Enabling Carbon-Free Commercial Aviation through Integrated Multidisciplinary Analysis and Optimization

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Purpose

This research effort has two major points of focus:

Build and validate a suite of software tools capable of quickly evaluating and optimizing aircraft (including those with unconventional configurations, power, and propulsion systems).

Use the aforementioned software suite to perform preliminary design and optimization of viable commercial aircraft configurations that include synergies not possible with conventional power and propulsion sources, and understand the technology requirements for the propulsion systems that are needed to make these vehicles realizable.

By completing these two objectives, the research will produce the needed metrics for energy storage, energy conversion, and propulsion systems to enable carbon-free aircraft that may be competitive with current technology in terms of economics and performance.

Background

Commercial aviation is one of the fastest growing sources of greenhouse gas emissions and yet a critical component of the global economic infrastructure. A recent report, co- authored by the U.S. Department of Transportation, forecasts global CO2 emissions due to commercial aviation of 1.5 billion tons per year by 2025, considerably worse than previous predictions of the International Panel on Climate Change. By comparison the entire European Union, some 457 million people, currently emits about 3.1 billion tons of CO2 annually. The same report found that growth of CO2 emissions on this scale will considerably outstrip any gains made by improved technology and ensure that commercial aviation is an even larger contributor to global warming by 2025 than previously thought. In addition to climate change, more than 30 million people will also be subjected to serious aircraft noise by 2025 (despite the anticipated introduction of quieter next- generation jet engines). In 2004 alone, the U.S. government spent roughly $500M on sound insulation and land purchases near airports for noise abatement purposes.

Commercial aviation is already an industry economically driven by fuel efficiency. Growth is so rapid that the projections above exist in spite of a 70% increase in industry-wide fuel efficiency over the last four decades. A projected 1.4-3.0x growth in the number of flights by 2025 signals that fundamental improvements in technology are needed to curb greenhouse gas emissions in a significant way without severe economic restrictions. The only path to long-term reductions in greenhouse gas emissions is to power commercial aircraft with a greenhouse-free fuel. By leveraging electricity and / or hydrogen as fuel sources, a sustainable future for the industry is possible. In addition, both the noise pollution and the total operating cost of the commercial fleet may be considerably reduced, resulting in both economic and additional environmental incentives for improvement.

Previous efforts in electric or greenhouse-free aviation have focused on small aircraft with conventional configurations or on hybrid concepts (hydrocarbon-fueled turboelectric). This is due primarily to (a) the lack of any viable energy source of sufficient energy density for aviation, and (b) the lack of sufficiently high fidelity, integrated design approaches for fundamentally new concepts such as those planned for this study. Numerous previous studies have shown that a "clean sheet" design approach, in which the propulsion and aircraft systems are simultaneously optimized, yields considerable performance gains even for traditional fuels. However, the level of fidelity in typical conceptual design environments is sufficiently low (to enable rapid design iterations and sizing), that the uncertainties in resulting designs are significant, especially for new and unconventional configurations. This study aims to evaluate not only performance but also environmental impact and commercial viability of greenhouse-free aviation, establishing a blueprint for near-future energy sources.

The potential impacts to commercial aviation and aeronautics in general are profound. Greenhouse-free aviation not only addresses serious climate change and pollution concerns (consistent with NASA's Environmentally Responsible Aviation and N+3 initiatives) but also impacts national aviation issues such as fuel price volatility, economic health (e.g. transportation and shipping), national security, flight safety, and energy independence. NASA ARMD is uniquely qualified to assist

in and lead such a bold new effort in aviation.