In Mar 2014, five partners came together to work on a £13.4 million ATI-funded project called ATI Horizon (AM) in order to develop Additive Manufacturing (AM) techniques into viable production processes for aerospace parts and components over the following 3.5 years. Now in its closing stages, the project has helped enhance UK business competitiveness, safeguard jobs, and ensure that the UK remains at the forefront of cutting-edge technology development in a rapidly developing field.

The ATI Horizon team is led by GKN Aerospace, with AM Equipment OEM Renishaw Plc and Software OEM and machining specialists Autodesk. To exploit the UK’s wealth of innovation and knowledge, the team also includes two leading UK universities, Sheffield and Warwick.

The ATI Horizon (AM) project consists of 11 work packages covering key aspects of AM technology development required and covers the whole manufacturing value chain. The 8 main work packages are shown below in Figure 1.
It is a diverse programme progressing over various metallic and polymer AM technologies shown below in Figure 2. The programme is in its final stages – producing test demonstrators of key technologies.

![Figure 2 – AM Technology for ATI Horizon (AM)](image)

**Table 1: Summary of the project grant details**

<table>
<thead>
<tr>
<th>Project</th>
<th>Funding</th>
<th>Lead Partner</th>
<th>No. of Partners</th>
<th>Partner Composition</th>
<th>Duration</th>
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<tr>
<td>113036</td>
<td>Horizon</td>
<td>GKN</td>
<td>4</td>
<td>Industrial: GKN, Renishaw, Autodesk</td>
<td>Mar 14 – May 18</td>
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<td></td>
<td>Total: £13.4m</td>
<td></td>
<td></td>
<td>Academic: University of Sheffield</td>
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<td></td>
<td>Grant: £7.0m</td>
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<td></td>
<td>University of Warwick</td>
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**Table 2: Summary of the project focus areas**

<table>
<thead>
<tr>
<th>ATI Value Streams</th>
<th>ATI Enablers</th>
<th>ATI Attributes</th>
<th>Strategic Horizon</th>
<th></th>
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<tbody>
<tr>
<td>Whole Aircraft</td>
<td>Aerodynamics</td>
<td>Safety</td>
<td>Secure</td>
<td></td>
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<tr>
<td>Structures</td>
<td>x Manufacturing</td>
<td>x Cost</td>
<td>x Exploit</td>
<td>x</td>
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<tr>
<td>Propulsion</td>
<td>x Materials</td>
<td>x Environment</td>
<td>x Position</td>
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<td>Systems</td>
<td>Infrastructure</td>
<td>Fuel Burn</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Process and Tools x</td>
<td>Operational Needs</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Passenger Experience</td>
<td></td>
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</tbody>
</table>

**Technology Achievements:**

The ATI Horizon (AM) programme focuses on progressing three key AM technologies through GKN’s Technology Readiness Assessment (TRA) process in order to development them into viable production processes. To date, TRL 3 have been achieved for Polymer AM and TRL 4 for LPB. It is also collaborated with other ATI projects and GKN sites to produce flight test hardware for flight trials of next generation ice protection systems developed in WIST and ALFET. After TRL 4 focus will shift from the process to product development with a focus on TRL 4 for Polymer, TRL 5 for LPB and the continuing industrialisation of the EBM technology achieving TRL 4 for a high rate engine component.
Economic Impact:
Through ATI Horizon the AM Centre at Filton has:

- Increase in staff numbers from 8 → 20 Engineers, Scientists and support staff
- Grown from 2 → 10 AM Machines
- Single material and process capability → Multi-material and process capability
- No post processing → Wire-EDM & other post processing equipment
- Fully Functional Material Analysis Lab
- Increased collaborations with key customers on AM

ATI Horizon also secured the employment of 20 highly skilled engineers, scientists and support staff ensuring that the UK workforce is developing the skills to compete in a cutting-edge area of technology with a market prediction of $65.6bn by 2025 (Source: Counterpoint Aerostructures, 2014)

Due to the technology development achieved through ATI Horizon, GKN were excellently positioned to collaborate with an existing customer to produce flight trial hardware which required a rapid delivery. This collaboration led to further work being awarded to GKN to other areas of the customers’ business where AM could be applied.

Further Reading:
In order to demonstrate the progress made and anticipated benefits for the UK manufacturing industry, the consortium has produced 2 detailed case studies. These case studies document the challenges that have been encountered, the technical approach taken, and the potential economic benefits.
GKN LPB AM Technology enables Next-Generation Ice Detection system to fly

Project details:
The aim of this project was to investigate the whole life cycle of producing airworthy components using the Laser Powder Bed (LPB) additive manufacturing (AM) process and be the first LPB parts produced by the GKN Additive Manufacturing Centre, Bristol, UK to fly. The project formed part of the work in maturing the LPB technology at GKN towards TRL5.

In collaboration with other ATI funded projects, WIST and ALFET as well as other GKN Aerospace divisions, this project delivered Laser Powder Bed components to house a novel aircraft Optical Ice Detector (OID) and next generation ice protection heater mats. The assembly was attached onto an instrument pylon and flight tested using the BAe 146-301 large Atmospheric Research Aircraft (ARA) owned by Facility for Airborne Atmospheric Measurements (FAAM).

The Flight Trial provided a fantastic opportunity to progress the development of three technology strands; the first flight of the OID and Type 8 Spraymat® Ice Protection heater mat, developed by GKN Aerospace Special Products Group, Luton, and the first LPB flying parts produced by GKN Additive Manufacturing Centre (AMC), Bristol.

The Additive Manufacturing work is part of the wider Aerospace Technology Institute (ATI) Horizon project, which will take a number of promising additive manufacturing techniques from research and development through to viable production processes. It is funded by Innovate UK and is a collaboration between the following partners: GKN, Autodesk, Renishaw, University of Sheffield, and University of Warwick.

Figure 4: (left) The LPB components housing the OID and Type 8 Spraymat® assembled onto the aircraft; (right) The LPB components at various stages of completion prior to assembly

Technology Achievements:
The project helped mature the following technology strands:

- Laser Powder Bed AM towards TRL5
- Optical Ice Detectors towards TRL6
- Ice Protection Heater Mats (ALFET) towards TRL6
The AM parts needed to interface with the aircraft’s instrumentation canisters, the OID sensors and an external video camera used to verify if ice had accreted. It was important to minimise the surface roughness of the parts external surfaces and maintain the tight tolerances needed between the AM parts and the other metallic components.

**Development of Design for Additive Manufacturing methods (DfAM) and techniques**

Designing parts for AM needs to be done in conjunction with the orientation in which the parts will be built. This project supported the improvement in knowledge and understanding of LPB capability for producing part features and geometries. It enhanced understanding the impact of part orientation, nesting and support structure and as a result helping provide DfAM rules for future LPB applications.

It also promoted awareness to the aerospace design community of the capability of AM, highlighting the benefits of AM such as improved functionality by geometrical freedom opposed to the design constraints of subtractive processes.

**LPB Process Development**

Using components that were going to be used for a flight test really pushed the development of the LPB process understanding. Machine settings and parameters were investigated in order to produce conforming parts with suitable material properties. This learning and understanding the effects of process variables is a key step in maturing the technology readiness of LPB.

**Post Processing Knowledge**

Various post processing operations were required to meet part requirements. During the LPB process extremely large thermal gradients are created within the parts. In turn, these gradients lead to the build-up of residual stresses. Therefore, heat treatment is required to relieve the stresses. This was an assembly of LPB parts and as such, the mating faces had to fit within a tolerance. CNC (Computer Numerical Control) & EDM (Electrical Discharge Machining) methods were used to produce the tolerances required at the interfacing features.

The AM parts are in the airflow and therefore the external surfaces required a good surface finish. Finishing techniques were investigated to improve the surface finish of LPB parts. Finally, for safety of flight qualification the parts had to be tested to ensure mechanical properties requirements were met. Many of these post processing operations were outsourced to the UK supply chain. This project helped improve their knowledge of working with these new materials.
Although a number of these operations are mature technologies, this project helped advance the understanding of using these technologies with a material produced using a novel manufacturing method, LPB AM.

Figure 6: Nose Cone (left) and Canister (right) LPB components following the post processing operations

Economic Impact:

This project has:

- Ensured that GKN is able to compete in Electro-thermal Ice Protection market that will be worth £400m by 2030
- Developed the unique skills required to be able to produce components in Additive Manufacturing
- Provided an excellent example of cross-collaboration between ATI funded projects to prove multiple technologies with a trial flight
- Ensured that GKN Aerospace remains the Global #1 supplier of Electro-thermal Ice Protection Technology

The ability of AM to deliver a component with a quick turnaround was key for this project.

According to Dr Rob Sharman, Global Head of Additive Manufacturing:

“...it was all about the timing. We had a window of opportunity in which to fly that demonstrator on the research aircraft, and that window was very short. AM had a lead-time advantage compared to the other processes, and we were able to get the final part in a way that traditional manufacturing technology just couldn’t.”

Next Steps:

The Horizon programme will now progress the LBP technology to TRL 5 which requires the technology to be tested in a real-world or near real-world condition. The work from this project has provided a strong foundation to achieve this step.
Simulation Driven Design Aid Engineers to Design Next Generation Aircraft Components

This project investigates Design for Additive Manufacture (DfAM) throughout the whole life cycle by exploring simulation driven design methodologies on an Elevator Hinge Bracket. The work is part of the wider Aerospace Technology Institute (ATI) Horizon project, which will take a number of promising additive manufacturing (AM) techniques from research and development through to viable production processes.

By combining Simulation Driven Design with the manufacturing capability of AM, engineers are able to create components that could be as much as 50 per cent lighter than their conventional counterparts, with complex geometries that cannot be cost effectively manufactured today. This will unlock innovations in low drag, high-performance wing designs and lighter, even more efficient engine systems - and lead to dramatic reductions in aircraft fuel consumption and emissions.

The aim of this work package is to plan a single AM process for five (5) distinct optimised designs of an Elevator Hinge Bracket using five (5) different software packages. The designs are to be built and mechanically tested on a rig with the positive expectation that all pass. It is funded by Innovate UK and is a collaboration between the following partners: GKN, Autodesk, Renishaw, University of Sheffield, and University of Warwick.

*Figure 7: Current Elevator Hinge Bracket and 5 Topology Optimised Brackets using different software packages*
Technology Achievements:

The Elevator Hinge Bracket demonstrates the following benefits:

- A reduction of the Buy-to-Fly Ratio from 3.5 to approximately 2 – 1.5
- Potential for weight reduction of up to 53%
- A reduction in the machining requirement leading to reduced material wastage
- Potential for reduction in number of parts
- Potential reduction in design time by 10-fold

Build preparation simulation allows generation of optimised support structure and compensation for distortion that will reduce the number of trial and failed builds, making the manufacturing process more efficient and cost effective.

Economic Impact:

Application of the processes described above can have the following impact:

- Reduction in Buy-to-Fly Ratios → Reduced Material Costs
- Part Weight Reduction → Fuel Cost Reduction during Aircraft Operation
- Decrease in Design Time for the Part → Overall reduction to delivery time

Next Steps:

This project has demonstrated how new technologies improve existing components within the aviation market. The general conclusions and studies can be transferred to other components deemed suitable for Additive Manufacture, which are currently manufactured using processes subject to long lead times and high material wastage.

The study provides evidence that parts which are designed within limits of traditional manufacturing processes can be replaced with optimised parts that offer cost and weight savings. The wider application for assemblies of structural components being built as one part in AM has been identified as a further potential area for development.

The relatively limited scope of this project has developed the technology to TRL4 in the aircraft structures application. The work has been validated by static strength testing of one of the parts. This technology will mature to TRL6 and undergo flight demonstration.