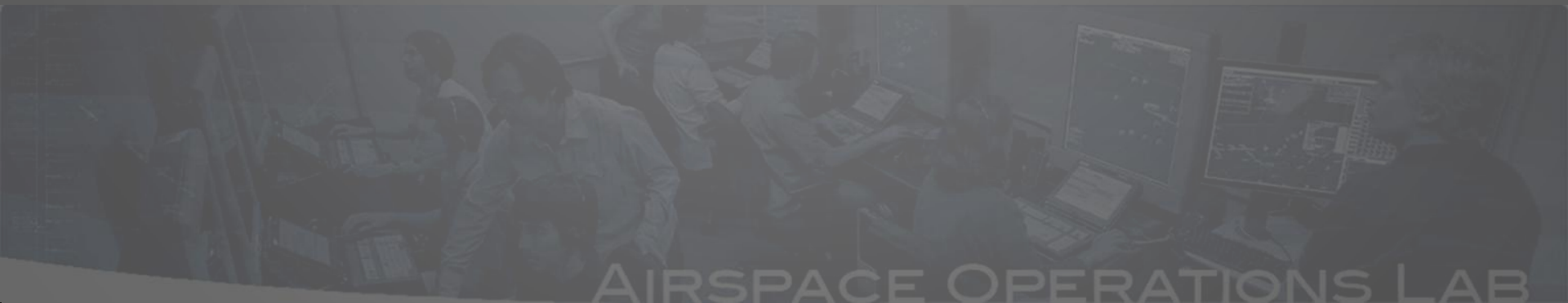




MACS Overview

Tom Prevot

NASA Ames Research Center





Multi Aircraft Control System (MACS)

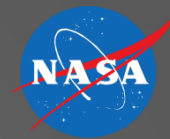
What is MACS?

- Research software for simulating and evaluating air traffic operations



Intended Use

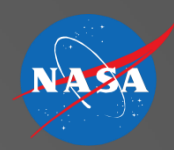
- Provide a better understanding of roles, responsibilities, and requirements for human operators and automation in future air traffic management (ATM) systems.
- Develop and evaluate operational concepts and technologies for the Next Generation Air Transportation System (NextGen) in a high-fidelity human-in-the-loop (HITL) environment.



Multi Aircraft Control System (MACS)

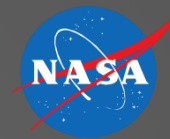
AIR TRAFFIC CONTROL OPERATIONS NEAR-TERM / 2016

18 aircraft are allowed in Airspace “sectors” at any given time
Teams of 2 Air Traffic Controllers per sector required for high traffic
Video shows 8 controllers handling ~75 aircraft



Air Traffic Control





Multi Aircraft Control System (MACS)

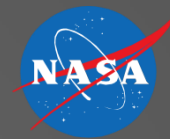
AIR TRAFFIC CONTROL OPERATIONS MID-TERM / 2022

25 aircraft are allowed in Airspace “sectors” at any given time
1 or 2 Air Traffic Controllers per sector possible
Video shows 7 controllers handling ~150 aircraft



Air Traffic Control in the Mid-Term





Multi Aircraft Control System (MACS)

AIR TRAFFIC CONTROL OPERATIONS FAR-TERM / 2030

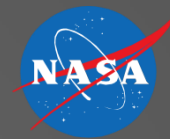
30, 40, or 50 aircraft are allowed in Airspace “sectors” at any given time
1 or 2 Air Traffic Controllers per sector possible
Video shows 8 controllers handling ~300 aircraft

AIRSPACE OPERATIONS LAB



Air Traffic Control in 2030 ...





Multi Aircraft Control System (MACS)

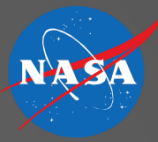
AIR TRAFFIC CONTROL OPERATIONS CONTROLLER MANAGED SPACING (CMS) IN THE TERMINAL AREA

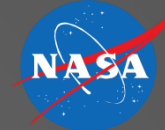
5-10 aircraft are handled by Terminal area controllers at any given time

1 Air Traffic Controllers per sector

Video shows 5 controllers handling ~20 aircraft

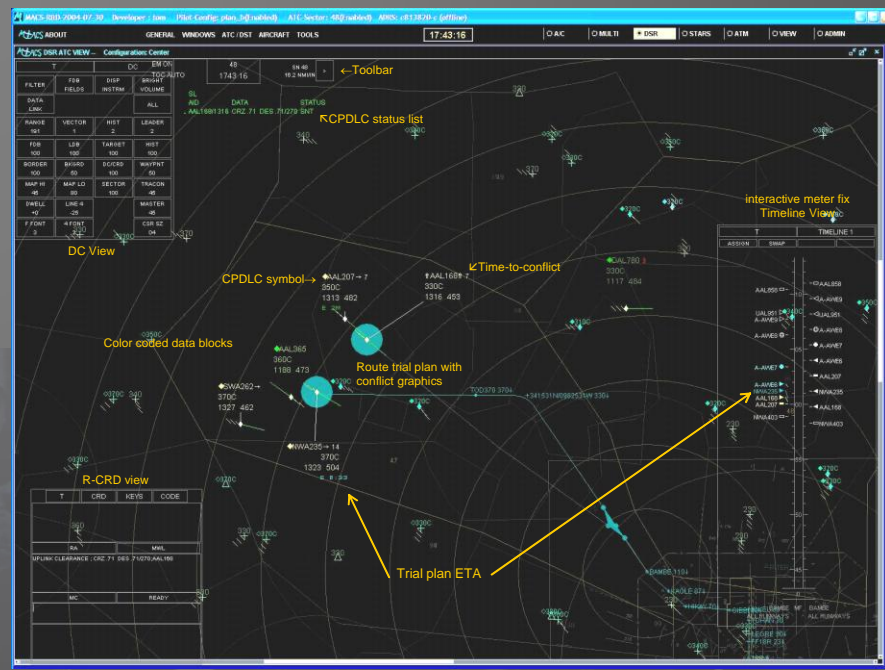
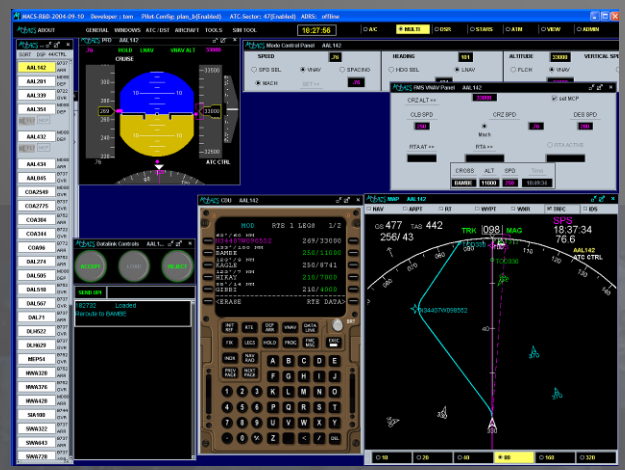
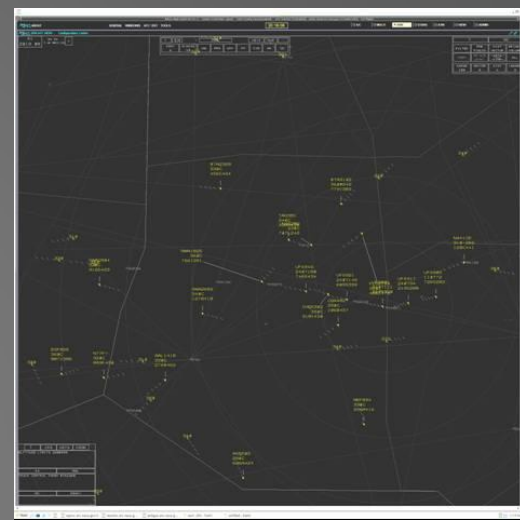
Terminal Area – Controller Managed Spacing

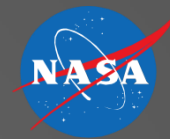




RECAP: What is MACS ?

- Portable JAVA program that emulates and simulates current and future air traffic operations in the NAS
- A comprehensive environment for large scale and small scale real-time integrated air/ground simulations
 - From standalone laptop application to 50+ networked operator stations
- Rapid prototyping environment and test bed for future air traffic concepts
 - ATC/ATM automation and interfaces
 - Flight deck automation and interfaces
 - Air/ground technologies and procedures
- System for education and training





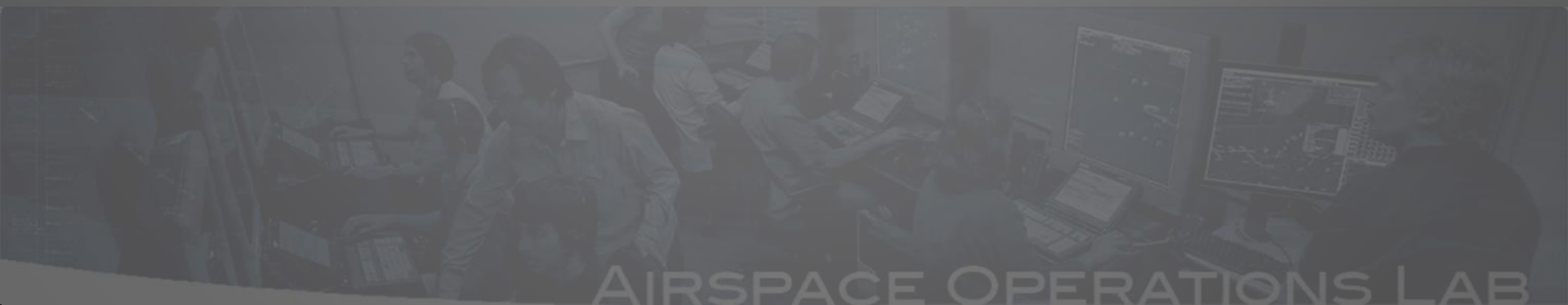
What is the Main Idea?

- All operators (human and automation) look at the same situation from different viewpoints
 - MACS maintains a central representation of the air traffic situation and provides access to all the objects stored therein
 - The different viewpoints are realized through a variety of displays and input devices
- All operators (human and automation) need to perform many of the same functions
 - MACS provides a knowledge-base with classes and methods for commonly used functions like route parsers, trajectory generators, performance calculators, etc.
 - Displays and automation access the common knowledge-base tailored to their task



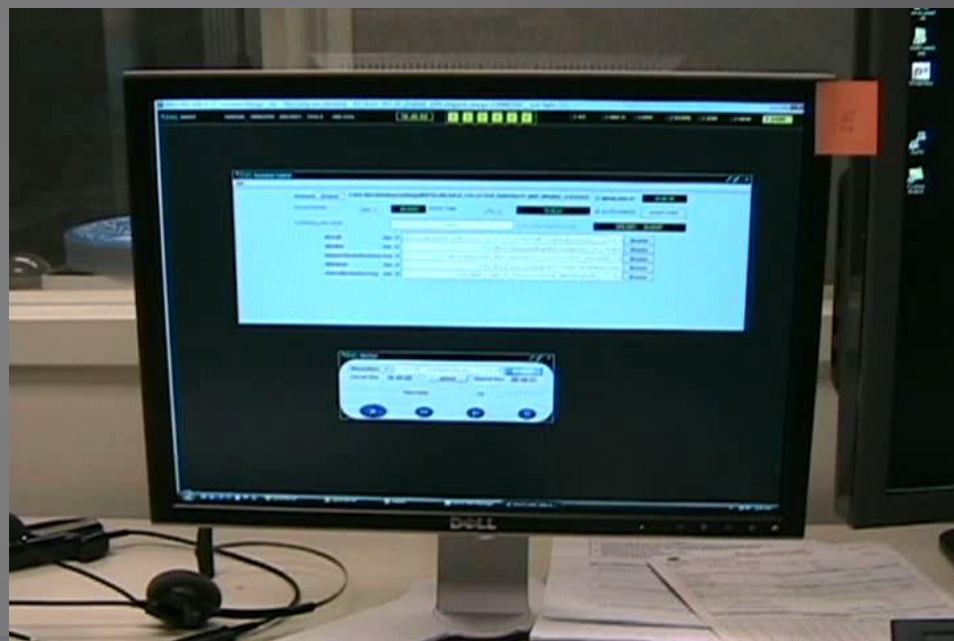
Multi Aircraft Control System (MACS)

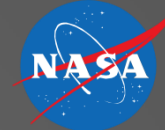
CAPABILITIES



MACS Simulation in the AOL

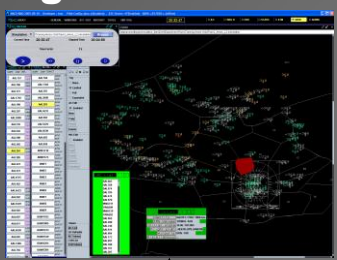
- Experiment management
- Scenario Generation
- Flight decks and flight management
- Air traffic management
- Air traffic control (domestic, oceanic, approach)
- Advanced Automation
- Weather



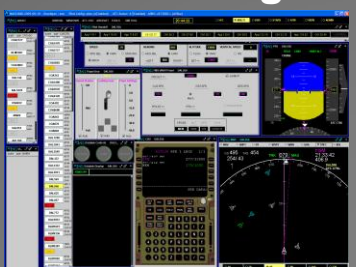


MACS Capabilities

Air traffic simulator /target generator



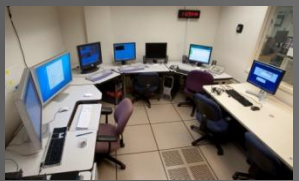
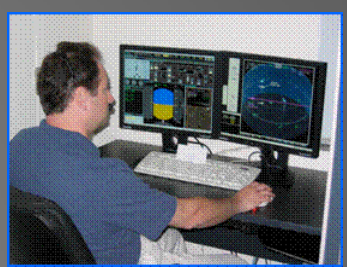
Multi aircraft autonomous agent



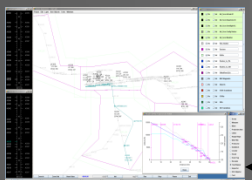
Multi aircraft control flight deck



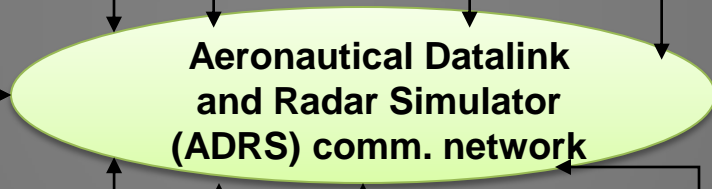
Single aircraft flight deck (B777 style)



Experiment control



Data collection Analysis



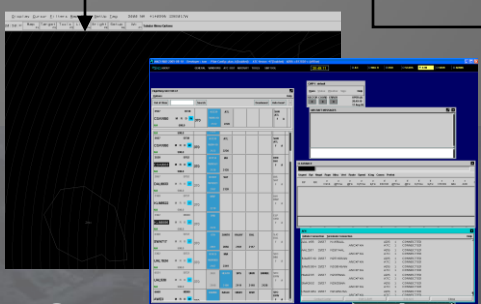
Traffic and weather generation



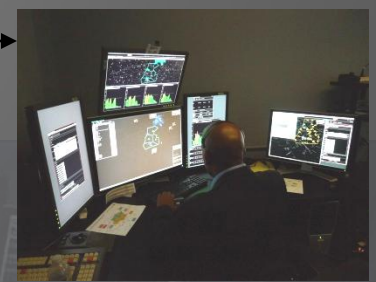
Center controller workstation (DSR)



TRACON controller workstation (STARS)



Oceanic controller workstation (ATOP/Ocean21)

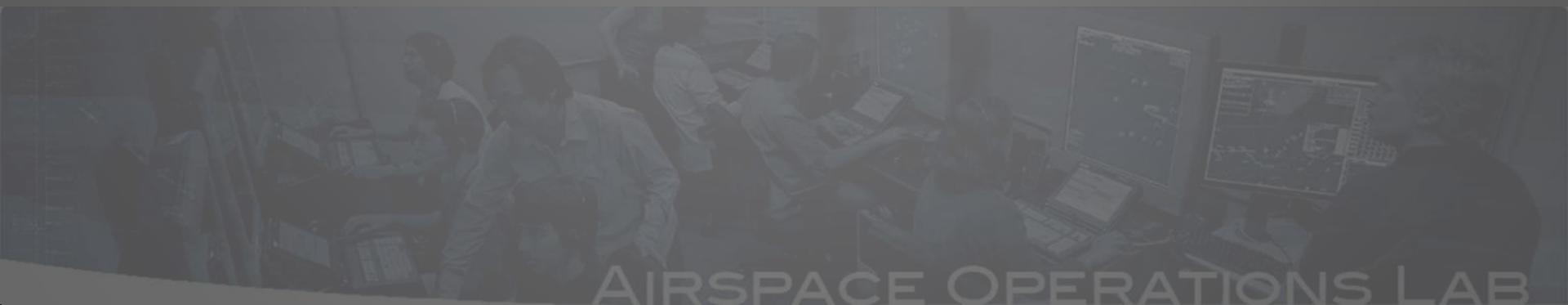


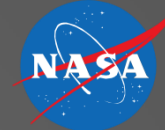
Traffic flow and airspace management workstations



Multi Aircraft Control System (MACS)

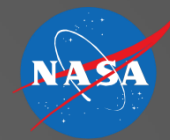
REAL-TIME CAPABILITIES





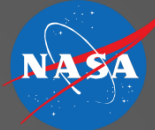
Aircraft Simulation and Flight Deck Displays





Aircraft Simulation and Flight Deck Displays

- Full flight simulator
- Selectable dynamics model (Motion Predictor, 4DOF/PAS-Aero, ...)
- Flight deck for external target generator
- Performance models for the majority of current aircraft types
- Selectable equipage
- Glass cockpit displays
- Full FMS capabilities with RTA (Also used in Standalone mode)
- ASAS spacing and merging logic
- Conflict detection logic for (airborne self-separation)
- FANS – style CPDLC interface
- Interface to advanced Cockpit Display of Traffic Information (CDTI)
- Automatic processing of selected data link messages with predefined delays
- Agent support for pseudo pilots (reminders or automation)

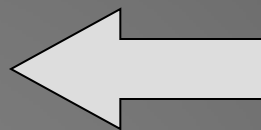


Aircraft Simulation and Flight Deck Displays

This screenshot shows the MACS pilot interface for a single aircraft, MEP54. The interface includes several key components:

- Top Panel:** Shows system status (AC, MULTI, DSR, STARS, ATM, VIEW, ADMIN) and the current time (17:13:39).
- Flaps/Gear Panel:** Controls for Speed Brakes, Landing Gear, and Flaps Settings.
- MCP (777 Style):** Mode Control Panel with various buttons for altitude, heading, and other flight parameters.
- Datalink Controls:** Buttons for ACCEPT, LOAD, and REJECT.
- Datalink Display:** A display for sending uplink data.
- PFD (Primary Flight Display):** Shows airspeed, altitude, and other primary flight information.
- CDU (Crew Display Unit):** Displays active flight data for BITE 1, including altitude and speed.
- Radio Panel:** Shows active and standby frequencies.
- Central Display:** A large radar display showing the aircraft's position (317) and other nearby aircraft (370, 320, 330).

MACS pilot interface with FDDRL's Cockpit Situation Display (CSD) for participant pilot working one aircraft



MACS pilot interface for a pseudo pilot working multiple aircraft simultaneously



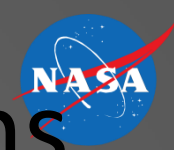
This screenshot shows the MACS pilot interface for a pseudo pilot working multiple aircraft simultaneously, specifically NWA935. The interface is more complex, showing multiple data panels:

- Top Panel:** Shows system status and the current time (23:31:15).
- Flight Deck Panels:** Includes MCP, Datalink Controls, Datalink Display, and PFD.
- CDU:** Displays active flight data for BITE 1, including altitude and speed.
- Radio Panel:** Shows active and standby frequencies.
- Central Display:** A large radar display showing the aircraft's position (256/43) and other nearby aircraft (370, 320, 330).
- Bottom Panels:** Includes a keyboard layout and various control buttons.



ATSP capabilities and workstations





ATSP capabilities and workstations

- Highly Advanced NextGen automation:
 - Multi-layered rapid feedback conflict probing
 - Weather penetration probe
 - Data comm. integration
 - Fully automated, semi-automated, manual operations
 - AAC Auto-Resolver with Weather avoidance *(Erzberger et al.)
 - Interactive and closed loop automated
 - TSAFE conflict resolver (Erzberger & Heere)

- New Paradigms in Display Design
 - High-lighting/ low-lighting scheme with interactive filters
 - Multi Aircraft Selection and command processing
 - Multi aircraft trial planning

- Complexity Management
 - Interactive graphs and tables for various complexity factors

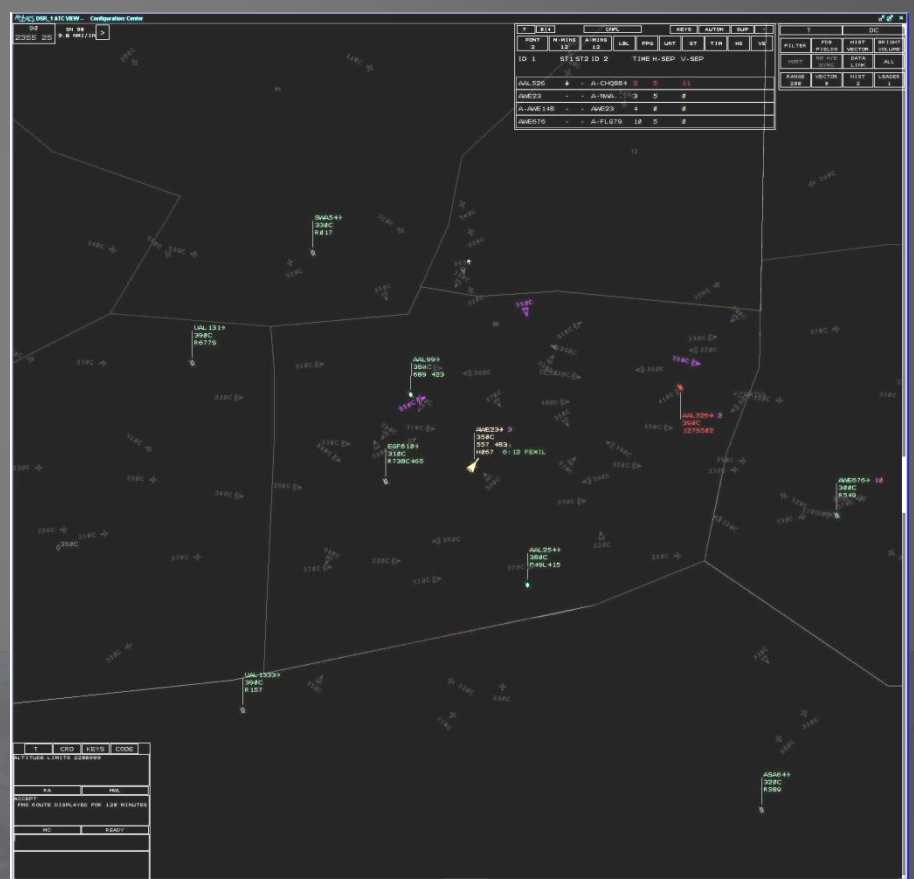
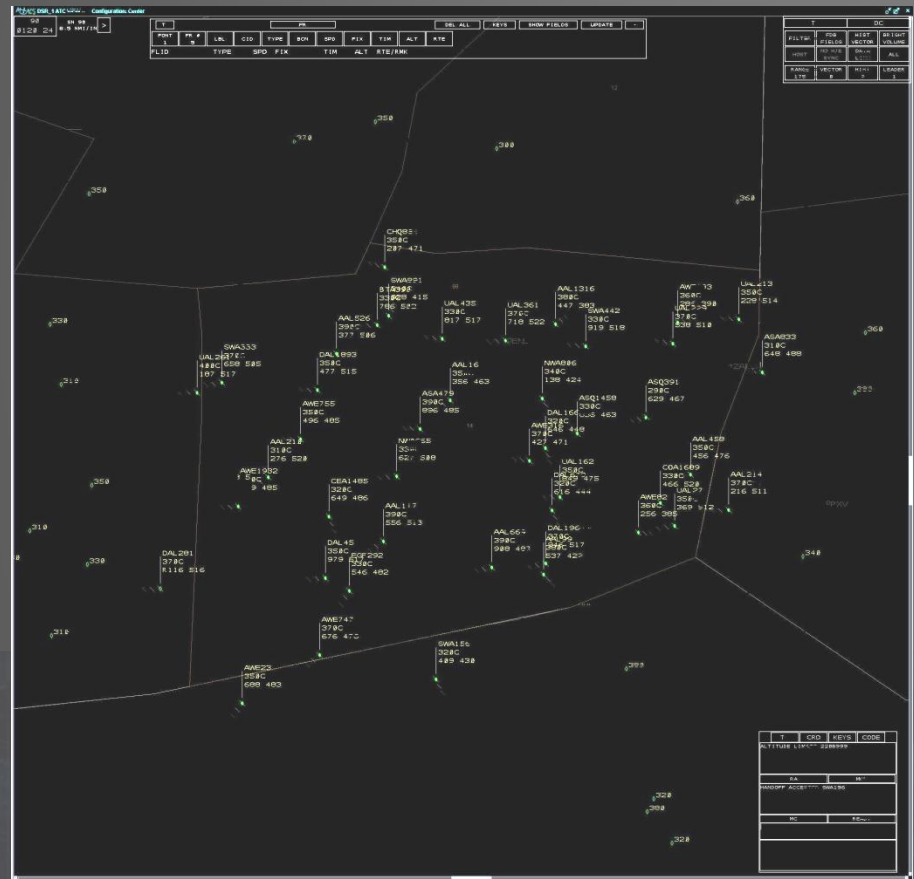


ATSP capabilities and workstations

- NAS Controller workstation emulations:
STARS, DSR, ATOP/Ocean 21, ERAM to come
- Selectable data sources:
 - Perfect, Center radar, TRACON radar, ADS-B
- Multi-Center adaptation
- Advanced ATSP automation:
 - 4D trajectory generation for flight plan routing, scheduling, reported FMS trajectories, ADS-B reported state and flight control system targets
 - Arrival scheduler and timelines
 - Medium-term Conflict detection
 - Trial planning and speed advisory functions for metering support
 - Automation for automatic transfer of communication and RTA uplinks



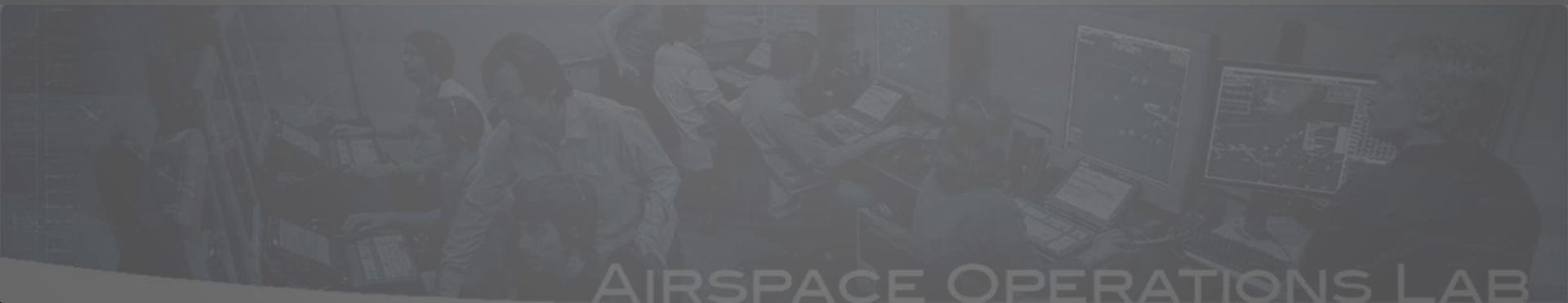
ATSP capabilities and workstations

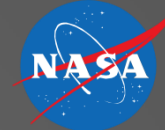




Multi Aircraft Control System (MACS)

OFF-LINE CAPABILITIES





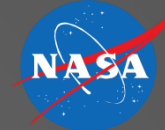
MACS Scenario Editor

- Spreadsheet-style editor
 - Error checking and correction
 - Automatic functions
 - Load graphs

The screenshot shows the 'MACS AC Table Editor' window with a spreadsheet of flight data. The columns include call sign, altitude, mach, route, filedRoute, timeToEnter, startPointName, atcType, indicatedDir, inMach, inVnav, and inI. Below the spreadsheet, the 'MACS Load Graph Window' displays six graphs for different flight numbers: ZKC_92, ZKC_94, ZKC_90, ZID_81, ZID_80, and ZKC_98. Each graph shows a load profile over time.

The screenshot shows the 'MACS Scenario Editor' interface. On the left, a map displays aircraft trajectories and weather data. On the right, there are several panels: 'Configuration Center', 'Connective Weather Editor' with a time slider, and 'Simtool' with a 'Start Time' and 'Stop Time' control.

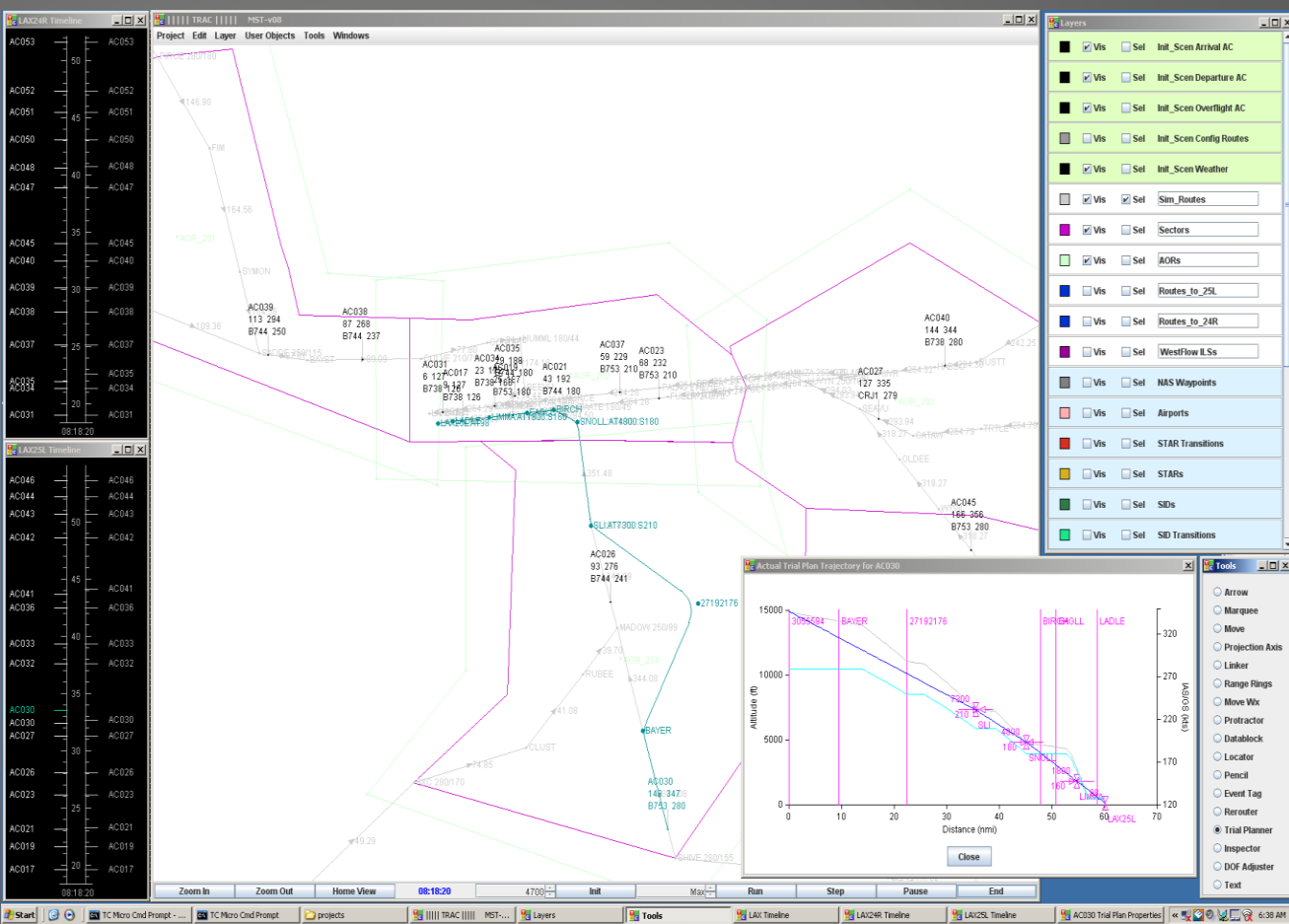
- Graphical editor
 - Trajectories for aircraft and convective weather
 - Time slider
 - Weather and conflict probing
 - Trajectory planning



TRAC

(TCSim Route Analyzer/Constructor)

- Airspace design
- Fast time simulation
- Data analysis

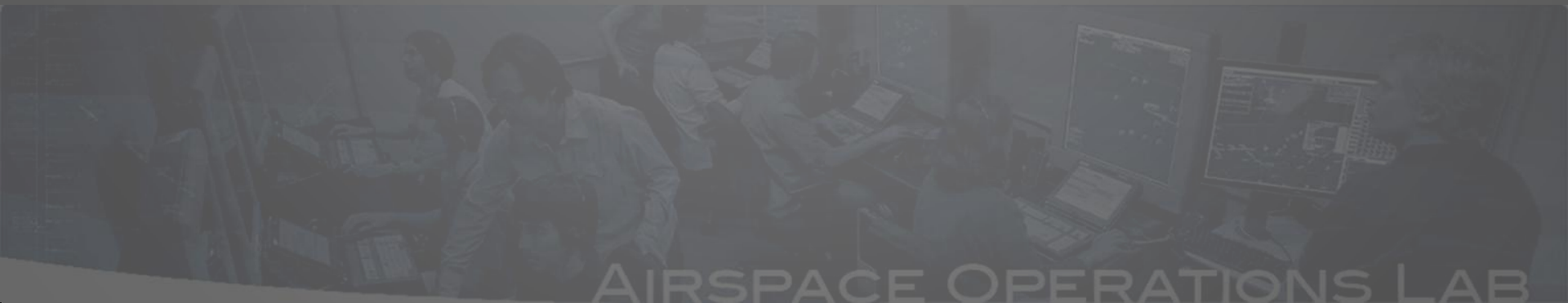


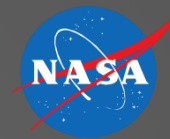
Wednesday 8/4 1300 hrs AIAA-2010-8364
Graphical Specification of Trajectory Modification Options in TRAC T. Callantine



Multi Aircraft Control System (MACS)

SOFTWARE

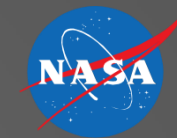




MACS Software (state 2010)

- 415,000 Source Lines of Code (JAVA)
- 2230 files
- Up to 194 parallel threads
- Unique automatic thread monitoring and restart
- Same software used at all MACS stations in a simulation
- Standalone version provides all capabilities of distributed simulation
- Very robust and scalable:
E.g. experiment runs in 2010 of 3 hour length, 3000+ aircraft, 16 controllers and 10 pilots

Basic Software Architecture



Thread Name	✓	✓	□	1000	1222	1127
CatsPredictorThread:Thread-116	✓	✓	□	1000	1222	1127
CatsInterpreterThread: Thread-117	✓	✓	□	1000	1222	1127
MsgHandlerThread:Thread-118	✓	✓	□	5000	5188	5120
AutoControllerThread:Thread-119	✓	✓	□	1000	1322	1433
AtcAuxiliaryThread:Thread-121	✓	✓	□	2000	2133	2114
AtcFlightStateTrackerThread:Thread-122	✓	✓	□	250	551	482
AtcSchedulerThread:Thread-123	✓	✓	□	1000	1222	1244
ConflictAlertThread:Thread-124	✓	✓	□	3000	3135	4206
SimulationManagerThread:Thread-125	✓	✓	□	470	631	832
PlayBackManagerThread:Thread-126	✓	✓	□	1000	1222	1126
PlayBackDataHandlerThread:Thread-127	✓	✓	□	1000	1222	1127
ProgressManagerThread:Thread-128	✓	✓	□	500	631	667
SingleAcSimManagerThread:Thread-129	✓	✓	□	220	220	333
WeatherManagerThread:Thread-130	✓	✓	□	1200	1479	1323
WeatherStationThread:Thread-131	✓	✓	□	5000	5188	5119
AudioManagerThread:Thread-132	✓	✓	□	1000	1222	1127
GuidanceControllerThread:Thread-133	✓	✓	□	2000	2133	2155
TesterThread:Thread-134	✓	✓	□	1000	1222	1126

MACS LOGIN

Operator-Mode

Single-Aircraft-Pilot Multi-Aircraft-Pilot

Center-Controller TRACON-Controller Oceanic-Controller

Planning-Controller Traffic-Manager

Observer Analyst

Developer Developer-Lite Simulation-Manager

new user

tom

guest

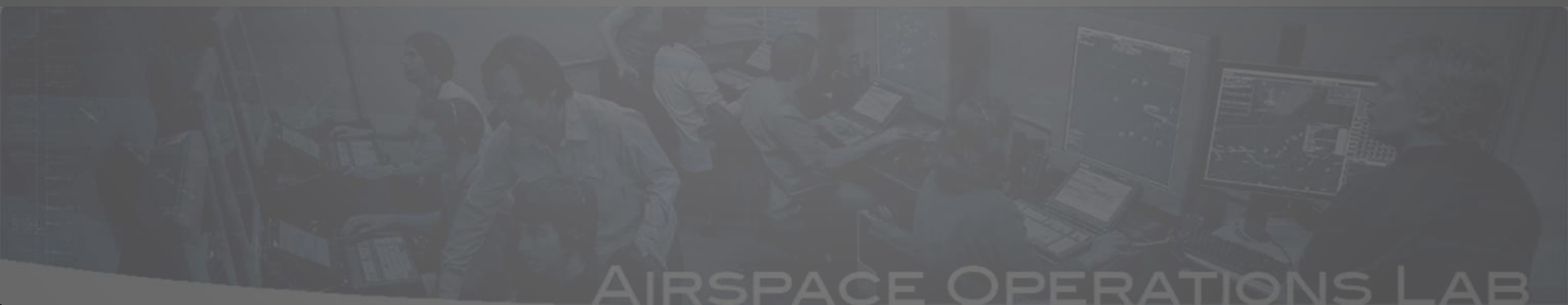
AirSideConflictProbeThread:Thread-151	✓	✓	□	6000	6450	6442
AcinputMsgThread:Thread-152	✓	✓	□	200	200	278
ThreadControllerThread:Thread-4 : Thread Control	✓	✓	□	1000	1322	1118
WinUpdaterThread:Thread-5 : CATS State Window	✓	✓	□	1000	1222	1114
WinUpdaterThread:Thread-6 : CATS Config	✓	✓	□	1000	1222	1117
WinUpdaterThread:Thread-7 : CATS Model Window	✓	✓	□	1000	1222	1115

- Each MACS station runs the identical software independently
- 1 of 12 operator modes can be selected
 - Low: TRACON-Controller:
 - High: Developer:
- Thread Management Process handles 150 – 200 threads
- Each functionality and each window is controlled by it's own thread

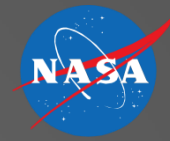


Multi Aircraft Control System (MACS)

RESEARCH EXAMPLES



Recent Research in the AOL (2010-2011)

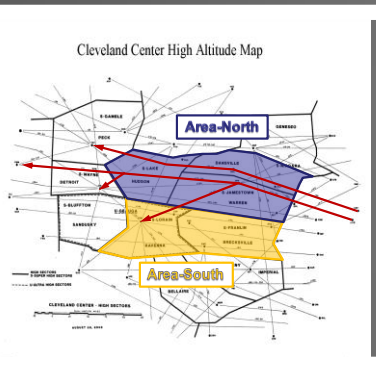
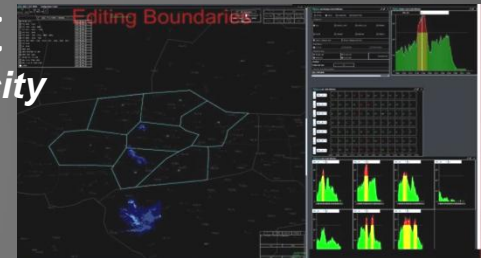


Flow Based Trajectory Management

Use tools and procedures to develop and coordinate trajectory clearances that span multiple sectors, meet traffic management objectives and provide user benefit

Flexible Airspace Management

Dynamically change airspace to distribute capacity more evenly between sectors

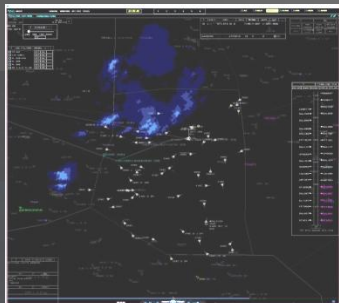


Corridors-In-The-Sky

Use flow corridors for dominant homogeneous flows to increase airspace throughput

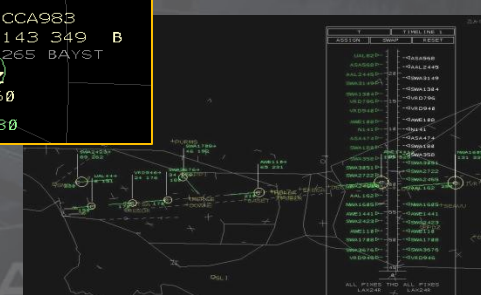
Separation Assurance/Functional Allocation

Use automation to manage aircraft separation to achieve much higher airspace capacity than today



Controller Managed Spacing

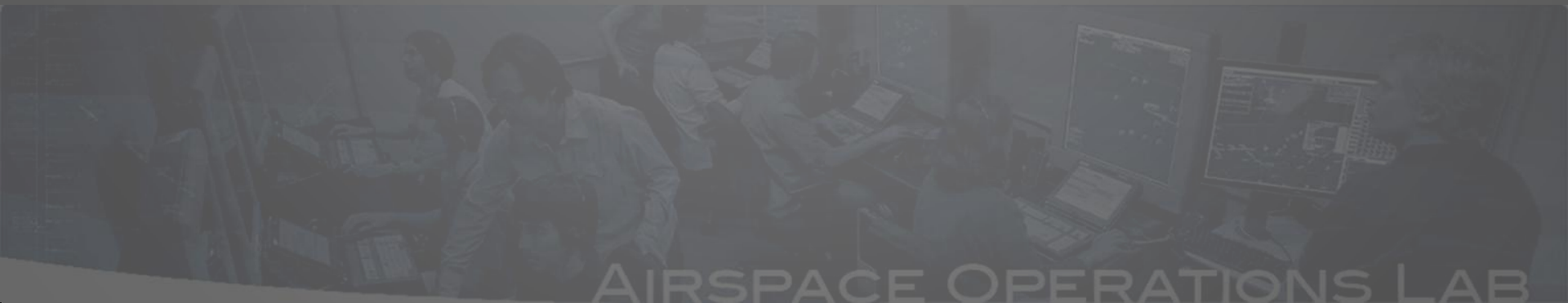
Use tools, displays and procedures to enable Optimized Profile Descents with High Throughput

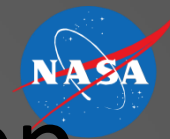




Multi Aircraft Control System (MACS)

WORKSHOP





What to expect from this workshop

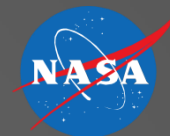
- Overview of MACS capabilities
- Introduction into MACS simulation architecture
- Detailed discussions on primary functions (Center/TRACON ATC, pilot)
- Instructions and hands on training on installation, configuration and running a standalone simulation
- Discussion of scenario and weather Editor
- Data collection and analysis
- Opportunity for questions



Tuesday (01/10/2012)

Briefings

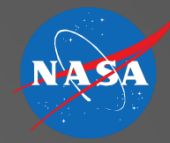
08:30	Intro and MACS Overview
09:40	Break
10:00	MACS/ADRS simulation architecture and integration with ATOS and TMA
11:00	Using MACS to simulate aircraft operations <i>Simulation Manager and Flight Deck Stations</i>
12:00	Lunch
1:00	Basic Air Traffic Control Operations.
1:30	Using MACS to simulate near-term air traffic control operations. <i>Focus ATD-1, Center/TRACON workstations, Scheduling, CMS</i>
2:45	Break
3:00	Using MACS to simulate far-term automated air traffic control operations. <i>Focus on Separation Assurance</i>
3:45	Developing MACS Software
4:30	End of day



Wednesday (01/11/2012)

Hands-On Training with standalone version of MACS

8:30	Installing MACS
9:40	Break
10:00	Preparing and running a MACS simulation
11:00	MACS Data Output and Analysis
12:00	Lunch
1:00	Scenario Editing in MACS
2:10	Break
2:30	hands on training (ATD-1 (CMS) standalone setup, SA standalone setup)
4:30	End of Day



What else to expect from this workshop

- INFORMATION OVERLOAD
- VARIOUS ITEMS TO TAKE HOME
- Many More Questions

The MACS-Training Team (@LaRC)



- Chris Cabrall
- Sarah Gregg
- Michael Kupfer
- Joey Mercer
- Tom Prevot
- Terry Smith

