R&D | Aerospace and defense | Product design and testing | Regression analysis

Model-based Technology Roadmapping for Sustainable Aviation

BUSINESS PROBLEM

As the aviation industry aligns towards net zero commitments, a new generation of aircraft will need to be introduced around 2035. Airplane program timelines from announcement to first delivery have grown since the turn of the century to 15-20 years while the foundational technology for low-emissions aircraft (batteries, fuel cells, cryogenic engines, etc.) is still immature and unproven in commercial flight. Technology roadmapping is a critical tool but is often qualitative and inflexible. A quantitative, flexible methodology is needed to identify key technology sensitivities and improvement.

APPROACH

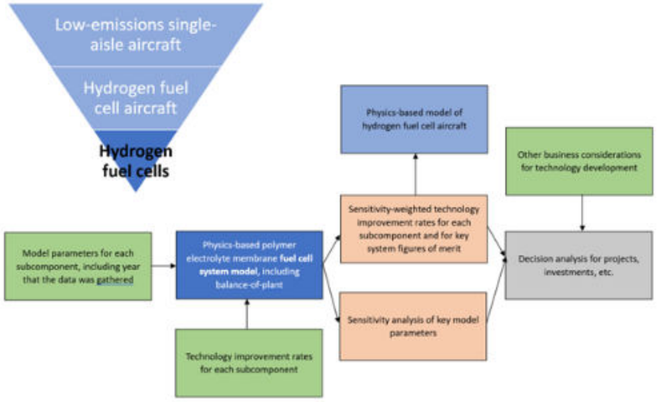
This project used the Advanced Technology Roadmapping Architecture (ATRA), focusing on figures of merit and their improvement. We build a methodology that can be used to evaluate sensitivities and project improvement rates in a system, using polymer electrolyte membrane hydrogen fuel cells as a pilot case. This approach links research in technology improvement to first-principles system models.

DATA SOURCES

Hydrogen fuel cell model parameters - academic papers, prior work in fuel cell modeling Hydrogen fuel cell performance data - manufacturer specification sheets, industry reports Technology improvement rate estimates - technologyrates.mit.edu

Data Types and Format

N/A



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IMPACT

Developing new products relying on maturing technologies is risky, particularly in an industry where product development cycles are long and costly. The next generation of sustainable aircraft will be using technologies that are still at low technology readiness levels. The approach developed here is scalable at different levels of detail for an aircraft and provides a quantitative method to identify key leverage points for technology improvement. A bottoms-up approach allows the user to model a system from first principles, conduct a sensitivity analysis, and combine this with improvement rates for each subcomponent. This approach yields a pareto analysis of the subcomponents and parameters that will both be most impactful for improvement and be most likely to improve quickly. Combined with a top-down approach looking at overall technology or system improvement rates, this methodology provides more detail to the user about key leverage points in the technology. This information can be used to develop an investment portfolio, conduct directed research, and work with supplier partners in product development. This methodology is more quantitative than other roadmapping approaches that rely on consensus opinion about how a technology may improve and can be used for a suite of technologies to evaluate options.

DRIVERS	The aviation industry has broadly aligned with net zero commitments and begun to develop new products with lower emissions. Boeing's Sustainability and Future Mobility team is working on identifying new aircraft concepts that could become future products. Many potential energy carriers are still being developed, though new products will be released around the 2035 mark. New approaches are needed to model technology improvement in systems.
BARRIERS	Technology roadmapping is not a standardized process and varies widely amongst groups at Boeing. The hydrogen fuel cell community is small and does not have a single model of best-in-class performance. Historical performance data was time-consuming to gather and difficult to find.
ENABLERS	This project has significant momentum within the team and support across stakeholders. It is well-aligned with aircraft modeling efforts that are underway, allowing the team to work and learn together. A number of people across the company had historical context on fuel cells, technology roadmapping, and corporate strategy that helped reveal potential pitfalls.
ACTIONS	The methodology was presented to the group at the culmination of the internship and turned over to the team. A new team member picked up the work about a month later, supported by the team manager and other teammates who had supervised the work.
INNOVATION	This methodology builds more detail into part of the ATRA technology roadmapping process. The process tests a novel, model-based approach to evaluating technology improvement levers by combining technology learning rates and physics-based models. The method also leverages a patent centrality method for determining technology improvement rates that dramatically reduces the resources required to find them.
IMPROVEMENT	The methodology shortens the time to determining technology improvement rates from weeks to minutes. It provides a quantitative approach to identifying key levers for technology improvement.
BEST PRACTICES	Determine the level of detail required to achieve the business objective – first-principles models may be too much detail if the components being modeled are outside the typical scope of supply for the firm. Identify the key interfaces with other projects and teams, including the inputs/outputs to the model needed and key stakeholders. Build alignment of stakeholders around the business process for building and maintaining the roadmap.
OTHER APPLICATIONS	This solution would be applicable in other industries with long and/or costly product development cycles. In these cases, being able to model future performance is helpful for informing potential investments, technology derisking efforts, and technology selection.