



# Linear Polyphenylene Sulfide (PPS) for Thermoplastic Composites

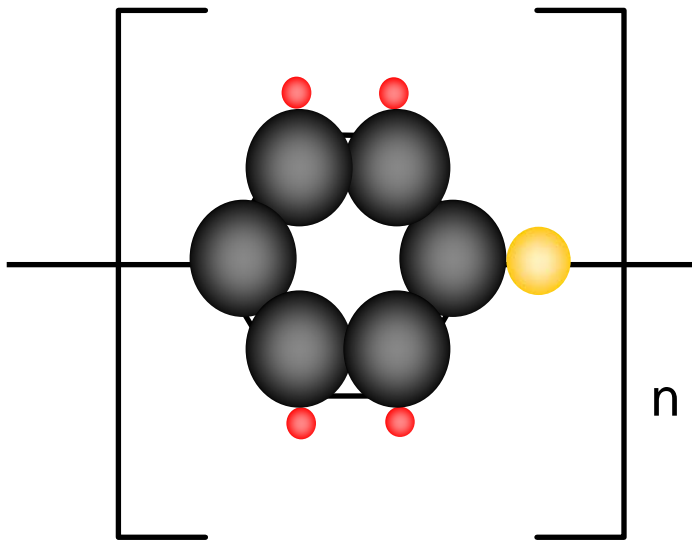
Harsh Bhagat  
Ticona Engineering Polymers  
September, 2008

# Contents

- Fortron® Linear PPS
  - Chemistry
  - Properties
- Long Fiber Molding Compounds
- Fortron® PPS Continuous Fiber Thermoplastic Composites
  - Processes and Applications
- Summary and Questions

# Fortron® PPS

## Summary – Structure and Properties



### **Polyphenylenesulfide (PPS)**

Poly(thio – 1,4 - phenylene)

- Linear, semicrystalline
  - Tg 85°C, TM 285°C
  - Density 1.35 g/cm<sup>3</sup>
- Inherently flame resistant
  - UL94-V0, LOI > 45
- Chemical resistance – dimensional stability
  - Fuels, oils, solvents
  - Water-glycol
- Easy to process
  - Injection molding
  - Extrusion

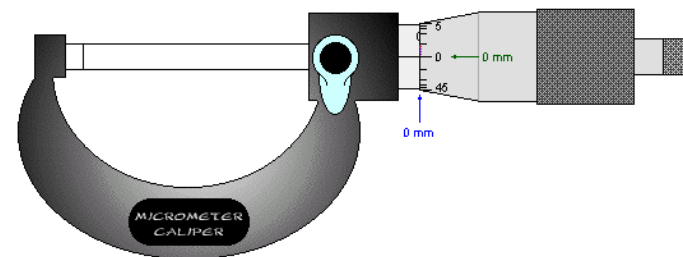
## Fortron® PPS Has No Known Solvent

- Chemical resistance with minimal attack or swelling even at elevated temperatures
  - Resists: acids/bases pH 2 to 12
  - Resists: strong bleaches
  - Resists: auto fluids – coolants, transmission & brake
  - Resists: gas & alternate fuels (methanol, ethanol)
  - Resists: hydrolysis



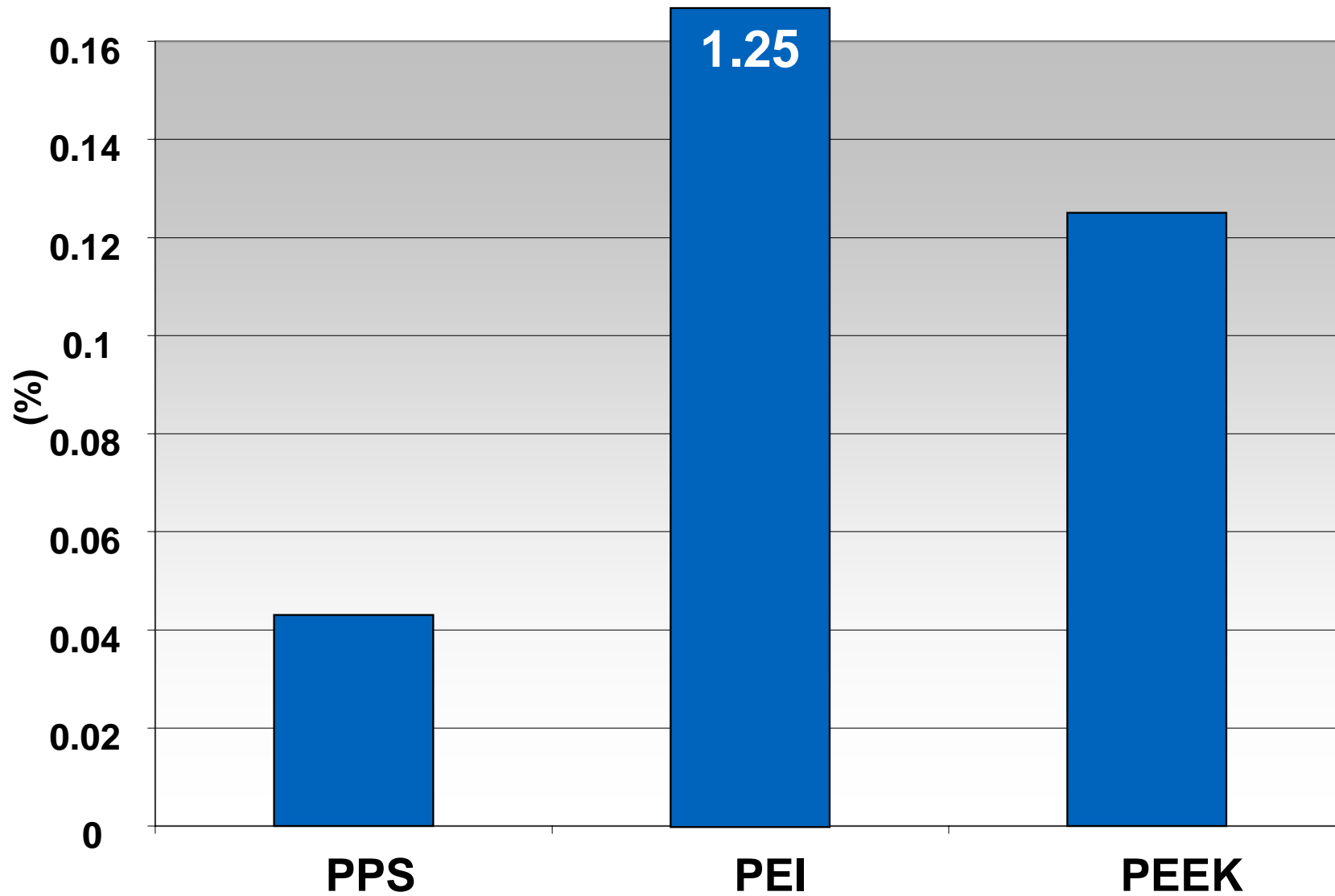
## Fortron® PPS Dimensional Stability

- Extremely low moisture absorption – 0.02%
- Minimal effect of temperature
- CLTE –  $19 \times 10^{-6} / ^\circ\text{C}$  (6165A4)
- Precision molding
- Low shrinkage – 0.3% (6165A4)
- Creep resistance



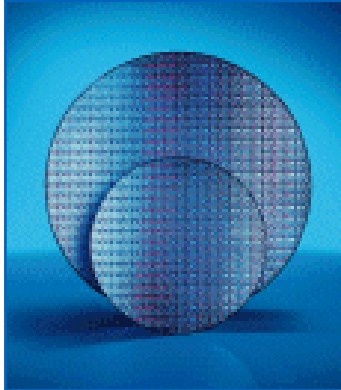
**For Precision Parts Even at Elevated Temperatures**

# Water Absorption



# Top Fortron® PPS Segments

**Semicon**



**Industrial**



**EE & Sensors**



**Fibers**



**Automotive**



**Composites**



# Fortron® PPS

## Automotive: Under the Hood

Throttle Body – 1140L4



Inlet Tank for CAC 1140L4



Water Pump 6165A6, 1140L6



Crankshaft Flange – 4332L6



Water Pump Impeller – 1140L4

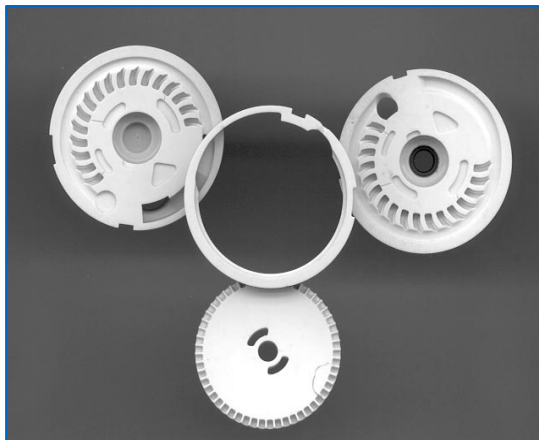
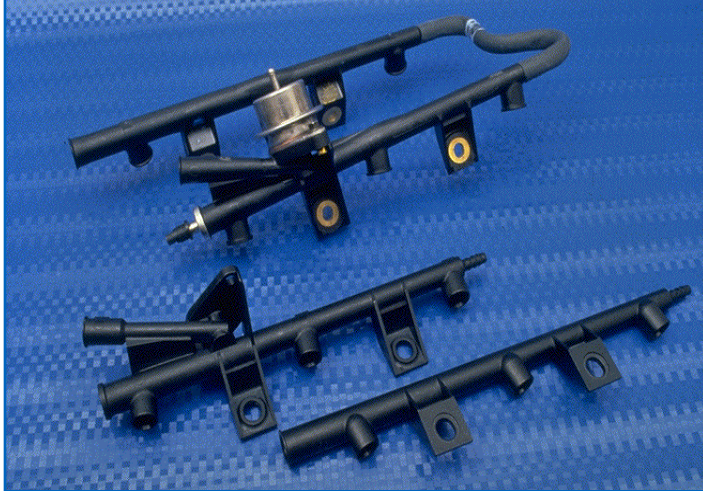




# Fortron® PPS

## Automotive: Fuel Applications

Fuel Injection Rail



Fuel Pump Parts

### Fortron PPS was selected for:

- Resistance to all sorts of fuels including auto-oxidized fuels up to 120°C
- Excellent mechanical and impact strength at elevated temperatures
- Inherently flame resistant (UL 94 V-0 down to 0.4 mm thickness)
- Lower specific gravity than metal
- Simplified fabrication by eliminating secondary operations

# Fortron® PPS 1140L4 Water Pump Impellers



- The challenge:
  - Improve pump efficiency
  - Decrease water pump cost
  - Improve fuel efficiency (Lower HP requirements)
- The innovation:
  - Exotic blade shapes improve pump efficiency by 10-20% vs. sheet metal
  - Fortron PPS has required chemical / hydrolysis resistance to OAT coolants
  - Excellent fatigue properties withstand pressure cycles
  - Excellent erosion resistance

# Fortron® PPS Injection Blow Molded Applications

## Hot Air and Corrosive Fluid Applications



**Diesel Engine Charge Air Duct  
15% Glass Fiber Reinforced Linear PPS**



# Long Fiber Molding Compounds



# Celstran® LFT Compared to Other Common Processes

## Advantages of Celstran Long Fiber Pellets vs. Short Fiber

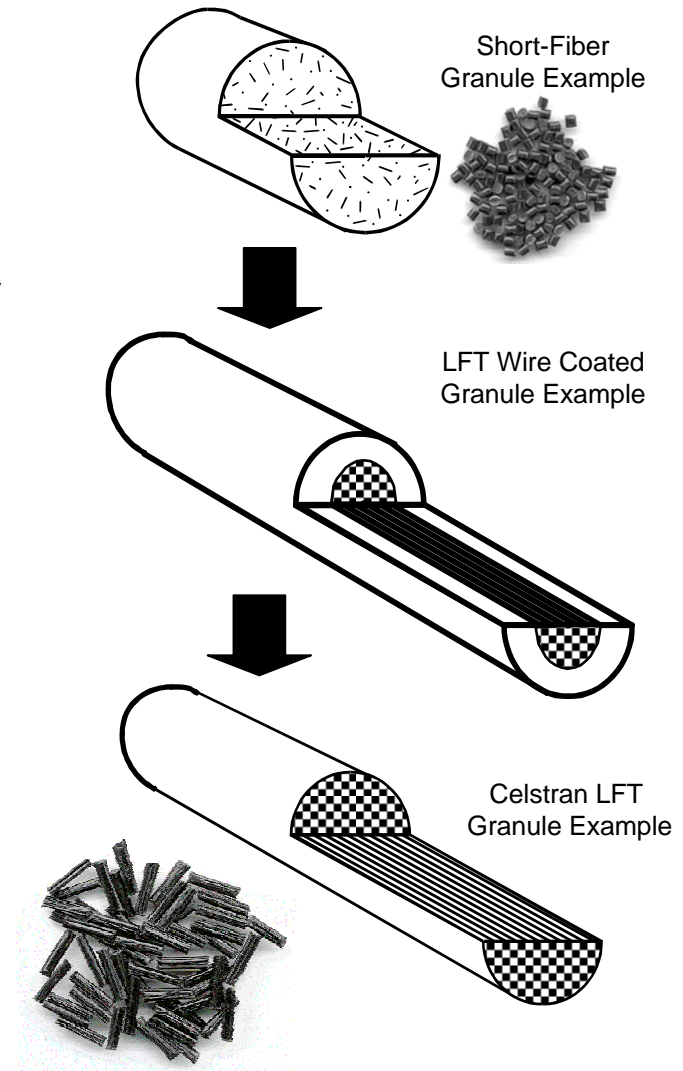
- Higher mechanical properties combined with significantly higher impact strength
- Reduced creep tendency
- Lower warpage and better dimensional stability

## Advantages of Celstran Long Fiber Pellets vs. Wire Coated Long Fibers

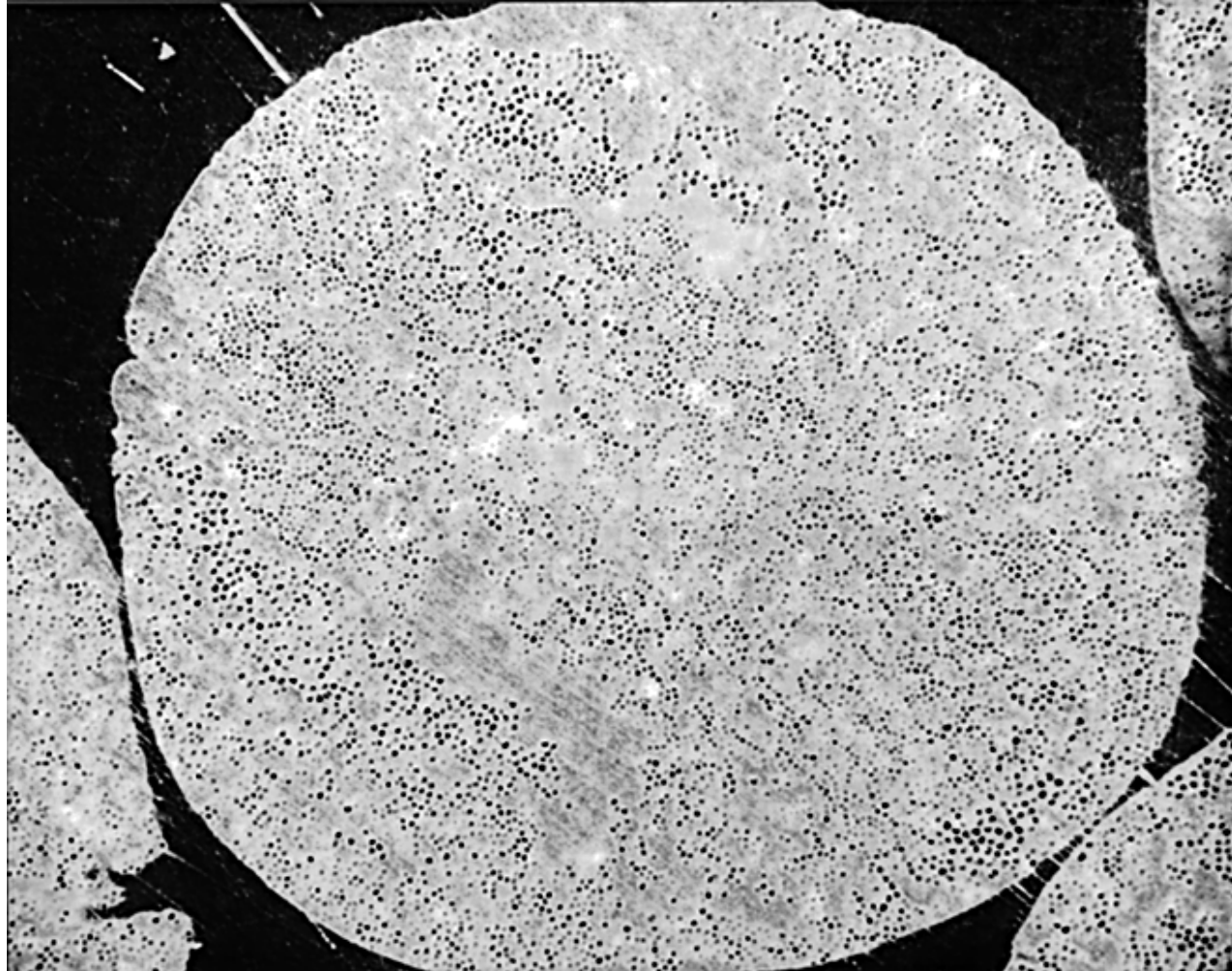
- More homogeneous fiber distribution
- Higher impact strength
- Better surface / part appearance
- Lower wear on cylinder and tool

## Celstran Granule Schematic

Note the uniform fiber distribution surrounded by polymer matrix throughout the whole pellet.



# Pellet Cross Section



# Celstran® Glass Fiber PPS Material Properties

Reinforced with Glass Long Fibers				Tensile			Flexural		Notched	Comp.	DTUL
Product Name	Resin	Fiber %	Specific Gravity	Strength psi x 10 <sup>3</sup>	Modulus psi x 10 <sup>6</sup>	Elong. %	Strength psi x 10 <sup>3</sup>	Modulus psi x 10 <sup>6</sup>	Izod ft-lb/in	Strength psi x 10 <sup>3</sup>	°F @ 264 psi
ASTM Method:			D-472	D-638	D-638	D-638	D-790	D-790	D-256	D-695	D-648
PPS-GF30-01	Polyphenylene	30%	1.52	23.9	1.91	1.3	33.2	1.68	5.9	33.7	490
PPS-GF40-01	Sulfide	40%	1.62	25.5	2.43	1.2	36.0	2.04	6.4	35.6	535
PPS-GF50-01		50%	1.72	25.6	2.93	1.0	38.4	2.51	6.9	33.6	540



# **Fortron® PPS for Continuous Fiber Thermoplastic Composites**



# Why Thermoplastic PPS Composites vs. Thermoset Composites?

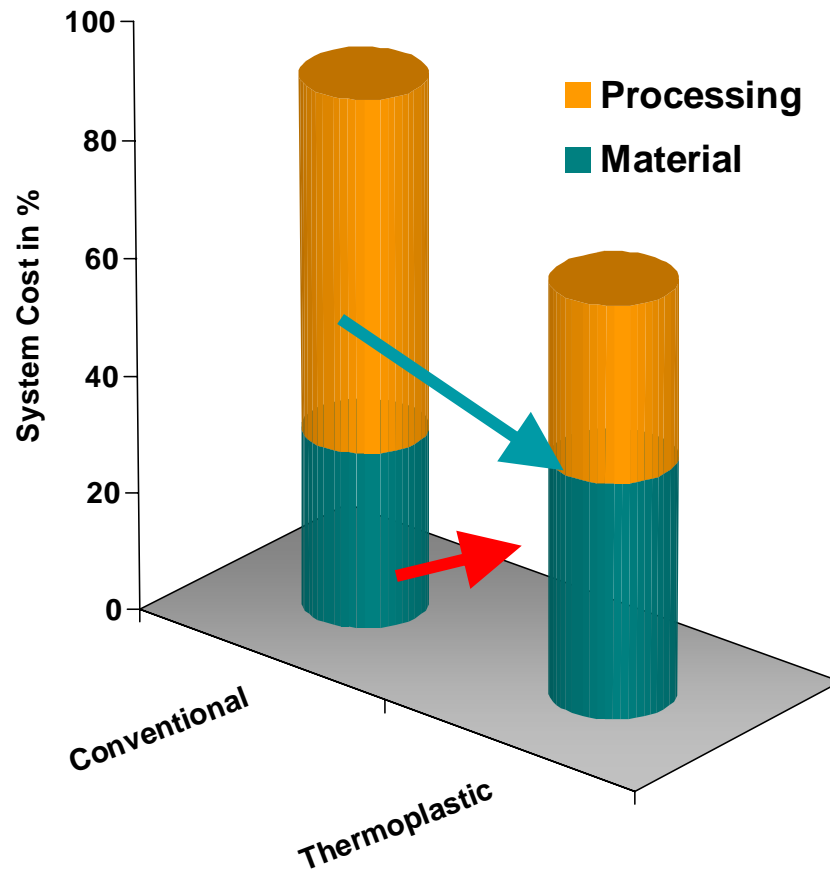
## Improved Properties

- Tougher, good fatigue performance
  - 4x tougher than toughened epoxies
- Damage tolerant
- Insensitive to moisture
- High temperature performance
- Very low flammability, smoke, toxicity
- Low residual stress in molded parts
- Excellent chemical resistance

## Improved Processing

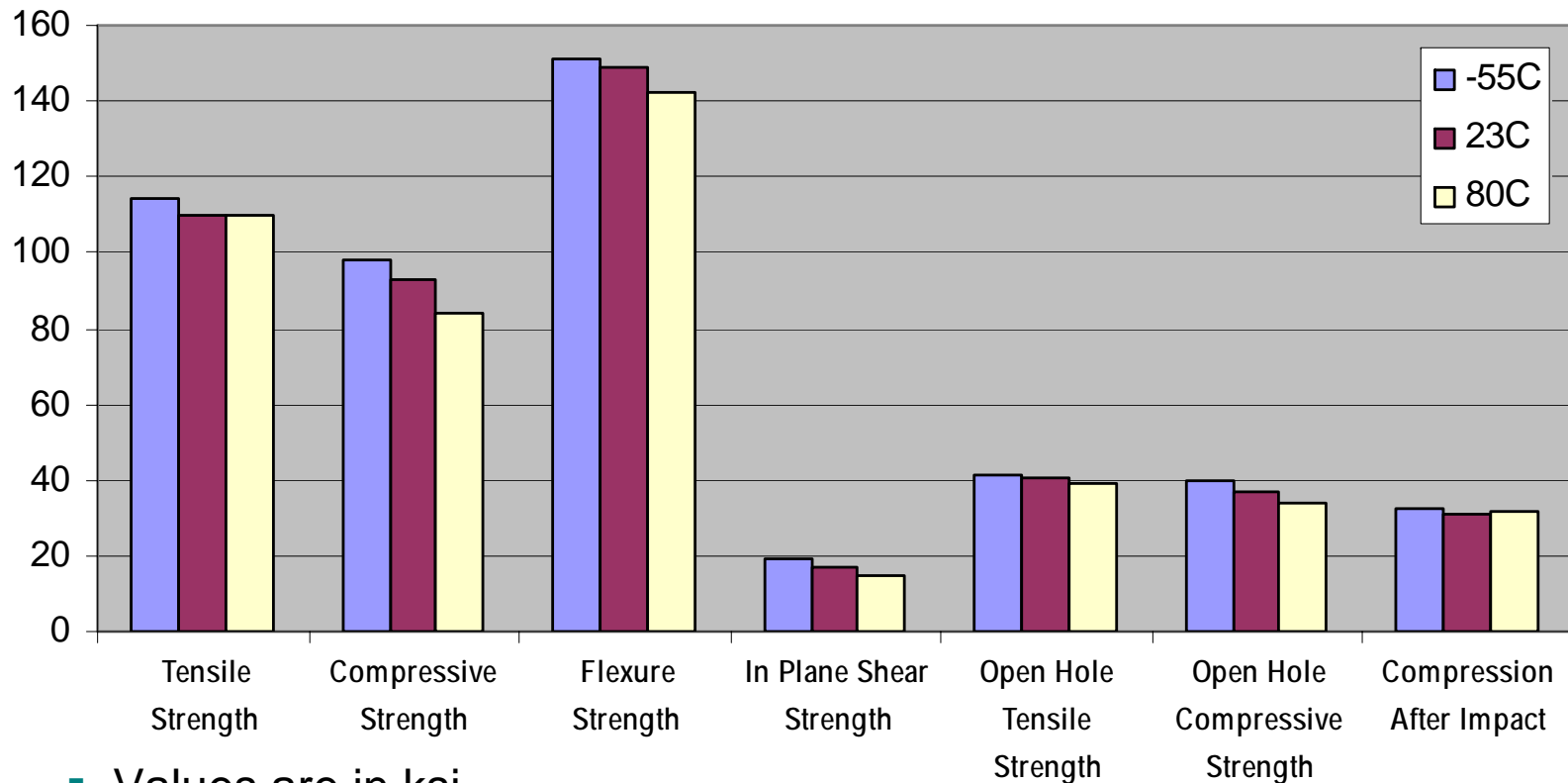
- Eliminate bagging materials and labor
  - May also eliminate kitting and debulking steps and equipment
- Eliminating autoclave possible
  - Cost, space and bottleneck issues
- Rapid processing vs. thermosets
- Can be reformed
- Simple, longer-lasting tool
- Fusion bonding eliminates fasteners and adhesives
  - Reduces cost and weight
- Green processing
  - Recyclable
  - No VOCs in processing
  - Less process scrap

# Thermoplastic Composite Matrix Cost Advantage



- The material cost for a thermoplastic matrix might be equal or even higher
- Lower cost for handling, processing and assembly can lead to a substantial advantage in total cost

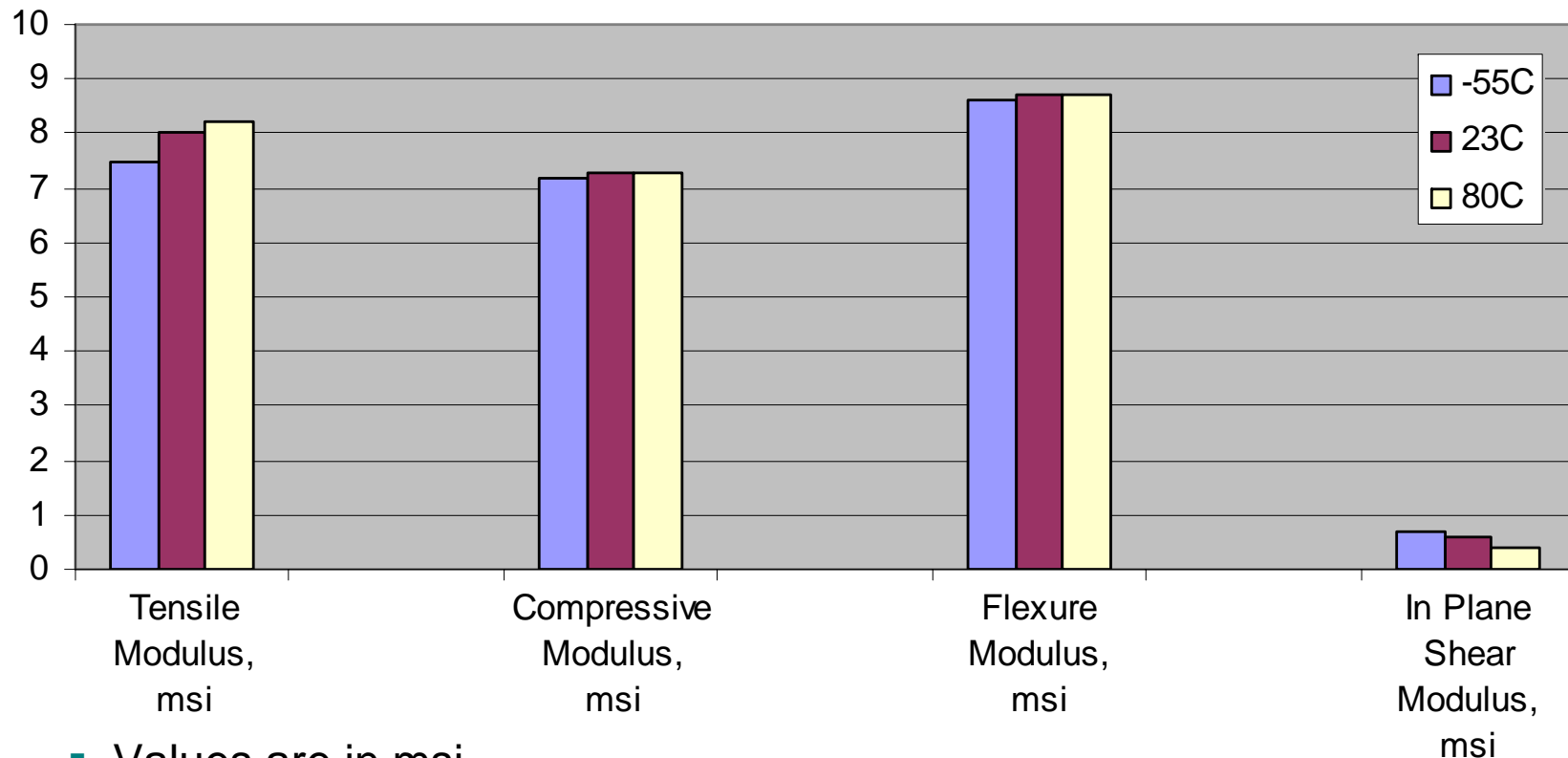
# T300 3K Carbon Fabric/Fortron® PPS Composite Property Data\*



- Values are in ksi
- Warp direction data
- Average values - Tested per Mil-R-17

**Steady and Stable Across Use Temperature**

# T300 3K Carbon Fabric/ Fortron® PPS Composite Property Data\*



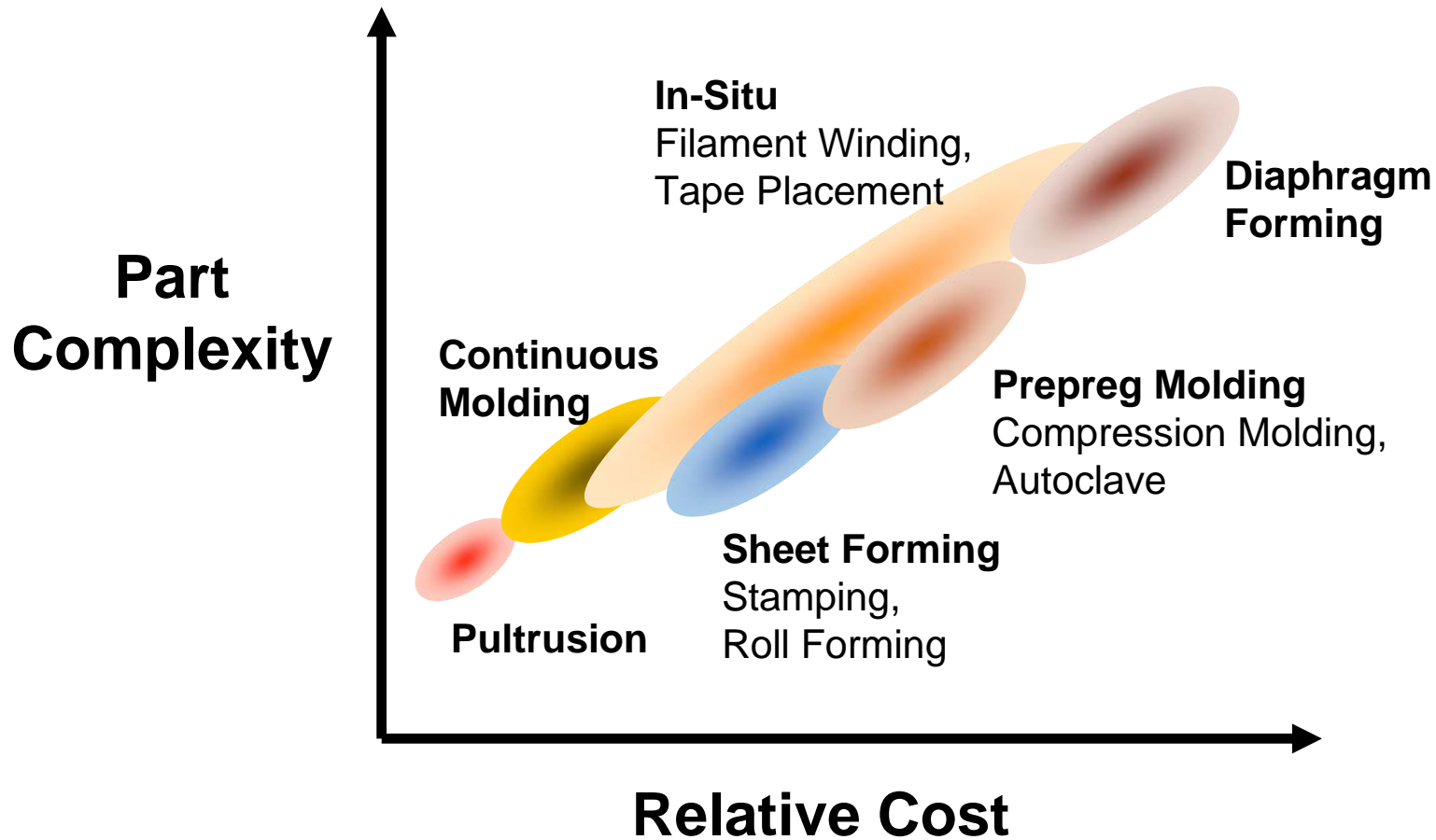
- Values are in msi
- Warp direction data
- Average values - Tested per Mil-R-17

**Steady and Stable Across Use Temperature**

# Thermoplastic Composite Processing Technologies

- Pultrusion
- Continuous laminating
- Compression molding
- Thermoforming
- Automated tape laying/fiber placement
- Bladder molding

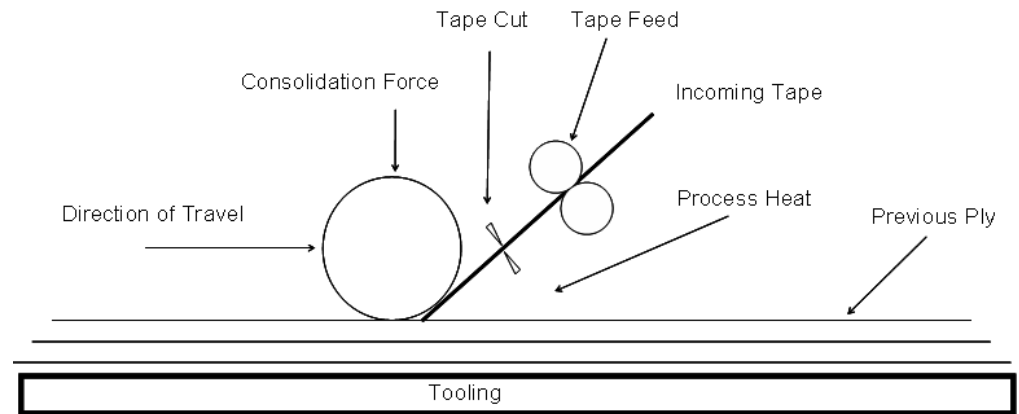
# Process Cost vs. Part Complexity for Continuous Fiber Reinforced Parts



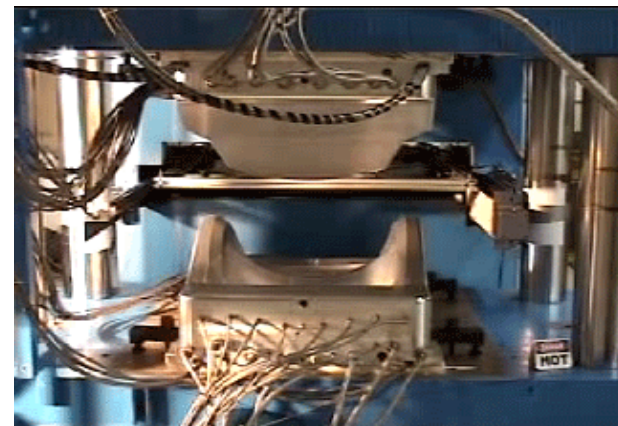
# Additional Thermoplastic Composite Manufacturing Processes



Automated Dynamics –  
Fiber Placement



Lingol –  
Thermoforming



FiberForge –  
Compression Molding

# Advantages of Thermoplastic Composite Automation Processes

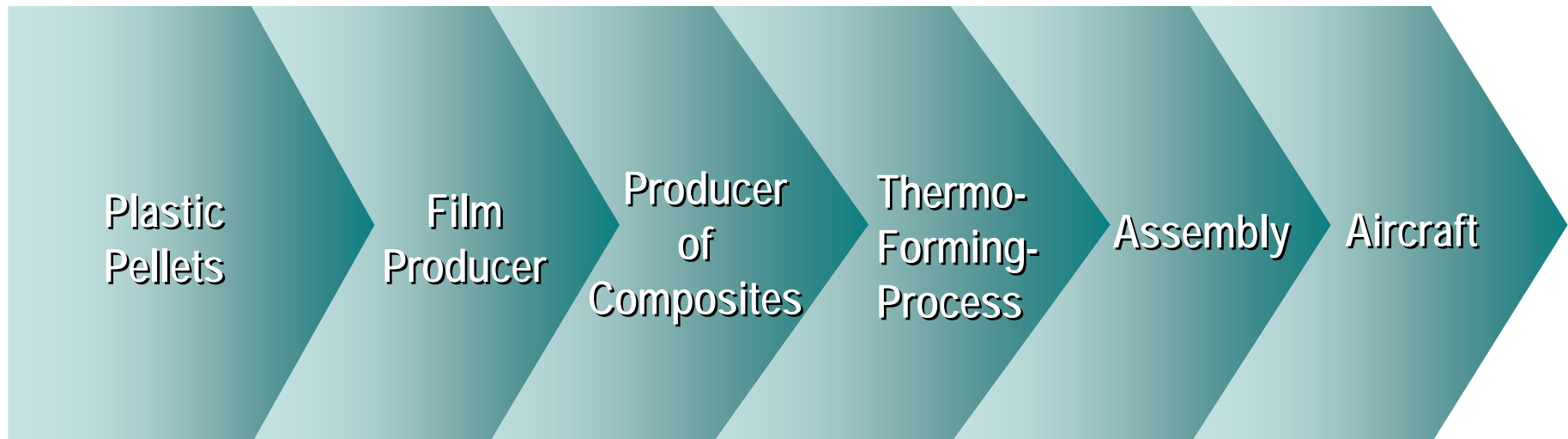
- Accurate fiber placement at any angle
- Material savings
- Labor savings
- Quality improvement
- Automatic debulking
- Reduced manufacturing space
- Reduced assembly costs



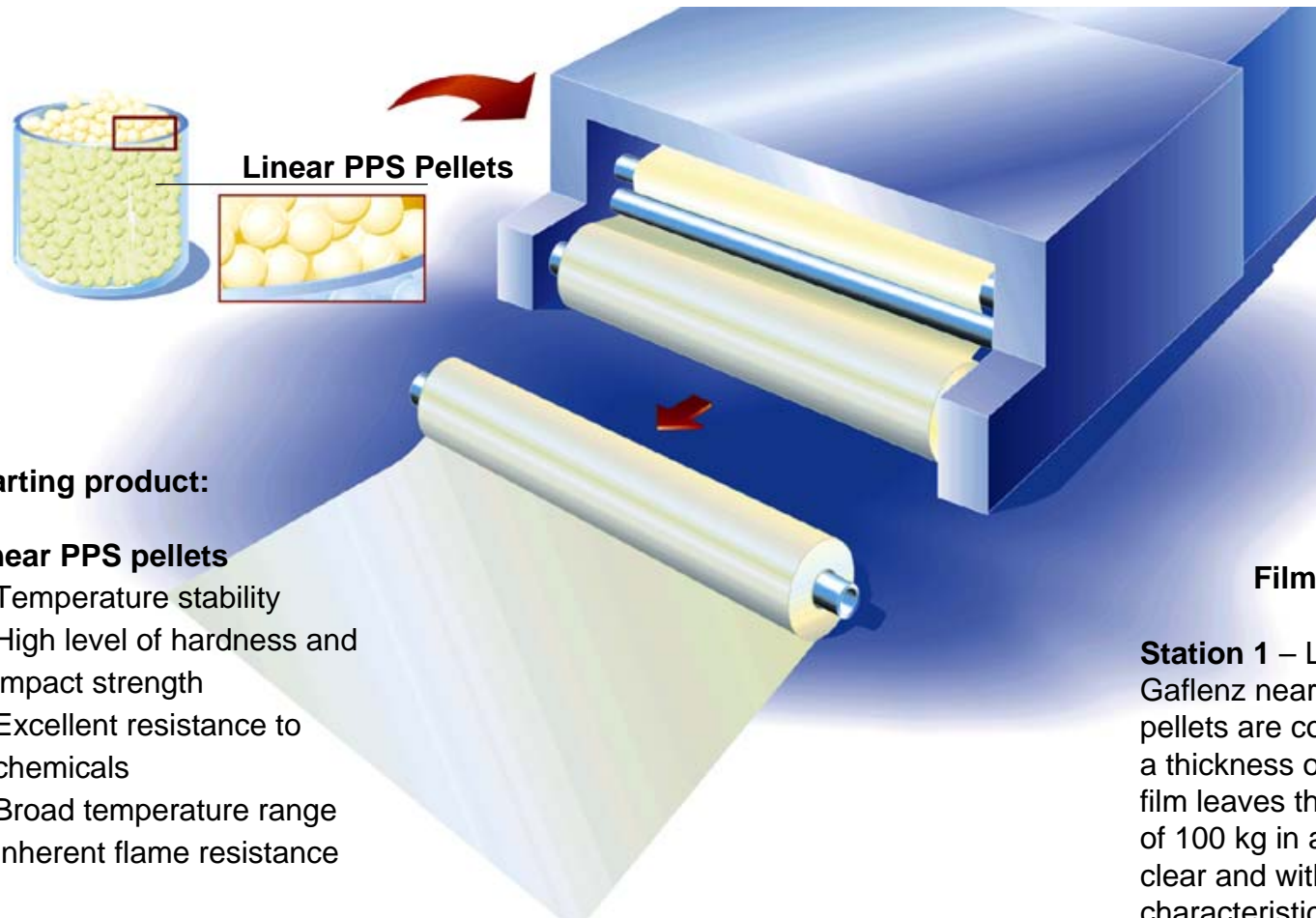


# Airbus A340/A380 Leading Edge Process

## Example for Thermoplastic Composite Value Chain in Aircraft Industries



# Station 1: Film Production



## Starting product:

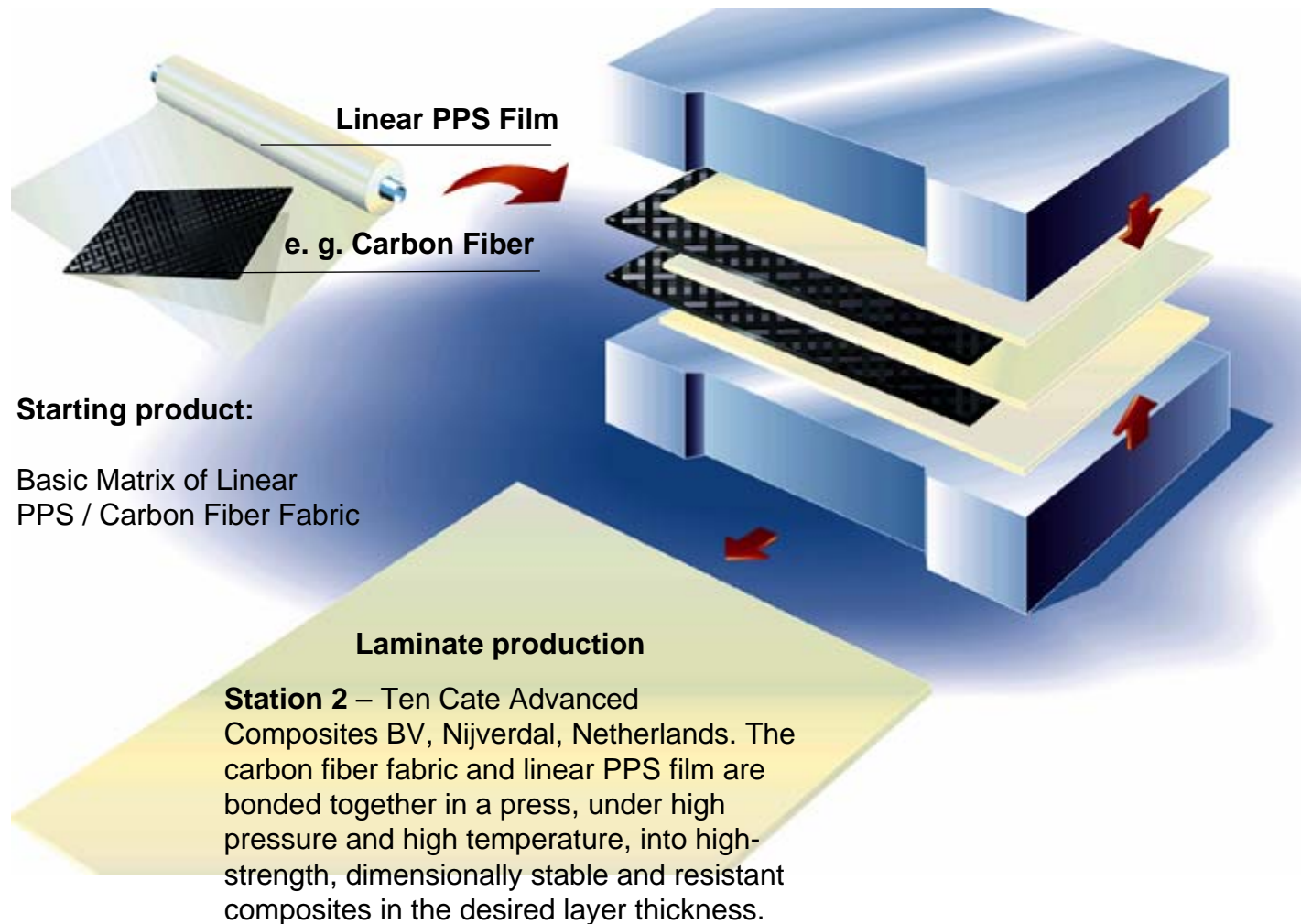
### Linear PPS pellets

- Temperature stability
- High level of hardness and impact strength
- Excellent resistance to chemicals
- Broad temperature range
- Inherent flame resistance

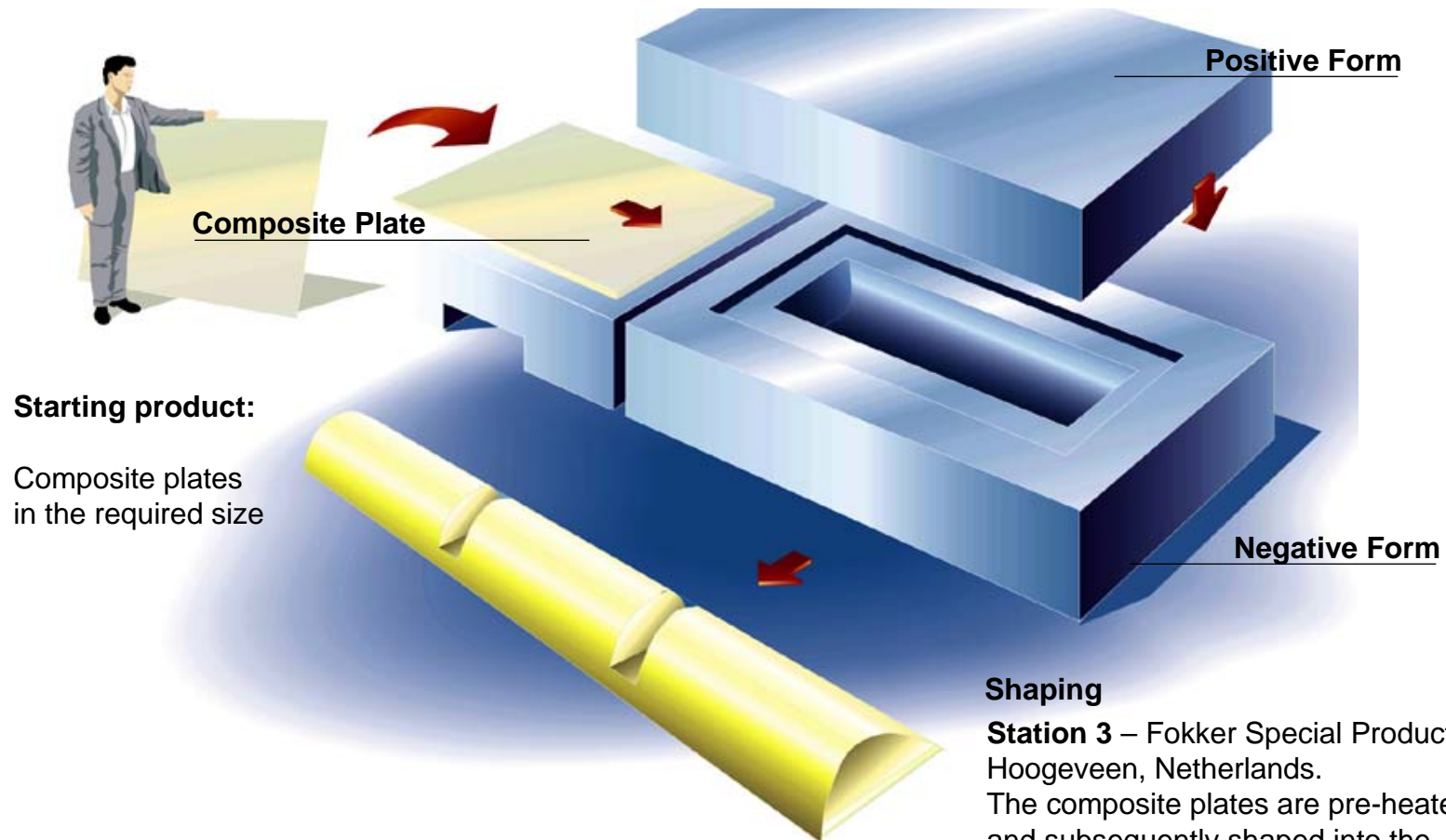
## Film production

**Station 1** – Lipp-Terler GmbH in Gaflenz near Linz, Austria. The pellets are converted into films with a thickness of 50 to 200  $\mu\text{m}$ . The film leaves the special plant in rolls of 100 kg in a flawless state, crystal clear and with the required characteristics with regard to strength and dimensional stability.

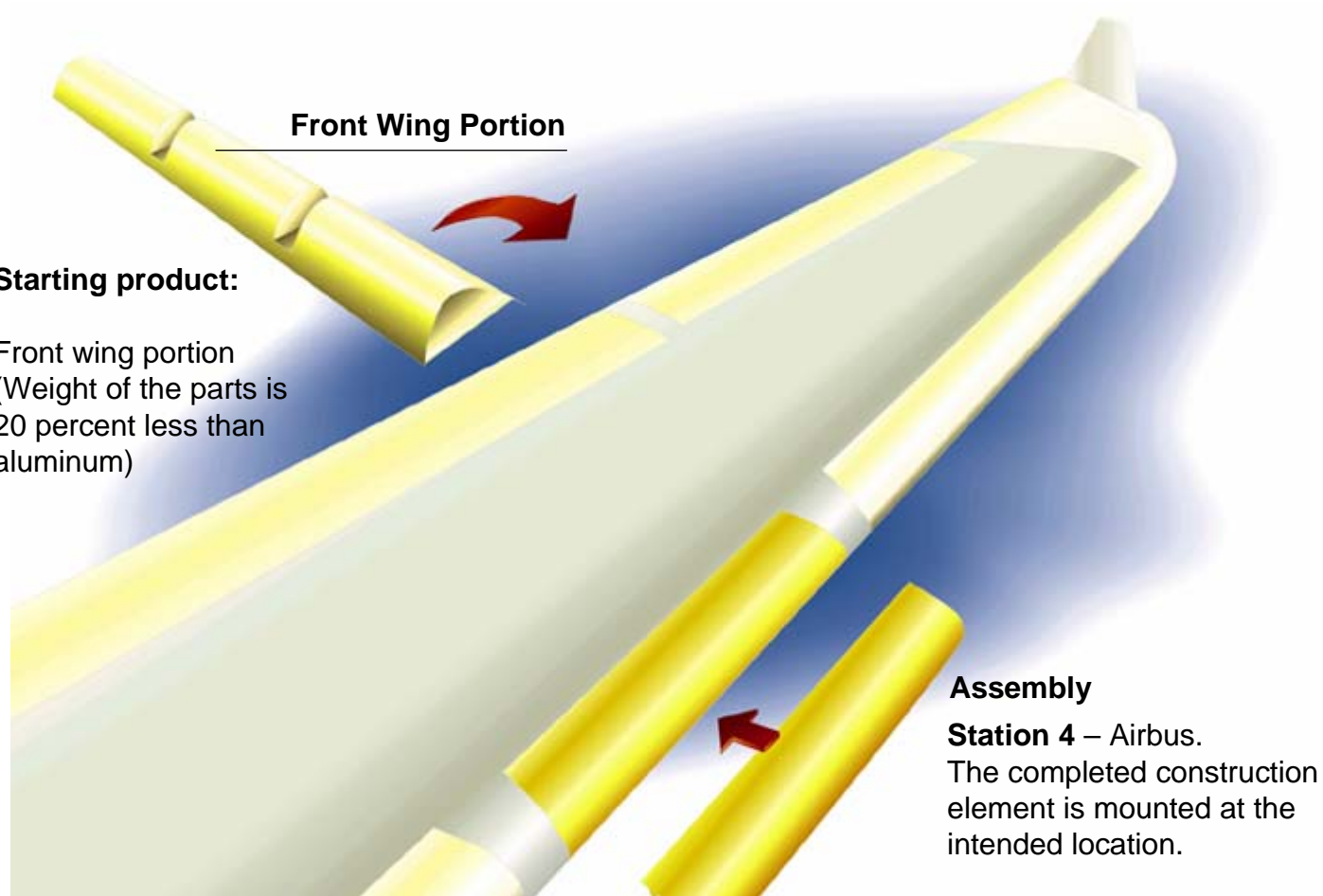
# Station 2: Composite Production



# Station 3: Thermoforming



# Station 4: Assembly



# Technology Breakthrough: Fixed Wing Leading Edge Airbus A340 and A380

- Welded structure
- Low weight and low cost monolithic design
  - 200 kg weight reduction on A380



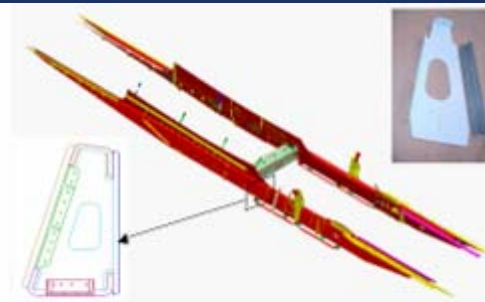
## Technology Validation – Carbon/PPS: Fokker 50 Undercarriage Door

- Press-formed ribs and spars
- Welded assembly
- Qualified carbon / PPS material
- Certified by the  
Airworthiness Authorities
- Flown on KLM aircraft





## Metal Substitution with Linear PPS Composite Resulted in 20–50% Lighter Components



- KB WP : 18 m, 2.5 tons -



- Main Ribs (L&R) -

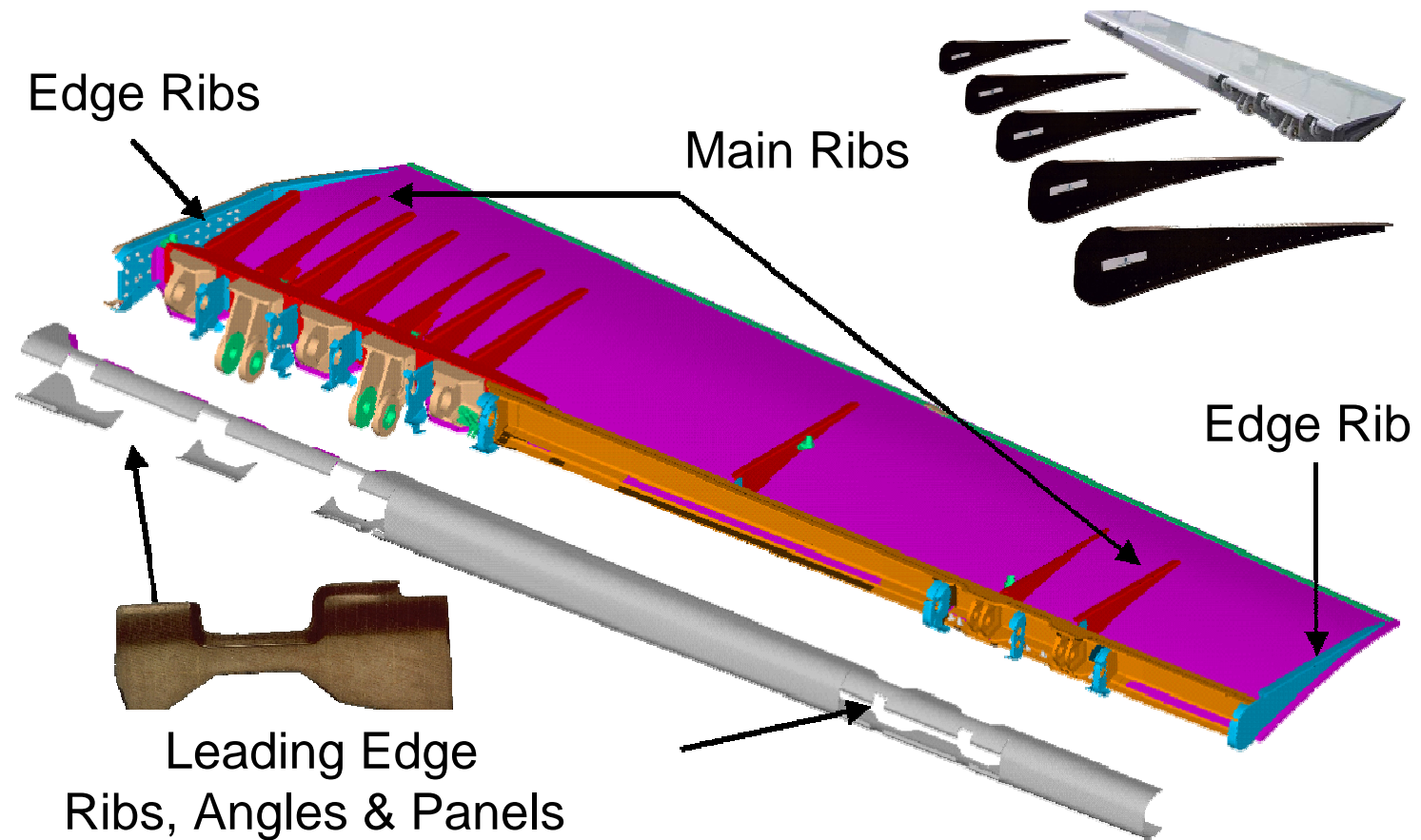
## Keel Beam Application

- Multi-Technology Concept :
- Panels and Spars : Thermoset Prepreg Lay-Up,
  - TP Ribs and Angles
  - Alu. and Titanium Brackets





# Airbus A340 500/600 Aileron Thermoplastic Composite Parts



# Weight Reduction – The Vision Fortron® PPS in Aircraft Interior



Product Innovations for Composites

Aluminum 280 g - Fortron 150 g

## Supporting Various Interior Applications

- Seat frames
- Ducting
- Panels
- Brackets
- Ribs
- Fasteners

**46% Lighter Seat Parts Due to Metal Substitution**

# Summary

- Fortron® Linear PPS is a demonstrated, producible, low-cost, high-performance thermoplastic for aerospace composite applications
  - Aircraft interior and exterior applications
  - Flammability, Smoke, and Toxicity Performance (FST)
  - Corrosion resistant environments
  - High temperature usage
  - Wide variety of forms available
- Industrial thermoplastics composites manufacturing is a proven production process
  - Used in production of critical aerospace structures



# **Fortron® PPS for Thermoplastic Composites**

**Harsh Bhagat**  
**Senior Design Engineer**  
**Harsh.Bhagat@ticona.com**  
**(248) 340-7460**

**Michael Favaloro**  
**Technical Marketing Specialist – Fortron® PPS Composites**  
**Michael.Favaloro@ticona.com**  
**978) 270-6011**

**Walt Maruszczak**  
**Market Development Engineer - Fortron® PPS**  
**W.Maruszczak@ticona.com**  
**(248) 656-4848**

Information is current as of July 30, 2008 and is subject to change without notice.

The information contained herein should not be construed as a promise or guarantee of specific properties of our products.

Any determination of the suitability of a particular material and part design for any use contemplated by the user is the sole responsibility of the user. We strongly recommend that users seek and adhere to the manufacturer's current instructions for handling each material they use.

Any existing intellectual property rights must be observed.

© 2008 Ticona. Except as otherwise noted, trademarks are owned by Ticona or its affiliates. Fortron is a registered trademark of Fortron Industries LLC.

# Backup slides

# Fortron® PPS

## Extrusion: Film, Fiber, Netting, etc.

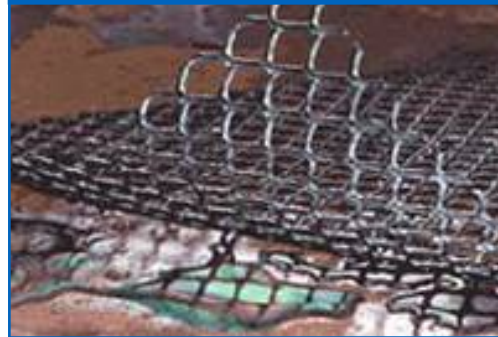
Aircraft Composite



High Tenacity Monofilament



Filter Netting



Stock Shapes



CPI Filter

# Applications: Sensors

## ABS Sensor Components



- Dimensional stability
- Creep resistance
- Corrosion resistance within the required temperature range