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Introduction: Understanding Aviation Particulate Matter Emissions

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COMMERCIAL aviation has transformed the world over the last century. It plays a key role in the world's economic growth and has redefined the concept of "neighbor." This success, however, has been accompanied by concerns about the adverse environmental by-products of aviation: primarily noise and emissions.

The past few decades have seen major advances in reducing these environmental impacts from aviation, mainly driven by the availability of new technologies. Nevertheless, public concerns involving the environmental impact of aircraft and airport operations, as well as increasingly stricter requirements embodied in laws and regulations, often impede capacity growth. In the United States, public concern over aviation's environmental impacts will likely increase as we seek to develop an aviation system with potentially tripled capacity by 2025. Other nations are experiencing (or will likely experience) similar constraints. Aviation environmental challenges, if not addressed effectively, may severely constrain the ability of the aviation system to meet the world's need for mobility, increased trade/market access, and sustained economic growth.

Although secondary to noise in the United States, air quality is becoming an increasing concern. Emissions of oxides of nitrogen (NO_x), carbon monoxide (CO), unburned hydrocarbons (UHC), some of which are classified as hazardous air pollutants, and particulate matter (PM) are of concern in the vicinity of airports [generally below 900 m (~3000 ft)]. Emissions of carbon dioxide (CO_2), water vapor, NO_x, and PM in the upper troposphere and stratosphere are detrimental because of their potential impact on Earth's climate.

Although aviation remains a relatively small contributor to transport emissions, about 25% of U.S. commercial service airports (including 41 of the top 50 airports) are in areas that are in the category of either nonattainment or maintenance, based on the national ambient air quality standard. The former refers to an area that does not meet the national primary or secondary ambient air quality standard established by the U.S. Environmental Protection Agency (EPA). The latter is any nonattainment area that has been redesignated by EPA to the attainment status. At the same time, stricter ozone and particulate matter standards are coming into effect under the Clean Air Act. Not surprisingly, airports located in air quality nonattainment or maintenance areas increasingly find that air emissions add to the complexity, length, and uncertainty of the environmental review and approval of expansion projects.

As late as 2003, reliable data on PM was simply not available for commercial aircraft, according to the U.S. Government Accounting Office. Calculation of the aviation portion of PM for environmental impact assessments was difficult until the completion of the Aircraft Particle Emissions Experiment (APEX) series of experiments between 2004 and 2006. The last several years have seen field measurements campaigns at the NASA Dryden Flight Research Center in the California desert, and at commercial service airports in Atlanta, Georgia, Oakland, California, and Cleveland, Ohio. Industry (manufacturers and operators), research establishments, and regulators have come together in an unprecedented manner to fill the research gap.

This issue of the *Journal of Propulsion and Power* features some of this research. Like all research, it often has led to more questions than it has answered. Nevertheless, the research is groundbreaking. The research has yielded data to improve the first-order approximation (FOA) to quantify particulate matter. The Aviation Environmental Protection Committee of the International Civil Aviation Organization has endorsed the methodology to estimate particulate matter emissions. The endorsement means that FOA will quickly become the interim global standard for measuring PM. And research has made this possible. The papers included in this special issue represent high-quality research. They are also a testament that high-quality research can and does make an impact in the short term. In a few years, the FOA will be a thing of the past. Continued research on aviation PM will result in the metrics and models to understand the impact of aviation PM and, if warranted, to develop the technology to mitigate its impact. The first steps archived here will remain an example of what the research community can accomplish when it focuses on a very practical problem.

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