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Manufacturing Technology

AFFORDABLE COMPOSITE STRUCTURES:

A MANUFACTURING TECHNOLOGY OBJECTIVE

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Introduction

The Army's vision for the future is to make its heavy forces lighter and its lighter forces more lethal. Composite manufacturing technology is being called on to achieve the first part of this goal. Polymer matrix composites are significantly lighter than metals and are being considered for ever-increasing roles in Army weapon systems. Composites have long been a staple in the DOD aircraft business, however, composite components have been costly to produce. Consequently, one of the overall goals of the manufacturing technology objective (MTO) is to decrease the cost of composite components 25 percent.

The first weapon system platforms to be addressed are the Comanche, Apache, and Crusader. The Comanche currently has a predominantly composite (70 percent) airframe structure. There are, however, opportunities to reduce cost and extend the use of composites to other components such as fittings and shafts.

Conversely, the Apache currently has a metallic airframe. As part of the Rotary Wing Structures Technology Demonstration (RWSTD), a prototype Apache composite midfuselage will be fabricated with the primary objective of reducing weight.

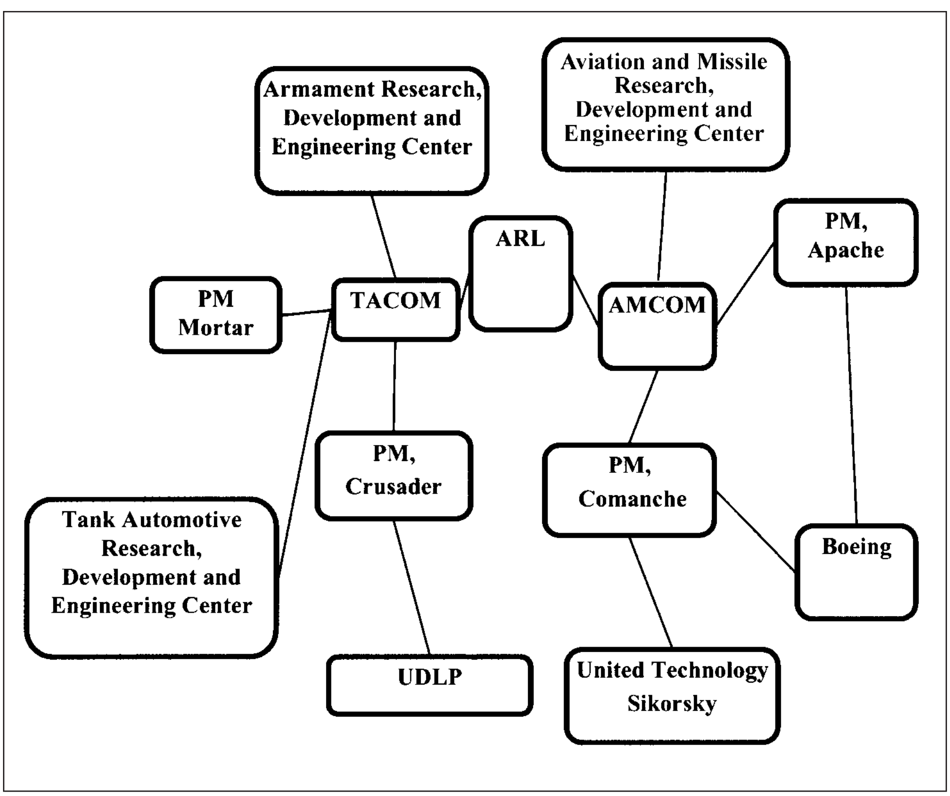

Figure 1.
Program participants

For the Crusader and its resupply vehicle, composite turret prototypes are being constructed. Initial prototypes were significantly more expensive than production targets. Several tasks are being initiated through the MTO that will help meet production cost targets. In the munitions area, an effort is underway to develop an inexpensive composite 120mm mortar fin to replace the current aluminum one. This will provide a 25-percent cost savings and improved performance.

Management Approach

The Army Research Laboratory (ARL), the Tank-automotive and Armaments Command (TACOM), and the Aviation and Missile Command (AMCOM) are teamed to execute the Composite Manufacturing Technology Program. The key to the successful transition of any technology is the involvement of the prime contractors. In this program, the prime contractors of each major weapon system are involved: Boeing for Apache and Comanche (tail section), Sikorsky for Comanche, and United Defense Limited Partnership (UDLP) for the Crusader. Figure 1 shows the primary program participants. In addition to these participants, a number of subcontractors and the Center for Composites Manufacturing at the University of Delaware are involved.

A number of partnerships have been established to leverage MTO resources (approximately $3 million annually plus cost sharing from the prime contractors) with other Army and DOD composite technology efforts. The most significant of these partnerships is with the Composites Affordability Initiative (CAI), which is a Defense Technology Objective (DTO) funded by the Navy and Air Force to support the Joint Strike Fighter. Even though the technologies of the CAI are directed

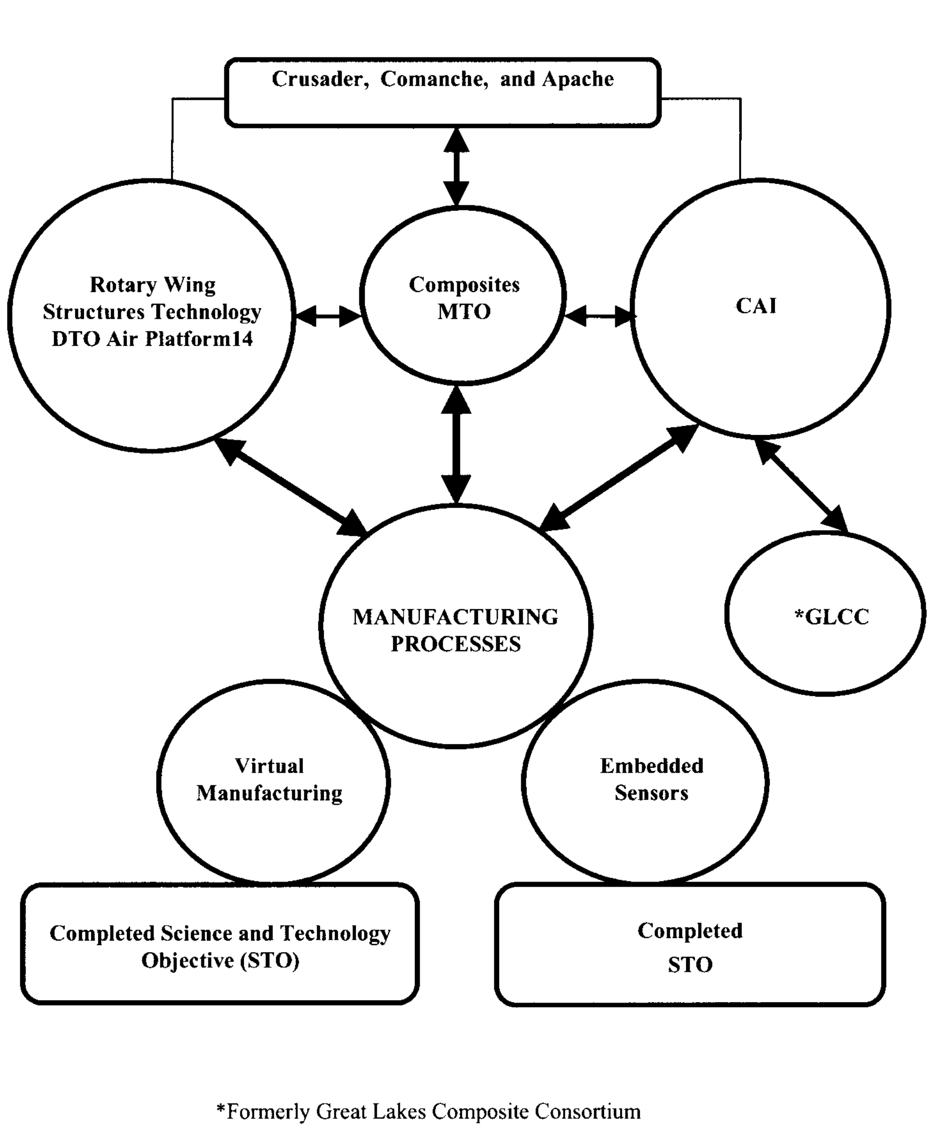

Figure 2.
MTO linkages

toward fighter aircraft, there are many generic technologies applicable to Army needs. Within the Army, other efforts such as the RWSTD are being leveraged to increase effectiveness of MTO resources. Figure 2 shows the leveraging and cross-linking arrangements.

Program Goals

As stated earlier, the major objectives of the Composite Manufacturing Technology Program are weight savings and cost avoidance. All three of the major systems being addressed by the MTO have weight-saving requirements that will result in reduced logistic requirements (such as to-theater transportation and in-theater fuel requirements) and will improve performance (such as range or survivability). An example is the composite turret on the Crusader, which is 15 percent lighter than the standard metallic baseline, without a threat to the crew. Even though the Comanche is now 70 percent composites, the Army expects to reduce the weight another 15 percent. The MTO will help enable the 15-percent weight reduction in the lower forward fuselage with an additional goal of 25-percent reduction in labor hours.

Cost-benefit goals are significant. Cost avoidance with the Comanche is projected to be several hundred million dollars throughout production of the fleet. In addition, logistical benefits from reduced weight can be even more impressive for heavy vehicles such as the Crusader. Crusader weight reductions enabled by composite components can save several hundred million dollars in fuel costs. Even a 25-percent cost savings for a relatively inexpensive fin for the 120mm mortar ($4 for a $16 fin) can result in a large cost avoidance when procurement quantities are in the hundreds of thousands.

Technologies

This MTO is primarily a technology maturation and transition program. There are a number of technologies addressed throughout the program, including a generic baseline of common technologies applicable to all of the systems. Examples of these technologies are modeling, electron beam (e-beam) curing, sensor-based process control, improved vacuum-assisted resin transfer molding (VARTM), improved quality assessment, and cost modeling. More system-specific technologies include automated preform fabrication and lay-up for Crusader, improved thermoplastic processing using inductive curing, paintless finish for helicopters, lean tooling, primary adhesive bonding, and self-locating assembly. Figure 3 shows common technologies and specific applications.

During the first year of the MTO, one of the most significant developments was the improvement and application of a resin flow model for the VARTM process commonly used for many weapon system applications. Prior work was performed to develop a model for the resin transfer molding process. This model was enhanced to simulate the VARTM process.

The obvious advantage of modeling is risk reduction. Components can be resin-filled in a virtual environment to identify potential problem areas that will be difficult to completely fill with resin, thus creating lean or dry spots. The accepted practice is to base the design of the component, mold, and injection location on past experience and then use trial and error to perfect the process. This is a very expensive way to produce quality parts. With an accurate model, the fill-out of a virtual component can be accomplished and potential problem areas identified in minutes. On subsequent virtual runs, process parameters such as the location of injection ports can be changed and the resultant resin flow evaluated.

The improved model has been applied to virtual components for both the Apache and Comanche helicopters and combine favorably with actual results from risk-reduction prototypes. Model improvements will continue to be made to make it more user friendly and improve its computational speed.

Ground Vehicles (Crusader)	Rotorcraft (Comanche and Apache)	Munitions (M829E3 Sabot)
Applications	**Applications**	**Applications**
▪ Complex Preform ▪ Thick (Multimaterial) Section ▪ Armor Tiles ▪ Susceptibility ▪ Sustainment ▪ Ballistic Event Management	▪ Thin Structural Sections ▪ Part Consolidation ▪ Highly Loaded Graphite ▪ Few Structural Fasteners ▪ Ballistic Event Management ▪ Transverse Loading	▪ High-Loading Conditions ▪ Severe Environment ▪ Hypervelocity ▪ Expendable Components
Specific Technologies	**Specific Technologies**	**Specific Technologies**
▪ Automated Preform Processing ▪ Optimization of VARTM/Tooling ▪ Automated Tile Placement System ▪ Industrial Simulation ▪ Repair Technologies	▪ Fiber Placement ▪ Alternative Curing ▪ Advanced Fiber Preforms ▪ Toolless Assembly ▪ Co-Curing ▪ Graphite Fibers ▪ Bonding ▪ Self-Locating Assembly	▪ Thermoplastic Graphite ▪ Automated Thermoplastic ▪ High-Speed Machining

Common Technologies

- Process Simulations
- Alternative Resins and Fibers
- Material Performance Specifications
- Cost Modeling
- Health Monitoring
- Process Sensing and Control
- Alternative Manufacturing/ Cure Processes
- Quality
- Composite Fittings
- Assembly Simulations

Figure 3.
Technologies and applications

Another area where progress has been made is the development of an e-beam curable adhesive with improved properties. E-beam curing offers the potential to significantly reduce process time for assemblies. Parts of the assembly can be injected with an e-beam resin that will set to a hard but uncured stage, allowing the tooling to be removed. The e-beam adhesive can then be used to bond together the parts, and the entire assembly can be cured at once. E-beam processing is an emerging area where work is ongoing.

To save resources and accelerate the work, the MTO is linked to the CAI. The CAI has a test matrix for e-beam resins to identify those with the best properties and potential for aviation applications. The Army e-beam adhesive is being entered into the CAI test program to achieve a comparative assessment with currently available materials.

Conclusion

The approach taken in this MTO should serve as a model for future efforts, where the resources of other Services are being leveraged into the Army program. Within the Army, multiple major commands, program managers (PMs), and programs are teamed in common pursuit of affordable manufacturing technology for composites development. This approach avoids potential proprietary issues and creates a more uniform capability among the Army's contractor base.

As the demand for new composite technologies (including fibers and resins) increases, costs will decrease. This will ultimately benefit future systems because contractors will have a relatively equal composite manufacturing capability.

Future Army systems, such as the Joint Transport Rotorcraft (JTR), will also benefit from the results of this MTO. The JTR is projected to see a 6-percent cost avoidance in the program definition and risk reduction and engineering and manufacturing development phases based on advances in composite technology through the MTO and leveraged efforts. In addition, the increased use of composites will make possible the goals of a 55-percent increase in range or a 36-percent increase in payload over current baselines.

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