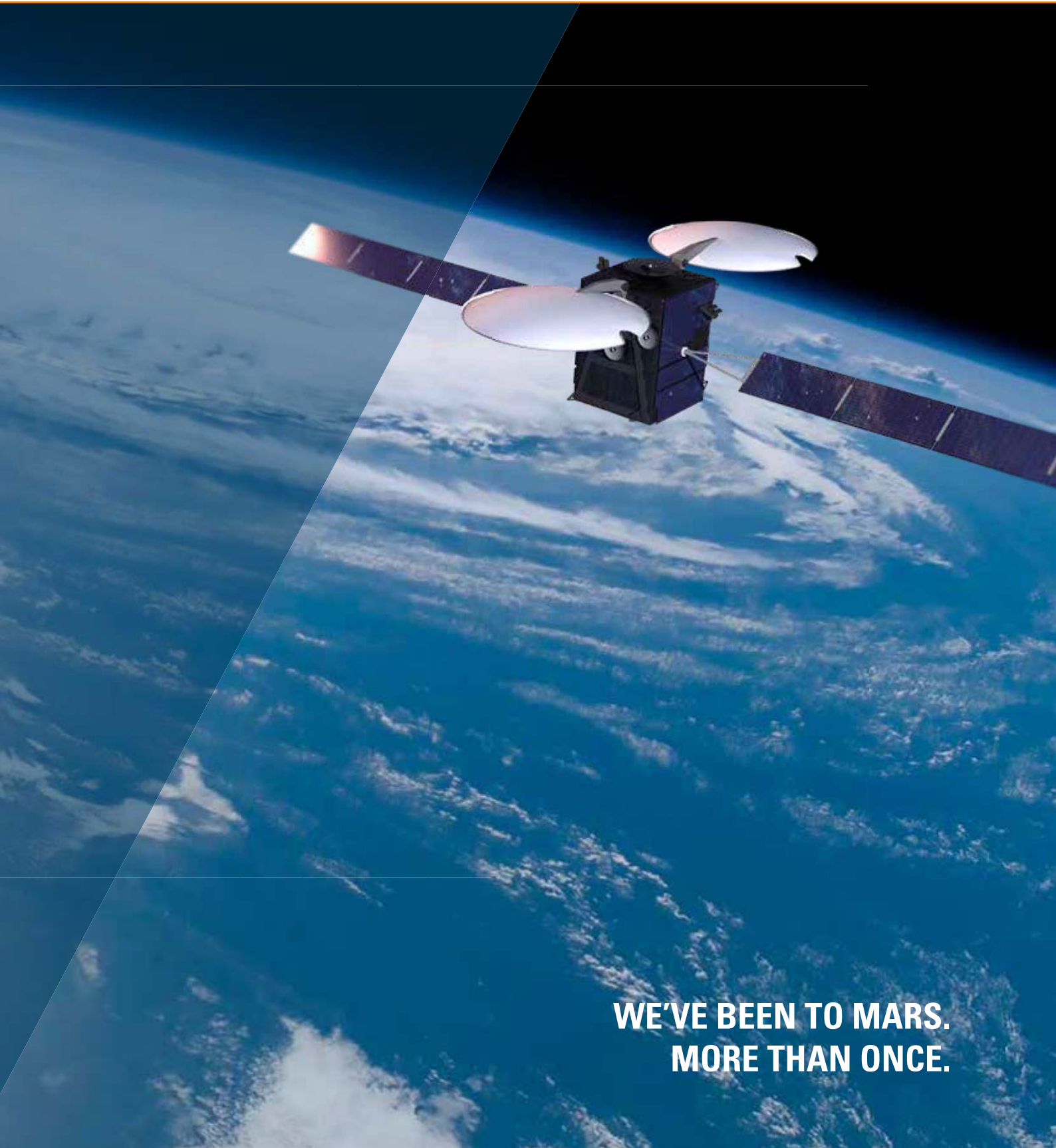


SPACE, SATELLITE, & LAUNCH

Advanced Composite Materials Selector Guide



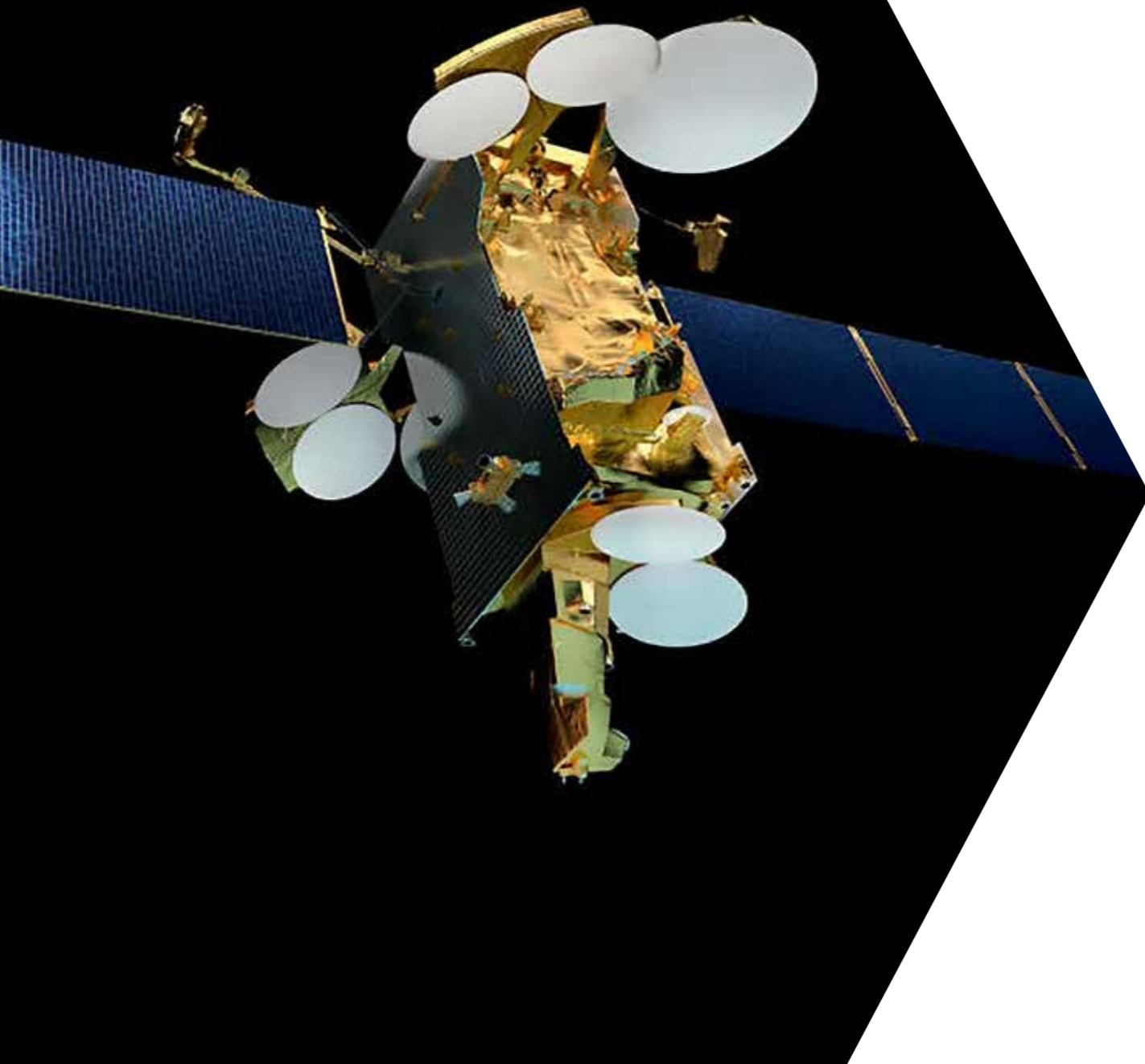
**WE'VE BEEN TO MARS.
MORE THAN ONCE.**

'TORAY'

Toray Advanced Composites

SPACE, SATELLITE, & LAUNCH

Introduction



OUR OBJECTIVES

- ▲ Connecting the planet
- ▲ Furthering scientific understanding
- ▼ Reducing weight
- ▲ High reliability

Credit: Airbus Defence and Space

SPACE FLIGHT HERITAGE

With more than 25 years of space flight heritage, Toray Advanced Composites is the undisputed leader in developing and manufacturing cutting-edge, high-reliability materials for the space market. Our products are found on most satellites, spacecraft, and planetary rovers launched from the Western world. No other materials company offers the pedigree, experience, or breadth of product knowledge to meet the demanding needs of the space, launch, and satellite industry.

In partnership with our customers and with a close eye to evolving market needs, we have developed a comprehensive product portfolio of industry-leading resin systems for use on high-modulus PAN and pitch carbon fiber and specialty fabrics, as well as standard reinforcements.

COMMERCIAL SATELLITES AND LAUNCH VEHICLES

We continue to develop and serve our long-standing customers, who are building ever larger telecommunications satellites to accommodate more powerful and sophisticated payloads - offering higher resolution, more deployable structures, and larger, more accurate reflectors.

Toray also offers a full range of products to meet the demands of today's heavy-lift commercial launch vehicles being utilized today to send high-value missions reliably into space.

SCIENCE AND EXPLORATION

Our next generation materials support science missions, going further than ever before to unlock the secrets of the universe. Tomorrow's spacecraft will journey to more aggressive,

hotter, and colder environments, and with greater numbers of planetary rovers and landers. Toray's materials are also playing a key role in sending humans to Mars.

NEW SPACE

Today's rapidly emerging New Space market is bringing new opportunities to meet material demands for mass-produced satellite constellations, small launch-on-demand vehicles, and swarms of high-flying pseudo-satellite drones. New Space will bring internet connectivity, new science, and big data to billions more people.

For more product information such as product data sheets, case studies, or technical papers, please use the following resources:



Search for the Toray TAC Product Selector



www.toraytac.com/space

Go to our online resource center for product data sheets and technical resources.



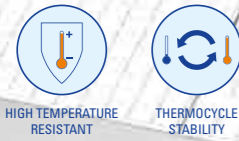
“

To confine our attention to terrestrial matters would be to limit the human spirit.

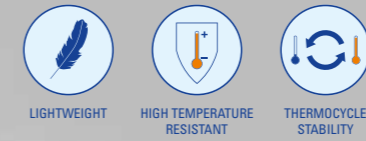
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Stephen Hawking

HEAT SINKS Composite plates and tubes are manufactured with Toray highly conductive pitch-based carbon fiber prepregs. These unique materials provide superior thermal conductivity to channel heat from electrical components. Toray prepreg systems for these applications are designed to withstand high temperatures while providing exceptional resistance to the effects of thermocycling.



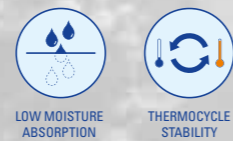
REFLECTORS AND ANTENNAS Toray space flight-approved cyanate ester and epoxy systems utilize high-modulus carbon fiber and specialized weaves. These materials are designed to deliver low CTE on reflectors, antennas, and deployable structures over space temperature extremes.



SOLAR ARRAY PANEL SUBSTRATES, BOOMS, AND TRUSSES These satellite applications utilize Toray high-modulus carbon fibers with resins that provide low coefficients of thermal expansion (CTE), low coefficients of moisture expansion (CME), low outgassing, and radiation resistance.



PRECISION STRUCTURES Toray materials protect the payload during launch and resist moisture to prevent outgassing in orbit. Toray high-modulus PAN or pitch-based carbon fiber prepregs are utilized for strength, stiffness, and light weight. Structures made from Toray products, including benches for optics and instrumentation, withstand extreme conditions in space, including thermal cycling, atomic oxygen, and radiation.



LAUNCH VEHICLE

Product Applications

BARREL FUSELAGE ASSEMBLIES, PAYLOAD SHROUDS, AND FAIRINGS

The latest generation of launch vehicles utilize Toray out-of-autoclave (OOA) processable prepreg systems for cost-competitive vehicle barrel assemblies, inner and outer stages, payload shrouds, and fairings for weight and cost savings.



OUT-OF-AUTOCCLAVE PROCESSABLE



LIGHTWEIGHT

CRYOTANKS Launch vehicle cryotanks utilize Toray toughened epoxies to provide high strength, low weight tanks.



STRONG

STRUTS AND TUBES Toray exceptionally durable and microcrack-resistant thermosets deliver a lightweight, high-strength structure for landing leg assemblies, secondary tubes, and struts and conduits.



MICROCRACK RESISTANT



LIGHTWEIGHT



HIGH TEMPERATURE RESISTANT



THERMOCYCLE STABILITY



LIGHTWEIGHT



HIGH TEMPERATURE RESISTANT

HEATSHIELDS Toray high-temperature cyanate ester prepreps create lightweight, thermally stable structures.

SPACE, SATELLITE, & LAUNCH

Product Overview

THERMOSET PREPREGS EPOXY

	RESIN MATRIX	DRY T _g ONSET	CURE TIME AND TEMPERATURE	KEY PRODUCT CHARACTERISTICS	OUTGASSING, CTE/ CME OR HOT/WET DATA	OOA/VBO	TOUGHENED	LOW MOISTURE ABSORPTION	SPACE/ SATELLITE	LAUNCH
EX-1522	Modified Epoxy	180°C (356°F)	2 hours at 177°C (350°F)	<ul style="list-style-type: none"> ▶ Excellent mechanical properties ▶ Good balance of properties between cyanate ester and epoxy ▶ Low D_k and D_L 	TML 0.28 % CVCM 0.01 % WVR 0.16 % TML-WVR 0.12 %		○	○	○	
TC250	Epoxy	140°C (285°F) or 180°C (356°F) with post cure	60 minutes at 88°C (190°F), followed by 2 hours at 130°C (265°F)	<ul style="list-style-type: none"> ▶ NCAMP qualified ▶ Long out life of 60 days and the ability to post cure makes it ideal for large structures 	Wet T _g 125°C (257°F) Cured at 130°C (265°F) TML 0.27 % CVCM 0.01 % WVR 0.32 %	○	○			○
RS-36 / RS-36-1	Epoxy	181°C (358°F) or 190°C (374°F)	90 minutes at 177°C (350°F)	<ul style="list-style-type: none"> ▶ ESA qualified for solar array ▶ High toughness ▶ Low moisture absorption 	TML 0.4 % CVCM 0.01 % WVR 0.17 % TML-WVR 0.12 %	○	○	○	○	
TC275-1	Epoxy	164°C (327°F) or 183°C (362°F) with 177°C (350°F) post cure	6 hours at 135°C (275°F) Optional post cure of 2 hours at 177°C (350°F)	<ul style="list-style-type: none"> ▶ Ideal for large structure fabrication ▶ Low density ▶ Excellent toughness for impact resistance 	Wet T _g 136°C (277°F) TML 0.44 % CVCM 0.01 % WVR 0.22 %	○	○	○	○	○
TC275-1E NEW	Epoxy	168°C (334°F)	6 hours at 135°C (275°F) Optional post cure of 2 hours at 177°C (350°F)	<ul style="list-style-type: none"> ▶ Long out time version of TC275-1 ▶ Allows construction of thick or larger composites structures ▶ OOA/VBO processable 		○	○	○	○	○
TC350-1	Epoxy	191°C (376°F)	2 hours at 177°C (350°F)	<ul style="list-style-type: none"> ▶ OOA/VBO processable ▶ Good hot/wet properties 	Wet T _g 160°C (320°F) TML 0.55 % CVCM 0.01 % WVR 0.27 %	○	○	○		○
TC380 NEW	Epoxy	204°C (399°F)	2 hours at 177°C (350°F)	<ul style="list-style-type: none"> ▶ Extreme toughness for structural and cryogenic applications ▶ Excellent balance of CAI, OHC, and hot/wet properties 	TML 0.83 % CVCM 0.01 % WVR 0.75 %	○	○	○		○

THERMOSET PREPREGS BMI

	RESIN MATRIX	DRY T _g ONSET	CURE TIME AND TEMPERATURE	KEY PRODUCT CHARACTERISTICS	OOA/VBO	TOUGHENED	LOW MOISTURE ABSORPTION	SPACE/ SATELLITE	LAUNCH
RS-8HT	BMI	203°C (397°F) or 285°C (545°F) with post cure	2 hours at 204°C (400°F) followed by 6 hours at 250°C (482°F)	<ul style="list-style-type: none"> ▶ Excellent elevated temperature performance ▶ Good moisture resistance 			○		○

SPACE, SATELLITE, & LAUNCH

Product Overview

THERMOSET PREPREGS CYANATE ESTER

	RESIN MATRIX	DRY T _g ONSET	CURE TIME AND TEMPERATURE	KEY PRODUCT CHARACTERISTICS	OUTGASSING, CTE/ CME OR HOT/WET DATA	00A/VBO	TOUGHENED	LOW MOISTURE ABSORPTION	SPACE/ SATELLITE	LAUNCH
EX-1515	Cyanate Ester	121°C (249°F) or 174°C (345°F) with post cure	3 hours at 121°C (250°F) Optional post cure of 2 hours at 177°C (350°F)	<ul style="list-style-type: none"> Low density Resistant to microcracking Low residual stress with 121°C (250°F) cure 	TML 0.18 % CVCM 0.01 % CTE 61 ppm/°C		○	○	○	
TC410	Cyanate Ester	112°C (234°F) or 181°C (358°F) with post cure	3 hours at 121°C (250°F) Optional post cure at 177°C (350°F)	<ul style="list-style-type: none"> Low CTE 58.4 μm/m/°C Extremely low CME 1205 μm/m/% Ideal system for stable structures 	TML 0.29 % CVCM < 0.01 % WVR 0.17 % TML-WVR 0.12 %		○	○	○	
BTCy-1A	Cyanate Ester	185°C (365°F) or 207°C (405°F) with post cure	2 hours at 177°C (350°F) Optional post cure of 60 minutes at 204°C (400°F)	<ul style="list-style-type: none"> Tough High T_g 	CTE 77 ppm/°C		○	○	○	
RS-3/ RS-3C	Cyanate Ester	191°C (375°F) or 254°C (490°F) with post cure	2 hours at 177°C (350°F) Optional post cure of 60 minutes at 232°C(450°F)	<ul style="list-style-type: none"> Extensive qualification portfolio Low CTE, CME High stability RS-3C is controlled-flow version 	TML 0.22 % CVCM 0.01 %	○	○	○	○	
TC420	Cyanate Ester	176°C (349°F) or 348°C (658°F) with post cure	3 hours at 177°C (350°F) Optional post cure at 260°C (500°F)	<ul style="list-style-type: none"> Good resistance to microcracking Capable of high-temperature service Ideal for heat shield and ablative applications 	TML 0.41 % CVCM < 0.01% WVR 0.28% CTE 55 ppm/°C	○	○	○	○	○

RTM RESINS

	RESIN	DRY T _g ONSET	CURE TIME AND TEMPERATURE	KEY PRODUCT CHARACTERISTICS	00A/VBO	TOUGHENED	LOW MOISTURE ABSORPTION	SPACE/ SATELLITE	LAUNCH
EX-1545	Cyanate Ester	173°C (345°F)	2 hours at 177°C (350°F)	<ul style="list-style-type: none"> Toughened resin system with low viscosity of 140 cPs at 43°C (110°F) Long pot life for complex parts 				○	
RS-16	Cyanate Ester	151°C (304°F) or 252°C (486°F) with elevated post cure	2 hours at 135°C (275°F)	<ul style="list-style-type: none"> Low-temperature cure resin system Post curable for higher T_g 				○	
EX-1510	Cyanate Ester	193°C (380°F)	2 hours at 177°C (350°F)	<ul style="list-style-type: none"> Low room temperature viscosity of 150 cPs Post curable for higher T_g 			○		

TORAY MICROPLY™ FILM ADHESIVES EPOXY

	RESIN MATRIX	DRY T _g ONSET	CURE TIME AND TEMPERATURE	KEY PRODUCT CHARACTERISTICS	00A/VBO	TOUGHENED	LOW MOISTURE ABSORPTION	SPACE/ SATELLITE	LAUNCH
RS-15H	Epoxy	99°C (211°F)	6 hours at 93°C (200°F) Alternate cures are available	<ul style="list-style-type: none"> Low-temperature curing adhesive 	○	○		○	
TC263	Epoxy	110°C (230°F)	2 hours at 121°C (250°F)	<ul style="list-style-type: none"> High peel strength Ideal for metal or composite bonding 	○	○		○	○
TC310	Epoxy	157°C (315°F)	2 hours at 177°C (350°F)	<ul style="list-style-type: none"> Ideal composite bonding film adhesive 	○	○		○	○

TORAY MICROPLY™ FILM ADHESIVES CYANATE ESTER

	RESIN MATRIX	DRY T _g ONSET	CURE TIME AND TEMPERATURE	KEY PRODUCT CHARACTERISTICS	00A/VBO	TOUGHENED	LOW MOISTURE ABSORPTION	SPACE/ SATELLITE	LAUNCH
EX-1516	Cyanate Ester	126°C (258°F)	5 hours at 121°C (250°F)	<ul style="list-style-type: none"> Compatible with Toray EX-1515 prepreg 		○	○	○	
RS-4A	Cyanate Ester	195°C (383°F) or 238°C (460°F) with post cure	2 hours at 177°C (350°F) Optional post cure of 1.5-2 hours at 232°C (450°F)	<ul style="list-style-type: none"> Moisture resistant 		○	○	○	
EX-1543	Cyanate Ester	191°C (376°F) or 211°C (412°F) with post cure	2 hours at 177°C (350°F) Optional post cure of 2 hours at 204°C (400°F)	<ul style="list-style-type: none"> Compatible with 177°C (350°F) curing cyanate ester prepregs Low shrinkage Low outgassing 			○	○	
TC4015	Cyanate Ester	176°C (349°F) or 321°C (610°F) with post cure	2 hours at 177°C (350°F) Optional post cure of > 60 minutes at 232°C (450°F)	<ul style="list-style-type: none"> Excellent high-temperature properties Compatible with TC420 	○		○	○	○

TORAY MICROPLY™ SYNTACTICS EPOXY

	RESIN MATRIX	DRY T _g ONSET	CURE TIME AND TEMPERATURE	KEY PRODUCT CHARACTERISTICS	00A/VBO	TOUGHENED	LOW MOISTURE ABSORPTION	SPACE/ SATELLITE	LAUNCH
EM-3	Epoxy	~116°C (240°F)	60 minutes at 121°C (250°F)	<ul style="list-style-type: none"> High expansion (8-10 x) 0.64 g/cc (40 pcf) density T_g estimated from base resin data 				○	
TCF4035	Epoxy	140°C (284°F)	3 hours at 130°C (265°F)	<ul style="list-style-type: none"> Low density 0.64 g/cc (40 pcf) Compatible with TC250, may be post cured for higher T_g 	○	○			○

SPACE, SATELLITE, & LAUNCH

Product Overview

TORAY MICROPLY™ SYNTACTICS CYANATE ESTER

	RESIN MATRIX	DRY T _g ONSET	CURE TIME AND TEMPERATURE	KEY PRODUCT CHARACTERISTICS	00A/WBO	TOUGHENED	LOW MOISTURE ABSORPTION	SPACE/SATELLITE	LAUNCH
TCF4001	Cyanate Ester	176°C (349°F)	2 hours at 177°C (350°F) Optional post cure of 60-90 minutes at 232°C (450°F)	▶ Low density 0.38 g/cc (24 pcf)	○			○	
TCF4050	Cyanate Ester	176°C (349°F) or 232°C (450°F) with post cure	2 hours at 177°C (350°F) Optional post cure of 60-90 minutes at 232°C (450°F)	▶ Expanding syntactic film/core splice ▶ Density of 0.28-0.55 g/cc (17-35 pcf) ▶ Compatible with TC420 prepreg system	○	○		○	
EM-5A	Cyanate Ester	204°C (400°F)	2 hours at 177°C (350°F) Optional post cure of 60-90 minutes at 232°C (450°F)	▶ Expansion ratio of 4 x	○			○	

TORAY MICROPLY™ SYNTACTICS OTHER THERMOSET MATRICES

	RESIN MATRIX	DRY T _g ONSET	CURE TIME AND TEMPERATURE	KEY PRODUCT CHARACTERISTICS	00A/WBO	TOUGHENED	LOW MOISTURE ABSORPTION	SPACE/SATELLITE	LAUNCH
SF-4	BMI	295°C (563°F)	2 hours at 204°C (400°F), then 6 hour post cure at 250°C (452°F)	▶ Low density 0.62 g/cc (39 pcf) ▶ Compatible with RS-8HT and other BMI systems	○			○	

BMC THERMOSET EPOXY

	RESIN MATRIX	DRY T _g ONSET	CURE TIME AND TEMPERATURE	KEY PRODUCT CHARACTERISTICS	00A/WBO	TOUGHENED	LOW MOISTURE ABSORPTION	SPACE/SATELLITE	LAUNCH
MS-1A	Epoxy	164°C (327°F)	15-30 minutes at 138°C (280°F) followed by post cure of 1-2 hours at 177°C (350°F)	▶ Chopped fiber epoxy BMC with high-modulus fiber				○	○
MS-1H	Epoxy	191°C (375°F)	15-30 minutes at 138°C (280°F) followed by post cure of 1-2 hours at 177°C (350°F)	▶ Chopped fiber epoxy BMC with intermediate-modulus fiber				○	
MS-4H	Epoxy	191°C (375°F)	15-30 minutes at 138°C (280°F) followed by post cure of 1-2 hours at 177°C (350°F)	▶ Chopped fiber epoxy BMC with high-strength (standard-modulus) fiber				○	○

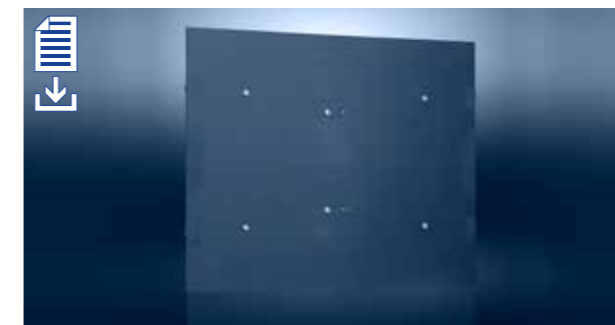
TORAY CETEX® BMC THERMOPLASTIC

	RESIN MATRIX	DRY T _g ONSET	PROCESSING TEMPERATURE	KEY PRODUCT CHARACTERISTICS	00A/WBO	DURABILITY/TOUGHNESS	LOW MOISTURE ABSORPTION	SPACE/SATELLITE	LAUNCH
MC1100	PPS	90°C (194°F)	330°C (626°F)	▶ PPS based BMC ▶ Fire retardant		○	○	○	○
MC1200	PEEK	143°C (290°F)	385°C (725°F)	▶ PEEK based BMC ▶ Fire retardant		○	○	○	○



LEARN MORE ABOUT THE USE OF OUR PRODUCTS IN SPACE

Find this case study and more at www.toraytac.com/success-stories



Learn about Airborne's Advanced Solar Array designed by Airbus Defence and Space for use in future ESA missions

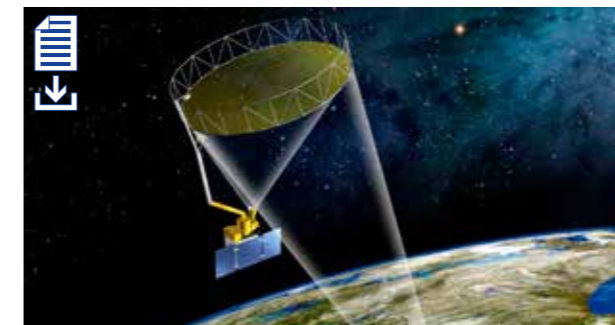
Solar Arrays for Next Generation Satellites

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ENABLING SMAP MISSION SUCCESS

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Deployable Space Structure for SMAP Made Using Toray Cetex® (published in Composites World)

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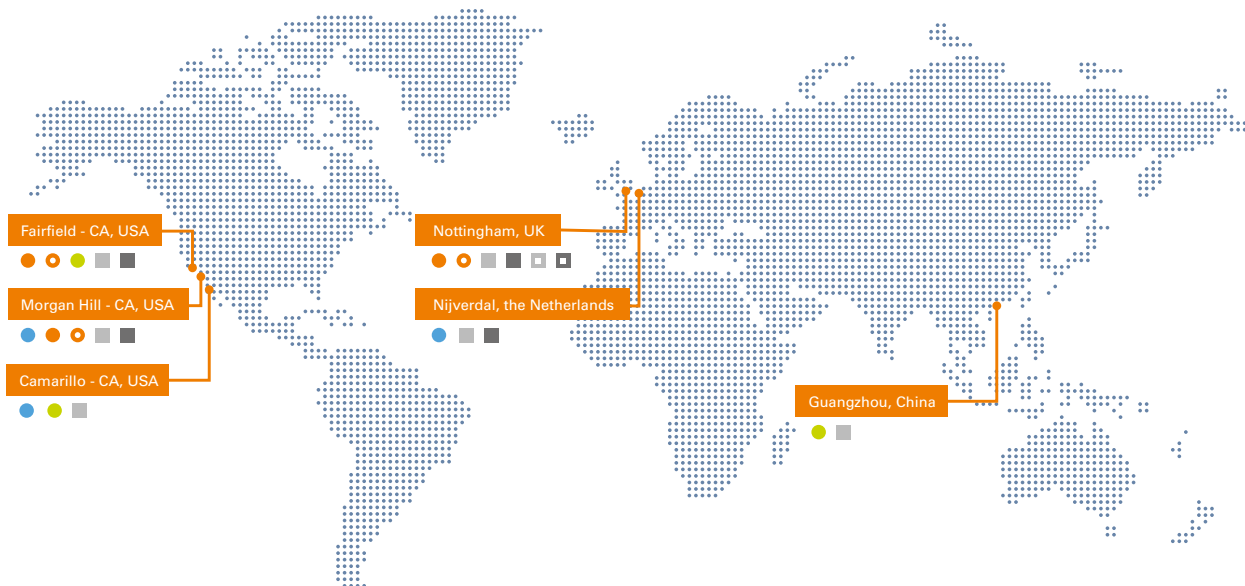
LOCATIONS AND CAPABILITIES

SOLUTIONS

- Thermoplastic composites
- Carbon-free manufacturing
- Thermoset composites
- Parts manufacture

CERTIFICATIONS

- ISO 9001:2015
- ISO 14001:2015
- AS9100D
- ISO 45001:2018



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