AFRL

FEMORPH

Target Surface Computational Mesh Morphing

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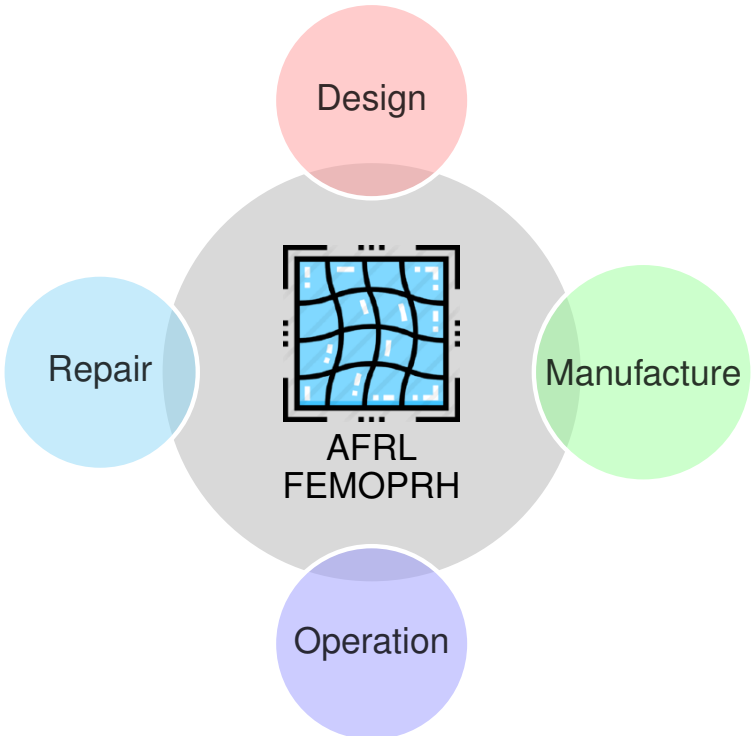
AFRL FEMORPH

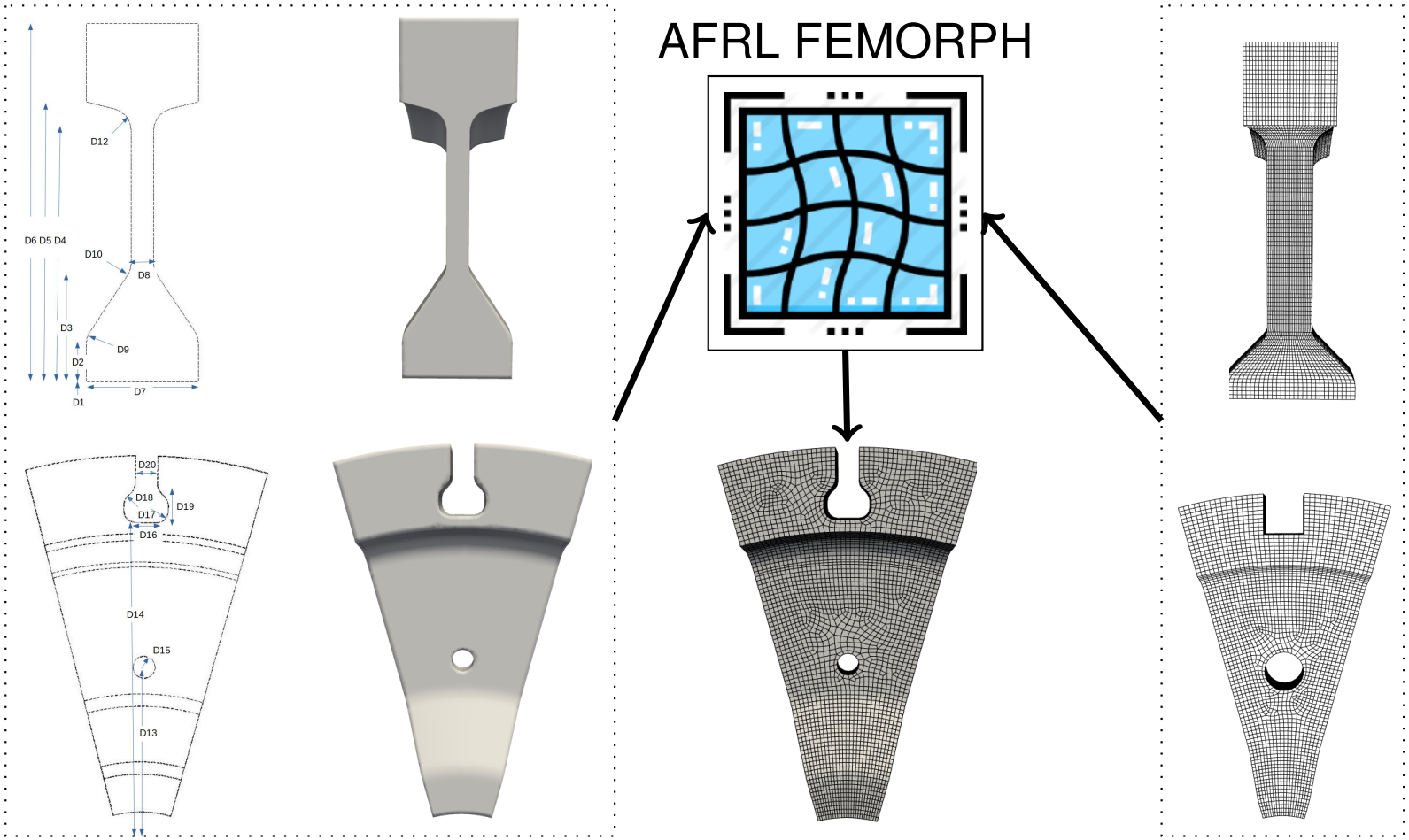
3D Mesh Morphing Software - FEM, CFD, .STL, CMM data, ...

- Simplify 2D and 3D shape opimizaion
- Robustly generate computer experiment designs
- Save design time by removing mesh generation bottlenecks
- Assess impacts of as-manufactured geometry on design intent
- Learn the effects of operational damage on continued use
- Design and validate the suitability of component repair
- And more...



Design with AFRL FEMORPH

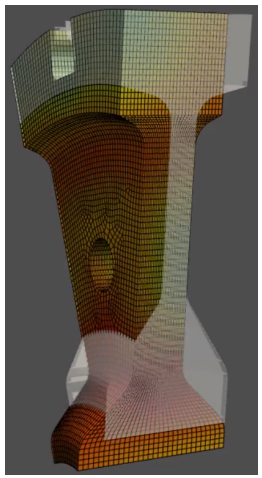
Morph FEM to Parameterized CAD Model



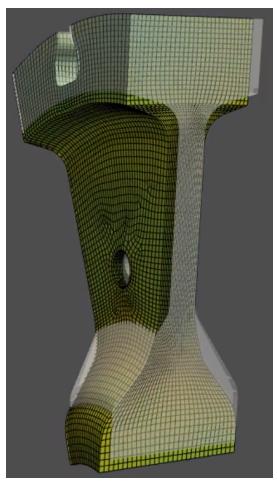
Parameterized CAD | Morphed FEM | Initial FEM

Design with AFRL FEMORPH

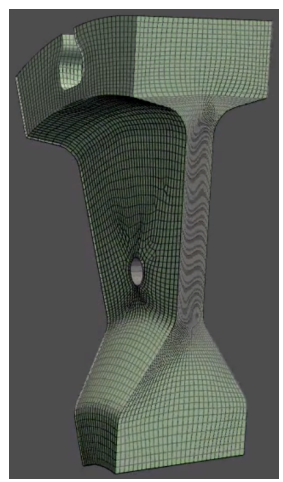
Morphing FEM to CAD



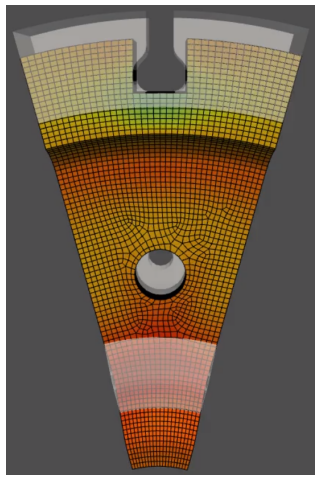
0% Morph

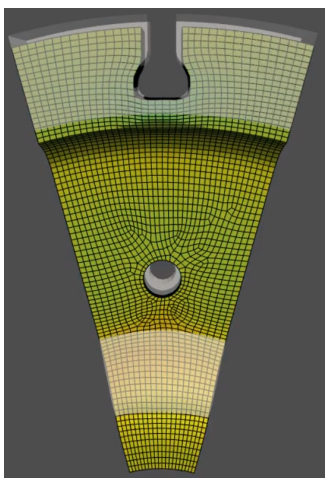


50% Morph

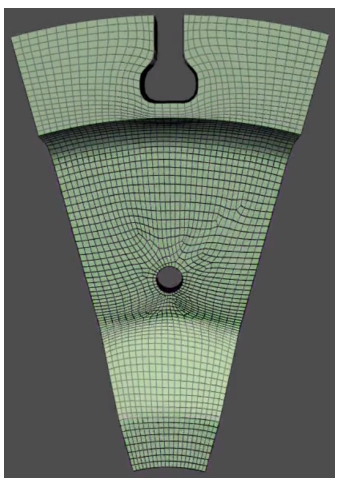


100% Morph



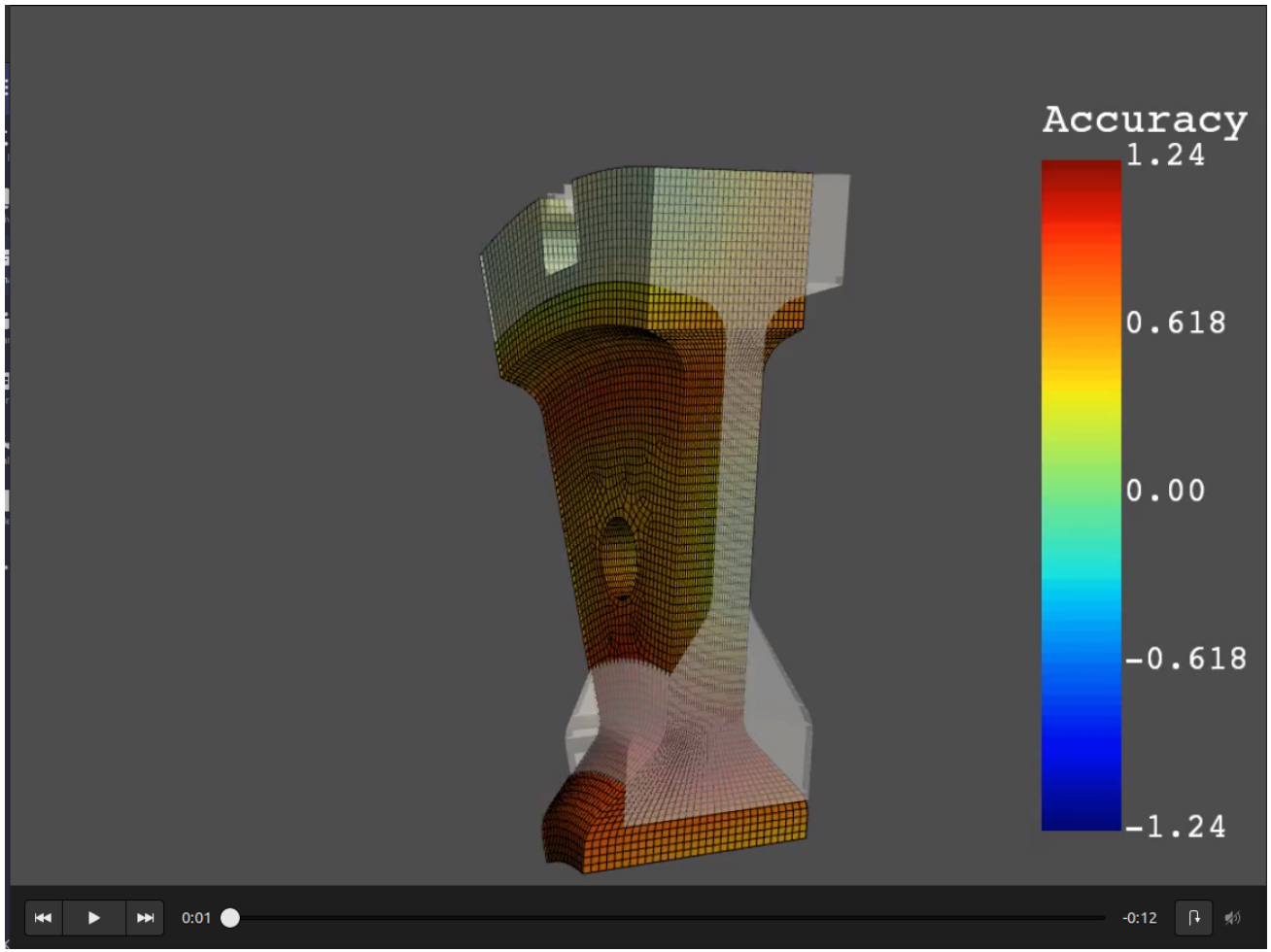


50% Morph

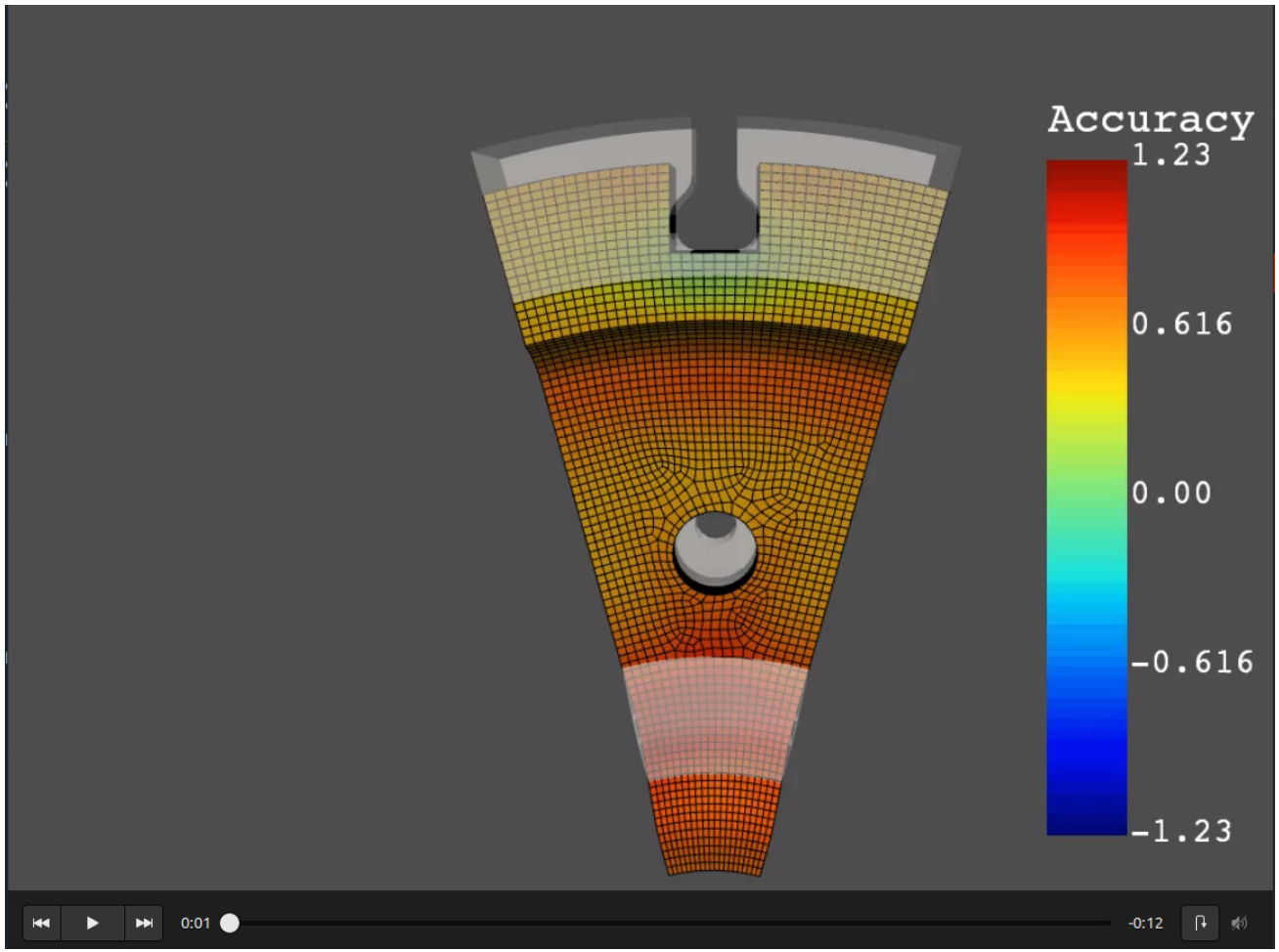


100% Morph

Animation - Click image to Play (disk_side.mp4)

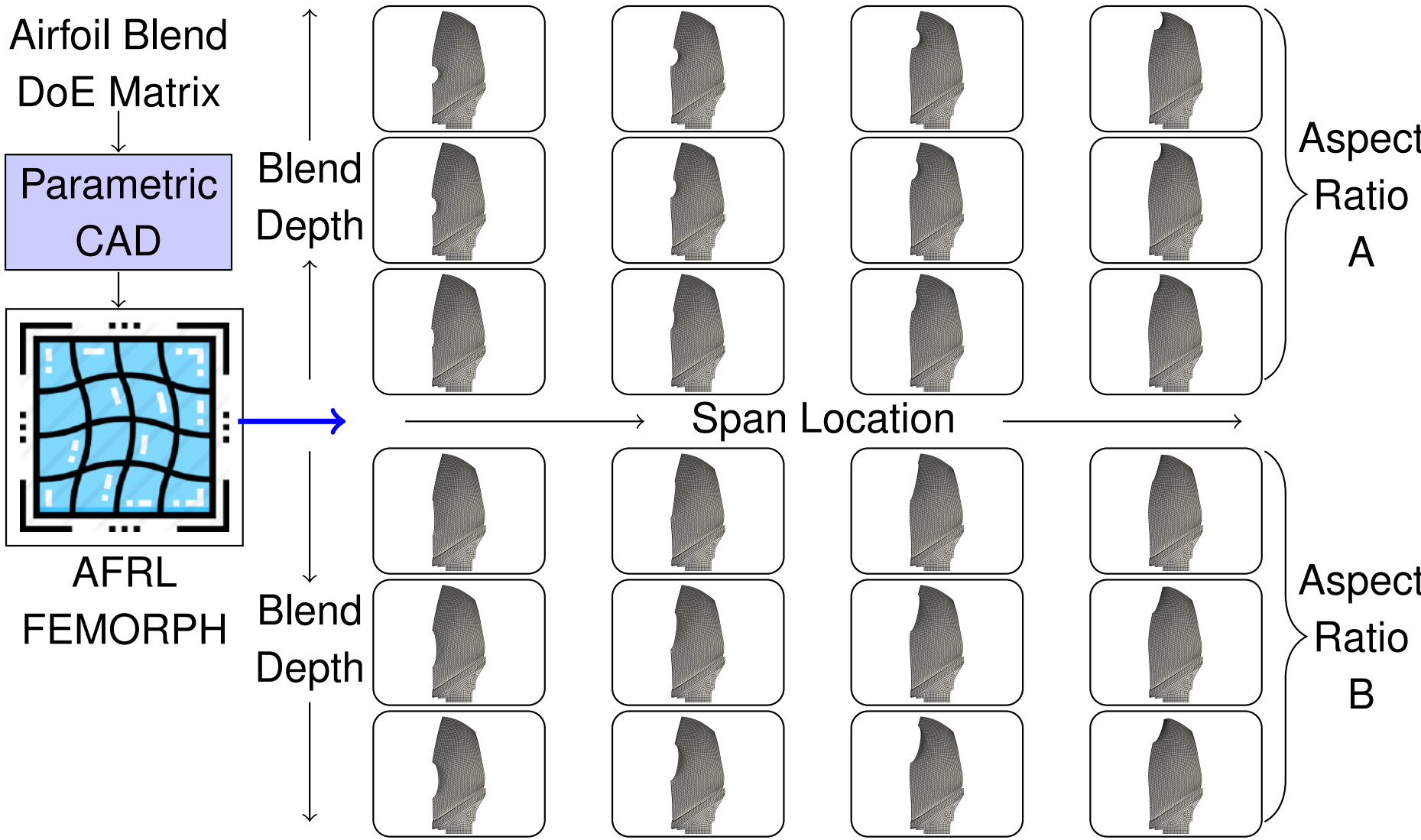


Animation - Click image to Play (disk_front.mp4)



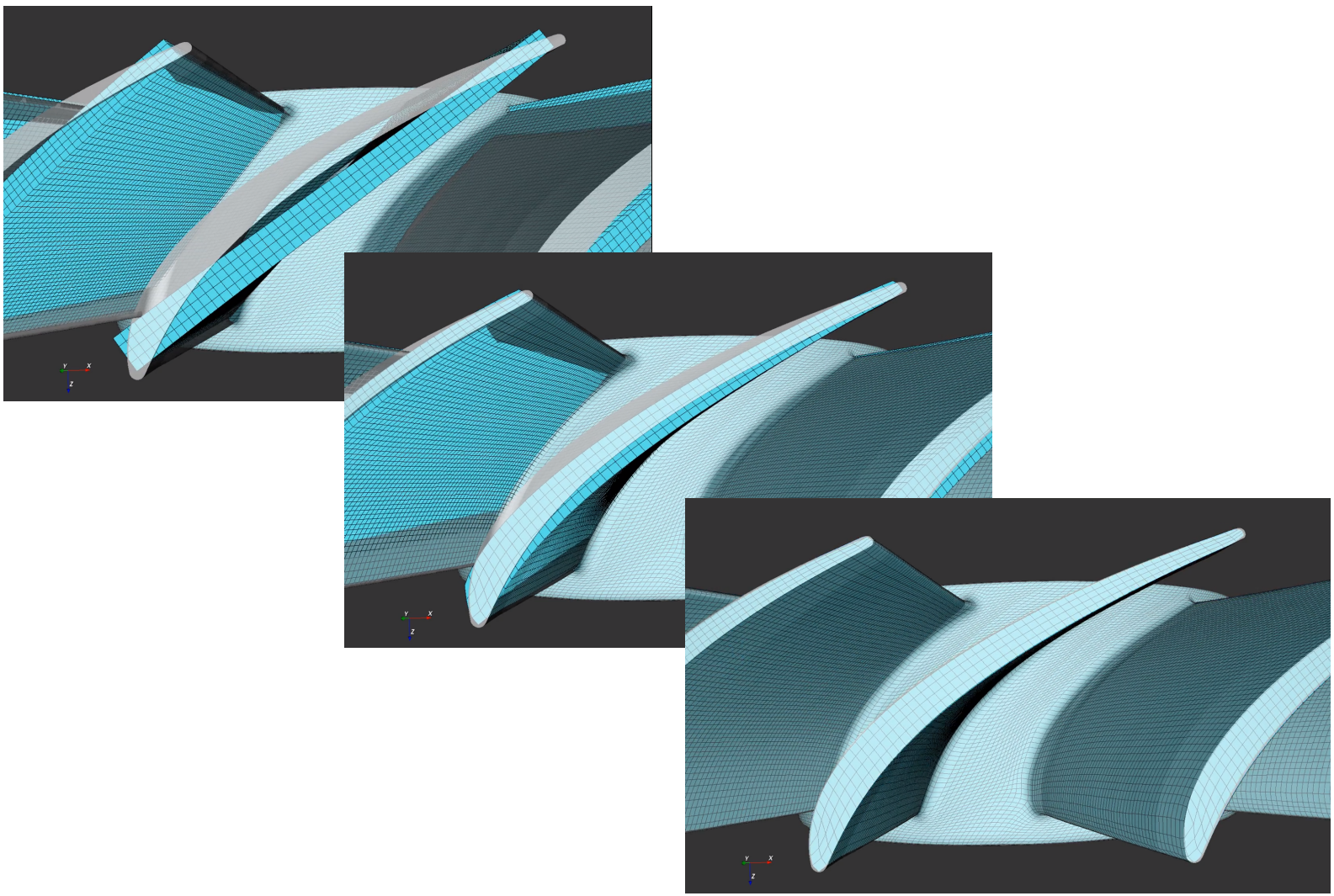
Design with AFRL FEMORPH

Sample Large Design Spaces Without Remeshing Challenges

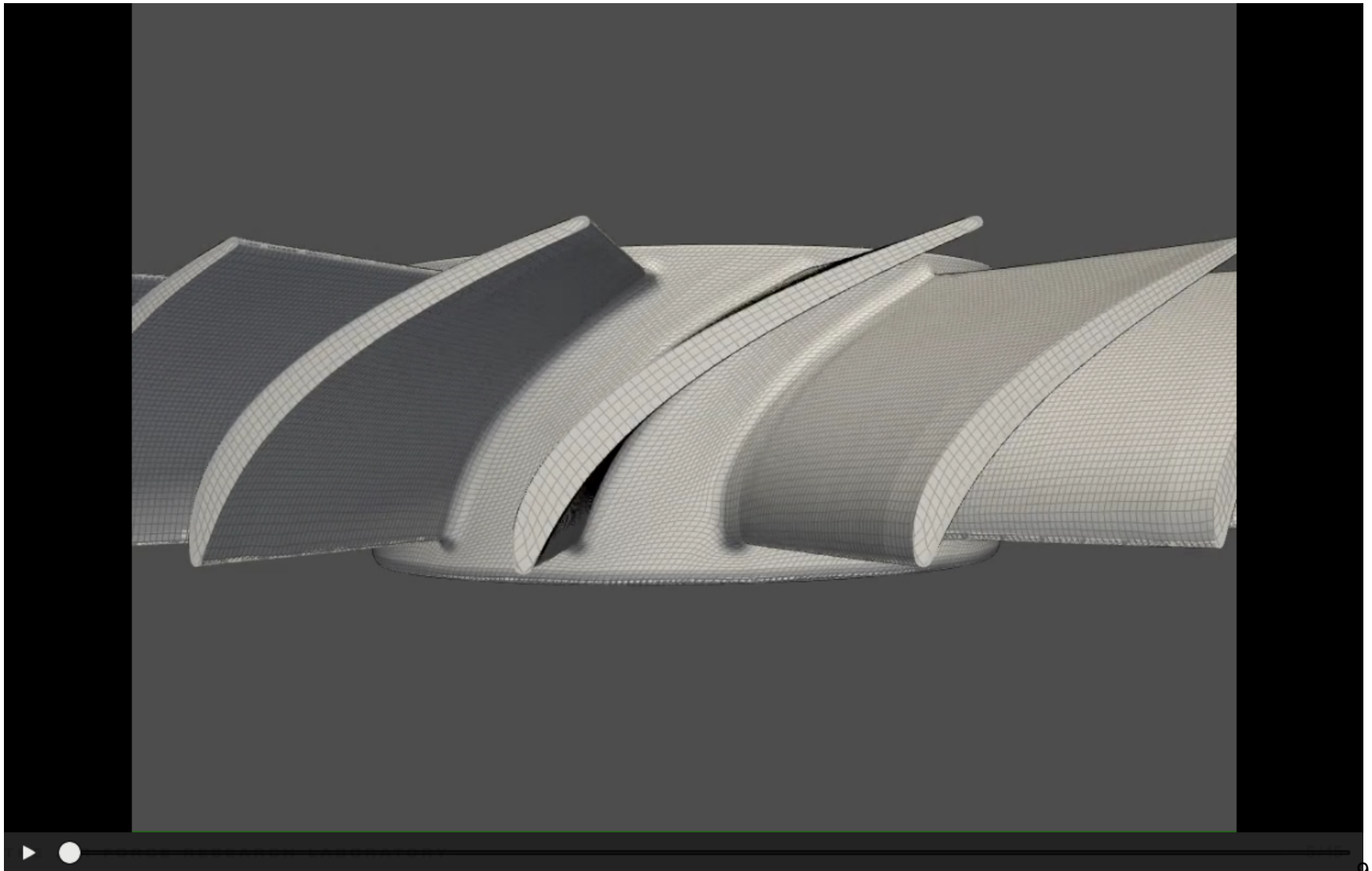


Design with AFRL FEMORPH

Simplify Hex Mesh Generation - Morph defeatured FEM to Complex Surface

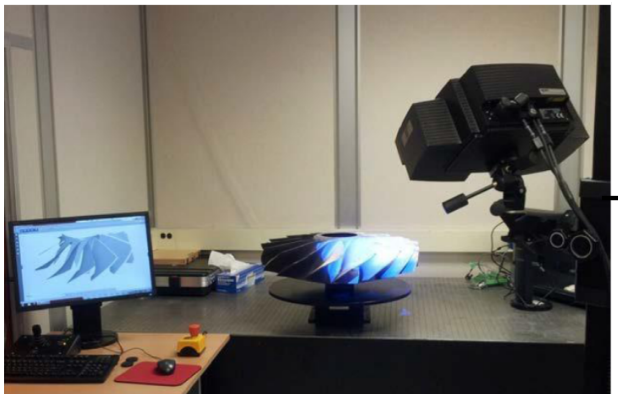


Animation - Click image to Play (blade_plate.mp4)

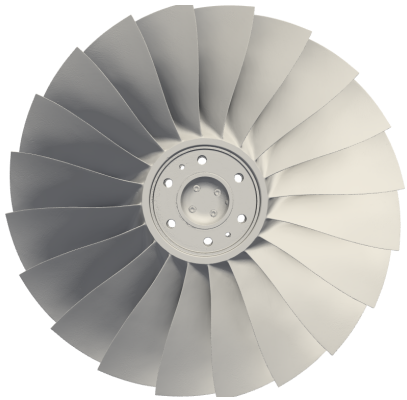


Manufacturing with AFRL FEMORPH

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

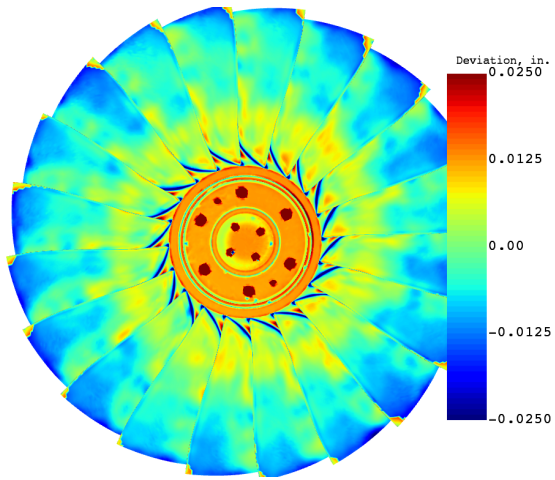


Geometry Measurement



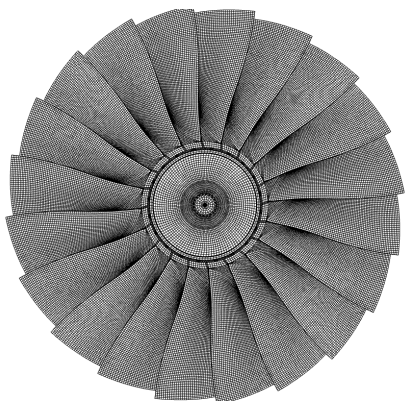
STL Surface

Manufacturing Deviations



Ansys

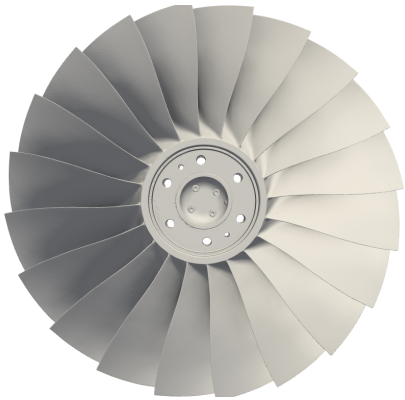
FEM Software



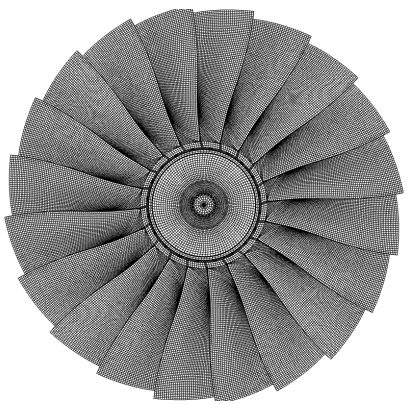
Design FEM

Manufacturing with AFRL FEMORPH

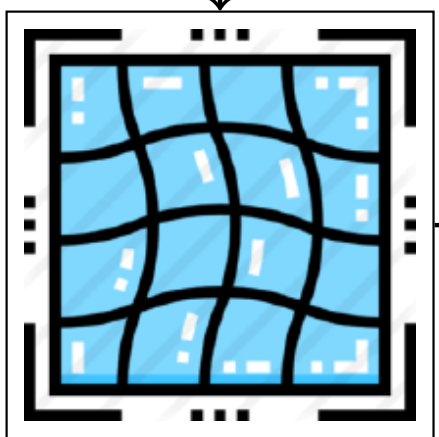
AFRL FEMORPH updates the Design FEM to match the STL surface within 0.001”



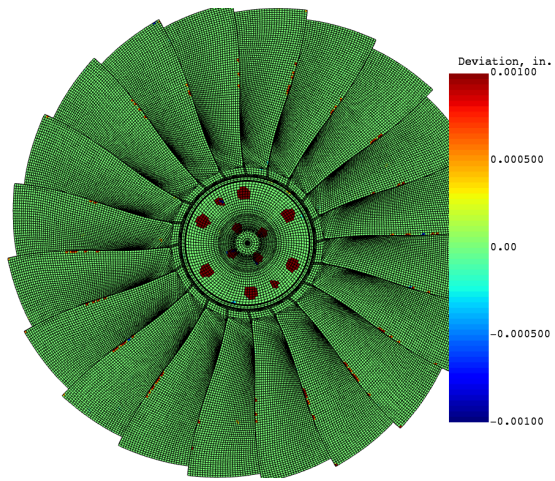
STL Surface



Design FEM

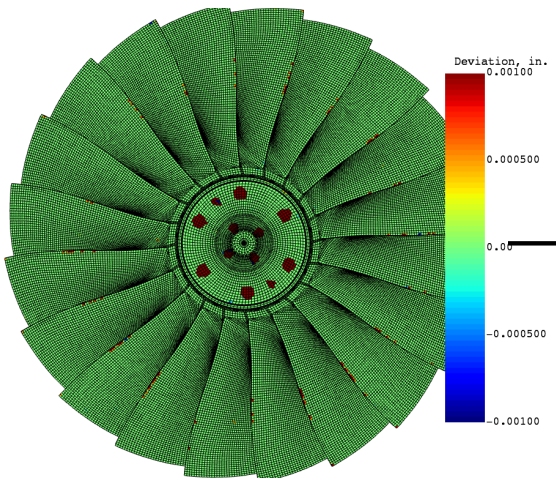


Morphed FEM
Deviations from STL



Manufacturing with AFRL FEMORPH

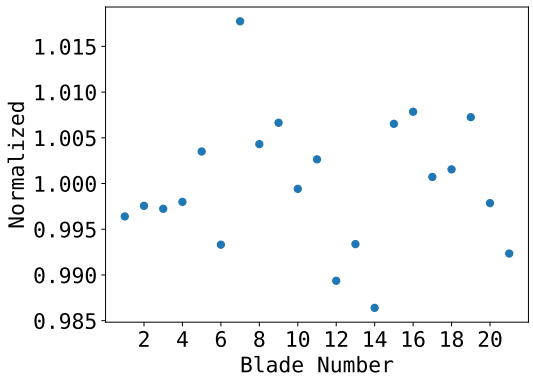
Morphed FEM is a Computational Replica of Physical Part



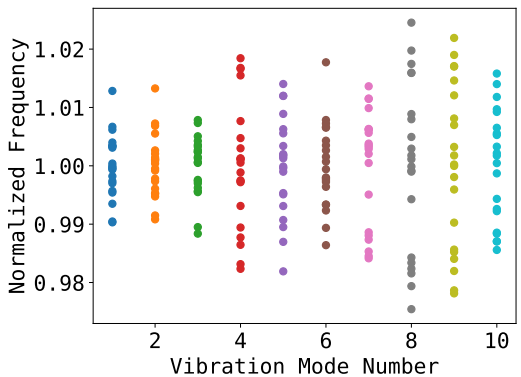
Morphed FEM
Computational Replica

Ansys

FEM Software

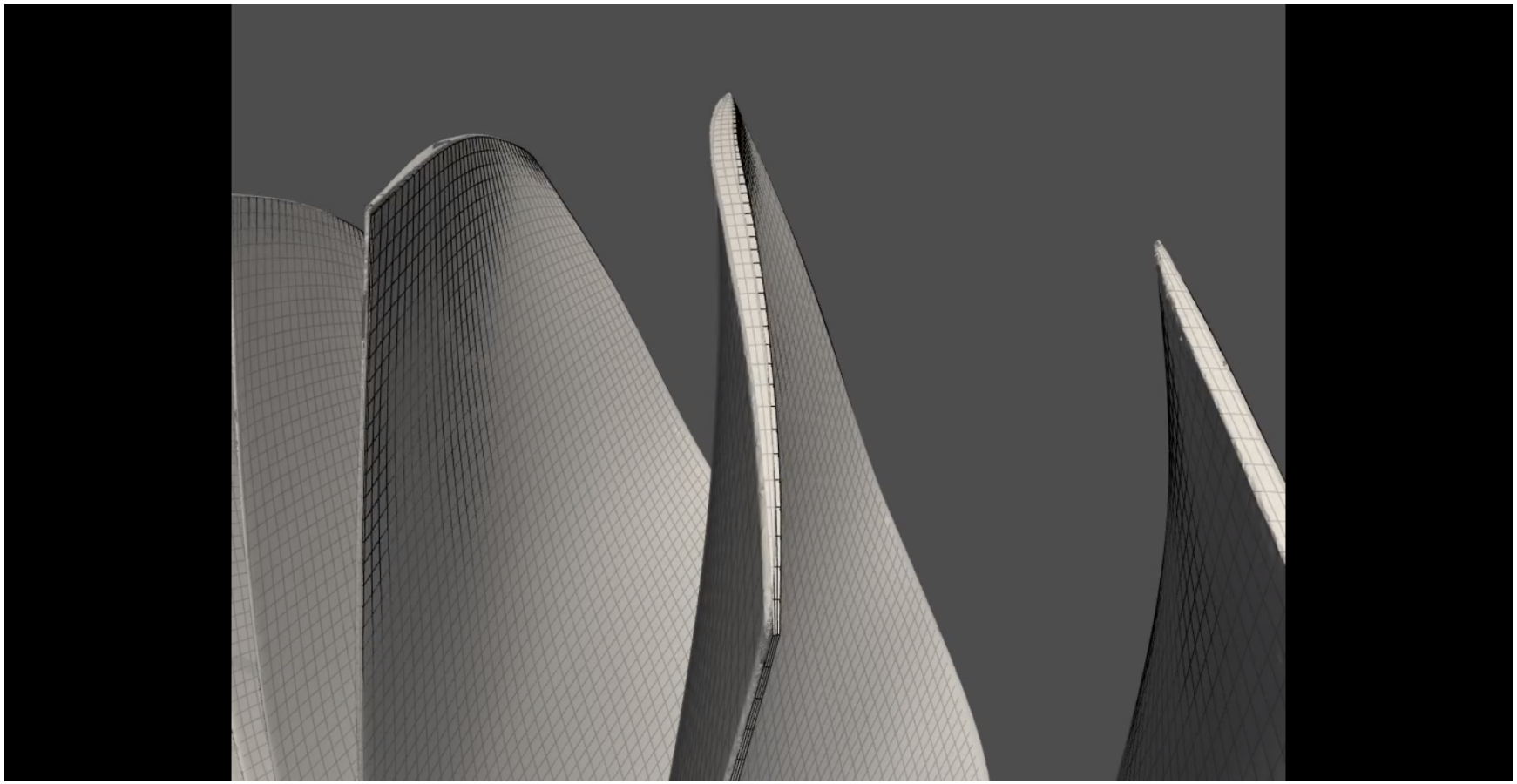


Blade to Blade
Variation



Rotor to Rotor
Variation

Animation - Click image to Play (blade_morphvid.mp4)

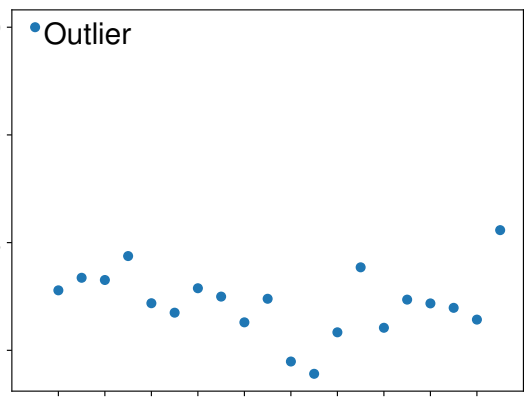


Operations with AFRL FEMORPH

Integrating with Maintenance, Repair, and Operations with FEMORPH

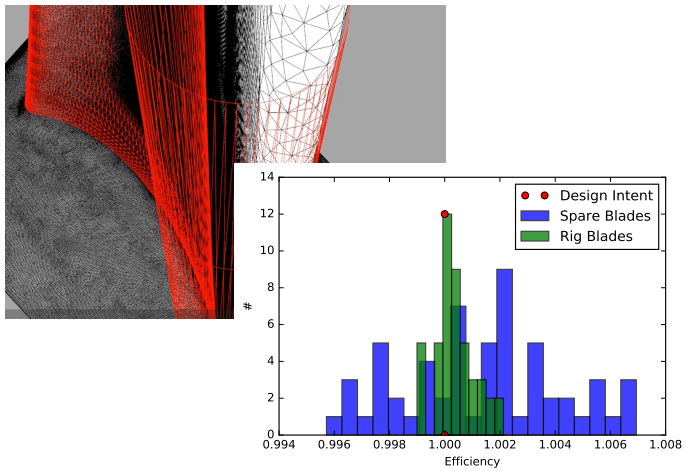
Airfoil Leading Edge Blend Repair

Assess Damage

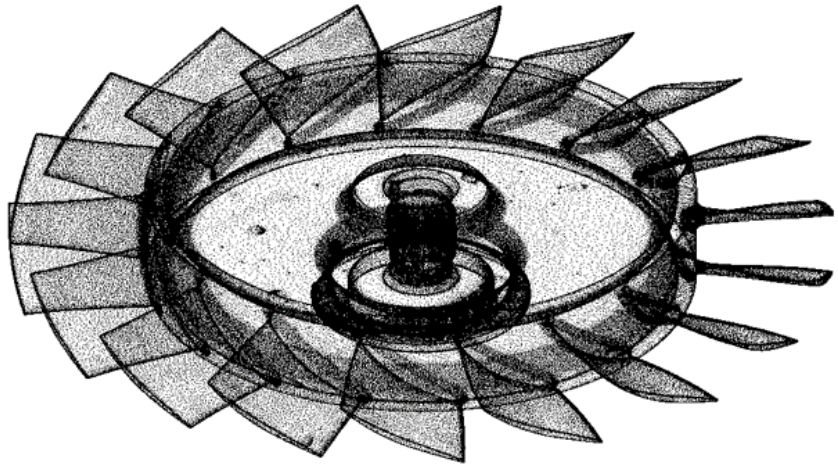


Safety Review Board

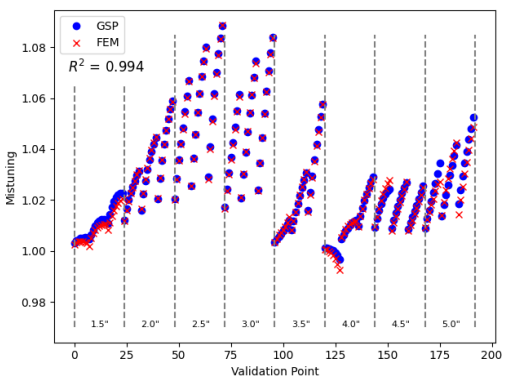
More with AFRL FEMORPH



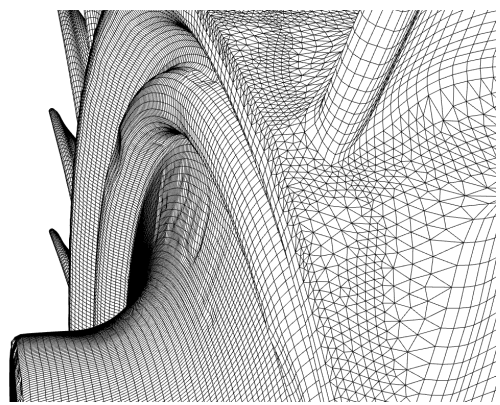
Turbine CFD Mesh Morphing



First Article Analysis

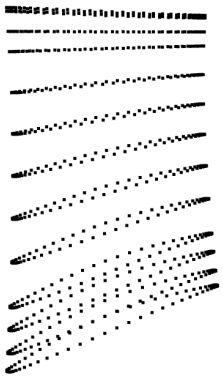


ML/AI Training Data Generator



Additive Part Models

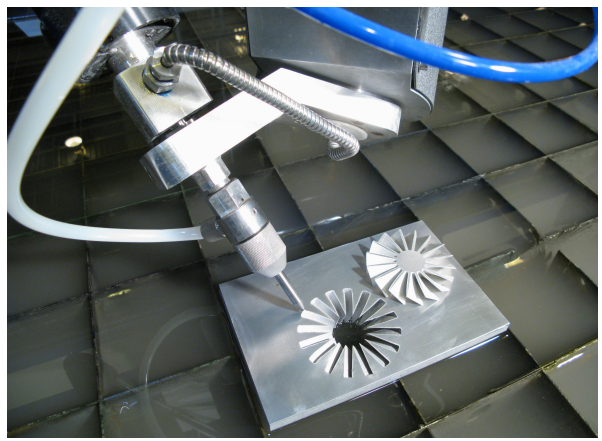
Even more with AFRL FEMORPH



CMM Data Capable

Improved Gage Limits

Improved Model Validation

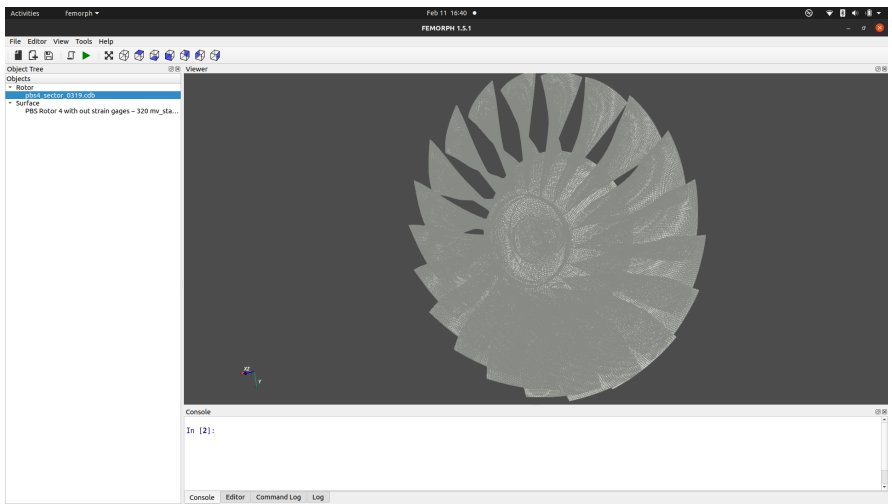


Adaptive Toolpath Generation

AFRL FEMORPH Interface

Python API for 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 FEMORPH Background

- Developed in Python, C, and C++ for 8+ years
- Compatible with Linux, Windows, and Mac OS
- Beta tested by Pratt & Whitney for two years
- In fourth year 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 and customer support activities

AFRL FEMORPH Background

Software Testing

- AFRL FEMORPH follows standard software development practices.
- Unit and regression tests ensure new features are added without breaking existing ones.
- Code coverage of $\geq$ 95% required for all modules, and $\geq$ 98% for core modules

```
tests/test_surface.py::test_surface_blend SKIPPED (Requires femorph_blender)    [ 91%]
tests/test_surface.py::test_boolean PASSED                                       [ 92%]
tests/test_surface.py::test_load_g3d PASSED                                      [ 92%]
tests/test_tree.py::test1d PASSED                                                [ 93%]
tests/test_tree.py::test3d PASSED                                                [ 93%]
tests/test_tree.py::test3d_float32 PASSED                                        [ 94%]
tests/test_tree.py::test3d_float32_mismatch PASSED                               [ 94%]
tests/test_tree.py::test3d_float32_mismatch2 PASSED                              [ 95%]
tests/test_tree.py::test3d_8n PASSED                                             [ 95%]
tests/test_tree.py::test3d_8n_ub PASSED                                          [ 96%]
tests/test_tree.py::test3d_8n_ub_leaf20 PASSED                                   [ 96%]
tests/test_tree.py::test3d_8n_ub_eps PASSED                                      [ 97%]
tests/test_tree.py::test3d_large_query PASSED                                    [ 97%]
tests/test_tree.py::test_scipy_comp PASSED                                       [ 98%]
tests/test_tree.py::test1d_mask PASSED                                           [ 98%]
tests/test_tree.py::test1d_all_masked PASSED                                     [ 99%]
tests/test_tree.py::test3d_mask PASSED                                           [ 99%]
tests/test_tree.py::test6d PASSED                                                [100%]

====================== 210 passed, 2 skipped in 88.92s (0:01:28) ======================
```

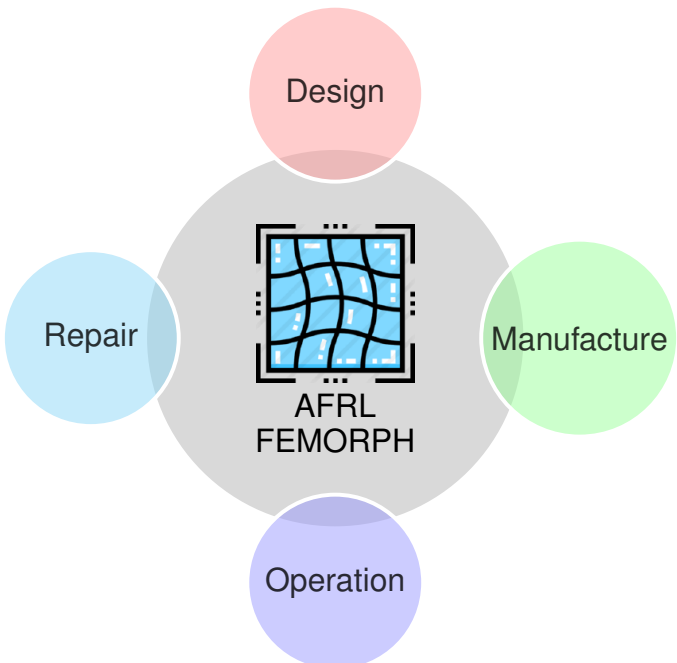
AFRL FEMORPH Background

Software Design: Modularity

- Software is a non-monolithic, modular, and composed of several packages. Includes both GUI and batch packages.
- Designed to be expandable, adaptive, and compatible with modern Python 3.6 - 3.8 environments on Windows, Mac, and Linux.
- Compatible with standalone virtual environments, Jupyterlab webpages, or standard Python.

Closing Remarks

- AFRL FEMORPH 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

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