AEROSPACE TECHNOLOGY INSTITUTE

UHBR ENGINE ROADMAP

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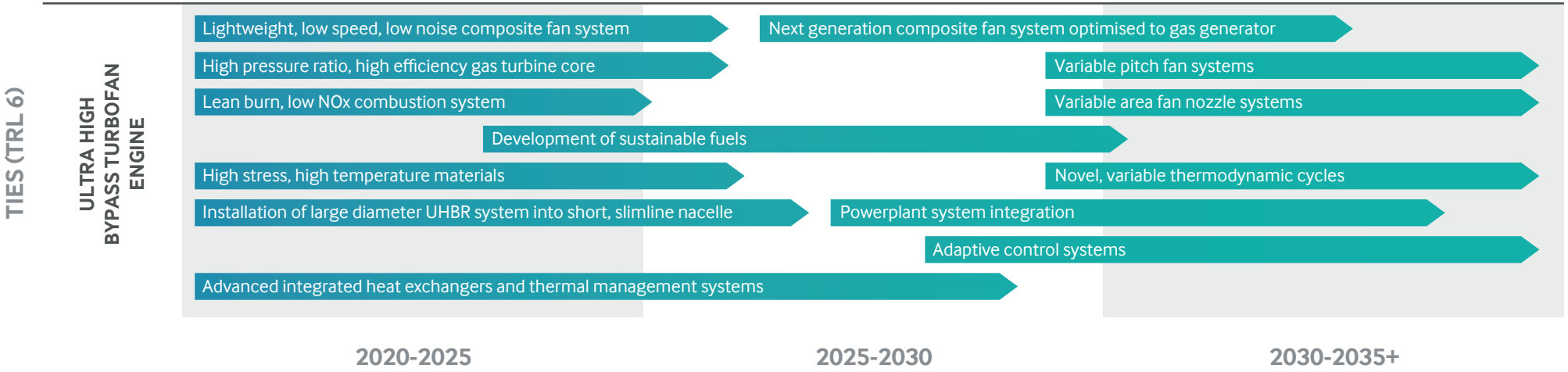
The ATI, through its Working Group dedicated to Ultra High Bypass Ratio (UHBR) Turbofan Engines, has compiled this document to outline what each of the key supply chain opportunities are in relation to the technologies in our UHBR roadmap from our Strategy, 'Accelerating Ambition'. This details the key underpinning technologies and the products that these align with, as well as the fundamental drivers behind these.

Organisations that think they may be able to help deliver some of these technologies are encouraged to engage with the ATI and the UHBR Working Group to discuss what these mean in more detail via our contact pages on the ATI website, with a reference 'UHBR Roadmaps'.

DRIVERS	**Reduce Cost:** reduce waste, improved manufacturing productivity and better utilisation of resources/skills **Improve Energy Efficiency:** improved propulsive efficiency through novel architectures **Protect the Environment:** reducing CO_2, NOx, nvPM, perceived noise, material usage and waste **Meet Operational Needs & Flexibility:** resilient and efficiently-maintainable propulsion and power systems **Enhance Passenger Experience:** reduce in-cabin perceived noise **Improve Safety:** damage tolerance, intrusion tolerance, predictability, quality assurance

TARGET (EIS)	
ENVIRONMENT	**CO_2** (% margin/fuel burn, 2000 baseline)**:** 20% reduction by 2025, 25% reduction by 2035 **NOx** (% margin relative to AEP6, 2000 baseline)**:** 55% reduction by 2025, 65% reduction by 2035 **Perceived Noise** (Propulsion, relative to Chapter 3, LR2 average)**:** 30 EPNdB cumulative reduction by 2025, 36 EPNdB cumulative reduction by 2035



LIGHTWEIGHT, LOW SPEED, LOW NOISE COMPOSITE FAN SYSTEM

Aerospace is continually focused on reducing component weight to lower fuel burn, carbon-fibre composites are ideal materials for the fan system, saving almost 700kg per aircraft, the equivalent of seven passengers and their luggage. Lower cost processes and net zero manufacturing are key to successful application of the technology.

TECHNOLOGY	PRODUCTS	DRIVERS
Advanced methods of composite component manufacture including infusion, preforming, fibre placement and associated tooling	Blades, casings, tanks, housings, pipes, shafts, ducting, annulus fillers, vanes, mounts, brackets	Reduced cost and weight of components, improved strength and lifing
Novel repair and inspection techniques of composite and metallic materials	Fan blades, casings, tanks, housings, pipes, shafts, ducting, annulus fillers, vanes, mounts, brackets, discs	Enhanced material understanding, faster repair processes, better component reclaimability
Acoustic technologies for noise absorption and mitigation	Fan blades, casing, engine inlet, acoustic panels and liners	Reduced sound profile, noise attenuation
Novel sensors for improved data collection and monitoring	Temperature sensors, vibration monitoring, wear, photonic and optical sensors	Improved diagnostic capability, embeddable, low cost, smart
Advancing joining techniques for composites and metallics including welding, bonding and mechanical solutions	Fan blades, casings, tanks, housings, pipes, shafts, ducting, annulus fillers, vanes, mounts, brackets, discs	Enhanced ability to join similar and dissimilar materials, part integration, enhanced maintainability

HIGH PRESSURE RATIO, HIGH EFFICIENCY GAS TURBINE CORE

A high pressure ratio, high efficiency turbine core is key to delivering fuel burn efficiency, low emissions, and successful product life cycle. Key capabilities required included advance alloys and manufacturing methods, high temperature sealing solutions and sensors as well as novel repair and inspection techniques for in-service products.

TECHNOLOGY	PRODUCTS	DRIVERS
Advanced alloys including titanium, nickel	Blades, vanes, discs, drums, shafts, casings	Improved fatigue performance, enhanced joining capability, low cost, lightweighting
Optimised manufacturing processes for near-net shape production, including casting, forming, forging, machining etc.	Blades, vanes, discs, drums, shafts, casings	Fast make, lightweighting, modular structures, integrated structures
Novel sealing and bearing solutions including contactless, composite, air, ALM and magnetics	Static and dynamic seals, pressure seals, brush seals, O-rings, gaskets, fire seals	Higher temperature capable, enhanced wear performance, enhanced pressure capability, reduced maintenance
Novel sensors including smart sensors, optical sensors and high temperature sensors	Sensors for speed, pressure, temperature, vibration monitoring and others	Harsh environment, higher temperature capability, lightweight, low cost, improved diagnostics, intelligent communication, improved accuracy
Novel repair and inspection techniques of composite and metallic materials	Blades, vanes, discs, drums, shafts, casings	Enhanced failure detection capability, low cost, faster repair processes, enhanced component lifing

LEAN BURN, LOW NOx COMBUSTION SYSTEM

UHBR engines will employ advanced combustion systems to enable reductions in emissions and particulate generation, while incorporating future sustainable fuels. New fluid control mechanisms will optimise fuel delivery, combined with smart, electrical actuation and the use of additively manufactured flow devices. Harsh environment, low-cost sensing capability and improved inspection and repair techniques are needed for effective continued operation.

TECHNOLOGY	PRODUCTS	DRIVERS
Novel repair and inspection techniques	Combustion liner, tiles, thermal barrier coatings, fuel spray nozzles	Enhanced failure detection capability, low cost, faster repair processes, enhanced component lifing
Optimised fluid control systems	Fuel spray nozzles, manifolds, valves, pipes, pumps, fuel flow transmitter	Improved control of fuel supply and staging, reduced fuel coking, lightweight, low cost
Novel sensors including smart sensors, optical sensors and high temperature sensors	Sensors for speed, pressure, temperature, vibration monitoring and others	Lightweight, low cost, improved diagnostic, intelligent communication, improved accuracy, harsh environment capability
Additive layer manufacturing for novel component designs	Fuel spray nozzles, manifolds, valves, pipes	Component integration, lightweight, low cost, improved flow control
High temperature electrically actuated components and associated control systems	Valves, solenoids	Improved control and modulation, lightweight, low cost, replacement of hydromechanical units

DEVELOPMENT OF SUSTAINABLE FUELS

Biofuels, synthetic e-fuels and hydrogen are all under consideration as future sustainable fuels for aviation. The primary challenges for biofuels and synthetic e-fuels are feedstock availability and cost respectively; but both require minimal changes to the gas turbine engine. Hydrogen fuel is another potential route to zero carbon aviation with its primary challenge being creation of a fuel supply infrastructure. The introduction of hydrogen fuel into UHBR engines would require technology steps in the thermal, fuel and combustion systems.

TECHNOLOGY	PRODUCTS	DRIVERS
Ground and flight testing of gas turbine and aircraft using increased blends above 50%	Studies and detailed impact analysis of the demonstration of increased blends on the fuel, combustion system and engine architecture. Studies on the fundamentals of the understanding of greenhouse gas emissions produced by synthetic and bio fuels.	Increasing blend ratios with kerosene to drive down the CO_2 footprint of the end product
A digital twin of the SAF product and process to replicate the lifecycle performance	A standard universal methodology to assess the lifecycle performance of SAF products. Adoption of methodology early in SAF definition phase through to utilisation.	Being able to assess the true sustainability of fuels through full lifecycle analysis (LCA)
Hydrogen-enabled gas turbine fuel, control and combustion systems	Gas turbine systems capable of running on gaseous or liquid hydrogen fuels.	Zero carbon emissions flight and hydrogen production

HIGH STRENGTH, HIGH TEMPERATURE MATERIALS

Reduced weight, enhanced performance and increased operating temperatures for UHBR engines drives the need for advanced materials and manufacturing processes. Development of higher strength, higher temperature composites and metals, combined with joining techniques and wider use of additive layer manufacture, can be applied to a wide range of core engine and external systems components.

TECHNOLOGY	PRODUCTS	DRIVERS
Higher temperature capable materials, including metals and composites	Core component systems, pipes, harnesses, tanks, pumps, fire proofing, shields, sensors	Enhanced hot section capability, enhanced fire protection capability, packing of systems closer to core, low cost
Advanced coating systems, including additives	Environmentally resistant thermal barrier coatings, tribological, hydrophobic, iceophobic	Improved wear resistance, temperature capability, harsh environment capability
Materials for transmission systems including metallic and composites	Gears, gearboxes, shafts, lubricants, bearings, seals	Higher load carrying capability, improved wear performance, corrosion resistance, light weighting
Advanced composite systems (including ceramic and metal matrix composites)	Seals, blades, heat shields, rotating components, exhaust structures, discs, rings, vanes	Higher temperature capability, improved wear performance, light weighting, recyclability, improved joining performance
Additive layer manufacturing processes and material qualification	Heat exchangers, fluid control, mounts/brackets, fuel spray nozzles, pipes, seals	Lightweighting, enhanced component design capability, low cost, repairability, process friendly composites

INSTALLATION OF LARGE DIAMETER UHBR SYSTEM INTO SHORT, SLIMLINE NACELLE

The nacelle for a large UHBR powerplant will contribute significantly to installed propulsion system performance. The operating environment is harsh, therefore enabling technologies are required to provide nacelle configurations characterised by their low aerodynamic drag, constituent lightweight components and technologies that are embodied for noise attenuation, thermal management, fire safety and environmental protection.

TECHNOLOGY	PRODUCTS	DRIVERS
Integrated structural optimisation tools	Load sharing solutions, mounting solutions	Closer packaging of nacelle to engine, optimisation of structural elements, lightweight, low cost
Advanced methods of composite component manufacture including infusion, preforming, fibre placement and winding	Air inlet, panels, casings, cowlings, thrust reverser, pylon, mounts	Lightweight, low cost, improved strength and lifing
Acoustic technologies for noise absorption and mitigation, including novel materials	Air inlet, panels, casings, cowlings, thrust reverser	Reduced sound profile, noise attenuation, improved modelling
Thermal protection technologies, including new novel materials and cooling solutions	Thrust reverser, panels, actuation devices, fluid conveyance	Increased thermal loading on components due to closer packaging of nacelle to engine, low cost, enhanced performance
Smart structures including morphing and integrated health management	Air inlet, panels, casings, cowlings, thrust reverser, pylon, mounts	Enhanced aerodynamic performance of nacelle, improved diagnostics, intelligent communication

ADVANCED INTEGRATED HEAT EXCHANGERS AND THERMAL MANAGEMENT SYSTEMS

Future UHBR engine architectures will demand a step improvement in the performance, size, weight and cost of the thermal system that cools the engine oil. Introduction of sustainable fuels such as hydrogen and some degree of hybridisation which would present further thermal system technology challenges. Technology advances will be required for a range of heat exchangers, together with new mini systems for their integration into the parent engine.

TECHNOLOGY	PRODUCTS	DRIVERS
Compact oil and air cooling systems	Heat exchangers and heat exchanger integration	Increased heat generation, heat exchangers relocating from fan to core case
Additive layer manufacturing for novel component designs	Heat exchangers	Enhanced topology optimisation, complex flow designs, low cost, fastmake, enhanced repairability
Novel heat exchanger installation concepts including integrated coolers and structural and aerodynamic elements	Air-oil, fuel-oil, mini-systems	Increased heat generation, heat exchangers relocating from fan to core case
Cooled cooling air systems	Air-air heat exchanger, mini-system	Increased engine pressure ratio driving turbine temperature and increased peak temperatures, low weight, low cost
Advanced thermal systems modelling, testing and validation capability	Toolsets and models for new concepts and architectures, test rigs, facility developments	Demonstration of novel thermal system concepts, enhanced thermal energy dissipation and energy reutilisation

NEXT GENERATION COMPOSITE FAN SYSTEM OPTIMISED TO GAS GENERATOR

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TECHNOLOGY	PRODUCTS	DRIVERS
Advanced methods of composite component manufacture including infusion, preforming, fibre placement and associated tooling	Blades, casings, tanks, housings, pipes, shafts, ducting, annulus fillers, vanes, mounts, brackets	Reduced cost and weight of components, improved strength and lifing
Composite load bearing structural elements	Structures, casings, vanes, housings, struts	Reduced weight of powerplant
Smart structures including morphing and integrated health management	Blades, casings, tanks, housings, pipes, shafts, ducting, annulus fillers, vanes, mounts, brackets	Intelligent, adaptable and reconfigurable structures to adapt to environment, increased sensing and decision-making capability

VARIABLE PITCH FAN SYSTEMS

The variable pitch fan concept varies the pitch of the fan as the engine is throttled to improve specific fuel consumption (SFC) and potentially remove the need for a thrust reverser. Timescale for application would be UHBR engines post 2030. Enablers for the concept include actuation, control and monitoring technologies, smart structures, and modelling tools.

TECHNOLOGY	PRODUCTS	DRIVERS
Smart structures including morphing and integrated health management	Fan blades, casing, seals	Intelligent, adaptable and reconfigurable structures to adapt to environment, increased sensing and decision-making capability
Modelling and integration tools for variable pitch	Models, analysis tools, sensitivity studies, structural and flow analysis	Improved understanding of constraints and technical assessments, thrust reverser removal
Actuation and pitch control technologies including control philosophy for pitch control	Actuators, system models	Improved control and modulation, assessment of failure modes, system reliability, physical constraints

VARIABLE AREA FAN NOZZLE SYSTEMS

A variable area fan nozzle (VAFN) provides the ability to control fan nozzle exit area to match engine operation and deliver reduced fuel burn and noise benefits. It could be applicable to a 2030+ timescale UHBR engine and requires the development of actuation, sealing, monitoring and smart structure technologies.

TECHNOLOGY	PRODUCTS	DRIVERS
Actuation technologies including electrical, pneumatic and hydraulic	Actuators, system models	Improved control and modulation, improved sensing and decision-making capability, lightweight
Novel concepts for aerodynamic sealing	Static and dynamic seals, pressure seals, brush seals, O-rings, gaskets, fire seals	Improved reliability, lightweight, repairability, minimising leakage
Smart structures including morphing and integrated health management	Nozzle structure, seals	Intelligent, adaptable and reconfigurable structures to adapt to environment, increased sensing and decision-making capability

NOVEL, VARIABLE THERMODYNAMIC CYCLES

Complex cycles, such as heat exchange cycles (intercooling and recuperation) and bottoming cycles (where waste heat is turned into power), can provide further improvement in cycle thermal efficiency for engines in a 2035+ timescale. Feasibility studies are required in the near term to lead into technology development and system demonstration.

TECHNOLOGY	PRODUCTS	DRIVERS
Platform level thermal systems to recover distributed, low grade heat back into propulsion cycle	Systems demonstrations, heat recovery units, energy management systems	Increased thermal energy reutilisation and management requirements
Novel cycle feasibility assessments including intercooling and recuperated thermodynamic cycles including component and system performance assessment	Feasibility studies using advanced cycles	Increased energy efficiency at aircraft level

POWERPLANT SYSTEMS INTEGRATION

Increased integration of both structural and system components, including those that cross traditional boundaries of component assembly, is required to fully exploit performance benefits of large UHBR powerplant. Advanced architectures will challenge both physical and functional interfaces and take advantage of improved simulation, advanced materials and novel technologies for manufacturing and assembly.

TECHNOLOGY	PRODUCTS	DRIVERS
Integrated systems on to engine	Oil tank, control units, cables, harnesses, rafts, heat exchangers, pumps, pipes, ducts	Enhanced integration, use of modular system approaches, improved maintainability, improved system operability
Toolkit for optimising systems integration	Models and tools for structural, thermal, aero, acoustic, mechanical and electrical analysis	More collaborative approach between suppliers and OEMs
Novel component and element mounting solutions	Brackets, mounting systems	Enhanced integration, use of modular system approaches, improved maintainability, vibration isolation, enhanced structural performance

ADAPTIVE CONTROL SYSTEMS

Future control systems need flexibility to adapt to increased data coming from aircraft systems and components. Technologies such as smart sensors, integrated health management and intelligent actuator control will lead to development of new products, driven by the need to enhance reliability, increase efficiency and reducing weight; This theme covers products including miniature connectors, new anti-icing solutions, smart vanes, and advanced controllers.

TECHNOLOGY	PRODUCTS	DRIVERS
Advanced cabling/harnesses and connectors	Connectors, backshells, cables, wiring, relays, contactors	Embedded harnesses, increased data carrying capability, lightweight, wireless connectors, fastmake, high temperature cables, miniaturisation, modular connectors
Novel ice protection systems	Electro-thermal heater mats, electro-expulsive systems, thermal components, coatings, fluid –based systems	Reduced power and energy consumption, lightweight, environmentally-friendly, enhanced understanding of icing behaviour
Novel sensors including smart sensors, optical sensors and high temperature sensors	Sensors for speed, pressure, temperature, vibration monitoring and others	Lightweight, low cost, improved diagnostic, intelligent communication, improved accuracy, harsh environment capability
Advanced integrated health management technologies	Controllers, monitoring units, fluid conveyance, electrical power, communications, protection systems	Self-diagnostic and prognostic systems including life usage monitoring and prediction, data fusion from multiple sensors and model-based information
Intelligent component control mechanisms	High bandwidth actuation systems, flow valves, solenoids, smart vanes	Enhanced reliability, improved control and decision making capability