Thermoplastic Composites Conference

Aircraft Structural Brackets Using Additive Molding™

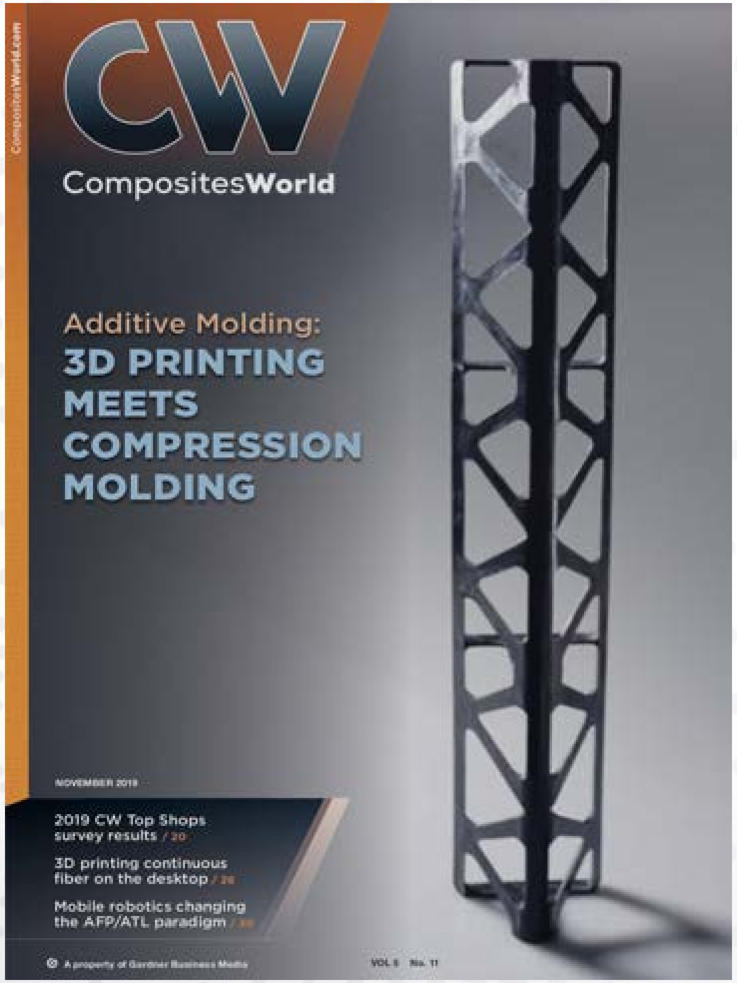
Overview of Technology, Examples, Etc.

Riley Reese, Co-Founder & CTO

ARRIS Composites, Inc.

Aircraft Structural Brackets Using Additive Molding™

- ARRIS Company Overview
- Additive Molding™ Process + Design
- Customer Examples
- Aerospace Applications



ARRIS Overview

Carl Bass

Former Autodesk CEO and ARRIS Composites Advisor

"For decades, we've been on the verge of broadly realizing the superpowers of composites, but they've been limited to a small segment of the market. ARRIS' technology gives us the possibility of moving this to the broader market."

Jeff Immelt

NEA Venture Partner (ARRIS' VC) and Former GE CEO

"What we did at GE Plastics in automotive to replace non-structural metal with low cost/lightweight injection molded composites in the 1980s, ARRIS has now enabled for the rest of the vehicle."

Composites Landscape

Shorter Cycle Times

Lower Strength

Higher Fidelity

Longer Cycle Times

Higher Strength

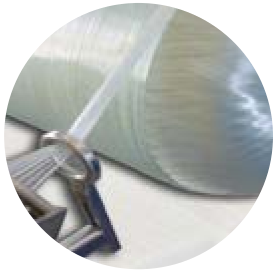
Lower Fidelity

Chopped Fiber

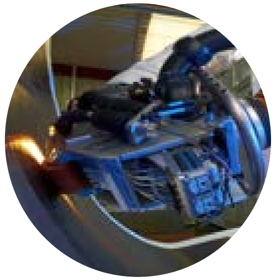
Injection Molding
"Short fiber"
(up to a few mm in length)

Compression Molding
"Long fiber"
(up from a few mm in length)

Continuous Fiber



Braiding & Filament Winding



Automated Fiber Placement & 3D Printing

Hand Layup / Sheet Molding Techniques

Higher Unit Production

Lower Unit Production

Geometry Constraints—Aligning Fibers In Complex Composite Structures

Ideal Material Efficiency

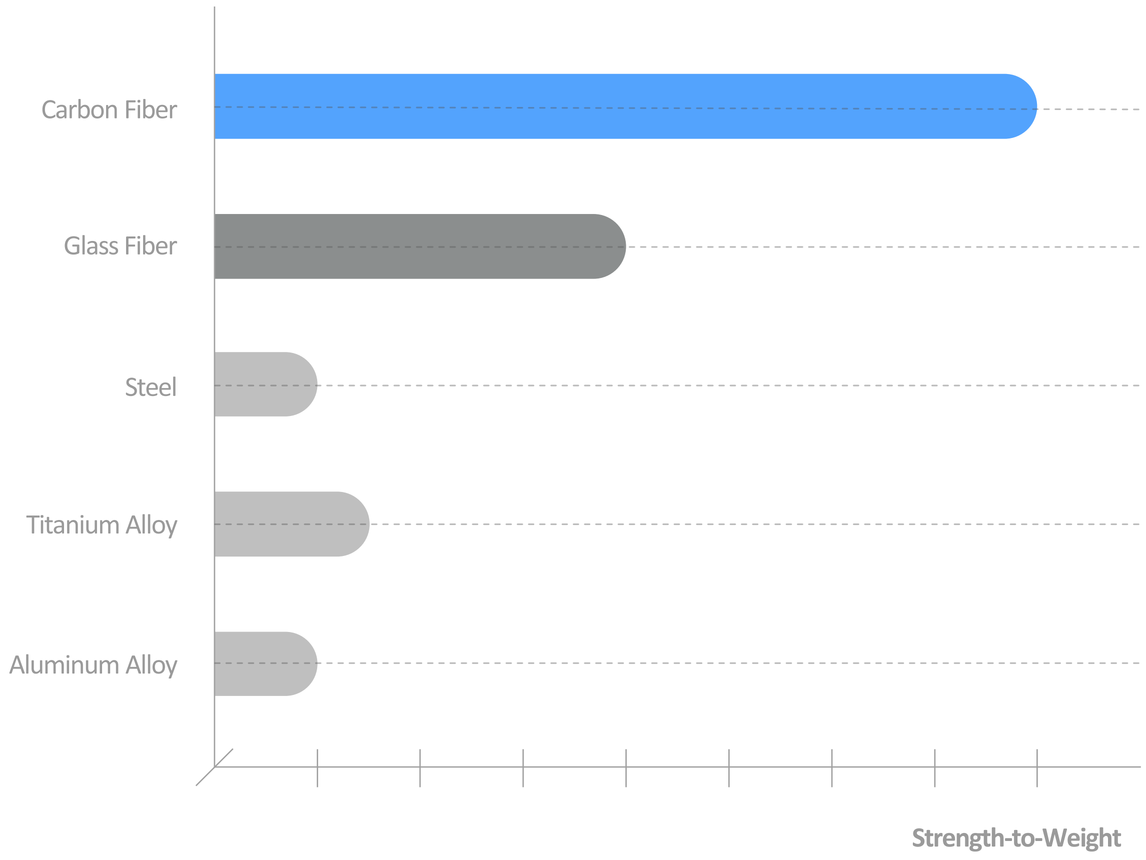
Biologically optimized wood grain alignment—analogous to optimized composite fiber alignment.

Conventional Composites

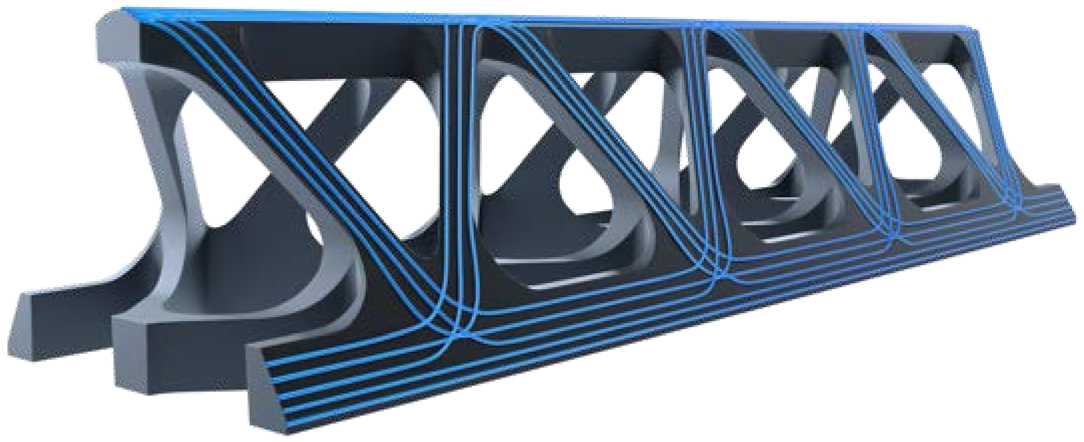
Fibers not optimally aligned—suboptimal material and structural performance.

Fiber Optimized Complex Parts

Fibers 3D-Aligned With Principal Stress Vectors



Truss with optimized carbon fiber alignment – schematic of select pathways within ARRIS part



Manufacturing Constraints Have Limited Composites

Why do continuous fiber composites look like this?

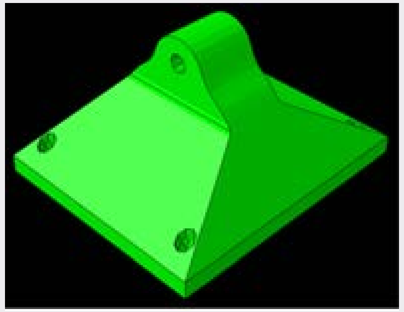




When optimal structural designs look like this?

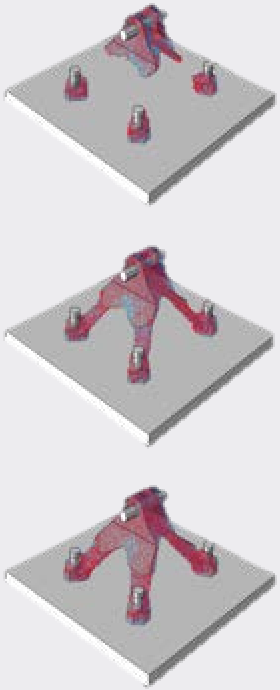



Additive Molding™ Design Software



1 **Define Requirements**

Functional, Geometric, Etc.

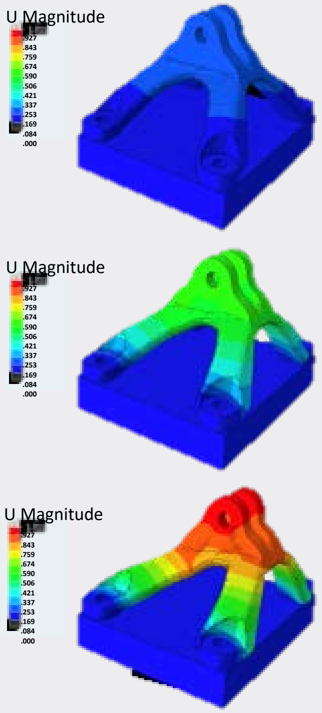


2 **Computer Aided Design (CAD)**

Topology & Fiber Alignment-Optimization

3 **Computer Aided Manufacturing (CAM)**

Additive Molding System Manufacturing Instructions & Composite Preform Design

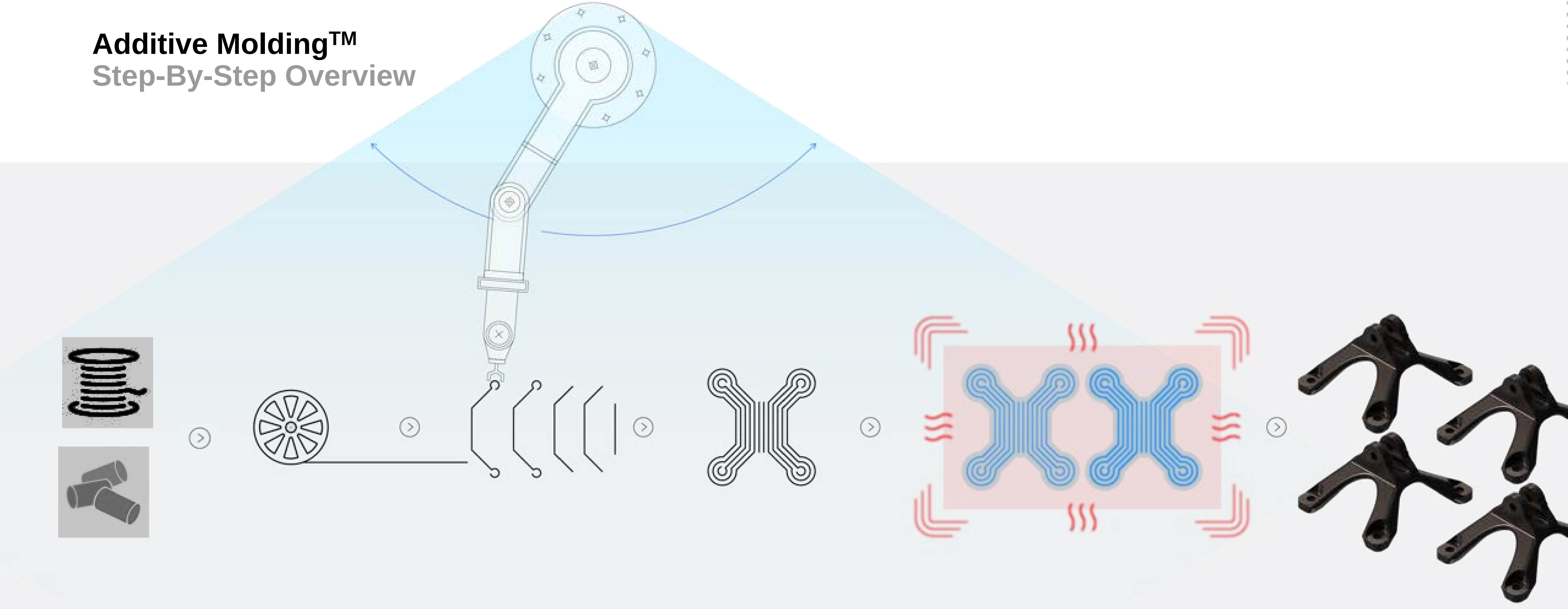


4 **Computer Simulation of Part**

5 **Final CAD & CAM locked**

Additive Molding™

Step-By-Step Overview



1 Raw Material

2 Impregnation Of Composite Material

3 Preformed Composite Pieces
4 Assembled Into Near-Net-Shape Composite Preform Assembly

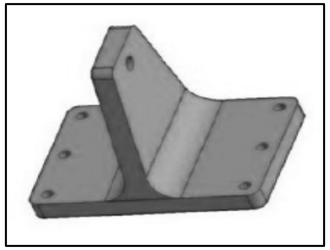
5 Mold Processing Of Preformed Composite Material

6 Final Part + Testing

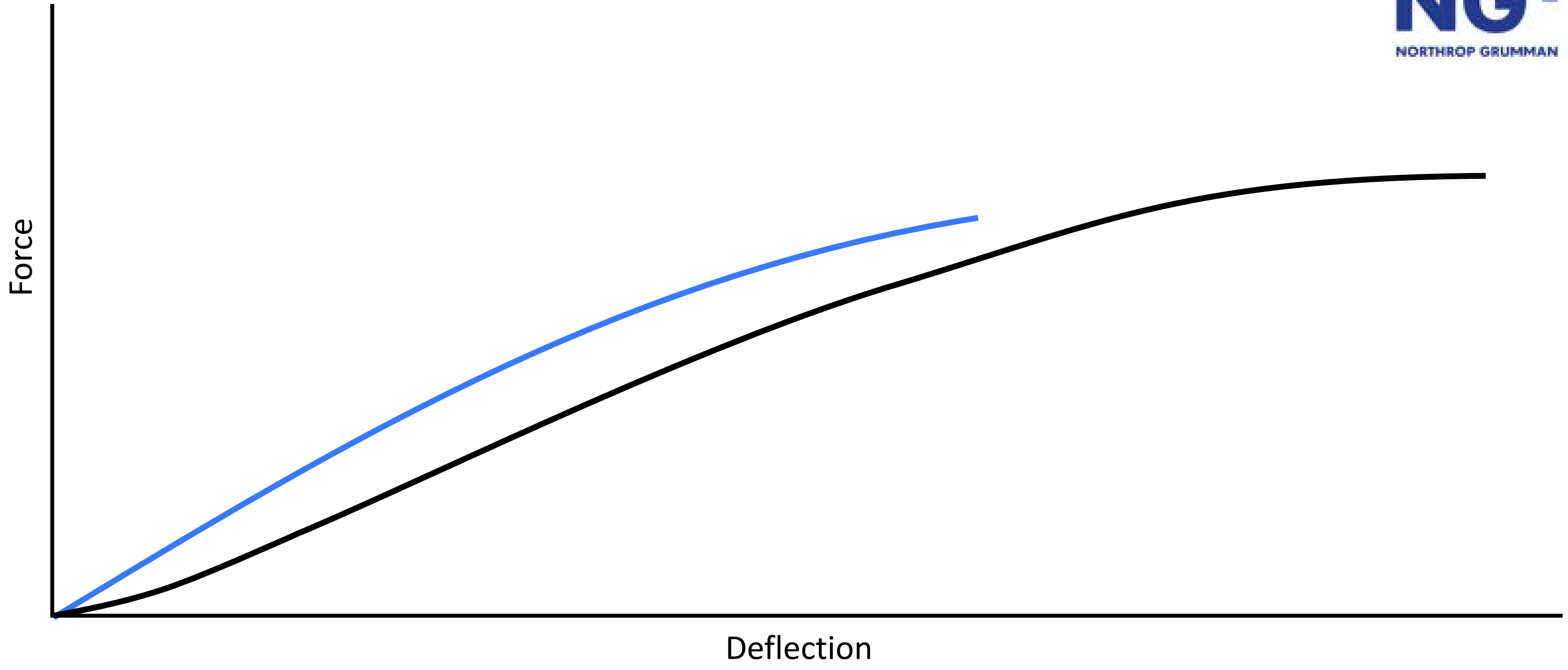
Northrop Grumman Study

ARRIS Bracket matches stiffness of titanium bracket at 21% of the weight

Titanium 3D Printed T Design (Baseline)



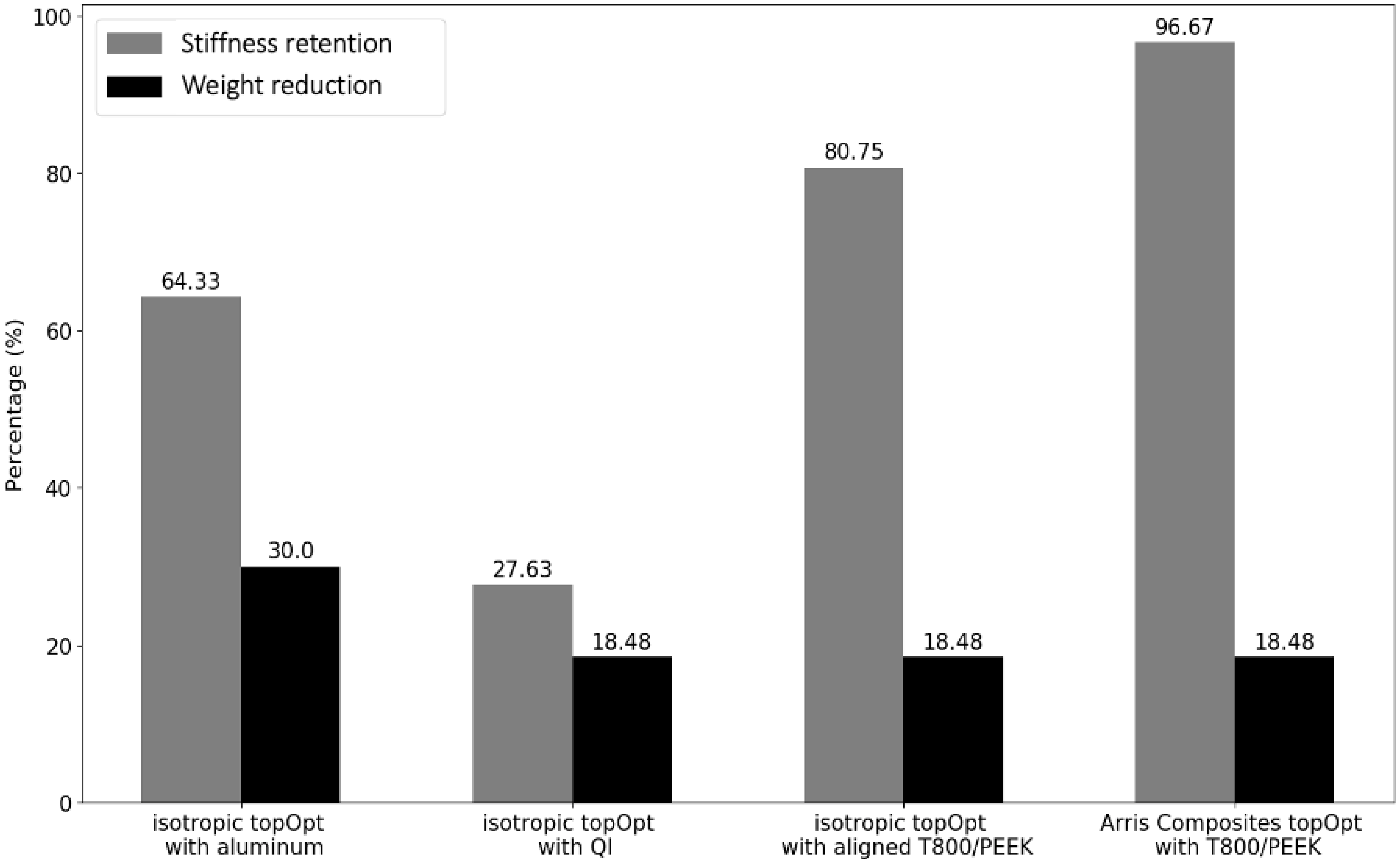
CF Additive Molded™ Topology Optimized



Material, Manufacturing Process, & Design	Weight	Weight Reduction
Titanium 3D Printed - T Design (baseline)	76 grams	-
CF PEEK Additive Molded™ - Topology Optimized	16 grams	**79%**

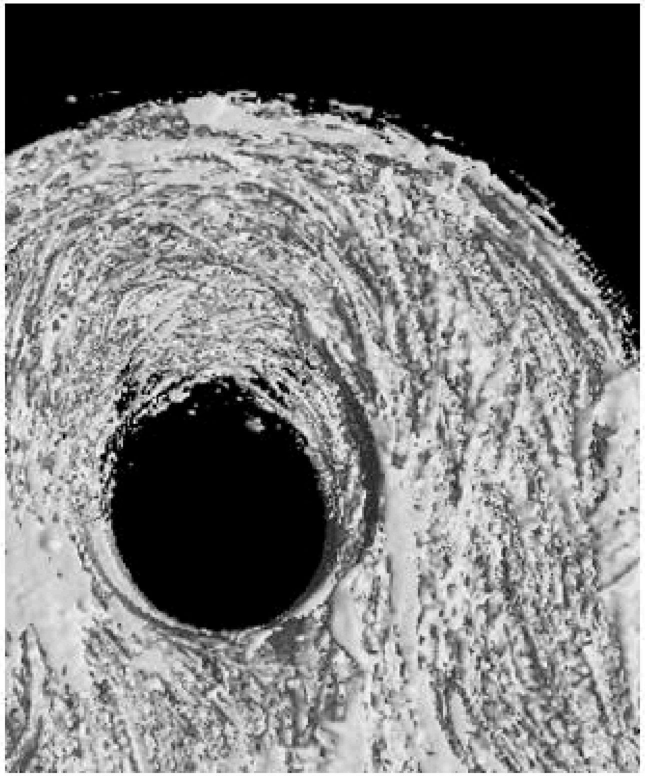
Testing performed by Hunter Lee, Structural Engineer & Dr. Ed Silverman, NG Fellow of the Northrop Grumman Space Systems Division

Bracket Study



Fiber Optimized Complex Parts

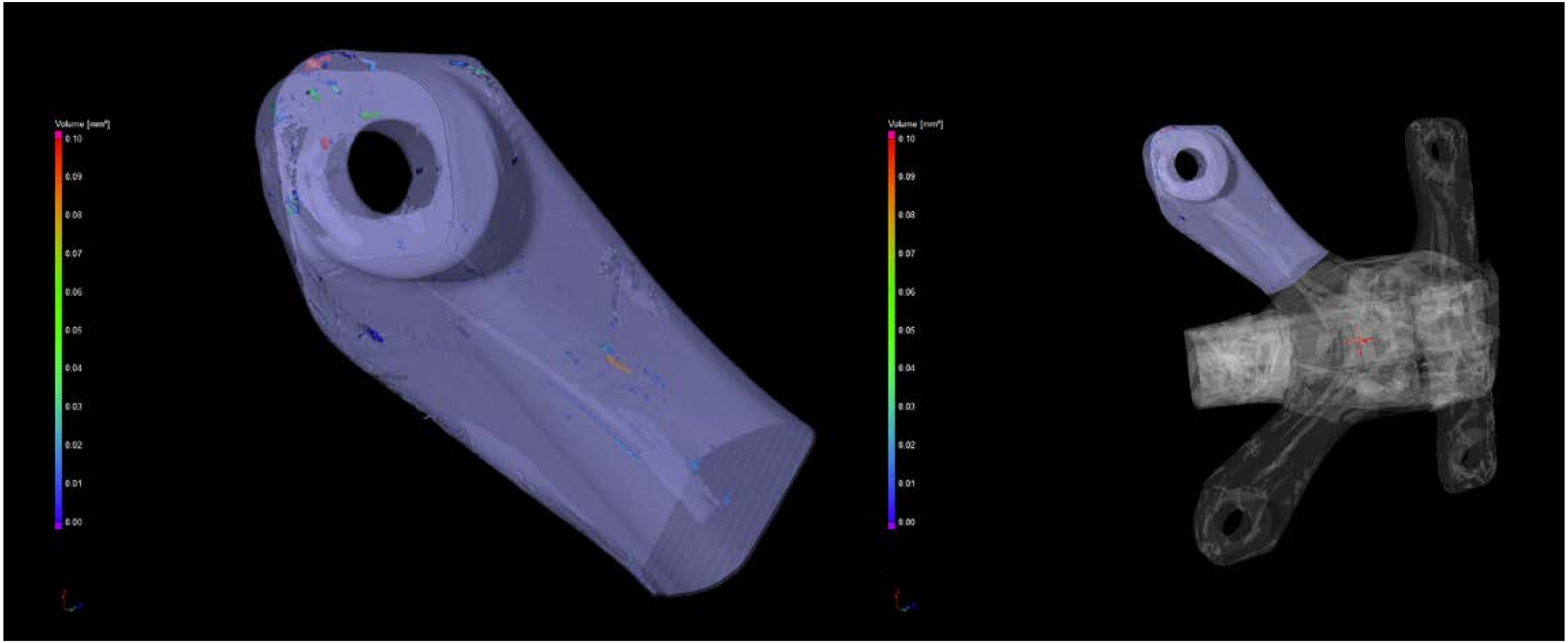
Additively Molded Topology-Optimized Continuous 3D-Aligned Carbon Fiber Bracket



CT Scan of Fastener Hole

CT Scan of Bracket Leg

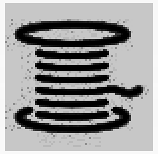
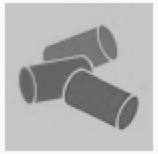
Aerospace Quality Composites
Analysis Shows <0.5% Voids

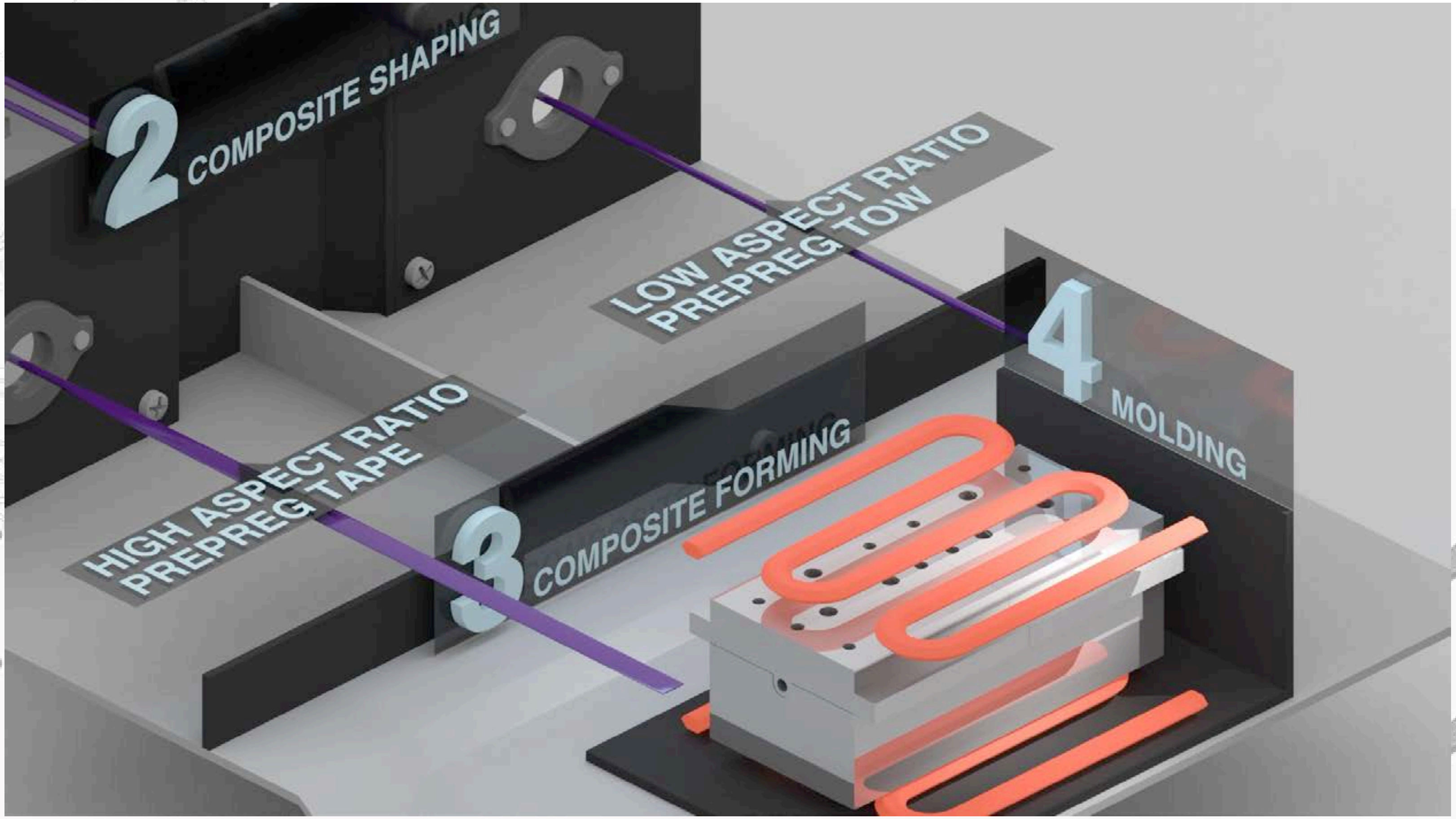


Additive Molding^{TM}

Highest Strength-To-Stiffness, Complex Geometries, Scalable

Additive Molding™
Animation



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Advanced Materials Toolbox

Products may consist of multiple zones of dissimilar materials.

- **Weight & size reduction**
- **Reduced part count**
- **Fewer failure modes & process steps**
- **Multiple functions**

Material	Function
Carbon Fiber *	High strength-to-weight ratio (electrically & thermally conductive)
Glass Fiber *	Circuit board (electrically insulative
Kevlar / Plastic Fiber *	Flexures & ultra-tough features, etc.
Thermoplastics	High quality surfaces & wide range of properties
Metal	Ductility, shape memory fiber *
Wire	Electrically conductive
Embedded Electronics	Sensors, antenna, power, battery, fiber optics, circuits

* Fibers mixed with a matrix material (typically thermoplastic)

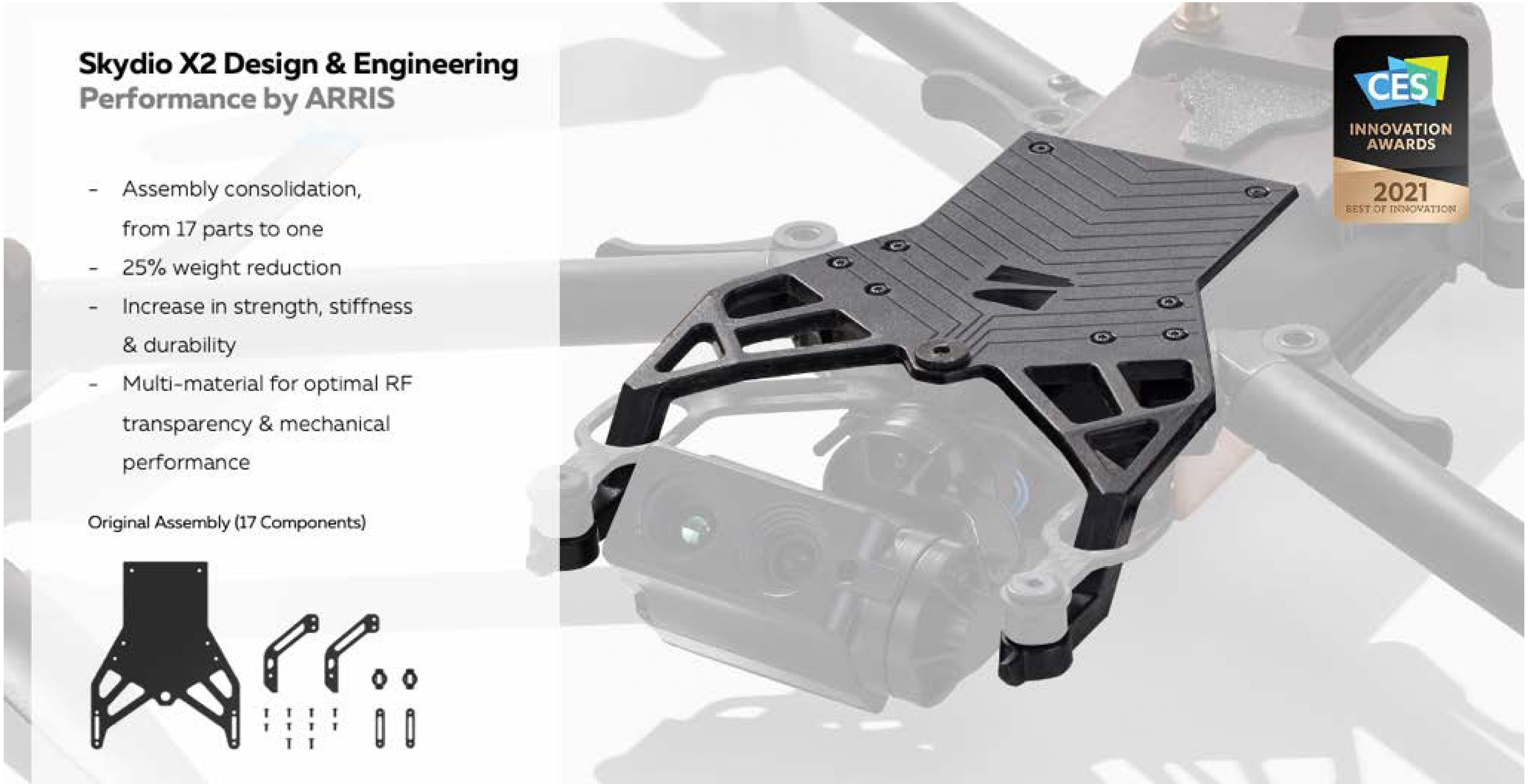
Additive Molding™
Multi-Material = Multi-Functional

Mechanical	Functional	Electrical / Thermal
Tough Zone	Embedded Electronics	Thermal Insulator / Conductor
Wear Zone	Metallic Inserts	Electrical Insulator / Conductor
Stiff Zone	Ruggedized / Corrosion Proof	EMI Shielding / Transmitting
Strong Zone	Vibration Dampening	Structural Health Monitoring
	Lightweight	

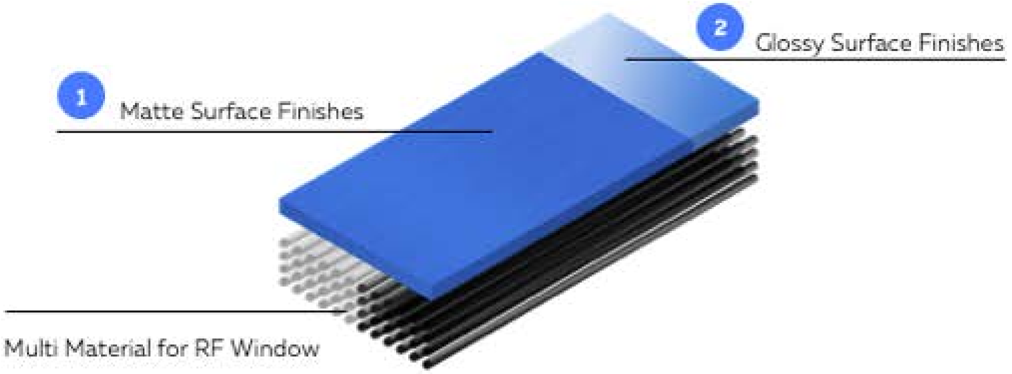
Part Examples

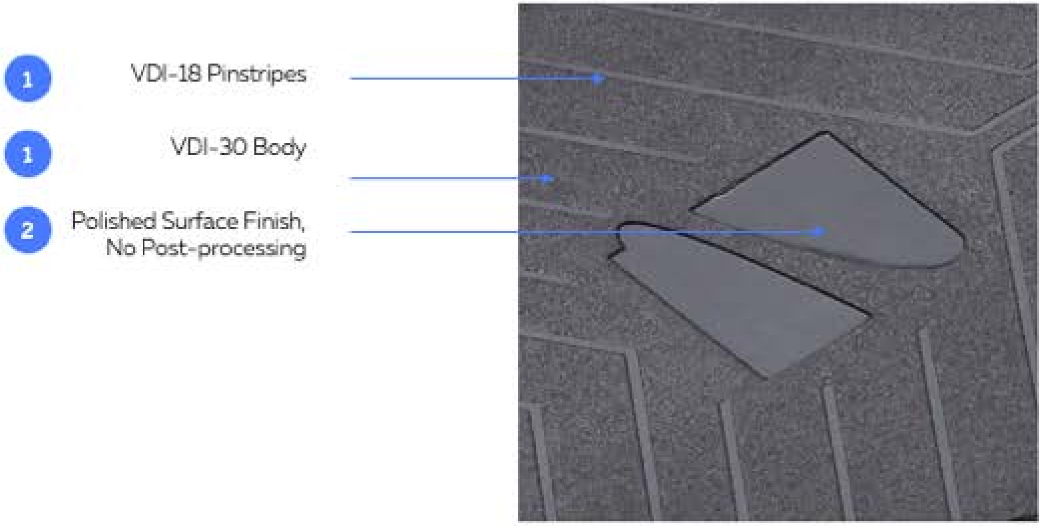
Additive Molding™

Featured Customer Example



Featured Customer Example





REDUCTION IN CO_2 EMISSIONS

CABIN BRACKET & OVERHEAD STOWAGE BRACKET

Conventional Part
220 G

VS

ARRIS Part
50 G

MORE THAN 75% WEIGHT REDUCTION

At 500 brackets per plane and 100 planes per year…

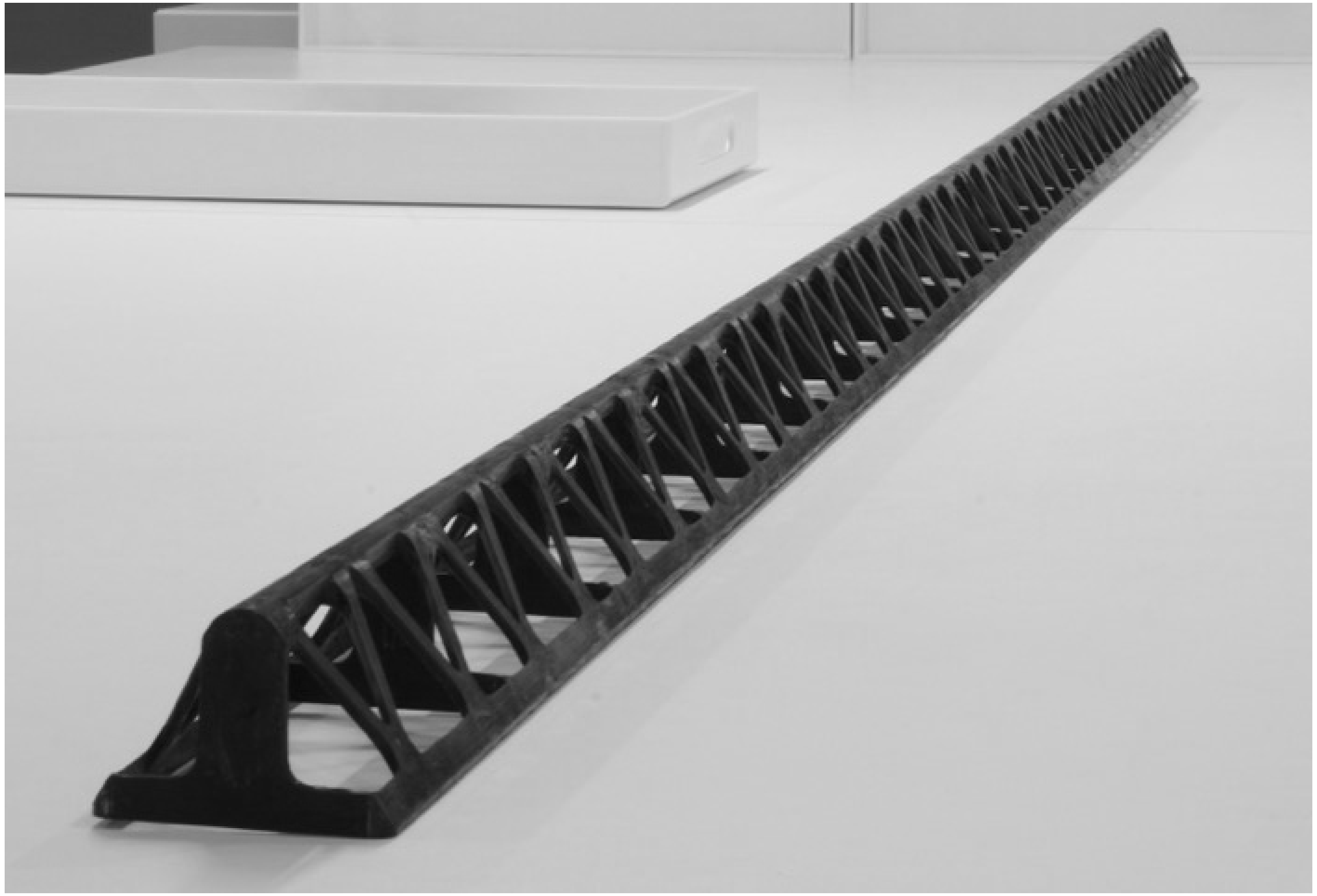
50,000 brackets made per year which contributes to 113M metric tons of fuel saved over the lifetime of airplanes…

That's 357M metric tons less CO_2 emissions.

THIS IS THE EQUIVALENT OF 22M US PERSONS EMISSIONS IN A YEAR.

WATCH VIDEO | READ PRESS RELEASE

Carbon Fiber + Polycarbonate: Part Examples



Aerospace Applications

Weight critical applications requiring high strength and stiffness

- High performance vehicles, especially EVs
- Typically >$10/kg value in weight savings
- Especially unsprung, rotating, and high center-of-gravity mass

Design critical applications

- Complex loading scenarios
- Joining structures
- Small/thin features

Volumes typically 10k to 1M parts per year

Part Size

- Current - 360 x 250 x 150 mm (14 x 10 x 6 inches)
- Q3 2022 – Large structure system

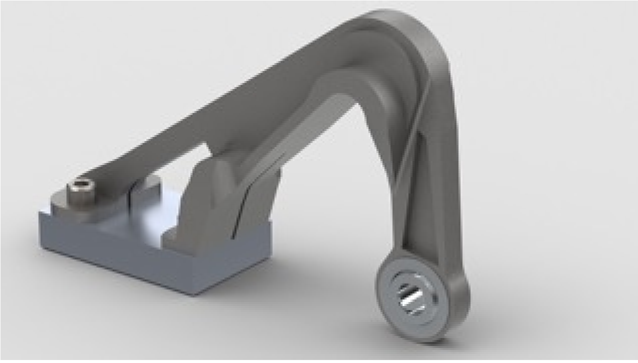
Current manufacturing methods to replace with Arris

- Forged, Die-cast, Machined: Magnesium, Aluminum, Steel, Titanium
- Laminate or infusion: Carbon Fiber + Epoxy
- Especially, Complex/Expensive assemblies of above parts

Assemblies which can be consolidated by leveraging design freedom of molding and capability to integrate:

- Electronics
- Metal inserts
- High-load and energy absorbing structures
- Innovative ID

Sustainability premium for lightweight, recyclable, bio-based composites.



Thank You

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riley@arriscomposites.com