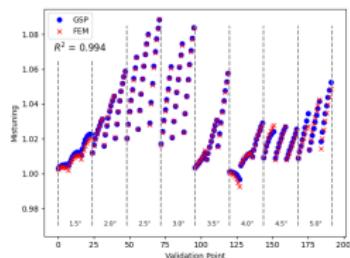
More with AFRL Morph X



Turbine CFD Mesh Morphing

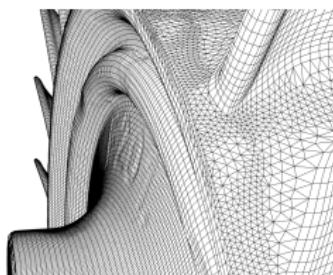


First Article Analysis



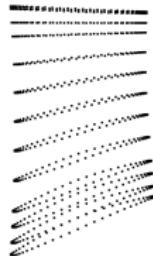
ML/AI Training Data Generator

THE AIR FORCE RESEARCH LABORATORY



Additive Part Models

Even more with AFRL Morph X



CMM Data Capable



Improved Instrumentation



Improved Model Validation

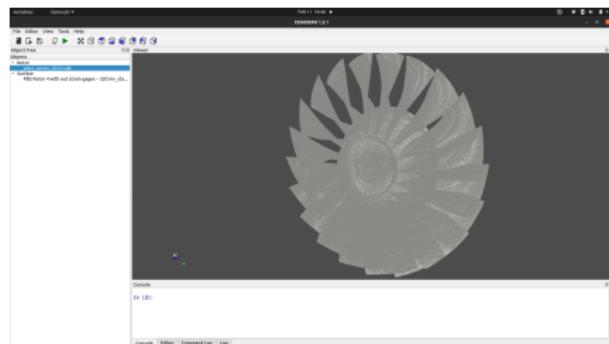


Adaptive Toolpath Generation

AFRL Design X Interface

Scriptable for integration in automated workflows and GUI for user experience

```
File Edit Options Buffers Tools Python Virtual Envs Elpy YASnippet
1 import femorph
2 import femorph_blender
3
4 jetcat_surf = 'jetcat_scan.ply'
5 jetcat_cdb = 'jetcat_sector.cdb'
6
7 surf = femorph.Surface(jetcat_surf)
8 fem = femorph.Rotor(jetcat_cdb)
9 fem.replicate_cyclically()
10 fem.align(surf)
11 fem.morph(surf, settings=set_morph)
12 fem.write_cyclic_sectors()
13
14 blend = femorph_blender.Blender(fem)
15 blend.define_edge('LEAD_EDGE_NODE')
16 span = 2.5
17 aspect = 2.0
18 depth = 0.2
19 blend.blend_on_edge(spans, aspect, depth, 0.0, 0.0, 100)
20 blend.write_archive()
```



AFRL Design X Background

- Developed in Python, C, and C++ for 8+ years
- How many commits? Testing coverage?
- Accessible through GUI and Python API, Linux, Windows, and Apple
- Beta tested by Pratt & Whitney for two years
- Operating in year 4 of 10 year non-exclusive license with Pratt & Whitney
- P&W provides licensing fees for use and support
- Utilized by large P&W user base for wide range of applications
- Applied pervasively in AFRL research activities

Closing Remarks

- AFRL MORPH X adds value across the life cycle, from design, to manufacture, and through operations
- Rigorous software development practices have enabled rapid development and successful deployment
- Windows demo software available and licensing opportunities



AFRL