Energy Efficient Thermoplastic Composite Manufacturing

DE-EE0005780

Project Team/Boeing, Solvay (Cytec), Temper, AjaxTOCCO

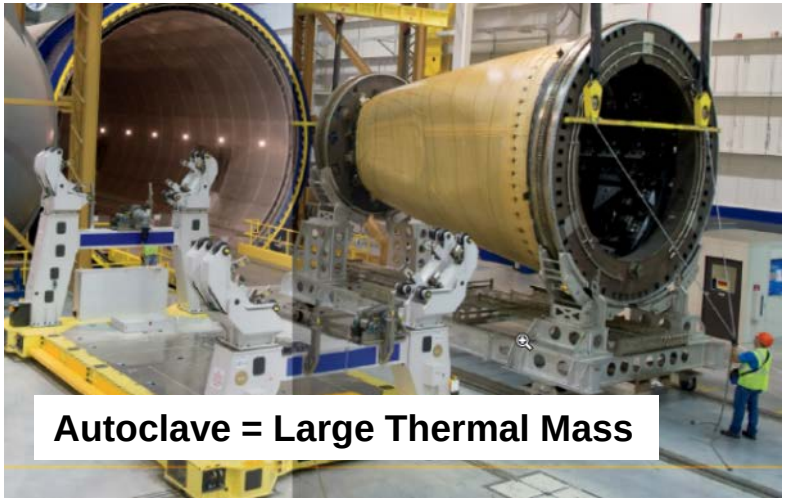
Budget Period #2

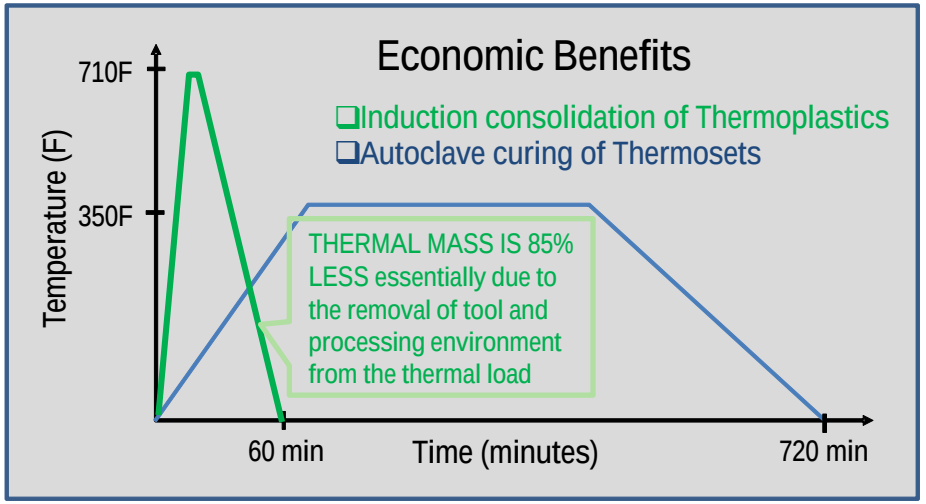
Boeing Research & Technology (Marc Matsen)

U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
June 13-14, 2017

Project Objective

- *Project Objective:*
  - *Establish an effective and affordable method to lay-up, consolidate/join large thermoplastic composite aerospace structure*
  - *Cycle times measured in minutes rather than hours.*
- *Problem Statement:*
  - *Current composite airplane designs have proven efficient and effective*
  - *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.*
- *Difficult Challenge:*
  - *Efficiently lay-up then rapidly/precisely heat, consolidate, and cool large complex composite structures plus very accurately tool them (i.e. matching CTE of composite materials)*

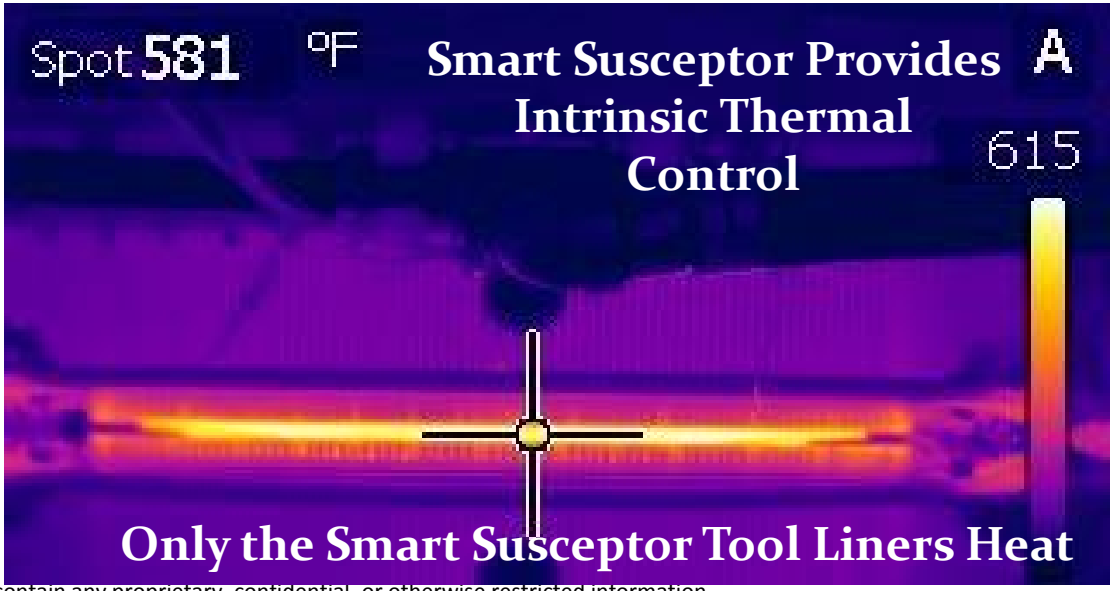




Technical Innovation

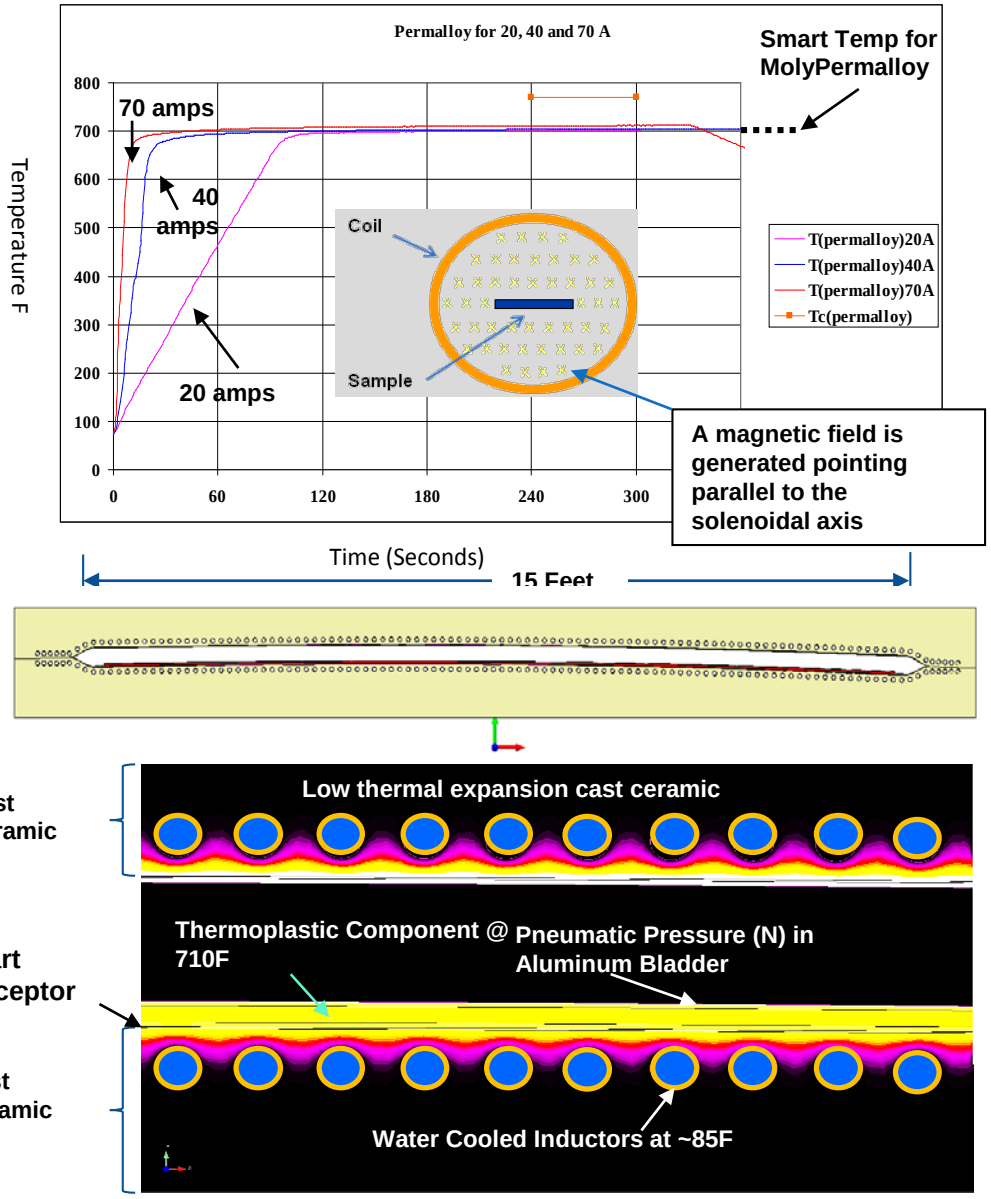
- *Current Approach Autoclave Curing of Thermoset Composites:*
  - *Autoclave processing of thermoset materials require long cycle times due to method of heating and the large associated thermal masses.*
  - *These extended cycle times inhibit the ability to meet higher rate production scenarios due to the need for multiple sets of equipment and tools.*
- *New Approach Induction Consolidation of Thermoplastic Composites:*
  - *Thermoplastic composite materials are being used to facilitate more rapid cycle times via the elimination of a need for a cure dwell at temperature and their tolerance of quick heat-up and cool down thermal ramps.*
  - *Utilization of induction heating with smart susceptors to enable the quick cycle times needed while providing precise intrinsic thermal control.*

Induction Consolidation & Molding Press and Tool



Technical Innovation (cont.)

- *The smart susceptors act as the thermal control mechanism:*
  - *As the smart susceptor sheet metal becomes substantially non-magnetic it's heat generation drops by ~1 order of magnitude or more.*
  - *This essentially creates a thermal ceiling when properly engineered.*
  - *The appropriate ferromagnetic alloy is chosen to match the desired processing temperature.*
- *Reinforced cast ceramic tooling allows the inductive magnetic field to pass through it thereby eliminating the need to heat (and cool) the bulk of the tool mass*
- *Rapid thermal cycles result in significant non-recurring cost savings when considering a 70 airplanes per month (or greater) "greenfield" facility.*

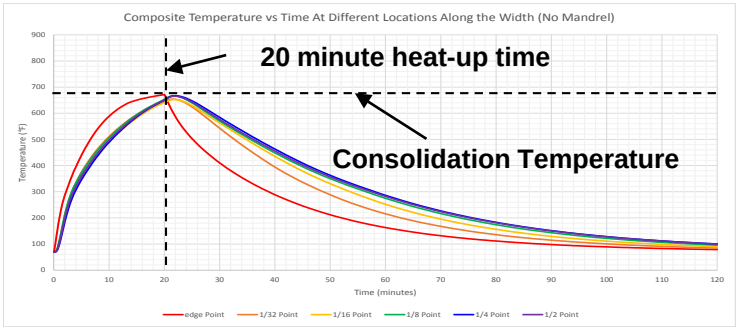


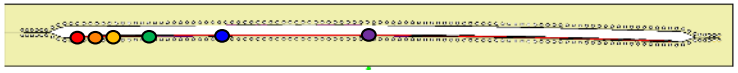
Technical Approach

- *Induction heating using smart susceptors in conjunction with the reinforced cast ceramic tooling for rapid heating and cooling along with the precise control of the temperature during consolidation of the component will be used to fabricate process verification components.*
- *It is this unique processing capability 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, Solvay (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*
  - Solvay (Cytec) - *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*

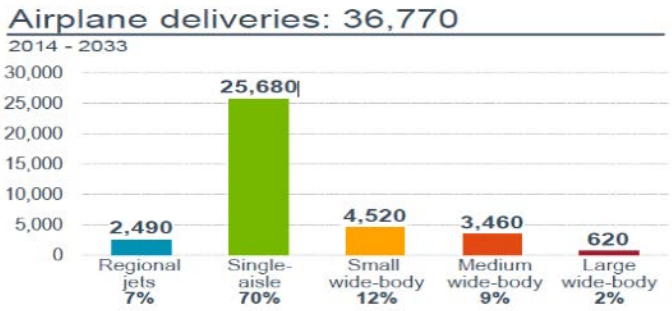
Technical Approach (cont.)

- *Project Risks:*
  - *Large scale induction heating and the resulting smart susceptor and power supply response*
  - *Robustness of large scale induction consolidation reinforced ceramic tooling*
  - *Financial 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:*
  - *The forecast of accelerated production rates and the recent performance successes of composites in airplane manufacture provide an opportunity for this processing technology to have significant influence.*
  - *This project will establish process verification data that will assist in erasing a number of unknowns surrounding this technology and enable its consideration for future production applications*



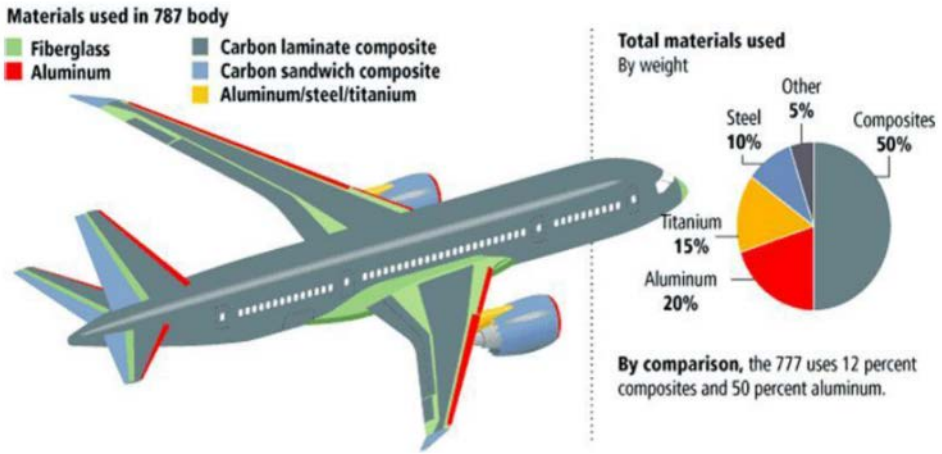


15 Feet



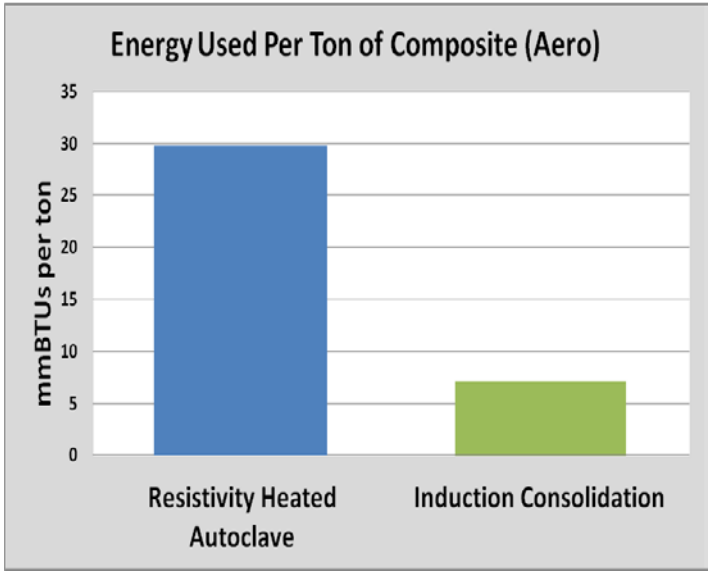
Transition (beyond DOE assistance)

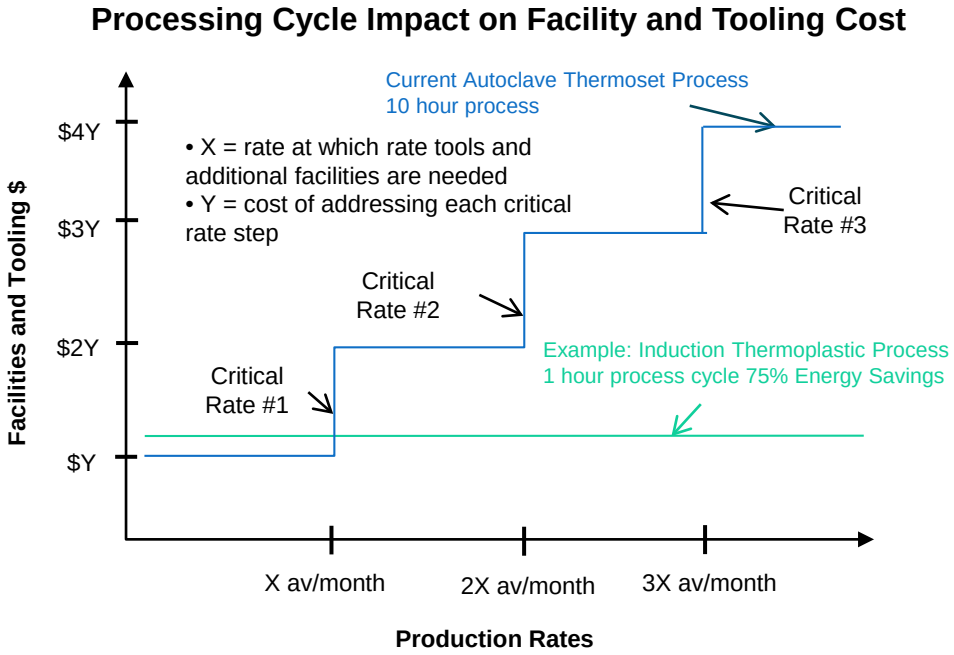
- *Stakeholders Interests:*
  - *As Boeing defines its future products, new more efficient production methods that enable improved performance like this process will help in reaching long term goals.*
  - *The Department of Energy and Boeing will be interested in the significant energy savings that is enabled by this technology over the use of standard processes like autoclaves.*
- *Aerospace Industry will be the End User:*
  - *The intent is that this process will be used to fabricate composite aerospace structure affordably and efficiently at accelerated rates of production.*
  - *Composite aerospace structures have shown to provide significant performance advantages.*
- *Sustainment Model:*
  - *Boeing would further develop this process for internal and external fabrication sourcing for medium to 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

- *Success Criteria:*
  - *Provide 75% energy savings (or more) over standard autoclave processing*
  - *Enable fabrication of large high performance composite aerospace structure with rapid and controlled thermal cycles*
  - *De-risking the establishment of an affordable and efficient high rate composite structures fabrication capability*
  - *Efficient processing of high quality composite components*





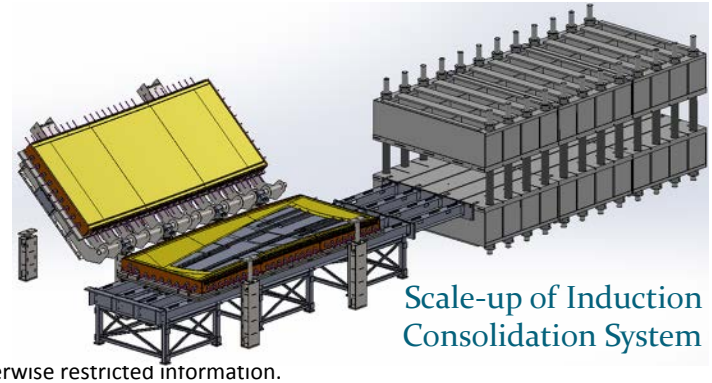
Project Management & Budget

- *Start date is 5/14/2015 --- End date is 12/31/2018*
- *Budget Period #1: Q5 – Task 2 – milestone 2.3 (completed month 14): 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: Q10 – Task 8 – milestone 8.4 (complete month 30): Establishment and integration of scale-up fabrication system capable of processing the 5' by 15' component scale-up demonstration*
- *Budget Period #3: Q14 – Task 14 – milestone 14.2 (complete month 40): 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*

Induction Consolidation of Mid-Sized Thermoplastic Composite Demo-Panel

Large Panel Thermoplastic Lay-Up Capability

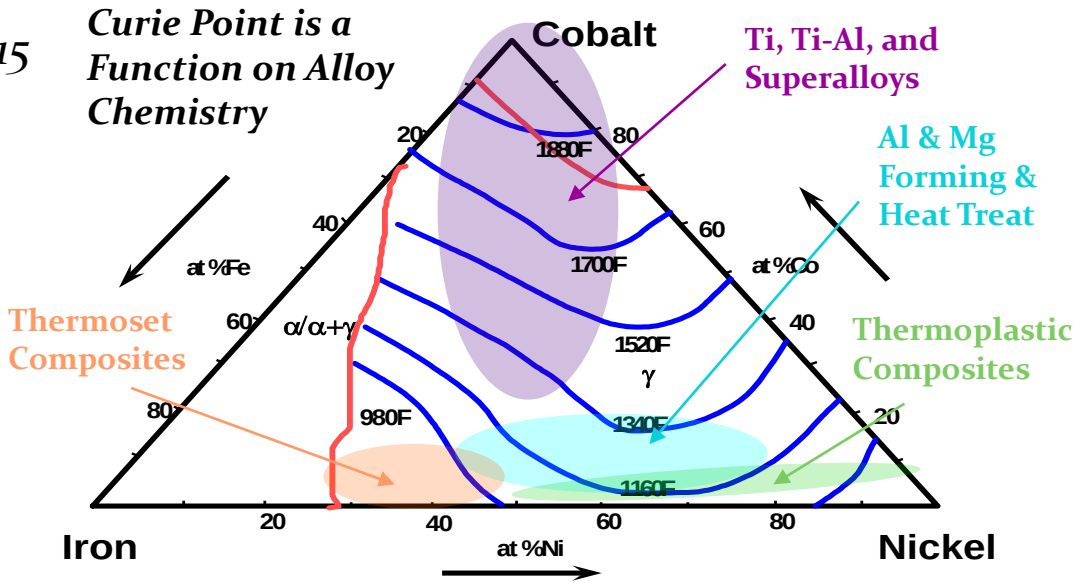
Total Project Budget	
DOE Investment	$4,500,00
Cost Share	$1,865,603
Project Total	$6,365,603



Scale-up of Induction Consolidation System

Results and Accomplishments

- *This project was initiated : 5/14/2015*
- *Recent accomplishments include:*
  - *Successful consolidation of complex contour panel*
  - *Tools and pre-form elements are ready for co-consolidation of complex contour blade stiffened panels*
  - *The large restraint fixture, die handling mechanism, and demonstration tool are all currently under construction*



Boeing is Leveraging these Smart Susceptor Energy Saving Developments Over a Broad Spectrum of Materials & Structures

- *The main objective of this project is to verify 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:*
  - *Process verification on a medium scale component initially for risk mitigation (completed)*
  - *Successful fabrication of a large scale component will verify the process to be capable of meeting high production rates for aerospace thermoplastic composite structures.*

Questions?