

# Air Force Sustainment Center

---

## Innovation at the Speed of Production: How Reverse Engineering and Additive Manufacturing is Changing the Face of Sustainment



**Lt Col Chris Blackwell**  
**Director, AFSC Innovation Centers**  
**AFSC/EN**



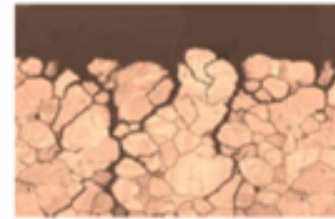
# Aging A/C Provide Engineering Challenges



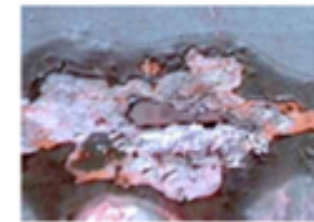
Structural Fatigue



Power Cycles



Stress  
Corrosion  
Cracking



Corrosion  
Exfoliation



Ti Disk Failure



Chafing



UV and  
Chemical Exposure



Thermal  
Exposure

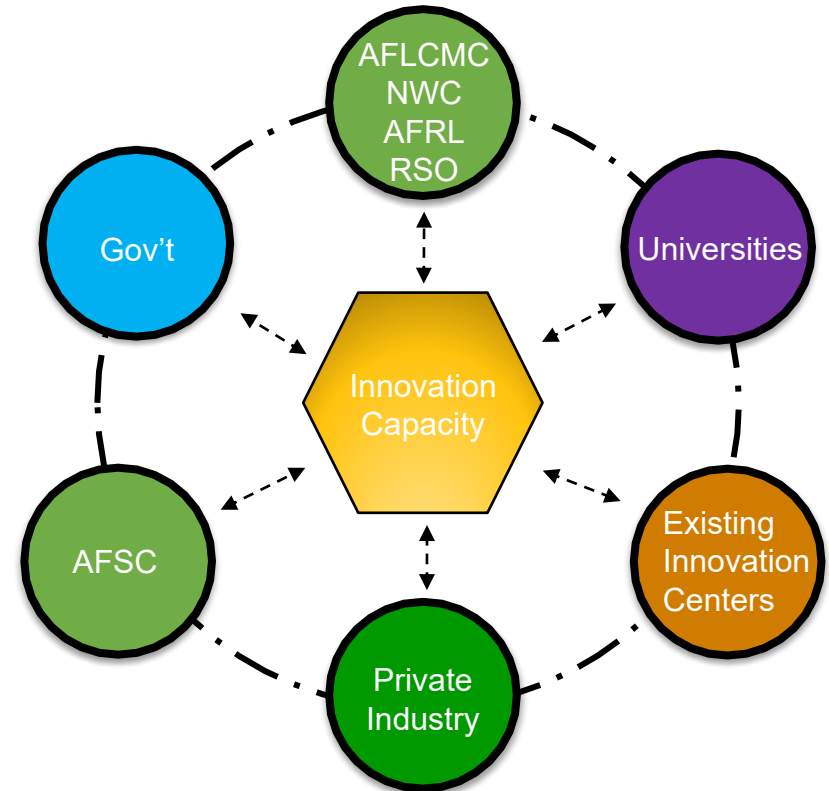
**Challenging problems require innovative thinking!**

*Delivering combat power for America!*



# Innovation Ecosystem

- Fosters collaborative environment to:
  - Leverage other's contributions & capabilities
  - Optimize available resources
  - Answer workforce needs
  - Build relationships





# Why AFSC Innovation Centers



Approximately 13,000 AFMC Scientists, Engineers and Technicians  
Nearly 50% (6,332) reside at AFSC locations

**Problem:**

Aging W/S  
No Tech Data  
Redesign: 4.6 yrs  
New Repair: 3.2 yrs  
Test/Qual: 2.1 yrs  
Part availability  
Time critical need  
Low quantity buys

**Solvers:**

REACT  
REARM  
RECLAIM

Collaboration with:  
RSO  
AFLCMC  
AFRL  
Academia  
Industry

**Solutions:**



**Impact (FY18):**

Solved constraints for:  
16 Weapon systems  
Supply Chain  
DLA

Saved:  
\$900K  
58K+ man hours  
1500+ items 3D mfg

Laser De-paint: 15 F-16s

**Those closest to the problem are closest to the solution**



# AFSC Innovation Vision

**Centers where govt, industry, & academia collaborate to innovatively solve problems**

- Provide advanced, state-of-the-art, agile, manufacturing technology
- Enable partnerships to generate rapid, innovative solutions
- Develop organic agile manufacturing capabilities
- Train organic workforce to think innovatively

## Solutions That Span Spectrum of Innovation

Innovating with  
Mature Technology

Pushing boundaries  
of S&T

**Now Term**

**Spectrum of Innovation**

**Long Term**

- Polymer Printers
- Metal Printers (Tooling)
- Laser De-paint
- Laser Scanners

- Sand Casting Printers
- Metal Printers for A/C worthy Parts

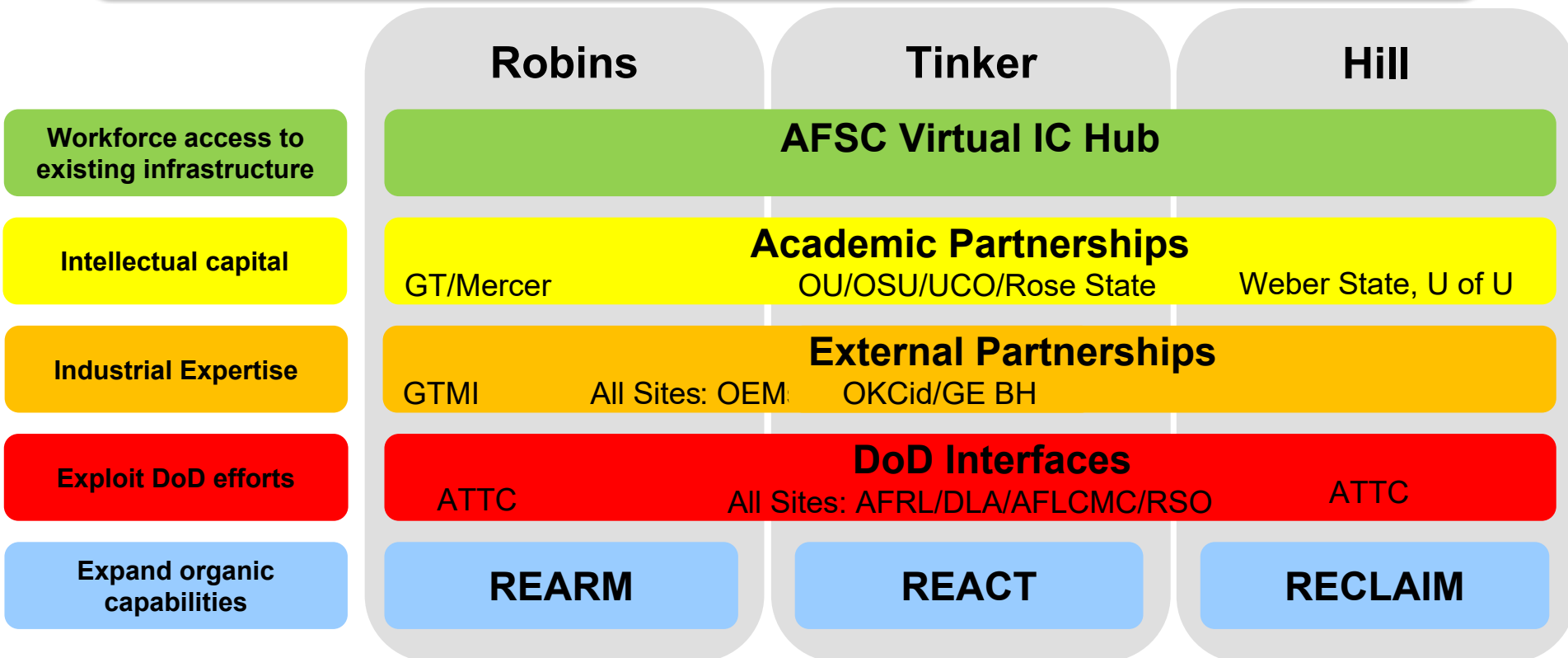
- Exotic materials and Processes
- Whole A/C single pass inspection

*Delivering combat power for America!*



# AFSC Innovation Ecosystem

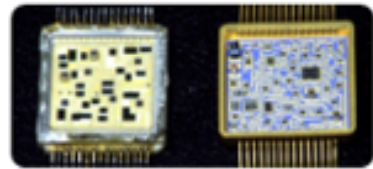
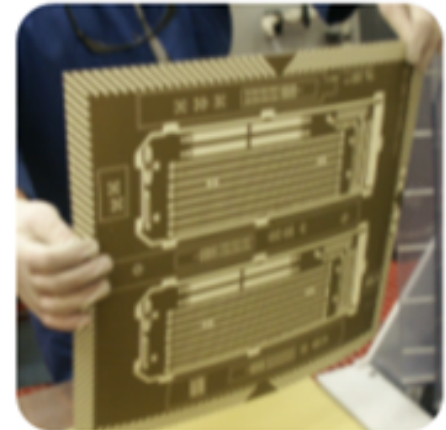
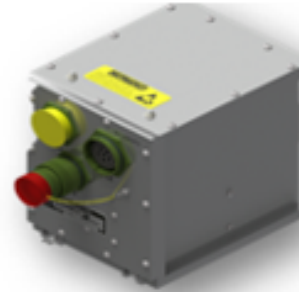
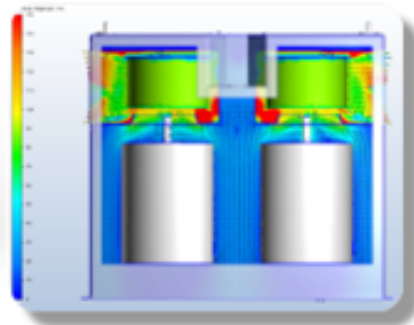
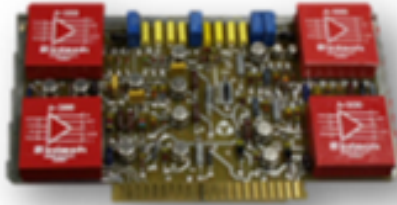
5 elements executed across the ALCs maximize overall value and take advantage of unique opportunities





# AFSC Organic Innovation Center

Reverse Engineering, Avionics Redesign, and Manufacturing



WARNER ROBINS AIR LOGISTICS COMPLEX

## REARM

### Reverse Engineering

- Technical Data Development
- Test and Requirements Generation
- CAD Generation

### Hybrid Manufacturing

- Integrated Circuits
- Hybrid Microelectronics
- RF Components
- PWB, CCA

### Avionics Redesign

- Form/Fit/Function Redesign
- New System Development
- LRU, SRU

Enable continued operation of aging aircraft systems  
Filling the gap between industry capability and USAF requirements



# REARM Capabilities

- Printed Circuit Board (PCB) Computer Aided Design
- Electronics Repair Capability Development
- Technical Data Package Creation
- Software/Firmware Extraction
- Form-Fit-Function Avionics Redesign
- Electronics Development
- In-house Avionics Prototype Production
- Technical Order Generation
- Hybrid Microcircuit Manufacturing (MIL-PRF-38534)
- MIL-STD-883 Tests and Inspections
- Counterfeit Part Screening
- First Article Tests
- Manufacturing of Avionics Systems
- Manufacturing Multilayer PWBs (up to 22 layers)
- Manufacturing Flex Circuits (up to 6 layers)
- Manufacturing Single/Double Sided PWBs
- Manufacturing of Cables



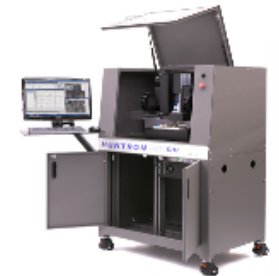
Multi-layer 3D PCB Printing



Laser PCB Prototyping



Power/Glitching Analysis



PCB Fault Verification



3D Polymer Printing

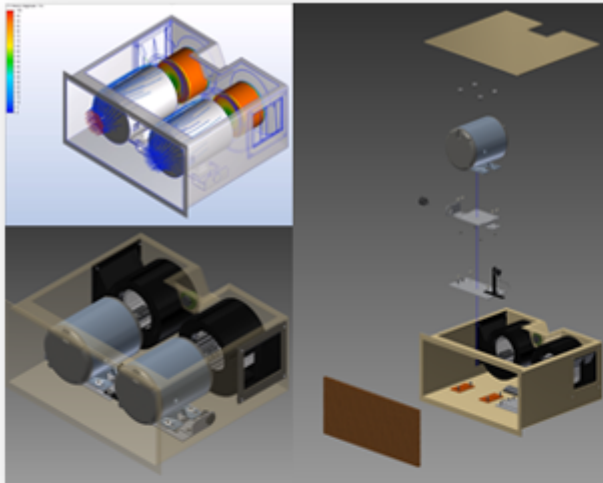


Handheld 3D Measurement

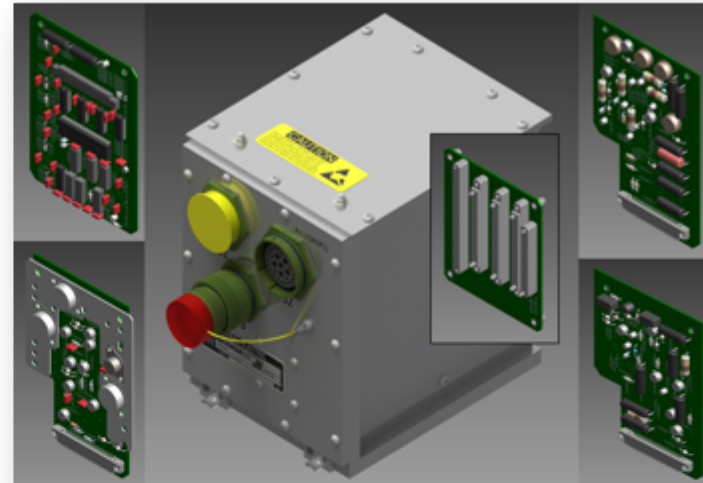




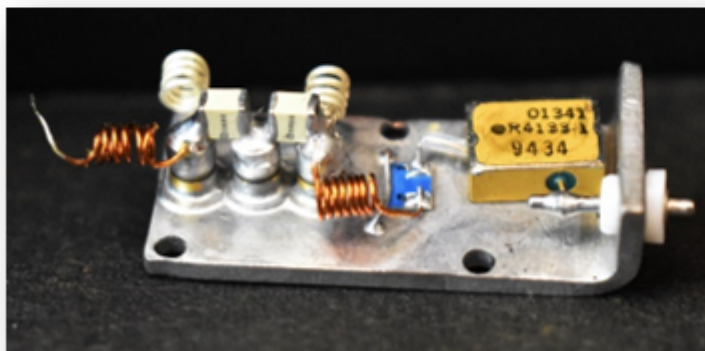
# REARM Successes



**F-15 AIS 750 CFM Blower Assembly**



**A-10 Gun Control Unit Redesign**



**F-15 ALR-56 Filter Board Assembly**



**A-10 LFWD JSECST RWR Coupler**

*Delivering combat power for America!*



# ***REARM Impact***

(a/o 26 Sept 19)

---

## **FY19:**

- **\$5.7M+ in cost benefits (avoidance/savings) to customers**
- **19+ DoD projects, 27K+ labor hours, \$3.6M+ in revenue**
- **Supported 10+ DoD customers**
  - **15+ different Weapon Systems**

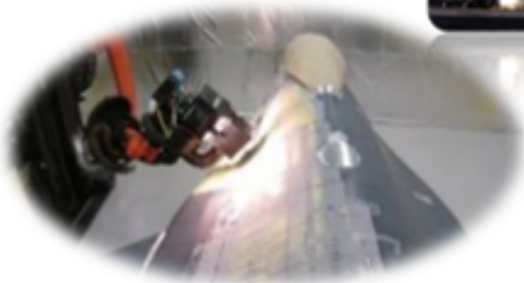
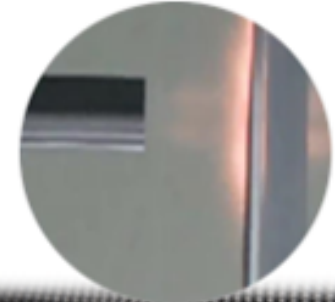
## **Since October 2016 (Innovation Center inception)**

- **\$80M+ in cost benefits (avoidance/savings) to customers**
- **50+ DoD projects, 80K+ labor hours, \$13M+ in revenue**
- **Supported 10+ DoD customers**
  - **20+ different Weapon Systems**



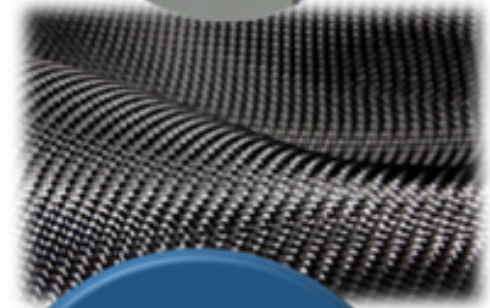
# AFSC Organic Innovation Center

Rapid Engineering of Composites, Low Observables, And Innovative Materials



OGDEN AIR LOGISTICS COMPLEX

# RECLAIM



## Rapid Engineering

- Technical Data Development
- Test and Requirements Generation
- Model-Based Maintenance

## Advanced Manufacturing

- Robotics
- Laser Applications
- Depot Transformative Technologies

## Innovative Materials

- Advanced Composites
- Low Observable Coatings
- Additive Materials and Processes

Enable continued operation of aging aircraft systems  
Filling the gap between industry capability and USAF requirements



# RECLAIM Capabilities

## LARGE INDUSTRIAL 3D PRINTERS



**3D SYSTEMS PRO X 950**

### 3D Systems Pro X 950

- Stereolithography (SLA)
- 59 x 29.5 x 21.65 inch build volume
- Accura Xtreme White 200 material
- 0.004 inch layer height
- Accuracy 0.001-0.002 in./in.
- Very Fine Detail – 0.0005 in. resolution

Printable CAD file types:  
Solidworks, STL, Parasolid, IGES, STEP



**STRATASYS FORTUS 900MC**

### Stratasy Fortus 900mc

- Fused Deposition Modeling (FDM)
- 36 x 24 x 36 inch build volume
- Multiple thermoplastic materials
  - ASA, ABS, ABS-ESD7, PC, ULTEM 9085, ULTEM 1010, Nylon 12 Carbon Fiber
  - Additional materials available
- 0.005 – 0.020 inch layer height range
- Accuracy +/- 0.0035 in. or +/- 0.0015 in./in., whichever is greater



### Creaform HandySCAN 700

- Portable
- Quick – 480,000 measurements/s
- Metrology-Grade Accuracy – 0.0012 in.
- High Resolution – 0.0020 in.
- Recommended Part Size – (0.3 – 13 feet)

### Other capabilities include:

Reverse Engineering  
Computer Aided Design (CAD)  
Technical Data Packages  
Engineering Drawings  
3D Scanning

# RECLAIM Successes



## A-10 APU Cover Mold



Without Mold



3D Printed Mold

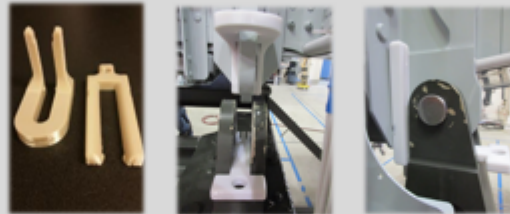


With Mold

## A-10 Center Wing Guards



Wing Damage Without Guards



3D Printed Guards

## F-16 Drill Templates



## F-35 Throttle and Joystick Covers

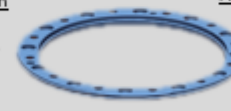


## B-52 Generator Ring



1. Original Part

3D Scan Part



2. 3D Mesh Scan Data

Model Part From Scan Data



3. 3D CAD Model

Produce Drawing From CAD Model



4a. 2D Drawing

Send CAD Model to 3D Printer



4b. 3D Printed Prototype



# ***RECLAIM Impact***

(a/o 18 Sep 19)

---

## **FY19:**

- **\$1M+ in cost benefits (avoidance/savings) to customers**
- **297 DoD projects, 1K+ labor hours, \$300K+ in revenue**
- **Supported 20+ DoD customers**
  - **12+ different Weapon Systems**

## **Since October 2016 (Innovation Center inception)**

- **\$2M+ in cost benefits (avoidance/savings) to customers**
- **775+ DoD projects, 3K+ labor hours, \$600K+ in revenue**
- **Supported 20+ DoD customers**
  - **12+ different Weapon Systems**



# AFSC Organic Innovation Center

## Reverse Engineering and Critical Tooling



OKLAHOMA CITY AIR LOGISTICS COMPLEX

# REACT



### Reverse Engineering

- Technical Data Development
- Dimensional Inspection
- CAD Generation
- Recreating Requirements

### Advanced Manufacturing

- Metal & Polymer Additive
- Rapid Prototyping
- Tooling & Fixture
- Non-Flight Critical Components

### Analysis

- Tooling Validation
- Finite Element
- Root Cause
- Data validation
- Fit Check

Re-engineering, Additive Manufacturing, Advanced Manufacturing supporting Air Logistics Complexes, Supply Chains, and SPOs



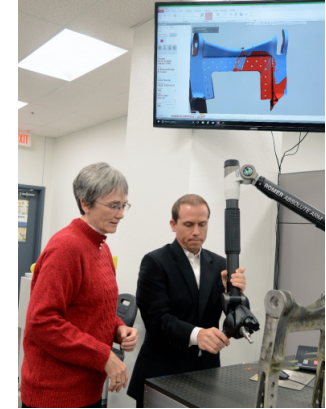
# REACT Reverse Engineering Capabilities



Optiv Classic (3D Probing & Optics)  
-Highly accurate measurement of small parts <15"



Leica AT960-LR (3D Probing & Laser Scanning)  
-Good for large volume measurements



Romer Absolute Arm (3D Probing & Laser Scanning)  
- Quick data collection for small to medium volumes



Artec Space Spider (Structured Blue Light)  
-Ideal for small volumes and can collect color/texture of object



Creaform HandyScan 700 (Laser Scanner)  
-Quick data collection for small to medium volumes

## Software

- SolidWorks/Autodesk Inventor/Catia (Computer Aided Design)
- Geomagic ControlX/Metrolog/Spatial Analyzer (Metrology)
- Geomagic DesignX (Reverse Engineering)

**Delivering combat power for America!**





# REACT Additive Manufacturing Capabilities



**MakerBot Z18s (2 machines)**  
**MakerBot X2s (2 machines)**

**CJP (Color Jet Printing)**  
*3D Systems Projet 860*  
*Build Volume: (20"x 15"x 9")*  
*Material: Gypsum Powder*  
*Accuracy:*



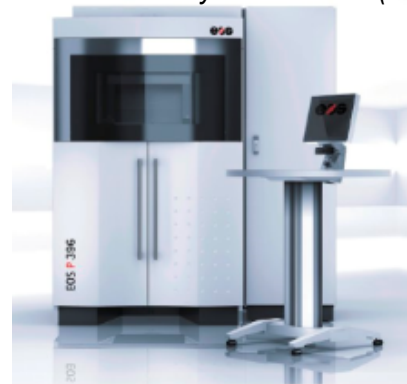
**FDM (Fused Deposition Modeling)**  
*Stratasys Fortus 450*  
*Build Volume: (16"x 14"x 16")*  
*Material: Polymer Filament*  
*Accuracy:  $\pm .005"$  (OR  $\pm .0015$  in/in)*  
*Layer Thickness: (0.013 in to 0.005 in)*



**FDM (Fused Deposition Modeling)**  
*Stratasys Fortus 900*  
*Build Volume: (36"x 24"x 36")*  
*Material: Polymer Filament*  
*Accuracy:  $\pm .0035"$  (OR  $\pm .0015$  in/in)*  
*Layer Thickness: (0.013 in to 0.007 in)*



**SLA (Stereolithography)**  
*Formlabs Form 2*  
*Build Volume: (5.7"x 5.7"x 6.9")*  
*Material: Photo cured resins*  
*Accuracy: Geometry dependent (ballpark  $\pm .005"$ )*



**SLS (Selective Laser Sintering)**  
*Laser Sintered Polymer Powder*  
*EOS P396*  
*Build Volume: (13.4"x 13.4"x 23.6")*  
*Laser: 70-watt fibre laser*  
*Material: Nylon Powder*

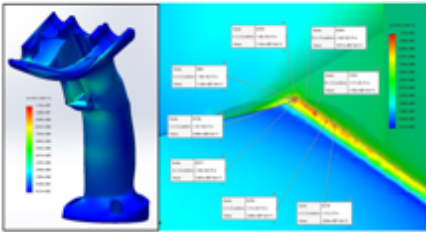
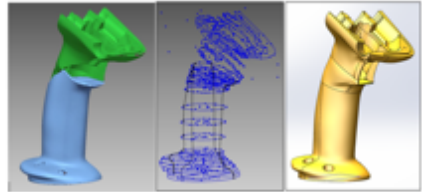


**DMLS (Direct Metal Laser Sintering)**  
*Laser Sintered Metal Powder*  
*EOS M290*  
*Build Volume: (9.8"x 9.8"x 12.8")*  
*Laser: 400-watt fibre laser*  
*Material: Stainless Steel Powder 17/4 PH*

**Delivering combat power for America!**



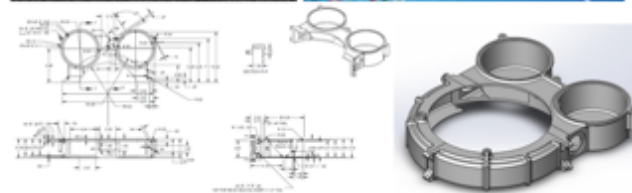
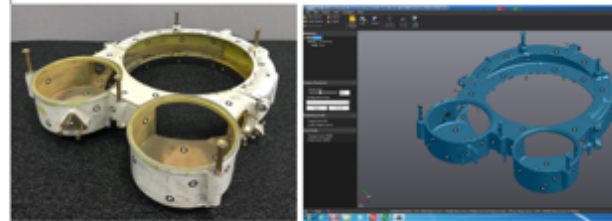
# REACT Successes



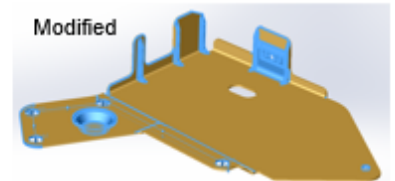
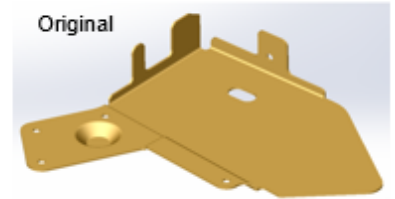
**B-1B Stick Grip  
Fatigue Analysis**



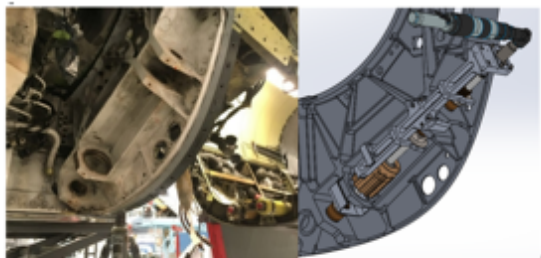
**B-1B SPR Defuel &  
Pressurization Tool**



**B-1 FWD Landing Gear Wheel Cover**



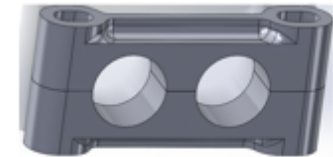
**B-52 Ejection Seat Cover**



**F-16 MLG Bushing Bore Repair Tool**



**B-1 Interior Panels**



**F-16 Fuel Tank  
Hydraulic Clamp**



# ***REACT Impact***

(a/o 15 Aug 19)

---

## **FY19:**

- **\$30M+ in cost benefits (avoidance/savings) to customers**
- **308 DoD projects, 13K+ labor hours, \$2.5M+ in revenue**
- **Supported 20+ DoD customers**
  - **12+ different Weapon Systems**

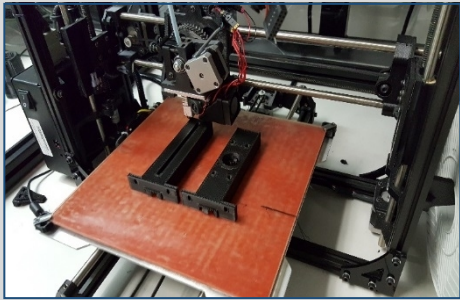
## **Since October 2016 (Innovation Center inception):**

- **\$50M+ in cost benefits (avoidance/savings) to customers**
- **625+ DoD projects, 15K+ labor hours, \$3M+ in revenue**
- **Supported 20+ DoD customers**
  - **12+ different Weapon Systems**



# Innovation Breeds Innovation

## Custom Circuit Card Guides



76<sup>th</sup> Software Mx Group (OC-ALC, Tinker AFB)

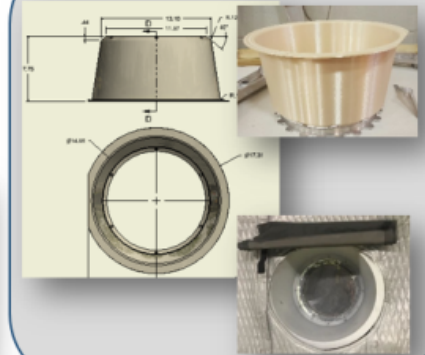
## ITA Backplane Dust Covers



## F-15 Cooling Duct



## C-5 Window Reveal

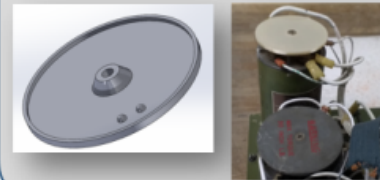


## TF33 Diffuser Case Plasma Spray Mask



76<sup>th</sup> Propulsion Mx Group  
(OO-ALC, Tinker AFB)

## C-5 Transformer Cover



## C-5 Dust Cover



402 Commodities Mx Group  
(Robins AFB)



# Post Processing Capabilities

- 3 & 5 Axis Mill
- Wire EDM
- Bandsaw
- Shot Peen
- Bead Blast
- Wet Blast
- Heat Treat

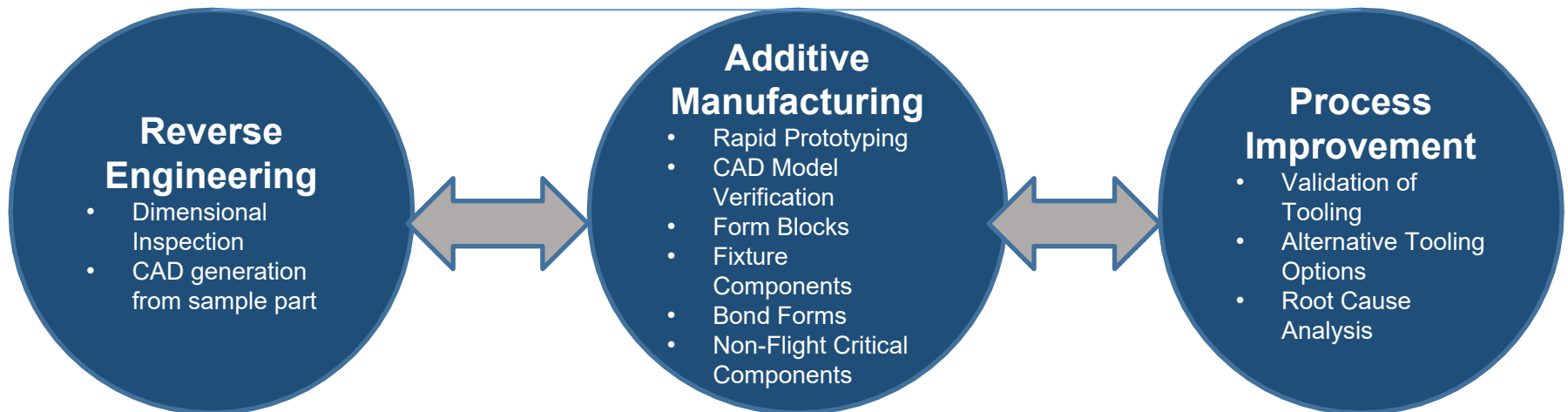


*Delivering combat power for America!*

# REACT

REVERSE ENGINEERING AND CRITICAL TOOLING

## *What Can REACT Do For You?*



**76 CMXG - REACT Engineering Team – B9001 Post DD-20**

Supervisor: Jason McCurry

405-582-4015

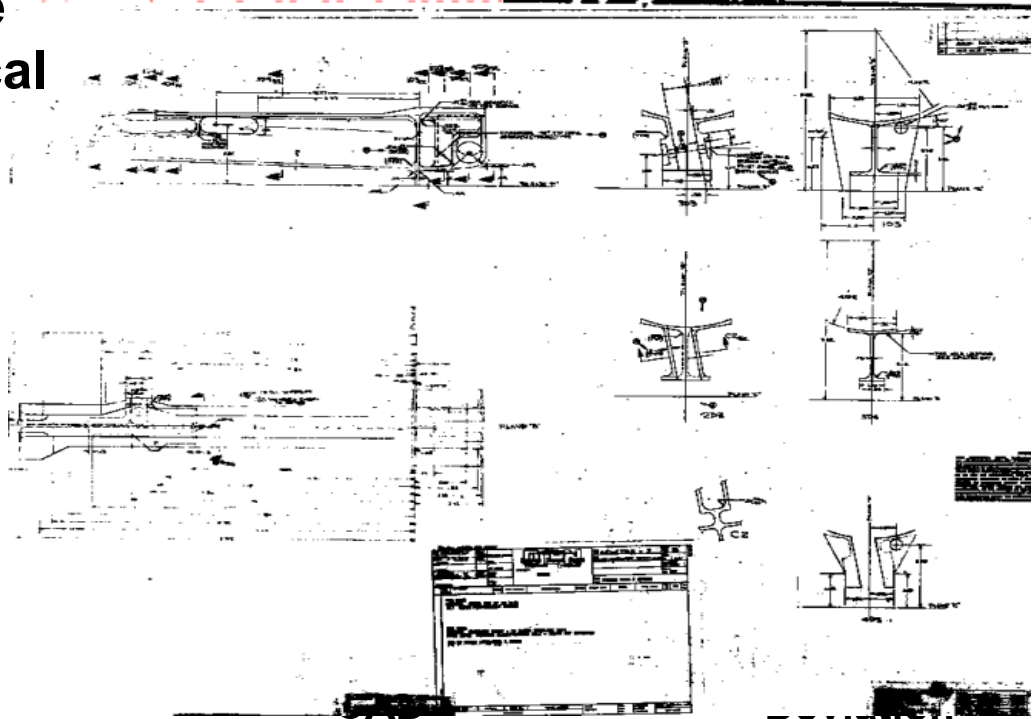
[jason.mccurry.1@us.af.mil](mailto:jason.mccurry.1@us.af.mil)

*Delivering combat power for America!*

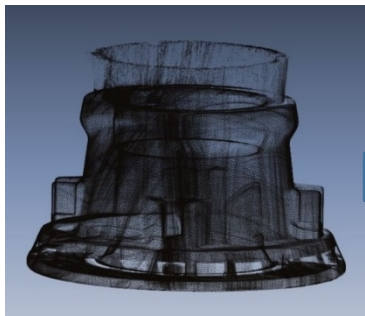


# Why Are We Reverse Engineering

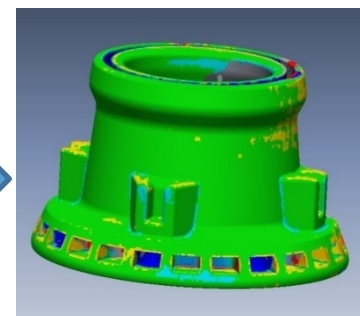
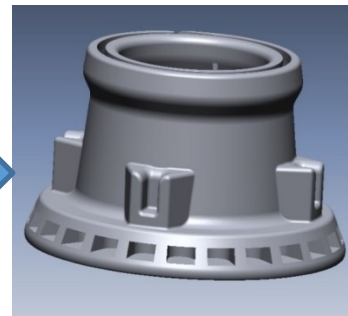
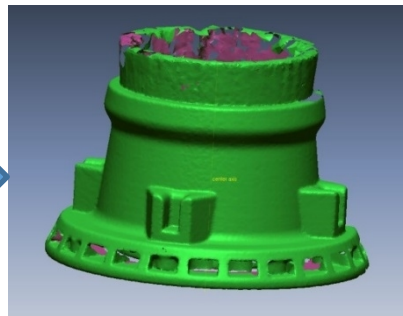
- Legacy Weapon Systems Have Missing or Inadequate Technical Data
- Legacy Tooling Is Worn
- No Tooling
- Custom Repairs
- Dimensional Verification
- Equipment Repairs



Point Cloud



Mesh

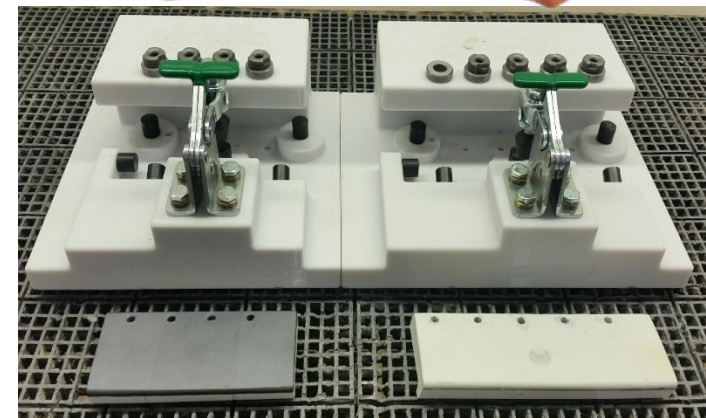
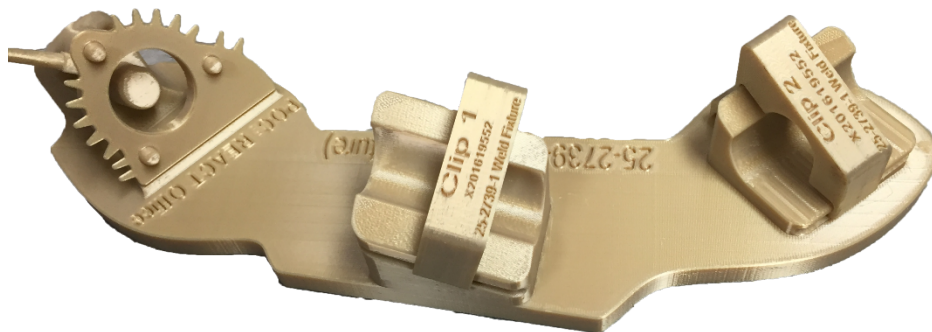
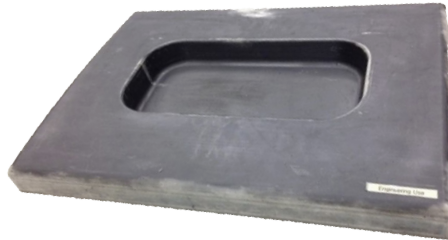


*Delivering combat power for America!*



# Why Additive Manufacturing?

- Minimize Depot Maintenance Costs
  - Flow Time & Material
- Rapid Prototyping
- Dimensional Verification
- Rapid Design Iteration
- Low Volume Tooling



*Delivering combat power for America!*





# *What Are We Making With AM*

---

## ■ Tooling and Prototyping

### ■ Sheetmetal Form Blocks

- Verification Before Designing Form Block
- Form Blocks – Solid & Partial Fill
- Shell For Casting Epoxy Form Blocks

### ■ Fixtures

- End Item Assembly
- Fit Check Verification
- Machining
- Welding
- Drilling

### ■ Equipment

- Replacement Parts

### ■ Non-Flight-Critical Aircraft Parts

- Verification Of Custom Repairs
- Plastic Parts
  - Dust Covers
  - Switches
  - Arm Rests
  - Clamps
  - Dash Panels
  - Cable Retention



# B-1 Nose Landing Gear Cover Tech Data Package Creation

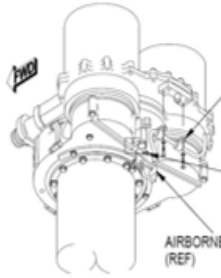


Image from TO 32-51-11-2 represents the only tech data available for the gear box cover



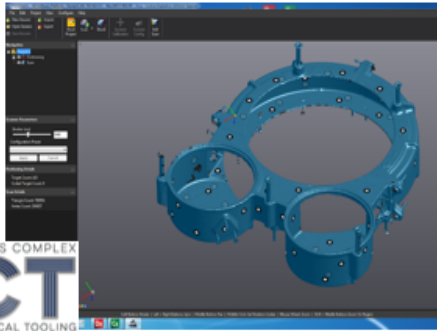
PN 30513-2

PN 30511-1

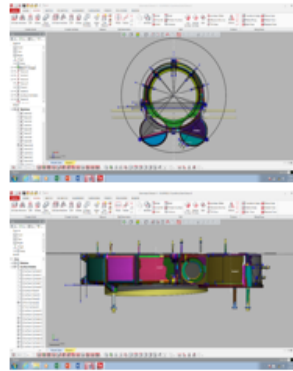
PN 30513-1

Port View Aft View Starboard View

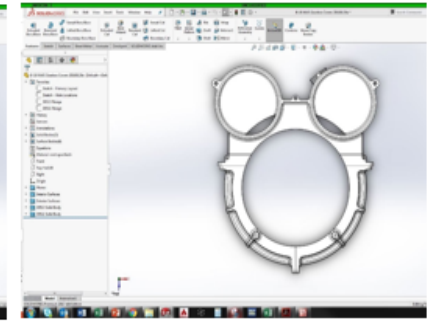
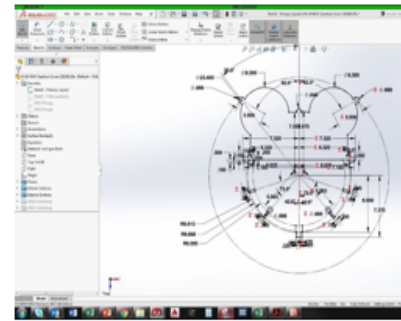
Digital Scan Of Sample Parts Create A Mesh



OKLAHOMA CITY AIR LOGISTICS COMPLEX  
**REACT**  
REVERSE ENGINEERING AND CRITICAL TOOLING

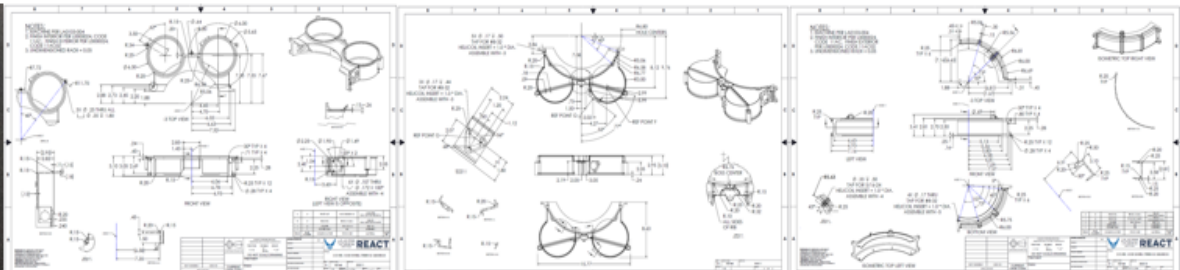


Make CAD Model Based On Sample Part Measurements



Additively Manufacture Ideal CAD Model & Perform Fit Checks

Deliver TDP including CAD Model & Level 3 Drawings



**Delivering combat power for America!**



# F-16 MLG Bushing Bore Repair Problem



341 Bulkhead

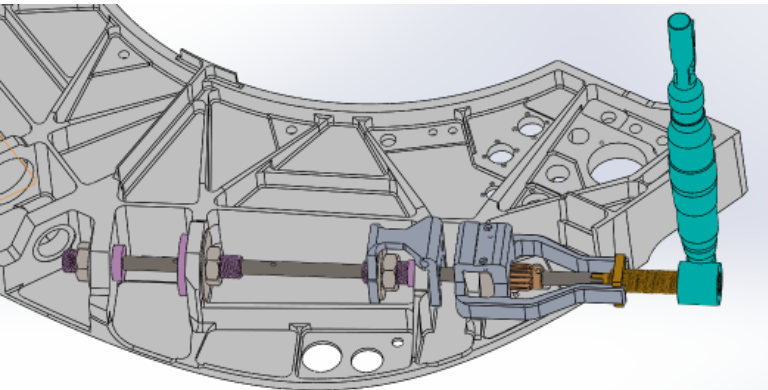


View Looking Aft



# F-16 MLG Bushing Bore Repair

## Fit Check

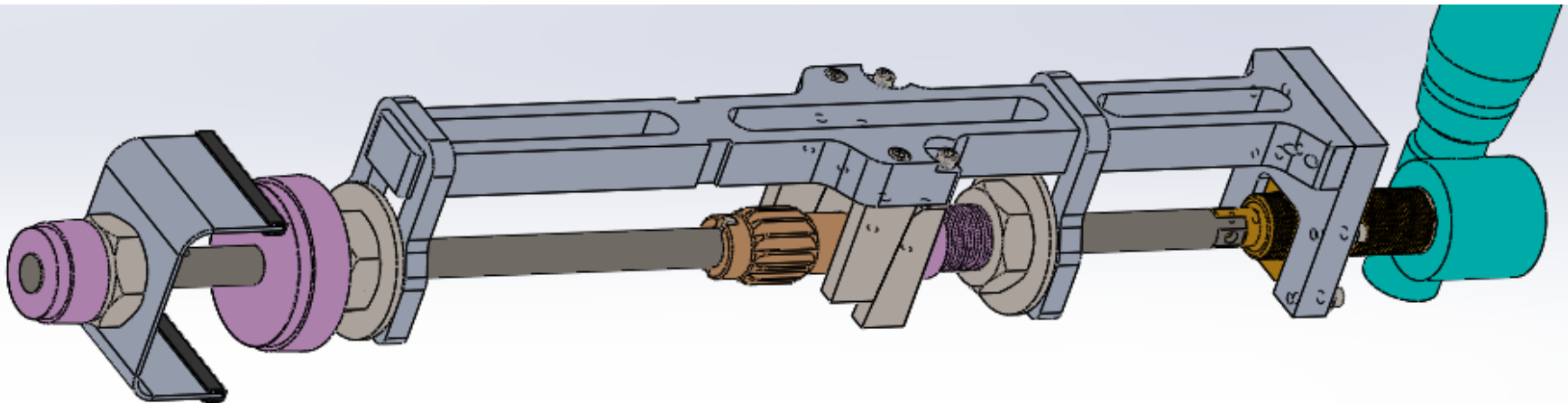




# F-16 MLG Bushing Bore Repair

## Impact

- Easily transportable
- Minimized travel requirements
- Reduced repair time from 2 weeks to 2 days
- Improved concentricity of end results
- Moved repair to lower working level
- Reduced Aircraft downtime



**Available to field units**

*Delivering combat power for America!*



# B-1 Wing Sweep Drive Shaft Testers

## Project Info:

- B-1 PDM is overhauling 10-15 drive shafts annually, but cannot safely test overhauled shafts to 7,000 in-lbs per specs
- Previous failures have occurred in flight damaging the part and surrounding structures in the intermediate weapons bay
- To verify the metal AM tool a test spline was printed and torqued to 10,500 in-lbs. The part showed no damage or signs of yielding

## Projected Savings:

- Current methods used to test the shafts are dangerous for personnel and risk damaging the part
- If typical manufacturing methods were used the design would have been manufactured in several additional parts using multiple machines
- **Overall cost avoidance by using Metal Additive Manufacturing vs Traditional Manufacturing was 90 flow days and \$29,520 (120 hours at \$246 local man's shop rate)**



OCCM240



# B-1 Interior Panels AM Phase I and II

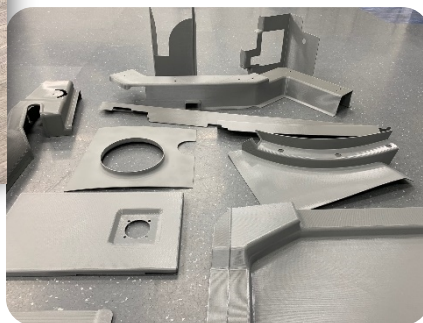
## Problem Statement

- B-1B aircraft interior panels are deteriorating due to 40+ years in service and spares are not readily available and AMAR
- Phase I: B-1 SPO funded reverse engineering of 8 interior panels and create technical data package that allows them to be additively manufactured.
- Phase II: SPO funded additional RE for 13 more panels along with TDPs for using AM techniques.

## Project Description

- REACT engineers modeled parts with existing technical data from JEDMICS and provided samples, working with the SPO to improve panel design and durability
- REACT additively manufactures these reverse engineered panels for B-1s during depot level maintenance to replace old, worn, and damaged panels.
- Current ship set of reverse engineered panels is currently 21 part numbers, with one ship set provided every month.

## Part Image



## Annual Cost Avoidance

- Average panel savings compared to historical procurement cost: \$1,640.32 per panel
- Current # of panel replacements per aircraft: 21
- Current savings per aircraft: \$34,446.72
- Savings per year based on twelve 21-panel ship sets: **\$413,360.64**
  - Phase I = ~\$157,470.72 annually
  - Phase II = ~\$255,889.92 annually

***Delivering combat power for America!***



# Conclusion

- Innovation is core to AFSC operations
- Expanding Innovation Network
  - Solving constraints at the speed of production
  - Growing our problem solving capabilities
- Leveraging technologies ahead of the TRL curve
- Creating a world class innovative workforce

**Not only for AFSC...but available to the entire DoD**





# USAF Portal Page

**AF PORTAL**

NEWS & ANNOUNCEMENTS **BASE, ORG & FUNCTIONAL AREA** APPLICATIONS CAREER & TRAINING LIFE & FITNESS LIBRARY & RESOURCES

AF Portal This Page White Pages

SEARCH AF PORTAL

SAVE AS MY FUNCTIONAL AREA

**AFSC INNOVATION NETWORK**  
All Functional Areas A-Z: AFSC Innovation Network

Those Closest to the Problem are Closest to the Solution!

**DEATH STAR**

AFSC is committed to modernizing the sustainment enterprise by making revolutionary capabilities available to the USAF and DoD workforce. Why is this important? Because we are bringing these capabilities NOW to where the challenges exist and putting them into your hands so that you are empowered to find solutions. These capabilities range from high-end design and analysis software to reverse engineering and 3D printing. We are able to...

CHALLENGES > DEATH STAR > INNOVATION > SOLVING PROBLEMS AT THE SPEED OF P... >

**AFSC INNOVATION NETWORK**

DISCUSSIONS

- Contact the Content Manager
- Recently Modified

**HILL RAPID DEVELOPMENT TOOLS** + ADD

**RECLAIM**

OO-ALC has begun the initial strategic vision of the RECLAIM Lab to fill the niche of current and next generation materials application consistent with the mission at OO-ALC.

Read More...

- RECLAIM pptx
- RP Flyer (New Printer 6-27-18).pdf
- SBID OO-ALC AM and RE.PPTX

**DEATH STAR**

Information coming soon

Read More...

Visual Innovation Center

**AFSC ENGINEERING STANDARD DESKTOP** + ADD

**AFSC Engineering Standard Desktop**

The Under Secretary of Defense has implemented the directive for Better Buying Power 3.0 with a goal of achieving dominant capabilities through technical excellence and innovation. As part of this directive, AFSC/EN is working to strengthen organic engineering capability by improving access to analytical tools and facilities infrastructure.

**MY STUFF**

- MY ALERTS
  - Urgent (0)
  - Notice (0)
  - My Inbox (0)
- MY WORKSPACES
  - Workspace
- MY FAVORITES
  - 62X Homepage
  - ACMS (Acquisition Career Managem...
  - ADLS (Advanced Distributed Learnin...
  - ADP (Airmen Development Plan) (Fo...
  - AFNet EIS Support (formerly AF Kno...
  - AFPC Secure - AF Personnel Center S...
  - AHS (Assignment Management Syst...
  - myPay
  - SAF/AQR - Science, Tech. & Engineer...

# Contact Info



Jason McCurry, Chief  
REACT Lab  
(405) 582-4015  
[jason.mccurry.1@us.af.mil](mailto:jason.mccurry.1@us.af.mil)

Mark Lucash, Lead  
Reverse Engineering  
(405) 582-4302  
[mark.lucash@us.af.mil](mailto:mark.lucash@us.af.mil)

Jason Mann, Lead  
Additive Manufacturing  
(405)-622-7607  
[jason.mann.6@us.af.mil](mailto:jason.mann.6@us.af.mil)



Lt Col Chris Blackwell  
Director, AFSC Innovation Centers  
(405) 736-3042  
[christopher.blackwell@us.af.mil](mailto:christopher.blackwell@us.af.mil)



Damon Brown, Chief  
REARM Lab  
(478)-327-8655  
[damon.brown@us.af.mil](mailto:damon.brown@us.af.mil)  
[402EMXG.REARM.Workflow@us.af.mil](mailto:402EMXG.REARM.Workflow@us.af.mil)

## RECLAIM

Dr. David Hansen, TD  
Hill AFB  
(801) 777-5318  
[david.hansen.12@us.af.mil](mailto:david.hansen.12@us.af.mil)

Slade Knightly, Chief  
RECLAIM  
(801) 775-2167  
[slade.knightly@us.af.mil](mailto:slade.knightly@us.af.mil)

