

**'TORAY'**  
Innovation by Chemistry

**Partnering for success –  
Advanced composites enabling  
eVTOL scalability**

March 2, 2022

**Raoul Starmans – Segment Manager General Aviation EMEA**



# AAM the next Mobility Revolution

1903



2023



[aamrealityindex.com](http://aamrealityindex.com)

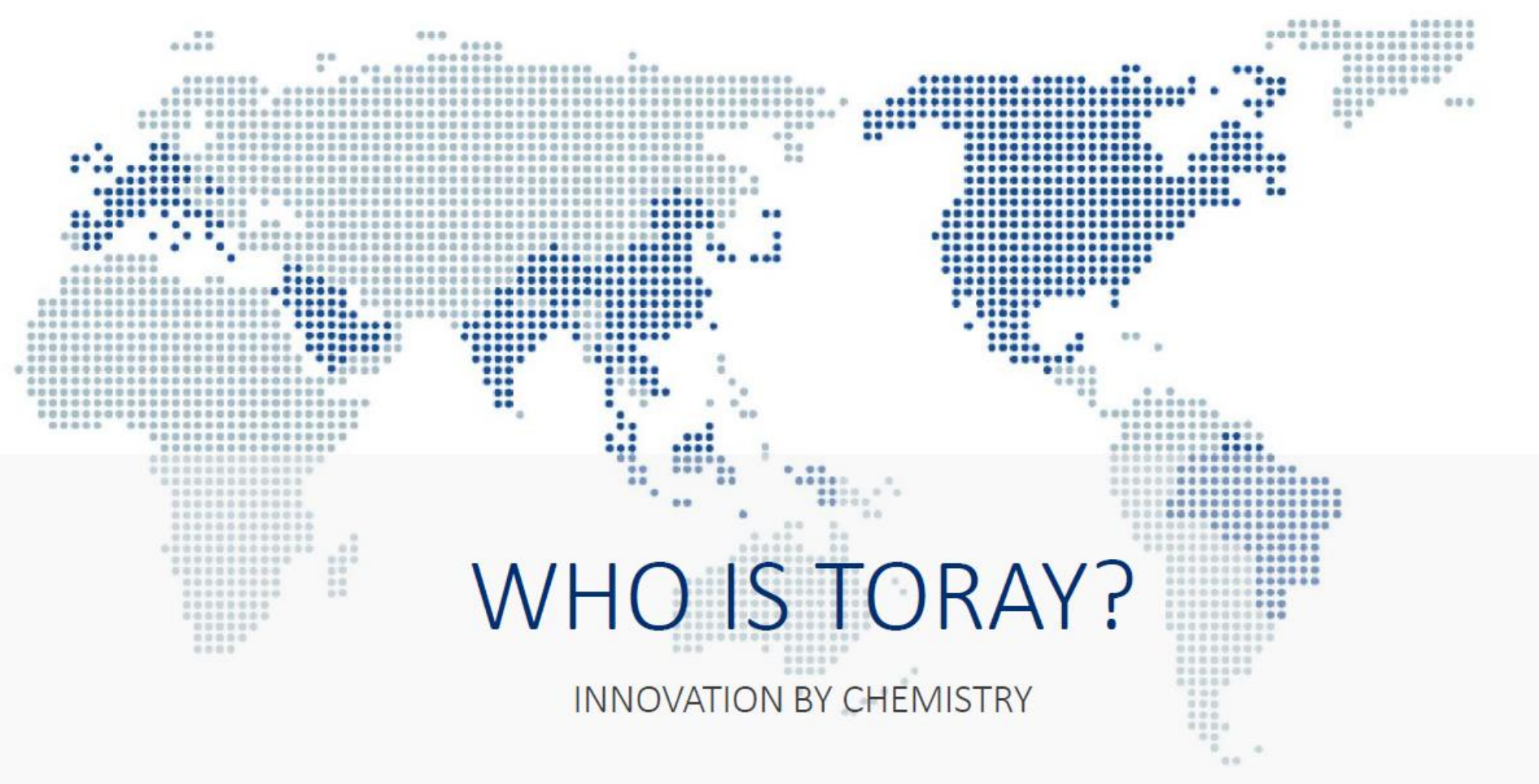
- AAM Infrastructure / Vertiports
- Social Acceptance
- Air Space Regulations
- Vehicle Design / Build & Qualification → **Toray**





## AGENDA

- **Toray Company Overview**
- UAM Market Drivers
- Partnering for Success
- Product Portfolio
  - UAM Material Solutions
  - Database Materials
  - Tooling Prepregs
- Sustainability



# WHO IS TORAY?

INNOVATION BY CHEMISTRY

## BUSINESS DIVISIONS

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- Fibers and Textiles
- Performance Chemicals
- Carbon Fiber & Composites
- Environment & Engineering
- Life Sciences

FOUNDED  
**1926**

OPERATING  
COUNTRIES  
**29**

SUBSIDIARIES &  
AFFILIATES  
**275**

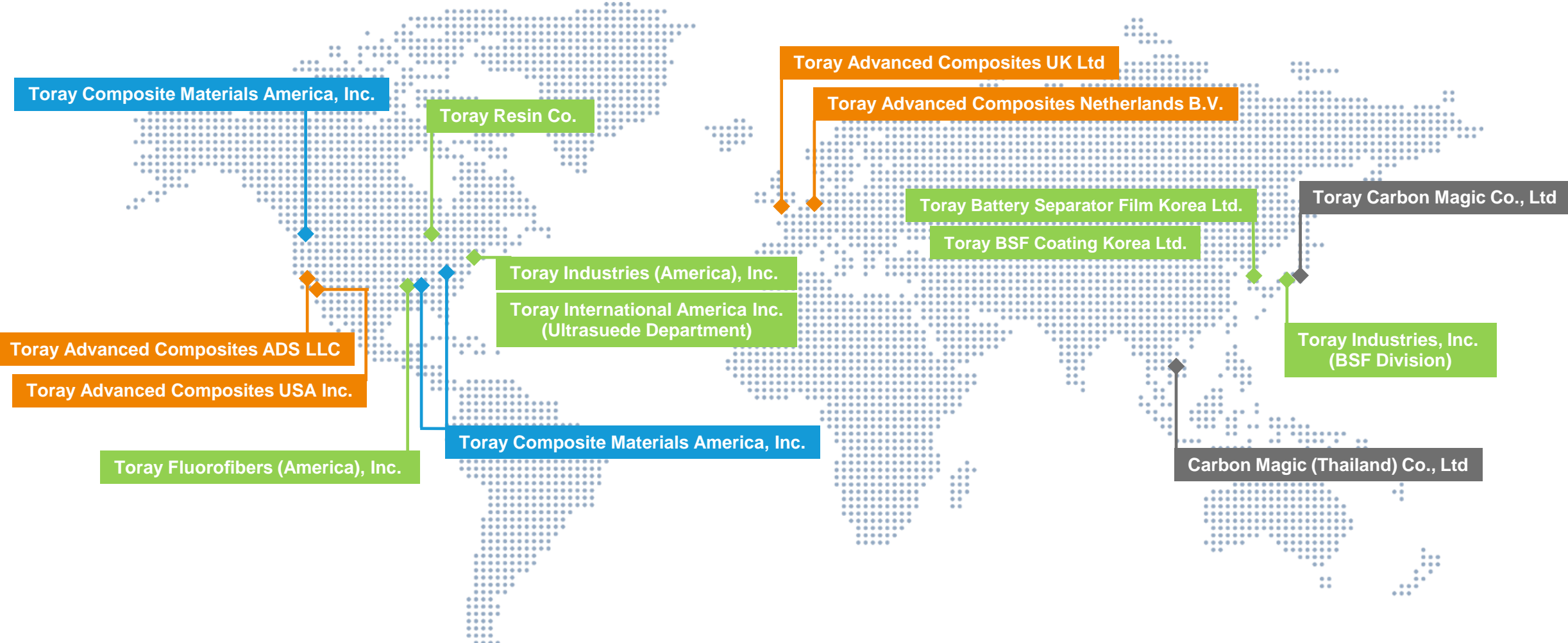
2021 ANNUAL  
REVENUE  
**\$21B**

EMPLOYEES  
**48,320**



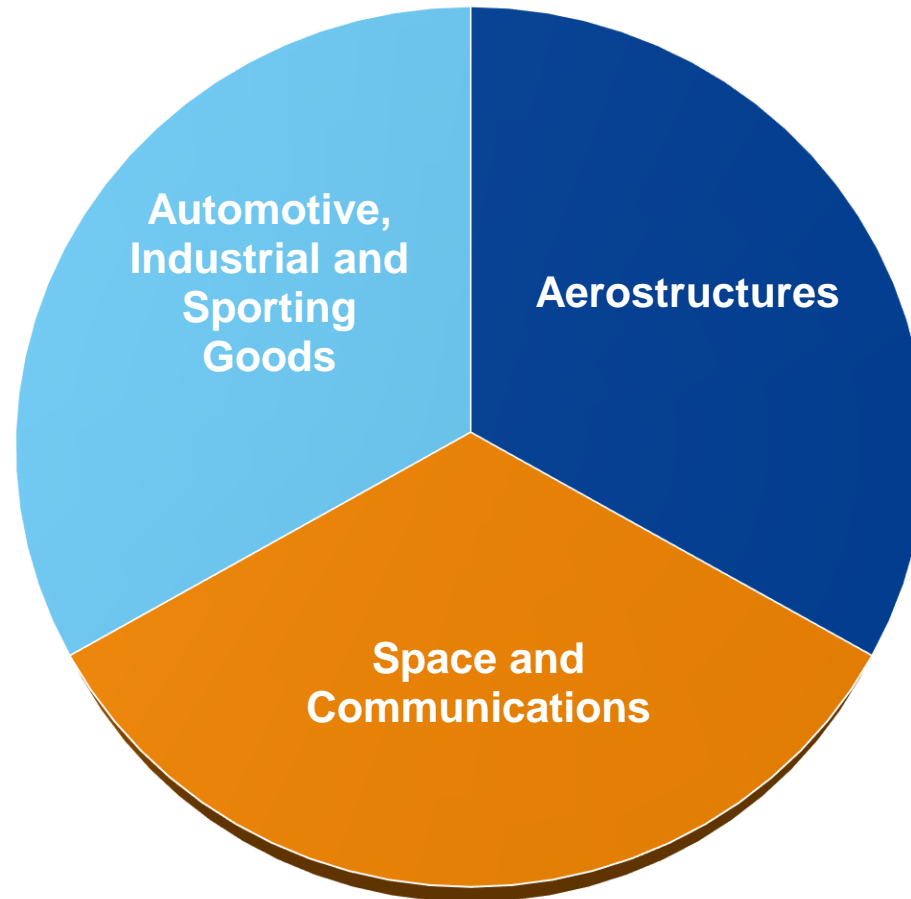
# Team Toray on eVTOLs

## Global AAM/UAM Network



# Market Segments and Key Customers

Well diversified customer base, supplying the world's leading brands with advanced materials



# Toray supports a broad section of the Aerospace Industry



Commercial Aviation



Regional Aviation



General Aviation



Vertical Lift



UAM eVTOL





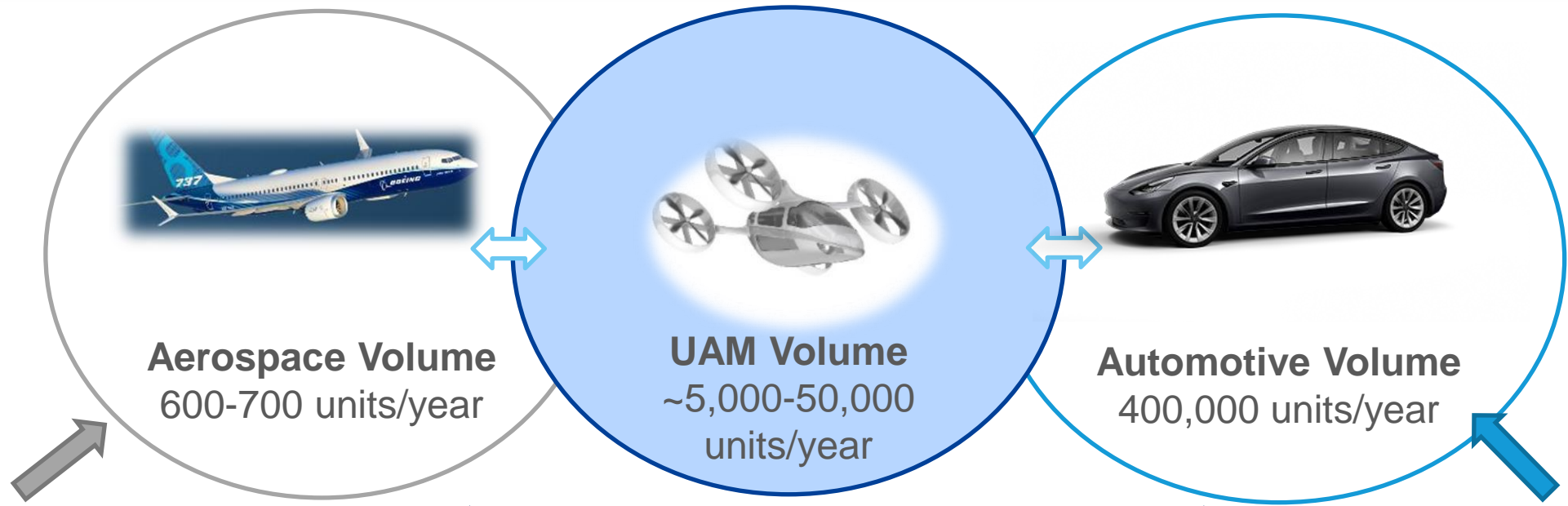


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- Manufacturing Process Review



# Current and Future Needs of UAM eVTOL Market



**Aerospace Volume**  
600-700 units/year

**UAM Volume**  
~5,000-50,000 units/year

**Automotive Volume**  
400,000 units/year

- Hand Layup (*slow*)
- AFP/ATL (*medium-fast*)
- Vacuum Bag Only (*slow*)
- Bladder Molding (*slow*)
- Autoclave (*medium*)
- Press Molding (*fast*)
- Extrusion/Pultrusion (*fast*)

**UAM Materials & Process Requirements:**  
Flexible materials that allow...

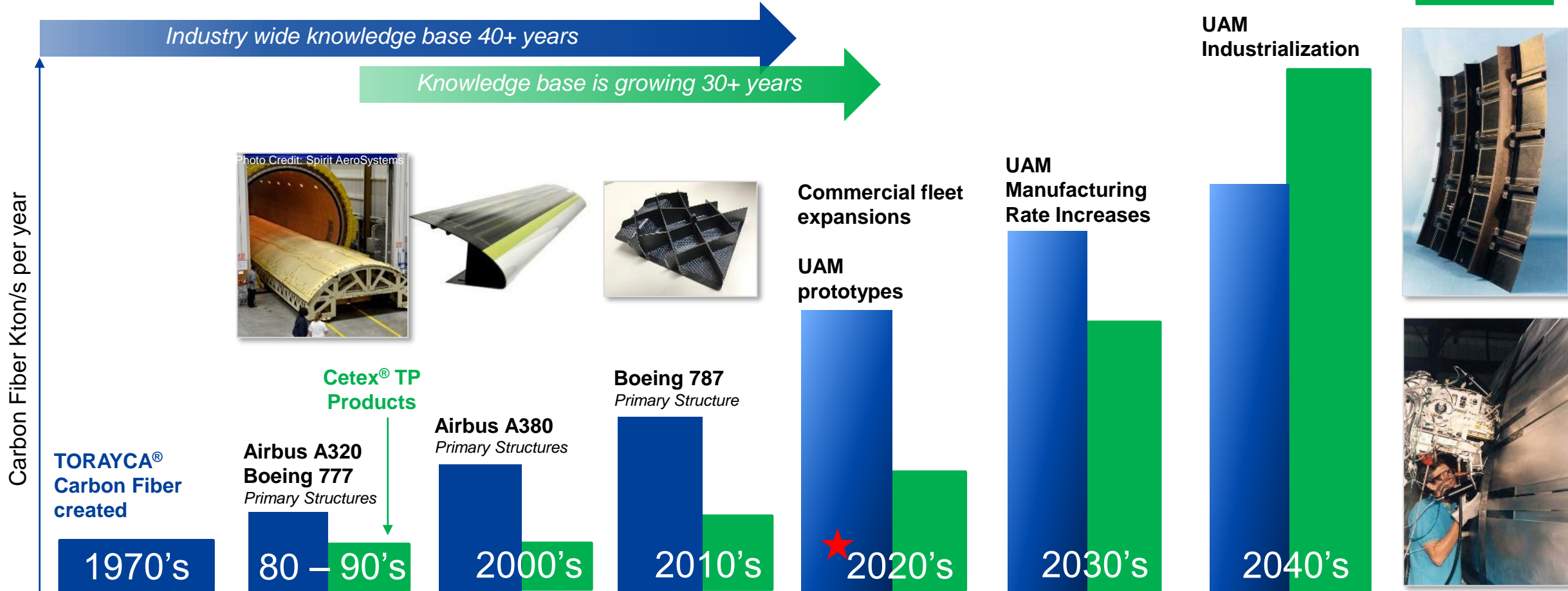
- **Prototypes & LRIP:** HLU/OOA
- **High volumes:** Automation and Molding

**Thermoplastics, High-Rate Molding (press injection), Snap Cure**

- Injection Molding (*fast*)
- Stamp Molding (*fast*)
- Press Molding (*fast*)
- Robotic "Pick & Place" (*fast*)
- High Pressure RTM (*fast*)
- Extrusion/Pultrusion (*fast*)
- Metal fabrication (*fast*)

# Advanced Carbon Composites in Aerospace

- Increasing use in all aircraft – lightweight, strong, durable
- Essential with electric/hybrid power for minimizing weight







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# UAM Material Selection Process

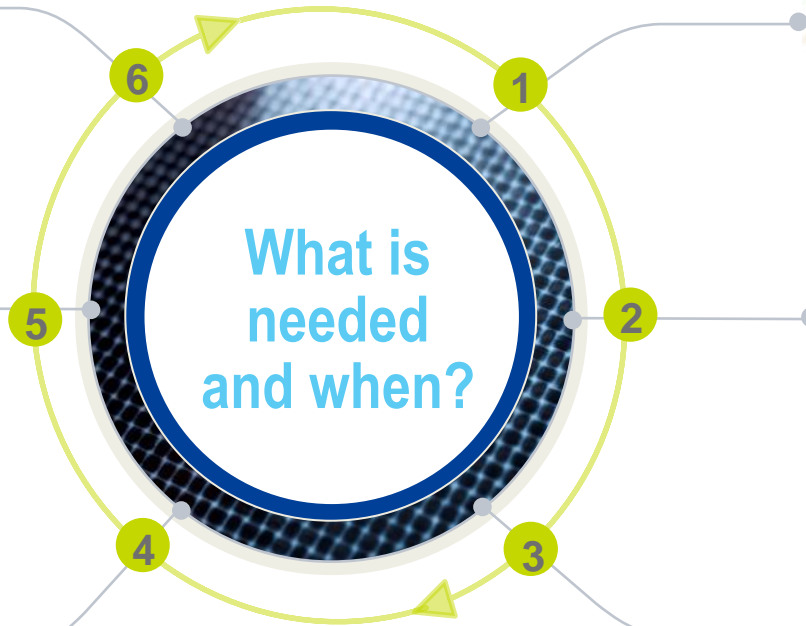
**Certification**



**Databases/  
Qualification**



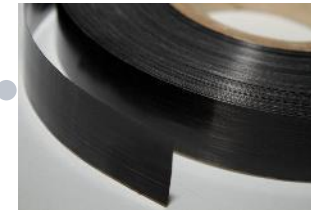
**Adaptable  
Process  
Technology**



**Material  
Supplier  
Partnership**



**Material &  
Process  
Selection**



**Prototyping**





# Why Toray Advanced Composites for your UAM project

TORAY — Your AAM *Material* Partner





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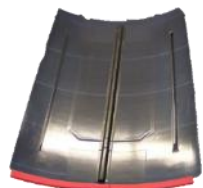
# Advanced Composite Material Technology

## Light and Strong Primary Structures

### PRODUCTS

- Thermoset Prepregs
- Thermoplastic Prepreg/Laminates
- Thermoset Ancillary Products
  - Film Adhesives
  - Surfacing Films
  - Syntactic Foams
  - Aerospace RTM Resins
  - Lightning Strike (LSP) solutions
- Tooling Prepregs
- TS & TP Molding Compounds
- Compression Molded Parts

### SOLUTIONS



Fuselage Panel  
Cf/LMPAEK



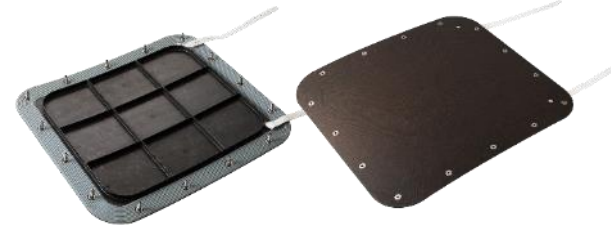
Fuselage Structure  
Cf/Epoxy



TPC Compression  
Molded Parts



Lightweight TPC Seating Structure  
Cf/PPS UDPP – Gf/PEI FPP

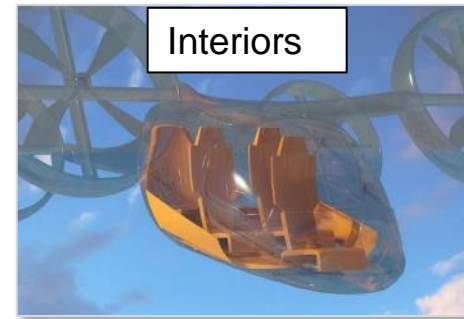


Cf/Epoxy Compression Molded Hatch



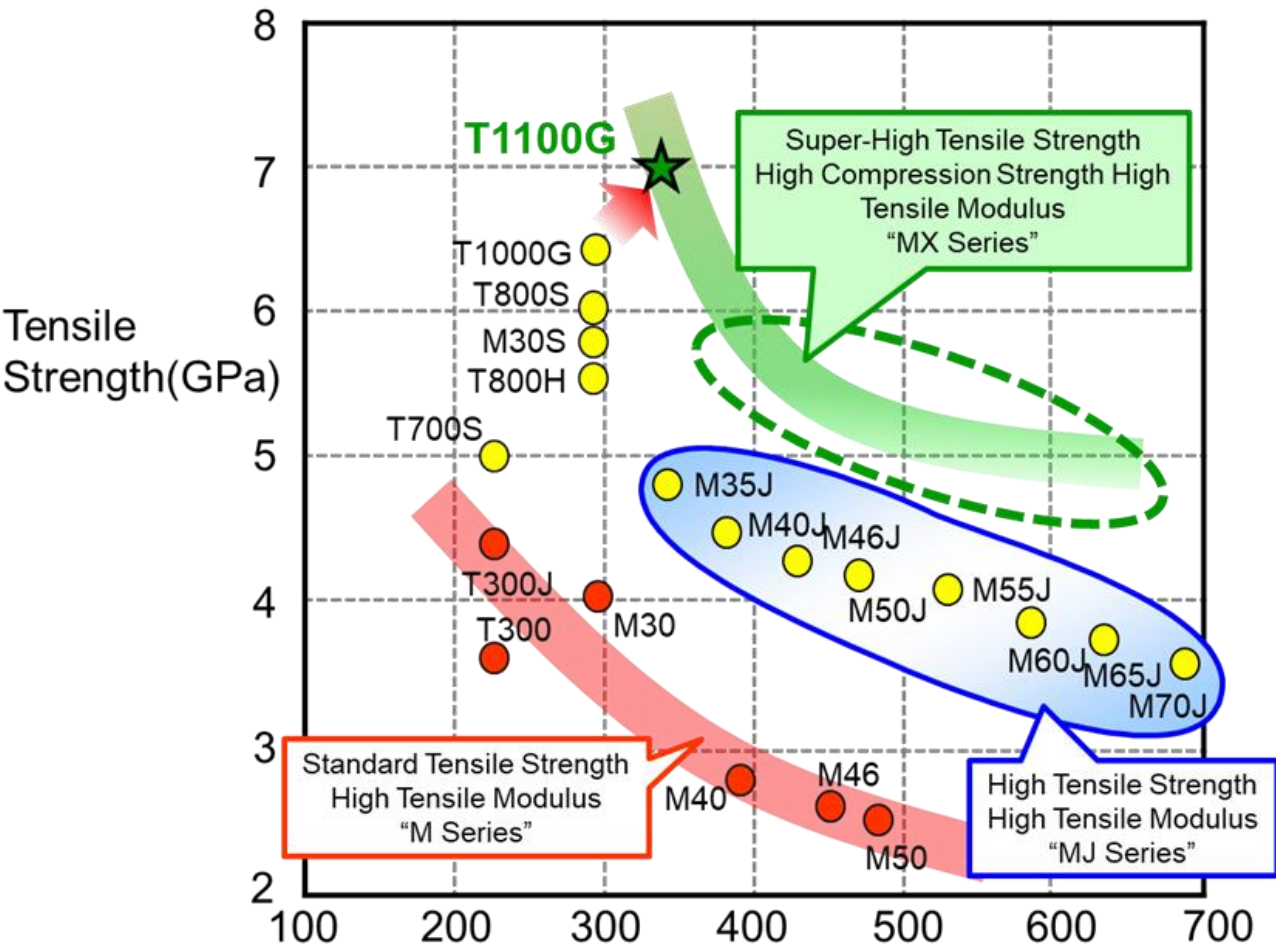
Compression Molded  
Parts with integrated  
LSP Foils

### APPLICATIONS



**Cetex<sup>®</sup>**  
**AmberTool<sup>®</sup>**  
**MicroPly<sup>™</sup>**

# TORAYCA® Carbon Fibers



**T1100 Carbon Fiber- Breakthrough Technology**

- High Volume Production Capabilities
- Active Qualifications in Multiple Markets
  - Prepreg Reinforcement
  - Filament Winding COPV's
  - Additive Manufacturing

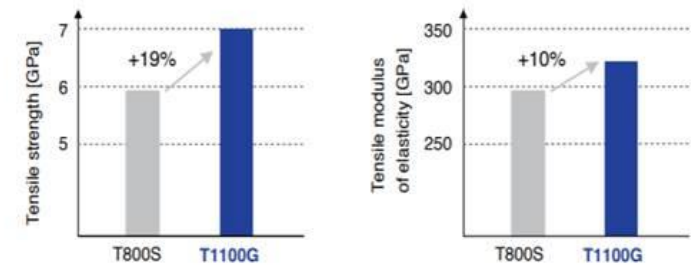


Figure 1. T800S vs. T1100G comparison of tensile strength/modulus of elasticity

Item	T1100G	T1000G	T800S
Tensile strength [GPa]	7.0	6.4	5.9
Tensile modulus of elasticity [GPa]	324	294	294

Table 1. Characteristics of tensile strength and modulus of T1100G

Diverse Portfolio with Industry leading Performance

**Lighter Weight Airframes = Extended Range / Increased Payloads**



# Composite Material Choices

What to consider when selecting a composite material:

## Design Drivers

Operating Environment  
(e.g. - Hot/Wet Temp)  
Key Properties  
(e.g. - OHC, CAI, etc.)

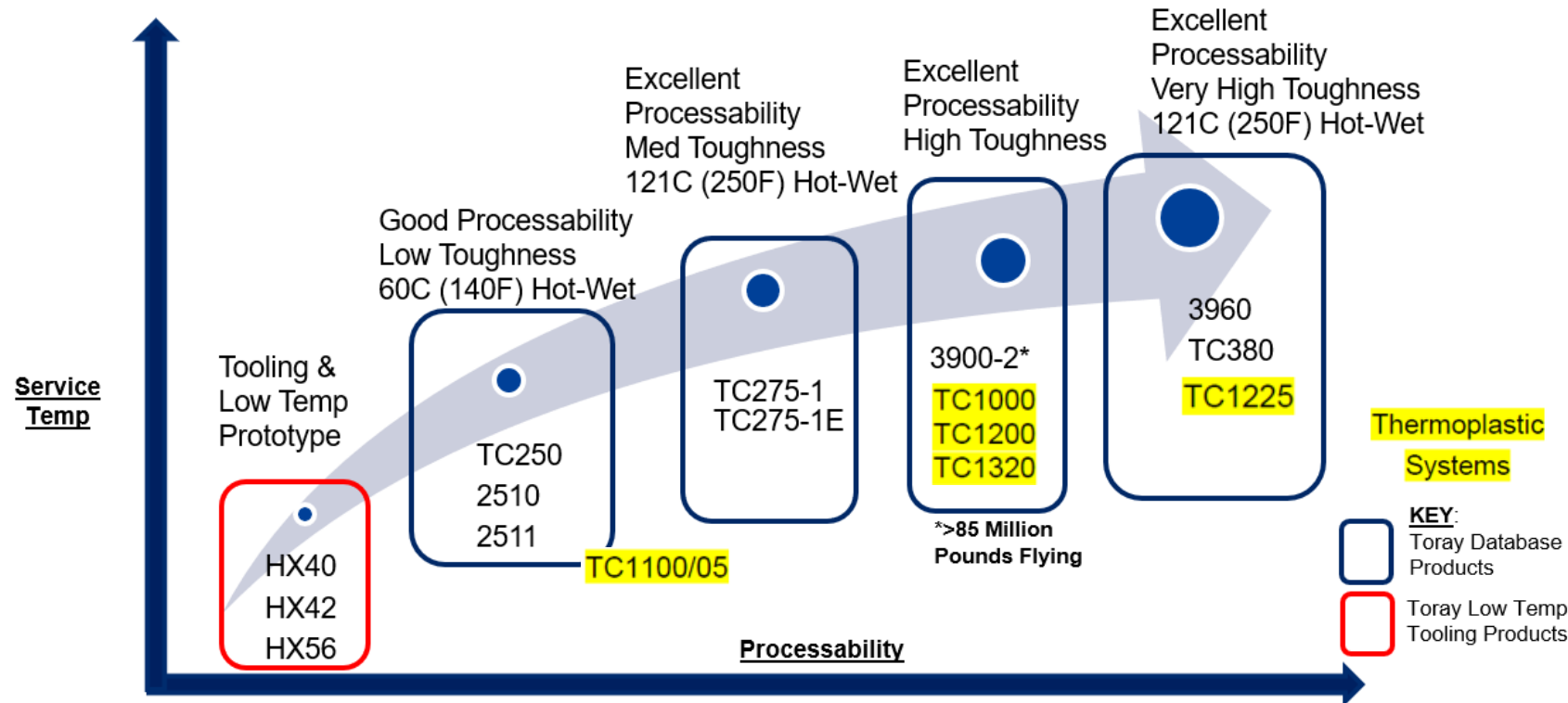
## Database Type

Public/Private  
A-Basis/B-Basis  
Properties tested

## Manufacturing Process

Vacuum Bag  
Autoclave  
Press Forming, AFP, etc  
Sandwich Structure

## Toray Product Options



Materials must be tuned for both performance ... and the production system

# Toray Composites PUBLIC Material Database Products

Product	Std Mod Carbon		Int Mod Carbon		Int Mod+ Carbon		Glass	
	Tape	Fabric	Tape	Fabric	Tape	Fabric	Tape	Fabric
BT250E-6	-	xxx	xxx	-	-	-	xxx	-
TC275-1	xxx	xxx	-	-	-	-	-	-
2510	xxx	xxx	-	-	-	-	-	xxx
2511	-	xxx	-	-	-	-	-	-
TC380	-	-	-	xxx	xxx	-	-	-
3900	-	-	xxx	xxx	-	-	-	-
3960	-	-	-	-	xxx	xxx	-	-
TC1225	xxx	-	-	-	-	-	-	-



250/275F Cure Thermosets

350F Cure Thermosets

Thermoplastic



# Toray Aerospace Thermoplastic Materials

## HIGH PERFORMANCE THERMOPLASTIC COMPOSITE MATERIALS

● UD tape    ● Fabric prepreg    ● Laminate    \* Laminate parts



### High performance thermoplastics

High operating temp

TC1320, PEKK

**NEW TC1225, Engineered PAEK**

TC1220 / TC1200, PEEK

TC1100, PPS

### Engineering thermoplastics

Mid operating temp

TC940, PET\*

TC910\* / TC912, PA6

### Standard thermoplastics

Low operating temp

TC960, PP

TC930, HDPE

TC920, PC/ABS

Increasing Price, Performance, and Processing

Amorphous

Semi-crystalline



### Major Benefits

- Toughness
- FST
- Chemical Resistance
- Rapid Processing
- Welding
- Overmolding
- Recycling

# Toray Material Portfolio for eVTOLs

## STRUCTURAL MATERIALS

<p><b>Primary Structures</b>  <b>Propulsion System</b>  <b>Panels &amp; Covers</b>  <b>Communication</b></p>	<p><b>TORAYCA®</b> Carbon Fiber                  Thermoset Prepreg  <b>CETEX®</b> Thermoplastic  <b>AMBERTOOL®</b> Prepreg  <b>MICROPLY™</b> Adhesives &amp; Syntactics  <b>BMC</b> Bulk Molding Compounds</p>
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## EXTERIOR

<p><b>Platform Protection</b>  <b>Millimeter-Wave Radar</b>  <b>Window Film</b>  <b>Front Bumper (nose)</b>  <b>Sensor Covers</b></p>	<p>Epoxy Surfacing Film  <b>PICASUS™</b> Nano-Layered Film  <b>Lumirror™</b> Polyester Film  <b>Teflon™</b> PTFE Fiber</p>
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## POWERTRAIN

<p><b>Battery Racks/Boxes</b>  <b>Thermal Management</b>  <b>Electrical Cases</b>  <b>Bus Ring/Bar</b>  <b>Filter &amp; Cords</b>  <b>Drive Motor Insulator</b>  <b>DC/DC Converter</b>  <b>Battery Separator Film</b>  <b>Motor Insulating Film</b></p>	<p>Thermoset Prepreg  <b>CETEX®</b> Thermoplastic  <b>TORELINA™</b> PPS Resin  <b>TORCON™</b> PPS Fiber  <b>TORAYMICRON™</b> Fabric  <b>SETELA™</b> Separator Film  <b>Teflon™</b> PTFE Fiber</p>
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## INTERIOR

<p><b>Structures &amp; Reinforcements</b>  <b>Seat Fabrics</b>  <b>Console &amp; Cockpit</b>  <b>Trims &amp; Covers</b>  <b>Lighting</b></p>	<p>Thermoset Prepreg  <b>CETEX®</b> Thermoplastic  <b>ECODEAR™</b> Polyester Fiber  <b>PICASUS™</b> Nano-Layered Film  <b>Ultrasuede™</b> Fiber Fabric  <b>RAYTELA™</b> Optical Fiber</p>
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## ELECTRICAL

<p><b>ECU Case</b>  <b>Current Sensor</b>  <b>Touch Panel</b>  <b>Display</b>  <b>IR Sensor</b></p>	<p><b>TORCON™</b> PPS Fiber  <b>TORELINA™</b> PPS Resin  <b>RAYBRID™</b> Photosensitive Paste  <b>Photoblack™</b> Black Ink  <b>Teflon™</b> PTFE Fiber</p>
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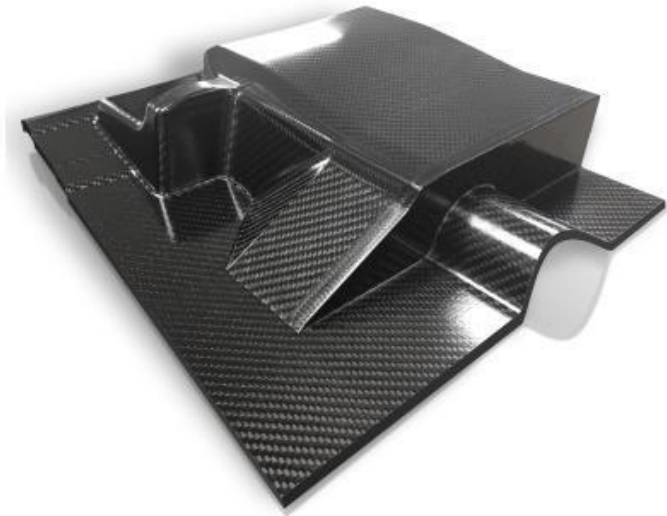
*Automotive + Aerospace Product Experience tailored for eVTOL needs*



# Toray Ambertool® Prepregs

*Composite tooling for low-cost prototyping and volume production*

	RESIN MATRIX	DRY T <sub>g</sub> ONSET (AFTER POSTCURE)	MIN CURE TEMP	TYPTICAL CURE TIME AND TEMPERATURE	KEY PRODUCT CHARACTERISTICS
HX40	Epoxy	203°C (397°F)	50°C (122°F)	12 hours at 65°C (149°F)	▶ Large tooling applications
HX42	Epoxy	200°C (392°F)	50°C (122°F)	60°C (140°F)—8 hours	▶ Proven system for aerospace ▶ Excellent surface finish
HX56	Epoxy	185°C (365°F)	40°C (104°F)	50°C (122°F)—8.5 hours	▶ Improved handleability ▶ Excellent surface finish ▶ Excellent drape for complex shapes

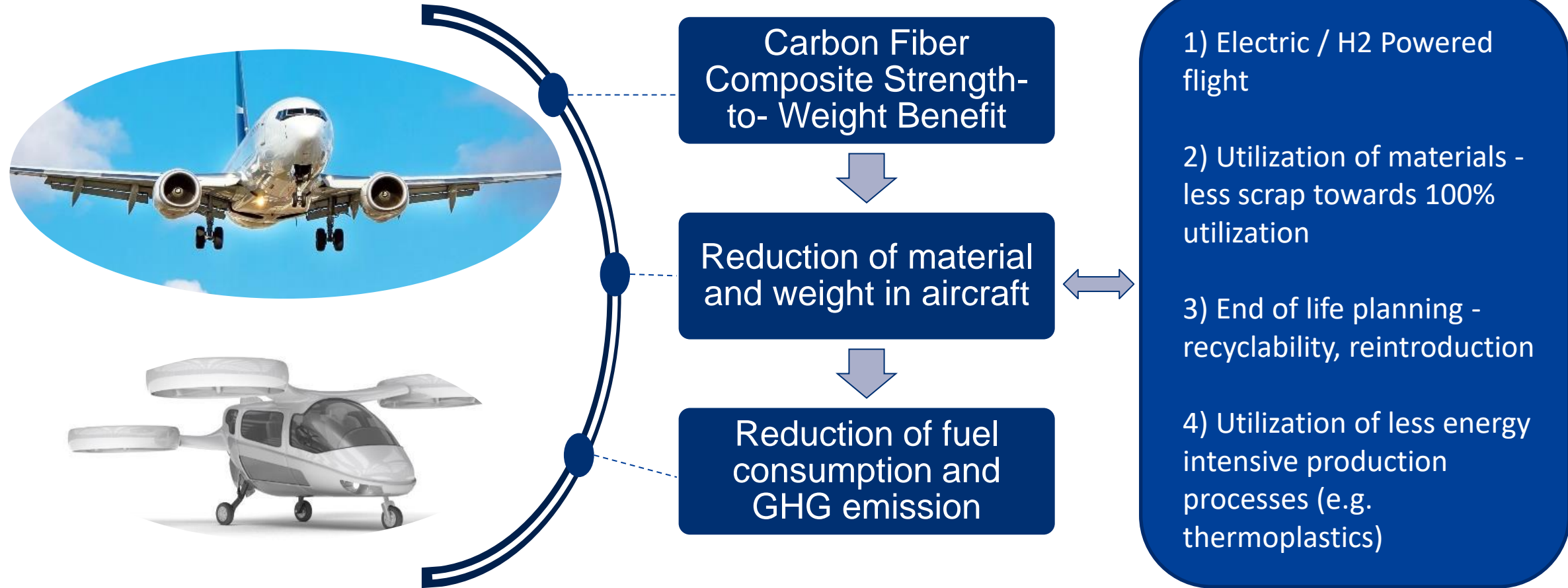


## Typical Laminate Construction ( approx. 5.2mm thick )

Fiber Areal Weight	Tow count	Resin content (wt)	Plies/Laminate
205g	3K	35%	2
650g	12K	46%	8

# Toray Group is Committed to Sustainability

*Providing Technologies and Advanced Materials to Help Address Global Issues*



**Innovative Light weighting Materials Providing Sustainable Solutions**





# Contact Information

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