



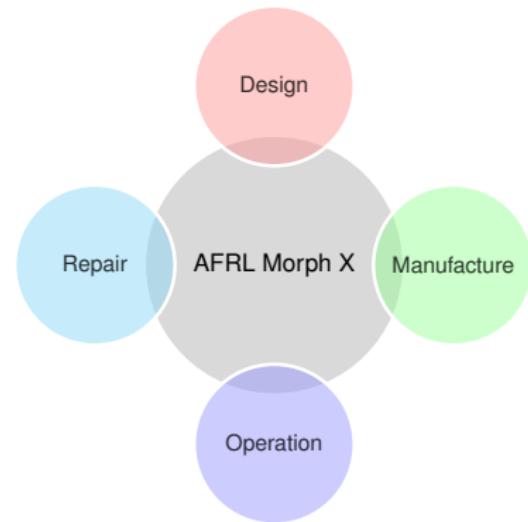
AFRL Morph X

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**ENGINE INTEGRITY BRANCH
TURBINE ENGINE DIVISION
AEROSPACE SYSTEMS DIRECTORATE**
24 FEB 2019

AFRL Morph X

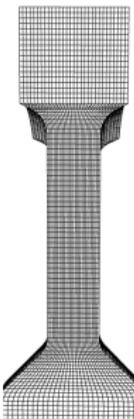
3D Mesh Morphing Software

- 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

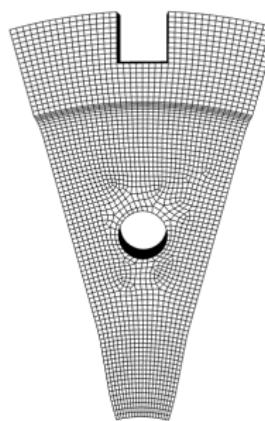
Update FEM to Parametrically Variable CAD Surface



FEM
Side View



Target CAD
Side View



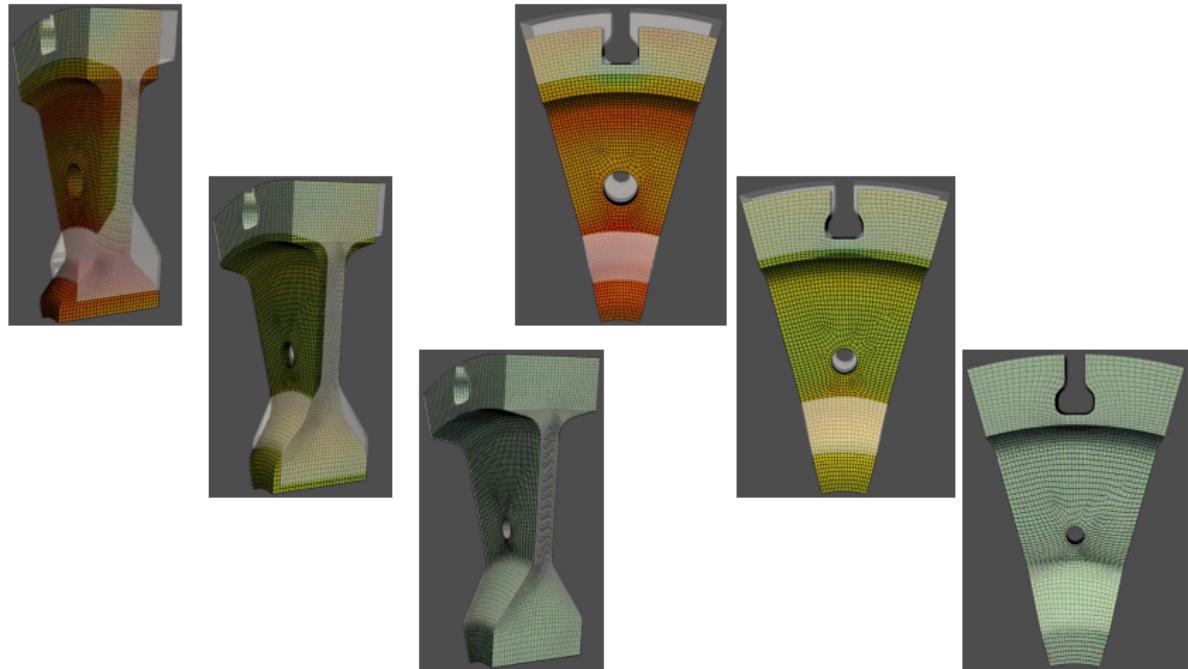
FEM
Front View



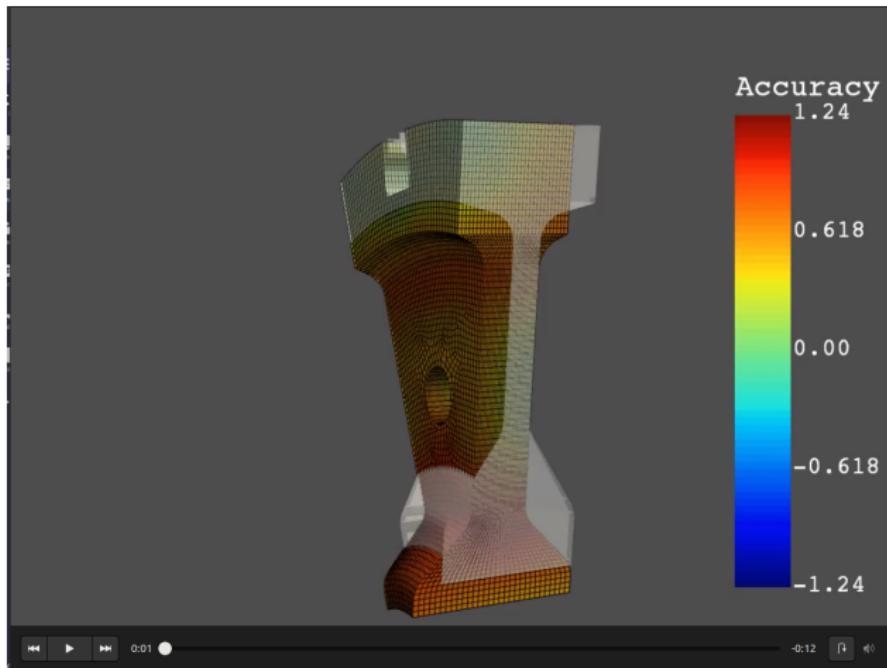
Target CAD
Front View

Design with AFRL Morph X

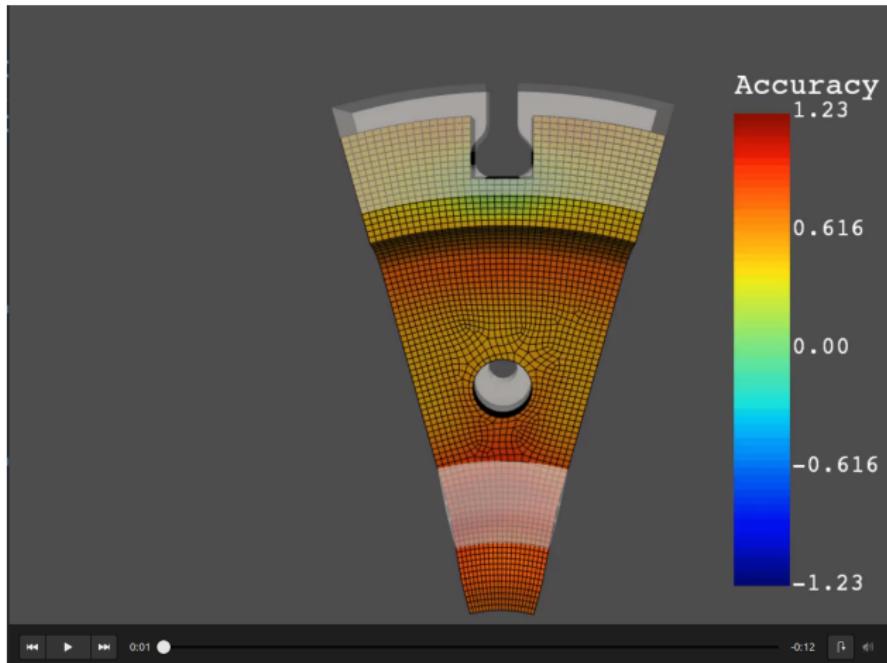
Update FEM to Parametrically Variable CAD Surface



Animation - Click image to Play

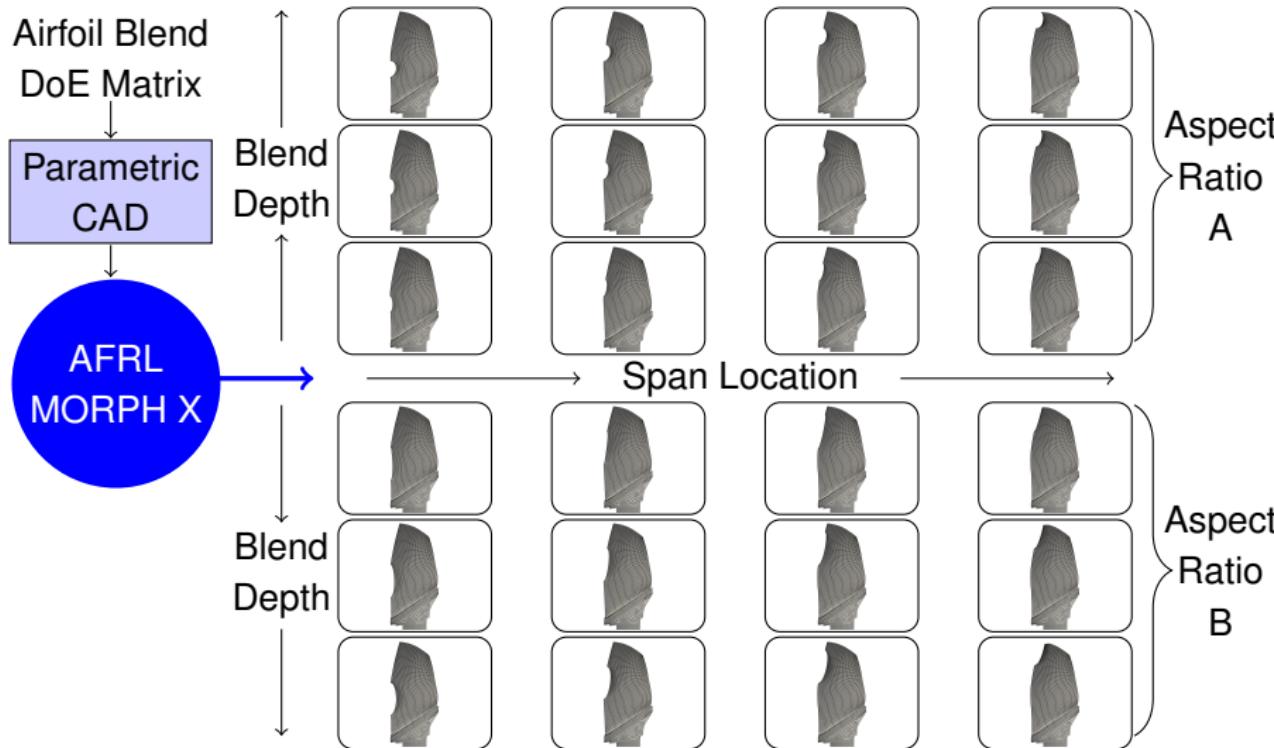


Animation - Click image to Play



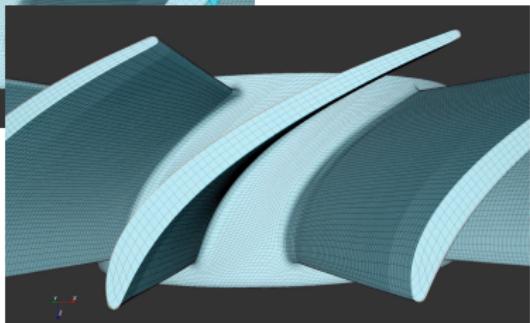
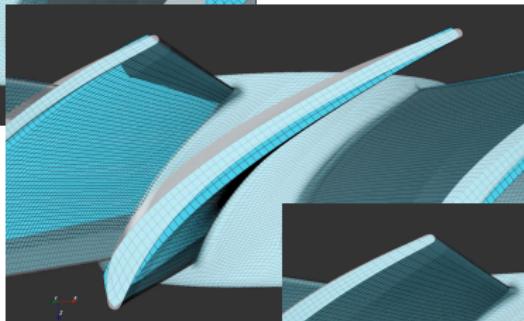
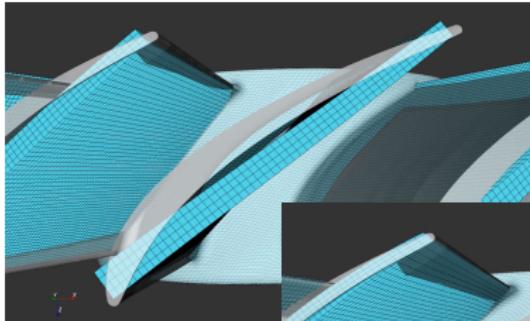
Design with AFRL Morph X

Sample Large Design Spaces Without Remeshing Challenges

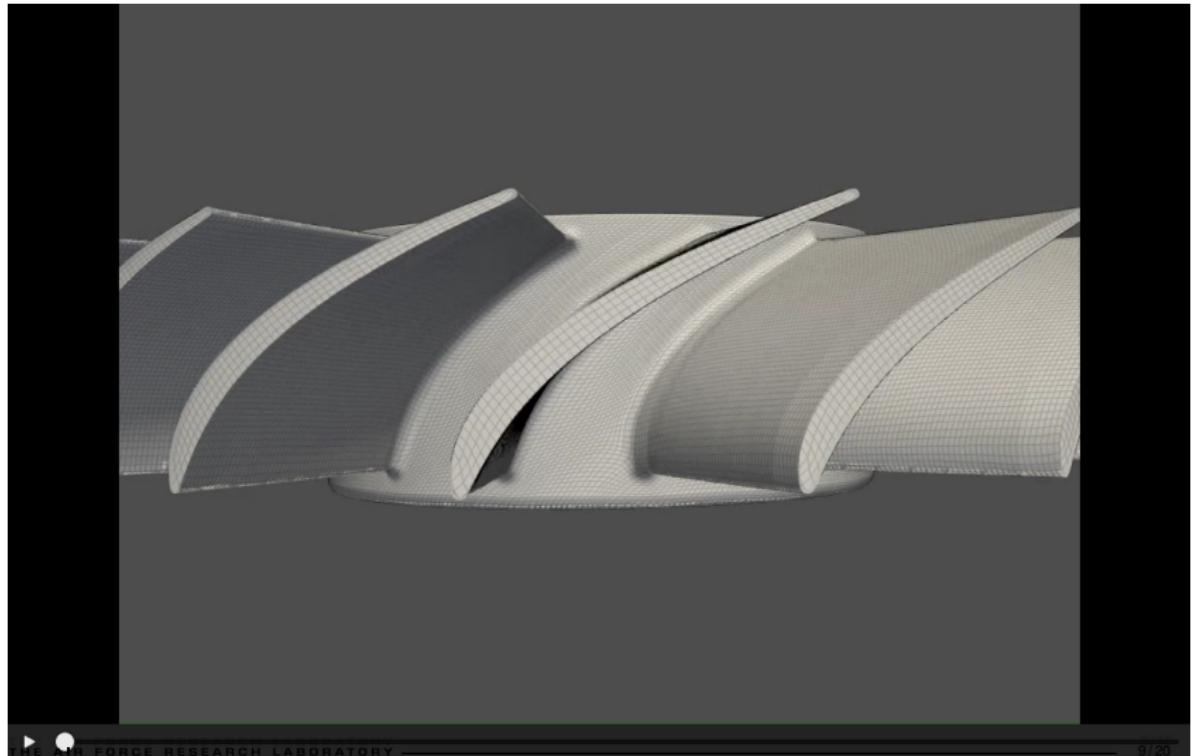


Design with AFRL Morph X

Simplify Hex Mesh Generation - Morph defeatured FEM to Complex Surface



Animation - Click image to Play

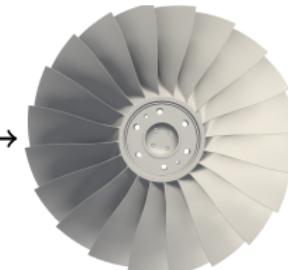


Manufacturing with AFRL Morph X

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

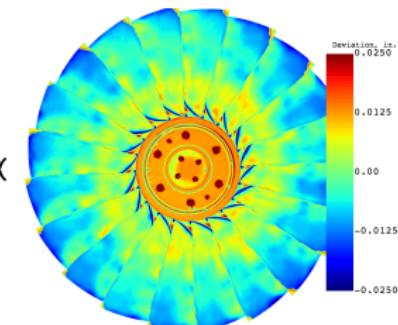


Geometry Measurement

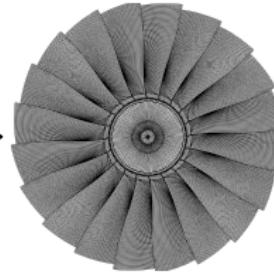


STL Surface

Manufacturing Deviations



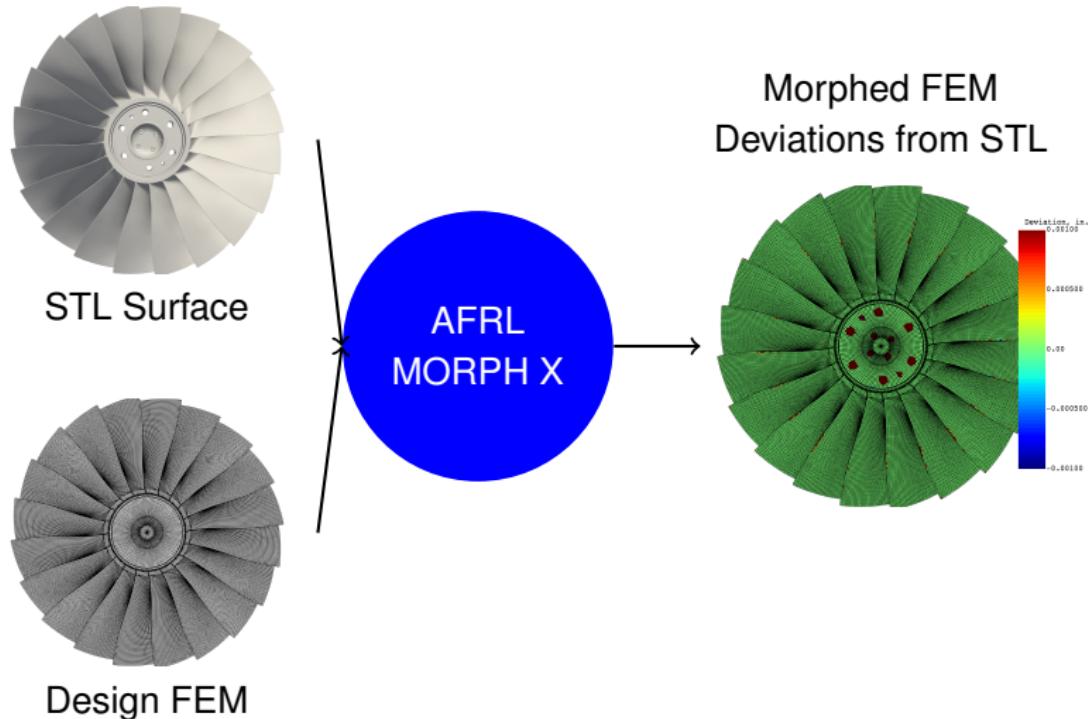
FEM Software



Design FEM

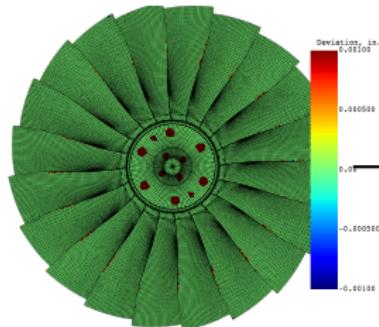
Manufacturing with AFRL Morph X

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



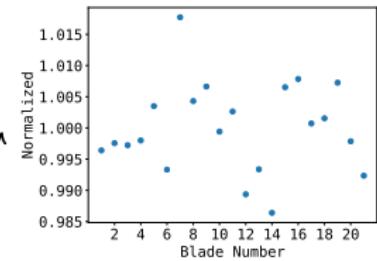
Manufacturing with AFRL Morph X

Morphed FEM is a Computational Replica of Physical Part

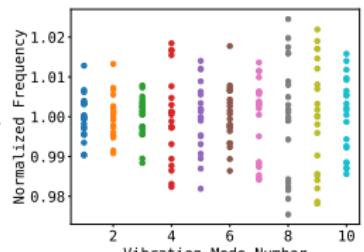


Ansys

FEM Software

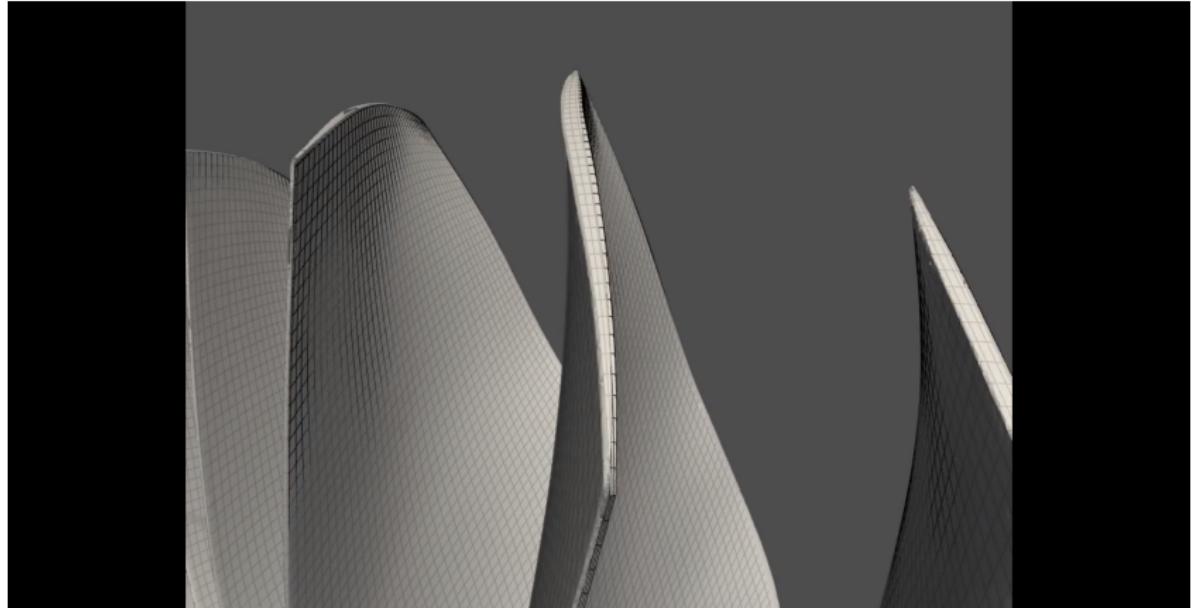


Blade to Blade
Variation



Rotor to Rotor
Variation

Animation - Click image to Play

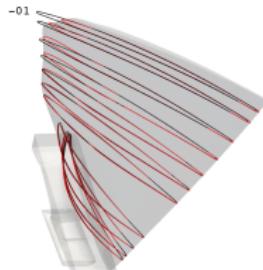


Operations with AFRL Morph X

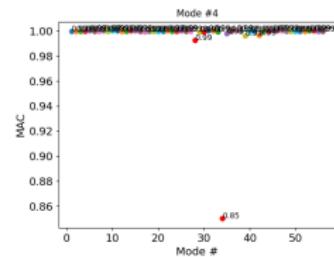
Integrating with Maintenance, Repair, and Operations with Morph X



Airfoil Leading Edge Blend Repair

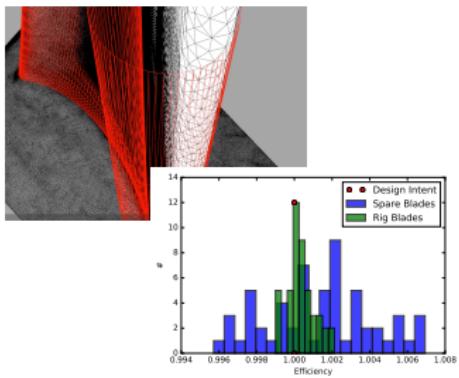


Assess Damage

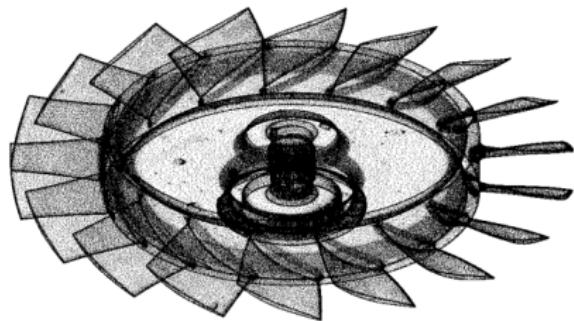


Safety Review Board

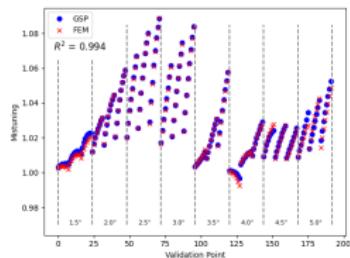
More with AFRL Morph X



Turbine CFD Mesh Morphing

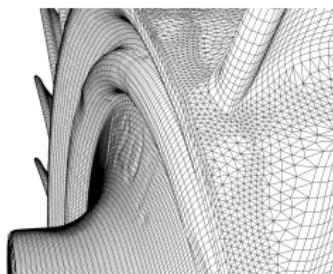


First Article Analysis



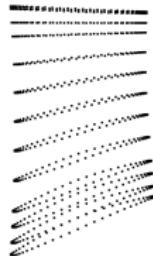
ML/AI Training Data Generator

THE AIR FORCE RESEARCH LABORATORY



Additive Part Models

Even more with AFRL Morph X



CMM Data Capable



Improved Instrumentation



Improved Model Validation

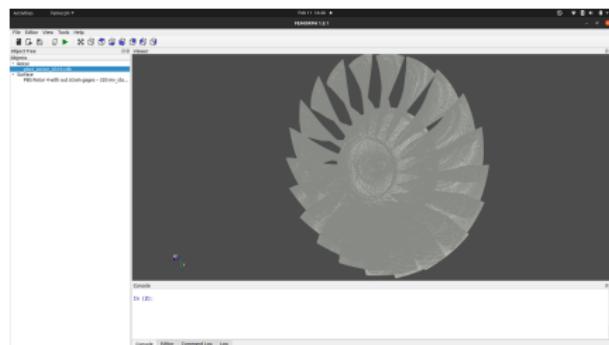


Adaptive Toolpath Generation

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

Closing Remarks

- AFRL MORPH X adds value across the life cycle, from design, to manufacture, and through operations
- Rigourous software development practices have enabled rapid development and successful deployment
- Used pervasively on AFRL Turbine Engine Division Research, product development, and field support
- Used extensively by P&W in many applications
- Windows demo software available and licensing opportunities



AFRL