CENTS: A Research Network for the Sustainable Transport Community

Circular Economy Network+ in Transportation Systems

British Geological Survey

UNIVERSITY OF CAMBRIDGE

Cranfield University

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UKRI Engineering and Physical Sciences Research Council

CENTS Feasibility Funding Case Study:
Identifying the Potential for Zero Waste Decommissioning of Commercial Aircraft

Executive summary

COVID-19 has had a profound impact on the aviation sector with airlines collapsing and several thousand aircraft being prematurely retired. With the pressure towards adopting sustainable practices and an over availability of aircraft the impact on the decommissioning sector cannot be understated.
This project focused on the UK aircraft decommissioning sector identifying key stakeholders, current practices, supply chains and new opportunities. While the role of the decommissioner does not yield great wealth there are opportunities to incorporate new technologies and move away from the current shredding process used for reducing the fuselage and interiors into waste for further reprocessing.

Repurposing opportunities were identified through engagement with various organisations, including office work pods, textile reuse and the downcycling of composite material.
Some of the lessons learnt and opportunities identified have potential cross-over to other modes of transportation which are reaching their end-of-life and where disposal may no longer be a viable or attractive option.

The scope of the project was:
1. Industry landscaping and current supply chain mapping.
2. Technical analysis of aircraft decommissioning.
3. Supply chain gap analysis.
4. Proposed strategy to engage and develop the supply chain.

Opportunities exist in both the actual decommissioning process and the current waste streams. The process is relatively labour-intensive and has potential to benefit from productivity gains associated with technology implementation. The valorisation of the waste streams could both help to reduce the carbon footprint while at the same time increasing revenue for the stakeholders.

The research questions being addressed can be summarised as *What are the alternatives and opportunities to the current decommissioning practices to promote a more sustainable industry?*

The methodology which was followed was:

- Identify and engage various stakeholders in the sector to determine current challenges and opportunities.
- Shadow the actual decommissioning process of an aircraft to understand at first hand.
- Analyse current waste streams of UK decommissioning companies.
- Identify some of the key parts and materials which are currently destined for landfill or scrap.
- Undertake an in-depth analysis of specific parts and identify potential alternative end-of-life routes

Cents
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Project Team

David Butler (PI)

David is a reader at the University of Strathclyde, prior to that he spent 18 years in Singapore where he helped establish the Advanced Remanufacturing & Technology Centre (ARTC) – a 250 strong translational research centre with over 75 industrial members. At the ARTC he held a number of posts including Business Development Director and Research Director. David has worked with a wide range of aerospace companies on remanufacturing including P&W, GE, Rolls-Royce, Boeing and ST Aerospace.

Paul Cantwell (CI)

Paul is a knowledge exchange fellow at both the Advanced Forming Research Centre part of the High Value Manufacturing Catapult and the Scottish Institute for Remanufacturing. He is on part secondment to the Scottish Institute for Remanufacturing. Since joining SIR he is leading on High Value sector engagement, looking to identify sector specific programs, building sector roadmaps and identifying program opportunities.

Fiona Gutteridge

Fiona is currently undertaking a part-time PhD in Life Cycle Analysis. She currently runs her own consultancy company focusing on waste management

Leigh Patterson

Leigh is currently pursuing a PhD in the Circular (considerate) Economy. Leigh has a background in product design and a strong interest in repurposing products.

Industry Partner

CHEVRON
TECHNICAL SERVICES
& AIRCRAFT MAINTENANCE

Project Rationale

This is the first project to focus on the challenges surrounding the post-COVID aviation decommissioning landscape. With sustainable aviation in the spotlight and the need to consider more sustainable end-of-life options for aircraft, the project is quite timely. Only by looking at novel approaches to the actual decommissioning process and the valorisation of waste can we start viewing the sector as being green.

Key Findings

1) The current UK aircraft decommissioning sector operates on relatively slim profit margins with income derived from labour costs associated with removal of key assets from the aircraft and the potential value for scrap materials.

2) There is potential to decommission aircraft in a more sustainable manner, but this is currently thwarted by high labour costs and no economic reward. Going forward this is likely to change due to societal, environmental, and legislative drivers which push for greener alternatives. The application of automation and new technology will be a gamechanger in increasing productivity and lowering costs.

Results

Background

The UK is currently the 3rd largest decommissioner of aircraft with between 100 and 120 aircraft processed annually. It is estimated that each year between 750 and 900 aircraft are scheduled to be decommissioned. However, current global decommissioning capacity is estimated to be around 500 pa resulting in aircraft graveyards seen around the world. Post-COVID, it is estimated that there will be a rise to between 1100 and 1500 aircraft targeted for decommissioning.

Decommissioning

Boeing indicates that each plane has over 3,000,000 discrete parts and have developed approaches to recycle and recertify 6,000 parts from each retired airplane. Air Salvage International state that the elapsed time to decommission a narrow-body aircraft is around eight weeks rising to 10-15 weeks for a wide-bodied aircraft.

The ATI Report on Sustainable Aviation recognises that whilst 40 to 50% of aircraft parts are returned to the aerospace market and a further 40% are repurposed in other sectors or recycled the remainder, approximately 15 to 20% of the weight of aircraft cannot be reused and is either disposed or sent to landfill. The cost of aircraft recycling is high and not necessarily offset by the value received from materials markets and so maximising the value through part resale and reuse or upcycling in alternative markets is currently favoured (Figure 1)

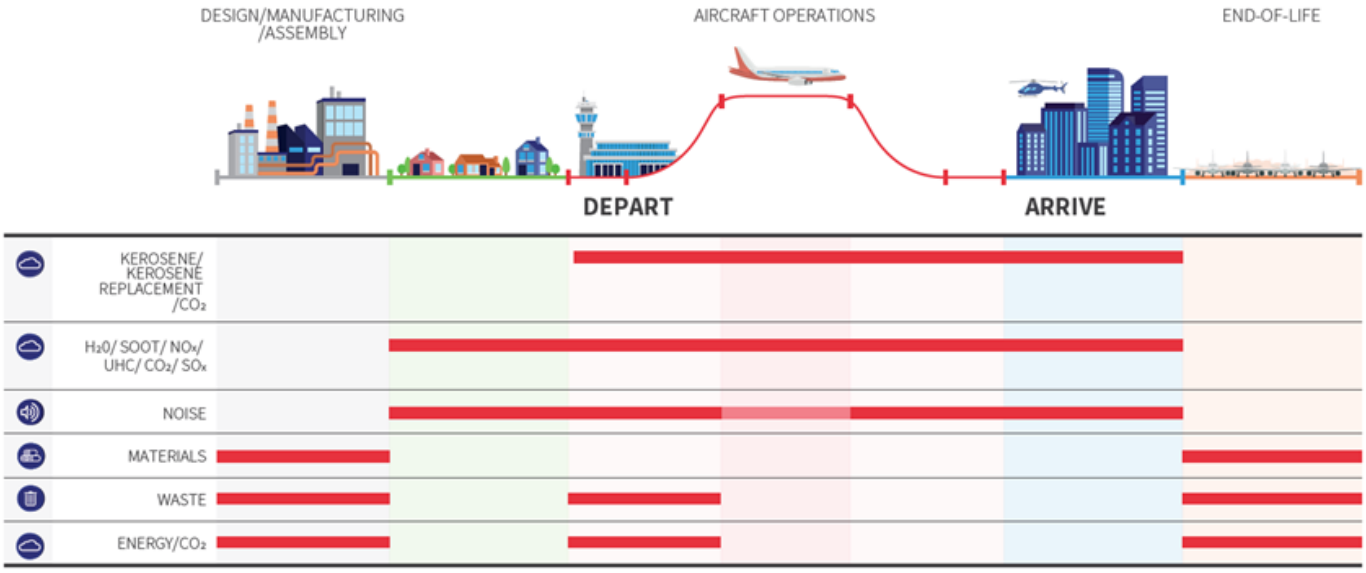

Figure 1. Summary of life cycle impacts of aircraft & wider aviation (Aerospace Technology Institute, 2020)

Figure 2 summarises the various options available in the decommissioning process.

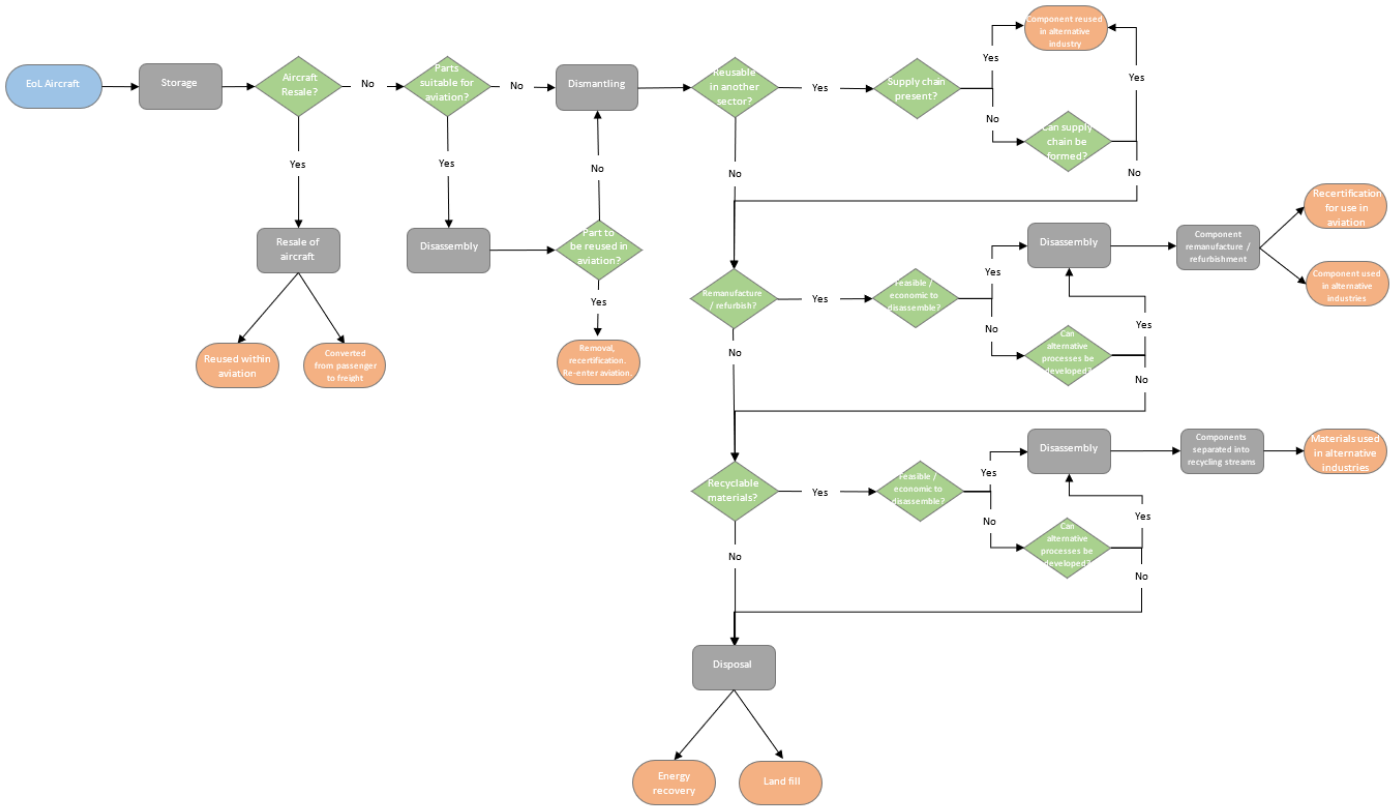

Figure 2. Current state of decommissioning practice

Key players

There are several decommissioning companies in Europe. The main players are indicated on figure 3.

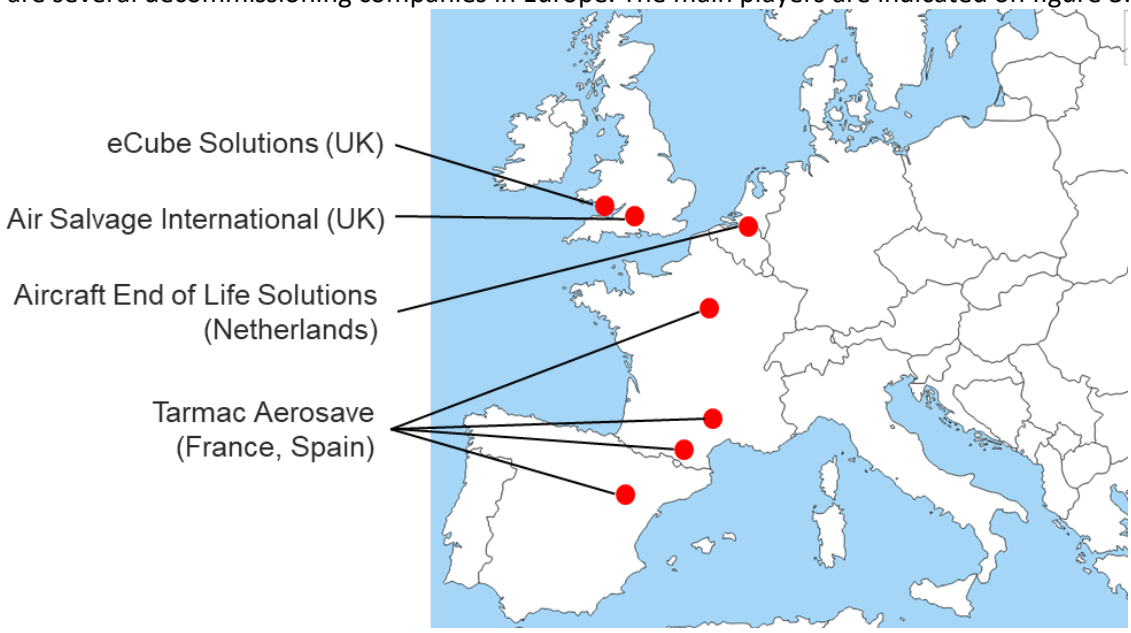

Figure 3. European Decommissioning Companies

Decommissioning Strategies

There are several strategies which can be adopted for the decommissioning of aircraft, these can be categorised as the *extreme strategies* and a combination of these known as *intermediate strategies*.

Extreme strategies are *systematic disassembly* and *shredding* which represent the most and least environmentally friendly processes, respectively. Systematic disassembly involves the separation and categorisation of components based on material composition. Shredding is at the opposite end of the spectrum where the aircraft is cut into small pieces for transportation to a recycling centre. There are a wide range of intermediate strategies which are shown in figure 4.

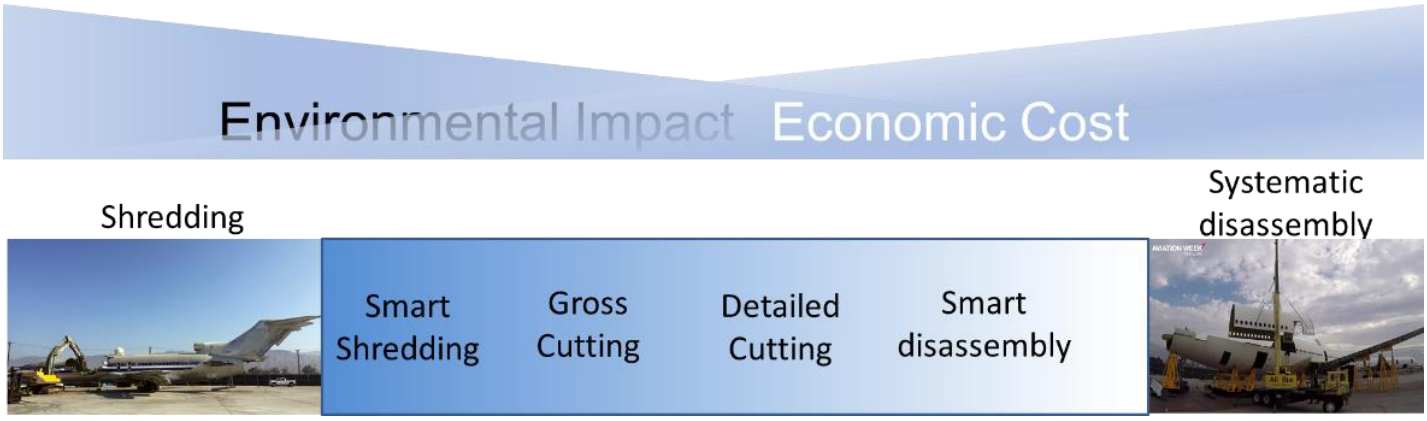

Figure 4

Waste Management

An analysis was undertaken of current UK decommissioning organisations with most of the waste being identified as metal with the waste either being landfilled, recovered, or incinerated (see figure 5).

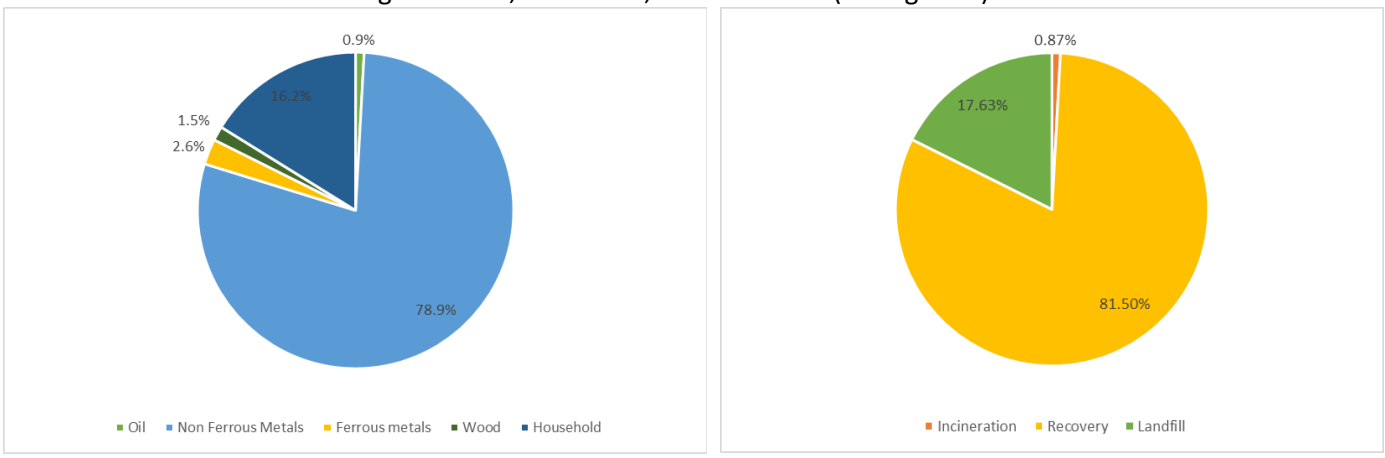

Figure 5. Summary of waste by (left) material type and (right) by fate.

The metal tonnages above are likely to represent a revenue stream, whereas the other materials are likely to represent a cost. Material going to landfill, and incineration will incur a cost per tonne for disposal and transport. Landfilled waste will also incur a landfill tax payment that is included in the overall waste management cost.

Supply Chain Gap & Opportunities

The supply chain is well-established around the reuse and certification of high-value components such as avionics, engines, and landing gear. For a typical decommissioning operation, up to 1000 parts are removed from the aircraft and re-enter the aftersales market. The removal of the remaining unwanted airframe, interiors, inflight entertainment system etc. is, in most cases, dealt with by specialist recycling companies who will collect the shredded material in bulk for separation and further processing. While a handful of companies exist, which may repurpose a seat, part of the wing as a desk, or a whole cockpit for a school this is generally a piece-meal activity which has a negligible impact on the overall scrap rate.

A gap exists in both identifying companies and aerospace parts which could be repurposed for a second life. As part of the strategy to engage potential supply chain entrants, a circular design consultancy was approached along with a remanufacturing company. The former was tasked with generating new ideas/products while the latter focused on the repurposing of electronic waste. Ideas included repurposing of aircraft interiors for office and storage applications, redesigning of parts of the fuselage as work pods and use of backseat monitors for coding. Figure 6 proposes a potential restructure of the decommissioning practice to highlight alternative outcomes for 'unwanted' material.

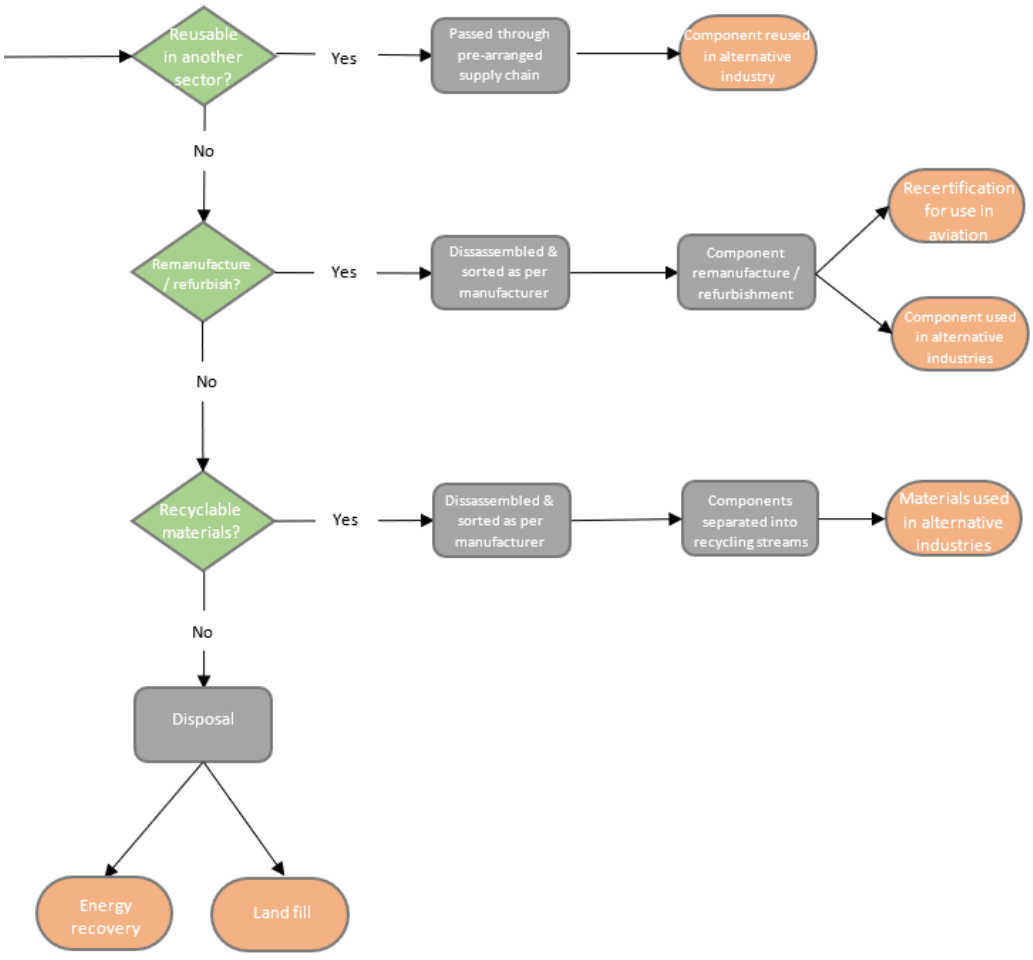

Figure 6. Potential restructure of decommissioning practice

Impact

There is potential for significant impact beyond the close-knit decommissioning community. By nature of the need to upcycle, the team has reached out beyond the aviation sector to a wide range of organisations and SMEs. These include companies which focus on the repurposing of seat fabric into bags, the application of interior fixtures for COVID-19 friendly work pods, repurposing of In-Flight Entertainment screens for coding in schools as well as opening discussions with a circular design consultancy interested in the challenges of repurposing.

Next Steps

The research has already impacted several activities which have been linked to this area. Currently the PI has been seconded to the Scottish Government Aerospace Response Group as a National Aircraft Decommissioning Champion tasked with developing a blueprint for a Scottish decommissions sector.

Some of the challenges and gaps identified around the decommissioning process, composite recycling and automation have been developed into a large-scale multi-partner bid (£2 to 3M), led by the PI and CI of this project, which is currently under discussion with the ATI.

The outcomes from the project have already provided a foundation for the £880K Low Carbon Challenge Fund project (Jan'21 to Feb'23) which is focusing on building a sustainable aircraft decommissioning supply chain. The PIs for this project are David Butler and Paul Cantwell.

Part of the project work will also be used as an introduction session to participants undergoing the National Transition Training Fund courses in Aircraft Decommissioning. The course will run from April'21 to June'21 and will be targeted at individuals aiming to enter the decommissioning sector. The project value is £ 300K and is led by David Butler.

Currently one journal article is being drafted along with a white paper to promote decommissioning as part of a wider industrial decarbonisation initiative. There are also on-going discussions to present at one of the events at COP26 in November 2021.

Testimonials

From the Early Career Researcher(s)

"My involvement in the aircraft decommissioning project through CENTS has helped me grow as an early career researcher in a number of ways. Firstly, I have extended my network through the programme, particularly by participating in the workshop. Additionally, I hosted a table at the workshop - something I had not done before - which proved to be a learning experience as well as a networking opportunity. The platform used was excellent and has definitely taught me new ways of interacting digitally for events and collaborative working alike. I had not been involved in aircraft decommissioning before and did not know much of it, so diving right into the project was a great experience. It has not only introduced me to the subject area but allowed me to explore it in great depths, whilst furthering my knowledge of my own specialism (circular economy and materials life cycle). Overall, I can say that my participation in the project has improved my research abilities and expanded my knowledge into another sector, aspects of both I will be able to apply in my future work." Leigh Patterson

From the Industry Partner(s)

"The work undertaken in collaboration with Chevron has taken a look at the current decommissioning landscape and identified potential applications for some of the challenging-to-dispose parts of the aircraft. In addition, some of the preliminary work around the technology solutions is something that we are keen to see implemented going forward. Rather than this work remaining as a purely academic exercise we will be working with the team on applying the knowledge to the actual decommissioning of an Airbus aircraft. In particular, the process of dismantling the panels (a major consumer of time and labours) will be carefully documented with as much data as possible being captured to identify more efficient ways of decommissioning." Chevron Aerospace