Appendices

N.B. These Appendices support the report entitled: 'The Policy and Regulatory challenges arising from New Aviation Technologies' authored by Chris Cain and Northpoint Aviiaton, and published by the ITC and the CAA in November 2025. These Appendices are the responsibility of the authors alone and the publishers accept no liability for loss or damage arising from their use.

Appendix A: The Commissioning Brief

The Policy Challenges Arising from New Aviation Technologies

A wide range of technologies are being developed that could transform the aviation sector over the next few decades. Many of these new technologies are likely to be disruptive to conventional business models and policy frameworks, and so a clearer understanding of their impact is urgently needed. This is particularly so when the demand for travel by air (both people and goods) is expected to grow, and at the same time the environmental impacts (particularly CO_2 emissions and noise) are becoming less and less acceptable. The industry is expecting technology to play a major role in addressing these issues and enabling aviation to grow in an environmentally sustainable fashion.

Scope

The chief purpose of this study will be to explore the policy, commercial and regulatory issues arising from these new technologies (rather than an in-depth exploration of the technologies themselves). We are particularly interested in those technologies which will plausibly enter commercial service during the next 30 years (i.e. by 2050), not those which are unlikely to become commercially viable until later. There are several new technologies already in development which might become commercially viable over this timespan, including:

- **Supersonic and Hypersonic Aircraft.** The development of new-generation supersonic aircraft is underway, with technologies such as super turbo and ramjet engines now being tested. Lockheed Martin is producing a prototype of a low-noise supersonic aircraft, while other prototypes are in development (Boom Technologies & Spike Aerospace). In addition hypersonic aircraft (above Mach 5) are being explored by Boeing (which unveiled a Hypersonic Airliner design at the 2018 AIAA conference), and the Chinese Government, using rocket or scramjet engines.
- **Electric and hybrid propulsion of aircraft.** Electric propulsion has the potential to make aircraft both quieter and have significantly reduced emissions. However, it is suited to lighter, smaller craft. Hybrid power mechanisms might have a wider applicability. Over shorter distances, such technology could create a paradigm shift in air travel.
- **Space Travel and Tourism.** In recent years there has been increasing interest in the commercialisation of space travel. Private firms including Virgin Galactic, Blue Origin and SpaceX have been developing technologies that will make spaceflight (both orbital and sub-orbital) available to paying customers. As research and development progresses, and marginal costs decrease, this is expected to become an increasingly important market, bringing with it new challenges for aviation and airspace regulators and policy makers.
- **Autonomous aircraft (drones) and artificial intelligence.** Small autonomous flying vehicles (drones) are already with us and causing significant disruption. Research and development is now underway to create viable passenger drones that could develop into a major new form of passenger transportation. Associated with this is the development of artificial intelligence aviation systems that raise new safety questions for policy makers.

- **New IT software/platforms.** The way we book and manage our travel is rapidly changing with the development of new online platforms and management systems. Some of these are looking to use spare capacity in private aircraft (Jetsmarter, Ubair, Airpooler); others are attempting to create seamless journey door-to-door booking that will integrate flights and land-based transport. Advances in IT systems could also allow for more efficient management of airspace.
- **Smart Structures.** New materials are in development that could dramatically change aeronautics. These could help improve aircraft performance and operation, and adapt to environmental conditions. Shape-shifting structures, multifunctional materials, and structural health monitoring are some of the possibilities.

All these technologies could present significant challenges for the industry and policy makers, and yet there has been little analysis of these policy issues to date. The purpose of this project will be to explore and review these challenges, with a focus particularly on the following questions:

1. Which aviation technological innovations are likely to prove disruptive over the next 30 years (i.e. by 2050)? How might these disruptive effects manifest themselves and what challenges would these bring for policy makers? Conversely, which of these technologies are unlikely to present major challenges, or enter service on a significant scale over that time frame?
2. How might public attitudes respond to the widespread adoption of these technologies, and what impacts will the public risk appetite have on the development of regulation and policy responses? Aviation is held to a higher safety standard than other modes, and there are also likely to be visual, aural and privacy concerns surrounding mass-market small aerial vehicles. What can we learn from other modes about how the public respond to disruptive travel innovations?
3. What are the likely impacts of these technologies on the nature of the aviation industry? Will they provide opportunities for new or different kinds of services and service providers and, if so, what will this mean for future operating and business models? Will there be any potential conflicts or tradeoffs between a) the emerging technology and existing operations and b) the growth of the technology and social and environmental impacts. For example, will ‘smart structures’ encompass existing aircraft types? Can drones and hybrid aircraft and supersonic aircraft and spacecraft all operate from the same infrastructure, both physical (type of runway or launch required) and in airspace? Will carbon reduction and noise reduction both be possible, or will policies need to be imposed to steer one over the other?
4. What policy and regulatory issues will be raised by widespread adoption of these technologies, and what particular challenges will governments and regulators need to address? Will Government and regulators also have a role in bringing these technologies to fruition and, if so, how? What steps should regulators and policy makers take today to prepare for these changes? Recommendations would be helpful about a) regulatory agency discrepancies or overlap (i.e. are there issues which span aviation safety, environmental health and privacy); b) on the difference between law and policy, to help the Government understand which areas can be fixed more easily and which will require Bills, and lastly c) can a roadmap be drawn to explain when technologies are expected, and which policy or law may need reforming in advance.

We would like to commission a substantial report that investigates the potential impact of these technologies and addresses the key questions above. The main focus will be on the policy implications rather than on a detailed description of the technologies, in order that the industry, regulators and governments can start to consider how best to plan for their potential impact.

The international dimensions of these issues should also be considered, particularly where policy action would require co-operation across national boundaries, although the principal analysis should focus on UK-related issues and agents. The report will need to provide an overview of these issues in a way that is clear and intelligible to an educated lay audience and policy makers.

Methodology

The Steering Group will discuss the precise methodology with the chosen researcher(s). However, it is likely that the research will need to involve i) desktop research on the technologies as well as the current policy and regulatory framework, ii) interviews with industry experts, regulators and policy makers, and iii) analysis of the commercial viability of these innovations. The findings should be applied to the questions outlined above.

The CAA and ITC have connections with academics and policy makers in this field and it is possible that these can provide some data relevant to the report.

A Steering Group will be appointed comprising representatives from the ITC and CAA and this group will meet periodically with the researcher(s) to review progress.

Output

The research study will result in a substantial published report that will review technologies that will transform aviation over the next 30 years, consider the disruptive nature of these, and identify the main challenges that policy makers and regulators will need to address.

The report will provide fresh insights useful to policy makers, regulators, strategists and planners working in the aviation sector. An appropriate dissemination strategy, including a launch event, will be used to ensure that the research receives due attention from these groups.

Appendix B: Research Methodology – Further Detail

The Literature Review

The initial phase of research involved a comprehensive literature review covering the following emerging technology areas:

a. *Aircraft design* (Including mainframe, wings and optimisation of existing propulsion systems).
b. *Electrically powered fixed wing aircraft* (battery, hybrid and fuel cell).
c. *Green Fuels* (including SAF and direct burn Hydrogen).
d. *AAM* (i.e. Drones, e-VTOL, S/C-VTOL, UTMs and UAV operations).
e. *Technologies to enhance the passenger experience* including security focused (e.g. cyber and biometrics), passenger facing (e.g. virtual reality, robotics, MaaS surface access systems), and freight orientated (digitalisation, automated handing) systems.
f. *Airspace management technologies* (including new air navigation systems, increased cockpit autonomy, and those facilitated by generic ne digital technologies – e.g. machine learning and quantum computing, and gate to gate).
g. *High speed propulsion systems* - Scramjets, Hypersonic and deep space rocket systems.
h. *Satellite delivery, repair and discontinuation technologies* – focusing on near earth and stratospheric platforms.

The research was conducted within a broad *horizon scanning* framework, covering a period out to 2050, which drew upon drawing upon departmental government review documents, regulatory assessments (Federal Aviation Administration (FAA), CAA, EASA, IAA), academic papers, industry journals, OEM white papers and press releases and summaries from trade associations to produce a series of technical papers designed to provide key source material from this main report (References are provided in the further Reading Appendix of this report. In addition, we also investigated wider technology perspectives focussing on materials science and generic digital/AI technologies and how these might be applied to aviation, we also looked at issue and policy-based themes such as costs, security, safety, operational, commercial and Social Equity and Social License concerns.

The literature review also identified theoretical technological life cycles/models for consideration of new innovations, highlighting their prospects, commercial potential and the challenges (e.g. certification by regulators and at-risk financing) and timescales for resultant technologies being brought to market and scaled to reach commercial maturity. Insights were drawn from industry reports, academic studies, policy documents, media reporting, and other relevant sources, all of which are referenced either in relevant footnotes of the 'Further Reading' appendix. The research team have also continued to track government policy announcements and industry progress reporting until very close to the publication of the report with a view to ensuring it is up to date and remains relevant for some time to come.

Stakeholder Questionnaire and Thematic Roundtables

In addition to the literature review, the desktop research process was augmented through engagement with a range of industry, government and academic stakeholders, using a structured questionnaire and a series of thematic roundtable discussions where invited participants were able to address more complicated and nuanced questions than those that were practical in the questionnaire.

The Stakeholder Questionnaire

The stakeholder questionnaire was developed by Northpoint with the assistance of the project Steering Group and issued to close to 200 organisations or individuals considered as expert in the context of the technological innovations being reviewed. The response rate was disappointingly less than 15%, and hence any statistical analysis of the completed questionnaires that were received was considered of limited value. However, those same questionnaire responses did contain a lot of supporting written commentary, which proved extremely useful as a starting point for further reading, discussions at the subsequent roundtables and some cases insights in formulating sections of this report.

Thematic Roundtable Discussions

Five thematic roundtable discussions were conducted with carefully chosen stakeholders with an interest in shaping the policy framework for emerging aviation technologies. Each roundtable had a different technological or functional theme as below:

1. Policy Frameworks for New Aviation Technologies.
2. Environmental Technologies Roundtable.
3. Air Transport Infrastructure & Service Providers Expert Roundtable.
4. Airspace Management and Navigation Systems.
5. Policy Makers & Regulators Roundtable.

The insights and discussions from these roundtables contributed to range of outputs supporting this report including technical working papers on different technologies, the development of key graphics in this report and to the structure and conceptual content at the heart of this main report.
When taken together, these separate but co-ordinated activities, yielded valuable insights and perspectives that helped the synthesis of the information already gathered (e.g. on which technologies were likely to be the most significant, those offering the best prospects for commercial success, likely timescales for take-up) whilst beginning to prompt questions about key issues such as:

- the barriers being faced to the industrialisation and scaling of key technologies,
- whether extant government interventions were sufficient to ensure the UK remains competitive in the sector, and
- where shape of UK policy and regulatory frameworks supporting emerging aviation technologies need further work or more financial commitment/risk sharing from government.

Appendix C: An Overview of Second Tier (Group D) Technologies

Cyber Security

UK airports are increasingly adopting advanced technologies to bolster their cybersecurity defences, ensuring the safety and efficiency of their operations. Relevant technologies and services are sourced from both domestic and international providers, including UK-based companies like Darktrace, known for their AI-driven cybersecurity solutions, and global firms such as Genetec. Key strategies and technologies include:

- *Unified Security Platforms*: Airports like London Heathrow have implemented unified physical security platforms to enhance their security infrastructure. For instance, Heathrow has collaborated with Genetec to transform its airport operations through continual innovation of security measures.
- *Intelligent Surveillance Solutions*: Companies such as Aralia Systems Ltd specialize in intelligent surveillance solutions tailored for airports. These systems integrate advanced software to secure airport buildings and physical systems and equip digital control rooms with enhance monitoring and threat detection capabilities.
- *Cybersecurity Services*: Firms like Microminder Cyber Security offer comprehensive services to various industries, including aviation. Their solutions are designed to secure every entry point of a company's digital ecosystem, pre-empting and circumventing breach attacks to ensure continuity, integrity, and confidentiality.
- *Supply Chain Security*: Airports are also focusing on securing their supply chains to mitigate risks. For example, Gatwick Airport's Head of Cyber Security has discussed challenges related to supply chain security, emphasizing the importance of managing third-party risks to protect airport operations.

The collaborative efforts between airports and private sector companies respond to government and CAA/Transec initiatives designed to address the evolving cyber threats faced by the aviation industry. The UK government has been proactive in enhancing airport security through funding and regulatory measures. Competitions like the HADES (Hardened Airport Detection Equipment System) offer up to £500,000 to innovators developing advanced airport security technologies. Additionally, the Department for Transport (DFT) has outlined strategies to provide clear guidance to the aviation industry, aligning with the National Cyber Security Strategy to enhance resilience against cyber threats.

Generic Enabling technologies

Generic enabling technologies such as artificial intelligence (AI), machine learning (ML), and quantum computing are gradually being introduced into aviation as part of technological innovations designed to enhance efficiency, safety, and sustainability. Current Applications in Aviation can be summarised as follows:

<u>Artificial Intelligence & Machine Learning</u>

- *Predictive Maintenance*: AI-driven algorithms analyse sensor data from aircraft to predict component failures, reducing unplanned downtime.
- *Air Traffic Management (ATM):* ML is improving air traffic flow by optimising routes, reducing delays, and enhancing collision avoidance systems.
- *Pilot Assistance & Autonomous Systems:* AI is enabling semi-autonomous operations, such as Boeing's autonomous flight tests and Airbus's AI-powered autopilot enhancements.
- *Customer Experience:* Airlines use AI-powered chatbots, personalised recommendations, and demand forecasting to improve passenger services.

Quantum Computing

- *Optimisation Problems*: Quantum algorithms can solve complex logistical challenges, such as scheduling flights, fuel optimisation, and route planning.
- *Materials Science & Design*: Quantum computing is aiding in the development of lighter, stronger materials for next-generation aircraft, improving fuel efficiency.
- *Cryptography & Cybersecurity*: Quantum encryption will provide stronger security for aviation communications and data networks.

However, by 2050 their impact is expected to be transformative, creating a more sustainable, efficient and safer aviation ecosystem, encompassing:

- *Fully Autonomous Flight*: AI and ML will enable highly automated, possibly pilotless, commercial aircraft with enhanced safety and efficiency.
- *Zero-Emission Aviation*: AI-optimised hydrogen and electric aircraft designs, coupled with quantum-driven material innovations, will contribute to net-zero targets.
- *Air Traffic Flow Optimisation*: AI will enable dynamic, real-time air traffic control, significantly reducing congestion and carbon emissions.
- *Quantum-Powered Simulation & Modelling*: Aircraft design and aerodynamics testing will be revolutionised, cutting development times and costs.

Very High-Speed (Hypersonic) Propulsion

Hypersonic technology, enabling aircraft to travel at speeds exceeding Mach 5, holds the potential to revolutionize civilian aviation by drastically reducing flight times, even to the furthest long-haul destinations to 2-3 hours. Several companies have development programmes for hypersonic passenger aircraft, but the key players are:

- *Hermeus*: A U.S. based startup developing the "Quarterhorse" hypersonic aircraft, designed to reach speeds up to Mach 5. High-Mach flight tests are planned for 2026.
- *Venus Aerospace*: This company is working on the "Stargazer M4," a hypersonic jet capable of reaching speeds up to Mach 6 (approximately 3,600 mph) – see Figure. Test flights are scheduled to begin in 2025.
- *China's "Nanqiang No 1"*: Is a hypersonic passenger jet capable of cruising at Mach 6, aiming to enable travel to any location worldwide within two hours. Prototype tests have been successful, with full-sized test flights planned for 2025.

The introduction of hypersonic passenger aircraft is currently anticipated in the mid to late 2030s, although this could be delayed by politically sensitive environmental issue relating to noise (sonic boom) and CO_2 emissions. If they secure certification and move into commercial production, the aircraft are expected to accommodate a limited number of passengers, focusing on premium services due to the substantial development and operational costs. Initial routes will likely connect major international hubs, especially where much of the routing is over water, offering significantly reduced travel times compared to current commercial flights.

However, despite some promising technical advancements, several key problems need solutions before hypersonic travel can become a reality:

- *Technical Hurdles:* Developing engines capable of sustained hypersonic speeds, requires significant innovation. Reaction Engines, the UK company behind SABRE, was believed to be closest to achieving a stable hypersonic engine, but recently entered administration, highlighting the difficulties and risks associated with this sector.

- *Safety and Environmental Impact:* Ensuring passenger safety at extremely high speeds and altitudes, alongside environmental concerns such as emissions and noise pollution, are critical issues that need to be overcome if the technology is to become commercial.
- *Financial Viability:* The high costs associated with developing and operating hypersonic aircraft pose questions about their commercial feasibility and certainly suggest they may remain inaccessibility to the broader public.

In summary, while significant progress is being made in hypersonic technologies for civilian aviation, the transition from experimental phases to commercial availability involves overcoming substantial technical, safety, and economic challenges. The next decade will be pivotal in determining the feasibility and adoption of hypersonic passenger travel. Eric Briggs, the Chief Operating Officer of Velontra, one of the developers of the Stargazer, has said that it requires "*an engine concept that has lived mostly in textbooks but never as a production unit in the air*" and hence any short-term solutions look unrealistic.

Autonomous Operations

Autonomous operation technologies, including automation, AI and sensor fusion, are making advances in the aviation sector, but full autonomy in commercial aviation currently remains no more than a long-term goal that to be preceded by a series of incremental steps which being taken over the next few decades.

<u>Short-Term (Now–2030)</u>

- *Enhanced Automation*: AI-assisted co-pilot functions, automated taxiing, and improved autopilot systems will become more widespread.
- *Single-Pilot Operations*: The industry is exploring reducing commercial airliners to a single pilot with AI assistance, particularly for cargo flights before passenger services.

<u>Medium-Term (2030–2045)</u>

- *Cargo Flights & Regional Autonomy*: Cargo aircraft will probably transition to fully autonomous operations before passenger flights, starting with drones but moving onto larger aircraft flying medium-haul and regional routes.
- *Advanced AI Decision-Making*: AI will improve in handling emergencies, managing dynamic airspace, and coordinating with ATC systems.
- *Regulatory & Infrastructure Development*: Governments and aviation authorities will begin developing policy and regulatory frameworks to support autonomous commercial flights.

<u>Long-Term (2045+)</u>

- *Fully Autonomous Passenger Flights*: Autonomous commercial airliners could be viable, but widespread adoption depends on regulatory approval and public acceptance.
- *Global Standardisation*: International agreements on autonomy in controlled airspace will be necessary for cross-border flights.

However, the introduction of autonomous operations is going to be heavily dependent on a series of policy and regulatory barriers being overcome:

- *Regulatory and Certification*: Aviation authorities (e.g. CAA, EASA, ICAO) require extensive safety validation before approving autonomous aircraft; this will be made more difficult by the fact current certification processes are built around human pilots, necessitating fundamental regulatory changes.

- *Safety & Reliability*: AI will need to demonstrate superior decision-making compared to human pilots, particularly in emergency scenarios and robust fail-safe systems are needed to handle software failures, cyber threats, and unexpected flight conditions.
- *Cybersecurity Risks:* Autonomous aircraft will be vulnerable to hacking and electronic warfare, requiring highly secure communication and control systems.
- *Air Traffic Management (ATM) Integration:* ATC systems will need to be adapted to accommodate autonomous aircraft, requiring real-time communication and traffic coordination with human-piloted planes.
- *Technological Maturity:* AI, machine learning, and sensor fusion must improve to handle complex and unpredictable situations, such as extreme weather or mid-air emergencies.
- *Public & Industry Acceptance:* Passenger confidence in pilotless air travel will take time to build. Early adoption may focus on cargo flights before extending to commercial services.

Therefore, while autonomous operation in aviation will progress gradually, with cargo flights and urban air mobility leading the way before passenger aircraft, full autonomy in commercial aviation is unlikely before 2050 due to regulatory, safety, but most importantly we suspect societal barriers. However significant automation advancements will be integrated into flight operations much sooner.

Appendix D: Possible 'Mission Statement' for the UK's emerging aviation sector

The Mission Statement Concept

Mission Orientated Innovation Programmes (MIOP) have developed in many OECD countries in response to major global challenges (e.g. biodiversity, mobility, healthier living, tackling plastics, implementing circular economy principles, developing Smart Cities and facilitating open knowledge and life-long learning) and national priorities. There are four principal types of MOIP, varying from an overarching strategic framework containing multiple subsidiary missions which lie at the heart of a government strategic agenda shared by all of its representatives, through to more limited Challenge-based programmes to Thematic missions (see Table below).

Table A The Basic Characteristics of the Four Main Types of MOIP[1]

Type	Leadership	Missions	Examples
Overarching mission-oriented strategic frameworks	• Center of government • High-level committee	• Multiple missions or mission areas • Pursuing ambitious challenges • Long-term horizon	• Horizon Europe's missions (EU) • Mission-driven Topsector and Innovation Policy (NL) • High Tech Strategy 2025's missions (DE) • Moonshot R&D Program (JP))
Challenge-based programmes and schemes	• Agency	• Focused • Seeking acceleration of (most often technological) innovation • Mid- to long-term horizon	• Pilot-E (NO) • Industrial Strategy Challenge Fund (UK) • The Genomics Health Futures Mission (AU) • Science Foundation Ireland's Innovative Prize (IE)
Thematic mission-oriented programmes	• Ministry • Agency	• Focused on competitiveness in the research consortia of the 1980s – 1990s • Mix of societal and competitive challenges in current programmes	• VLSI (JP) • USABC (US) • Mobility of the Future (AT) • Building of Tomorrow/Cities of the Future (AT)
Ecosystem-based mission programmes	• Ministry • Agency	• Innovation agenda developed by the innovation actors themselves, with neutral support from public authorities	• SIP (SE) • Vision-Driven innovation milieus (SE)

Examples of the former include:

- *Japan Moonshot Programme* - which was designed to co-ordinate the countries' scientific, technology and innovation efforts, in a way that would ensure resource efficiency while optimising outcomes; and
- *East Germany* – where in there has been a 25-year socio-economic regeneration programme since the unification of Germany to bring the East German economy, living standards and welfare systems up to a point where they match those in West Germany.

But the AvTech challenges, which although multi-faceted are smaller in scale and thematically focused seem to us to require some hybrid combination of the latter. Examples might include:

- *Pilot E and CLIMIT programmes* in Norway which are designed to move the country's economy away from dependence on oil and gas and in so doing solve pressing societal challenges such as climate change emissions and adaption.

[1] OECD Publishing: The Design and Implementation of Mission-Oriented Innovation Policies - A New Systemic Policy Approach to Address Societal Challenges; OECD Science Technology and Industry Policy Papers No. 100 (Feb 2021)

- *UK strategic challenge fund* goal of by 2035 ensuring the UK population would on average enjoy an additional 5 years of healthy independent living, whilst also narrowing the gap between the richest and the poorest.

Another form of typology was developed by Wittmann et al [2,3] based on research supporting the German high-tech strategy, and is set out in Table B below.

Table B: Typology of MIOP Missions and Corresponding Governance Needs[4]

	Accelerator Mission		Transformer Mission	
	Type 1	Type 2	Type 1	Type 2
Type of problem	Market failure	Market and structural failure	Transformational system failure	Transformational system failure
Type of solution	Scientific innovation	Technological/ regular. change	Transformation of system	Transformation of system (behavior)
Problem vs. goal oriented	Problem-oriented	Goal-oriented	Goal-oriented	Problem-oriented
Demand for governance	Low	Medium	High	Very high
Examples of missions	Combating cancer	AI, Battery cells, CO2 emissions, Intelligent medicine	Open knowledge, Circular economy	Mobility, Biodiversity, Good life, Plastic

Source: Wittmann *et al.*, 2020a

Applying the Wittmann et al. Typology to UK Missions

The Wittmann et al. (2020a) typology classifies missions based on problem complexity (simple: clear, well-defined challenge; complex: multi-faceted, systemic) and solution space (narrow: known pathways/technologies; broad: exploratory, diverse approaches). This yields four types:

- **A-F (Accelerator-Focused)**: Simple + Narrow – Scale known solutions.
- **A-S (Accelerator-Systemic)**: Complex + Narrow – Integrate known solutions across systems.
- **T-F (Transformer-Focused)**: Simple + Broad – Innovate new solutions for clear goals.
- **T-S (Transformer-Systemic)**: Complex + Broad – Transform systems via innovation.

Tables C and D overleaf apply these typologies to historical UK missions. Notable features are:

Table C: Summary 20 of UK Historical Missions versus the Wittmann et al Typology

Type	Count	Examples
A-F	7	Smallpox, Penicillin, Prefabs, Decimalisation, Thames Barrier, Suez, Channel Tunnel
A-S	7	Radar, Electrification, Clean Air Act, Nuclear Power, North Sea Oil, BBC Micro, Great Exhibition
T-F	4	Longitude, Concorde, Jet Engine, Human Genome
T-S	2	NHS, BT Privatisation

[2] Wittmann F., Hufnagl M., Lindner R., Roth F., Edler J. (2020a), *Developing a Typology for Mission-Oriented Innovation Policies*, Scientific support for the Hightech-Forum of the German High Tech-Strategy. Karlsruhe. January, Unpublished.
[3] Wittmann Hufnagl M., Lindner R., Roth F., Edler J. (2020b), "Developing a Typology for Mission-Oriented In Policies", *Fraunhofer ISI Discussion Papers 'Innovation Systems and Policy Analysis'*, No. 64, Karlsruhe, April, https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cci/innovation-systems-policy-analysis/2020/discussionpaper_64_2020.pdf
[4] OECD (Feb 2021) Ibid

Table D: Further Details of Selected Historical UK Missions

Mission	Description	Classification	Rationale
Longitude Prize (1714)	Government-backed prize to solve accurate sea navigation by determining longitude, addressing shipwrecks and trade losses.	**T-F**	Simple problem (precise timekeeping at sea); broad solutions (open to astronomy, clocks, or other methods; spurred chronometer invention).
Radar Development (WWII, 1930s–40s)	Urgent R&D to detect enemy aircraft/ships via radio waves, integrated into air defence systems like Chain Home.	**A-S**	Complex problem (war-time multi-domain threats across air/sea); narrow solutions (building on emerging radio tech for system-wide deployment).
NHS Establishment (1948)	Create universal healthcare system post-WWII, tackling access disparities amid rationing and disease burdens.	**T-S**	Complex problem (systemic inequities in health, funding, and delivery); broad solutions (redesigned institutions, workforce, and tech integration).
Concorde Supersonic Jet (1962–2003)	Anglo-French collaboration to develop faster-than-sound passenger aircraft for transatlantic travel.	**T-F**	Simple problem (reduce flight times); broad solutions (aero-engineering R&D, materials, and aerodynamics experimentation).
Channel Tunnel (1980s–94)	Build undersea rail link between UK and France to boost trade and connectivity.	**A-F**	Simple problem (physical connection); narrow solutions (established tunnelling/boring tech scaled via engineering standards).
North Sea Oil & Gas Development (1960s – 1980s)	Rapid exploration and platform technology to exploit underwater reserves post-1973 oil crisis.	**A-S**	Complex problem (energy security, offshore engineering); narrow solution (drilling + pipeline tech).
Human Genome Project - UK Contribution (1990-2003)	Map all human genes to enable medical breakthroughs (via Sanger Centre).	**T-F**	Simple problem (decode DNA); broad solutions (sequencing tech, bioinformatics, collaboration).

What is notable from the preceding tables is:

- *The Dominance of Accelerator Types* (A-F + A-S = 14/20) → UK historically excelled at scaling known solutions (especially in crises: war, smog, housing, energy shocks). → Reflects strong engineering and deployment capacity.
- *Transformer Missions Are Rarer & High-Impact* → Only NHS and BT privatisation qualify as T-S — both reshaped entire systems. → T-F missions (e.g. jet engine, genome) were technology breakthroughs with clear goals.
- *Crisis-Driven Innovation* → WWII, 1952 Smog, 1973 Oil Crisis, post-war reconstruction → triggered A-F/A-S missions with rapid governance.
- *Shift Over Time* → 18th–19th c.: Prize-based T-F (Longitude) → 20th c.: State-led A-S/T-S (NHS, nuclear, telecom) → Today (2025 IS-8): Heavy T-S focus — reflects growing systemic complexity.

It also shows the UK's long tradition of mission-oriented policy, evolving from **T-F** or **A-S** focused prizes and wartime scaling (emphasizing targeted breakthroughs or rapid scaling) to systemic transformation in modern UK innovation policy. This trajectory has culminated in the 2025 Modern Industrial Strategy which has eight sectoral missions that predominantly fall into the **T-S** category, reflecting systemic grand challenges like climate and digital transitions, requiring adaptive, multi-actor governance. This aligns with Professor Mariana Mazzucato's emphasis on bold, cross-sectoral goals but highlights needs for flexible tools (e.g. experimentation labs – such as the CAA's Sandbox - for broad solutions).

Mazzucato's Work on Mission-Oriented Innovation Theory

Mariana Mazzucato is a leading economist and professor of Economics of Innovation and Public Value at University College London (UCL) and founding director of the UCL Institute for Innovation and Public Purpose (IIPP) at University College London (UCL). She is best known for redefining the role of the state as an active, entrepreneurial investor in innovation. Her mission-oriented innovation framework has revived and modernized the concept of 'missions' as bold, targeted, measurable societal goals that mobilize public and private resources across sectors to solve grand challenges. Her writings recognise historical successes (e.g. the Apollo program, DARPA, GPS) and contrast these with traditional market-fixing or basic-science-only approaches as in Table E below.

Table E: Mission-Oriented vs. Traditional Innovation Policy

Aspect	**Traditional Policy**	**Mission-Oriented Policy**
Goal	Fix market failures (R&D subsidies)	Shape and create markets
Role of State	De-risker, enabler	Investor of first resort, market shaper
Focus	Horizontal (sector-neutral)	Vertical & Horizontal (targeted + systemic)
Risk	Avoids failure	Welcomes smart risk-taking
Examples	Tax credits, grants	Apollo, DARPA, clean energy moonshots

The theory is most comprehensively outlined in her two key works:

- The Entrepreneurial State (2013)
- Mission Economy: A Moonshot Guide to Changing Capitalism (2021)

In these writings she defined several core principles but also five important criteria for good missions. They are detailed below in Tables E and F respectively) [5].

Table F: Core Principles of Mazzucato's Mission-Oriented Theory

Principle	**Explanation**
1. Directionality	Missions give clear direction to innovation efforts (e.g., "land a man on the moon and return him safely" vs. vague "support R&D").
2. Bold, Inspirational Goals	Must be ambitious, measurable, and time-bound to galvanize action across society.
3. Cross-Sectoral Mobilization	Involve multiple sectors (public, private, academia, civil society) in co-creating solutions.
4. Entrepreneurial State	The public sector must take risks, invest early, and shape markets, not just fix them.
5. Bottom-Up Experimentation	Top-down goals, but bottom-up solutions—encourage diverse pathways and learning.
6. New Policy Tools & Governance	Requires dynamic capabilities in public institutions: portfolio management, agile funding, public-private partnerships.
7. Spillovers & Public Value	Outcomes should create widespread societal benefits, not just private profit (e.g., internet from DARPA).

[5] Marian Mazzucato: Mission Economy – A Moonshot Guide to Changing Capitalism (2021)

Table G: The 5 Criteria for "Good" Missions

1.	*Bold but Realistic*: Ambitious enough to inspire, grounded in feasibility.
2.	*Clear Direction & Deadline*: e.g. "100% clean energy by 2030" or "plastic-free oceans by 2040"
3.	*Cross-Sectoral & Multi-Disciplinary*: Cuts across silos (energy, transport, health, etc.)
4.	*Encourages Bottom-Up Solutions*: Government sets the goal, but industry/academia propose pathways.
5.	*Measurable & Evaluated*: Success metrics beyond GDP (e.g. lives saved, emissions reduced)

In this context, UK ambitions in the aviation technology sector look to be a combination of a Type 2 'Transformer' Mission where the target is a transformation of a system that is failing such as aviation's dependency on carbon, with a range of Type 2 'Accelerator' Mission sub-components dealing with goal orientated programmes addressing market and structural failures as in the case of AAM of the UK's near earth satellite space programme.