CompositesWorld.com

CW

CompositesWorld

WhiteKnight & SpaceShip: LEVERAGING COMPOSITES FOR SPACE TOURISM

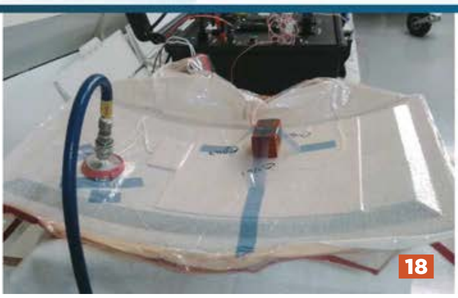
DECEMBER 2018

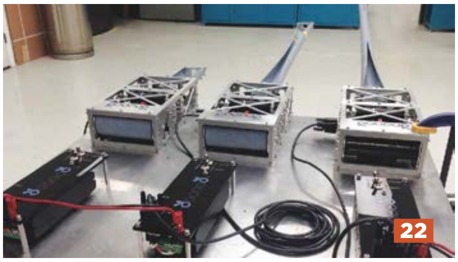
A property of Gardner Business Media

№ 4 VOL 12

DECEMBER 2018 / Vol: 4 №: 12

COLUMNS


18


22


26


32

FEATURES

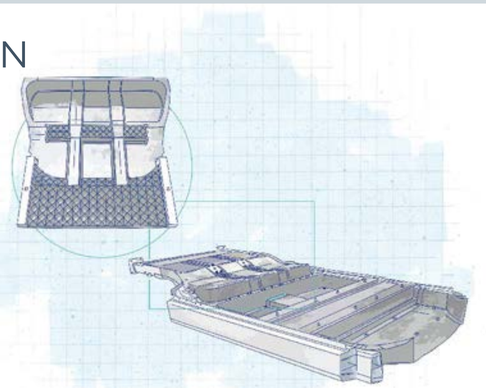
» DEPARTMENTS

» ON THE COVER

Virgin Galactic's all-composite *SpaceShipTwo*, shown here, is assembled primarily by bonding, with the addition of metal fasteners as needed. The leading edges of the wing and the horizontal stabilizer are faced with a thermal protection system derived from NASA's Space Shuttle program's thermal insulation systems. See p. 32.

Source / The Spaceship Co.

FOCUS ON DESIGN



CompositesWorld (ISSN 2376-5232) is published monthly and copyright © 2018 by Gardner Business Media Inc. 6915 Valley Ave., Cincinnati, OH 45244-3029. Telephone: (513) 527-8800. Printed in U.S.A. Periodicals postage paid at Cincinnati, OH and additional mailing offices. All rights reserved. POSTMASTER: Send address changes to *CompositesWorld* Magazine, 6915 Valley Ave., Cincinnati, OH 45244-3029. If undeliverable, send Form 3579. CANADA POST: Canada Returns to be sent to IMEX Global Solutions, PO Box 25542, London, ON N6C 6B2 Canada. Publications Mail Agreement #40612608. The information presented in this edition of *CompositesWorld* is believed to be accurate. In applying recommendations, however, you should exercise care and normal precautions to prevent personal injury and damage to facilities or products. In no case can the authors or the publisher accept responsibility for personal injury or damages which may occur in working with methods and/or materials presented herein, nor can the publisher assume responsibility for the validity of claims or performance of items appearing in editorial presentations or advertisements in this publication. Contact information is provided to enable interested parties to conduct further inquiry into specific products or services.

MEMBERSHIPS:

CW CompositesWorld

@CompositesWrld

PUBLISHER	Ryan Delahanty rdelahanty@gardnerweb.com
EDITOR-IN-CHIEF	Jeff Sloan jeff@compositesworld.com
SENIOR EDITOR	Sara Black sara@compositesworld.com
SENIOR EDITOR	Ginger Gardiner ggardiner@compositesworld.com
SENIOR EDITOR	Scott Francis sfrancis@compositesworld.com
ASSISTANT EDITOR	Hannah Mason hmason@compositesworld.com
DIRECTOR, STRATEGIC INITIATIVES AND EVENTS	Scott Stephenson sstephenson@compositesworld.com
ADVERTISING PRODUCTION MANAGER	Becky Taggert btaggert@gardnerweb.com
GRAPHIC DESIGNER	Susan Kraus skraus@gardnerweb.com
MARKETING MANAGER	Chris Saulnier csaulnier@gardnerweb.com

CW CONTRIBUTING WRITERS

Dale Brosius	dale@compositesworld.com
Donna Dawson	donna@compositesworld.com
Michael LeGault	mlegault@compositesworld.com
Peggy Malnati	peggy@compositesworld.com
Karen Mason	kmason@compositesworld.com

CW SALES GROUP

MIDWESTERN US & INTERNATIONAL	Dale Jackman / REGIONAL MANAGER djackman@gardnerweb.com
EASTERN US SALES OFFICE	Barbara Businger / REGIONAL MANAGER barb@compositesworld.com
MOUNTAIN, SOUTHWEST & WESTERN US SALES OFFICE	Michael Schwartz / REGIONAL MANAGER mschwartz@gardnerweb.com
EUROPEAN SALES OFFICE	Eddie Kania / EUROPEAN SALES MGR. ekania@btopenworld.com

COMPOSITESWORLD IS A PROPERTY OF

GARDNER Business Media, Inc.

HEADQUARTERS

6915 Valley Ave., Cincinnati, OH 45244-3029
Phone 513-527-8800 Fax 513-527-8801
gardnerweb.com
subscribe@compositesworld.com

CHAIRMAN	Rick Kline
PRESIDENT	Rick Kline, Jr.
CHIEF DATA OFFICER	Steve Kline, Jr.
CHIEF FINANCIAL OFFICER	Ernest Brubaker
CHIEF MARKETING OFFICER	Melissa Kline Skavlem
CHIEF TECHNOLOGY OFFICER	Phil Louis
AUDIENCE DEVELOPMENT MANAGER	Julie Ball
ADVERTISING AND PRODUCTION DIRECTOR	William Caldwell
CUSTOM CONTENT DIRECTOR	Tom Beard
CREATIVE DIRECTOR	Jeff Norgord
EDITORIAL OPERATIONS DIRECTOR	Kate Hand
STRATEGIC ENGAGEMENT DIRECTOR	Dave Necessary

GARDNER BUSINESS MEDIA ALSO PUBLISHES

Modern Machine Shop Moldmaking Technology
Plastics Technology Automotive Design & Production Production Machining
Products Finishing PF Mexico Additive Manufacturing

» Four years ago, in the fall of 2014, Virgin Galactic was, by all accounts, well on its way to becoming the first space tourism service provider. The company, through its subsidiary The Spaceship Co. (TSC), built its carbon fiber-intensive, eight-passenger *SpaceShipOne* craft and had been busy testing it throughout the year. It had constructed a new and impressive launch facility near Las Cruces, NM, US, called Spaceport America.

Spaceport America was to be the starting and end point for passengers who would pay $250,000 each to ride in *SpaceShipOne* to the edge of the Earth's atmosphere — an altitude of about 351,000 ft/110,000m — at which point they would be allowed to unbuckle from their seats and enjoy about 7 minutes of weightlessness, plus an unbeatable view of Earth, before gliding back to the ground. As of July 2018, some 600 people had signed up for a chance to have this experience.

> How will we look back on this age of corporation-led space flight?

Then, in late October 2014, during a test flight of *SpaceShipOne*, as the spacecraft was still in powered flight and approaching its apogee, co-pilot Michael Alsbury prematurely and inexplicably activated *SpaceShipOne*'s feather mechanism. The mechanism rotates the wings to a vertical orientation and help guide the craft, shuttlecock-like, for its return to Earth. However, its premature activation destroyed *SpaceShipOne*, causing it to break apart. Alsbury was killed; pilot Peter Siebold, although injured, miraculously survived.

There was plenty of blame to go around for this accident. The US National Transportation Safety Board (NTSB) in 2015 issued its report on the accident and pointed to inadequate safety standards, lack of regulatory oversight and co-pilot error. Further, the NTSB noted, *SpaceShipOne* should have had mechanisms in place that would have made premature feather activation impossible.

In the meantime, Virgin Galactic and TSC went back to the drawing board and started working on *SpaceShipTwo* (also called *VSS Unity*), and you can read about that spaceship and the composites fabrication being done for it, starting on p. 32 of this issue of *CW*. *VSS Unity* is now going through flight testing of its own and, in late May 2018, completed its second supersonic flight, reaching an altitude of 114,500 ft/35,000m. With the 2014 accident surely weighing heavily on Virgin Galactic, it is taking its time testing *VSS Unity*. As a result, it has not yet committed to a service start date.

Virgin Galactic, of course, is not the only company pursuing space tourism services. Blue Origin is working on its own craft, *New Shepard*, which will take passengers to 351,000 ft/110,000m for a similar suborbital experience. Other companies are working on plans for space hotels, lunar tours and more.

We look to these programs with some excitement because all of them do or will make substantial use of composites, in everything from passenger and crew structures to launch vehicle bodies. Indeed, when fighting gravity, as all spacecraft must, reducing vehicle mass is a necessity, and that is where composites typically excel.

Accidents like *SpaceShipOne*'s, however, give us pause, and remind us that sending humans into space is difficult and fraught with danger. The challenges faced today by Virgin Galactic and others put in stark relief the challenges associated with man's attempt, nearly 50 years ago, to land on the moon. Neil Armstrong and Buzz Aldrin's first steps on the lunar surface in July 1969 are, today, taken for granted as established, successful historical events. However, the *Apollo 11* moon mission (heck, the entire *Apollo* program) seems nearly miraculous when you consider the meager materials, computing and communications technology available to us at the time.

And so I wonder, in 50 years, how we will look back on this new age of corporation-led space flight. Will we see here the seeds of programs destined to populate the moon and Mars? Will we, eventually, take for granted the complexity and risk associated with breaking away from Earth's gravity? What challenges will we face 50 years from now that, today, are purely speculative?

Stay tuned.

JEFF SLOAN — Editor-In-Chief


SCHULER


SCHULER

Innovation in SMC: A long history and great potential

CW's August 2018 article, "Teaming to define what CFRP could be," on the CFRP front subframe developed by Ford Motor Co. (Dearborn, MI, US) and Magna International (Aurora, ON, Canada), illustrates innovation in sheet molding compound (SMC) — specifically, overmolding noncrimp carbon fiber fabric SMC with chopped carbon fiber SMC. This idea of using a *continuous fiber* SMC comolded with conventional chopped fiber SMC, *and* the use of chopped *carbon fiber* SMC, may seem new, but these innovations actually go back more than 30 years to the GMC *Astro* Class 8 truck door using SMC developed by Premix/EMS. Several other projects contributed further developments over the years. The history of SMC development shows how far the industry has come, but also that the future belongs to those who understand the big picture, and thus, are willing to take risks.

The future of SMC development belongs to those willing to take risks.

The GMC *Astro* Class 8 vehicle door was one of the parts that impressed me the most when I joined the industry in 1986 as a technical sales representative for Premix/EMS (North Kingsville, OH, US). A heavy truck fleet owner even remarked that the SMC door was the best thing about that truck. The three-piece assembly had inner and outer structural parts with a decorative cover panel. But I was most impressed with the addition of *continuous unidirectional* material in the window frame area. It was an example that I used often when talking with vehicle design engineers who needed higher tensile strength than what our conventional discontinuous fiber materials offered.

My lesson learned: A vehicle designer considering development of a comolded part must have enough confidence in all phases of part development to know whether he or she is creating a breakthrough or just another science experiment.

The next step

In 2003, the Dodge *Viper* represented the first use of *carbon fiber* SMC in a production vehicle[1]. The vehicle manufacturer, Chrysler, and the SMC supplier, Quantum Composites (Bay City, MI, US), developed breakthrough solutions in three structural systems:

- Thin-walled sections in fender supports,
- Carbon fiber SMC and low-density glass fiber SMC in door panels,
- Comolded unidirectional carbon fiber with structural SMC on the windshield surround.

In a 2002 paper published by the Society of Plastics Engineers (SPE, Bethel, CT, US), the development engineers at Chrysler and Quantum cite lack of understanding carbon fiber as one of the key factors limiting prior use of it in SMC. I think another key issue was the need to understand how randomly oriented fibers behave in structural applications. Material suppliers, molders and design engineers had decades of experience in making thermoset fiberglass composite structural parts. They were accustomed to these being stronger than thermoplastics, using materials with clear data sheet values, and if you needed more strength, you could just add material. The parts were characterized by long-term resistance to creep, which insured that structures remained in place under stress. But the SMC industry was not ready for the examination that Boeing would conduct into discontinuous fibers.

New challenges

As the Boeing Co. (Chicago, IL, US) developed its 787 *Dreamliner* commercial aircraft, it began looking at a variety of new materials, including Hexcel's (Stamford, CT, US) HexMC chopped carbon fiber/epoxy material. The push at Boeing to use this material for primary structure created a need for a deeper characterization of discontinuous fiber performance, including understanding the variation and predictability of SMC. This was the type of data and analysis the industry was ill-prepared to provide.

To understand the answers to Boeing's questions, I went to Dr. Paolo Feraboli at the Automobili Lamborghini Advanced Composite Structures Laboratory (ACSL), which was created with the University of Washington (Seattle, WA, US). Feraboli's work, summarized in the 2009 paper "Notched behavior of prepreg-based discontinuous carbon fiber epoxy systems,"[2] helped the industry understand the underlying principles of coupon and part testing, and provided insight into why parts worked and the limits to assumptions from coupon test values alone. A summary of similar work was presented at the 2013 SPE Automotive Composites Conference & Exhibition (ACCE) by Matt Kaczmarczyk and Tim Langschwager of Quantum Composites[3]. This gave Quantum the data and confidence that we not only understood our materials but could explain their performance to others.

Performance at the next level

As head of the ACSL, Feraboli had performed testing and development work on the *Sesto Elemento*, the first Lamborghini model to use CFRP not only in its monocoque, but also in its suspension control arms. The *Sesto Elemento* also pioneered application of carbon fiber SMC in both of these applications. This development was in parallel with Callaway Golf Co.'s (Carlsbad, CA, US) use of the material for driver crowns (golf club heads) and Quantum Composites's AMC 8500 family of chopped 12K carbon fiber/vinyl ester resin products. Both Lamborghini and Callaway were seeking to expand the limits of performance and practical part size. The *Sesto Elemento*'s suspension arm actually used unidirectional carbon fiber overmolded with carbon fiber SMC, one of the first commercial applications of the material[4].

Lessons learned

Material suppliers and creative design teams have shown that comolded hybrid material parts are the future. There is a 30-year history of product development and refinement of engineering techniques that have countered earlier challenges. But from my experience, the breakthrough needed to move forward will not be the engineering, it will be in the management of the innovation process by material suppliers and OEMs.

For example, one challenge is that SMC producers are good at making a wide range of very similar products. Making a "structural product" is different than making a good, consistent SMC. Small amounts of variation in proven or new products can turn into problems when the upper ends of mechanical properties are pushed. This puts a premium on process control and material characterization to create confidence in a material for the design team.

Experience has also shown me that little things kill projects. Too many secondary operations can add significant cost. The inability to control a small occasional warp in a key fit area or the need to prime paint can derail a project with great design breakthrough.

Overall, the question I would ask any team in the process of innovating with SMC is this: Did you find moving forward was a great and rewarding experience, or have you gone back to what you know and you do well? From my experience, the challenges of pushing the limits can create a mental cloud that can be tough to overcome. However, as these parts have illustrated, moving fast with conviction to make a better product can result in success.

Editor's note: Premix and Quantum Composites were acquired in 2011 and combined with Hadlock Plastics (Geneva, OH, US) to form The Composites Group (Kingsville, OH, US), but operate as individual suppliers. The Composites Group was acquired by Citadel Plastics (Chicago, IL, US) which was acquired by A. Schulman (Fairlawn, OH, US). LyondellBasell (Rotterdam, The Netherlands) acquired A. Schulman in August 2018. CW

REFERENCES

[1] quantumcomposites.com/pdf/papers/Viper-SPE-Paper.pdf

[2] researchgate.net/publication/229255007_Notched_behavior_of_prepreg-based_discontinuous_carbon_fiberepoxy_systems

[3] temp.speautomotive.com/SPEA_CD/SPEA2013/pdf/CF/CF3.pdf

[4] lambolab.org/wp-content/uploads/03research/pub/05chop/2011-ASC-montreal-forged-suspens-ICE.pdf and short.compositesworld.com/sesto_CFRP

ABOUT THE AUTHOR

Steve Brown has worked as a manufacturer's representative for Premix and Quantum Composites, selling composite materials and molded parts to aerospace and automotive OEMs since 1986. For much of that time, he has developed applications for high-performance SMC, and he continues to develop new and unique solutions where conventional composites struggle.

Passion, persistence and patience — winning the long game

> We are on the precipice of widespread adoption of FRP rebar in infrastructure construction.

» It's December and winter is nigh in the Northern hemisphere. For many of us, it brings cold, snow and ice for the next several months. On the plus side, it means that another road construction season has passed, and with it, the disappearance of the ubiquitous orange barrels, detours and delays that accompany it. Come spring, they will be back, as there will inevitably be more failed bridges and roads to be replaced.

The reason for this? Cracked concrete, typically caused by rusting of the steel reinforcing rods, or rebar, used internally to strengthen the concrete. Over time and use, reinforced concrete develops small cracks, which allow water to penetrate. As water oxidizes the steel rebar, it expands up to four times its original dimension, putting internal pressure on the concrete, exacerbating the cracks and allowing more water to penetrate. The concrete eventually breaks apart, a process called spalling, prompting eventual repair or replacement. Spalling is accelerated in chloride-rich environments, such as those where deicing salts are applied, and in coastal areas subject to seawater and salt air.

As a *CW* reader, you probably know the solution to this problem: Replace the steel rebar with one made of composites! Not only does composite rebar not corrode, it is 75% lighter and twice as strong as steel, plus it is electrically and thermally nonconductive. This solution seems obvious and easy, but change comes slowly to the infrastructure market. Composite rebar is more expensive than bare steel, yet compares well to epoxy-coated steel, and is cheaper than galvanized or stainless steel.

The German philosopher Georg Hegel once said, "Nothing great in the world has ever been accomplished without passion." To that, I would add two other attributes necessary to effect change in conservative markets — *persistence* and *patience*. One person that exemplifies these three attributes is John Busel, vice president, Composites Growth Initiative of the American Composites Manufacturers Association (ACMA). Because of the efforts of John, and many others, we are on the precipice of widespread adoption of fiber-reinforced polymer (FRP) rebar in infrastructure construction.

I sat down with Busel to better understand this journey, and what a long journey it has been! We in the composites industry typically see concrete as a material to replace; Busel sees it as an opportunity to *enhance*. In 1991, the American Concrete Institute (ACI) created ACI Committee 440, recognizing the emerging applications of composites in internal reinforcement with rebar and pre-stressed tendons and external reinforcement with column strengthening and seismic upgrade. In 1996, the committee developed a "state of the art" document regarding FRP use in concrete applications.

By the late 1990s, commercial FRP rebar products were introduced in field demonstrations. ACI issued a design guideline on composite rebar in its *Emerging Technology Series* in 2001, indicating this was a technology to follow. Busel chaired Committee 440 from 2004 to 2010, issuing seven standards in that time. ACI is very data-driven, and those early demonstrations provided field verification of the durability of composites, leading to removal of the "emerging" tag from the guideline in 2006.

ACI issued the current ACI 440.1R standard covering FRP rebar in 2015, and in 2017, ASTM issued a specification, ASTM 7957, covering testing standards and certification of FRP rebar. Committee 440 is currently authoring a dependent code to ACI 318, which covers all concrete structures, to incorporate the use of FRP rebar. While these documents are significant, what will truly drive market growth will be government buyers of roads and bridges demanding longer-life structures. Busel says many new projects in Canada today specify FRP rebar construction in bridges, and he expects this also will happen in the US and elsewhere, creating huge opportunities for composite rebar manufacturers.

Busel gives significant credit for the acceptance of FRP rebar to the leadership and vision of Antonio Nanni, professor and chair of the College of Engineering at the University of Miami. Nanni has studied composite rebar for years and has provided data to ACI that proves the material's long-term durability. Nanni also leads an effort to develop concrete mixtures using *seawater* instead of fresh water, initiating the SEACON project with US and Italian partners to demonstrate the technology at scale. FRP rebar is a key to success, as seawater contains *300-500 times* the chloride content of fresh water. The implications for island nations and arid coasts where fresh water is in short supply are significant, to say the least.

Composites offer many advantages for improving infrastructure applications. If we continue to play the long game, we will prevail. CW

ABOUT THE AUTHOR

Dale Brosius is the chief commercialization officer for the Institute for Advanced Composites Manufacturing Innovation (IACMI), a DOE-sponsored public-private partnership targeting high-volume applications of composites in energy-related industries including vehicles and wind. He is also head of his own consulting company, which serves clients in the global composites industry. His career has included positions at US-based firms Dow Chemical Co. (Midland, MI), Fiberite (Tempe, AZ) and successor Cytec Industries Inc. (Woodland Park, NJ), and Bankstown Airport, NSW, Australia-based Quickstep Holdings. He served as chair of the Society of Plastics Engineers Composites and Thermoset Divisions. Brosius has a BS in chemical engineering from Texas A&M University and an MBA.

Index extends strong expansion trend

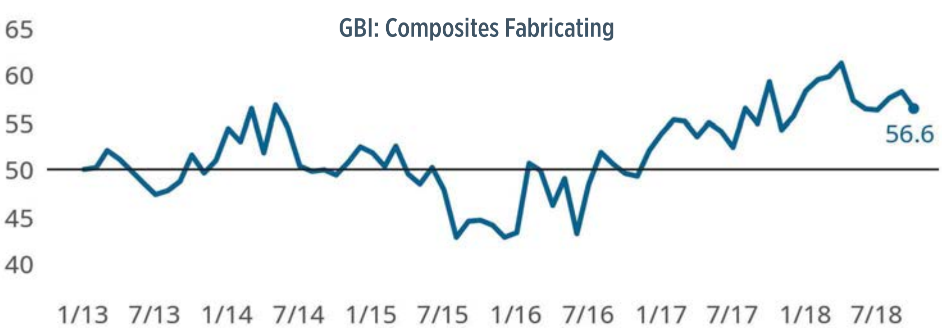
October 2018 — 56.6

» The GBI: Composites Fabricating Index retained its accelerated growth trend in October, registering a solid 56.6. This sets the year-to-date average index reading at 58.2, which if left unchanged, will establish 2018 as the best year in history for the Index. For comparison, the current record was established in 2017 at an average reading for the year at 55.1. The latest reading is 4.8% lower than during the same month one year ago; however, the prior year's reading at that time was also an all-time high monthly reading. Gardner Intelligence's review of the underlying data for the month indicates that the Index was pulled higher by supplier deliveries, new orders and production. The Index — calculated as an average — was pulled lower by backlogs, employment and exports.

During the month, supplier deliveries and new orders rose, while all other components grew at slower rates than in the prior month. For a fifth consecutive month exports contracted, yet the strong reading for new orders suggests that domestic demand is offsetting export weakness. The composites industry is particularly susceptible to export volatility induced either by trade regulations or foreign exchange fluctuations, or both. Since April, both factors have had a significant impact on the composites industry. In that time, the US dollar has appreciated by roughly 10% against the Chinese yuan and trade sanctions imposed by China have made several types of US aircraft and aerospace products more expensive.

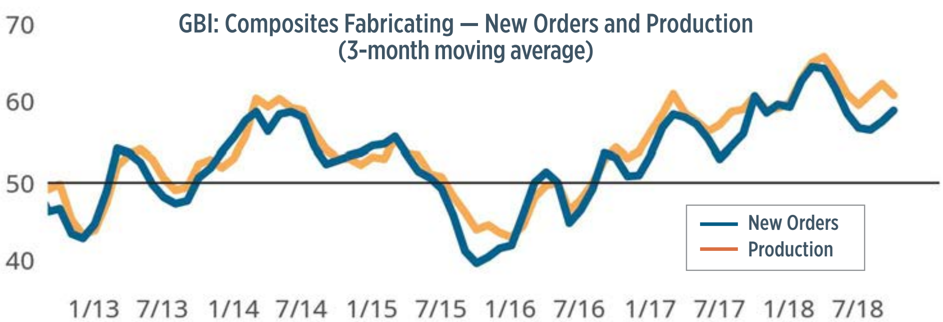
ABOUT THE AUTHOR

Michael Guckes is the chief economist for Gardner Intelligence, a division of Gardner Business Media (Cincinnati, OH, US). He has performed economic analysis, modeling and forecasting work for nearly 20 years in a wide range of industries. Guckes received his BA in political science and economics from Kenyon College and his MBA from Ohio State University. **mguckes@gardnerweb.com**



Market influenced by aerospace exports

The Composites Index was supported by quickly expanding levels of supplier deliveries, but was also pulled lower by a worsening contraction in exports. The composites market's strong reliance on aerospace products makes it particularly vulnerable to factors influencing exports.



Domestic demand for composites supports production growth

New orders readings have resumed their previous expansion path established prior to the surprise July slowdown. This has come despite a worsening contraction in exports. Overall production continues to expand.

Highlights from *CW* senior editor Ginger Gardiner's visit to IBEX 2018, growing use of graphene-enhanced parts in the automotive industry, steps forward on all-composite cryogenic tanks and more.

IBEX 2018: 3D printing, thermoplastic composites and recycling move forward as marine industry continues strong growth

In its seventh year of growth, the marine industry is surging in boat production and new models. This could be seen in the 28th International BoatBuilders' Exhibition and Conference (IBEX, Oct. 2-4, Tampa, FL, US), which posted a 23% increase in attendees to 4,300 and a 14% increase in exhibitors, representing 700 companies. Four International Pavilions — Australia, France, Italy and South Korea — were part of a growing global presence, with 55 countries represented in show attendees this year.

The heart of IBEX, its Education Conference, also saw growth this year, with seminar sales up 27%. Notable topics were 3D-printed composite production tooling and thermoplastic composites. Composites-focused offerings included resin infusion fundamentals, labor efficiency with infusion, making and breaking test panels, composite cosmetics, avoiding common repair mistakes and making structural parts with thermoplastics.

CompositesWorld produced the featured seminar "Future Materials" with co-presenters *CW* senior editor Ginger Gardiner, Gougeon Brothers Inc. (Bay City, MI, US) technical director Jeff Wright and Lingrove (San Francisco, CA, US) president Joe Luttwak. Wright explained how life cycle analysis (LCA) and sustainability are serious considerations as new resin formulations are explored for its West System, PRO-SET and Entropy brands of epoxy. This must be balanced, however, with composites structural performance, processing and supply chain needs. Regarding

IBEX 2018 welcomed 4,300 attendees and 700 exhibitors, an increase from the previous year of 23% and 14%, respectively. The show featured the first-ever Vacuum Bag Challenge (above right photo), with four teams bagging a balloon to 15 inches of mercury, without popping it, in the fastest time. The team of Accredited Marine Technologies and Schooner Creek Boat Works won with a time of 6 minutes, 22 seconds. Supplies and technical expertise were provided by PRO-VAC. Source | IBEX

processing, Wright noted developments designed to achieve higher glass transition temperature (T_g) with lower temperature post-cures. Luttwak offered the second look at thermoplastic composites within the 2018 seminars, discussing Ekoa thermoplastic composites for wood replacement, offering the look, feel and lightweight structural performance of old-growth wood, but via more sustainable flax fiber-reinforced bio-thermoplastic sheets and tapes. Attendees responded with interest for both interiors and structural applications.

Another seminar of note was "3D Printed Production Tooling," which reviewed how Alliance MG worked with Oak Ridge National Laboratory (ORNL, Oak Ridge, TN, US) to directly 3D-print a composite hull mold for a 34-ft production, resin-infused catamaran. *Professional BoatBuilder* magazine covered this project in the article "Just Print it!" by Dieter Loibner, who also penned an update on the Livrea Yacht 3D-printed boat in "Print Yourself a Boat." Though still in its early days, 3D printing is obviously moving forward in marine.

Perhaps the most impactful seminar for composites was "Developing Sustainable Solutions for End-of-life Fiberglass Boats," presented by Evan Ridley and Wendy Mackie of the Rhode Island Marine Trades Association (RIMTA, Bristol, RI, US). A pilot recycling network has been established by RIMTA in collaboration with other state organizations and government agencies. Modeled after a successful German system, the 2018 Rhode Island Fiberglass Vessel Recycling (RIFVR) project will collect end-of-life boats, drain their fluids, remove engines, metals and electronics, and then work with industry partners to shred fiberglass composite structures. This recyclate will then be trucked to a cement kiln where it will be used as fuel. It also may be combined with composite production waste — e.g., resin-filled vacuum bags, scrap laminate and resin — which increases the BTU content for the energy-intensive cement kilns.

The potential impact of this project is significant, enabling a technological leap for the composites industry in closing the loop and achieving zero-landfill manufacturing. RIMTA is seeking financial backing, but also partners to help with logistics, R&D and expansion to other durable waste streams (e.g., composite production waste), as well as further collaboration with cement industry partners. With this project's success, the composites industry should continue forward, refining and expanding across the country and into other markets, such as wind power, where first-generation composite turbine blades are beginning to be replaced.

Another highlight at the show was recognition of Structural Composites Inc.'s (West Melbourne, FL, US) development work that won it the IBEX 2018 Innovation Award in the Boatbuilding Methods & Materials category — Structural Composites' CoCure Technology used in Interplastic Corp.'s (St. Paul, MN, US) new Advanced Marine Coatings. Comprising a polyester/polyurethane hybrid, these coatings offer a 200% increase in impact resistance, with a 70% increase in elongation, offering boatbuilders a tougher, more flexible exterior surface and increased design freedom in the underlying composite structure.

In addition, Advanced Marine Coatings can be "tuned" for different strain requirements, with toughness tailored from rigid to elastomeric. This product line also reportedly provides a 20% decrease in hazardous air pollutant (HAP) content vs. conventional gelcoats. Structural Composites president Scott Lewit reviewed the technology development work in an IBEX technical seminar, noting that new formulations are in testing for the RV market, offering up to three times the weathering performance of current polyester gelcoats.

IBEX 2019 is scheduled for Oct. 1-3, 2019, at the Tampa Convention Center, where the show will remain for the next three years. For more information, visit ibexshow.com.

CONSTRUCTION

Teijin to build advanced fiber-reinforced wood building

Teijin Ltd. (Tokyo, Japan) announced that it will construct the world's first building made of advanced fiber-reinforced wood (AFRW), a structural timber product comprising a number of layers of dimensioned timber and high-performance fibers bonded together with structural adhesives. Teijin first developed the materials in 2015, which involved incorporating high-toughness aramid fibers and highly stiff carbon fiber, and hybrid materials incorporating these fibers.


Source | Teijin Ltd.


Source | Teijin Ltd.

The new building, which will be constructed in Teijin's Tokyo Research Center in Hino City, Japan, exploits the warm texture and unique timber composition of AFRW to help create a stress-free environment. It also aims to realize open and comfortable space by avoiding the use of columns, thus maximizing the inflow of natural light.

The project was approved by Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT, Tokyo) in May and construction was set to begin in October, with technical support provided by the professional construction firm Maeda Corp. (Tokyo) and the Structural Engineering Laboratory of Kochi University (Kochi, Japan). Upon completion, Teijin and Maeda will monitor adhesive stability and the vibration durability of AFRW for a period of seven years.

Teijin will continue to develop AFRW technology following construction of this first building and the initial monitoring phase. The aim is to realize safe, comfortable, earthquake-proof wooden buildings as well as the development of sustainable architecture using timber as sustainable resources that absorb CO_2. The company expects the new technology and materials to be deployed in general construction by around 2020.

AEROSPACE

Cimarron advances micro-strain performance for cryogenic pressure tanks

Source | Cimarron Composites

Cimarron Composites (Huntsville, AL, US) has made a leap forward in all-composite cryogenic tank manufacturing: development of a carbon fiber-reinforced composite storage tank capable of 15,000 micro-strain performance while in a pressurized liquid nitrogen environment. Cimarron founder Tom DeLay, formerly with the National Aeronautics and Space Administration (NASA, Washington, DC, US), says successful operation at such a high strain level allows the linerless composite tank structure, made with a combination of textiles with continuous wound fibers and an in-house resin, to be much thinner than previously required in these types of tanks, without the cost and mass of the liner. According to DeLay, earlier composite tank programs were limited to 3,000 micro-strain due to materials and processing limitations, and this resulted in extra mass. Cimarron's material system is said to perform well at extremely low temperatures without developing the microcracks that create leak paths for fluids like liquid oxygen, liquid hydrogen or liquid methane.

The company's 44-inch diameter test article is representative of the size required for the development of small rocket concepts used for nanosatellite (1-10 kg mass) deliveries. The same technology is also applicable for much larger upper stages in commercial launch programs, or for very small satellites and space probes. Says DeLay, "Cimarron is fortunate to have the materials expertise, manufacturing equipment and cryogenic testing facilities to develop and demonstrate such unique hardware. Cimarron Composites can currently filament wind structures up to 6 ft in diameter and 45 ft long. We also have extensive liquid nitrogen-based testing equipment for proof tests (up to 20,000 psi), cycle tests and burst tests as needed, which covers the low-temperature range of most cryogenic fuels and oxidizers, except liquid hydrogen."

Cimarron just signed a Space Act Agreement with NASA to have liquid hydrogen tank testing and liquid oxygen tests done at the Marshall Space Flight Center in Huntsville, AL, US. This testing capability at NASA will help further mature the composite tank technology for upcoming launch vehicle developments, says Cimarron. More information is available at cimarroncomposites.com.

Green Science Alliance Co. Ltd. manufactures new nano cellulose composites

Green Science Alliance Co. Ltd. (Kawanishi, Japan), a group company of Fuji Pigment Co. Ltd. (Kawanishi), reports that it has established a manufacturing process for mixing nano cellulose with various thermoplastic materials.

Nano cellulose is derived from natural biomass resources such as trees, plants and waste woods, and is therefore recyclable and biodegradable. It has a low coefficient of thermal expansion comparable to that of glass fiber. However, its elasticity modulus is higher than that of glass fiber, making it a hard, strong and robust material. The material shows potential for automotive, aerospace, architectural and other applications while enabling a positive environmental impact.

Source | Green Science Alliance Co. Ltd.

Green Science Alliance Co. Ltd. has combined nano cellulose with various thermoplastics so far, namely, polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), acrylonitrile butadiene styrene (ABS), polycarbonate (PC), polymethyl methacrylate (PMMA), polyamide 6 (PA6) and polyvinyl butyral (PVB). In addition, the company recently established a manufacturing process for mixing nano cellulose with various types of biodegradable plastics including polylactic acid (PLA), polybutylene adipate terephthalate (PBAT), polybutylene succinate (PBS), polycaprolactone, starch-based plastic and biodegradable plastics produced by microorganisms such as polyhydroxyalkanoate (PHA).

In the near future, the company says it aims to use this biodegradable plastic/nano cellulose composite to make products such as food trays and boxes, straws, cups and cup lids. The company also is planning to apply supercritical foaming technology, in order to make biodegradable plastic mold products even lighter and stronger.

TRANSIT

Hyperloop Transportation Technologies unveils passenger capsule


Source | Hyperloop Transportation

Hyperloop Transportation Technologies (HyperloopTT, Culver City, CA, US) recently unveiled its full-scale passenger Hyperloop capsule. The capsule, *Quintero One,* is manufactured almost completely out of a material HyperloopTT calls Vibranium, a specially made dual-layer "smart" composite material created using carbon fiber reinforcements and embedded sensors. The 32m-long capsule is comprised of 82 carbon fiber composite panels and was built at the Southern Spain aerospace facilities of HyperloopTT's partner Airtificial, a new company formed by the merger of composites engineering and fabrication firm Carbures (El Puerto de Santa María, Spain) and engineering company Inypsa (Madrid, Spain). Artificial supplies parts and structures for several leading companies including Airbus and Boeing. The capsule's design was created in collaboration with transport design consultancy PriestmanGoode (London, UK) and won the Gold award at the 2017 London Design Awards.

The capsule will be delivered to HyperloopTT's research and development center in Toulouse, France, for additional assembly and integration into the system, before it is used on one of the first commercial tracks.

Recently, HyperloopTT became the world's first company to be able to offer an insured commercial system. In collaboration with Munich Re (Munich, Germany), the world's largest reinsurance company along with global certification and inspection company TÜV SÜD (Munich, Germany), governments and partners, HyperloopTT is reportedly working to create the first regulatory guidelines and necessary legal framework for Hyperloop systems around the world.

MONTH IN REVIEW

Notes about newsworthy events recently covered on the *CW* Web site. For more information about an item, key its link into your browser. Up-to-the-minute news | www.compositesworld.com/news/list

ULA selects Blue Origin's BE-4 Engine to power Vulcan
The liquefied natural gas (LNG) fueled booster will be powered by a pair of BE-4 engines, each producing 550,000 lb of sea level thrust.
10/3/18 | short.compositesworld.com/BE-4Vulcan

Hexagon announces third composite hydrogen tank contract for fuel cell vehicles
A third automotive OEM commits to Hexagon Composites as supplier of composite hydrogen tanks for fuel cell vehicles.
10/12/18 | short.compositesworld.com/hydrotanks

Northrop Grumman and Airbus finalize Wing of Tomorrow program agreement
The agreement positions Northrop Grumman for work on next-generation composites manufacturing technology.
10/16/18 | short.compositesworld.com/NG_Airbus

3A Composites balsa core material selected by US Navy
The company's BALTEK SB balsa core has received ABS Certification and is currently the only balsa core material approved for the US Navy shipbuilding programs.
10/15/18 | short.compositesworld.com/3A_balsa

MultiMechanics and Opterus R&D partner on HSCs for space applications
The two companies are collaborating in response to a NASA solicitation seeking further exploration of the use of thin-ply high-strain composites (HSC) for space applications.
10/15/18 | short.compositesworld.com/HSCpartner

IACMI consortium aims to close the loop on automotive carbon fiber prepreg scrap
Carbon fiber recycling start-up Vartega leads a project to close the loop on automotive carbon fiber prepreg manufacturing scrap for use in new automotive applications.
10/16/18 | short.compositesworld.com/CF_prepreg

Aston Martin and TenCate partner on Valkyrie hypercar
TenCate to supply advanced composite materials for a broad range of end-use applications throughout the car.
10/18/18 | short.compositesworld.com/hypercar

LM Wind Power to supply wind turbine blades for Goldwind 3-4-MW onshore platform
The agreement covers three variants and includes 66.9m and 69.0m blade lengths.
10/19/18 | short.compositesworld.com/Goldwind

Scorpius Space Launch Company unveils carbon fiber cryogenic high-pressure tanks
SSLC's vessels are built with carbon fiber materials and the company's proprietary Sapphire 77 cryogenic resin system and feature anti-slosh baffles.
10/23/18 | short.compositesworld.com/cryo_tank

American Magic announces Airbus as innovation partner in America's Cup bid
Airbus will allocate engineering resources and modeling expertise to assist in the design optimization of American Magic's future AC75 racing boat.
10/24/18 | short.compositesworld.com/AMagic_Cup

ENERGY

GE launches onshore wind turbine with two-piece carbon fiber blades


Source | GE Renewable Energy

GE Renewable Energy (Paris, France) launched its new Cypress onshore turbine platform, and the next model from that platform, GE's 5.3-158 turbine. The platform advances the technology of GE's 2-MW and 3-MW fleets. It serves an installed base of nearly 20 GW while also using architecture and innovations from the 4.8-158 turbine, which was introduced in 2017.

The Cypress platform, which also includes the 4.8-158, is powered by a two-piece carbon fiber blade design, enabling blades to be manufactured at even longer lengths and improving logistics to offer more siting options. According to GE Renewable Energy, the new design enables blade assembly onsite, reducing the costs for permitting equipment and road work required for transporting longer blades.

Cypress is designed to scale over time, enabling GE to offer a wider array of power ratings and hub heights to meet customer needs throughout the 5-MW range. Longer blades improve annual energy production (AEP) and help drive down the levelized cost of electricity (LCOE). GE says the proprietary design of the new blades will allow these larger turbines to be installed in locations that were previously inaccessible.

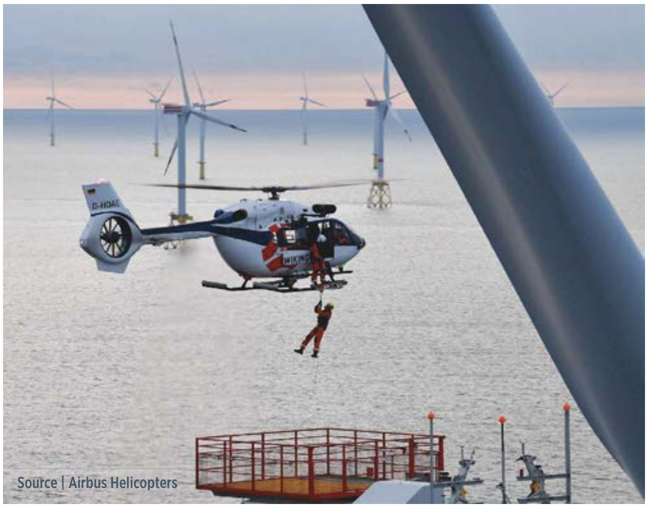
AEROSPACE

Airbus Helicopters puts focus on offshore wind market

Airbus Helicopters (Marignane, France) reports that it is looking at wind farms as a business segment that is undergoing global growth. The company expects demand for up to a thousand helicopters over the coming two decades, corresponding to revenues of approximately €9 billion.

"Helicopters are an integral part of any logistics concept for offshore wind farms," says Dennis Bernitz, head of Western Europe sales. "Our helicopters can complete missions for wind farms in a particularly quick, economical, safe and environmentally friendly manner. Helicopters can be used to deploy technicians or medical personnel in emergencies, even in rough seas, and can also transport operating personnel between the shore and the wind farm."

According to Airbus Helicopters, helicopter transport allows personnel to avoid problems with seasickness caused by traveling by sea in rough weather conditions, reducing the possibility of mistakes being made by seasick technicians.


Source | Airbus Helicopters

The company claims helicopters also contribute to efficiency. With turbine output rising, leading to a higher rate of electricity production, wind farm operators rely on an efficient, rapid-response logistics system, depending on high availability to keep losses to a minimum should a malfunction occur. At the same time, wind farms are being built farther and farther from the shore. A helicopter can cover 40 nautical miles (approximately 74 km) in 20 minutes, reaching the site and returning to shore faster than a transport vessel.

Airbus Helicopters has developed a logistics calculator for wind farm operators, which takes into account all relevant factors — weather, location and the number of turbines in the wind farm — to determine the most economical and environmentally friendly logistics solution, including the mix of transport and special-purpose vessels.

Companies do not usually purchase the means of transport themselves, but lease the services from operators. Airbus Helicopters offers the H135, H145 and H175 rotorcraft for crew transport, maintenance and rescue missions. In future, the H160 is also expected to be available to this market. With their two engines and four-axis autopilot, the helicopters have the ability to hover more accurately, and to safely and precisely winch down personnel or goods.

Worthington Industries launches recyclable composite propane cylinder

Source | Worthington Industries

Worthington Industries (Columbus, OH, US) recently announced the launch of its first fully recyclable Type IV composite cylinder for the propane (LPG) industry. Named Fourtis, the lightweight cylinder used for cooking, water heating and outdoor grilling was developed by Amtrol-Alfa (Guimarães, Portugal), a manufacturer of low-pressure steel and composite cylinders that was recently acquired by Worthington.

Fourtis is a lightweight (5 kg without valve), durable, composite cylinder that is wrapped in a customizable, easy-to-clean polymeric jacket with an ergonomic handle. It is demountable, making reassembling easy, and is said to have lower maintenance costs than steel cylinders.

The cylinder is resistant to impact, corrosion and permeability. It can be equipped with microchip technologies, such as RFID and NFC, for tracking, fast identification and real-time database assessment, which reportedly optimizes labor and filling costs.

According to Worthington Industries, the Fourtis can be manufactured according to many standards, including ISO 11119-3, EN 14427 and EN 12245, for Europe, Asia, Africa, the Middle East and South America.

AUTOMOTIVE

New research project aims to boost electric vehicle performance

A new research project, Tucana, will focus on lightweighting technology with the help of experts from the Warwick Manufacturing Group (WMG, Coventry, UK), a department at the University of Warwick focused on research in engineering, manufacturing and technology.

The research will develop scalable carbon fiber composite solutions with the goal of boosting the performance of electric vehicles. As part of the project, WMG will manufacture carbon fiber components in its new Materials Engineering Centre, which has dedicated facilities for composite and hybrid structures. To gather the material optimization and characterization, WMG will trial the manufactured materials on its newly installed composite materials processing equipment (which received £1.3 million in funding from the WMG Centre High Value Manufacturing Catapult). WMG will receive £4 million, of £18.7 million in government funding through the Advanced Propulsion Centre (APC, Coventry, UK).

Source | WMG

Tucana, led by Jaguar Land Rover (Coventry), brings together partners Expert Tooling & Automation Ltd. (Coventry), Broetje-Automation UK Ltd. (Chester, UK), Toray International UK Ltd. (London, UK), CCP Gransden Ltd. (Newtownards, UK) and Magna Exteriors Ltd. (Banbury, UK).

The goal of Project Tucana is to allow the true environmental credentials of electric vehicles to be realized by enabling wider adoption. The CO_2 benefit of the project, between the years 2023-2032, is projected at 4.5 million tons.

TPAC and TPRC develop thermoplastic composites recycling process

The ThermoPlastic composites Application Center (TPAC, Enschede, The Netherlands) and the Thermoplastic Research Centre (TPRC, Enschede) have developed a new recycling process for thermoplastic composites.

Known as TPC-Cycle, the project targets production scrap by developing a recycling route for high-end and high-volume markets. The objective is to retain the high mechanical properties of thermoplastic composites and reduce the overall environmental impact at affordable cost. The project includes the process from waste collection to shredding, reprocessing and application. The recycling solution boasts short cycle times, net-shape manufacturing and is said to enable the production of complex shapes. According to TPAC, high mechanical properties are obtained by retaining long fiber lengths. Three demonstrators for aerospace parts are currently being developed to show the application in a high-value market.

Source | TPRC/TPAC

In addition to TPAC and TPRC, the collaboration includes several industrial partners in the value chain, from materials to manufacturing, design and application: GKN Aerospace Fokker Business (Redditch, UK), TenCate Advanced Composites (Nijverdal, The Netherlands), Cato Composite Innovations (Rheden, The Netherlands), Dutch Thermoplastic Components (Almere, The Netherlands) and Nido RecyclingTechniek (Nijverdal, The Netherlands). The project is facilitated by Saxion University of Applied Sciences (Deventer, The Netherlands) and with the financial support of Regieorgaan SIA, part of The Netherlands Organization for Scientific Research (NWO).

AUTOMOTIVE

BAC, Haydale and Pentaxia to explore graphene use in automotive industry


Source | Briggs Automotive Company

Briggs Automotive Co. (BAC, Liverpool, UK) has received funding to undertake research on graphene, with a view to pushing the technology towards production-readiness for the automotive industry.

BAC, maker of the BAC Mono single-seat supercar, received the Niche Vehicle Network (NVN) grant alongside Haydale Composite Solutions (Loughborough, UK) and Pentaxia Composites (Derby, UK) and will now further explore the benefits of using graphene in composite body panels. The company will be the test bed for the technology and potentially the catalyst for larger-volume opportunities across the market.

BAC became the first car manufacturer in the world to develop a graphene-paneled car in 2016, creating graphene-enhanced carbon fiber composite rear wheelarches for Mono. The new venture will build on that proof of concept.

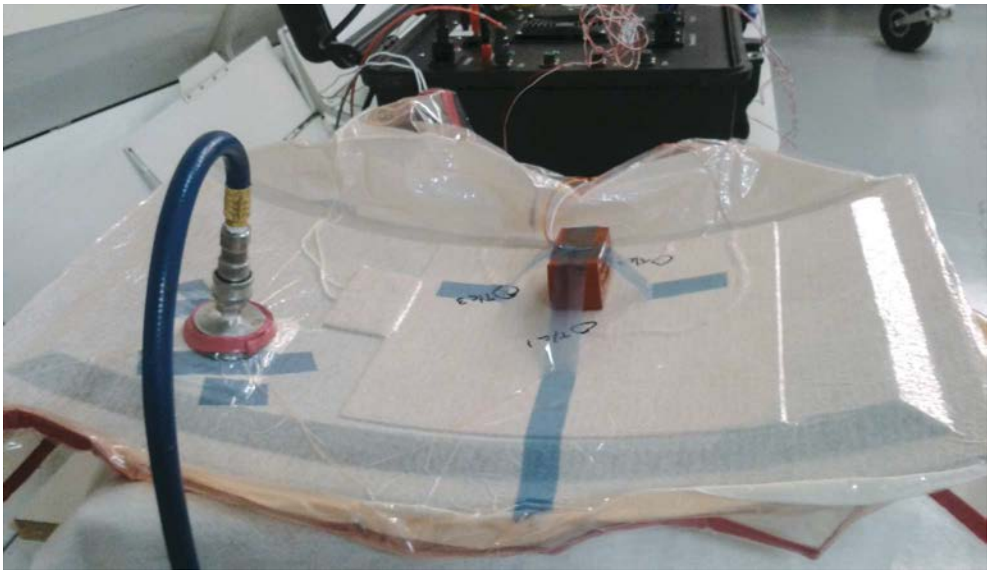
Graphene is made of sheets of carbon just one atom thick and is significantly lighter than standard carbon fiber. With the NVN funding, BAC, Haydale and Pentaxia hope to develop lightweight composite materials using graphene, and to manufacture a novel carbon fiber composite tooling system with enhanced thermal conductivity — resulting in a new body panel system with improved mechanical and thermal performance.

The project aims to bring benefits in terms of weight reduction, CO_2 emissions and manufacturing cycle times. Body panels will be installed and tested on the Mono supercar throughout the project, with the aim to reduce weight by 10% and cycle times by more than 25%.

Measuring temperature inside composites and bondlines

ThermoPulse sensors offer Industry 4.0 temperature measurement and digital cure cycle management for bonded composite repairs, laminates and more.

By Ginger Gardiner / Senior Editor



Wireless, remote in-situ temperature monitoring

AvPro's ThermoPulse system is being tested at Abaris Training and three other sites for statistical validation of its ability to measure temperature within a composite bondline during composite repair. Though the antenna (orange block) interrogating the microwire sensors is shown here taped to the test panel, AvPro is developing the ability for the antenna to read from overhead stations and robotic arms.

Source | Abaris Training and AvPro Inc.

» Having full visibility into a composite and/or adhesive bondline during cure has been an issue for decades. Current temperature sensors — thermocouples — are too large to be embedded without causing a defect in the part. Thus, it is now only possible to read temperature at the surface and perimeter of parts and bonded repairs. It is difficult to know the temperature of an adhesive at the bottom of a repair patch, inside a thick fuselage or wing skin laminate or between those skins and thick stringers. Yet, that temperature is crucial for proper resin flow, wetting and cure.

Currently, the composites industry compensates for this shortcoming by spending months and millions of dollars testing to ensure that estimated time and temperature recipes do indeed complete cure and produce the necessary properties. Despite this, suppliers still spend many man-hours and dollars each year reviewing and certifying parts where thermocouples fail or where leading/lagging thermocouples are sufficiently outside of prescribed boundaries to cast doubt on properties and in-flight performance.

In an effort to solve this temperature-measurement problem, AvPro Inc. (Norman, OK, US) has developed the ThermoPulse system, which enables wireless, remote, in-situ temperature monitoring during cure. The system comprises microwire sensors, a transmitting/receiving antenna and a reader box that collects antenna signals and uses software to convert that information into temperature data. The sensors remain embedded in the part and the system can be used with autoclave, oven, infusion or resin transfer molding (RTM). AvPro has already completed a Phase I Small Business Innovation Research (SBIR) contract with the US Air Force and is currently performing a Phase II effort (FA8650-17-C-5059), directly measuring bondline temperatures during composite repairs and composite part fabrication and verifying the accuracy of ThermoPulse via round-robin testing at four independent sites.

The potential for this technology is significant, offering real-time Industry 4.0 data not only for thermoset composites, but also the temperature-dependent melt and crystallinity formation of *thermoplastic* materials. Further, *measurement* is actually not the system's end goal. ThermoPulse ultimately will manage cure cycles based on the composite's viscoelastic change. Cure cycles can be shortened because cure completion can be seen from real-time data vs. a legacy time/temperature recipe. Cure cycles also can be optimized, enabling the use of microwave and induction heating to deliver highly targeted and near-instaneous temperature as needed to achieve fast cure rates without "overcooking" the entire composite part.

Macro vs. microwire sensors

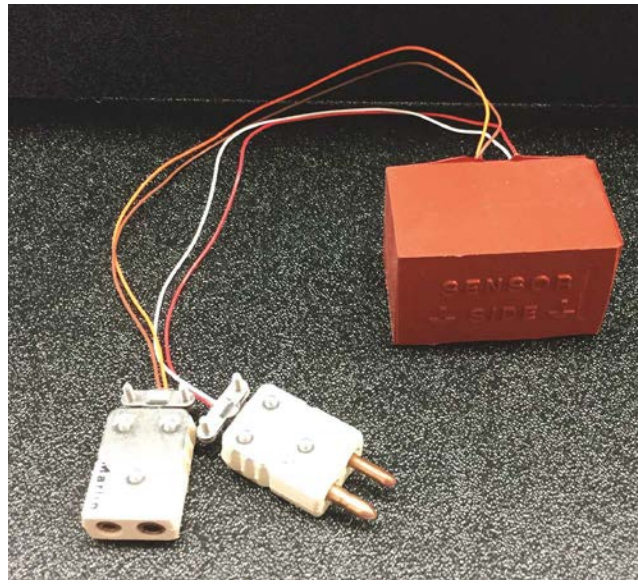
Thermocouples are the most common temperature sensor used in composites processing today. Formed by two wires of different metals joined at one end, they generate a current with change in temperature. Thermocouples are inexpensive and can provide accurate temperature readings, but they must be plugged into a voltmeter. Even though the individual wires may have a very small diameter, the completed, data-generating assembly cannot be embedded into a part or bondline without reducing structural properties and also posing vacuum bag challenges (i.e., source of potential leak paths) which may lead to poor quality composite parts.

In contrast, the microwire sensors in AvPro's ThermoPulse system are 0.25 mm in diameter and 32 mm long, and have successfully measured temperature while embedded beneath a carbon fiber-reinforced polymer (CFRP) laminate more than 25 mm thick. In lap shear test results, coupons with and without embedded sensors in the adhesive bondline are indistinguishable. The microwire sensors are made from amorphous metal alloys, mainly cobalt and iron. Their magnetic properties are unique. First, they polarize in only two possible states — along the wire length in one direction, or the opposite direction. Furthermore, the polarity changes nearly instantaneously — referred to as a Barkhausen Jump. When an alternating electromagnetic field is applied to a sensor, these Barkhausen Jumps cause sharp voltage pulses that can be detected remotely with an antenna. The integral of each pulse is temperature-dependent.

One more key component to this measurement mechanism is that the microwire metallurgy can be tailored to a specific Curie Temperature, which is the temperature above which the voltage pulse will no longer occur. Note, this is a certifiable physical property of the manufactured microwire. Precise temperature is able to be extracted from the microwire's voltage pulse because the magnitude of the integral decreases nonlinearly as the microwire's temperature approaches its Curie Temperature (Fig. 2, p. 20).

Thus, the ThermoPulse antenna sends out a low-frequency electromagnetic field to interrogate the embedded sensor and then receives the resulting voltage pulse, which is then converted by the reader box into a temperature measurement at that sensor location.

ThermoPulse sensors are autocalibrating and are actually made up of three microwires encapsulated in a rigid tube. (It is the tube that is 0.25 mm in diameter; each of the wires is 0.03 mm »



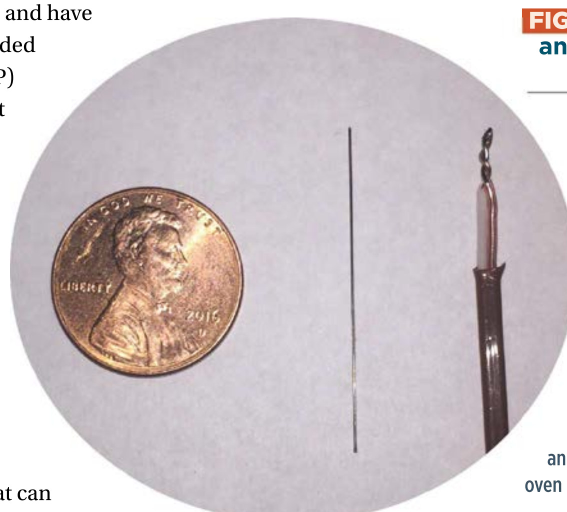


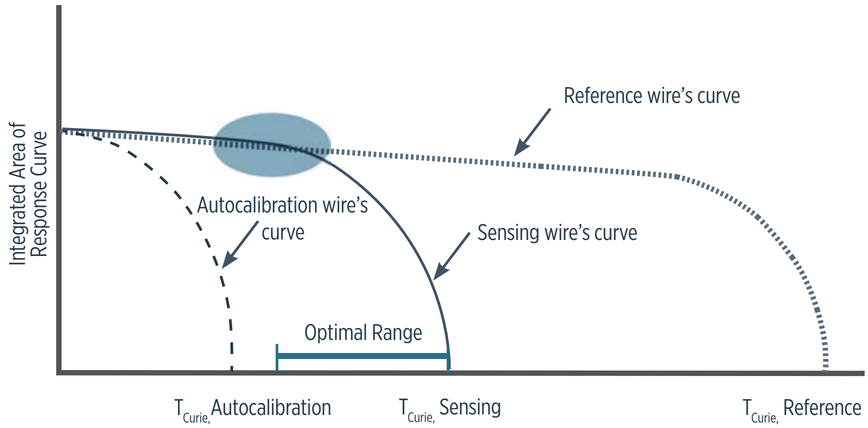
FIG. 1 Embedded sensors, antenna and temperature control

ThermoPulse microwire sensors are much smaller than thermocouples (center and right, respectively, left photo) currently used to measure temperature. These microsensors remain embedded in bondlines and parts without causing defects and are interrogated using a magnetic antenna (top photo) which plugs into a hot bonder (bottom photo) for data logging and analysis, temperature readout and control of heat blanket, autoclave, oven or other temperature/curing device.

Source | AvPro Inc.

FIG. 2 **Three microwires, one calibrated sensor**

When interrogated with an electromagnetic field from the ThermoPulse antenna, each of the sensor's three wires generates a voltage pulse that changes with temperature. The area under this voltage response is the temperature at a given time. Each microwire has a designed optimal range (highest sensitivity) starting at 100°F below its Curie Temperature (T_{Curie}). The autocalibration wire's T_{Curie} is set well below the composite/adhesive cure temperature, and once its voltage pulse disappears, the system is calibrated. The T_{Curie} of the sensing wire is set to 100°F above the desired cure temperature while the reference wire's T_{Curie} is set several hundred degrees above cure and provides a stable pulse for reference. Source | AvPro Inc.



in diameter.) One wire functions as the *measurement wire* and is alloyed to have a Curie Temperature approximately 50°F/10°C above the cure temperature for the resin system for which the sensor is designed. A second wire is termed the *reference wire* and is alloyed to have a Curie Temperature several hundred degrees above the desired dwell temperature, providing a constant pulse to normalize against. The third wire, called the *autocalibration wire,* is alloyed for a Curie Temperature above room temperature but significantly below the cure temperature. It will provide temperature readings until its known Curie Temperature is reached, at which point its pulse will disappear. At that instant, the temperature of the sensor is accurately verified and the ThermoPulse system has the calibration temperature needed to proceed with measurements and calculations.

> The ThermoPulse system enables wireless, remote, in-situ temperature monitoring during cure.

SBIR testing

Having completed an initial Phase I SBIR contract with the US Air Force to demonstrate feasibility, AvPro and its partners are now roughly halfway through the Phase II project, designed to validate the accuracy and precision of the ThermoPulse system. This is being achieved by testing at four independent sites, each using 25 ThermoPulse sensors and a prototype reader box incorporated into a type of hot bonder. Hot bonders are portable, small suitcase-sized equipment used to control the application of heat and vacuum to an adhesively bonded composite repair. The four test sites are AvPro's facilities, Abaris Training (Reno, NV, US), TSI Technologies Inc. (Wichita, KS, US) and AFLCMC/EZPT-ACO at Hill Air Force Base (near Ogden, UT, US).

AvPro has worked with Abaris Training for years to help validate and refine its Material State Management (MSM) system, while TSI Technologies is a key partner in developing and refining the microwire sensors. Hill Air Force Base is home to the Ogden Air Logistics Complex, which performs depot maintenance on several Air Force weapon systems, and the Air Force Life Cycle Management Center's Air Force Advanced Composites Office (AFLCMC/EZPT-ACO), a centralized resource for fielded composite materials. The research program is led by the Air Force Research Laboratory (AFRL, Wright-Patterson, OH, US) and project manager Kara Storage, with a view toward aircraft manufacturing and repair applications.

Each test site will complete 25 standardized bonded composite repairs using a 5-inch diameter scarf repair patch made from six plies of prepreg over a layer of film adhesive with a microwire sensor in the bondline. Each of these 25 repairs will also use thermocouples as a control for comparison with ThermoPulse microwire sensor results.

"We've completed all of the 250°F-cure repair tests and are now analyzing the data," says AvPro president Tom Rose. "So far, the microwire measurements are within ±5°F of the thermocouple measurements." Rose says all of the test sites are using CFRP laminates and patches except for Hill AFB, which has specific reasons for testing glass fiber laminates and repairs. "We are now starting testing with an additional 100 sensors for 350°F repairs and will complete the SBIR work by October 2019."

Another goal of this testing is to develop the statistical basis for an ASTM method. ASTM International (West Conshohocken, PA, US) is an organization that develops industry standards, including most of the test methods used for composite materials and structures. "The ASTM method for measuring temperature in a bondline during composite repair would also apply to any composite bondline," says Rose, "and will give the industry confidence in the accuracy of the ThermoPulse sensors." Completing the repairs for the SBIR testing will also provide feedback for refining the hot bonder prototype as a closed loop temperature control device. "Our goal is to control the repair cure based upon temperatures within the bondline," says Rose, "with the ultimate objective of providing significant time and cost savings."

Modernizing cure, documenting quality

"This sensor was developed to feed into our cure management system," Rose explains. "There really hasn't been much fundamental change in the way we're managing cure in composite structures." AvPro's material state control, however, *is* a significant change, which is one reason why its adoption has been slow. "The aerospace composites community is very conservative," notes Lou Dorworth, longtime instructor at Abaris Training. "Using AvPro's Material State Management system has required training and, initially, the units were not as user friendly as those being developed with ThermoPulse." Rose acknowledges that the goal of current development is to have a commercial product that is easy to use. "We are also refining the software and scaling the wire and sensor manufacturing for industrial production. Currently, we are projecting a cost of $25-$30 for each sensor, which is roughly the same price as a thermocouple."

"Our first priority is to get the technology finalized for commercialization and industrial production," says Rose. He adds that AvPro will next move forward with establishing an ASTM test method; the final step will be to conduct whatever additional testing is required for structural certification (i.e., effects of defects programs). "Getting equivalent results with and without the sensor bonded in is a good start," says Rose, "but structures engineers have to be convinced that the sensors can be placed at critical locations and improve their ability to achieve properties, without creating a defect." His goal is to pursue an initial qualification of the ThermoPulse system at an all-composite light sport aircraft (LSA) or personal jet manufacturer, which tend to have a flatter corporate structure than OEMs and large Tier suppliers.

Though change in composites aerostructures design and production is notoriously expensive and slow, there is more impetus now than ever to implement process control technologies that can accelerate the pace of composites manufacturing. Rose and Dorworth see the potential not only for aircraft manufacturing and repair, but for much wider applications such as managing temperature-dependent processes based on real-time, in-situ data. "Our system is giving the parts manufacturer the power to optimize its own cure cycles and correlate those to actual material properties," says Rose. "We now have the ability to measure temperature and viscosity as a function of time *in* the part *and* bondline. That gives us the ability to truly establish digital control and have documented confidence in the quality of our parts." CW

LEARN MORE

Read this article online |
short.compositesworld.com/thermopuls

ABOUT THE AUTHOR

CW senior editor Ginger Gardiner has an engineering/materials background and more than 20 years of experience in the composites industry.
ginger@compositesworld.com

High-strain composites for satellite applications

Carbon fiber takes deployable satellite mechanisms to new heights.

By Scott Francis / Senior Editor

» Early in 2018, during CW's visit to Ability Composites (Loveland, CO, US), CEO Frank Roundy held up a rolled-up piece of material that looked like the inside of a tape measure and fit in the palm of one's hand. Roundy unfurled the piece, which reached about 25 ft across the room, and explained that it was a deployable satellite boom.

The boom is made from a combination of carbon fiber and glass fiber in a thermoset matrix and was designed by Roccor (Longmont, CO, US), an aerospace company specializing in high-performance deployable structure systems, with the help of AnalySwift's (West Jordan, UT, US) SwiftComp engineering software for composites simulation.

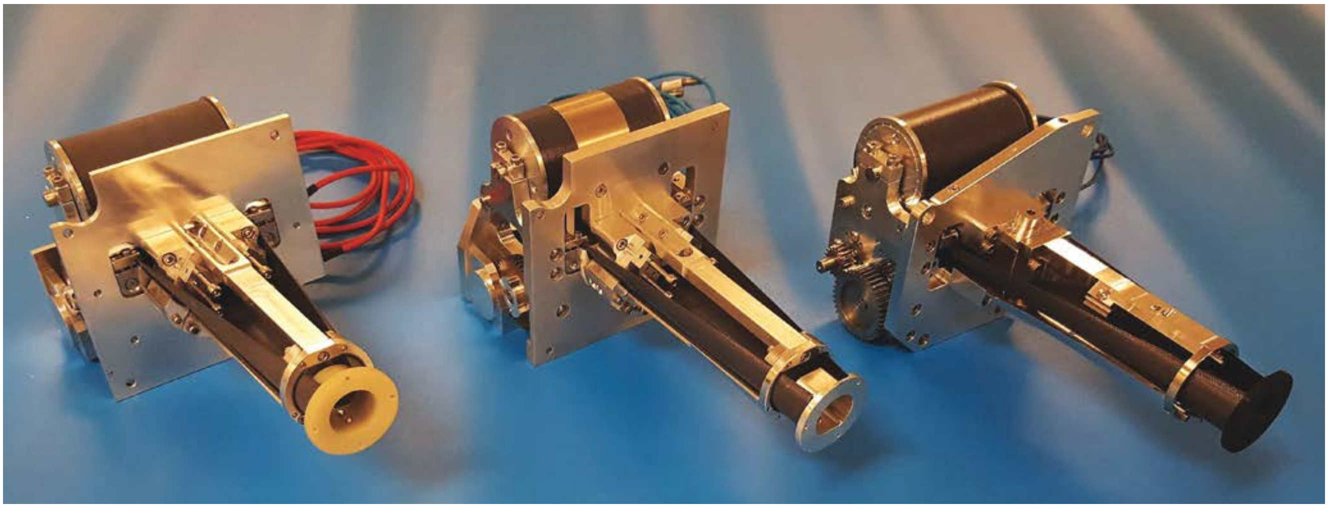
■ Engineered for small packages

The packing factor for HSC deployment systems is 10 times denser than traditional materials, which allows for the integration of payloads that unfurl to lengths of more than 15m.

Source | Roccor

The move to HSCs

Roccor began creating deployable mechanisms in 2011. Since then, the company has become a leader in a fundamental shift in the way satellite structures are created. In the past, deployable satellite structures mainly relied on clevis pin joints with springs



Deployers

Depending on the application, Roccor's HSC booms work with a variety of deployers. Shown here are deployers designed for microsats (right) and cubesats (top). Source | Roccor

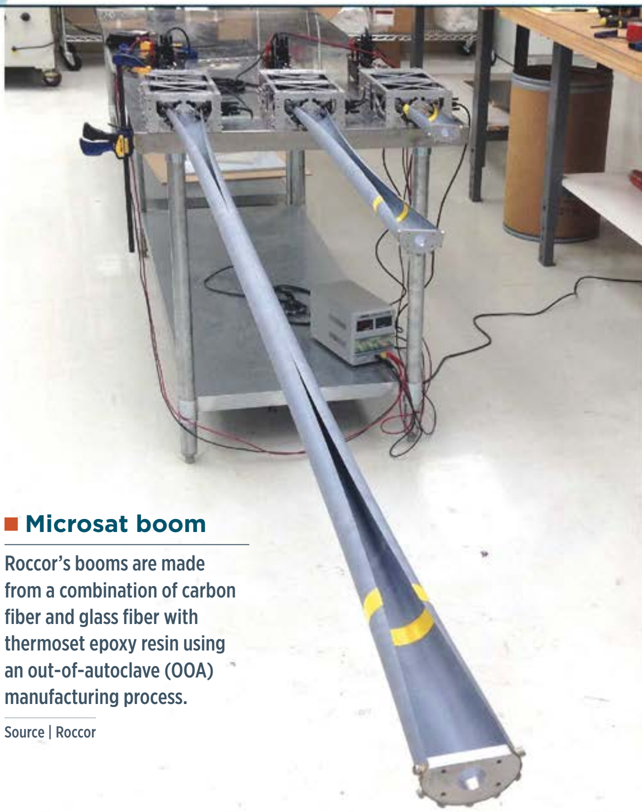
and latches for locking. These complex designs require motors to extend them, but these add weight. They're also expensive due to the extensive testing they require. Other mechanisms have used inflatable deployments that employed fabrics made of glass fiber, Kevlar and other aramids, but they run a risk of deflating.

To address these issues, the Air Force Research Laboratory (AFRL) at Kirtland Force Base, NM, US, developed high-strain composites (HSC) that improve the mass, complexity and cost of deployment systems. The AFRL worked with Roccor on solar array development systems and Roccor has used HSC technology to create simpler, lighter and therefore lower cost deployment systems. HSC technology is necessary because of the increased use of small satellite systems, including microsats, which typically weigh less than 220 lb/100 kg, and cube-shaped cubesats. Cubesats are modular and comprised of units weighing no more than 3 lb/1.33 kg per unit. These small satellites populate low-Earth orbit (LEO) and carry payloads engineered to fit into small packages. Once in orbit, they then deploy antennae, solar arrays, camera booms and sensors. These small satellites, simply put, just don't have room for traditional deployment technologies. And that's where HSCs come in. According to Roccor, the packing factor for HSC systems is 10 times denser than traditional materials, which allows for the integration of deployment systems that unfurl to lengths in excess of 49 ft/15m.

> High-strain composites technology is necessary because of the increased use of small satellites.

These structures often need to operate in multiple configurations with high precision and stability. The deployment mechanisms for these structures, which are Roccor's focus, are often made from HSCs and designed in flexible configurations using rolled components that can be unfurled. The tension exerted on such structures is formidable.

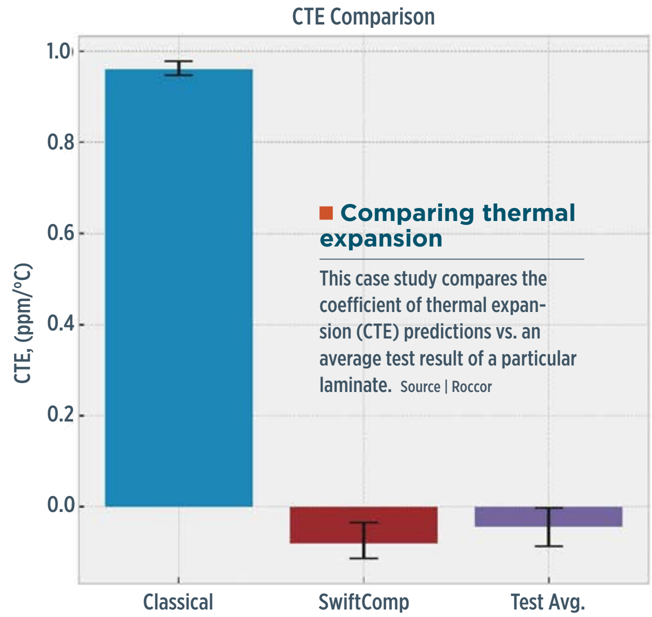
"Imagine a fly-fishing rod, flexing at high strain levels," says Will Francis, vice president of engineering at Roccor, speaking about the satellite booms that are being manufactured for Roccor at Ability Composites. »



Microsat boom

Roccor's booms are made from a combination of carbon fiber and glass fiber with thermoset epoxy resin using an out-of-autoclave (OOA) manufacturing process.

Source | Roccor



Comparing thermal expansion

This case study compares the coefficient of thermal expansion (CTE) predictions vs. an average test result of a particular laminate. Source | Roccor

Because these structures are engineered to fit into small packages and deploy by unfurling, dimensional precision is key to meeting deployment and performance requirements. Thermal expansion of materials must be taken into account given temperature extremes in space — temperatures in LEO can range from 120°C/248°F in full sun to -100°C/-148°F in shade. Therefore, simulation and testing are crucial.

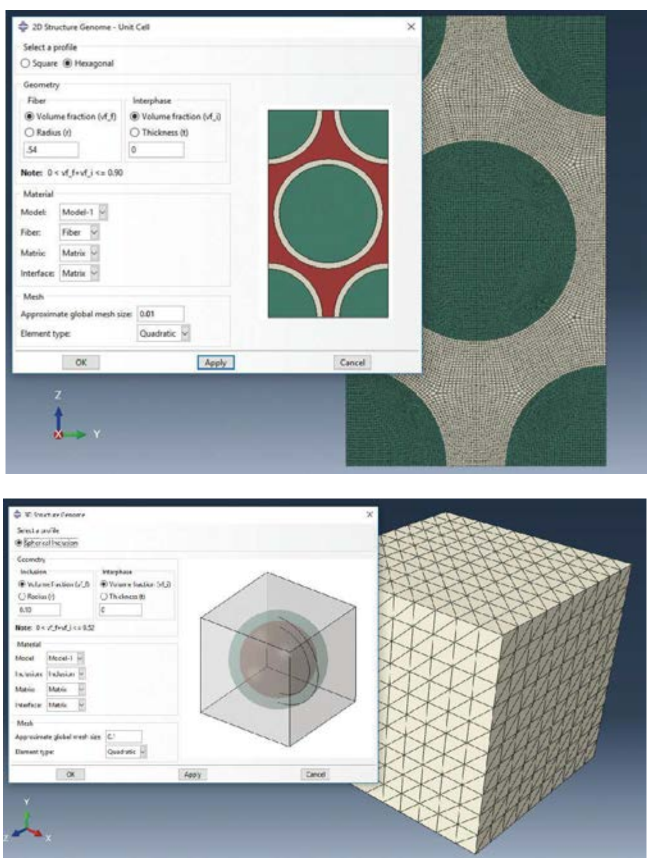
"Our booms are made using an out-of-autoclave manufacturing process using a thin combination of carbon fiber and glass fiber with thermoset epoxy resin," says Kamron Medina, aerospace engineer at Roccor. According to Medina, the combination of the carbon fiber and glass made predicting the coefficient of thermal expansion (CTE) of the laminate difficult.

A need for accuracy

Roccor, in the early days of its product development, needed more accuracy in predicting the thermal expansion of its products in order to meet high thermal stability requirements. The company turned to AnalySwift (West Jordan, UT, US) for a solution and licensed the company's SwiftComp software to perform simulation of these structures.

Roccor conducted a case study comparing the coefficient of thermal expansion (CTE) predictions vs. an average test result of a particular laminate. The CTE comparison chart above compares CTE predictions using classical laminate theory and SwiftComp. As shown, the classical prediction is not only significantly off from the test result but it also predicts a positive CTE when the actual CTE is slightly negative. The chart also shows that the SwiftComp prediction is well within the error bounds of the test average.

Allan Wood, president and CEO of AnalySwift, says, "We believe SwiftComp provides a unique solution as a



Modeling composites

SwiftComp can be used either independently as a tool for virtual testing or as a plugin to power conventional 3D finite element analysis (FEA) codes with high-fidelity modeling. Source | Roccor general-purpose multiscale modeling code that enables users to predict stiffness, strength and thermal expansion of composite structures."

According to AnalySwift, the software can be used either independently as a tool for virtual testing of composites, or as a plugin to power conventional 3D finite element analysis (FEA) codes with high-fidelity modeling for composites.

Wenbin Yu, chief technology officer of AnalySwift, says, "SwiftComp is a multiscale constitutive modeling code for unified modeling of composites beams, plates/shells or 3D structures. It can quickly and easily calculate all the effective properties needed for use in macroscopic structural analysis. It can also predict accurate local stresses and strains in the microstructure for the purpose of predicting strengths."

LEARN MORE

Learn More: Read this article online | short.compositesworld.com/satellites

According to Roccor, SwiftComp provides support for both elastic and thermal properties, but while most codes stop at the laminate level, SwiftComp scales to provide effective beam and plate properties generated from complex cross-sections. These features, along with tight FEA code integration, have allowed Roccor to develop computationally efficient workflows to solve challenging engineering problems.

The other space race

The time savings offered by the SwiftComp software, without loss of accuracy, is key, particularly as the number of applications for the kind of high-strain composite structures Roccor is developing continues to grow. Simpler, lower mass satellite systems reduce costs and open access to private entities looking to use the technology, as evidenced by the aggressive launch schedules of companies like SpaceX (Hawthorne, CA, US), which had 15 launches in 2018, and Rocket Lab (Huntington Beach, CA, US), which is aiming for a launch per month in 2019. The commercial space race is on and shows no signs of slowing down, and the smaller satellites get, thanks in no small part to HSCs, it seems the bigger the business of space grows. CW

ABOUT THE AUTHOR

Scott Francis, senior editor for CompositesWorld, has worked in publishing and media since 2001. He's edited for numerous publications including Writer's Digest, HOW and Popular Woodworking.

The building of a composites manufacturing niche

Equipped to meet vertical needs with rapid turnaround, Rock Hill, SC's Composite Resources has found the sweet spot between prototypers and large composites manufacturers.

By Karen Mason / Contributing Writer

» Travel through the Charlotte, NC, US, metropolitan area, where Composite Resources is situated, and to this day you will find abandoned textile mills dotting the landscape. Economically, the 1970s and 1980s were unkind to this region, as textile manufacturers moved their operations to other parts of the world. As recently as 2010, local newspapers reported little change in the jobless rate — 15.7% in York County, SC, just south of Charlotte, compared to 9.5% nationwide.

But positive economic signs began emerging in York County during the past decade, and today you will find vibrant and growing industrial parks, home to numerous manufacturing success stories. Composite Resources counts itself among them. The revitalization of this region, the training of a new composites workforce, and interestingly, the locale's passion for racecar driving, are intertwined with the founding and growth of Composite Resources and distinctively color the company's corporate culture.

Composite Resources describes itself as a "full service composite engineering and manufacturing company." Founded in 1992, the company employs more than 50 people at its 55,000-ft^2/5,102m^2 facility in the

Southeastern industrial park resident

Composite Resources built its current facility in 2001, in one of Rock Hill, SC's tree-lined industrial parks that reflect revitalization of the region.

Source | Composite Resources

mid-sized city of Rock Hill, SC, US, about 15 miles south of Charlotte. Next door, another 50-plus people staff two sister companies in a 60,000-ft^2/5,574m^2 facility: C.A.T. Resources, maker of the Combat Application Tourniquet (C-A-T), a one-handed tourniquet that has been issued to more than 1 million military personnel since 2004; and CORE autosport, which has fielded teams in both prototype and production-based motorsports since 2010. CORE autosport has also helped to feed one of the passions of CR founder Jonathan Bennett.

Not coincidentally for Bennett, 1992 marked the launch of both his road racing career and his composites industry brainchild. Bennett had been working for a large engineering company but decided that year to go out on his own as a composites engineering consultant, initially operating out of his garage, so that he would have the opportunity to work more in the automotive arena. The business grew and, by 2001, Composite Resources was ready to avail itself of attractive business incentives offered by the State of South Carolina, and built its current facility. The second building that houses CR's sister companies was added in 2010.

As is true of many industrial parks in revitalized southeastern US cities, the tree-lined boulevard entrance to Tech Park South, just off one of Rock Hill's main avenues, is marked by an unassuming brick and metal sign. From there, the approach to Composite Resources feels less "industrial" and more "park." Just beyond its small parking area and front lawn, the company's one-story, U-shaped building sits behind its own greenery-surrounded brick and metal sign — this one also displaying the company's ISO9001 and AS9100D certifications. The main entrance to the building is located at the end of the wing nearest the parking lot entrance.

Niche of opportunity

One testament to the way in which Composite Resources began is a display wall that welcomes visitors into the facility lobby. The diverse collection of products exhibited here, ranging from an orthopedic spar to a carbon fiber cooling duct, often became part of CR's story because of the company's ability to engineer composite solutions to unusual engineering problems.

"We were more of a job shop at first, focused on prototypes," recounts Mel Clauson, CR's director of business development. "And we will still look at interesting opportunities that come in," he continues. "This is what you get with a private company that's smaller and entrepreneurial. If it looks interesting and potentially profitable, we may buy a couple machines and make it happen." Clauson points out that the decision path for buying new equipment is very short for a private company like Composite Resources, because it is not tied to the kind of annual corporate budget that constrains capital investment for larger manufacturers.

This rapid response capability begins to define the niche in which CR has built its business. As a Tier 3 manufacturer with a design-build emphasis, Composite Resources has positioned itself between "smaller players, who are great at R&D and prototyping, and larger players who really want to focus only on production," explains CR COO Morgan Brady.

Engineering collaboration

The six engineers at Composite Resources share an open office space with variable-height desks configured in pods. The goal of this arrangement is to facilitate collaboration among the engineers. Source | *CW* Photo | Karen Mason

Engaged workforce

Stations in Composite Resources' climate-controlled hand layup area are staffed by workers of varying experience and skill levels. Jobs are carefully assigned to ensure a skill level commensurate with its demands, ranging from common industrial work to exacting aerospace projects. Source | *CW* Photo | Karen Mason

"We really fill this void," he continues. "We produce quick-turn prototypes, going from CAD to parts in a matter of days, yet when such a program is ready for production and the client needs 7,000 parts per year, we have the size to support that as well." Clauson agrees. "What a big business doesn't want or can't do, we can do," he says. "I think that's where Tier 3s survive, on the opportunities afforded them by larger companies."

Though the business has experienced modest growth for most of its existence, in early 2016 Brady took stock of CR's operations and decided to develop a more deliberate growth strategy. Prior to joining Composite Resources, Brady had worked as an engineer in motorsport, and this background led to a partnership with Bennett to start a race team — now CORE autosport — in 2010. By 2015, when Bennett was ready for a diminished role in CR's day-to-day »

Double duty

The main manufacturing floor at Composite Resources features several equipment pairs to ensure — as the company's racing inspired philosophy might suggest — that they are ready for the start flag to commence any task or project.

Source | *CW* Photo | Karen Mason

operations, Brady recognized the opportunity that Composite Resources might afford him to pursue his passion for business. He saw great upside potential for the company. "I asked Jon to let me have a financial stake and run the company," Brady recalls. "He gave me the keys and let me have a go at it starting in 2016."

Within a few months, Brady had identified the aerospace sector as a potentially great source of growth. Clauson, an aerospace veteran, was tapped to join CR that year. He notes, "We're diving into aerospace and defense at a time when this whole space is very busy and there are lots of opportunities."

CR's efforts in aerospace and defense have quickly begun to pay dividends. Clauson reports that the company added 12 positions in the past six months. The increased work load has also warranted major equipment purchases this year, including a new 5-axis machining center and two presses.

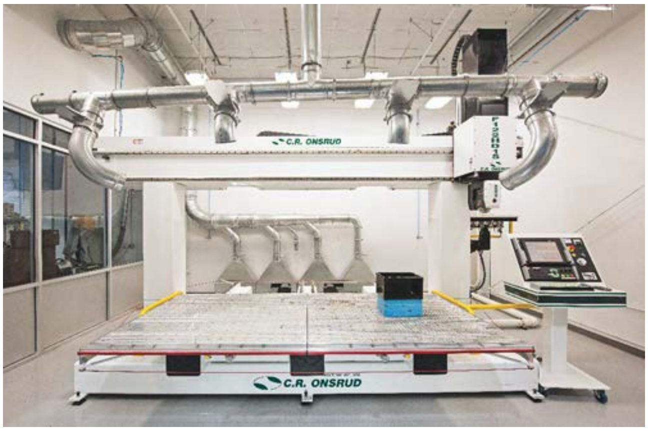
Key to this early success is the fact that CR is vertically integrated. "From those initial designing/scheming sessions on into production — cutting, kitting, moldmaking, inspection, coatings, machining — it's all here," Brady emphasizes.

Verticality

As our tour begins, behind the reception area and past offices for the purchasing department, we enter a small hallway. Clear glass panes make up the top half of the hallway's walls, providing a view into CR's engineering workspace on one side and quality/testing area on the other. Representing one end of CR's vertical capabilities, a team of six engineers brings the design of composite components to fruition. Their workspace consists of an open floor plan with variable-height desks, arranged in pods to facilitate collaboration. A dedicated conference room for the engineers is adjacent to the workspace, also enclosed with glass walls for a light, open environment.

Demands on the engineering team run the gamut. "On one end of the spectrum," Brady illustrates, "a more established aerospace client like Rockwell often has a fairly defined specification — a drawing, maybe the materials and procedures they want us to use. On the other end of the spectrum, a client less familiar with composites, or someone with a metal component they want to convert to composite, may simply ask us to make that happen. We can support that whole range."

The rest of the plant tour exhibits CR's capacity for vertical servicing, from design to tooling, to post-cure machining and painting as well as coating. Being vertically integrated helps CR control its scheduling and quality, as well as its profit margins, Clauson points out. But perhaps more significantly, it is an attractive feature to the company's customers. "A prospective customer walks in, and they want to be able to write one purchase order," he points out. "And they want their questions answered; they don't want to hear that you have to call another supplier."



■ **Blue block in service**

Prototyping and short-run components are often served cost-effectively with Huntsman Advanced Materials Renshape. Composite Resources machines this material for the full range of tooling applications — plugs, masters and molds.

Source | *CW* Photo | Karen Mason

■ **From CAD to coating**

Composite Resources has attracted some customers specifically because of the company's vertical integration, starting with engineering and design and finishing with painting and coating operations — all in house.

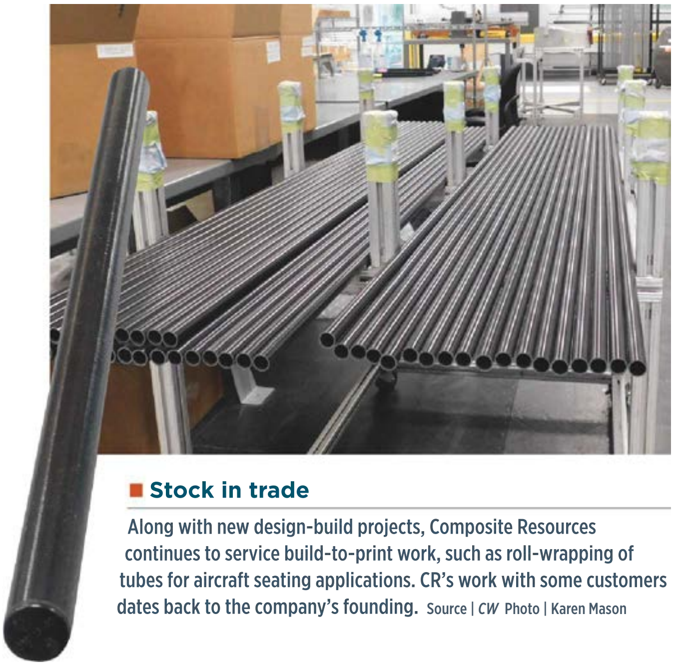
Source | Composite Resources

A staff of stakeholders

We emerge next into a wide corridor situated on the front side the U-shaped building's base wing. To our left is the facility's front lawn and parking area, and to our right, a glass wall with a view of the main manufacturing floor. This corridor hosts monthly company-wide luncheons, where tables and food are brought in and the owners talk about how CR is doing — new customers and work, financial status, etc. "The idea is to engage people," Clauson says, "because if they're engaged, you start to get that discretionary effort from people. They care more about our products. They're happier, and they stay longer."

Beyond the open corridor, we reach a climate-controlled hand layup area at the end of the building's far wing. This area includes as many as a dozen work stations, depending on the work schedule. One important consideration as the company assigns staff members to various projects is that both aerospace and non-aerospace components are part of the job mix. "You don't want to burden the non-aerospace parts with aerospace overhead," Clauson mentions, "but you want to make sure the right attention is paid to aerospace parts. We've set up teams to address this." Developmental articles are typically assigned to teams with the most experienced workers. Hand layup of industrial production parts is often a good starting point for new staff members.

Composite Resources has reached a size for which "we've run out of 'friends and family' and must hire new people," Clauson says. "Finding people with experience is difficult, but you can train people to do this kind of work." Machinists, on the other hand, must bring some level of experience. The nearby technical college includes a machine tooling program, which helps feed the pool of qualified applicants. Staffing will become an even greater focal point for the »



Stock in trade

Along with new design-build projects, Composite Resources continues to service build-to-print work, such as roll-wrapping of tubes for aircraft seating applications. CR's work with some customers dates back to the company's founding. Source | *CW* Photo | Karen Mason

company if a second shift is added. This option is under consideration to better leverage CR capital equipment.

We pass from the hand layup area through a manual trim area with downdraft tables, and on to the main shop floor, which spans the back side of the building's main wing.

Racecar philosophy

Moving through this main shop area, it is easy to surmise that preparedness is a core value of Composite Resources, as we come across two autoclaves (one from ASC Process Systems, Valencia, CA, US; and the other from American Autoclave Co., Jasper, GA, US), two Kolpak (Parsons, TN, US) freezers (a walk-in, 5 ft by 12 ft, and a drive-in, 25 ft by 25 ft), and two Global Finishing Solutions (Osseo, WI, US) Concept paint booths (one enclosed and one open-faced). Equipment for a mix of manufacturing processes — also often found in pairs — occupies the rest of the main floor. Though the company welcomes work for both pieces of equipment in each pair, Clauson explains that the idea is to ensure they make delivery dates. In fact, at the company-wide luncheons, the owners have admonished the team, "In the entire history of racing, a start flag has never been delayed because somebody wasn't ready." The paired equipment ensures readiness for each "race" the shop floor undertakes.

LEARN MORE

Read this article online | short.compositesworld.com/CR_tour

CR's largest autoclave is 17 ft long — long enough to accommodate large components. The company is considering additional autoclaves as part of its capital plan, anticipating ongoing autoclave work. "Even though there's a lot of work being done with out-of-autoclave processes, there's still a lot of autoclave work out there," Clauson believes. "And because of qualified material systems, I think there will be for many years."

Equipment on the main shop floor naturally is organized by process type. To our right, past the autoclaves and freezers, several staff members are using the two Wabash (Wabash, IN, US) presses to compression-mold carbon fiber/epoxy brackets designed to hold video monitors on airplane seat backs. Clauson points out, "Presses are very robust pieces of equipment. As long as you clean up the control system, they continue to work well." The press workload is nearly full, he reports, even though they came online a mere six months ago.

Beyond the presses, two McClean Anderson (Schofield, WI, US) WLH-1-2-4M filament winders are fabricating filter housings for ultra-clean water systems. CR winds the main section of these housings, then winds a flange area. The outside diameter and flange area are then machined to specification and coated.

To our left stand the two 5-axis machining centers, as well as several routers and turning centers, a gantry mill and a grinder. CR added its second Haas 5-axis machining center this year. The company machines its own products, completing post-cure trimming and drilling, for example, and also gets machining business from other companies. "Traditional metal machine shops are scared of machining composites," Clauson has found. This reluctance creates additional opportunities for CR to fill its machining capacity, and the company is getting more and more inquiries about machining. A high-end machining center may be purchased in the near future.

The two C.R. Onsrud (Troutman, NC, US) machining centers feature a 5-by-10-ft bed, which enables CR to machine fairly good sized parts and tooling. The company uses an outside supplier for steel, Invar or other heavy metal tooling, but it creates all other tooling in house, including plugs, masters and molds, made from tooling materials ranging from lighter metals like aluminum to RenShape (Huntsman Advanced Materials, The Woodlands, TX, US) "blue blocks" and honeycomb core. "We do a lot of work with blue block tooling," Clauson reports. "It's inexpensive and really good for prototyping and short runs." He notes that customers sometimes think they need metal tooling, but "if they only want five or 10 parts and they may change the design, blue block is faster and cheaper, and we can deliver parts pretty quickly."

Near the machining centers, several aramid parts, designed to house electronics and serve as radomes on military vehicles, are queued for trimming. Nearby, a glass-enclosed office space houses computers used primarily for CNC coding. On a desktop in this area rests an interesting prototype that represents another burgeoning application area: a carbon fiber/epoxy leg for a drone. Composite Resources engineers designed this one-piece leg based on the drone maker's initial design, which was comprised of 17 pieces. Part consolidation is often a more significant factor in drone applications than lightweighting, Clauson notes, as is the vibrational damping that composites offer.

Stock in trade

The two large workrooms that we enter next, located at the back of the U-shaped building's near wing, are dedicated to processes that support steady production work the company performs for its customers. "We have a good mix of legacy versus new projects and equipment," Brady notes. "Several clients have been around since Jon was in his garage."

In the first room, two Gerber Technology (Tolland, CT, US) DCS 2500 ply cutters, 6 by 22 ft, are creating ply patterns from carbon fiber/epoxy prepreg. Between prepreg and the towpreg used on the filament winders, carbon fiber/epoxy materials make up about 75% of Composite Resources' products. Off to one side of the cutters is a small product inventory area. On the day of our tour the shelves hold several lavatory sinks for commercial airliners, which CR manufactures from glass fiber/polyester, then gel coats the surface and post-forms the metal bowl in place. On the floor nearby sits a forming fixture for LEAP (CFM International, Cincinnati, OH, US) engine blades with a rather complex geometry. "The LEAP blades are really thick on one end and go down to a razor edge on the other," Clauson explains, "so the fixture helps form the part's preform before it is placed into an RTM mold." CR manufactures the fixtures from scratch, including the aluminum master.

The second room is dedicated to roll-wrapping of tubes. Through its history, CR has manufactured more than 100,000 seat tubes for commercial aircraft seating. Equipment in this room includes two CDi (San Diego, CA, US) M880 FB roll wrappers with 10-ft platens, three CDi M700C tape wrappers with 12-ft tape carriage travel; a CDi M3300 Mandrel Extractor with 15-ft travel; and several Grieve Corp. (Round Lake, IL, US) and DK Ovens (Rialto, CA, US) programmable ovens with Watlow (St. Louis, MO, US) controllers.

From these rooms, we return past a conference room and back to the lobby, where our tour ends.

To the future and beyond

While strategic planning for the next several years for Composite Resources occupies most of his time, Brady also entertains more visionary aspirations when possible. "Beyond five years, we expect commercial aerospace to be the bread and butter of our business," he says. "But I'm really interested in the category of 'future flight' — the Uber flying taxi program, commercial and interplanetary space flight, for example. That word, 'aerospace,' is going to grow to encompass a much broader field going forward, and that's what we're really excited about."

For today, though, Brady is happy to reap the fruits of CR's thriving niche. He points out that the company's experience seems to counter the prevailing view of the current market. "The narrative in a lot of aerospace today is cost pressures and squeezing of suppliers," he says. "If you read a lot of the press, it doesn't sound like a great place to be. But we're a great success story." CW

ABOUT THE AUTHOR

CW contributing writer Karen Mason focused academically on materials science and has been researching and writing about composites technology for more than 25 years.
kmason@compositesworld.com

Leveraging composites for space tourism

Virgin Galactic's *WhiteKnightTwo* will carry its *SpaceShipTwo* to launch position, then rocket passengers to suborbital space for a heavenly view of Earth.

By Donna Dawson / Senior Writer Emeritus

» It all started with the Ansari XPrize. Wealthy space enthusiasts Anousheh and Amir Ansari offered $10 million to the first private enterprise, worldwide, "to build a reliable, reusable, privately financed, manned spaceship capable of carrying three people to 100 km [62 miles] above the Earth's surface twice within two weeks," says the Ansari XPrize Web site.

The award, given in 2004, went to Mojave Aerospace Ventures (MAV, Mojave, CA, US), owned and funded by late Microsoft co-founder Paul Allen, for spaceship technology engineered by Burt Rutan and his Scaled Composites team at the Mojave Spaceport. The spaceship that reached the goal was an all-carbon fiber composite structure named *SpaceShipOne*. In one of the many departures from the ordinary in this venture, the spaceship did not launch from Earth's surface, but was delivered part of the way to its destination by the (also) carbon fiber composite *WhiteKnight*. Dubbed *the mothership*, *WhiteKnight* was designed to replace the first stage of a traditional rocket used to launch a craft from Earth's surface. When *WhiteKnight* reached its target altitude, *SpaceShipOne* was released from its mothership and a dedicated rocket on *SpaceShipOne* provided the second-stage boost, driving the spaceship up to its suborbital goal.

Suborbital goal for tourists

Rutan and Richard Branson of Virgin Group (London, UK) had an ambitious new idea for the *WhiteKnight* and its *SpaceShip*:

FIG. 1 *WhiteKnightTwo* ready for flight

The two 78-ft-long fuselages of *WK2* are identical in structure: a nose cone, cabin structure, and boom section that extends to the 26-ft-high horizontal tail. The right-side cabin is pressurized for crew: two pilots and an optional seat for a flight test engineer. The left-side cabin is unpressurized and contains ballast to keep the vehicle's center of gravity along the centerline. Source | TSC

tourism. Together they set up Virgin Galactic space flight company in Las Cruces, NM, US, and in 2005 announced plans to form The Spaceship Co. (TSC) in Mojave to produce the spacecraft that would lift passengers to suborbital space (~50 miles/80 km) for a heavenly view of Earth and a few minutes of weightlessness. Because the sight of Earth from space has been described as giving the viewer a "feeling of unity," TSC decided to name its next spaceship model, *SpaceShipTwo* (*SS2*), after that concept: *Unity*.

Rolled out in February 2016, *SS2* was officially named *VSS Unity* by the late Professor Stephen Hawking — famed scientist and Lucasian Professor of Mathematics at Cambridge University (Cambridge, UK) — who spoke at the ceremony: "A man with the vision and persistence to open up space flight for ordinary, Earth-bound citizens, Richard Branson made it his mission to make space flight a reality for those intrepid enough to venture beyond the boundaries of the Earth's atmosphere. I would be very proud to fly on this spaceship. Space exploration has already been a great unifier — we seem able to cooperate between nations in space in a way we can only envy on Earth. We are entering a new space age and I hope this will help to create a new unity."

As of July 2018, about 600 people have signed up and paid up to $250,000 each for that opportunity. Faithful to the initial concept, the current *WhiteKnightTwo* (*WK2*, named *Eve*) will deliver *SS2/Unity* and its passengers to an altitude of about 9 miles/15 km (Fig. 1). (The current *WK2* and *SS2* are named *Eve* and *Unity*, respectively; future ships will be named when they are rolled out. See the Names table in Fig. 6, p. 37.) At the apogee, *WK2* pilots will release *SS2* and *SS2's* pilots will ignite its hybrid rocket to thrust it and its passengers toward an unequaled tourist experience: A minute of intense thrust at Mach 3, then weightlessness, while watching Earth as it turns in their view. *SS2* will then return to Earth, offering the experience of the return of gravity (g-force) and high heat on re-entry to the Earth's atmosphere. All aboard will be protected from high temperatures as the spaceship decelerates through the atmosphere by proven thermal protection, originally developed by NASA for the Space Shuttle.

Composites enable space tourism

"We probably couldn't do this mission if we were not building these vehicles out of all carbon fiber construction," TSC President Enrico Palermo states. "We are leveraging the true benefit of composites in these spacecraft, designing and building structures that are efficient, and as a result lighter and therefore need less propulsion to soar into space."

TSC builds on a deep foundation of composites knowledge and experience from Rutan, who began conceiving, designing and building composite airplanes in 1974, and founded Scaled Composites in 1982. Acquired by Northrop Grumman in 2007, Scaled has been and is renowned for experimental composite aircraft designs and construction, plus the success of its spaceship approach for the Ansari XPrize.

With its access to this legacy, TSC is finding new techniques to successfully apply Rutan's basic manufacturing processes of hand layup, vacuum bag and out-of-autoclave (OOA) cure, while advancing its own methods for its specific spacecraft challenges. Alec Subero, TSC's chief engineer for the next two spaceship models, *SS2-003* and *SS2-004*, interprets TSC's own paradigm: "What's unique, what allows us to actually meet our space tourism goal, is that we use the processes in a different way. We have fine-tuned procedures based on the legacy from our predecessor technology that allow us to build the spaceships by less costly and faster methods, that allow us to be more nimble in our approach to changes, compared to a larger company that might be slower and more reluctant to react. For example, our combination of adhesives and OOA prepreg processing opens up flexibility in cure cycles, allowing us to make design changes quickly while minimizing disruption in the assembly flow of the spaceship.

"We also employ very talented technicians who are very skillful with their hands," he adds. Laser projection and automated ply-cutting technologies are used to reduce the manual labor content and to maintain accuracy of the hand-build approach and "we are

FIG. 2 All-composite spacecraft

VMS Eve (*WK2*) and *VSS Unity* (*SS2*) all-composite structures preparing for flight. WK2 has a 140-ft wing span, providing space for carrying a *SS2* to launch position. *SS2* moves into position to lock into *WK2* release mechanism (top photo); *WK2* and *SS2* together in flight (bottom). Source | TSC

FIG. 3 Composite parts for engine installation

Installation of Pratt & Whitney engine into composite cowlings and high-temperature composite inlet duct and exhaust nozzle. Source | TSC

1 Tooling is prepared for carbon fiber composite layup of new *SpaceShip* fuselage sections *SS2-003* and *SS2-004.* Tooling preparations include waxing, and application of an appropriate mold release and primer.
Source (all step photos) | TSC

2 Solvay MTM45-1 prepreg fabric is precision cut by automated ply cutter or hand cut by skilled technicians. Gerbercutter from Gerber Technology (Tolland, CT) performs automated ply cutting (top); a TSC technician hand-cuts prepreg to small shapes for custom layup (bottom).

continually exploring other automated approaches that might be compatible with our organization," Subero says.

Standard assembly procedures are followed, and the various structural sections of both vehicles are bonded together using an epoxy-based paste adhesive plus metal fasteners in some areas.

Primary structures

Nearly all primary airframe structures for *WK2* and *SS2* are sandwich structures. TSC builds the sandwich inner and outer skins using MTM45-1 plain weave fabric prepreg made by Solvay Composite Materials in Tulsa, OK, US (headquarters in Alpharetta, GA, US). The prepreg fiber is Tenax HTS40 standard modulus carbon fiber, now manufactured by Teijin at its Mishima factory in Shizuoka, Japan (Teijin headquarters is in Tokyo, Japan). One of the key benefits of the MTM45-1 system is OOA processing.

The sandwich core is aramid Nomex aerospace grade honeycomb, AHN4120, made by Advanced Honeycomb Technologies (San Marcos, CA, US); it is said to exhibit high strength and toughness in a small-cell, low-density, non-metallic honeycomb, according to Advanced Honeycomb. It is also known for providing corrosion and fire resistance as well as good thermal insulation properties. From a manufacturing standpoint, it is also considered well-suited for adhesive bonding.

The 42.6m/140-ft-long wing span on *WK2* is built with two single-piece carbon fiber composite spars that run nearly the full length of the wing. Built in the manner of a conventional wing, the spars and ribs are installed into the sandwich structure for the lower wing. After various lines and control systems are also installed, the lower wing is closed off with the sandwich structure for the upper wing. A similar approach is used for building the boom tails for *WK2* and *SS2*, "which are basically a pair of vertical wings," Subero says.

Two fuselages for strength and balance

WK2 presents the highly unusual design configuration of two fuselages, right and left of the center wing. This gives the aircraft both strength and balance for its job. The craft has a lifting capacity of 15 tons, which includes the *SS2* locked between them, and stability when the weight of *SS2* drops away from *WK2* by natural gravity upon release. Subero notes that the twin boom tail design allows for the *SS2* spaceship to be carried safely between the fuselages during flight and away from the structure when it is released by a pneumatically activated mechanism. These fuselages are identical in structure, each 23.8m/78 ft long, leading with the nose, which houses the landing gear, followed by a cabin, and then a boom section that extends to a 7.9m/26-ft-high horizontal tail. The right fuselage (facing forward) is a pressurized cabin fitted for two pilots, with an optional seat for a flight test engineer. The left cabin is unpressurized and contains ballast to keep the vehicle's center of gravity along the centerline.

SS2 has the normal single fuselage. It comprises a nose housing the landing gear, which is connected to a pressurized cabin and crew station of the same size, design and construction as *WK2*'s pressurized cabin, but is fitted for up to six passengers, in addition to the two-person crew. "The design commonality has multiple benefits," Palermo points out, "first in allowing for common composite tooling, but more importantly allowing the *WK2* to serve as a pilot trainer for *SS2* with a similar cockpit layout."

Feathered re-entry

The second half of the *SS2* includes what TSC calls the *feather*, which is part of the wing structure. After *SS2* has released from *WK2*, and after its rocket has burned out, *SS2* achieves the apex of its flight. At this point the pilot pneumatically actuates the feather to its folded-up position, from 0° to 90° (Figs. 4 and 5, p. 36), to

3 In general terms, composite manufacturers build sandwich structures in one of two ways: One is a multiple stage system where plies of prepreg fabric are laid up for the outside skin in the designated fiber architecture to meet specified loads and conditions — with appropriate sacrificial films and layers. The layup is vacuum bagged, debulked and cured. The film adhesive and core are then arranged over the skin laminate. The inside skin and film adhesive can then be similarly laid up and cured. Other manufacturers use a single-stage system where the entire structure is laid up, vacuum bagged, debulked and cured in a single operation.

5 Parts are typically oven-cured at the recommended resin time and temperature for OOA cure. After cure, parts are de-molded and prepared for assembly. Photo shows upper half of *SS2-003* cabin ready for assembly, with windows and emergency egress ports cut out. The crew and passenger cabin is 2.3m outside diameter (OD), by 3.7m long. Side windows are 43 cm OD; top windows are 33 cm OD; crew station windows are 53 cm OD.

4 An *SS2* fuselage skin panel is subjected to a thorough debulking process to force out any air trapped between the prepreg plies. Entrapped air can lead to porosity or other flaws in the final cured product. Typical debulking includes pulling a vacuum on the layup before cure.

6 Finished parts are assembled primarily by bonding, with addition of metal fasteners as needed. Photo shows assembly of *SS2* fuselage and wing. The leading edges of the wing and the horizontal stabilizer are faced with a thermal protection system derived from NASA's Space Shuttle program's thermal insulation systems.

increase drag and reduce speed for re-entry into Earth's atmosphere. If the spaceship were re-entering Earth's atmosphere from low-Earth orbit or higher, a different technology would be required to withstand greater heat and g-forces associated with re-entry from those altitudes. At *SS2*'s re-entry point from the edge of space, though, the feather is a sufficient and inventive way to safely slow the descent. (Following a deadly accident due to premature feather deployment during a test in 2014, TSC redesigned the system to prevent a repeat of this failure.)

Similar to the effect of a badminton shuttlecock, the right-angle position of the feather induces high drag forces from oncoming air resistance. Further, it holds the *SS2* at the correct aspect, descending belly down, to safely re-enter Earth's atmosphere. The ship is not powered during descent, but glides toward its destination. As it approaches the ground, the pilot again extends the feather to its normal wing position for safe landing.

The wing and feather are both carbon fiber composite sandwich structures, built from the same materials and process as the *WK2* wing and the fuselage sections. The feather includes a set of small wings called the *feather flaps* that are attached to the »

FIG. 4 Carbon fiber composite feathers

SS2 feather function is tested in TSC facility. The carbon fiber composite feather is folded up 90° to increase drag and reduce speed as *SS2* prepares to re-enter Earth's atmosphere. Source | TSC

FIG. 5 A Rocket testing

Extensive testing has been conducted on rocket technology to ensure performance of *SS2* in its drive to suborbital space. The rocket has now been qualified for human-rated service. The rocket is moved into position for testing (top photo), then fuel is ignited for the hot fire test (bottom photo). Source | TSC

wing at its aft spar by four metal clevis-and-lug fittings that allow the flaps to hinge up and down (Step 6, p. 35, and Figures).

Rocket technology

Extending to the rear of the *SS2* wing and feather assembly, the aft fuselage houses the rocket and the main oxidizer tank. The rocket propellant is a hybrid of solid hydroxyl-terminated polybutadiene (HTPB) rubber-based fuel ignited by a carefully controlled flow of liquid nitrous oxide. "Unlike a traditional solid motor fuel, our fuel is stable and does not require special handling procedures to prevent ignition," Palermo explains. A valve in the nozzle assembly connects the HTPB in the rocket motor case with the main oxidizer tank. The *throat nozzle assembly* connects the nozzle together with the chamber where the combustion reaction takes place. "It's a very robust architecture having a very limited failure mode, which made rating this rocket motor for transporting people a lot easier," Palermo explains. Following TSC's extensive ground test qualification program, the rocket motor is now qualified and human-rated for service.

The case is filament wound carbon fiber composite, but no details about the materials or process are available due to ITAR (International Traffic in Arms Regulations) restrictions. However, says Palermo, "Like the spaceship, its construction leverages the best properties of composite structures."

[*Author's note*: Unverified reports from within the composites industry suggest that motor cases for solid propellant are generally filament wound — sometimes directly over the solid propellant — probably using a mid-modulus carbon fiber and high-temperature resin. Structures for liquid fuel systems, such as liquid oxygen, tend to use automated fiber placement (AFP) systems using prepreg tape or fabric.]

WK2 engine cowlings are also composite, as are the inlet duct and exhaust nozzle, made with an unidentified high-temperature composite material. Palermo identifies *WK2*'s engines as "four highly efficient high-bypass turbofan jet engines made by Pratt & Whitney, Canada" part of the United Technologies Co. (East Hartford, CT, US) — "a great supplier to our program for many years," Palermo adds.

Onward, upward and return

On July 28, 2018, *WK2* successfully carried and launched *SS2* from the Mojave airport up to a height of 8.8 miles, where its rocket shot another 23.5 miles straight up to a record 32.3 miles above Earth — the nearest *SS2* has been to its ultimate goal of 50 miles. Several more test flights are planned before the space pair enters commercial service.

Commercial flights ultimately will take off from Virgin Galactic's Spaceport America facility near Las Cruces. Additionally, Virgin Galactic and TSC have signed a Memorandum of Understanding with Italian aerospace companies for construction of a spaceport in Grottaglie, Italy, to bring commercial spaceflights to Italy for science and tourism.

"Tourism is certainly our key market," Palermo states, "but we are also pursuing suborbital science. *SS2* is an excellent platform for microgravity research." In the near future, Virgin Galactic plans to fly suborbital research payloads for NASA as part of its Flight Opportunities Program, which strategically invests in the growth of the commercial spaceflight market by providing flight opportunities on suborbital platforms and small spacecraft.

Spaceships *SS2-003* and *SS2-004* are now in fabrication and assembly at TSC Mojave, following *SS2* and exploiting lessons learned in its design and manufacture.

Looking to the future, Palermo emphasizes TSC's need for engineers in all disciplines — "design engineers, stress analysts, composites specialists and more" — for its fully integrated, design-through-manufacturing-and-testing production cycle. "New engineers go through the same composites training that our new technicians take, so that they have similar exposure as the technicians and they understand the processes they are going to be designing for," he says.

TSC is working toward establishing a high-rate production plant for the rocket motors, "because we have one spaceship and soon will have two more," Palermo explains. "So when we have three spaceships in service we'll need to produce these rocket motors at a relatively high rate."

The rocket motor case and main oxidizer tank are essentially the fuel cartridges for TSC's mission to space and are the only part of the *SS2* that is not reused every flight.

Both *WK2* and *SS2* are fully reusable, Palermo emphasizes: "Reusability is at the heart of dramatically changing the economics of access to space to enable new markets to develop and enterprises to thrive. *WK2*, as the workhorse of our spaceflight system, is fully reusable and can release multiple *SS2*s per week." CW

Fig. 6 NAMING VIRGIN GALACTIC VEHICLES

Purpose	Type	Name of current ship	Future ships
The MotherShip	*WhiteKnightTwo (WK2)*	• *Eve* • *Virgin MotherShip Eve* • *VMS Eve*	• In design • Names of future ships to be announced
The SpaceShip	*SpaceShipTwo (SS2)*	• *Unity* • *Virgin SpaceShip Unity* • *VSS Unity*	• In construction • *SS2-003 and SS2-004* • Names to be announced

ABOUT THE AUTHOR

Donna Dawson is *CW*'s (previously) retired senior writer emeritus, now residing and writing in Lindsay, CA, US, in the foothills of the Sierras.
donna@compositesworld.com

BASALT FIBER GIVES PROSTHETICS MORE "GIVE"

Prosthetics and orthotics often take advantage of composite materials' strength and durability. Basalt fiber has given manufacturer Coyote Design a performance edge.

Source | Coyote Design

› Prosthetics and orthotics often take advantage of composite materials' strength and durability. One application in particular that benefits from composites are sockets, custom-shaped, hollow forms into which an amputee's stump fits; sockets also include hardware that accepts limb or hand/foot attachments. Manufacturer Coyote Design (Boise, ID, US) is well known for its composite "definitive sockets" (as distinguished from temporary, typically plastic, test sockets, for fit testing). To produce a socket, a hollow cast is made of the patient's stump and is then filled with plaster to create a positive shape. That plaster shape, fitted with a hollow pipe for handling inserted in the center, becomes the mold for the composite socket layup. The layup is wet-out with resin with the help of a vacuum (via the hollow pipe) and cured at room temperature, often with the help of a heat blanket, says Coyote Design's Rod Smith, director of marketing.

Dale Perkins, Coyote Design's cofounder, was an early adopter of composites and was not afraid to try new or exotic composite reinforcements. For example, one amputee patient and avid outdoor enthusiast (who later summitted Mt. Everest) suggested using aramid for a tough prosthetic. However, several sockets made with that fiber failed, due to a lack of adhesion to the polyester resin Perkins was using at the time. Materials improved with the advent of carbon fiber braided tubes, or "socks," wet out with epoxy resin or acrylic-modified epoxy. Carbon fiber prosthetic sockets exhibited good mechanical performance, but the material's brittleness produced a high rate of cracking failure, and patients often reported uncomfortable stiffness. In addition, manufacturing with carbon fiber required masks, protective gear and dust collection systems for health and safety.

After several years of searching for alternatives to carbon fiber, the company decided to try basalt fiber, which is similar to glass fiber but made from quarried basaltic rock. The goal, says Perkins, was to test whether the material could provide more flexibility and comfort for patients: "Using basalt fiber braid combined with nylon fiber braid gave us a socket that had the flexural characteristics we wanted, with dramatic reductions in structural failures." The basalt braid is sourced from a proprietary supplier. CW

Composites Events

Dec. 4-6, 2018 — La Jolla, CA, US
CW Carbon Fiber 2018
carbonfiberevent.com

Dec. 5-6, 2018 — Telangana, India
ICAPPM 2018
icappm.com

Jan. 10-12, 2019 — Mumbai, India
ICERP 2019
icerpshow.com

Jan. 16, 2019 — Detroit, MI, US
Additive Manufacturing Workshop for Automotive
additiveconference.com

Jan. 17, 2019 — Detroit, MI, US
CW Compression Molding Workshop
cwworkshops.com

Jan. 28-31, 2019 — Cape Canaveral, FL, US
43rd Annual Conference on Composites, Materials and Structures
advancedceramics.org/events

Jan. 30-Feb. 1, 2019 — Tokyo, Japan
TCT Japan 2019
tctjapan.jp/index_en.html

Feb. 19-20, 2019 — Charleston, SC, US
SPE 2019 Thermoset Topical Conference – TOPCON
spethermosets.org

Feb. 26-28, 2019 — Raleigh, NC, US
Techtextil North America 2019
techtextil-north-america.us.messefrankfurt.com/us/en.html

March 4-5, 2019 — Detroit, MI, US
Graphene Automotive 2019
usa.graphene-automotive-conference.com

March 6-8, 2019 — Rome, Italy
5th Annual World Congress of Smart Materials: 2019
bitcongress.com

March 12-14, 2019 — Paris, France
JEC World 2019
jeccomposites.com

March 21, 2019 — Belfast, UK
Joining of Composites Conference
ktn-uk.co.uk/events

March 24-28, 2019 — Nashville, TN, US
NACE Corrosion 2019
nacecorrosion.org

April 7-10, 2019 — Charleston, SC, US
TRFA Annual Meeting
trfa.org/meeting

April 8-10, 2019 — Rosemont, IL, US
North American Pultrusion Conference
s1.goeshow.com/acma/2017PultrusionConference/ereg419088.cfm

April 8-11, 2019 — Colorado Springs, CO, US
35th Space Symposium
spacesymposium.org

April 9-11, 2019 — Detroit, MI, US
SAE 2019 World Congress & Exhibition
10times.com/sae-world-congress

April 10-11, 2019 — Amsterdam, The Netherlands
CompIC 2019
compositesinconstruction.com

April 23-25, 2019 — Moscow, Russia
Composite-Expo-2019
composite-expo.com

April 29-May 2, 2019 — Long Beach, CA, US
AeroDef 2019
aerodefevent.com

April 29-May 2, 2019 — Chicago, IL, US
AUVSI XPONENTIAL 2019
xponential.org

May 20-23, 2019 — Charlotte, NC, US
SAMPE 2019 Technical Conference and Exhibition
nasampe.org/events/EventDetails.aspx?id=904362&group/

June 12-13, 2019 — Stade, Germany
CFK-Valley Stade Convention 2019
CFK-Valley.com

June 19-20, 2019 — Chicago, IL, US
JEC Chicago 2019
jec-chicago.events

LEARN MORE
See more events at:
short.compositesworld.com/events

New Products

» RESIN ADDITIVES & MODIFIERS

Additive for resistance to fractures and micro-cracking

Sumitomo Chemical Co. Ltd. (Tokyo, Japan) has produced a poly-ethersulfone (PES) micro-powder additive called SumikaExcel 5003P. The additive is said to boost fracture toughness and resistance to micro-cracking for fiber-reinforced epoxy composites over a broad temperature range, without negatively impacting dimensional stability, flame/smoke/toxicity (FST), creep resistance, modulus, impact or yield strength. The functional additive is said to be widely used by the aerospace industry for prepreg and resin-transfer molded carbon fiber-reinforced epoxy, is reportedly gaining ground in epoxy composites for automotive, and could be used for high-performance sporting goods as well.

PES is an amber-transparent, amorphous engineering thermoplastic known for its temperature capabilities, strength and impact resistance, creep resistance at elevated temperatures and loads, dimensional stability, low coefficient of linear thermal expansion (CLTE) over a broad temperature range, inherent flame retardance, low smoke, minimal outgassing, chemical resistance, and resistance to hot water (to 180°C). It is offered pelletized for injection molding, extrusion and film processes and in powder form for cast films, filtration membranes, and as an epoxy additive for composites, high-temperature paints and coatings and adhesives. **sumitomo-chem.co.jp**

» THERMOSET RESINS & ADHESIVE SYSTEMS

Epoxy adhesive for composite substrates

Techsil (Warwickshire, UK) has developed a new clear, epoxy adhesive called EP25880 Clear that cures fast and provides a strong, tough and durable bond on carbon fiber composite parts. It is a two-component, multi-purpose epoxy adhesive that is well suited for bonding various substrates including carbon fiber, wood, ceramics and metals. The adhesive reportedly cures to a completely water clear product with a shore hardness of 80D, a shear strength on steel of more than 20 MPa and tensile strength on steel of more than 30 MPa. **techsil.co.uk**

» TESTING, MEASUREMENT & INSPECTION SYSTEMS

PID temperature control panel

BriskHeat (Columbus, OH, US) has introduced a new PID temperature control panel to provide accurate and stable control of temperatures during critical commercial or industrial processes.

The BriskHeat high-performance MPC2 Multi-Point Digital PID Temperature Control Panel is configurable for a variety of applications and requirements, features auto-tuning control, and works with a broad range of surface heating products.

The control panel is said to enable the control, monitoring and display of temperatures for multiple heating zones simultaneously. It can store up to four programs to repeat temperature control as needed. Temperatures are programmable in Celsius or Fahrenheit.

The MPC2 has audible and visual alarms, a door keylock and power-disconnect options for improved safety. Communications ports for RS-485, RS-232 and Ethernet are meant to maximize communication versatility, and 15 voltage options enable compatibility in most industrial environments. The MPC2 can also be used to control individual zones requiring up to 60 amps, the company says.

The MPC2 has a standard NEMA 1 rating, but the use of hard-wired connections and a NEMA 4X enclosure help the control panel withstand harsher environments and outdoor use. **briskheat.com**

» PREPREG MATERIALS

Prepreg for advanced radome systems

Park Electrochemical Corp. (Melville, NY, US) has introduced RadarWave, a new family of prepreg materials used to manufacture advanced radome systems for aerospace and defense applications.

The prepregs are available with epoxy or cyanate ester resin systems, and are offered in E-Glass, quartz fiber or high-performance glass, up to 60 inches wide. The materials are available in thin, lightweight fabrics for flexibility in radome design and layup, and various weave styles are available, says the company.

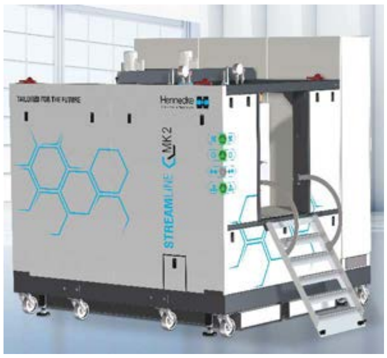
Radomes are structural enclosures that protect RF/microwave and other antennas that transmit and receive electromagnetic signals from air, space, marine and ground-based platforms. Increasingly advanced aerospace and defense electronics systems require radomes that are designed and engineered with radome materials necessary to accommodate the technical performance needs of these systems.

According to the company, RadarWave materials exhibit transmissivity properties similar to those of higher cost esoteric materials traditionally used to manufacture advanced radome systems. **parkelectro.com**

» METERING MACHINES

Second-generation metering machine for HP-RTM

Hennecke GmbH (Sankt Augustin, Germany) has announced its new STREAMLINE MK2 metering machine for HP-RTM and CLEARRIM/clearmelt applications. The second generation of this machine features improved production flexibility due to its space-saving layout and mobile frame, which can be lifted by crane. The STREAMLINE MK2 is equipped with a wireless operator panel, which implements a location-independent operation of all process parameters on the spot. The heating and metering cabins are joined together using quick-locking mechanisms which allow for easy dismantling, ensuring that all main components such as the high-pressure pumps can be quickly exchanged. **hennecke.com**



» PROCESS CONTROL SYSTEMS & SOFTWARE

Updates to measurement software

Verisurf Software Inc. (Anaheim, CA, US) has announced the release of Verisurf 2018 Update 1, the latest update of its measurement software for automated quality inspection and reporting, scanning and reverse engineering, tool building and assembly guidance. Advanced new features in this update are based on customer feedback, and reportedly deliver increased efficiency and improved quality functions.

Auto Align Minimum Zone Fit produces more accurate alignments of parts and features by allowing the centering of alignment errors, which reduces the maximum error result. This new algorithm extends the Verisurf Enhanced Bundle Adjust feature for high-accuracy, large-volume measurements using Leica, FARO and API laser trackers.

CSV Database Support simplifies integration with software partner applications for first article inspection (FAI), production part approval process (PPAP) and statistical process control (SPC) such as InspectionXpert and Dimensional Control Systems.

The update has other enhancements such as support for Catia V5 R28 file import, 3D model virtual device display for CMM Master 500 and Renishaw Equator 500, plus Software Development Kit (SDK) support for the import of nine different point cloud and mesh file formats, which is said to improve integration with many brands and models of 3D scanners. **verisurf.com**

MANUFACTURING SUPPLIERS

FOR SALE

RECRUITMENT/HELP WANTED

ADVERTISING INDEX

SHOWCASE


AIRTECH
ADVANCED MATERIALS GROUP
Toolfusion®1
45
Low viscosity epoxy resin
Room Temperature Curing Out of Autoclave - Avoids thermal expansion of master models which can lead to dimensional deviations.
High Quality Tooling - Resin infusion process for high quality laminates. Low cost, no freezer storage and no autoclave cure.
Save Money - Lower cost and low temperature materials can be used, significantly reducing total tooling costs.
Video Available Online
www.airtechonline.com
AIRTECH ADVANCED MATERIALS GROUP www.airtechonline.com
AIRTECH EUROPE Sarl www.airtech.lu
TYGAVAC ADVANCED MATERIALS LTD www.tygavac.co.uk
AIRTECH ASIA LTD www.airtech.asia
More than a manufacturer... A technical partner !


New Materials Require
New Testing Solutions
• COMPRESSION • TENSILE
• MECHANICAL • SHEAR
• FATIGUE • FRACTURE
• CREEP • FLEXURE
• PHYSICAL PROPERTIES
• THERMAL ANALYSIS
DMA • DSC • TMA • TGA • DLF-1200 • DIL
WESTMORELAND
MECHANICAL TESTING & RESEARCH
wmtr.com I 724.537.3131
Custom Setups • High Volume • Quick-Turnaround


Select the right adhesive
• EPOXIES, SILICONES & UV/LED CURING
• CUSTOM FORMULATIONS
• TECHNICAL SUPPORT
MASTERBOND®
ADHESIVES | SEALANTS | COATINGS
www.masterbond.com • +1.201.343.8983 • main@masterbond.com


CW Talks
Listen in!
THE COMPOSITES PODCAST
CW Talks: The Composites Podcast
CW Talks is a biweekly podcast that highlights the people, processes and technologies shaping the world of composites.
Interviews feature guests with expertise and insight about where composites have been, where they are and where they are headed.
Hear the stories behind the successes of the leaders and innovators in the composites industry.
Download CW Talks on iTunes or Google Play today!
Google play
Get it on iTunes
CompositesWorld.com/podcast

Hybrid thermoplastics give load floor impact strength

Project leads to development of new compression process for selective application of D-LFT on UD tape laminates.

By Peggy Malnati / Contributing Writer

Lighter battery-electric vehicle structures

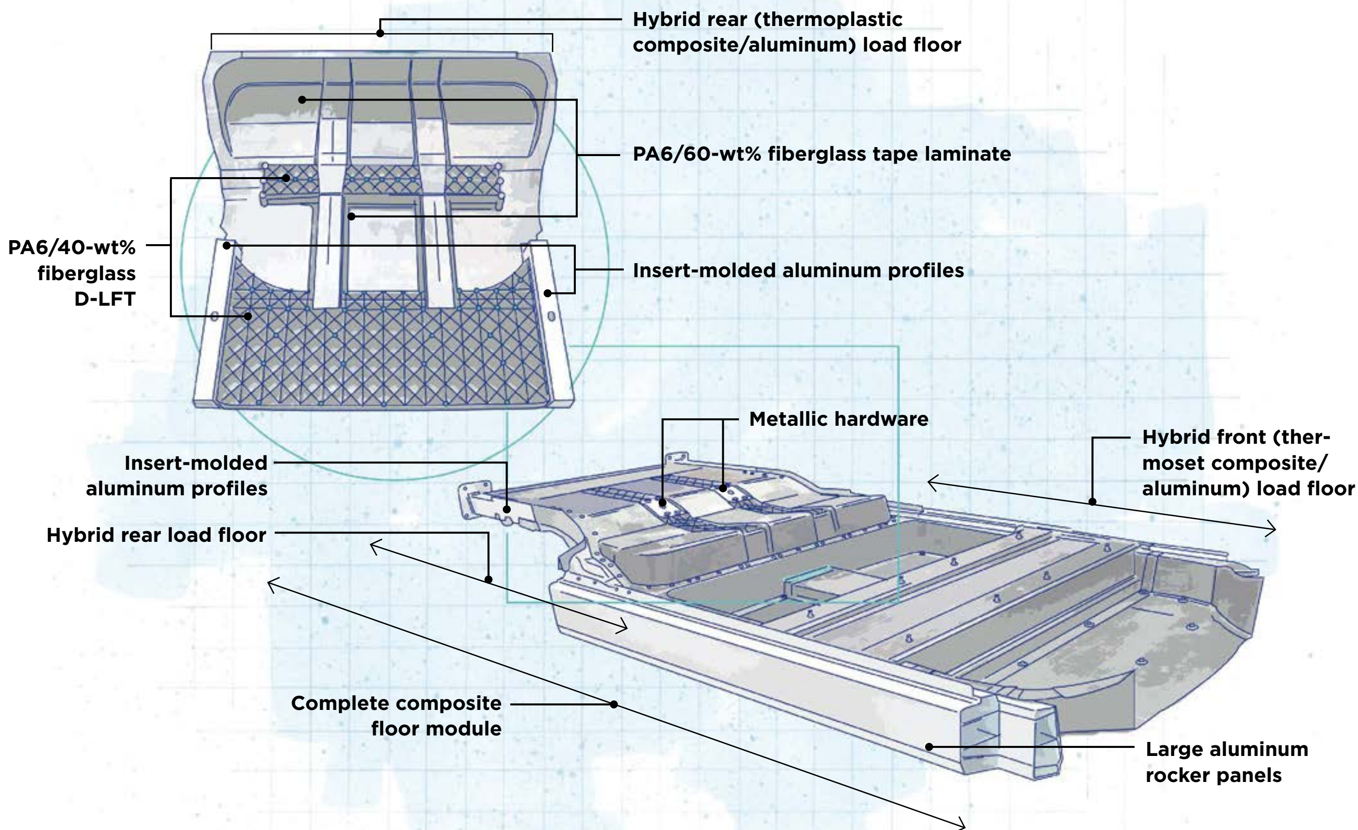
A multiyear, publicly funded research program called System integrated Multi-Material Lightweight Design for E-mobility (SMiLE) took a holistic approach to reducing mass and costs for the entire body-in-white structure (shown here) of a battery-electric vehicle by applying combinations of composites and non-ferrous metals. Some of the F-ICT members who participated in the project are (left to right): Dr.-Ing. Sebastian Baumgärtner, project leader for hybrid thermoplastic floor modules; Tobias Link, research engineer; Prof. Dr. Frank Henning, deputy head of F-ICT; and Felix Behnisch, project leader for thermoset floor modules.

Source | Fraunhofer Institute for Chemical Technology.

» An ambitious multi-year program by Germany's System integrated Multi-Material Lightweight Design for E-mobility (SMiLE) consortium has developed a demonstrator automotive load floor module that is part of a larger hybrid body-in-white (BIW) structure; it shows great promise for use of composites and metals in a hypothetical medium-volume production environment. This battery-electric vehicle's (BEV) rear load floor is comprised of two types of thermoplastic composite, plus metallic profiles and inserts. It functions as the floor of the trunk and rear passenger compartment. In turn, it's adhesively and mechanically joined to a second, hybrid thermoset composite load floor, which is resin transfer molded (RTM) from carbon fiber-reinforced epoxy with metallic inserts and local sandwich structures containing polyurethane-foam cores. This structure is the floor for the front half of the vehicle and holds its batteries. The complete load floor module is bonded and screwed to aluminum rockers/side rails, which are themselves bolted to crossbeams on the vehicle's aluminum monocoque. The entire load floor module demonstrator was designed to reduce mass and provide significant crash-energy absorption for a series-production vehicle with build volumes of 300 cars/day.

Design decisions

Consortium members who worked on the rear load floor included automakers Audi AG (Ingolstadt, Germany—also leader of the entire SMiLE program) and Audi owner Volkswagen AG (Wolfsburg, Germany); Karlsruhe Institute of Technology's Institute of Vehicle System Technology (KIT-*FAST,* Karlsruhe, Germany); Fraunhofer Institute for Chemical Technology (F-ICT, Pfinztal, Germany, leader for both front and rear load floor projects), and Fraunhofer Institute for Mechanics of Materials (F-IWM, Freiburg, Germany); thermoplastic composites supplier BASF SE (Ludwigshafen, Germany); machinery OEM Dieffenbacher GmbH Maschinen- und Anlagenbau (Eppingen, Germany), and toolmaker/molder Frimo Group GmbH (Lotte, Germany).



DESIGN RESULTS | **SMiLE Hybrid Composite Rear Load Floor for Battery-Electric Vehicle**

- Unidirectional fiberglass-reinforced PA6 tapes form thin, near-net-shape floor structure that resists buckling during rear impact
- Fiberglass-reinforced PA6 D-LFT strategically overmolded to form X-shaped ribbed lattice structure
- Insert-molded aluminum profiles provide additional stiffening, facilitate mounting load floor to surrounding structure, control crushing and transfer load to D-LFT rear crush zone
- Additional metallic inserts and plates permit second-row safety belts to attach to load floor

Illustration / **Karl Reque**

With goals to absorb higher impact energy while reducing mass and cost for both the rear and front load floors as well the larger BIW structure of which they were a part, the decision was made to produce the rear load floor using thermoplastic composites with metallic inserts. The team wanted to add trunk features and second-row seatbelt-attachment structures, but they also wanted to use the load floor to absorb significant crash energies. Normally, carmakers rely primarily on metallic profiles on the sides of metallic load floors to manage rear-crash energies on passenger vehicles. However, given the impact strength of thermoplastic composites, researchers wondered if the entire width and length of a composite load floor could be used to manage crash loads. They also wondered if higher crash energies could be absorbed.

Researchers reviewed common automotive thermoplastic composites. Polypropylene (PP) and polyamide 6 (PA6) matrices were considered but PP was eliminated for temperature reasons since the rear load floor travels with the BIW through the high-temperature electrophoretic coating (e-coat) rust-prevention process. Continuous fiber reinforcement was needed to achieve the highest stiffness and strength, so pretrial work focused on fabric-reinforced organosheet (a form of glass-mat thermoplastic (GMT) composite) and unidirectional (UD) prepreg tapes. For many reasons, tapes were selected for further prototyping.

Researchers knew the geometry of the rear load floor would be complex. Use of automated tape-laying (ATL) machines — which place UD tapes in any orientation and make windows/holes with less material than organosheet — would reduce scrap, mass and cost, and permit the most efficient use of fibers locally and globally across the part. Also, since fibers placed via ATL lie flat and parallel in each layer of the ply stack and are not woven like fabrics, there is no undulation and consequent loss of stiffness and strength.

UD tapes do have limitations, however: They are relatively expensive and have poor drapeability with almost no flow, making it difficult to fill complex geometries. These issues were overcome »

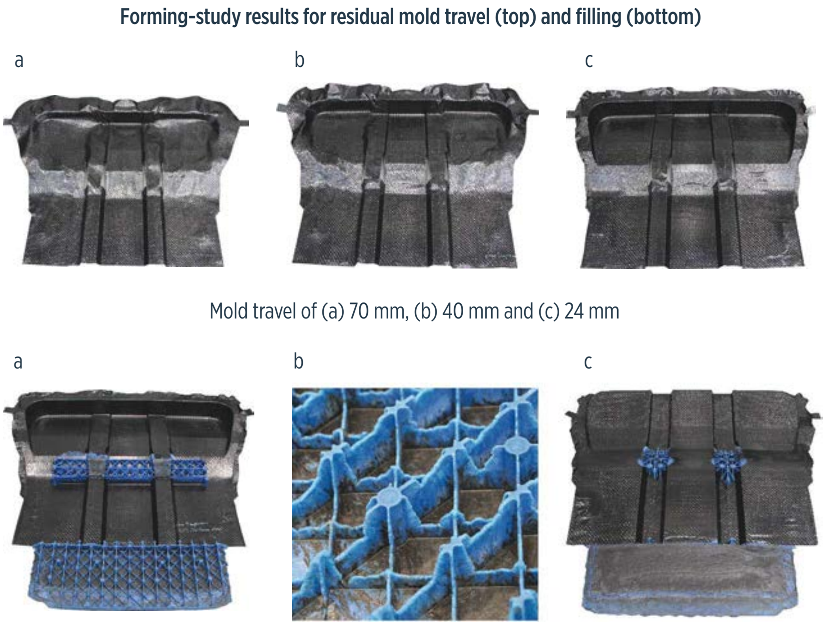


FIG. 1 Forming-study results for residual mold travel and filling

Extensive simulation work that was subsequently verified by small- and large-part testing was done on all major aspects of the rear floor module's design, processability and performance. For example, several forming studies looked at the impact of mold travel (top) and filling (bottom).

Source | Fraunhofer Institute for Chemical Technology

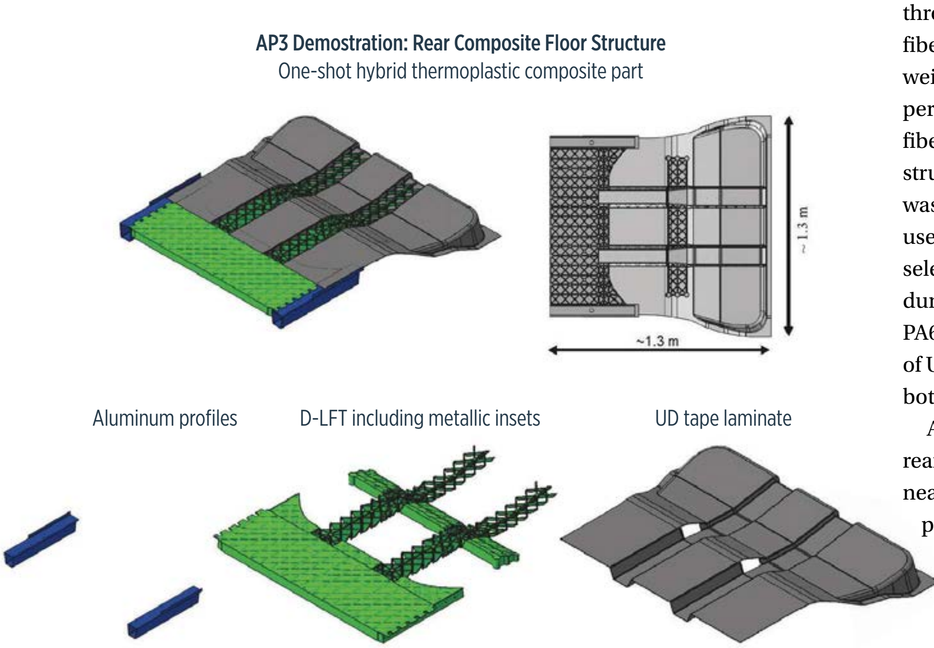


FIG. 2 Rear composite floor structure

The final rear floor module demonstrator featured a thin-shell, near-net-shape structure produced from UD tapes preconsolidated into a laminate (gray) as well as D-LFT ribs (green) in X-shaped lattice structures with select use of integral metallic inserts and aluminum profiles (blue) on the axial side of the part. D-LFT ribs are 2.5-3.8 cm tall. Source | Fraunhofer Institute for Chemical Technology

by selectively using discontinuous/chopped direct-long fiber thermoplastic (D-LFT) composites, which are flowable, allow high levels of functional integration/parts consolidation and are far easier to form into complex ribs without fiber bridging, yet can absorb significant crash energy. With D-LFT, it also is easier to insert metallic attachments, especially if inserts are predrilled so holes permit composite to flow through and around the metal, creating a strong bond via mechanical interlocking. Further, D-LFT is less costly than tapes or organosheet and far easier to mold in thick sections. Compounded at press side, D-LFT simplifies materials inventory management and offers high flexibility on development programs to quickly change material features — fiber length and type, fiber-volume-fraction (FVF) and matrix — as parts are made and evaluated. During production, material/process settings are controllable to achieve high levels of repeatability and reproducibility, which is why automotive has used the process for medium-to-high-volume production for almost two decades.

Because researchers wanted to keep the rear load floor thin and light and able to resist buckling while absorbing high impact loads, they conducted simulations and initial development through small-part testing with glass and carbon fiber-reinforced tapes and D-LFT at different fiber-weight fractions (FWFs) to evaluate mechanical performance vs. filling behavior. Although carbon fiber composites produced thinner, lighter, stiffer structures than did glass fiber, because cost also was a concern and the front load floor already used carbon fiber reinforcement, researchers selected glass fiber to reinforce the rear load floor during scale-up to full-size parts. Ultramid B3K PA6 D-LFT with 40-wt% fiberglass and eight layers of Ultratape B3WG12 PA6 with 60-wt% fiberglass, both from BASF, were used.

After much simulation work, the 1.3-by-1.3m rear load floor's final design comprises a thin-shell, near-net-shape structure produced from UD tapes preconsolidated into a laminate overmolded with a thicker D-LFT crush zone (Fig. 2). Large corrugations, also made of UD tape, with deep troughs (50 mm high by 115 mm wide) were molded along the part's longitudinal axis for high stiffness at low mass and thickness. Additionally, two windows were formed during tape layup to allow D-LFT to penetrate through the laminate to where it was needed. Because deep corrugations are difficult to form in large laminates, it was necessary to modify both molding process and tool to produce good parts. These corrugations, in combination with two charges of D-LFT that formed complex ribs in X-shaped lattice structures, generate a high moment of inertia for the area, increasing part stiffness in the thin, lightweight design while avoiding buckling in a crash. D-LFT lattices at the part's rear formed a crush zone to absorb energy in rear crashes. Aluminum profiles were integrally molded on axial sides of the load floor and bonded to D-LFT and laminate via special surface treatments as well as holes that provide interlocking. These profiles were carefully designed to further increase part stiffness, provide good buckling behavior and transfer force into the D-LFT crush zone during a crash. They also provide attachment points for direct mounting of the rear load floor to surrounding metallic structures. Additional metallic inserts, also integrally molded into the structure, provided direct mounting for seatbelt locks.

FIG. 3 Molding trials for load floor design

During the final molding trial for the rear thermoplastic composite load floor, more than 100 test parts were produced (top). Some of those were joined with the front thermoset composite load floor and side rockers to produce demonstrator parts for further evaluation (left).

Source | Fraunhofer Institute for Chemical Technology

Successful implementation

Simulation work as well as small- and large-part testing verified that the entire hybrid rear load floor could be used to manage crash loads. Further assessment revealed that this technology should be as safe as conventional metallic structures.

One larger project goal — reducing total BIW mass to 200 kg — was theoretically met during simulation and small-part development. However, as the project evolved, better crash performance was desired, which required adding mass to composite structures. In addition, cost considerations led to a switch from carbon fiber to glass fiber reinforcement for the rear load floor. The resulting rear load floor weighs 32.9 kg, while the front load floor (with inserts but without batteries) weighs 12.1 kg. For final test parts, the mass target was missed by just 4% for a total BIW mass of 208 kg to achieve higher safety and lower costs. The SMiLE BIW also would be more costly than conventional metallic systems owing to the intensive use of carbon fiber reinforcement in the front load floor.

+ LEARN MORE

Read this article online |
short.compositesworld.com/load_floor

Read more about the development of a new D-LFT/compression molding subprocess |
short.compositesworld.com/D-LFT

The rear load floor project led to F-ICT's development of a D-LFT/compression process called *local advanced tailored LFT*, which selectively applies D-LFT material to largely UD-tape structures to produce locally complex geometries (like ribs) that cannot be made with tapes. Another F-ICT technology developed before SMiLE but used on the project is a method to rapidly heat and consolidate thermoplastic tapes via *radiation-induced vacuum consolidation,* a technology now commercially available from Dieffenbacher on a machine called Fibercon.

Remarkably, the experimental process and highly complex tool produced by Frimo worked from the start and more than 100 parts were produced for subsequent testing and demonstration. Although the team designed the molding process to be done in a single step, Dr.-Ing. Sebastian Baumgärtner, F-ICT team leader for thermoplastic processing and leader of the rear load floor project, believes that in a production environment it would be more efficient to form this complex part in two steps, with laminate preforming done in a separate tool. "We opted to try the harder one-step process first and it worked well," Baumgärtner explains. "However, the tool was very complex and process control was not so easy. If the laminate got too hot in spots, it had a very strong interaction with the LFT strands. To ensure good repeatability during production, it would be better to simplify things and choose a two-step process, which would be more robust." Still, given the large size of this composite part and the complex process used to form it, the team was very pleased with the end results. "We demonstrated that we could produce an innovative and economic part that was weight and performance optimized and featured high functional integration using commercial technology," he adds.

The complete load floor won the 2018 CCE-JEC Innovation Award in China and the German government recognized the larger SMiLE program as a Lighthouse project, meaning the technology will be important for use in future mobility design. The team is in discussion about next steps. CW

ABOUT THE AUTHOR

Contributing writer Peggy Malnati covers the automotive and infrastructure beats for *CW* and provides communications services for plastics- and composites-industry clients.
peggy@compositesworld.com