

# Aerospace Structures

## Overview

# Our Company

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Leading global security company

\$36.6 billion sales in 2022

\$78.7 billion total backlog

*(as of December 31, 2022)*

~95,000 employees

Leading capabilities in:

- Space
- Missiles
- Advanced Weapons
- Aeronautics
- Mission Systems



# Four Operating Sectors

## Aeronautics Systems

- Military aircraft
- Autonomous systems
- Aerospace structures
- Next-generation surveillance
- Strike
- Commercial solutions

## Defense Systems

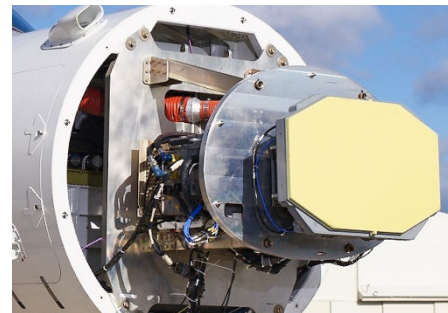
- Sustainment and modernization
- Training and simulation
- Integrated battle command systems
- Advanced weapons
- IT modernization

## Mission Systems

- Software-defined systems
  - Defense
  - Intelligence
  - Multiple domains

## Space Systems

- Space and launch systems and capabilities
  - National security
  - Civil
  - Commercial



# Aeronautics Systems Divisions

## Air Dominance

F-35 Lightning II  
 F/A-18 Hornet and Super Hornet  
**Aerospace Structures**  
 Advanced Fighter Concepts

## Global Surveillance

E-2D Hawkeye  
 MQ-4C Triton  
 MQ-8B, 8C Fire Scout  
 E-8C Joint STARS  
 RQ-4 Global Hawk  
 NATO Airborne Ground Surveillance  
 Firebird  
 Airborne Laser Mine Detection System

## Strike

B-2  
 Restricted Programs

### Key Technologies

Survivability

Autonomy

Battle Management Technologies

Advanced Manufacturing

Vehicle Technologies

### Research and Advanced Design





# Aerospace Structures



# Aerospace Structures Overview

**World class manufacturer of composite structures for commercial and military aircraft and launch vehicles**

**Leader in composite automation innovation**

- Invented automated fiber placement process
- Developed world's fastest fiber placement machine
- Invented automated stiffener forming machine

**Approximately 2,100 Employees**

**Headquarters in Clearfield, UT**

- Facilities in California, Massachusetts, Mississippi, Ohio and Utah



# ASBU Product Segment Portfolio

## COMMERCIAL SEGMENT



- Fuselage Stringers and Frames
- Fan Case and By-Pass Ducts
- Airframe and Primary Stiffening Structures
- Composite Door Springs

## EXTERNAL MILITARY, MISSILES & LAUNCH SEGMENT



- Wing Skins, Fixed Skins, Nacelles
- Bull Nose and Blade Seals
- Straps and fairings
- Screens
- Apertures
- Electromagnetic materials
- 4m and 5m Payload Fairings
- Thermal Shields
- Center Stages
- Nosecones
- Composite Overwrapped Pressure Vessels

## INTERNAL MILITARY SEGMENT



- Large Assemblies
- Core Components
- Radomes and Antennas
- Survivable Structures
- Advanced Materials
- RF Testing

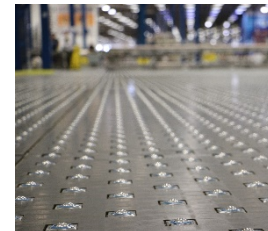
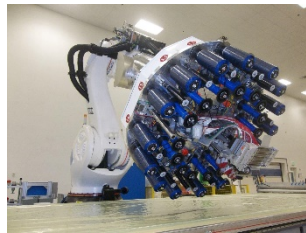
# Aerospace Structures Locations





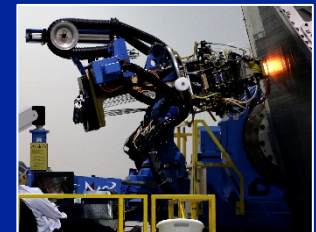
# Aeronautics Composite Center Elevated (ACCE)

- Floor Space: 615,000 ft<sup>2</sup> (57,135 m<sup>2</sup>)
- Clean rooms 100,000 ft<sup>2</sup> (9,290 m<sup>2</sup>)
- Open Capacity of 90,000 ft<sup>2</sup> (8,361 m<sup>2</sup>)
- Automated Stiffener Forming Capacity
- Automated Linear Stringer Machines
- Automated Radial Frame Machines
- Engine Case Wrap Capacity
- CNC Milling Machine Capacity
- Large Diameter Autoclave Capacity
- NDI Systems - Automated Ultrasonic Inspection (AUIS)
- Water Jet and Machining Capacity
- Hot Drape Forming



# Freeport Composite Center

- **Floor Space: 403,000 ft<sup>2</sup> (37,440 m<sup>2</sup>)**
  - Clean room 48,100 ft<sup>2</sup> (4,469 m<sup>2</sup>)
- **6 Fiber Placement Machines**
- **3 Ovens**
- **5 CNC Milling Machines**
- **5 Autoclaves**
- **Automated Ultrasonic Inspection Systems (AUIS)**
- **ASFM R&D Machine**
- **Leica Measurement Systems**
- **Laser/Radar Measurement Systems**
- **Virtek Projection Systems**

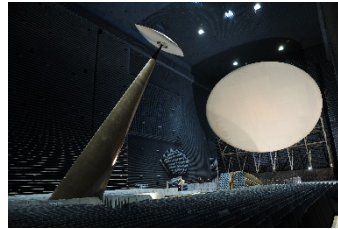


# Dayton Site: Advanced Aperture Solutions

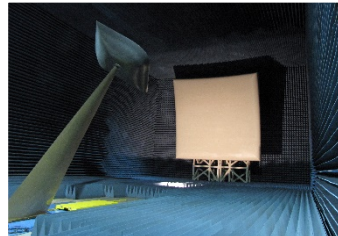


- **Floor Space: 175,000 ft<sup>2</sup> (16,258 m<sup>2</sup>)**
  - (4% clean room)
- **Radomes**
- **Antennas**
- **Advanced Materials (Loaded Core Structure)**
- **RF Components and Testing**
- **Survivability Structures – B1 and B2**

## PERFORMANCE VERIFICATION



*Rancho Bernardo Test Facility*



*Dayton Compact Range*



*Vacuum Optical Bench*

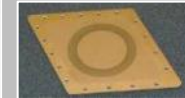
## APERTURES: ANTENNAS AND RADOMES



*LOCOMM Antenna*



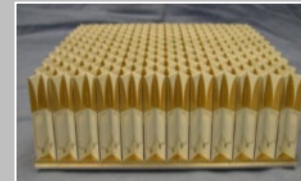
*Link 16 Antenna*



*Notch Array Antenna*



*Horn Comparator*



*TacSat 2 CDL AESA*



*Rigid Structures*

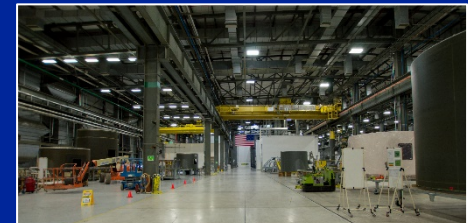
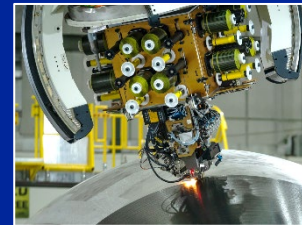


*Flexible Structures*



# Iuka Site: Large Structures

- **Floor space: 320,000 ft<sup>2</sup> (29,729 m<sup>2</sup>)**
  - Clean room: 85,600 ft<sup>2</sup> (7,953 m<sup>2</sup>)
  - Open Capacity 150,000 ft<sup>2</sup> (13,935 m<sup>2</sup>)
- **Fiber Placement and Hand Lay Up**
- **Autoclaves**
  - 17.5 ft. Diameter x 50 ft. Length
  - 20 ft. Diameter x 83 ft. Length
- **Machining Centers**
  - 23m Belotti Machining Center
  - 5-axis CNC Water Jet
  - 3-axis Machining Center
  - 5-axis CNC Router
- **Automated Ultrasonic Inspection (AUIS)**
  - Horizontal and Vertical
  - 13 Degrees of Freedom
  - Modular: Wet, Dry and Radiographic NDI
- **Advanced ATL and AFP on one machine**





# Northrop Grumman: A Leader in Composite Automation Innovation

## Northrop Grumman Contribution to Composite Automation

1950's–1970's: Automated Filament Winding			2003 – Future	2007 – Future	2009 – Future	2014	2015+
<p>1950's: Allegany Ballistics Laboratory Manufacturers First Filament-Wound Rocket Motor</p>	<p>1971: Introduces S-glass/Epoxy &amp; Kevlar/Epoxy Materials</p>	<p>1978: Introduced Carbon/Epoxy Materials in Filament Winding</p>	<p><b>Out of Autoclave Processing</b></p> <p>Northrop Grumman is advancing Out-of-Autoclave capability using its Ultrasonic Tape Lamination (UTL™) and other in-situ consolidation technologies</p>	<p><b>Invented the Automated Stiffener Forming Machine</b> (8 Patents)</p> <p>Automated Stiffener Forming (ASF) allows high rate production of uniquely designed complex parts, historically built by hand layout</p>	<p><b>High Speed NDI</b></p> <p>Northrop Grumman developed high speed automated Non-Destructive Inspection (NDI) technology to increase throughput, detection fidelity and data evaluation</p>	<p><b>High Speed Waterjet</b></p> <p>Water jet robotics holding fixture means no monuments and no Machining Restraint Fixture (MRF). Water jet robot bases saves 15-30 minutes per part in MRF alignment, scanning and removal</p>	<p><b>Advanced Dockable Automated Manufacturing System (ADAMS)</b></p> <p>Combines both ATL and AFP in a single work cell. Capable of handling very large parts. Technology potential to change how we make large structures</p>
1982: Invented Automated Fiber Placement							
<p>1982: Invented the Fiber Placement Process</p>	<p>2002: Developed World's Fastest Fiber Placement Machine</p>	<p>2005: Manufactured Largest One-piece Fiber Placed Part on Any Military Aircraft</p>					

### Why Automation?

**Improved Manufacturing Flow**

- Reduced labor hours
- Higher through-put
- More effective use of staff

**Improved Repeatability**

- Machine optimized performance
- Quality Improvement: accuracy/repeatability
- Reduced product scrap

**Improved Cost Performance**

ASBU Innovation and Automation Drives Our Competitive Advantage

# Northrop Grumman: A Leader in Advancing Composite Technology

## AEROSPACE STRUCTURES HAS BEEN AWARDED 75 PATENTS SINCE 1985

**3 PATENTS**

**AUTOMATED CASE FORMING TECHNOLOGY**

OCT-09-2012 8282757  
AUG-20-2013 8512497  
ONE PENDING



**2 PATENTS**

**ADVANCED HARDENED STRUCTURES**

AUG-03-2021 11077627  
ONE PENDING

**15 PATENTS**

**AUTOMATED STIFFENER FORMING**

JUL-31-2007 7249943  
APR-07-2009 7513769  
AUG-03-2010 7767128  
OCT-26-2010 7819651  
OCT-26-2010 7820092  
NOV-08-2011 8052823  
JUL-24-2012 8226787  
FEB-05-2013 8366981  
NOV-19-2013 8585952  
MAY-13-2014 8721316  
MAY-30-2017 9662841  
JAN-07-2020 10525640  
JAN-07-2020 10525641  
JUN-02-2020 10668672  
JUN-22-2021 11040512

**7 PATENTS**

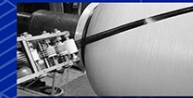
**ASSEMBLY**

MAR-03-1987 4647078  
OCT-24-1989 4875717  
JUN-11-1991 5022845  
AUG-10-1993 5233737  
SEP-21-2004 6793479  
MAY-26-2015 9038866  
DEC-29-2015 9221142

**7 PATENTS**

**MATERIAL PREP MACHINE**

APR-07-2015 8999098  
APR-26-2016 9321220  
AUG-28-2018 10059044  
DEC-18-2018 10155348  
APR-27-2021 10987882  
TWO PENDING



**2 PATENTS**

**PAYLOAD FAIRINGS**

MAY-01-2001 6224020  
MAY-28-2002 6394394



**13 PATENTS**

**AUTOMATED FIBER PLACEMENT**

SEP-03-1991 5045147  
APR-06-1993 5200018  
DEC-28-1993 5273602  
MAR-01-1994 5290389  
DEC-16-1997 5698066  
FEB-22-2000 6026883  
APR-18-2000 6050315  
AUG-01-2000 6096164  
SEP-18-2001 6290799  
DEC-10-2002 6491773  
APR-08-2003 6544367  
FEB-07-2006 6994324  
DEC-23-2008 7467782  
OCT-25-2011 8042594

**1 PATENT**

**COUNTERBALANCE ASSEMBLY**

APR-07-1998 5735020

**3 PATENTS**

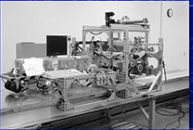
**VARIABLE MACHINE STRETCHING**

FEB-23-2016 9266279  
AUG-04-2020 10730227  
ONE PENDING

**2 PATENTS**

**CONSOLIDATION**

DEC-27-2016 9527237  
ONE PENDING



**3 PATENTS**

**TOOLING**

NOV-21-2000 6149851  
NOV-12-2002 6478922  
ONE PENDING



**9 PATENTS**

**PRESSURE VESSELS**

FEB-12-1985 4499240  
JUN-24-1986 4596619  
MAR-22-1988 4732634  
SEP-19-1989 4867824  
APR-16-1991 5007343  
DEC-24-1991 5075356  
JUN-02-1992 5117757  
JUN-16-1998 5766357  
DEC-17-2002 6495259



**2 PATENTS**

**CORE MACHINING**

MAR-16-2021 10946489  
ONE PENDING

**1 PATENT**

**CRYOTANK**

ONE PENDING

**2 PATENTS**

**THERMAL PROTECTION SYSTEMS**

MAY-24-2005 6896834  
APR-03-2007 7198231

**3 PATENTS**

**ULTRASONIC TAPE LAMINATION**

AUG-13-2002 6432236  
JAN-28-2003 6511563  
JUL-01-2003 6585839

**6 PATENTS**

**NON-DESTRUCTIVE INSPECTION**

JUN-21-2016 9372173  
MAY-28-2019 10302600  
MAR-30-2021 10962506  
THREE PENDING



**1 PATENT**

**SURVIVABILITY**

OCT-08-2021 11135763

**1 PATENT**

**IN PROCESS INSPECTION**

OCT-20-2020 10808353

**2 PATENTS**

**OUT OF AUTOCLAVE**

JUN-22-2004 6752190  
NOV-13-2012 8308889

**1 PATENT**

**ADDITIVE MANUFACTURING**

ONE PENDING

# Automated Fiber Placement (AFP) An Industry Standard

## AFP is the Industry Standard in Large Structure Composite Manufacturing

- Commercial aircraft structures
- Aircraft engine components
- Launch structures
- Liquid propulsion and reusable launch vehicles
- Propulsion cases
- Armored vehicles
- Oil and energy industry structures
- Satellite structures

## Northrop Grumman Leads the Industry with Fiber Placement Machines

- 5 Northrop Grumman design and built machines
- 7 Fives machines (formerly MAG)
- 2 NG/Fives co-developed machines
- 1 Electro Impact



*Electro Impact AFP Machine  
at Northrop Grumman*



*Northrop Grumman  
AFP Machine*



*Northrop Grumman  
AFP Machine*



*Northrop Grumman / Fives  
AFP Machines*

AFP For Complex Layups On Large Surfaces: Steer, Drop/Add Narrow Prepreg Tow



# Automated Stiffener Forming (ASF) Process



ASF: Stringer Production Machine



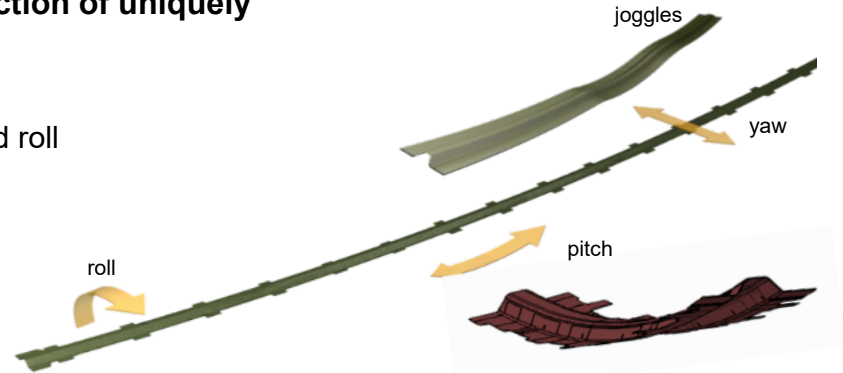
Automated Engine Case Forming



ASF: Frame Production Machine

**Automated Stiffener Forming (ASF) allows high rate production of uniquely designed complex parts, historically built by hand layup**

- Uses woven fabric and/or unidirectional prepreg material forms
- Complex stringer geometries easily manufactured: pitch, yaw and roll
- Ramps, joggles and variable cross sections: Omega, C, Z, etc.



Northrop Grumman Innovation = Design Flexibility, Speed and Quality Improvement = Lower Cost



# Advanced Dockable Automated Manufacturing System (ADAMS)

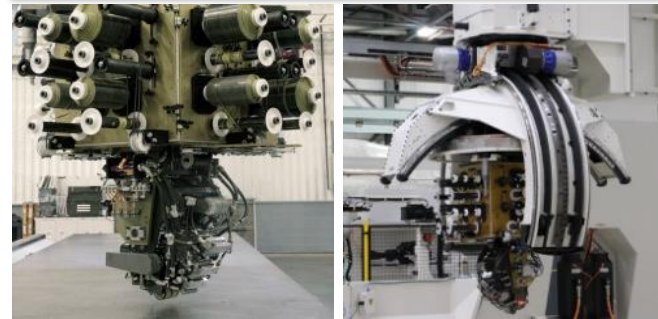


- First of kind in industry
- Northrop Grumman plans to add end-effectors (EEs) to ADAMS for flexibility and productivity of the work cell:
  - Ability to change heads makes it affordable to add different EE configurations: 1/8" Tow, 1/2" Tow, 3" tape, etc. increases optimization for efficiency of part geometries

## End Effectors (EEs) under consideration include:

- Multiple tow width AFP Heads
- AFP heads of same Tow width
- Dual Phase ATL Head
- Automated Stiffener Forming Heads
- Ink Jet Marking Heads
- Adhesives and Coatings Application Heads
- Dry Preform Heads

## Dual head: ATL & AFP Head change <2 min



Part Layup Capacity: ~ 21' W x 98' L x 10' V

# Automated High Speed NDI

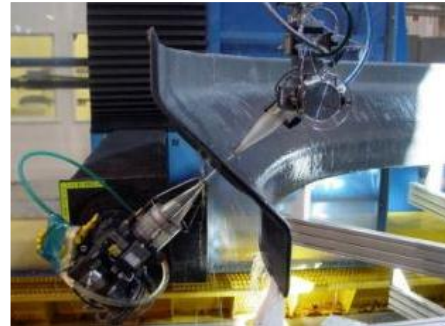
**Northrop Grumman developed high speed automated Non-Destructive Inspection (NDI) technology to increase throughput, detection fidelity and data evaluation**

**Northrop Grumman developed NDI technology:**

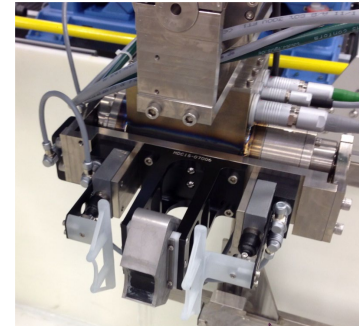
- Multiple independently operated detection heads, coupled with advanced signal processing software to greatly reduce scanning time
- Integrated ultrasonic phased array inspection technology in automated scanner with 3D full contour following capabilities
- Up to 15 inch per second inspection speeds
- Dual probe machines have eliminated the need to change out probes during scan



*CINSP-AUIS-2 11-Axis 18m UT Scanner*



*Inspection of complex surface*



*Radial Phased Array*

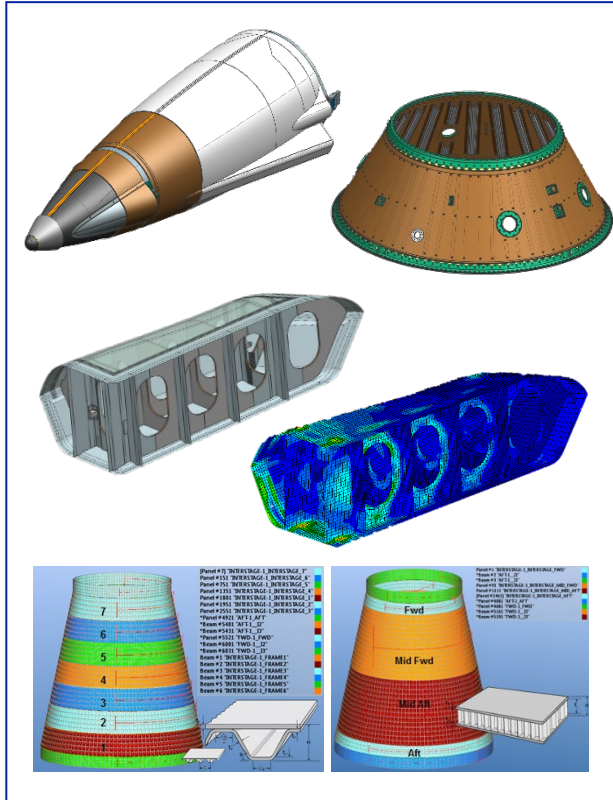


*3D Laser Displacement Sensor*

**Advanced Ultra-Sonic Systems**

# Experienced in Design to Specification

## Experienced in Design and Analysis of Advanced Composite Structures



### Design and Analysis Expertise

- Design and analysis of composite structures for a broad range of launch vehicle and aircraft applications
- Optimization of composite structures
- Design for manufacturing - close integration between product design and process development
- Materials development

### State-of-the-Art Tools

- **FE Analysis:** ABAQUS, MSC. NASTRAN, NX NASTRAN, ANSYS
- **Pre/Post Processing:** ABAQUS CAE/Viewer, MSC. Patran, Altair HyperMesh and HyperView
- **Structural Optimization:** HyperSizer, Altair OptiStruct and HyperStudy
- **Computational Fluid Dynamics:** Fluent
- **Solid Modeling and Drafting:** Catia V5, NX
- **Special Purpose Applications:** Composite pressure vessel design and analysis, damage simulation, CLT and micromechanics, fracture mechanics and fatigue

# Aerospace Industry Approvals

**AS9100 accredited since 1997 – Revision D certified by Eagle Registrations, Inc. in June 2018**

**NADCAP accredited by PRI (Performance Review Institute)**

- Composite Fabrication accredited since 2004
- Non Metallic Material Testing, accredited since 2012
- Non Destructive Testing system, accredited since 2006



Aerospace Structures Has All Standard Industry Certifications



# Contacts

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**NORTHROP  
GRUMMAN**

The logo graphic consists of a thick horizontal line on the right side of the word "NORTHROP", which extends to the right and then turns 90 degrees downward to form a vertical line. This graphic element is positioned to the right of the word "NORTHROP" and partially overlaps the word "GRUMMAN".