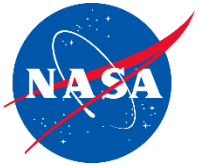

Statistical Engineering in Air Traffic Management Research

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National Aeronautics and Space Administration

Langley Research Center

Spring Research Conference

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NextGen

- **FAA is predicting a substantial increase in the number of revenue passenger miles flown over the next 20 years**
- **If left unmodified, the current air transportation system cannot indefinitely sustain this projected growth without inducing delays, inefficiencies, and environmental impacts**
- **FAA's NextGen concept envisions a comprehensive transformation of the National Airspace System to support this continued growth in a safe, reliable and efficient manner**
- **NASA is collaborating with the FAA and industry partners to develop advanced technologies necessary for NextGen**

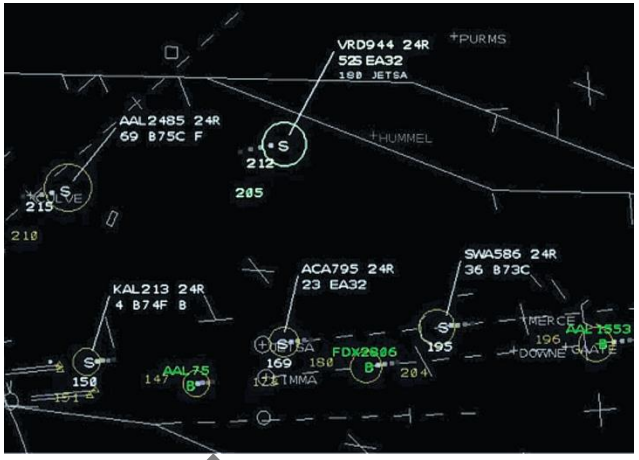
ATM Technology Demonstration – 1

- **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 will operationally demonstrate the feasibility of efficient arrival operations combining ground-based and airborne NASA technologies**
- **This integrated arrival solution is being verified and validated in laboratories and transitioned to a field prototype**

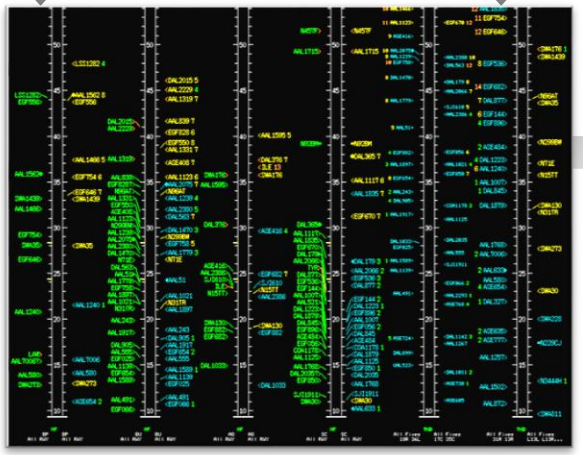
ATD-1 Integrated System

Flight Deck-based Interval Management (FIM) Equipped Aircraft

Controller Managed Spacing (CMS) in Terminal Airspace



Guidance for controllers to issue IM clearance to FIM aircraft

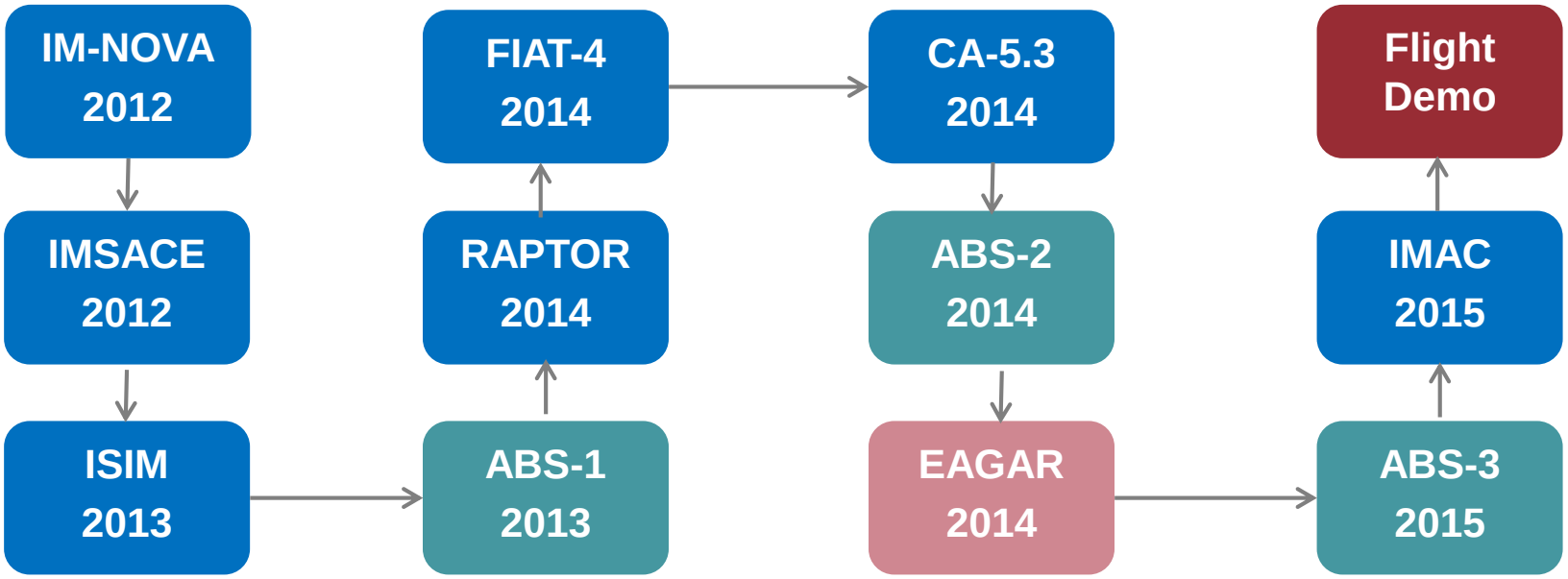


Traffic Management Advisor with Terminal Metering (TMA-TM)

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

Sequential Experiments

- **Multi-year iterative experimentation process**
- **Batch computer simulations and Human-in-the-Loop (HITL) experiments in preparation for a flight demonstration**
- **Collaborative effort between NASA Langley and Ames Research Centers**



Flight Simulation Facilities

Integration Flight Deck (IFD)

- High fidelity replication of B737-800 flight deck
- Full mission functionality; operating in fixed or motion base
- Two-crew cockpit with columns and rudders

Development and Test Simulator (DTS)

- B-777 / MD-11 / A-320 functionality
- Full mission functionality; operating on fixed base
- Two-crew cockpit with side stick controllers

Air Traffic Operations Laboratory

- **The Air Traffic Operations Laboratory (ATOL) is a multi-fidelity, part-task, aircraft and air traffic operations simulation facility**

- **Integrates airborne vehicles with ground-based air traffic management tools and other research facilities**

- **Medium-fidelity desktop simulators can be flown by human pilots or pilot model**

- **Medium fidelity pseudo-pilot stations allow a single research pilot to fly multiple traffic aircraft**

- **High-fidelity air traffic controller stations**

Challenges

Series of sequential experiments conducted across multiple Centers, facilities, and simulation environments over several years

- **Communication and collaboration across Centers**
- **Difficult to compare results from multiple experiments**
- **Currently no standard or efficient method to synthesize data from multiple sources**
- **Simulation environments have different limitations and constraints**
- **Experiments can take different approaches with respect to the fundamental principles of design of experiments**
- **Incorporating findings from one experiment to the next experiment in the series**

Common Experiment Reporting Process

- **Document the experiment throughout the entire process**
- **To facilitate communication and collaboration within project and support the transfer of NASA technologies**
- **Lessons learned, action items, and development needed for upcoming experiments**

Documents include:

- **Test Plan**
- **Executive Summary**
- **Experiment Outbrief**
- **Controller and Pilot Training Materials**
- **Controller and Pilot Questionnaires**

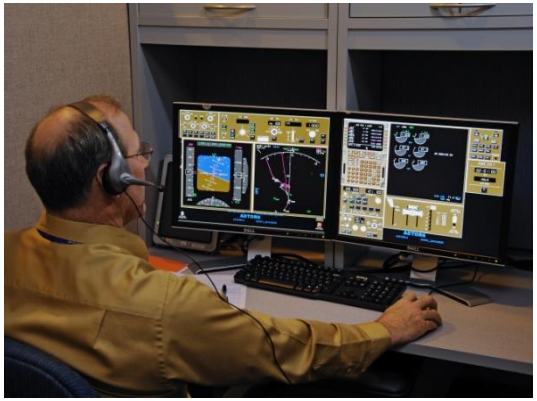
Measures of Performance

- **Metrics to determine whether the system is expected to meet its performance objectives while operating within the allowable limits**
- **Quantitative measure that can be recognized when achieved**

Defines:

- **Measurement approach**
- **Improvement threshold**
- **Validation criteria**
- **Performance goals**
- **Performance calculation method and sources**

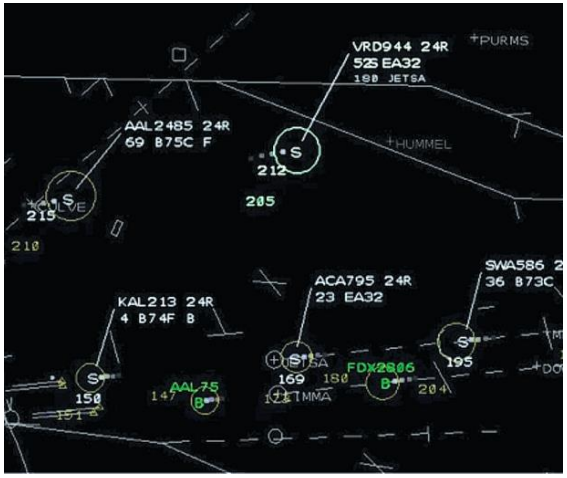
Simulation Facilities and Equipment



Desktop Pilot Interface

Full Mission Cockpit

Batch Aircraft



ATC Stations

Traffic Management Advisor

Pseudo-Pilot Interface

Database System

- **Data from each tool, simulator, and facility is recorded in a different format**
- **Need to be able to integrate and synchronize data from all sources**
- **Defined requirements for new database system and is currently being implemented**
- **Provides ability to assess system-level performance goals in order to meet research objectives**
- **Will decrease time and resources needed for data post-processing**
- **New capability available to all projects conducting research in the Langley facilities**

Sequential Experiments

- **Multi-year iterative experimentation process**
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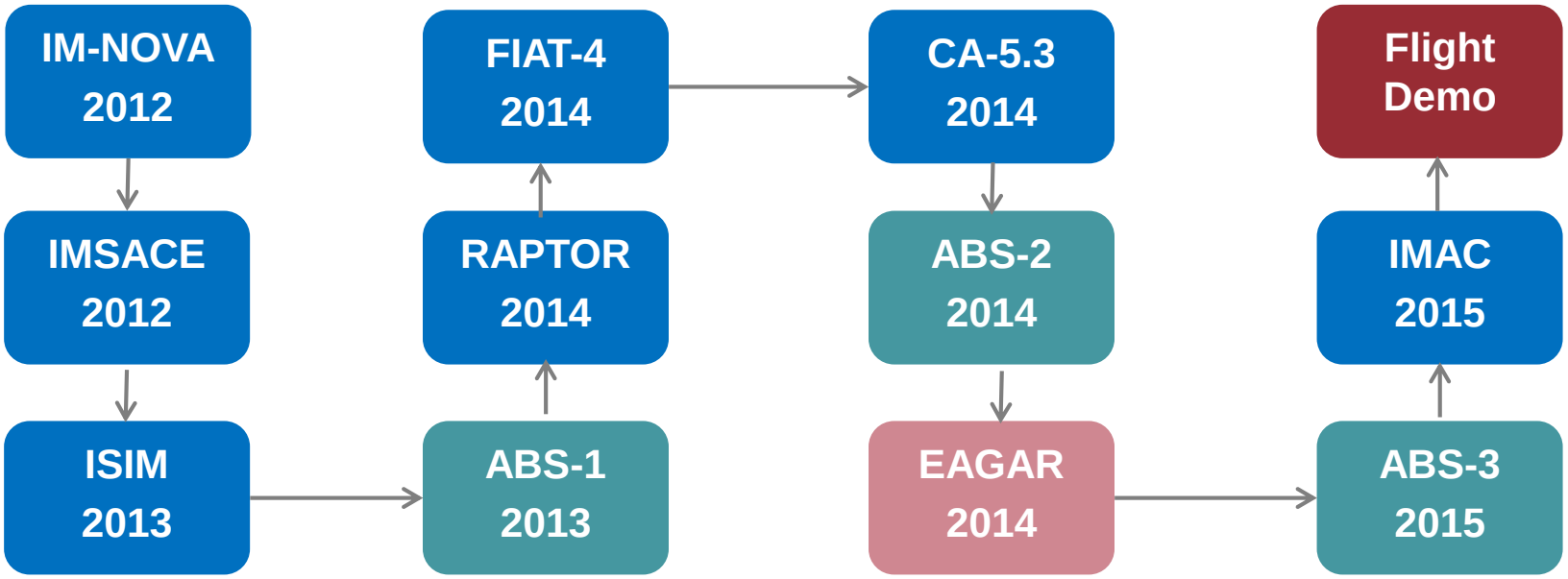


Batch and HITL Experiments

Batch Computer Simulation	Human-in-the-Loop Experiment
Fast-time	Real-time
Low / medium fidelity	Medium and/or high fidelity
Airborne technologies only	Integrated system of ground-based and airborne technologies
Scripted scenarios	Dynamic scenarios
Reduced realism	Realistic controller and pilot actions
Single facility and simulation environment	Multiple facilities and simulation environments
Lower cost, fewer resources, less time	Higher cost, more resources, more time

Batch Computer Simulations

- **Batch simulations can be used as a screening experiment**
  - **Ability to evaluate large number of factors in short time for fewer resources**
  - **Identify factors to be further investigated**
- **Batch simulation typically focuses on stressing the system, and so often explores larger region of interest**
  - **Identify treatment combinations to be further investigated**
- **Incorporated into research objectives of upcoming experiment**

Human-in-the-Loop Experiments

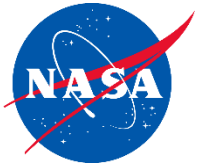
- **HITL experiments involve human participants**
  - **Pilot and controller subjects**
  - **Pseudo-pilots and confederate controllers**

- **Collaborate with Human Factors SMEs to incorporate constraints resulting from pilot and controller participants into experiment design and analysis plan**
  - **Within-subject design**
  - **Order effects**
  - **Counterbalancing**
  - **Correlation structure**

Human-in-the-Loop Experiments

- **HITL experiment utilizes simulated flight environment with high level of realism**
- **Results lead to design guidance for phraseology and procedures in ConOps, and can also be used to increase the level of realism in batch computer simulations**
  - **Voice communication**
  - **Data entry times**
  - **Trajectories**
- **Research effort with Virginia Commonwealth University (Dr. David Edwards)**
- **Increasing realism increases knowledge gained from batch simulation**
- **Saves time, money, and resources if able to meet research objective with batch simulation rather than HITL experiment**

Summary



- **Improved communication and collaboration within multidisciplinary team**
- **Supported clearly defined experiment objectives with quantitative metrics that can be recognized when achieved**
- **Increased comparability across experiments**
- **New capability to efficiently synthesize data from multiple sources and assess system-level performance goals**
- **Incorporation of findings from one experiment to the next for more strategic investment of resources, better defined objectives, and increased knowledge gained**