

# **Energy Efficient Thermoplastic Composite Manufacturing**

**DE-EE0005780**

**Project Team/Boeing, Cytec, Temper, AjaxTOCCO**

**Budget Period #1**

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Boeing Research & Technology (Marc Matsen)

U.S. DOE Advanced Manufacturing Office Program Review Meeting

Washington, D.C.

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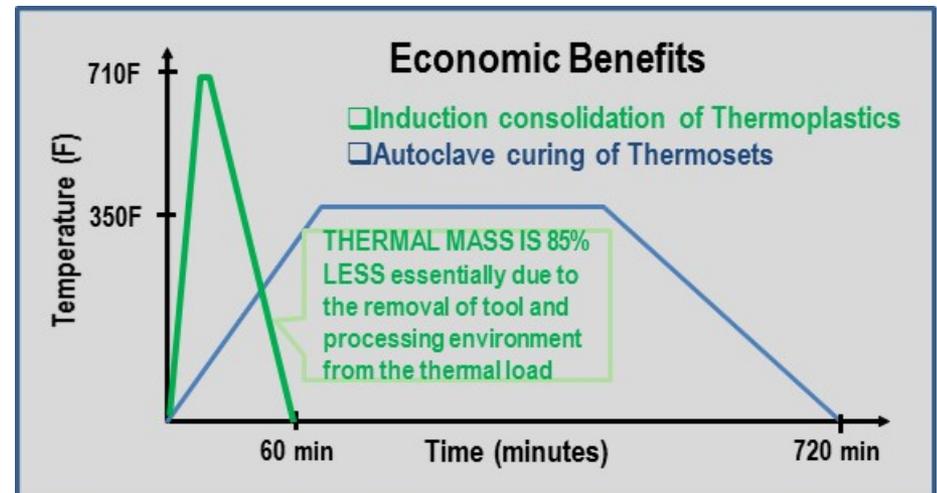
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# Project Objective

- *The objective of the project is to establish an effective and affordable method to lay-up and consolidate/join large thermoplastic composite aerospace structure with cycle times measured in minutes rather than hours.*
- *Composite airplane designs have proven efficient and effective however future potential product production rates are challenging what the current systems can efficiently produce due to material lay-down constraints and extended thermal cycle times.*
- *The ability to lay-up then rapidly heat, consolidate, and cool large complex composite structures plus very accurately tool them (i.e. matching CTE of composite materials) along with very precise thermal control is a difficult challenge.*



**Autoclave = Large Thermal Mass**

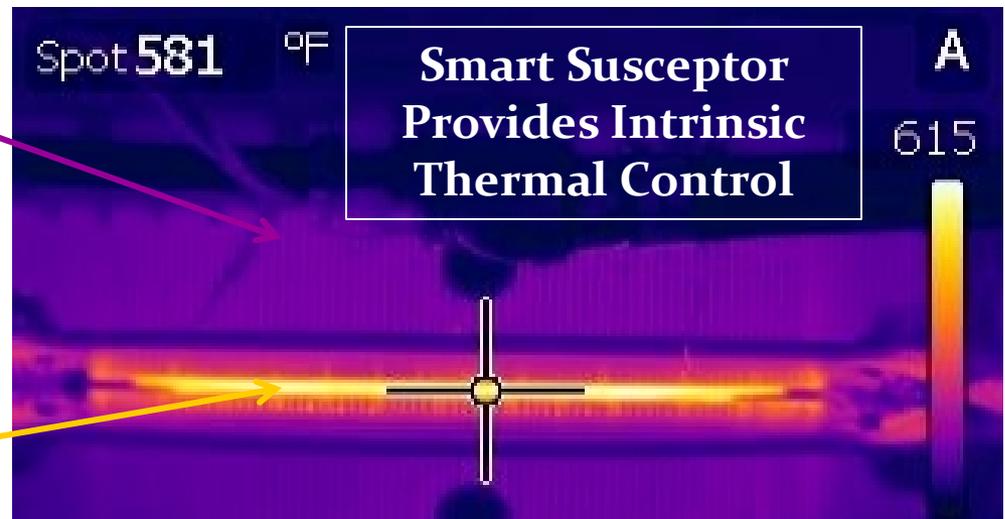


# Technical Innovation

- *Current systems such as autoclave processing of thermoset materials require long cycle times due to method of heating and the large associated thermal masses. These extended cycle times inhibit the ability to meet higher rate production scenarios due to the need for multiple sets of equipment and tools. In addition, lay-up of thermoset resin based composite requires significant facilities and process flow restrictions at rate.*
- *Thermoplastic composite materials are being used to facilitate more rapid cycle times via the elimination of a need for a cure dwell at temperature. Also, we are utilizing **induction heating along with smart susceptors** to enable the quick cycle times needed while providing **precise intrinsic thermal control**.*

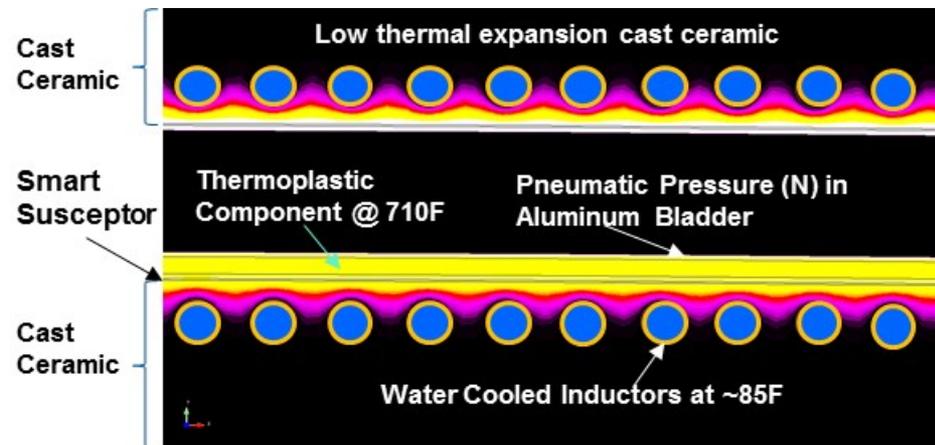
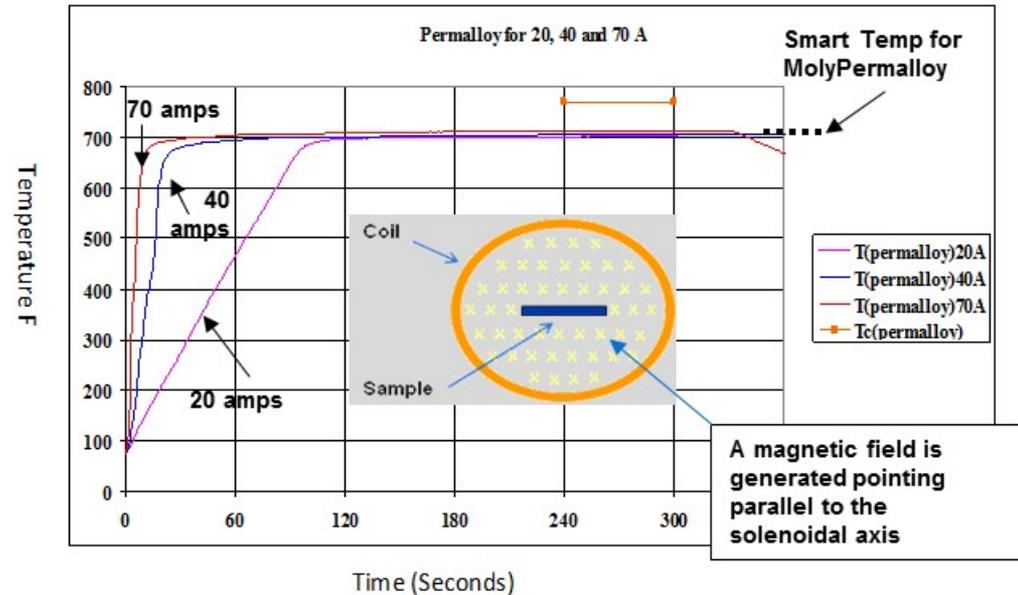
The tooling material and/or construction is chosen as to not interact with the induction field and therefore the tool body remains at essentially ambient conditions

Only the smart susceptor surface of the tool is heated with the remainder of the tool not effected by the magnetic field from the coil



# Technical Innovation (cont.)

- *The smart susceptor acts as the thermal control mechanism when at the processing temperature. When the smart susceptor sheet metal becomes substantially non-magnetic it's heat generation drops by ~1 order of magnitude. This essentially creates a thermal ceiling when properly engineered. The appropriate ferromagnetic alloy is chosen to match the desired processing temperature.*
- *Rapid thermal cycles are estimated to enable significant non-recurring cost savings over existing methods. The biggest benefit is exhibited when considering the needed curing or consolidation equipment for a **high rate production** “greenfield” facility.*



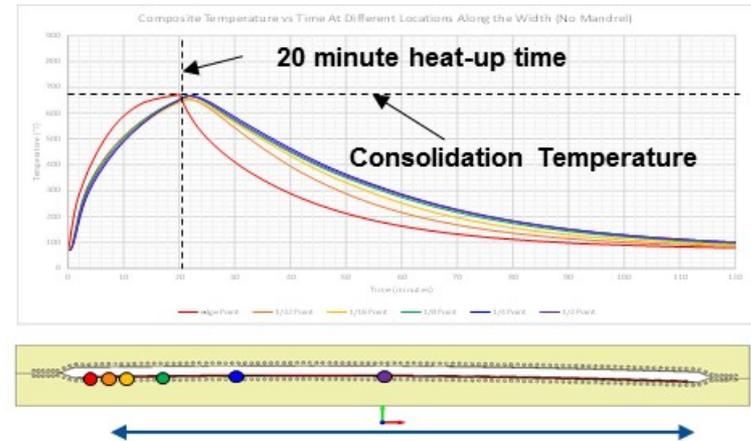
# Technical Approach

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- *The intrinsic control of the induction heating process via the smart susceptors is the key innovation. The ability to rapidly heat and then precisely control the temperature of the consolidation component is paramount to the success of this project. It is this unique processing attribute coupled with the thermoplastic material characteristics along with rapid lay-up methods that are novel and advantageous.*
- *The project team consists of Boeing as the prime and Temper, Cytec, and Ajax TOCCO as sub-recipients. This team provides the key industrial elements for making the technical progress needed to be successful.*
  - *The Boeing Company - OEM - product pull - project leader - preform process development - part design - ceramic tool analysis - part fabrication requirements - characterization of smart susceptors*
  - *Cytec Solvay Group - materials leader - material supplier - thermoplastic processing - recyclability (deliverables / reports)*
  - *Temper, Inc. - tool and equipment leader - tooling design - forming equipment design (FEA) / build - process design and tryout*
  - *Ajax TOCCO - induction heating leader - FEA of induction heating integrated with thermal response - inductive heating equipment - die assembly and coil manufacturing*

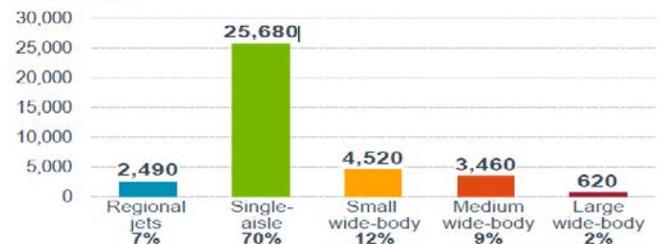
# Technical Approach (cont.)

- *Project risks include as follows: 1.) scale-up of induction heating and resulting smart susceptor and power supply response 2.) scale-up of tooling 3.) Significance of thermal cycle and resulting cost savings -- Computational modeling and cost models are being used to understand these risks and assist in mitigation efforts as needed.*
- *Boeing has a key leadership position within the aerospace industrial community. While many requirements and influencing factors decide the materials and processes utilized for future airplane construction, the forecast of accelerated production rates and the recent performance successes of composites in airplane construction provide an opportunity for this processing technology to have significant influence. This technology has the potential to assist in reducing financial risk of high rate composite structure fabrication capability thru rate insensitivity.*



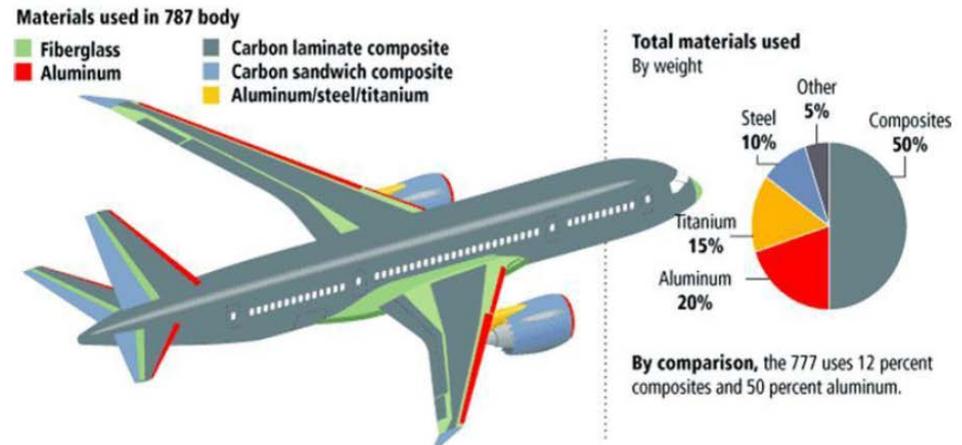
Airplane deliveries: 36,770

2014 - 2033



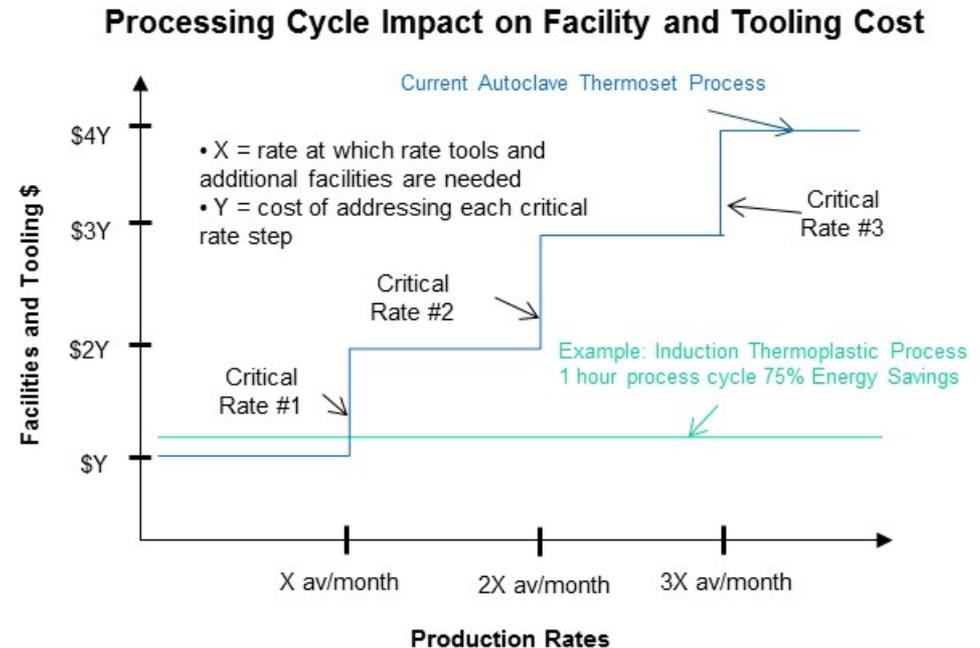
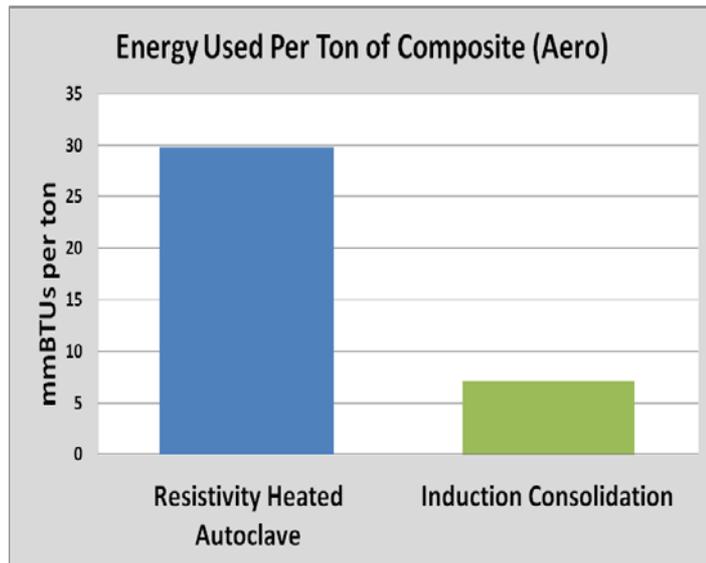
# Transition and Deployment

- *As Boeing defines its future products, new more efficient production methods that enable improved performance like this process will be vital to reaching long term goals. The Department of Energy and Boeing will be interested in the significant energy savings that is enabled by this technology over the use of standard processes like autoclaves.*
- *The aerospace industry will be the end user of the process. The intent is that this process will be used to fabricate composite aerospace structure affordably and efficiently at accelerated rates of production. This is important since composite aerospace structures have shown to provide significant performance advantages.*
- *Boeing would further develop this process for internal and external fabrication sourcing for large components.*
- *Internal use by Boeing could provide technology sustainment with further growth provided by out-sourcing and adoption by composite fabrication industry in general.*



# Measure of Success

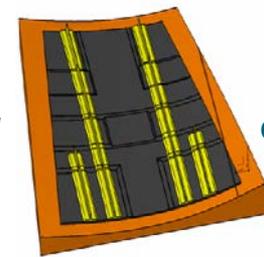
- When successful, this technology could enable affordable and efficient high rate production of large composite aerospace structure. This technology has the potential to assist in *de-risking the establishment of high rate composite structures fabrication capability thru rate insensitivity*. Lay-up rate and consolidation cycle time along with quality of the components will be key metrics.
- This technology is projected to provide *75% energy savings (or more) over standard autoclave processing*. The economic advantage is lower risk implementation of *affordable and efficient high rate production of large composite aerospace structure*.



# Project Management & Budget

- Start date is 5/14/2015 --- End date is 5/14/2018
- Budget Period #1: Q4 – Task 2 – milestone 2.3 (complete month 15 ): *Complex part consolidation with +/- .050” per lineal foot part to engineering accuracy; +/- .030” per lineal foot part per part accuracy; less than 4% porosity; +/- 30F thermal uniformity; less than 120 minutes processing time; with 40% improvement in energy consumption over autoclave processing*
- Budget Period #2: Q8 – Task 8 – milestone 8.4 (complete month 24 ): *Establishment and integration of scale-up fabrication system capable of processing the 5’ by 15’ component scale-up demonstration*
- Budget Period #3: Q11 – Task 14 – milestone 14.2 (complete month 32 ): *Consolidation of large 5’ by 15’ complex scale-up component with +/- .030” per lineal foot part to engineering accuracy; +/- .010” per lineal foot part per part accuracy; less than 2% porosity; +/- 10F thermal uniformity; less than 60 minutes processing time; with 80% improvement in energy consumption over autoclave processing*

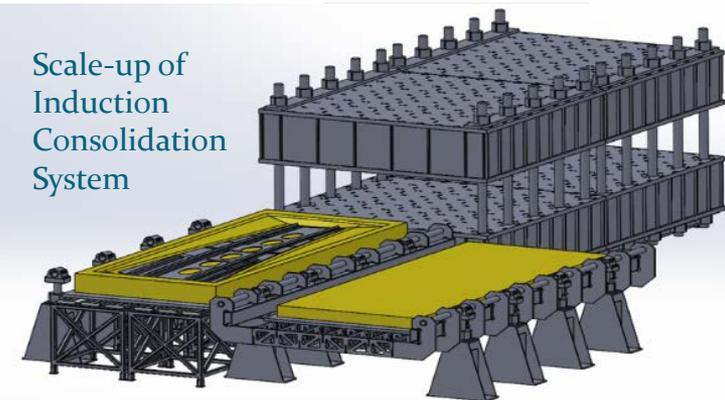
Laser Assisted Fiber Placement and Induction Consolidation of Mid-Sized Thermoplastic Composite Demo-Panel



Design of Complex Scale-up Component

Total Project Budget	
DOE Investment	\$4,500,00
Cost Share	\$1,865,603
Project Total	\$6,365,603

Scale-up of Induction Consolidation System



# Results and Accomplishments

- *This project was initiated : 5/14/2015*
- *Recent accomplishments include:*
  - *Selection and design of 5' by 15' demonstration component (section of a notional lower wing panel) for a high rate airplane*
  - *Improvements in laser assisted fiber placement capabilities (staggered tow adds and drop) for complex pre-forms*
  - *Initial blade stiffened co-consolidation panel processing demonstrations*
- *The objective of this project is to demonstrate and document the energy efficiency plus the technical and economic viability of induction consolidation using smart susceptors for full-scale integrated thermoplastic composite structures on an aerospace application. This will be accomplished thru the demonstration on a medium scale component initially for risk mitigation purposes and then development of equipment, tooling, and processes along with the subsequent fabrication of a full-scale component will be performed. This component, when successful fabrication is complete, will demonstrate an improved capability to meet high production rates for large aerospace thermoplastic composite structures.*

