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The Underrated Value of Incremental Research in Aviation

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In the aviation industry, the excitement of groundbreaking discoveries often overshadows the significant impact of incremental research. This paper argues that small, continuous improvements are just as crucial as revolutionary innovations in advancing aviation research. First, we illustrate how incremental steps have collectively transformed aviation research—such as the evolution of jet engines, winglet technology, and composite materials. We further explore the role of incremental research in addressing modern aviation challenges while highlighting this approach's economic and practical benefits. Finally, we discuss how to establish a research agenda/platform that considers these issues while emphasizing the importance of maintaining a balanced focus on both incremental and revolutionary research. This approach provides a reliable path to continuous improvement while fostering a successful research future for aviation.

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Every few years, the world of aviation reports groundbreaking discoveries and revolutionary technologies. It's easy to get caught up in the excitement of these earthshaking findings that promise to transform the industry; however, while these major breakthroughs bring much value, it's crucial not to overlook the significant impact of incremental research—those more minor, continuous improvements that gradually enhance our technology and processes (Lindblom, 1959; Lindblom, 1979).

Aviation has a rich history of advancements that haven't necessarily made headlines. These incremental findings have collectively brought about profound changes in safety, efficiency, performance, and environmental concerns (Lee & Mo, 2011; Pereira et al., 2022). From refining the aerodynamics of winglets to improving the materials used in aircraft construction, these incremental steps have been the backbone of sustained progress in the field (Mowery, 2015).

In this paper, we'll explore why incremental research is just as vital as those significant leaps forward. We'll look at historical examples, present-day case studies, and discuss this approach's economic and practical advantages. By the end, we hope to demonstrate that incremental research isn't merely a stepping stone to bigger things—it's a crucial path to steady, reliable advancement in aviation.

Common Criticisms and Possible Disadvantages of Incremental Research in Aviation

Before discussing incremental research's value, we should highlight some of the common criticisms. While incremental research is valuable, it's not without its critics—frequently in academic circles. Understanding these criticisms can provide a more balanced view and highlight areas where incremental research can improve or be better communicated.

People criticizing incremental research often point out that it lacks the excitement and perceived value of revolutionary breakthroughs (Weiss & Woodhouse, 1992). In academia, where the pressure to publish novel findings is high, incremental improvements are often seen as less impactful. Scientists who focus on incremental research are frequently misjudged as unambitious and/or incapable of contributing significantly to the body of knowledge (Zdrazil et al., 2024).

Securing funding for incremental research is challenging compared to projects that promise groundbreaking results. Funding agencies and grant committees often prioritize innovative, high-risk projects that have the potential to make headlines (Bradley, 2016). This bias results in fewer resources allocated to incremental research despite its long history of delivering steady progress. Similarly, academic journals favor publishing studies with novel discoveries over those presenting incremental advancements (Bradley, 2016; Lai et al., 2022). This publication bias discourages researchers from pursuing—or even reporting—incremental findings, as they fear that their work won't be valued or rewarded.

Another criticism is that overemphasizing incremental research could lead to general stagnation in the field. Critics argue that if too much focus is placed on small, iterative changes, the field will fail to produce bold, visionary projects pushing the boundaries of what's possible

(Zdrazil et al., 2024). These critics contend that while incremental improvements are valuable, they should not come at the expense of pursuing revolutionary ideas that could lead to major leaps forward. Additionally, incremental research is often considered redundant when multiple groups work on similar small-scale improvements. This redundancy might lead to duplication of efforts and resources, which is perceived as inefficient in conducting science. Critics maintain that if incremental research is the only way forward, it should be pursued to maximize impact and avoid unnecessary repetition (Schöch, 2023).

We contend that criticisms of incremental research don't negate the value of this type of research but instead highlight the need for a more balanced approach in aviation. Both incremental and revolutionary research have their place, and each can benefit from the strengths of the other. While revolutionary research pushes the envelope and explores new frontiers, incremental research ensures continuous improvement with potentially less risk and cost. By integrating both approaches, the aviation industry and academia can foster a more holistic and sustainable path to innovation.

Historical Perspective

To appreciate the value of incremental research in aviation, it is helpful to look back at how the industry has evolved over the past decades. Many of the advancements we take for granted today didn't arrive in one fell swoop but rather through a series of gradual improvements that eventually produced the desired result (de Graaff, 2014; Lee & Berente, 2013; Pereira et al., 2022).

Take jet engines, for example. When they first emerged, they were a marvel of engineering. But it wasn't just one massive leap that made them what they are today—decades of fine-tuning and enhancements in materials, design, and efficiency turned nascent engines into the reliable powerhouses of today. Each slight improvement is built upon the latter, leading to better overall performance and greater fuel efficiency (Geels, 2006; Pereira et al., 2022). Similarly, developing avionics and flight control systems has been a journey of small steps (Thurber, 2024). Early aircraft relied on basic mechanical systems, but over the years, we've seen a steady stream of innovations—digital fly-by-wire systems, advanced autopilots, and sophisticated navigation aids, to name a few (Fielding, 2001). Each advancement might have seemed minor on its own, but collectively, they have improved flight safety and operational efficiency in ways unimaginable only a century before.

These historical examples highlight an important point: the cumulative impact of incremental research can be just as transformative as any single groundbreaking discovery. By continually refining and improving our existing technologies, we've made aviation faster, safer, more efficient, and significantly more reliable (FAA, 2024; Ney et al., 2023). This approach mitigates risk and ensures that we're constantly moving forward, even if the steps seem minor at the time.

Case Studies

To fully appreciate the power of incremental research, we will discuss three specific examples that illustrate how small, steady improvements can lead to significant advancements in aviation.

Winglet Technology. Winglets are those small, vertical extensions at the tips of airplane wings. They might not look like much, but their impact on fuel efficiency is substantial (Eguea et al., 2020; Gavrilović et al., 2015; Guerrero et al., 2020). The initial concept of winglets dates back to the 1970s (NASA, 2023); however, it took decades of incremental research and development to perfect the modern design. Engineers experimented with different shapes, sizes, and angles to improve performance gradually. Early winglet designs, dating back to the 1970s, focused on reducing drag and improving fuel efficiency. For instance, NASA's early concepts evolved over decades with adjustments in winglet shape, size, and angle. This gradual refinement led to modern winglets, which now yield a fuel efficiency improvement of approximately 6% per flight. Airlines have embraced these small, continuous gains due to their cost and environmental benefits, with models like the blended winglet on Boeing 737s and Airbus A320's sharklets highlighting this evolution.

Today, modern winglets reduce drag and enhance fuel efficiency, which translates to significant cost savings and environmental benefits in the world of aviation (Daniele et al., 2012; Eguea, Silva, & Catalano, 2020). While 6% may seem meager to the average consumer, airlines often scrutinize many aircraft items to reduce weight and save money on fuel costs (Mattos et al., 2003; Morris, 2018). A tiny savings on one aircraft translates into huge overall savings, considering that most airlines schedule hundreds of daily flights.

Composite Materials. The use of composite materials in aircraft construction has changed since a century ago; however, these changes didn't occur suddenly. Early airplanes were built with wood and metal, which were heavy and limited in performance (Schatzberg, 2002). The introduction of composites like fiberglass and carbon fiber represented big steps forward, but again, this didn't happen overnight (Trzepiecinski et al., 2022). It took decades of incremental research to develop strong, lightweight, and reliable composites for widespread use in aviation. Initial improvements involved simple fiberglass composites, but newer advancements in resin formulas and bonding techniques have led to stronger, lighter, and more resilient materials. These improvements make modern aircraft significantly lighter, resulting in reduced fuel consumption and enhanced safety due to greater durability against corrosion and fatigue. Each slight improvement in material science (e.g., better bonding techniques, new resin formulations, enhanced manufacturing processes, etc.) has improved aircraft performance and safety over time (Parveez et al., 2022; Williams & Starke, 2003).

Technological Flight Deck Enhancements. The increase of technology and automation within the flight deck has occurred through incremental advancements (Abbott et al., 1996). The technologically advanced aircraft of today did not develop overnight but rather through a series of innovations and the release of various components. Ground proximity warning systems and traffic collision avoidance systems are two technologies that have been developed and adapted over time (Dhami & Panthi, 2023). The resulting outcome from these continued advancements is

a drastic reduction in controlled flight into terrain and mid-air collision accidents. The flight deck's evolution began with basic mechanical systems and has advanced through multiple smaller innovations, including digital fly-by-wire systems and, more recently, ground proximity and traffic collision avoidance systems. Each technology, developed and refined incrementally, now contributes to a drastic reduction in mid-air collision and terrain-related accidents. The gradual integration of these systems has enhanced flight safety and operational reliability without disrupting the established framework.

These case studies illustrate that incremental research isn't just about making minor tweaks; it's about a continuous improvement process that can lead to significant advancements over the long haul. By focusing on refining and optimizing existing technologies, the field has achieved significant benefits that might have been missed if researchers were only chasing after the next big thing. This steady progress ensures that we're continually enhancing aviation's safety, efficiency, and sustainability—one small step at a time.

The Role of Incremental Research in Modern Aviation

In today's fast-paced world, the aviation industry faces a multitude of emerging challenges. Incremental research plays a pivotal role in addressing these challenges by providing steady improvements that help the industry adapt and evolve. One of the most pressing issues is the need to comply with new environmental regulations. Incremental research has been vital in developing more fuel-efficient engines, lighter materials, and better aerodynamics, significantly reducing aviation's carbon footprint (de Graaff, 2014). Small engine design and fuel formulation improvements have gradually increased efficiency, helping airlines meet stringent emission targets without needing entirely new technologies (Lee et al., 2001).

Another challenge involves cybersecurity in avionics. As aircraft systems become more digital and interconnected, the potential for cyber threats becomes increasingly concerning (Ukwandu et al., 2022). Incremental research in this area focuses on enhancing security protocols and improving software resilience (Alsulami, 2021). These improvements help protect critical flight systems from cyber-attacks, which ensures safer skies for all.

Incremental research also facilitates the gradual integration of cutting-edge technologies in aviation. Take artificial intelligence (AI) and automation, for example. While the ultimate vision of fully autonomous flight might be years—or decades—away, incremental advancements have already begun making a difference. AI-driven systems for predictive maintenance and flight path optimization are being implemented step by step (Kim et al., 2022). Each new application is tested and refined before being widely adopted, ensuring long-term reliability and safety.

Similarly, improvements in aircraft systems—such as enhanced weather radar and collision avoidance systems—are often the result of incremental research (Sghairi et al., 2008). These technologies have evolved through several small enhancements, each building on the last. This approach allows for continuous upgrades and ensures that new systems are vetted and integrated smoothly into existing frameworks. Incremental research is indispensable for modern aviation. It enables the industry to address new challenges and integrate advanced technologies in a controlled, reliable manner. By focusing on continuous improvement, aviation can adapt to

changing conditions and maintain its trajectory of progress while ensuring safer and more environmentally friendly skies.

Economic and Practical Considerations

Incremental research in aviation also offers significant economic and practical advantages beyond just the technical benefits (Richards, 2021). These often-overlooked aspects highlight why small, continuous improvements are beneficial and essential for the industry's sustainable growth. One of the most significant advantages of incremental research is cost. Developing entirely new technologies from scratch can be expensive and risky. In contrast, making smaller, iterative improvements to existing technologies usually involves lower costs and fewer resources, with much less risk (Pacific Research Laboratories, n.d.). An incremental failure doesn't require starting over from scratch—it merely means redoing that one particular change. This incremental approach allows companies to spread their investments and makes it easier to allocate funds efficiently.

Incremental research excels in risk management. When changes are made in small, manageable steps, testing and validating each modification is easier (Tahera et al., 2019). This approach reduces the likelihood of unforeseen problems often arising with large-scale, revolutionary changes. By implementing and testing improvements incrementally, the aviation industry can ensure that each new advancement is safe and reliable before widespread adoption. This approach also allows for more effective troubleshooting. If an issue does arise, it's typically easier to identify and address when changes have been made incrementally. This contrasts with the challenges of diagnosing problems in entirely new systems where multiple variables have changed simultaneously.

While each incremental improvement might seem minor on its own, their cumulative impact is profound. Small gains in fuel efficiency, slight weight reductions, or modest safety protocol enhancements all add up over time, leading to significant overall benefits (Bradley, 2016). These cumulative improvements contribute to lower operational costs, reduced environmental impact, enhanced passenger safety and comfort, and savings for companies and consumers. The economic and practical benefits of incremental research are undeniable. This approach provides a financially sustainable way to keep advancing aviation technology while minimizing risks associated with large-scale changes. Over time, this approach delivers substantial cumulative gains. By investing in incremental research, the aviation industry can continue to progress steadily in the future with lowered risk and a considerable upside. Future studies would provide value to the literature by completing a cost-benefit analysis to assess these differences.

Potential Future Incremental Research Opportunities

Looking ahead, the future of aviation will, as it has done in the past, continue to rely on a balance between incremental research and revolutionary breakthroughs. By focusing on incremental advancements, the industry will continue to ensure steady improvements that address current and emerging challenges.

One area ripe for ongoing incremental research is battery technology for electric aircraft (Schäfer et al., 2019). While electric propulsion represents a major shift, the path to fully electric commercial aviation has been and will continue to be, paved with numerous small improvements. This approach involves enhancing battery capacity, improving charging infrastructures, optimizing energy management systems, and improving safety throughout the system. These improvements contribute to making electric flight more likely to achieve long-term goals in sustainable aviation.

Noise reduction technology is another promising area of aviation (Grampella et al., 2017). Incremental research into quieter engines, insulation materials, more efficient flight paths, and training methods can reduce the noise impact on communities. By continually refining these aspects, the industry can address environmental concerns while maintaining high levels of performance and efficiency. To maximize the benefits of incremental research, it is critical to foster collaboration and knowledge sharing within the industry. Partnerships between academia, industry, and government agencies can accelerate the pace of innovation while ensuring that all parties benefit from the collaborations (Castaneda & Cuellar, 2020; Le et al., 2020). By sharing data and insights from incremental improvements, organizations can build on each other's work and avoid duplicating efforts.

Open research initiatives and collaborative platforms also play a pivotal role here. Encouraging transparency and the free exchange of information helps ensure that incremental advancements are published and disseminated widely, leading to quicker adoption. This collective approach not only speeds up innovation but also ensures that the benefits of incremental research are spread throughout the entire industry (Le et al., 2020; Lee & Jin, 2019). Recognizing the importance of continuous, small-scale improvements creates a more stable and predictable path of progress, and this balanced strategy ensures that while we strive for the next giant leap, we don’t lose sight of the steady gains that typically drive long-term success. The future of aviation depends on a sustained commitment to incremental research, and by focusing on continuous improvements and fostering collaboration, the industry can achieve significant advancements in a reliable and economically sustainable manner. This approach will ensure that aviation remains on a path of steady progress for years to come.

Establishing a Research Agenda that Embraces Incremental Advancements

For new aviation researchers, establishing a research agenda that values incremental advancements while navigating the associated challenges can be both challenging and rewarding (Foster, 2016). In light of this, we offer a guide to help build a research platform that balances the benefits of incremental research with the need for impactful, recognized contributions. A new research lab should start by identifying areas within aviation where incremental improvements can make a significant long-term difference. We recommend examining current technologies and processes to pinpoint opportunities for enhancement while focusing on topics where small advancements can lead to substantial benefits over time.

Researchers need to keep abreast of industry trends and needs (Xu et al., 2018). We should all engage with industry stakeholders, attend conferences, and participate in professional organizations to understand the pressing issues that face aviation today. We must align our

research agenda with these needs to ensure that our work is relevant and valuable to academia and industry. Collaboration is vital to overcoming the challenges of incremental research. We want to establish partnerships with other researchers, students, industry experts, and academic institutions to take advantage of the shared knowledge. Collaborative projects can pool resources, share insights, and avoid redundancy, making our incremental research more impactful (Le et al., 2020). Networking also increases the visibility and credibility of our work and helps to counteract professional biases against this type of research.

When presenting our research, we want to emphasize the cumulative impact of incremental advancements. It is essential to highlight how each small step builds upon previous work and contributes to broader goals. Case studies and historical examples are valuable ways to illustrate the transformative power of continuous improvements (Baker, 2011). This approach can help convey the significance of our work to funding bodies and academic journals. Researchers should balance incremental research with exploratory or revolutionary projects. By diversifying our research portfolio, we can balance the reliability of incremental improvements with the innovation of groundbreaking studies. This mixed-method approach makes our research agenda more attractive to funding agencies and publishers and showcases our ability to contribute to both steady progress and novel insights.

Effective communication is crucial in overcoming the perception challenges of incremental research (Ghobadi & Mathiassen, 2016; Gui et al., 2022). Researchers should clearly articulate the significance of our findings, both in academic papers and public presentations. Data and real-world examples can demonstrate the practical benefits of our work, and engaging storytelling can make incremental advancements more compelling and accessible to a broader audience. Unless funding is plentiful—which is usually not for new researchers—labs should look for funding opportunities explicitly aimed at incremental research (Foster, 2016). Some grants and funding bodies recognize the value of continuous improvement and provide resources for such projects. Researchers should tailor grant applications to highlight the practical, long-term benefits of the research and emphasize how it addresses current industry challenges.

One should cultivate a culture that values continuous improvement within a research group or institution (Norman & Verganti, 2014). Principal investigators should encourage iterative testing, peer reviews, and ongoing learning for all their staff. They should create an environment where small advancements are celebrated and considered essential contributions to the larger body of knowledge. This cultural shift can help reinforce the importance of incremental research among peers and colleagues. Establishing a research agenda that embraces incremental advancements requires strategic planning, effective communication, and collaborative efforts. By focusing on relevant industry needs, emphasizing cumulative impact, and seeking supportive funding opportunities, new aviation researchers can build a platform that advances their careers and contributes meaningfully to the continuous improvement of aviation technology and safety.

Conclusions

In the field of aviation research, there is value in groundbreaking and revolutionary advancements. However, this paper has also expressed the value of incremental research in

driving the aviation industry forward. Continuous, smaller-scale enhancements can achieve significant safety, efficiency, and sustainability advancements while minimizing the risks and costs that can come with major overhauls. The historical examples of jet engines and avionics—along with case studies on winglet technology, composite materials, and aircraft safety features like ground proximity and traffic collision warning systems—demonstrate the power of incremental steps. Though individually modest, these advancements collectively transform aviation in profound ways over the long haul. Incremental research addresses emerging challenges, integrates new technologies smoothly, and offers economic and practical benefits essential for sustainable growth.

As we look to the future, the importance of incremental research becomes even clearer. By maintaining a balanced approach that values incremental and revolutionary advancements, the aviation industry can continue innovating while managing risks and costs effectively. Collaborative efforts and knowledge sharing will further enhance this progress, ensuring that every small improvement builds on the last. The value of incremental research can be found in its ability to produce stable and reliable paths to progress. It keeps the aviation field adaptable, resilient, and forward-looking. Through investing in these continuous improvements, we remain committed to ensuring the skies remain safer, more efficient, and environmentally friendly.

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