

Air Traffic Operations Laboratory

where ideas take flight





Airspace and Traffic Operations Simulation (ATOS) and the Air Traffic Operations Laboratory (ATOL)

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- **What is the ATOL?**
- **Key Airspace and Traffic Operations Simulation (ATOS) Attributes**
- **Simulation Platform**
- **ATOS Experiment Process**
- **ATOL/ATOS upgrades**
- **Research examples using ATOL/ATOS**

What is the ATOL?



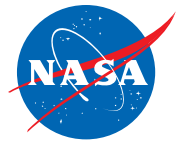
- **ATOL is a World-unique lab facility that supports investigations / proof-of-concept studies to explore NextGen operations, procedures, and technologies.**
- **ATOL was originally created to fill a research gap at LaRC between low fidelity desk-top simulations and the high fidelity Cockpit Motion Facility for human-in-the-loop studies.**
- **Development began more than 10 years ago to study new ATM concept feasibility and distributed ATM flight deck capabilities in the en-route domain. First formal experiment in 2001.**
- **Capability was created as research requirements/goals dictated.**
- **Development philosophy is to develop models to the level of fidelity needed for studies. Simulation has numerous models/capabilities at varying levels of fidelity.**

Multi-fidelity, part-task, air traffic simulation environment in ATOL

Designed to explore inter-aircraft, aircraft / airspace, and air / ground interactions in a NextGen environment

- Concept-level operations research (human decision making, situational awareness, transfer of authority and responsibility)
 - Flight deck automation development
 - Technology / concept performance assessment
 - Initial flight deck interface development (displays, MCDU, EICAS and aural alerts, CPDLC messages, etc.)
- 
- Rapid prototyping
 - Requirements evaluation for future communication, navigation, and surveillance Infrastructure
 - Concept-level Safety Assessment

Simulation Platform



Aircraft Simulation for Traffic Operations Research (ASTOR) Pilot Interface



12 Piloted ASTOR Stations



Over 500 aircraft can be simulated – each aircraft is simulated on a single computer



8 Air Traffic Control Stations

ATOS Modes of Operation

- **Human-in-the-Loop (HITL) Mode:**

- Operations research
 - Flight procedures
 - Feasibility/acceptability
 - Human decision making
 - Situational awareness
 - Transfer of authority and responsibility

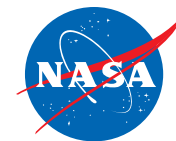


- **Batch Mode:**

- Pilot Model
- Enables stochastic simulation using large sample-sizes to achieve statistical significance



Batch Mode Example



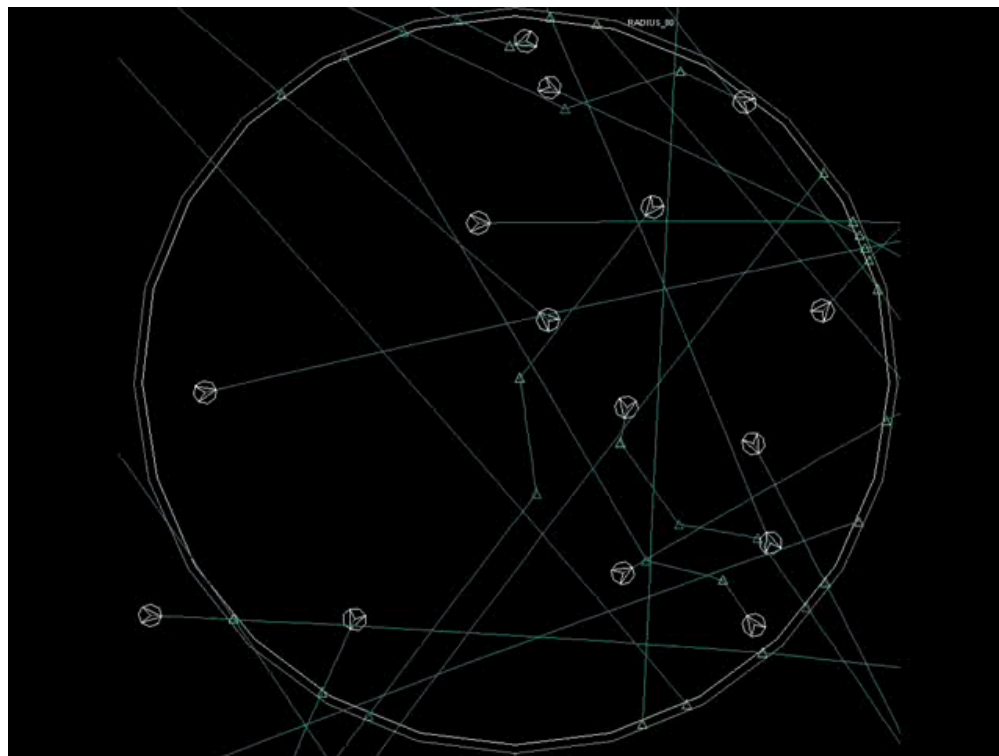
ATOL enables rigorous evaluation of:

- Concept design
- System behavior/performance
- Safety implications
- Airborne separation algorithms
- Airborne spacing algorithms

Variable parameters include:

- Airspace density
- Wind field
- Wind forecast errors
- Pilot delays
- ADS-B interference
- ADS-B range impacts
- Datalink
- 4D trajectories

2X capacity random lateral airborne separation

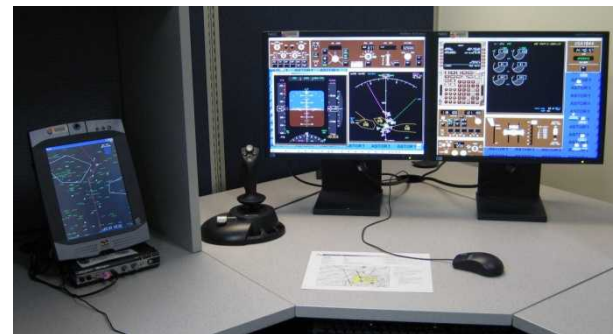


Animation speed is 106 times faster than actual time

ATOL enables subject pilots to fly within a batch simulation environment

ASTOR Components

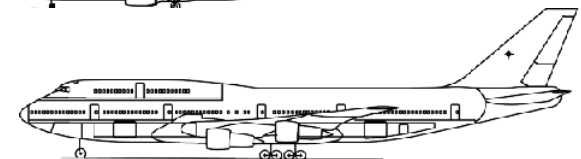
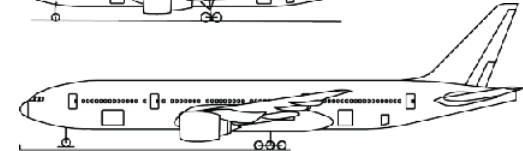
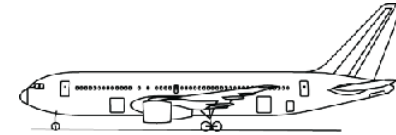
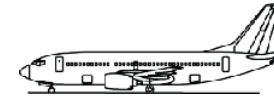
- **6-DOF Airframe models in real-time code**
- **Flight Management System (FMS) and Computer (FMC) Emulation**
 - 777, MD-11
 - Advanced capabilities (e.g., wind fields, continuous descent approaches)
- **Crew Interface – “Generic” Boeing Glass Cockpit**
 - Primary Flight and Navigation Displays, including display control panels
 - Mode Control Panel, Control / Display Unit (MCDU), Radio (utilizes VoIP)
 - Additional “panel” incorporating controls for throttles, flaps, speed brakes, landing gear
- **AutoFlight and AutoThrottle Systems Emulation**
 - Tactical modes control (Boeing)
 - EFIS, EICAS, Autopilot, Flight Guidance
 - Thrust Management Computer
- **Communication, Navigation, and Surveillance Emulations**
 - GPS, INS Sensors
 - Automatic Dependent Surveillance – Broadcast (ADS-B)
 - Controller-Pilot Data Link Communication (CPDLC)
- **ARINC 429 Avionics Bus Emulation**
- **TCAS II**
- **Class III Electronic Flight Bag Emulation**



ATOS Airplane Models

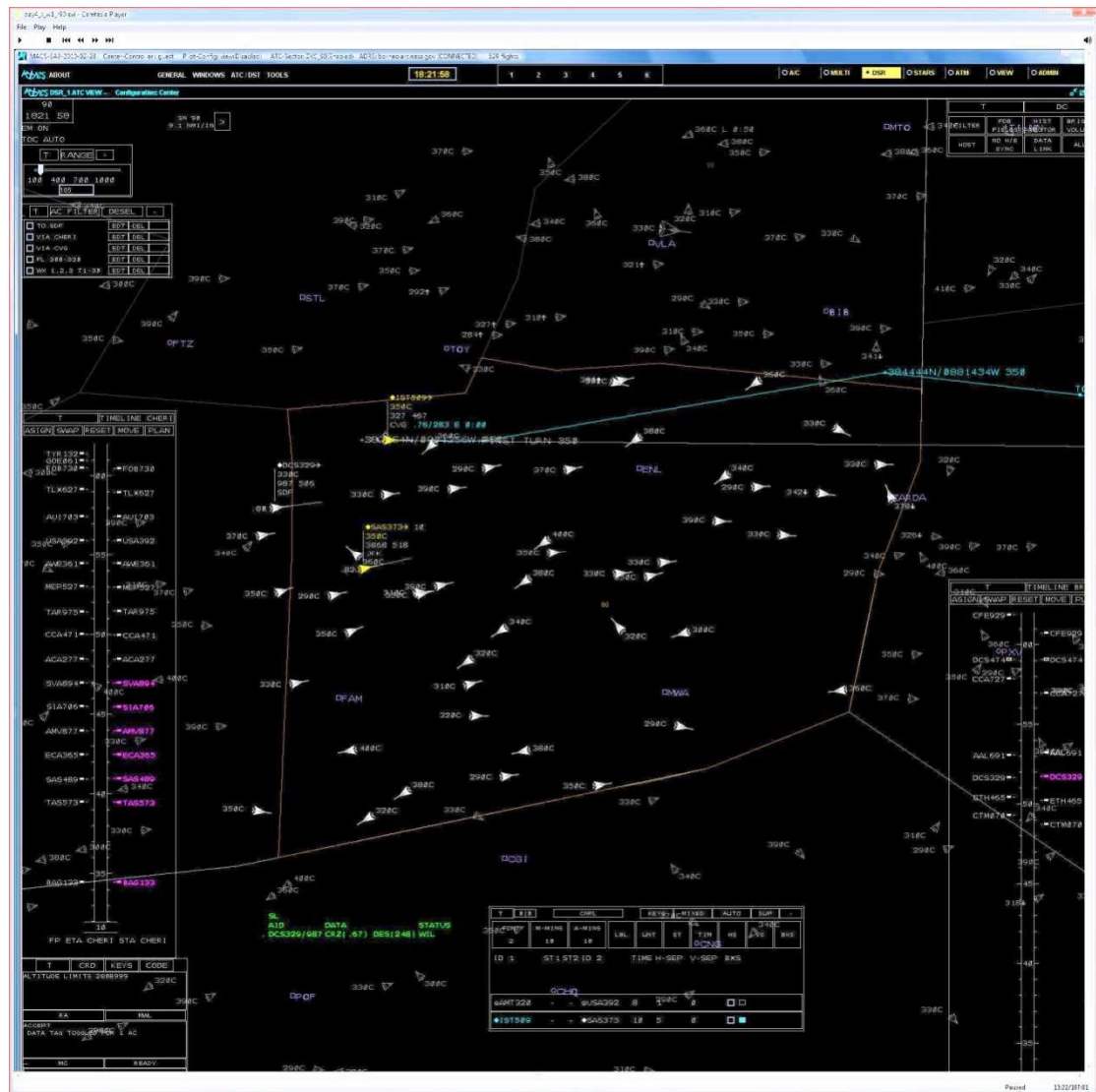


<i>Primary HITL aircraft</i>	
NB250_2E40 NASA_CMF	Narrow body jet, 250K lbs, 2 engine, 40K thrust
<i>Additional batch aircraft</i>	
NB137_2E22	Narrow body jet, 137K lbs, 2 engine, 22K thrust class
WB315_2E48	Wide body jet, 315K lbs, 2 engine, 48K thrust class
WB535_2E77	Wide body jet, 535K lbs, 2 engine, 77K thrust class
<i>Future batch aircraft</i>	
NB053_2E09	Regional jet, 53K lbs, 2 engine, 9K thrust class
NB172_2E27	Narrow body jet, 172K lbs, 2 engine, 27K thrust class
WB875_4E48	Wide body jet, 875K lbs, 4 engine, 48K thrust class



Multi Aircraft Control Simulation (MACS)

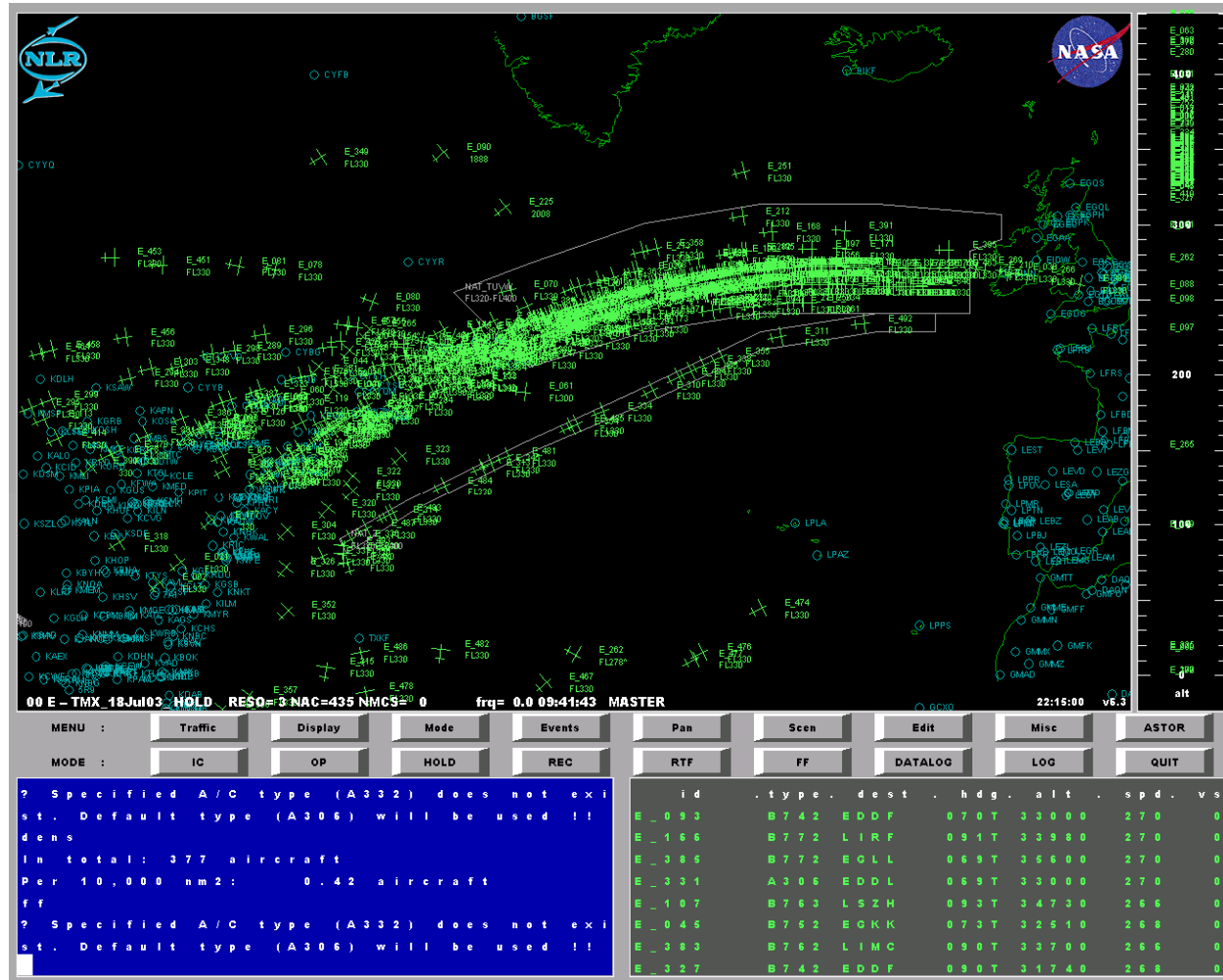
- ARTCC DSR (Display Replacement System) Display
- TRACON STARS (Standard Terminal Automation Replacement System) Display
- Background Traffic Generator



NLR/NASA TMX

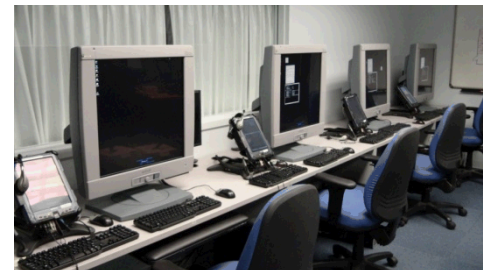


- Real Time and Fast-time simulation
- Background traffic generator

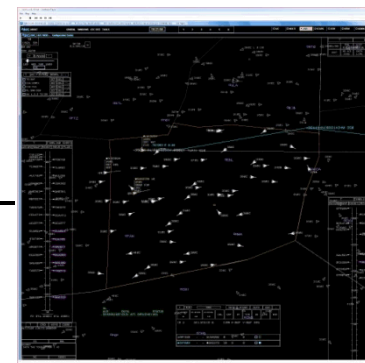


Joint Simulation with Other Labs

Langley Facilities



AVIATIONSIMNET™



Outside Facilities



ATOL Experiment Process

- **The ATOL Experiment Process builds on Center and Branch Processes/Policies for experimentation**
- **The ATOS Team Lead owns the execution of the ATOL Experiment Process**
- **ATOL Experiment Process:**
 - An Implementation Team is assigned at the conclusion of the Initial Branch Management Review.
 - PI works with Implementation Team to develop a Simulation Requirements Document (SRD) and implementation approach
 - Simulation Requirements Review (SRR)
 - The Team Lead, Lead Systems engineer, the ATOL Manager, and senior developers review the SRD with the PI to ensure common understanding of requirements and commit to meeting requirements.
 - Simulation Modification Requests (SMR) are created based on SRD or bugs identified during the process



- **ATOL Experiment Process:**
 - SMRs are actively tracked and managed using a configuration management system
 - Hardware and Software Requirements implemented based on SMRs
 - Scenario Development
 - Simulation Check-out
 - Pls periodically assess the simulation throughout the development cycle, looking for proper ASTOR operation, flight repeatability, and recorded data
 - Dry run
 - Finalization of experiment procedures
 - Last chance to correct software defects
 - Validation of data files
 - Dress rehearsal (for HITL experiments)
 - Formal data collection

Upgrades to ATOL since 2007



- **Lean 6 σ Kaizen Events led to formal experiment and s/w development processes, and operational improvements**
- **8 ATC stations that may serve as ARTCC, TRACON, and / or tower positions**
- **Introduction of “blade” computers**
 - Enterprise solution
 - Increased reliability over individual PCs
 - Ease of maintenance
- **Growth in number of ASTORs to over 500**
- **Upgraded Lab network from 100 Mb to Gigabit Ethernet (3 switches totaling 720 ports of gigabit connectivity)**
- **Electronic pilot survey system**
- **Dedicated data moving capability with fiber connection to the Center Storage System with 4 petabytes of storage**
- **Weather server with 1 year’s worth of weather data**

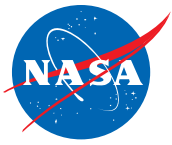
Upgrades to ATOL since 2007 (Cont'd)



New software to provide hardware and simulation administration

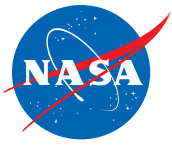
- **ATOLNet:**
 - Control of ATOL's network infrastructure
 - The network is divided into multiple virtual local area networks, called "strings," to allow multiple experiments to run in parallel
 - Allows for moving machines on and off strings without having to physically rewire the network
- **Simulation Master Control Program (SMCP):**
 - Batch control tool that allows use of multiple strings in parallel
 - Load balance between strings to maintain maximum utilization
 - Increases availability of computers for simulation runs, e.g., distributes simulation scenarios to other strings in event of a failure
- **Common Experiment Operations Framework (CEOF) – an application layer providing system and software management**
 - Enabled ATOL to process 528,000+ TMX experiment scenarios across 64 nodes in less than 8 hours time

Future ATOL Upgrades



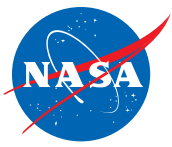
- **ASTOR prototype HITL stations under development**
 - Single pilot
 - Reconfigurable touch screen display
 - Out the window view
- **ASTOR Crew Research Station under development**
 - 2 pilots
 - Knob and pushbutton pilot interface
 - Out the window view
- **Additional piloted ASTOR stations**
 - Expands capacity for conducting HITL experiments
- **Incorporate UAS Experiment Capability**

Upgrades to ATOS since 2007



- Increased number of airplane models
- MACS integration
- Auto Scenario Generation Tool
- Dynamically configurable FAA navigation databases
- Crew flight-deck interfaces for multi-crew ASTOR
- Simulation Hardware flight control interfaces
- Integration of FAA TCAS II algorithm with ASTOR
- Added 4D capability to the Research Prototype Flight Management System
- Asynchronous (“lock-step”) batch capability
- Update ADS-B model (future development)

Examples of Research Conducted in the ATOL



- **Flight Deck-based Separation Assurance**
 - Airborne Separation Management
 - Airborne Trajectory Management
- **Airborne Precision Spacing and Interval Management**
 - Flight Deck Merging & Spacing
 - Single and Parallel Runways
- **ADS-B In-Trail Procedures**
- **4D-FMS Technology Development**
- **Collision Avoidance for Airport Traffic**

Backup Slides

