Project 015 Aircraft Operations Environmental Assessment: Cruise Altitude and Speed Optimization

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Project Lead Investigator

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- P.I.(s): R. John Hansman
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- Task(s):
  1. Identify operations with high fuel reduction potential from CASO
  2. Present results and discuss operational considerations with stakeholders
  3. Develop set of recommended operating procedures to improve fuel performance in domestic operations through cruise altitude and speed optimization
  4. Extend analysis to specific long-haul operations

Project Funding Level

Project Funding Level: $313,196.18 FAA funding and no matching funds. No source of match is required for this contract.

Investigation Team

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Project Overview

This purpose of this project is to examine the potential fuel burn benefits of altitude and speed optimization in the cruise phase of flight for domestic operations in the United States and certain long-haul operations. Airlines can achieve cost reductions and mitigate environmental impact by making small modifications to the cruise phase operating condition. With coordination between air traffic controllers, pilots, and airline dispatchers, the efficiency of air transport activities can be improved. This study builds off of prior work in this area to establish best-case benefits. High-benefit operations within the NAS are identified and potential implementation considerations are discussed. In order to achieve these objectives, a cruise-phase fuel burn estimator is developed using publicly-available radar tracks and weather data. This estimator is used to examine 217,000 flights from 2012 for optimization potential, with continuing analysis of more recent data from domestic and international operations.

Environmental and economic concerns provide motivation for fuel consumption reduction in air transportation. There are various techniques to control fuel-related environmental impact with varying implementation timelines and potential benefits. These include new aircraft technology (decade-scale implementation, high cost), retrofits to existing aircraft (multi-year implementation, medium cost), alternative jet fuel and propulsion technology (decade-scale implementation, high cost), and operational mitigation (rapid implementation, low cost) [1]. Operational mitigations are useful due to the potential for rapid implementation and low capital expenditure, although the long-term benefit is generally less than other technology-driven solutions. Prior research in academia and industry has identified potential operational mitigations. For example, Marais et al. proposed 61 specific operational mitigations with implementation timelines in the 5-10 year range [2]. Of these, eight mitigations dealt with opportunities in cruise altitude and speed optimization (CASO).

The fuel efficiency of an aircraft at any point along its flight path is a function of weight, altitude, speed, wind, temperature, and other second-order effects. At a fixed weight, there exists a combination of speed and altitude at which instantaneous fuel efficiency is maximized, as shown in **Figure 1** for a typical widebody long-range airliner. For a full flight, this becomes an optimal sequence of speeds and altitudes to minimize fuel consumption [3]. The speed and altitude at which aircraft are actually flown may differ from this optimal point for a variety of operational and practical reasons. Integrated fuel consumption depends on effective trajectory planning in speed and altitude as well as in lateral flight path. There are many examples in the literature demonstrating techniques and potential applications for single-flight trajectory optimization in lateral, vertical, and temporal dimensions (e.g. [4]–[11]). However, no research has demonstrated the systemwide benefits pool of such optimization concepts compared to current operating practices.

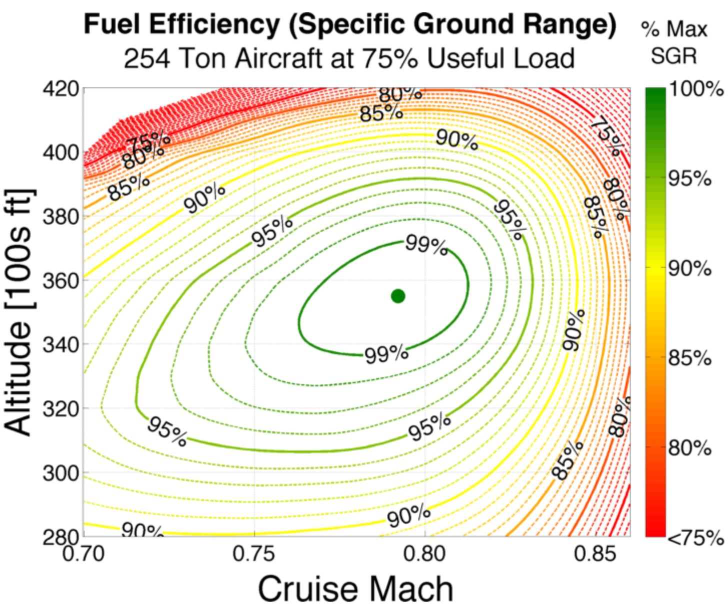

Figure 1. Instantaneous fuel efficiency of a typical long-haul aircraft at a fixed weight (calm winds, standard atmosphere)

The degree to which flights may operate at optimal altitudes and speeds depends on a variety of system characteristics, including prevailing weather conditions, congestion, airline schedules, operating costs, and Air Traffic Management (ATM) technologies available on the ground and in the cockpit of participating aircraft. In domestic US operations, the suite of communication, navigation, and surveillance (CNS) technologies allows for continuous very-high frequency (VHF) radio communication, and radio-based navigation, and radar tracking. However, traffic volumes prevent unconstrained altitude selection in most areas of the country. Speed selection is driven by a combination of ATM constraints and airline operational priorities

Task Progress and Plans

Task 1: Identify operations with high fuel reduction potential from CASO

Based on the distribution of benefits evident in the first part of this project, it was clear that some types of operations (i.e. airlines, aircraft types, and routes) had larger benefit potential from CASO implementation than others. Therefore, one objective of this phase of the project is to characterize current operations by type and identify particularly high-benefit candidates for cruise phase optimization. Potential drivers for off-optimal flight conditions, such as airspace congestion or weather impacts, can be investigated at this stage to inform discussions with stakeholders.

Task 2: Present results and discuss operational considerations with stakeholders (airlines and air traffic controllers)
In order to implement CASO concepts in operational contexts, it is necessary to understand system efficiency drivers from the airline and ATC perspectives. Therefore, an objective of this research is to meet with airline operational departments, dispatchers, pilots, and air traffic controllers to discuss the cruise efficiency analysis results generated under Task 1. Based on these meetings, the reasons for particular airline-specific or type-specific results can be understood and incorporated into implementation suggestions. Opportunities for improvement in meaningful, short-term operational contexts can be identified based on these meetings. A consultation with Delta Airlines in late 2014 provided feedback from the perspective of a single airline, so continued consultation with a wider range of operators will be pursued.

Task 3: Develop set of recommended operating procedures to improve fuel performance in domestic operations through cruise altitude and speed optimization
Based on analysis of historical flight records and discussions with airlines, operational procedures to improve cruise-phase altitude and speed efficiency will be proposed. Areas of potential application include flight planning, tactical altitude and speed assignment, and cockpit procedures. This objective may include development of cockpit and/or controller decision support tools, efficiency evaluation algorithms, or other tools that can be integrated within the existing air transportation infrastructure based on stakeholder input.

Task 4: Extend analysis to specific long-haul operations
The initial phase of this project focused on domestic US analysis. International and long-haul operations consume a larger amount of fuel in cruise, on an absolute and percentage basis, than short-haul small-gauge flights. Therefore, the environmental and economic impact of fuel burn reduction for these operations may be significant. The analysis framework will be expanded in this phase of the project to incorporate data sets other than the FAA flight records and domestic NOAA weather models used in the early stages of the project.

Major Accomplishments

Have met with groups from American and United airlines. Have completed analysis of long haul flights on the North Atlantic Tracks. Have extended CASO analysis to include 2015 data. Have developed initial prototypes of cockpit decision support tool

Publications

- "Cruise Fuel Reduction Potential from Altitude and Speed Optimization in Global Airline Operations." Jensen, L., Tran, H., and Hansman, R.J., 11th USA/Europe Air Traffic Management Research and Development Seminar (ATM2015), 23-26 June 2015, Lisbon, Portugal.
- "Commercial airline altitude optimization strategies for reduced cruise fuel consumption," Jensen, L., Hansman, R.J., Venuti, J., Reynolds, T.G., AIAA 2014-3006, 14th AIAA Aviation Technology, Integration, and Operations Conference (ATIO), 16-20 June, 2014, Atlanta, GA. DOI: 2514/6.2014-3006
- "Commercial airline speed optimization strategies for reduced cruise fuel consumption," Jensen, L., Hansman, R.J., Venuti, J., Reynolds, T.G., AIAA 2013-4289, 13th AIAA Aviation Technology, Integration, and Operations Conference (ATIO), 12-14 August, 2013, Los Angeles, CA. DOI: 2514/6.2013-4289
- "Fuel Efficiency Benefits and Implementation Considerations for Cruise Altitude and Speed Optimization in the National Airspace System." Jensen, L., SM Thesis, MIT, 2014.

Outreach Efforts

Meetings with Delta, United and American fuel efficiency, flight planning and operational groups.

Awards

Luke Jensen selected ASCENT 2014 Student of the Year.

Student Involvement

Graduate students have been involved in all aspects of this research and have been the key implementers.

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[11] E. T. Turgut, M. Cavcar, O. Usanmaz, A. O. Canarslanlar, T. Dogeroglu, K. Armutlu, and O. D. Yay, "Fuel flow analysis for the cruise phase of commercial aircraft on domestic routes," *Aerosp. Sci. Technol.*, vol. 37, pp. 1–9, 2014.