Automated Meta-Aircraft Operations

FOR A MORE EFFICIENT AND RESPONSIVE AIR TRANSPORTATION SYSTEM

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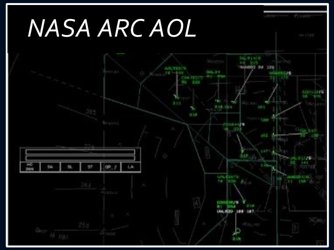
Innovation

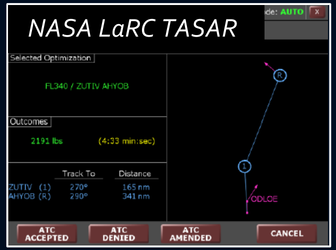
Transform the Air Transportation System through the introduction of civilian transport Meta-Aircraft.

Air-to-Air Data Sharing

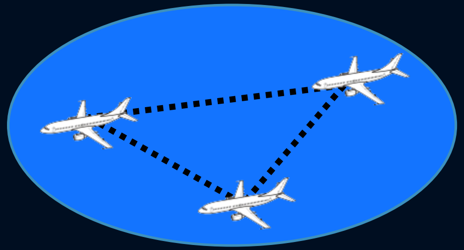
Autopilot Systems



Real-Time Scheduling/ Routing Tools



Automated Flight Planning System



Meta-Aircraft Concept

Big Question: How will automated meta-aircraft operations enable a cleaner, more efficient, and more responsive air transportation system?

Motivation

2010 Eyjafjallajökull Eruption

In 2010, the explosive eruption of the Eyjafjallajökull volcano in Iceland closed UK, European and North Atlantic airspace for 6 days. Over 95,000 flights were cancelled.

(University College London Institute for Risk and Disaster Reduction)

2014 Chicago ATC Center Fire

In 2014, a fire forced the Chicago Air Route Traffic Control Center to suspend operations for 4 hours, cancel over 1,700 flights, and transfer responsibility for thousands more to regional control centers. Delays cascaded across the country and the effects persisted for weeks.

(Reuters, Chicago Tribune)

Fuel Costs / Environmental Impact

By 2011, fuel made up 30% of airline costs ($50B). Energy prices are expected to continue to rise over the long term. Air transportation accounts for 2% of global CO_2 emissions, and will increase with continued growth in world-wide aviation needs.

(NASA Aeronautics Research Mission Directorate Strategic Implementation Plan)

Convergent Technologies:

Modern Digital Avionics, Data Sharing Networks, and Advanced Operational Concepts:

- By 2020 all aircraft in Class A,B and C airspace will be equipped with ADS-B Out to transmit position, velocity and intent.
- The FAA has approved ADS-B In flight deck applications to assist the pilot with Interval Management, In-Trail Procedures, and Traffic Awareness.
- In 2013, two C-17 transports demonstrated a 10% reduction in fuel usage on a flight from Edwards to Hickam AFB using prototype wake surfing technology.

FAA 14 CFR Part 91

ACSS SafeRoute®

AFRL/DARPA/Boeing $AVE Project

Meta-Aircraft Concept

Technical Feasibility Study

Communications (NASA GRC)

- ADS-B is primarily an air-to-ground communications architecture.
- Closed-loop flight path control using ADS-B data is not a solved problem:
  - security, reliability, timing, data quality, failure modes, etc.

Wake Surfing (NASA AFRC/LaRC)

- The impacts of wake surfing on civilian transport aircraft are unknown:
  - roll trim authority, control bandwidth, passenger ride quality, engine/actuator life, structural fatigue
- Wake models are needed for extended (1-2 nm), multi-aircraft formations

Operations (NASA AFRC/ARC)

- End-users are unsure how to integrate the meta-aircraft concept into their operations.
- Algorithms are needed to help identify, schedule and route groups of airplanes under realistic operational constraints
  - arrival/departure delays, common/distinct origins and destinations, existing routes and schedules, aircraft performance differences, robust contingency planning

Non-Technical Risks and Barriers

In addition to technical unknowns, a number of operational , regulatory and procedural challenges also exist:

1. Certification of onboard avionics
2. FAA and other agency (EASA) regulations
3. Responsibility for separation
4. Operator, aircrew and ATC acceptance
5. Cost of equipage

System-Level Impacts

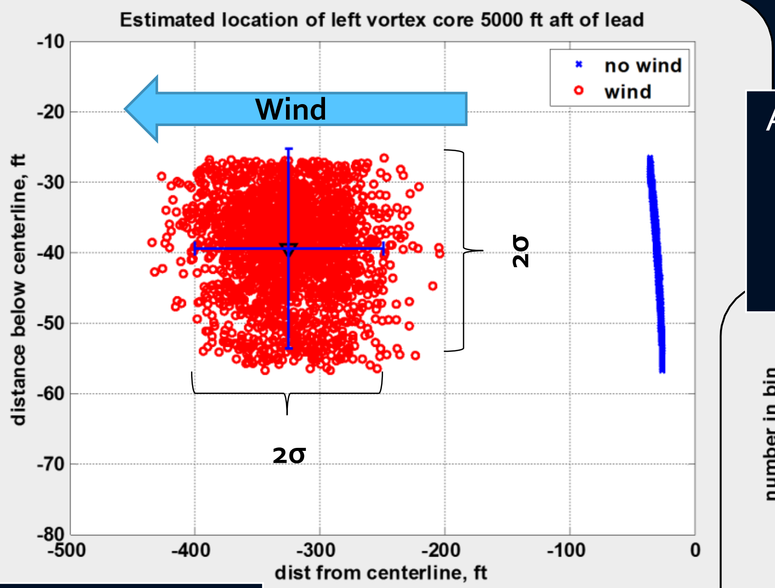
If successful, Meta-Aircraft Operations will:

- Increase flight throughput by at least 10% during severe restrictions in available airspace, and
- Demonstrate a return on investment within the first year for aircraft equipped with wake surfing technology.

Meta-Aircraft Operations will help NASA meet three of the six ARMD research thrusts.

- Safe, Efficient Growth in Global Operations
- Ultra-Efficient Commercial Vehicles
- Assured Autonomy for Aviation Transformation

NASA G-III HIL Simulation

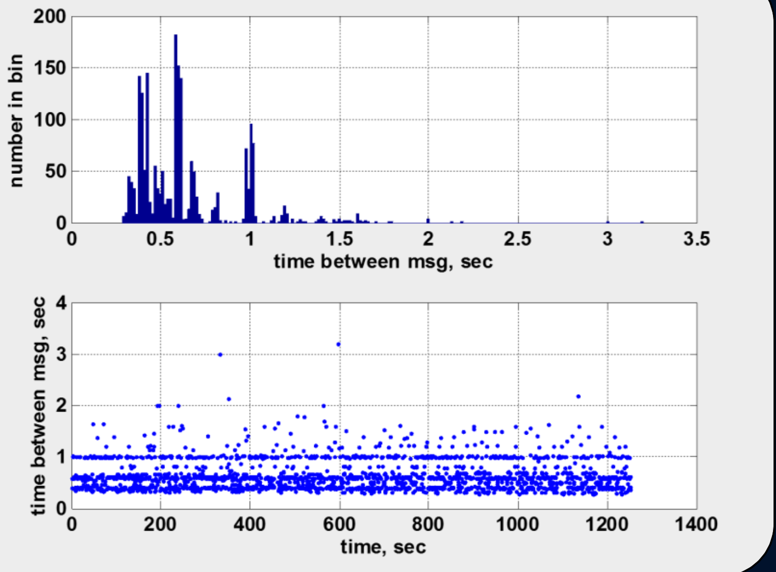


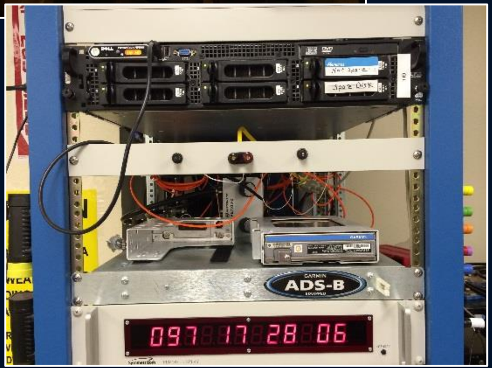
Wake Descent/Drift Study

- ±20 ft vertical dispersal due to wake structure uncertainty
- ±150 ft lateral uncertainty due to wind drift

ADS-B Communication Study

- Message clusters at 0.4, 0.6 and 1.0 second intervals
- Occasional intervals > 3 seconds





Technology Validation Roadmap

German Institute for Fluid Mechanics

1995

- Proof of concept
- No data link
- 10% power reduction
- Rudimentary peak-seeking control

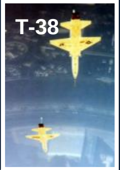
NASA Dryden Flight Research Center

2001

- Research data link and autopilot
- 14% fuel savings (manual)
- Validated system requirements
- Detailed wake effect mapping

US Air Force Test Pilot School

2001

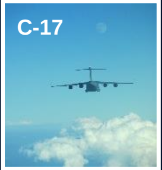


- Manually flown
- No data link or autopilot
- 9% fuel savings (2-ship)
- Inconclusive 3-ship evaluation

Close Formation Flight Research

NASA DFRC / USAF FTC

2010



- Proof of extended formation concept
- Production military data link and autopilot
- 7-8% fuel savings (manual)

DARPA / AFRL / Boeing

2012 - 2013

- Modified C-17 autopilot
- Production military data link
- 10% fuel savings (autopilot)
- Wake avoidance algorithms

Cooperative Trajectory Flight Research

Partnership between NASA AFRC, ARC, LaRC, GRC

2013 - 2017

- Commercial Data Link (1090 MHz ADS-B In and Out)
- Prototype cooperative trajectory autopilot mode
- Real-time wake estimation and robust wake avoidance

Integrated flight demo

Efficient ACT Routing and Scheduling Tools

Wake Modeling and Advanced Controls

Operational Demonstration with Industry Partners (to be determined)

2018 - 2020

- Commercial Data Link (1090 MHz ADS-B In and Out)
- ACT algorithms integrated with commercial autopilot
- FAA participation (in the US NAS)
- Pilot displays and procedures
- Demonstrate scheduling / routing tools
- Candidate trail aircraft:
  - Supplied by an industry partner
  - ecoDemonstrator

Path To Commercially-Viable Automated Cooperative Trajectory Operations

Questions?