Georgia Tech Manufacturing Institute

CAIIAC

Consortium for Accelerated Innovation and Insertion of Advanced Composites (CAIIAC)

WORKSHOP #3 : Composite Joining and Repair (CJAR)

Industry Expert Panel

March 26, 2015

Georgia Institute of Technology

About this Document

The National Institute of Standards and Technology (NIST) ran a competition for planning awards to support industry-driven consortia in developing research plans and charting collaborative actions to solve high-priority technology challenges and accelerate the growth of advanced manufacturing in the United States. This Advanced Manufacturing Technology (AMTech) Program aims to spur consortium-planned, industry-led R&D on long-term, pre-competitive industrial research needs. Major objectives also include eliminating barriers to advanced manufacturing and promoting domestic development of an underpinning technology infrastructure.

In May 2014, the NIST awarded the Consortium for Accelerated Innovation and Insertion of Advanced Composites (CAIIAC, pronounced "KAYAK") to work on issues that hinder bridging the gap between research and commercialization in advanced composites.

The overall vision of CAIIAC is to create an innovative domestic manufacturing ecosystem to significantly shorten the time required in manufacturing development cycles and provide "right-the-first-time material yields" for broad-based composite processes. Guided by this vision, the three-fold mission is to:

1) accelerate innovation and assist in speeding up the development and deployment of advanced composites;
2) develop broad-based applications for advanced composites; and
3) encourage "invent here, build here" in the United States to improve U.S. competitiveness and sell advanced composite products globally.

On October 14, 2014, the first CAIIAC workshop was held in Orlando, Florida, at the CAMX 2014 national composites materials conference co-sponsored by SAMPE and ACMA. All interested attendees at this conference were invited to provide technical and organizational inputs via a questionnaire during the session. The goals of this workshop were to introduce the CAIIAC program, organization, vision, and objectives to the composite manufacturing population at large, and to obtain critique and suggestions on how to make the program objectives broader to serve a larger portion of the composite industrial base.

On November 5, 2014, the Georgia Tech Manufacturing Institute welcomed 45 industry leaders and top manufacturing researchers to convene the second CAIIAC workshop. The goal of the meeting was to introduce the consortium to the invited guests and to gain input on its direction. This meeting, together with interviews of experts, led to the identification of "composite joining and repair" as a major topic to be addressed by the CAIIAC project.

The CAIIAC Team participated in and provided assistance/coordination for the ACMA Workshop on "Roadmapping the Future of Composites" held in Arlington, VA, on January 20-21, 2015. Dr. Chuck Zhang made a presentation on the progress of and future plans for CAIIAC. The CAIIAC Team also helped ACMA collect input/feedback from participants through breakout sessions.

On March 26, 2015, the CAIIAC Team hosted a third Workshop consisting of an Industry Expert Panel that was specially focused on Composite Joining and Repair (CJAR) for aerospace and automotive applications. Seven experts in the field shared their knowledge and experience on the current industry status, needs, gaps and challenges regarding CJAR, and how to answer the industry's needs for CJAR. This report is a summary of the discussions that occurred at this workshop.

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Presentation of the Participants and their Organizations

CJAR Industry Experts Panelists:

Michael D. BORGMAN, Expert, Composite Structures Strength, DADT & Repair, Spirit AeroSystems, Inc.

Spirit AeroSystems is the world's largest independent producers of commercial aerostructures. Their core products include fuselages, pylons, nacelles and wing components. Spirit AeroSystems has long-term agreements in place with their largest customers, Boeing and Airbus. Other major customers include Bombardier, Rolls-Royce, Mitsubishi, Sikorsky and Bell Helicopter. Based in Wichita, Kansas, Spirit AeroSystems operate sites in the U.S., U.K., France and Malaysia. The company also provides aftermarket services, including MRO services, spare parts and engineering support, through its Global Customer Support & Services organization.

Spirit AeroSystems is involved in the development and production of composites parts for aerostructures. The company has been chosen by Airbus to produce the fuselage sections and front wing spars for the Airbus A350 and was chosen by Boeing to produce the forward fuselage section for the 787. Along with the development and production of structural composites parts, Spirit Aerosystems is also involved in the development and implementation of repair techniques for all composite parts they produce.

Jan BREMER, Project Engineer, Composites, BCT GmbH

BCT GmbH, a system integrator founded in 1986, specializes in solutions for in-process scanning and adaptive machining. BCT's main activities are machine-integrated measuring and scanning, adaptive technologies and the automated machining of individually shaped workpieces. The company's solutions create fully automated processes by linking systems and technologies with proprietary modular software which enables adaptive machining. This approach enables improved accuracy and increased throughput while maintaining high flexibility.

BCT has developed a software solution for automated composite repair preparation by scarfing and has integrated additional process steps such as surface activation by atmospheric pressure plasma. The objective is to reduce human influence and increase controllability of the process. A fully automated adaptive milling process for scarfing was demonstrated, showing increases in precision with greatly reduced process times. Different scarfing geometries have been implemented according to customer requirements. To permit fully automated adaptive machining, precise knowledge of the part is required. Hence the component is scanned and the acquired geometrical data is used as basis for an individually adapted machining process.

Michael CANN, Senior Aerospace Engineer, FAA Federal Aviation Administration

The Federal Aviation Administration (FAA) is the national aviation authority of the United States. An agency of the United States Department of Transportation, it has authority to regulate and oversee all aspects of American civil aviation.

The FAA's roles include:

- Regulating U.S. commercial space transportation
- Regulating air navigation facilities' geometry and flight inspection standards
- Encouraging and developing civil aeronautics, including new aviation technology
- Issuing, suspending, or revoking pilot certificates
- Regulating civil aviation to promote safety, especially through local offices called Flight Standards District Offices
- Developing and operating a system of air traffic control and navigation for both civil and military aircraft
- Researching and developing the National Airspace System and civil aeronautics
- Developing and carrying out programs to control aircraft noise and other environmental effects of civil aviation

Certification occurs well after R&D and their main concern is safety.

Federal Aviation Regulation Classification:
Part 23 – Airworthiness Standards: Normal, Utility, Acrobatic and Commuter Airplanes
Part 25 – Airworthiness Standards: Transport Category Airplanes
Part 27 – Airworthiness Standards: Normal Category Rotorcraft
Part 29 – Airworthiness Standards: Transport Category Rotorcraft
Part 121 – Operating Requirements: Domestic, Flag, and Supplemental Operations
Part 145 – Repair Stations

Tom CARSTENSEN, Chief Engineer, Aerostructures, Sikorsky Aircraft Corporation

Sikorsky Aircraft Corporation is a world leader in the design, manufacture and service of military and commercial helicopters; fixed-wing aircraft; spare parts and maintenance, repair and overhaul services for helicopters and fixed-wing aircraft; and civil helicopter operations.

Sikorsky Aerospace Services provides full-spectrum service solutions to fixed and rotary wing, commercial and military customers worldwide. Its comprehensive support is designed to minimize operator downtime, improve ease of use, and reduce cost of ownership. Sikorsky helicopters are used by all five branches of the United States armed forces, along with military services and commercial operators in 40 nations.

Sikorsky's current commercial products are metal airframe but the next generation will be made of composites. There is an increasing trend in the use of composites in helicopters and there are prototypes with an all composites fuselage. Composite helicopter blades are already commercially available.

Frank HENNING, Deputy Director, Fraunhofer Institute for Chemical Technology (ICT)

Based in Germany, Fraunhofer is Europe's largest application-oriented research organization with 66 institutes and research units and 24,000 employees. Fraunhofer ICT's scientists carry out research and development work within the key competency areas of energetic materials, energetic systems, applied electrochemistry, environmental engineering and polymer engineering. The resulting knowledge and developments are applied in the following business areas: defense and security, air and space travel, automotive and transport industry, chemistry and process engineering, and energy and environment. Developments are followed through from the initial concept via basic research to applied research and the realization of customer-specific, pilot-level applications. Fraunhofer ICT's expertise covers conception and design, product development, processing technology, material development and characterization, and quality assurance.

The Fraunhofer ICT team worked with BMW on the i3 composite car. The objective was to integrate composites with metal in order to reduce weight and match the upcoming fuel regulation.

Shannon WHEATLEY, Component Engineer, Delta Air Lines Inc.

Delta Air Lines, Inc. is a major American airline company. The company serves more than 170 million customers each year. With an industry-leading global network, Delta and the Delta Connection carriers offer service to 326 destinations in 59 countries on six continents. Headquartered in Atlanta, Delta employs nearly 80,000 employees worldwide and operates a mainline fleet of more than 700 aircraft. Including its worldwide alliance partners, Delta offers customers more than 15,000 daily flights.

Delta TechOps is a division of Delta Air Lines. Over 9,600 Technical Operations employees system-wide provide full-service aviation maintenance to Delta and service its fleet of more than 750 aircraft. As the largest airline Maintenance, Repair and Overhaul (MRO) in North America and the third largest worldwide, Delta TechOps serves more than 150 aviation and airline customers from around the world, specializing in highly-skilled work such as engines, components, avionics, airframe and line maintenance. As a full-service MRO , Delta TechOps can provide comprehensive services including technical training, engineering support, line maintenance services, inventory management, component support, engine overhaul, and engine condition monitoring to keep a fleet flying. If in need of emergency services, Delta TechOps can dispatch its quick-response Disabled Aircraft Recovery Team (D.A.R.T.) to get an aircraft back in the air.

State-of-the-Art of Composite Joining and Repair

Current Status of Composites Applications in Aerostructures:

The vast majority of aircraft are constructed of metal. Composites are mostly used for secondary structures. However, this is paradigm changing. In recent years composite fuselages and wings are reaching the market of transport airplanes, as lightweight materials mean higher energy aircraft efficiency. Boeing offers the 787 Dreamliner and Airbus offers the A350. Both are over 50% composites by weight. In the helicopter market, all-composite helicopter blades are now used. Some skins and airfoil shapes are also 100% composites.

Damage to these composite structures is inevitable in service; therefore, repair technology is required to maintain them. Bonded repair is generally preferred over mechanically fastened repairs because it more effectively restores aircraft aesthetics. This is particularly important to operators who fly leased aircraft. Better aircraft aesthetics at lease end means higher aircraft residual value.

Typical damages are different for commercial than for military aircraft. Damage on commercial aircraft is usually caused by impacts, such as bird strikes, lightning strikes, material handling vehicle impacts, and foreign object damage. Military aircraft have all of these impact concerns, as well as blast and fragmentation damage from enemy projectiles. Front fuselage and lower wing skin components are commonly damaged by impact events. Composite sandwich structure is frequently used for engine nacelle panels. Since these structures are generally close to the ground (i.e., close to service vehicle traffic) they are also frequently damaged. Depending on the impact symmetry, velocity, local composite geometry and a myriad of other factors, local replacement of the material affected by the impact event is often required.

Metals vs Composites:

The aerospace and automotive industries have a long track record in developing, manufacturing and repairing metallic structures. Static strength, yield, and fatigue are well-known degradation mechanisms in metals. Previously, composites were used as secondary structures because they did not affect the flight safety of the vehicle, making their extended service time performance less critical. Now that the aerospace industry is moving to primary loaded composite structures, long time degradation behavior will be critical. Composites are highly process sensitive and allow local properties to be tailored to meet the design specific requirement. The aerospace industry has experience with composite repairs as secondary structures, but much work is required to develop the same confidence for primary safety of flight critical composite structures compared to the earlier nonstructural applications.

Automotive vs Aerospace industries:

Composite joining and repair processes are very different in the automotive and aerospace industries. There will never be a “one size fits all” process for these two industries because the business and technology drivers are different. Automotive is all about cost: the whole process has to be automated and the materials must be low cost. In aerospace, it is the opposite; safety and graceful structural degradation are the driving requirements.

The common thing, however, is that metal structures cannot simply be exchanged with composite structures. The whole design has to be redefined to take into account composites’ specificities and accommodate the new material.

In the automotive industry, the all-in-one-mold approach is used to reduce cost, but technology developments are required before intrinsic joining of composites can be achieved. To manufacture the BMW i3 electric vehicle, automated process lines are used to achieve a robust process to secure the performance of the composites. Regarding repairs, most of them are actually part replacement rather than repair. A huge doubler could be used, but in automotive, the repairs cannot be visually apparent. Esthetic is a key aspect of consumer satisfaction and they will not accept visible doublers. As cars featuring body-in-white structures made out of composites reach the mass market, performance and cost-effective repair processes have to be developed and used throughout the industry. (“Body-in-white” is a stage in automotive design or automobile manufacturing where a car’s body sheet of metal components has been welded together before moving parts, the motor, chassis sub-assemblies, or trim have been added and before painting has been done). The issue is how to spread these techniques to local repair shops that have no expertise or the tools required to repair complex composite structures. This is somewhat true for the aircraft industry too and education materials are being developed for aircraft shops who effect repair of primary composite structures. Expertise in composite repair is limited in the aircraft industry.

Repair Process:

A distinction should be made between two different types of repairs for each industry:

1. manufacturing-type repairs (rework), on damages or defects that occurred during the manufacturing process,
2. in-service type damages that require on field repairs

Composites joining and repair processes are not mature yet. In addition, the processes used for bonding are not as robust as required.

The MRB (Materials Review Board) types of repair are highly reliable because they are done in the manufacturing environment. The in-service repairs, in general, do not benefit from the manufacturing environment. Absence of a controlled environment makes all bonding processes more difficult, resulting in increased potential for formation of weak bonds. In addition, availability of appropriate tooling and inspection techniques is also more limited. As a result, all bonded repairs on primary structure must be validated using a fail-safe approach

In the aerospace industry, there is no generic repair process for composites parts, rather repair techniques must be adapted to each situation. While several repair techniques exist, their selection and implementation depends on the technician's experience. The tooling depends on the size and shape of the structure. The complexity of an aircraft's geometrical structure makes it difficult to generically tool a specific repair shape or contour. Repair technician skill is a major issue in the repairs process variability. A liquid spill, improper surface preparation, and even sneezing might negatively impact surface preparation and bond strength.

Repair Service Providers:

Aircraft operators have several options in addressing aircraft repairs and maintenance:

- Large transport airlines have their MRO centers and handle repairs and maintenance in-house. They might also offer maintenance and repair contracts at their centers to external customers, i.e. smaller airlines.
- Small aircraft companies find a qualified service provider to avoid going back to their aircraft supplier.
- Business jet companies often use the manufacturers for their repairs and maintenance.

Regulation implies that for major damage, the repair needs to have approved data from Type-Certificate holders (TC Holders), OEA. For minor damage, acceptable data is enough. For major repairs, a complete risk assessment of the repair might lead to a higher cost than simply replacing the part.

Materials:

The Composite Materials Handbook-17 (CMH-17) provides information and guidance necessary to design and fabricate end items from composite materials. Its primary purpose is to standardize engineering data development methodologies related to testing, data reduction, and data reporting of property data for current and emerging composite materials. In support of this objective, the handbook includes composite materials properties that meet specific data requirements. Designs of composite parts are usually proprietary (resins, fibers, fillers, processes).

In general, few advances have been made over the last 50 years in formulating resins for composite applications. Virtually all epoxies are composed of the same basic chemical entities: MY720, DGEBA and DDS. Various toughening agents are added to this basic resin formulation but all have negative consequences such as reducing the safe operating temperature of the composite. Existing resins also have inherent "free volume" which exacerbates moisture accumulation within the bulk composite. Moisture is known to degrade performance and inhibit bonding. Advancement in state-of-the-art resin formulation is required to mitigate the negative aspects of today's approach, to reduce moisture uptake, and to improve the reliability and strength of bonds to the material.

The cost of composites will decrease as its usage becomes more standard and more manufacturers can begin using them. If the bar is lowered more people will want to get into the market.

The current BMW i3 car is made out of thermoset materials. The use of thermoplastics is too immature; the supply chain is not ready. There may be thermoplastic parts in about two years for the next i3 generation. Damage containment is better in thermoplastics. Also, some simpler technologies, as ultrasonic welding, could be used for repairs.

Non-Destructive Evaluation (NDE):

Ultrasonic testing is the standard NDE technique used to detect damages and defects in aircraft structures. It has known limitations. First, it can only detect disbonds that are physically “open” (i.e., an air gap exists between adjacent layers in the composite laminate). X-Ray is used to detect core defects in sandwich laminates. MRI can be used in some cases, but it is extremely expensive. Thermography is also used, but it is only useful on relatively thin laminates. Light interferometry could replace ultrasonic testing, but you first have to be sure of the glass fiber absorption. The surface can be sprayed to limit absorption and ensure a better detection of the surface.

The standard water break test does not always identify “bond ready” substrates. There is no correlation between water test and bond strength test.

Finding delamination is relatively easy providing an air gap is present at the delaminated interface, but the problem is in finding areas where the bond strength is insufficient (weak bonds).

Design Tools:

Composite design tools are evolving for use in primary safety of flight critical structures. Most common CAD programs such as Pro engineer and Solid Works currently sell composite design features to supplement their finite element analysis engines. These tools are a good start, but specialty software specifically for composite joining and repair is immature and needs more real-world validation. Specialty software companies such as Altair Engineering have developed laminate on laminate mechanical analysis, but as of November 2014, this software was getting ready for product launch. Clearly, more design tools will be needed. Because of the multiple performance characteristics demanded of composite structures, simple substitution of metal designs into composites is simply not an option.

Training:

Training is basically done within companies with the expertise gathered during the years of repair implementation. The FAA developed Composite Structural Engineering Technology (CSET) training. CSET training is dedicated to standardizing original certification and providing a follow-up evaluation activity for air carriers operating aircraft with a seating capacity of 10 or more passengers.

Today, composite repairs are mostly secondary structures, not many are primarily loaded structures. DER training (Engineering Designee Recurrent Training) is in development to bring everyone at the same level of training. Training must be completed every two years.

The National Institute for Aviation Research (NIAR) is a Tech Center at Wichita State University funded by the FAA to conduct research, transfer technology and enhance education for the purpose of advancing the nation's aviation industry, and to assist non-aviation industries that may benefit from aviation-related technologies. NIAR has developed repair reports and made tests to compare designs to see variability.

Certification:

Up to now, composite repairs were on secondary structures, but as composites usage is gaining pace in primary structures, composite repairs will go to primary structures. The concern is that the standards for composites repairs on secondary structures will be extended to primary structures. Regulation is subjective; 50% is overly conservative.

FAA does not regulate the method of compliance; it just gives the expected end results. While the expectations outline the required parameters, the FAA leaves methodology up to the company. In composites, the number of plies, the resin system, the core, and about everything can be different so the FAA has no interest in being specific, but has great interest in harmonization of end use requirements and evaluations. With harmonization will come standardization and the ability to teach it to the next generation of aircraft engineers and scientists. Harmonized approaches will also enhance aircraft safety and reduce the amount of "shop specific" required training

Industry Needs, Gaps and Challenges

Building for Repairs:

Repairing composites is not just an after-sale process, rather it has to be considered upfront, together with part design. Composite structures need to be developed with a design for a repairability approach so they can be built in a way that allows for repairs. The manufacturer has to be able to support the product life cycle, so inspection criteria for safe operations of the aircraft need to be defined.

When you repair metal structures with a mechanically fastened doubler, if one fastener gets loose, the load is transferred to the other fasteners. With composites, it is completely different. Composites have limited ability to redistribute load. If the composite fails at the first fastener, the load will go to the next one and induce failure and on and on. There is no limited load redistribution capability.

Fundamental Research Needs:

As a result of our March 26, 2015, Expert Panel Workshop, future CJAR research needs were identified with the following items being found most critical for commercial application:

1. Very little has changed in bonding techniques since the 70s. There is a need to better understand the physics of bonding.
2. Kissing dis-bonds are a major issue in bonded composite repairs and they are hard to detect. There is a need for fundamental research on inspection technologies to detect kissing dis-bonds in bonded structure.
3. Surface preparation presents a real challenge in ensuring a good bonding repair process. New technologies are emerging, such as plasma surface treatments, to functionalize the molecular structure on the surface. Research is needed to evaluate the impact of surface preparation on bonded repairs and develop new techniques to improve the bonding strength.
4. There is no damage growth assessment and prediction approach for composites structures used in aerospace. Some cracking has been observed, although it had not been predicted to occur and researchers don't know why it happens. Each design is proprietary and specific so it is hard to build a general understanding. Another important question needs to be answered: What impact does the process have on the repair and end result? Further research is needed on quantifying the benefits of surface treatment.
5. New epoxy resin formulations would benefit industry. Further increased knowledge of today's systems is needed. Instances in composites fabrication are encountered where a process has worked successfully then is mysteriously unreliable. In some cases this has been tracked to inadequate control of the resin constituent ingredients. Study on the weaknesses of today's polymers would benefit development of new polymer systems for composites use

Inspection:

There is a need for advanced methods to obtain more information on bond strength. Thermography and shearography are used, but cannot detect all the different types of damages and defects. Five different techniques would be needed to cover them all. It would be expensive and time consuming to have to run experiments on all of them. Most companies currently use ultrasonic methods for experimentation and production.

The inspectability expectations vary: the level of detection is different from in-service and manufacturing. The thermography might be used in manufacturing, but not at an MRO. There is a push for training on inspection techniques. Inspectability after repairs should also be considered. Metal parts need continuous inspection because of fatigue. However, in the field, you apply what is realistic, but this is not always what is the most effective joining or repair technique. Non Destruction Inspection (NDI) is required to locate the damage before the repair and to inspect the bond after the repair or joining process.

Structural health monitoring could be achieved by the integration of sensors that would continuously monitor what is happening. Installation and integration of structural health monitoring on an aircraft is both difficult, expensive and heavy. Subsequent joining and repairing technologies could render some or all of the structural health monitoring electronics unusable if key sensor fibers and wires were cut during the repair or joining process. Some nondestructive inspection techniques, such as acoustic emission, place sensors at strategic locations and use triangulation to detect the location of the impact and its magnitude. Much research needs to be done in these situations to increase the signal-to-noise ratio of the specific nondestructive inspection technique.

Process Automation:

Automated processes are needed for repairs of composite aerostructures for several reasons:

- Repeatability and reliability: automated processes will reduce variability induced by operators
- Cost: automated equipment can reduce cycle times to achieve increased in-service time and reduce workforce cost.

Standardization:

For composite repairs, it is difficult to have one method for all. The objective would be to minimize the variability of data and standardize how the engineer and technician could do the repair. Work is needed on developing examples and scenarios. The big question is about how much information we can include in attempting to standardize the data? Considering the end user and categorizing the information by end user type is critical if there will be any insurance that the correct users get the correct data. This is a hugely expensive proposition for smaller companies. Large companies have the resources to gather and sort this kind of data.

It is difficult to find current literature on material standardization information for joining in repair. The MRO team would prefer not to have to rely on the OEM for repair data. Standardization of materials would make it easier, too, if only 10 to 15 materials would be kept in stock instead of the current practice of a few hundred. The standardization of materials is recommended by CACRC. Composite Materials Handbook-17 is a good start, but the time and expense it takes to qualify a particular material combination, including layup and cure variations, greatly limits new material design information. There are no regulatory requirements or no regulations to use to create a manual, and no baseline on how descriptive such a manual should be.

Repair tools and strategies are all developed in-house for IP issues. People feel they have a competitive advantage when keeping the information internally. The objective would be to find the common data that can be shared amongst users and subsequently grown to address joining in repair over a variety of industrial sectors. The automotive sector might be more open because there are not as many proprietary solutions.

Qualification:

Qualifying suppliers is a major step. Feedstock for the composite process must be consistent from order to order over long periods of time. The basic materials must not change over time because of moisture, pickup, exposure to solvents, and other contaminants commonly found in an industrial setting. For composites, qualification is nearly the same as for metals, but composites are highly process-sensitive. Design approver holders complete thorough testing and validating because it is their name that appears in the end. In most cases, for design approval holders, changing material providers is very difficult because it is process-centric. Furthermore, not all composites fabrication floors have consistent air quality in their shop, nor is there total control over surface contaminants. Each fabricator needs to be able to audit his sub tier materials suppliers to ensure a consistent product and then complete chemical and mechanical testing to validate product consistency. Reliable structures demand consistency in materials production and process implementation.

In aerospace, each part is inspected thoroughly, although there is room to improve the nondestructive inspection of joining in the repair process. But in the automotive sphere, economic pressures do not allow the manufacturer to treat composite joining and repair operations at the same disciplined level as in aerospace manufacturing. Tolerance of the repairs to subsequent impact should also be assessed. Repair of automotive composites is limited to body panels, which are essentially non-structural and only a “fairing”. Therefore, autobody repair of composite components can be developed much more cheaply for automotive application than for aircraft application (which are almost always structurally restorative).

How to Answer the Industry Needs?

The aerospace and the automotive industries have completely different requirements for composites and should be considered independently. Some best practices from one industry can benefit the other but in general, transfer of knowledge and experience from one industry to the other will be very difficult.

Fundamental research is needed in:

- NDE/NDI: development of emerging techniques or adaptation of existing techniques to ensure robust inspection and to detect damages. Detecting kissing bonds is also a critical aspect.
- Structural Health Monitoring: integration of sensors for continuous monitoring.
- Materials Development: self-healing materials could be an interesting approach to composite repairs.
- Process Robustness: Composites are highly process-sensitive and it would be helpful to know the effects of process parameters on the composite's final properties.
- Automation: automating repairs is key to reducing variability and improving cost-effectiveness.
- Reliability of Repairs:
    - Develop a better understanding of bonding mechanisms.
    - Develop new surface preparation techniques and evaluate the effects of surface preparation on the bond strength.
    - Develop a growth damage approach to understand and predict composites behavior over time.
    - Develop tests to evaluate the tolerance of repairs to subsequent impacts.

Composite repair is currently more of an art than a science so that finding qualified workers is a real issue. MRO companies have developed their internal training programs and rely on the expertise and experience of their repair technicians to mentor new teams. Developing new composites training programs would help companies find qualified workforce and would likely create greater demand for standardization into the composite repairs practice.

Next Steps of CAIIAC

The outcomes of the CAIIAC consortium will include:

- A complete and ready to implement technology transfer roadmap that clearly shows for each composite the TRL for transfer to key industrial markets and government
- An identifiable consortium organization that is ready to implement the CAIIAC mission
    - Identify key potential partners in the composites industry
    - Establish a database of potential partners to include composite expertise, market segments, and specialists who can work technologies into different businesses

Specifically, the following are the planned CAIIAC activities in the remaining project period:

- Refine the meta-roadmapping methodology;
- Continue to develop the CJAR roadmap;
- Host the final workshop (discussing and finalizing the roadmaps); and
- Deliver the CJAR roadmap to NIST.

Agenda - CAIIAC Composite Joining & Repair Industry Experts Panel Meeting
March 26, 2015
Meeting Venue: GTMI, Conference Room 114
Georgia Tech Manufacturing Institute, Georgia Institute of Technology
813 Ferst Dr., NW, Atlanta, GA 30332

8:00 AM	Overview of GTMI and introduction to the CAIIAC project - *Chuck Zhang, GTMI*
8:30 AM	Introduction of participants - *All* - Presentation of interest and activities in CJAR
9:15 AM	State-of-the-art of CJAR - *All* - Open discussion to detail the current practices in CJAR - Breakdown by industry to assess the similarities and differences
10:00 AM	Morning break
10:15 AM	Industry needs, gaps and challenges in CJAR (from aerospace and automotive perspectives) - *All* - Technological, IP, economic, human capital, regulatory, environmental…
12:00 PM	Lunch & informal discussion - *All*
1:00 PM	How to answer to the industry needs? - *All* - Research programs, demonstration projects, facility development, workforce training, partnerships…
2:45 PM	Concluding remarks and future plan - C*huck Zhang, GTMI*
3:00 PM	Meeting adjourn

March 26th Workshop participants

No.	Name	Organization	Organization Location
1	Atiq Bhuiyan	Georgia Institute of Technology	Atlanta, GA
2	Michael Borgman	Spirit AeroSystems	Wichita, KS
3	Jan Bremer	BCT Steuerungs-und DV-Systeme GmbH	Dortmund, Germany
4	Michael Cann	FAA Federal Aviation Administration	College Park, GA
5	Tom Carstensen	Sikorsky Aircraft Corporation	Stratford, CT
6	Frank Henning	Fraunhofer ICT, KIT	Pfinztal, Germany
7	Barbara Jeol-Pieters	Georgia Institute of Technology	Atlanta, GA
8	Les Kramer	Advanced Materials Professional Services	Orlando, FL
9	Kevin Wang	Georgia Institute of Technology	Atlanta, GA
10	Shannon Wheatley	Delta Airlines, Inc.	Atlanta, GA
11	Donggang Yao	Georgia Institute of Technology	Atlanta, GA
12	Chuck Zhang	Georgia Institute of Technology	Atlanta, GA