



# **Statistical Engineering Case Study: Flight Test Evaluation of an Airborne Spacing Application**

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Science of Test Workshop  
April 3-5, 2017

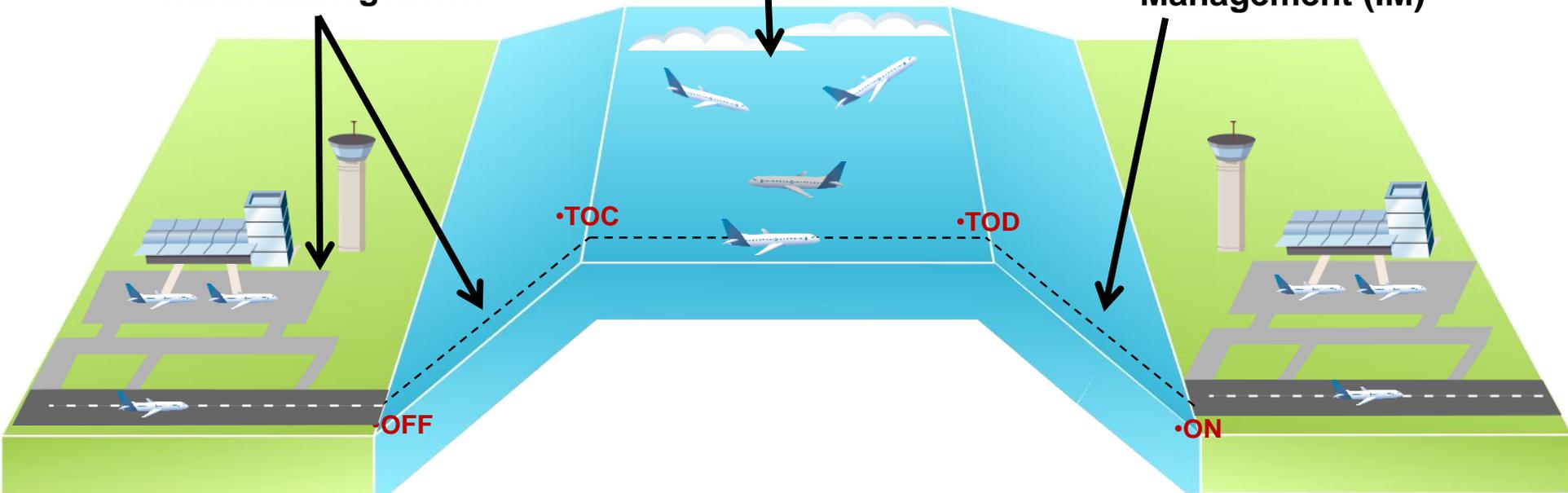
# Airspace Technology Demonstrations



**ATD-2**  
Integrated Metroplex  
Traffic Management

**ATD-3**  
Applied Traffic Flow  
Management

**ATD-1**  
Terminal Sequencing and  
Spacing (TSAS) and Interval  
Management (IM)



# ***Air Traffic Management Technology Demonstration – 1 (ATD – 1)***



- **Conditions in busy terminal areas today often result in inefficient arrivals**
- **More efficient arrivals are available, but current technology limits their use to periods of light to moderate traffic conditions**
- **New concepts and technologies are needed to make efficient arrival procedures feasible during heavy traffic**
- **NASA's ATD-1 is operationally demonstrating the feasibility of efficient arrival operations with ground-based and airborne NASA technologies**
- **This integrated arrival solution has been verified and validated in laboratories and the airborne technology was transitioned to a field prototype for a flight test**

# ATD-1 Integrated System



Interval Management (IM)  
Equipped Aircraft

Controller Managed Spacing  
(CMS) in Terminal Airspace



Guidance for controllers  
to issue IM clearance  
to IM aircraft

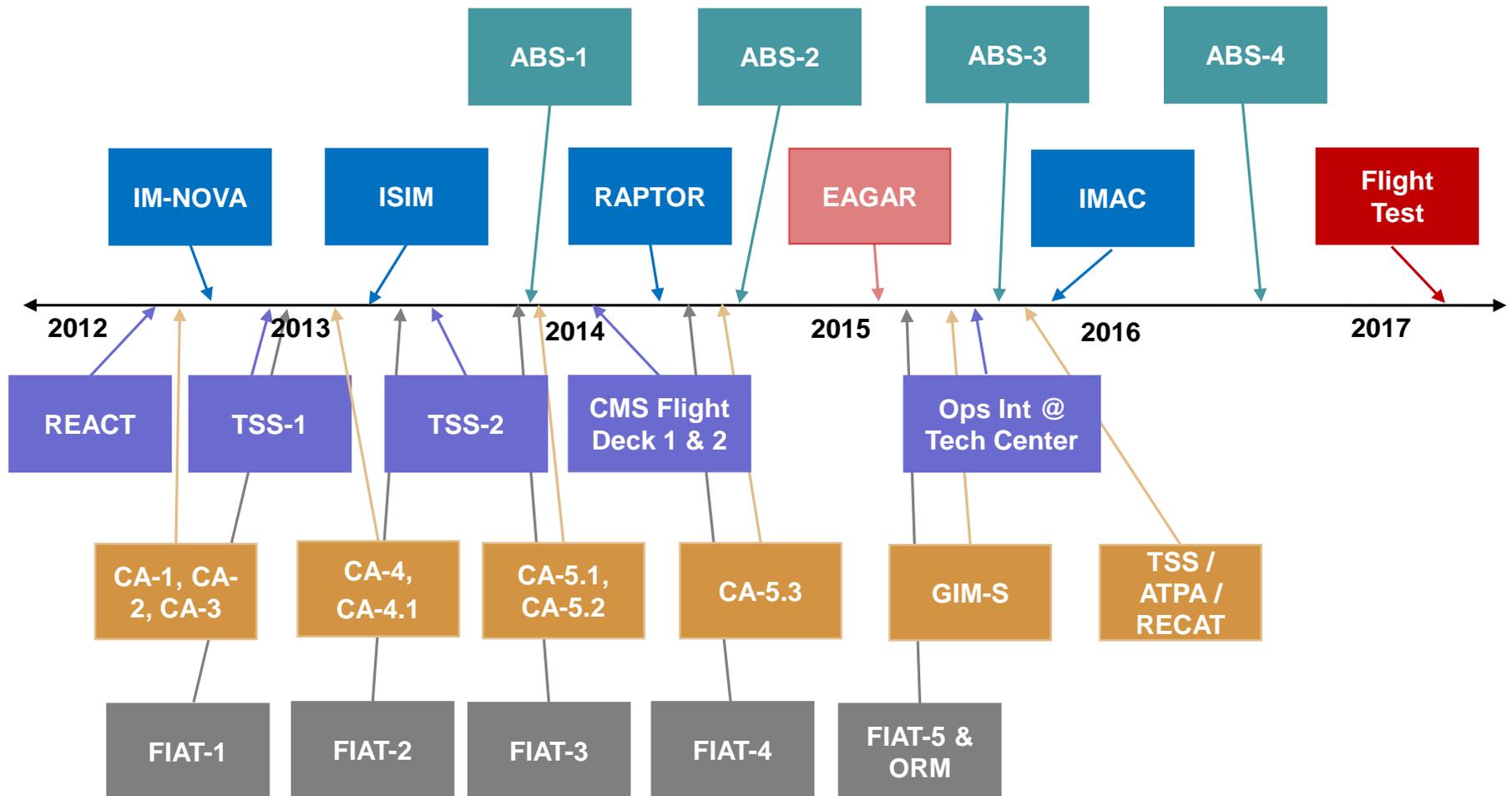
Guidance for controllers to  
issue speed commands to  
non-IM aircraft



Traffic Management Advisor  
with Terminal Metering (TMA-TM)



# ATD-1 Experiments



# ***Challenges***



**Series of sequential experiments conducted across multiple Centers, facilities, and simulation environments over several years leading up to the flight test**

- **Communication and collaboration across Centers**
- **Facilities have different limitations and constraints**
- **Experiments can take different approaches with respect to the fundamental principles of design of experiments**
- **Synthesize data from multiple sources**
- **Difficult to compare results from multiple experiments**
- **Incorporating findings from one experiment to the next experiment in the series**

# ***ATD – 1 Flight Test***



- **The objective of ATD-1 is to operationally demonstrate an integrated set of NASA ground-based and airborne technologies that provide an efficient arrival solution in high-density operations**
- **Two goals of the flight test are to:**
  - **Develop prototype avionics and IM application**
  - **Integrate the prototype avionics into two test aircraft and conduct validation flight tests**

# *Flight Test Aircraft*



**Honeywell  
Boeing 757**

**Honeywell  
Dassault Falcon 900**

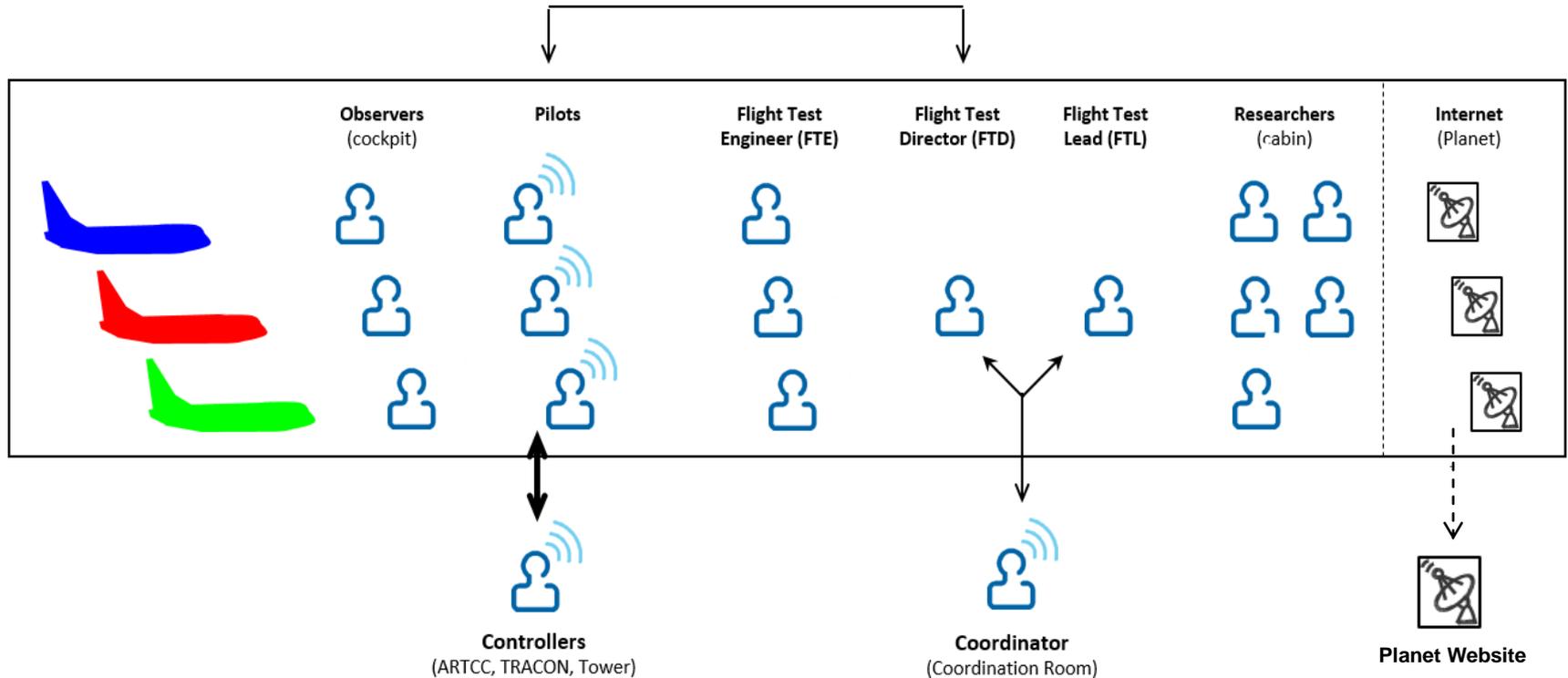
**United Airlines  
Boeing 737**

# *Flight Test Environment*



- **Departed Boeing Field (KBFI) and Seattle Tacoma International (KSEA)**
- **Conducted flight test at Grant County International, Moses Lake (KMWH)**
- **Air Traffic Control Facilities and Controllers**
  - **Seattle Air Route Traffic Control Center (ARTCC)**
  - **Seattle Terminal Radar Approach Control (TRACON)**
  - **Seattle Tacoma International Tower**
  - **Boeing Field Tower**
  - **Moses Lake TRACON**
- **Scenario characteristics:**
  - **Variation in wind from 10 knots to 150+ knots from the west**
  - **Some scenarios had significant wind shear turning onto final**
  - **Conducted in VMC and IMC (all weather conditions)**
- **High altitude en route, arrival, and IM operations within TRACON**

# Participants and Communication



**↔ Controller-pilot communication**  
 Normal ATC VHF frequency; each pilot talks to their respective controller (single aircraft ops)

**↔ VHF flight test frequency**  
 Dedicated VHF flight test frequency; FTD and pilots set scenario start time and discuss contingency operations; also communicate with Coordinator when within range

**↔ Intra-plane communication**  
 Two intercom nets: 1) cockpit, FTE, observers (workload permitting), and 2) researchers, FTD, FTL. Normal comm is observers to FTD, then FTD to FTE on intercom or over VHF flight test frequency (depends on situation).

**----- Internet chat communication**  
 Backup mode of non-directive communication between everyone with internet access; log into Planet website for traffic display and chat

# *Test Matrix*



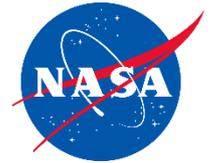
- **Test matrix partitioned into three types of scenarios:**
  - **En route (6 scenarios)**
  - **Arrival (24 scenarios)**
  - **Final approach (8 scenarios)**
- **Independent Variables:**
  - **IM Clearance Type**
  - **Time-based vs. Distance-based Operations**
  - **Target Delay**
  - **Spacing Error**
  - **Location of Achieve-by Point**
  - **Trajectory Geometry**

# *Experiment Design*

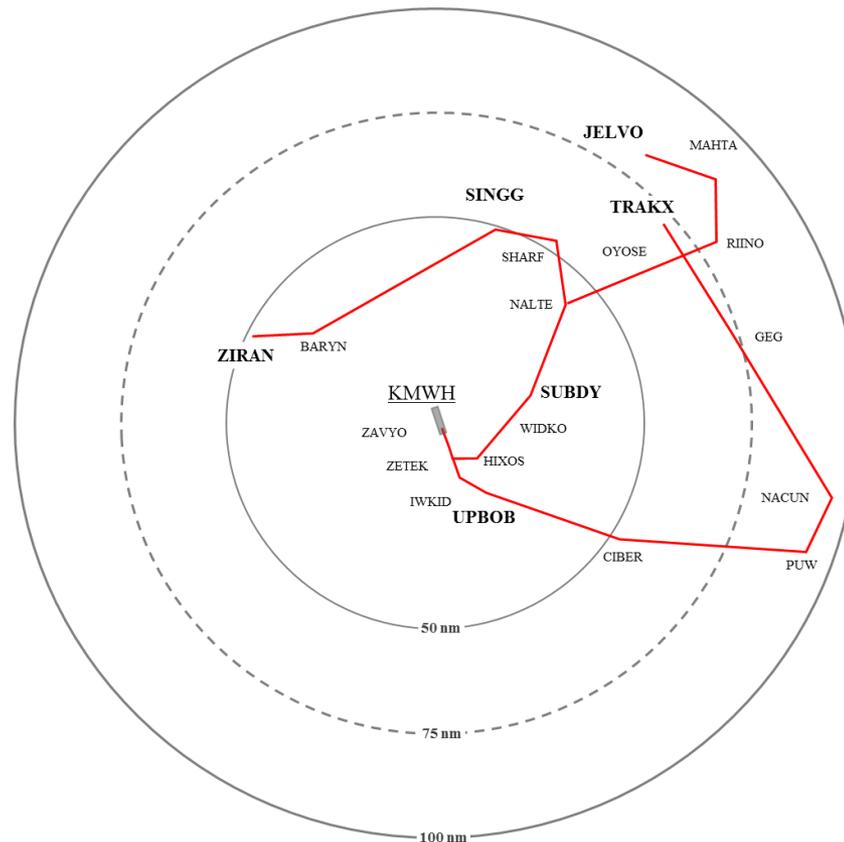


- **Incorporated constraints into experiment design and analysis plan**
  - **Order effects**
  - **Priority of test conditions**
  - **Schedule**
  - **Environmental variables**
  - **Winds**
- **Two replicates of each test condition**
- **Experiment protocol was designed to be able to be dynamically adapted to issues that arose during the flight test and to mitigate schedule risk**

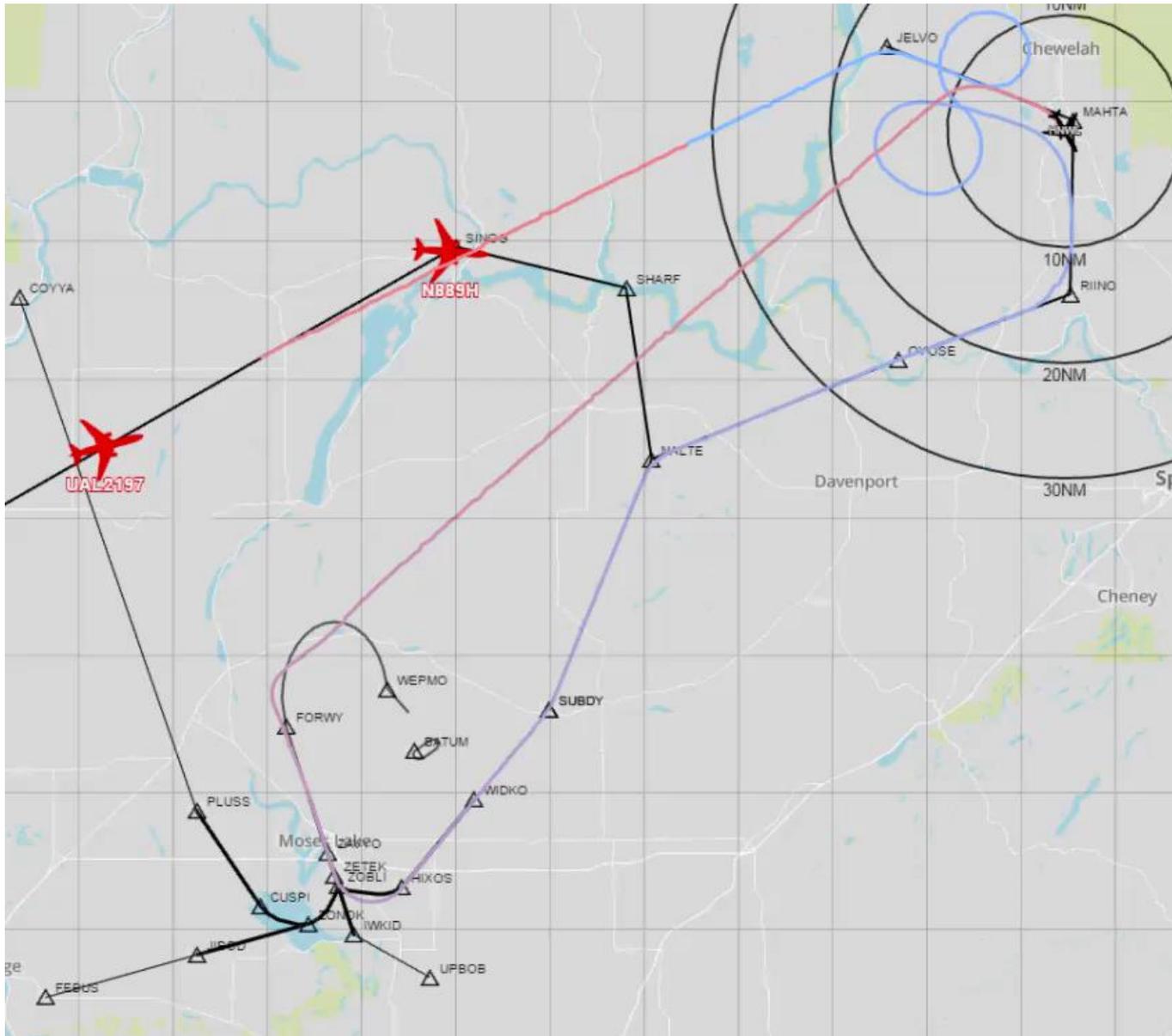
# Arrival and Approach Procedures



- Developed special Standard Terminal Arrival Routes (STARs) to
  - Enable medium altitude merge in ARTCC airspace (NALTE)
  - Enable low altitude merge in TRACON airspace (ZETEK)
  - Designed for both runways, intentionally used only runway 32R



# Example Test Run



# ***Data Management***



- **Data Gathering and Analysis Working Group**
  - **NASA, Boeing, Honeywell, United Airlines, FAA**
- **Define data parameters to be collected**
  - **Quantitative data**
  - **Qualitative data**
  - **Audio / video data**
- **Define and document format of data files**
- **Identify impact to hardware**
- **Identify and mitigate risks associated with data**
- **Define process for transfer of data**
- **Define analysis to be conducted by NASA, Boeing, Honeywell**
- **Daily analysis to assess test runs**

# *Summary*



- **Statistical engineering involvement throughout the project increased comparability across experiments and flight test**
- **Incorporated findings from previous experiments into planning of flight test**
- **Flight Test experiment design was developed to mitigate schedule risk and to be dynamically adjusted**
- **Data Collection and Analysis Plan was developed to identify and document data to be collected, and coordinate analysis efforts**
- **Flight Test data are currently being analyzed and results will be published later this year**
- **All documentation and data will be transferred to the FAA**