A Multi-fidelity Simulation Environment for Human-in-the-loop Studies of Distributed Air Ground Traffic Management

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Acknowledgements

Major Contributions for

- Creating the initial simulation environment:
  - NASA Ames Research Center: Dr. Stephan Romahn, David Encisco and the ACFS staff
    NASA Langley Research Center: David Williams and Rosa Oseguera-Lohr.
- Expanding the simulation environment to DAG-TM capabilities at NASA Ames:
  - “CDTI-group” headed up by Walter Johnson and Vernol Battiste with their research and development staff
  - the “MACS development team”
  - the AOL support staff.

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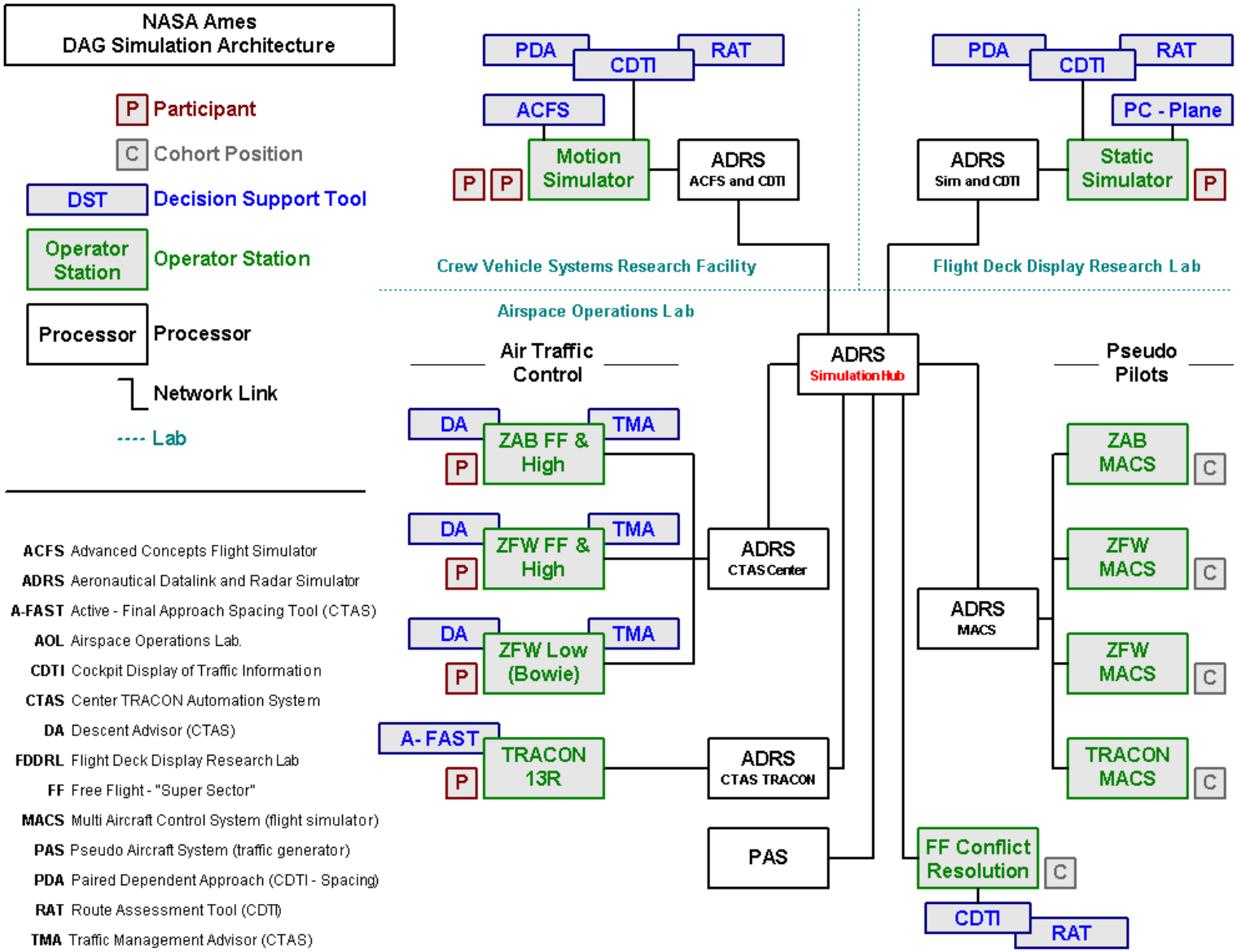
Background

- Air traffic management research of future concepts needs to address all players including flight crews, air traffic controllers/ managers and airline dispatchers adequately

- Among the ways of addressing the problem are
  - Include many participants (pilots, controllers, dispatchers) in a given air traffic simulation to work all sides of the problem adequately.
  - Include automated agents for side aspects and human participants only for the focus area of the research.

Simulation Architecture



ADRS*- The Distributed Simulation Hub

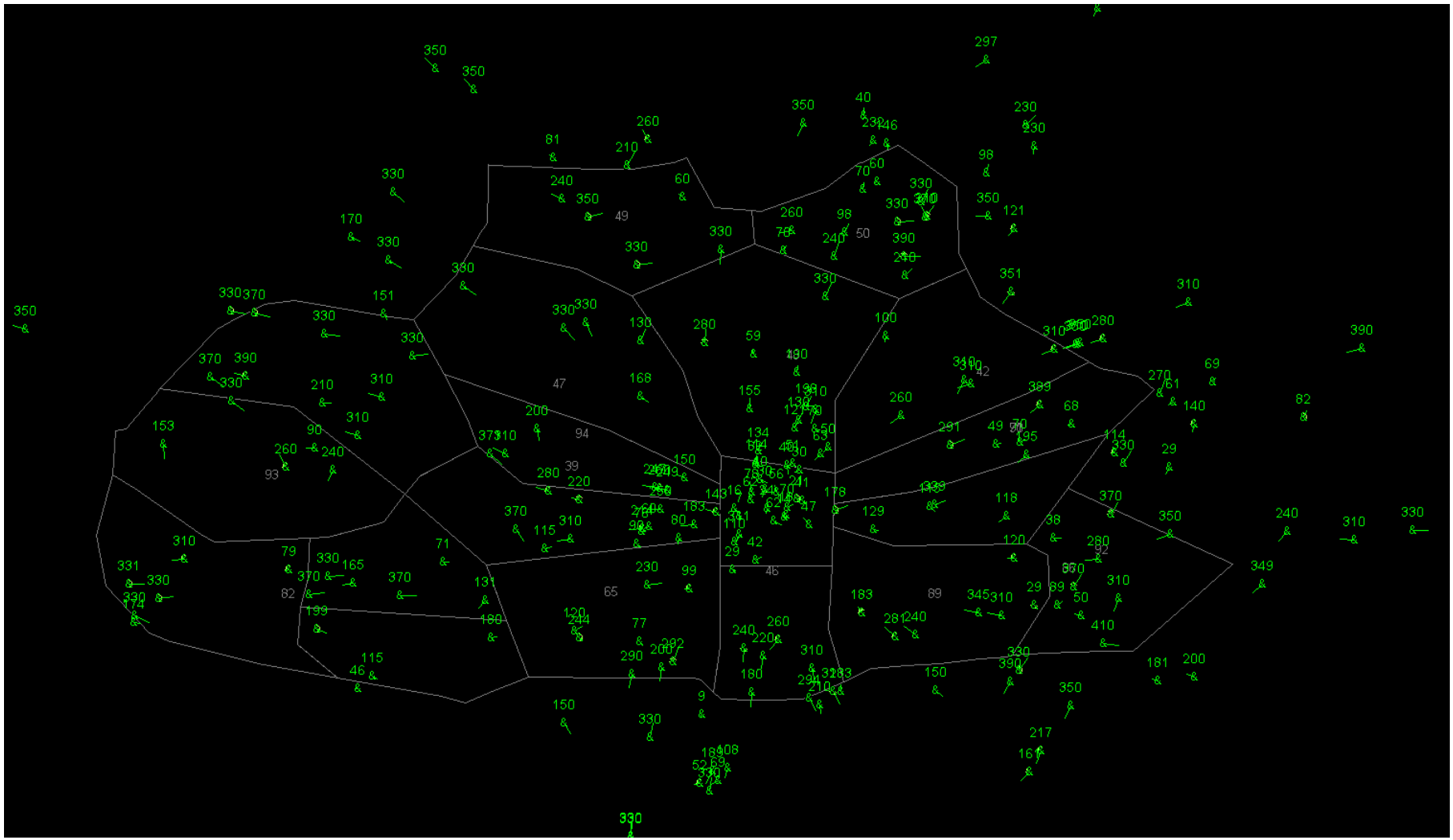
- **Aeronautical Datalink and RADAR Simulator*

- Distribution of communication load:
  - Unlimited number of servers and clients can be connected by adding identical ADRS processes to the simulation network that share their information
- Host emulation
- Radar simulation
- Datalink simulation
- Aircraft state and trajectory data harmonization and maintenance
- Process control and monitoring

Aircraft target generation

Full mission flight simulators
Pseudo Aircraft System PAS

Desktop based flight simulators
Prerecorded traffic



Flight Deck Simulation

Research Flight Deck
(NASA LaRC)

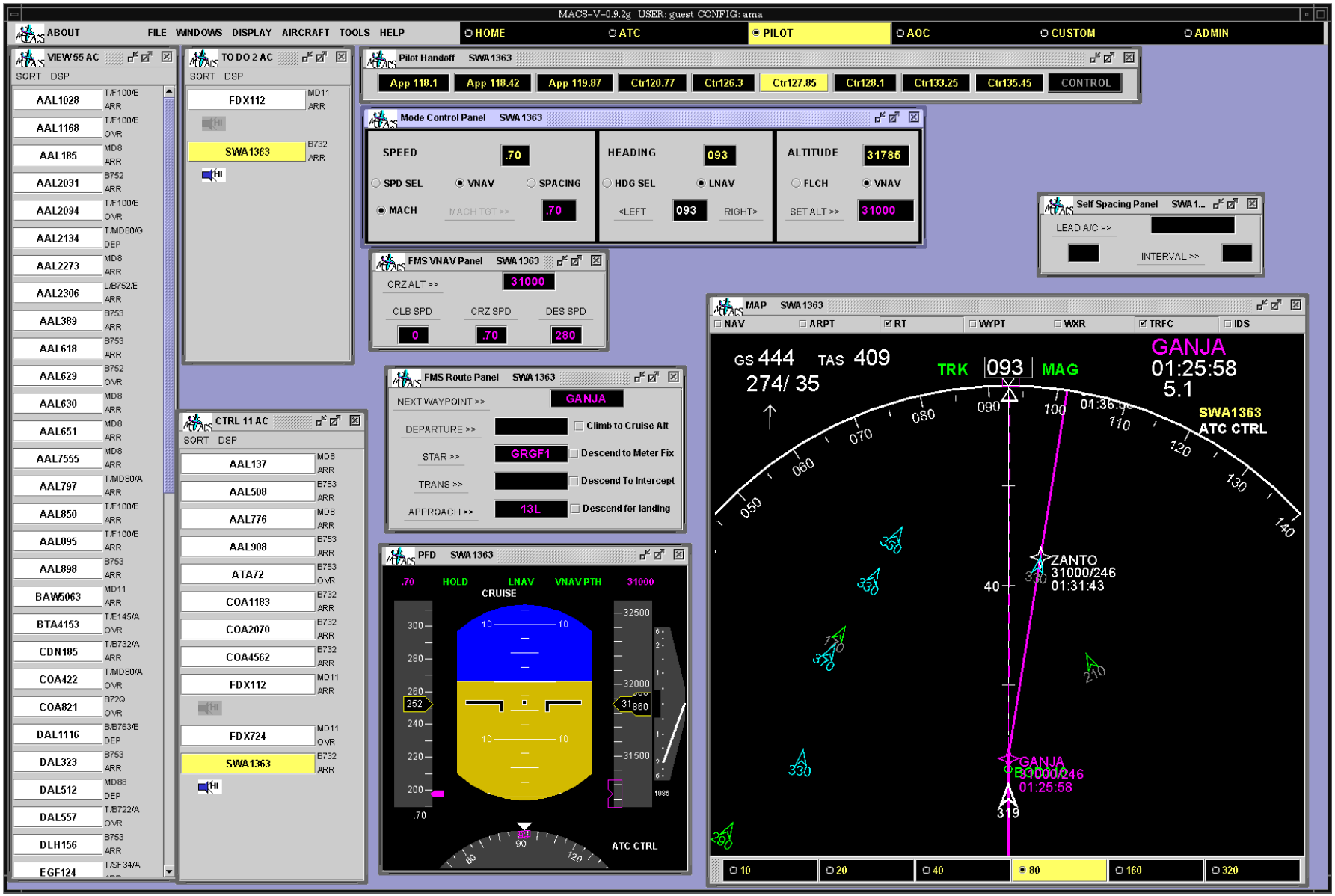
Advanced Concepts Flight Simulator
(NASA ARC)

Multi Aircraft
Displays and
Controls
(NASA ARC)

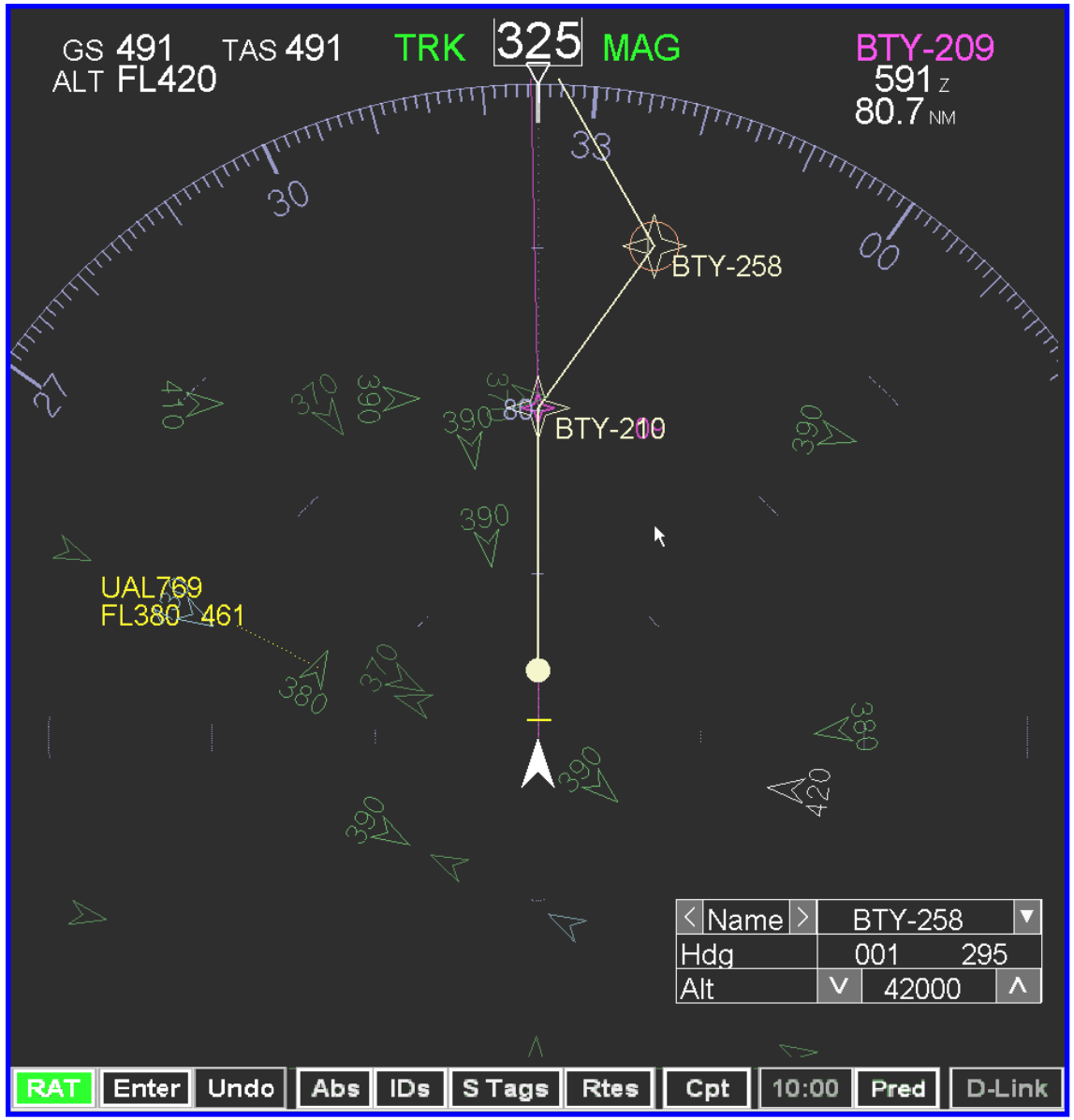
Desktop based single pilot station

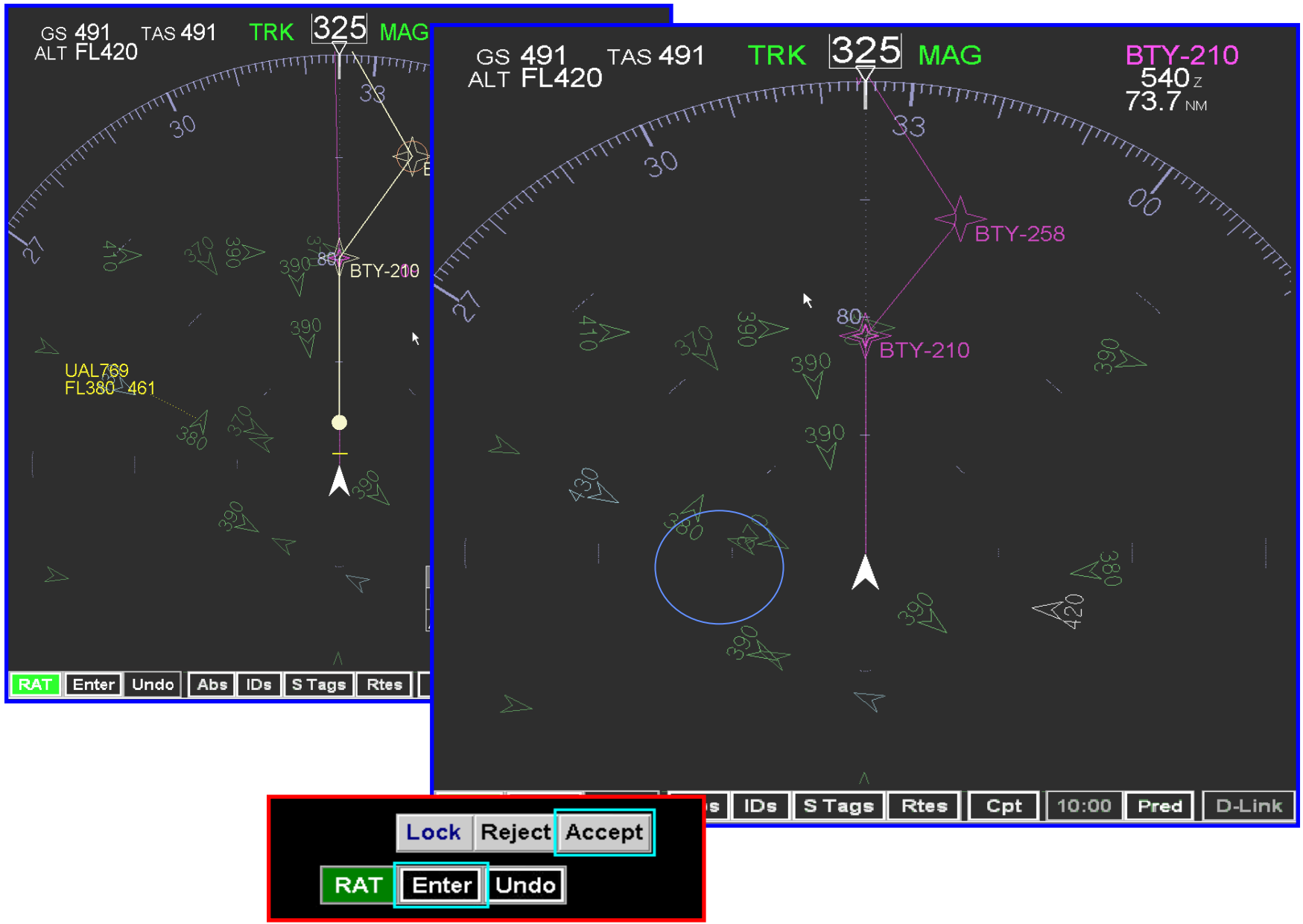
Integrates NASA Langley's PC-Plane with the CDTI and data link

Multi Aircraft Control System
MACS pilot station

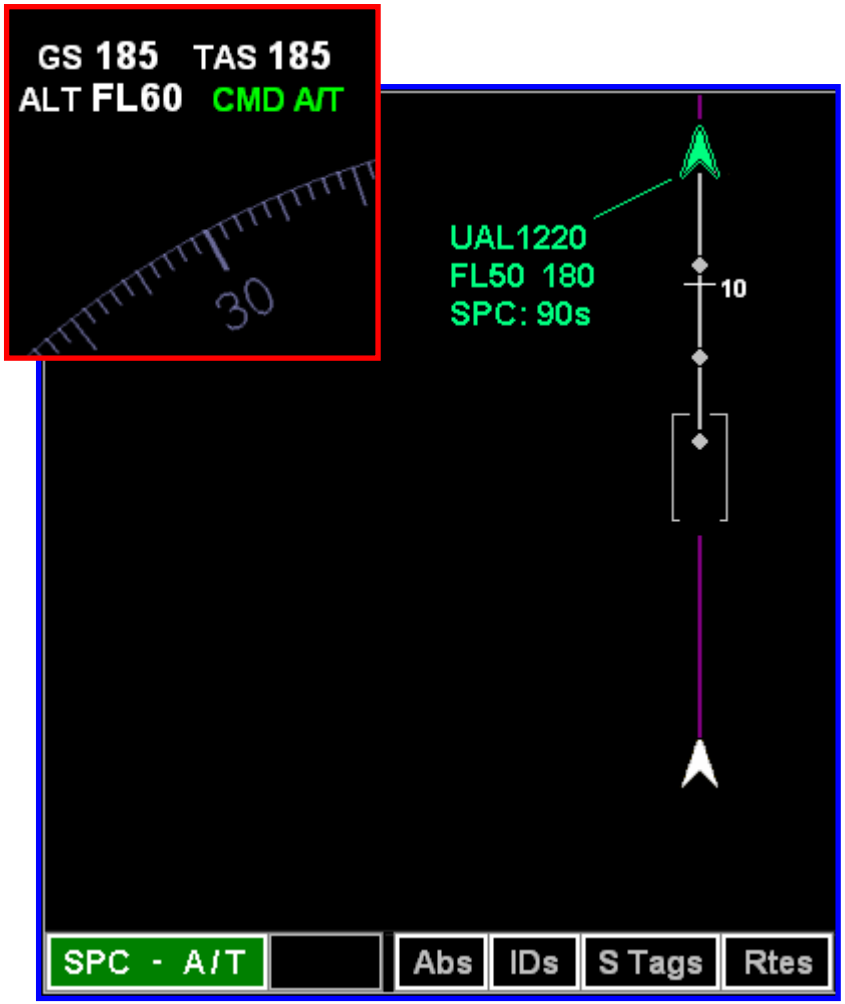


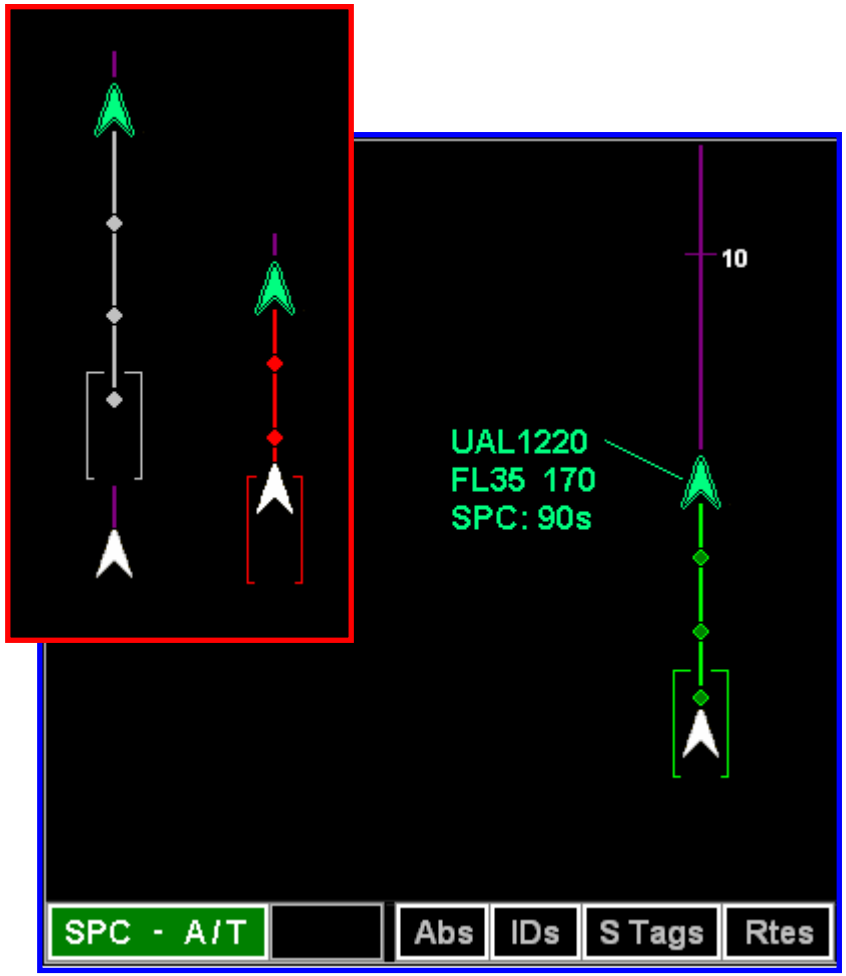
Cockpit Display of Traffic Information




GS 491
TAS 491
ALT FL420
TRK 325 MAG
BTY-210
UAL769
FL380 461
RAT
Enter
Undo
Abs
IDs
S Tags
Rtes
GS 491
TAS 491
ALT FL420
TRK 325 MAG
BTY-210
540 Z
73.7 NM
BTY-258
BTY-210
IDs
S Tags
Rtes
Cpt
10:00
Pred
D-Link
Lock
Reject
Accept
RAT
Enter
Undo

Flight Deck Spacing Tools





ATC Simulation

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

6 Center Controller positions

- 3 full size Radar displays (not shown)
- 3 wide screen Radar displays

1 Traffic Management postion

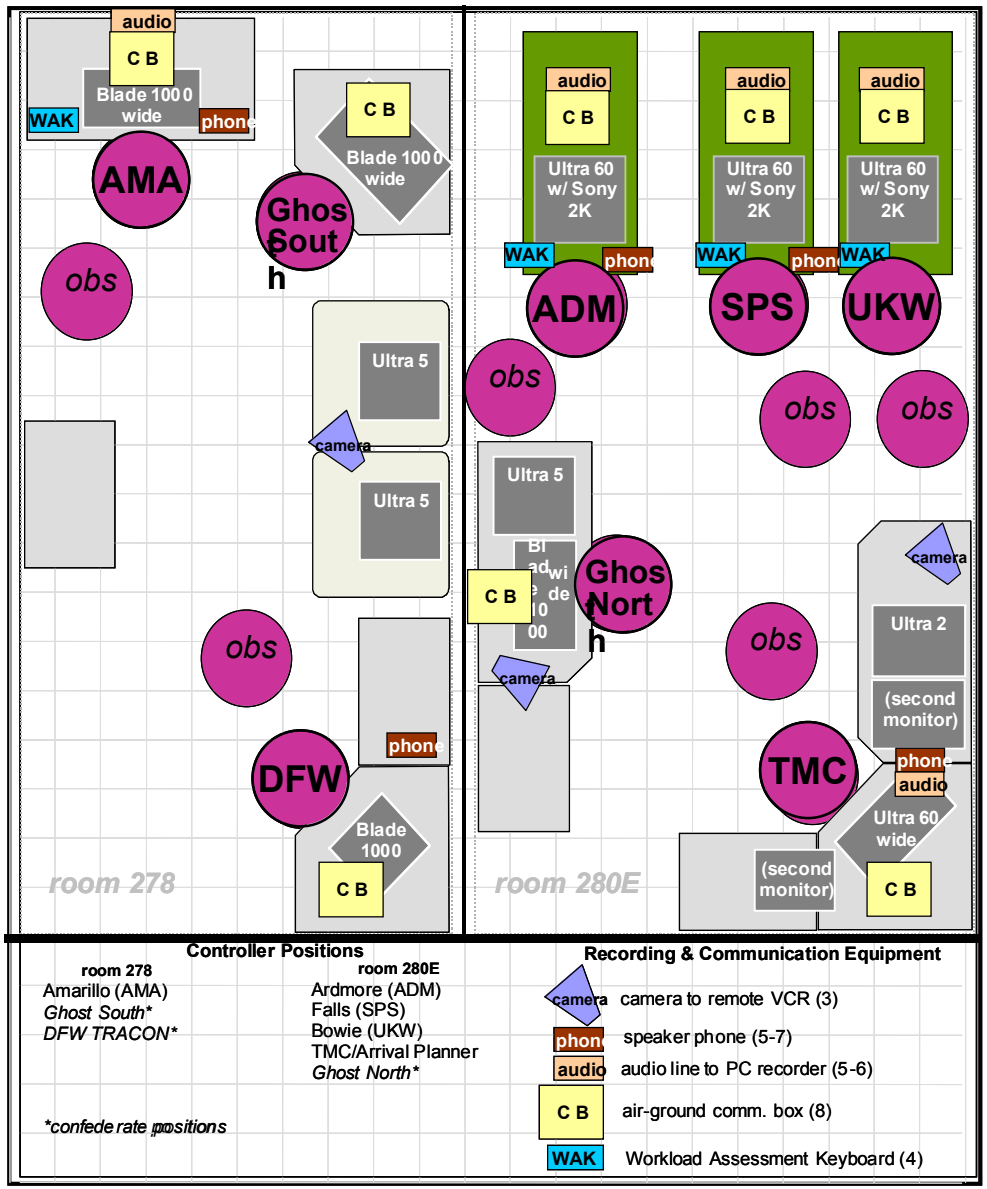
- Timeline Gui, Overview, Planning GUI

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

1-3 TRACON controller positions:

Up to 12 pseudo pilot positions on MACS stations

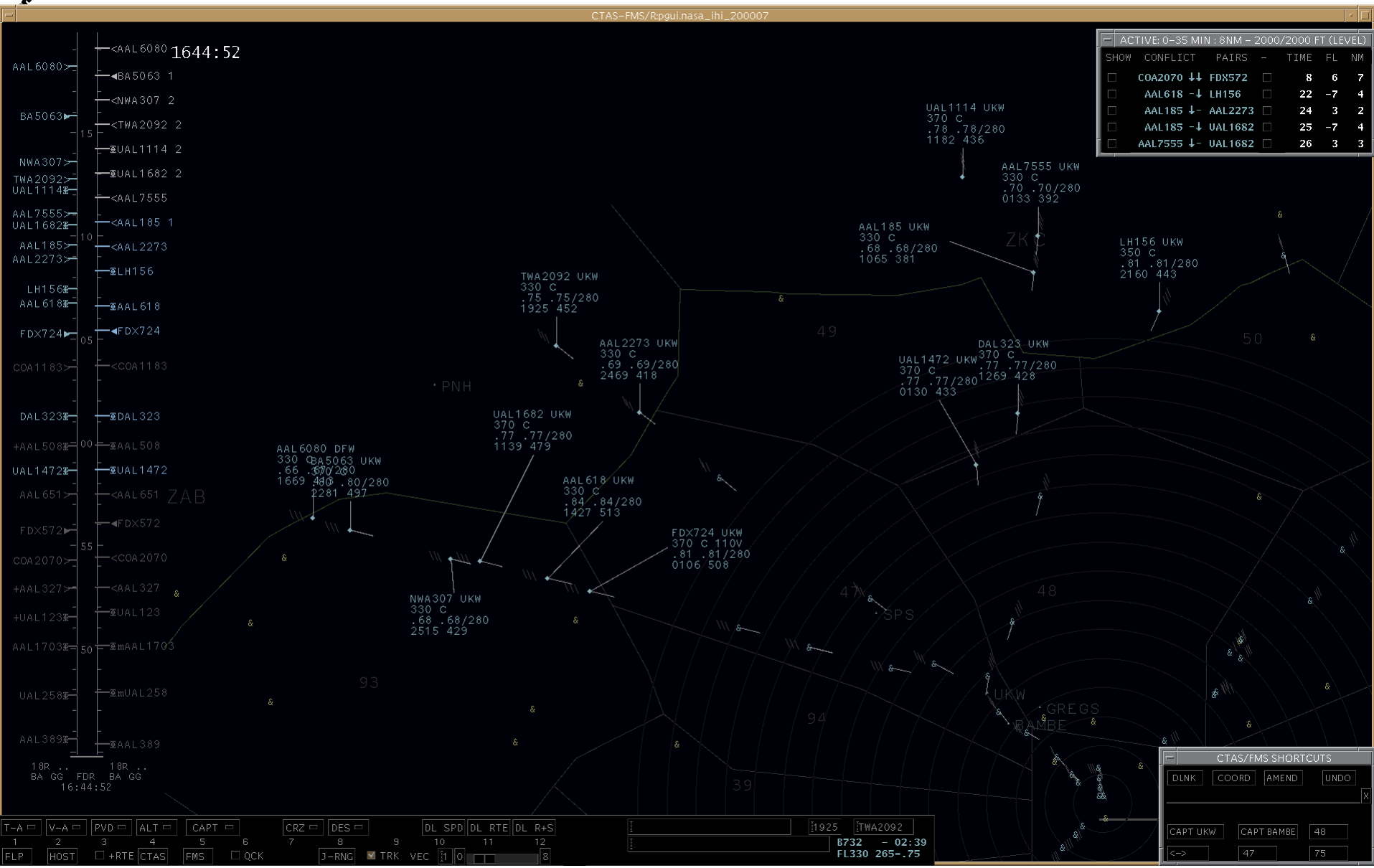
ATC stations in Airspace operations laboratory (AOL)



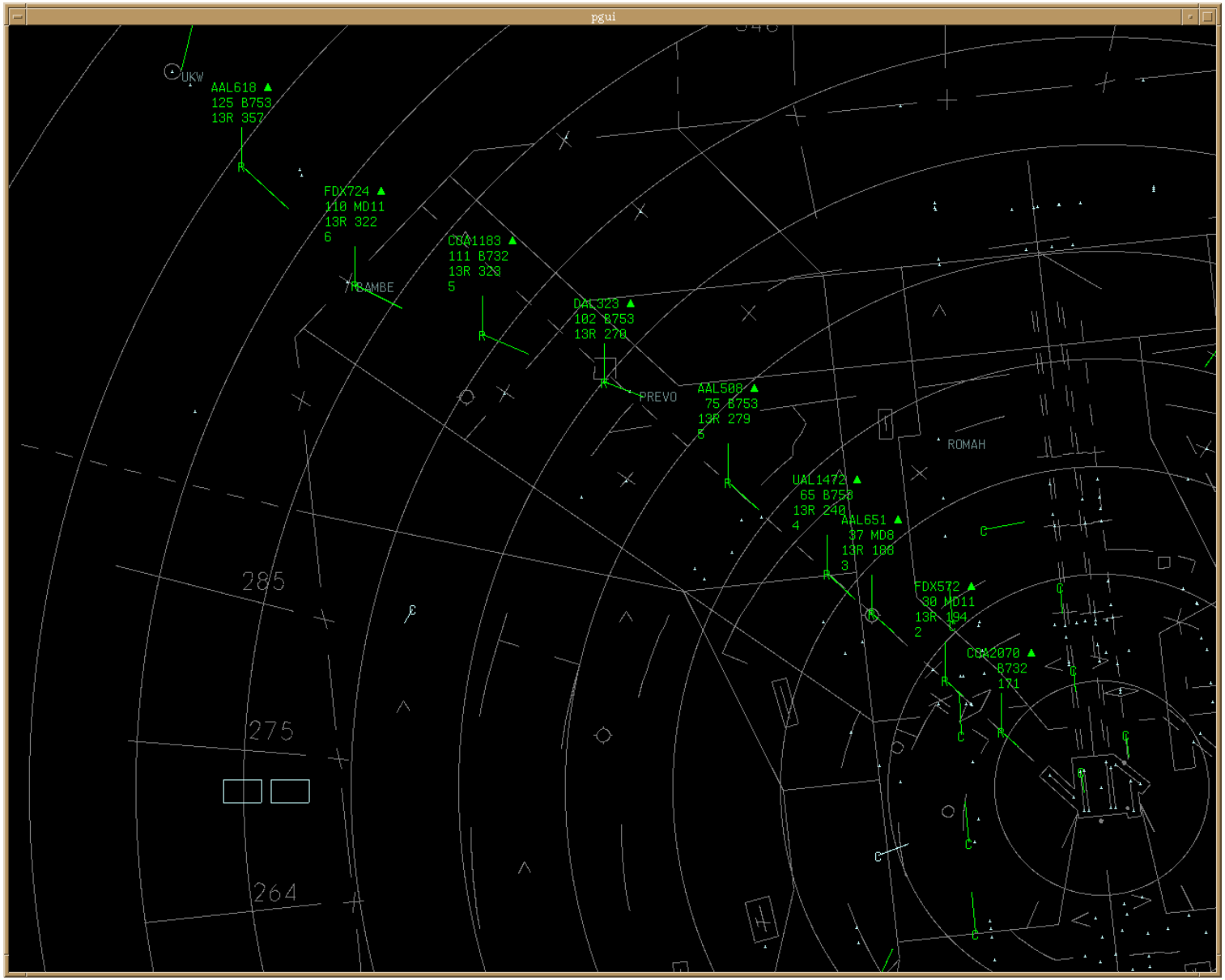
Controller Displays (Radar)

Currently CTAS Planview Graphical User Interfaces (PGUI)

Controller displays (Planning)



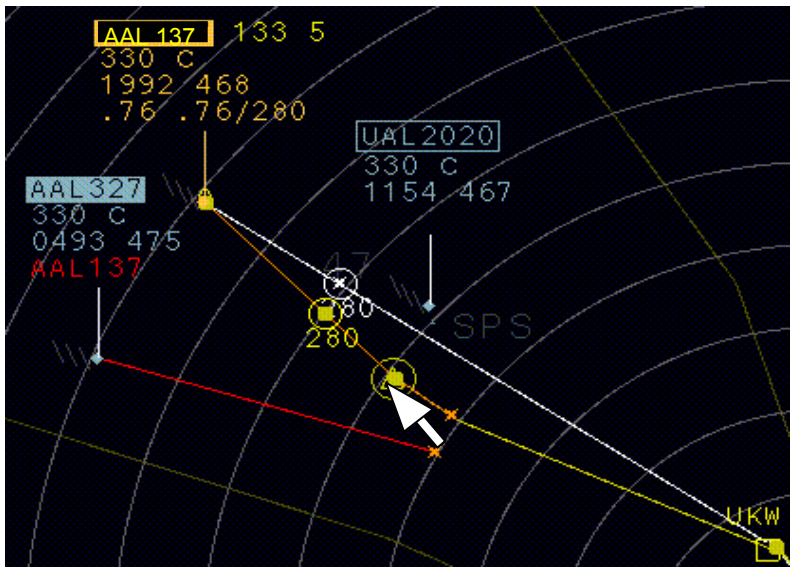
Controller displays (TRACON)

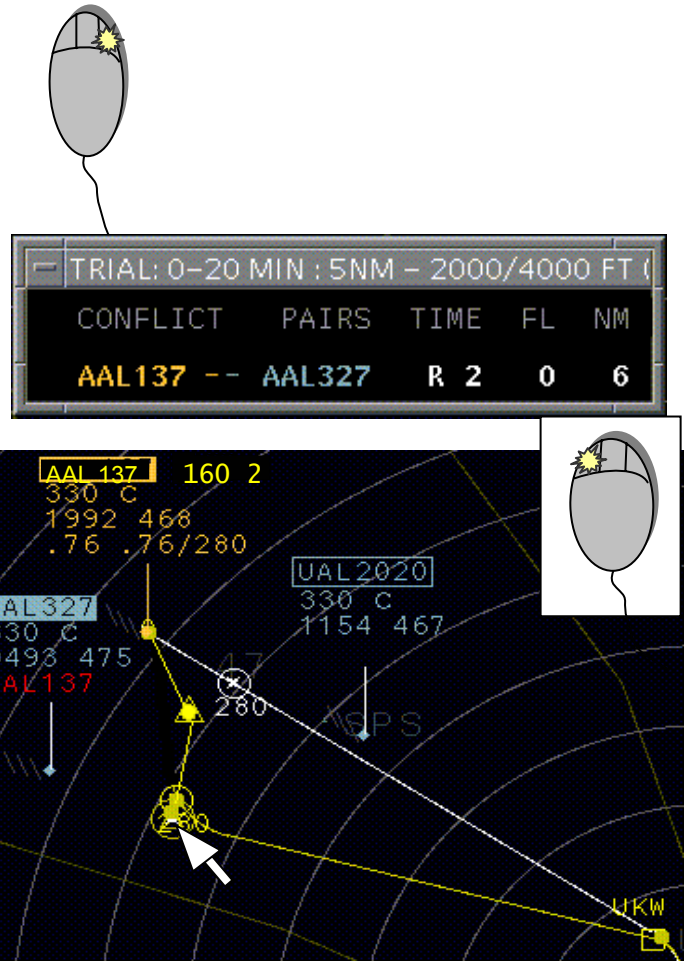


Decision support tools accessible for Air Traffic Controllers

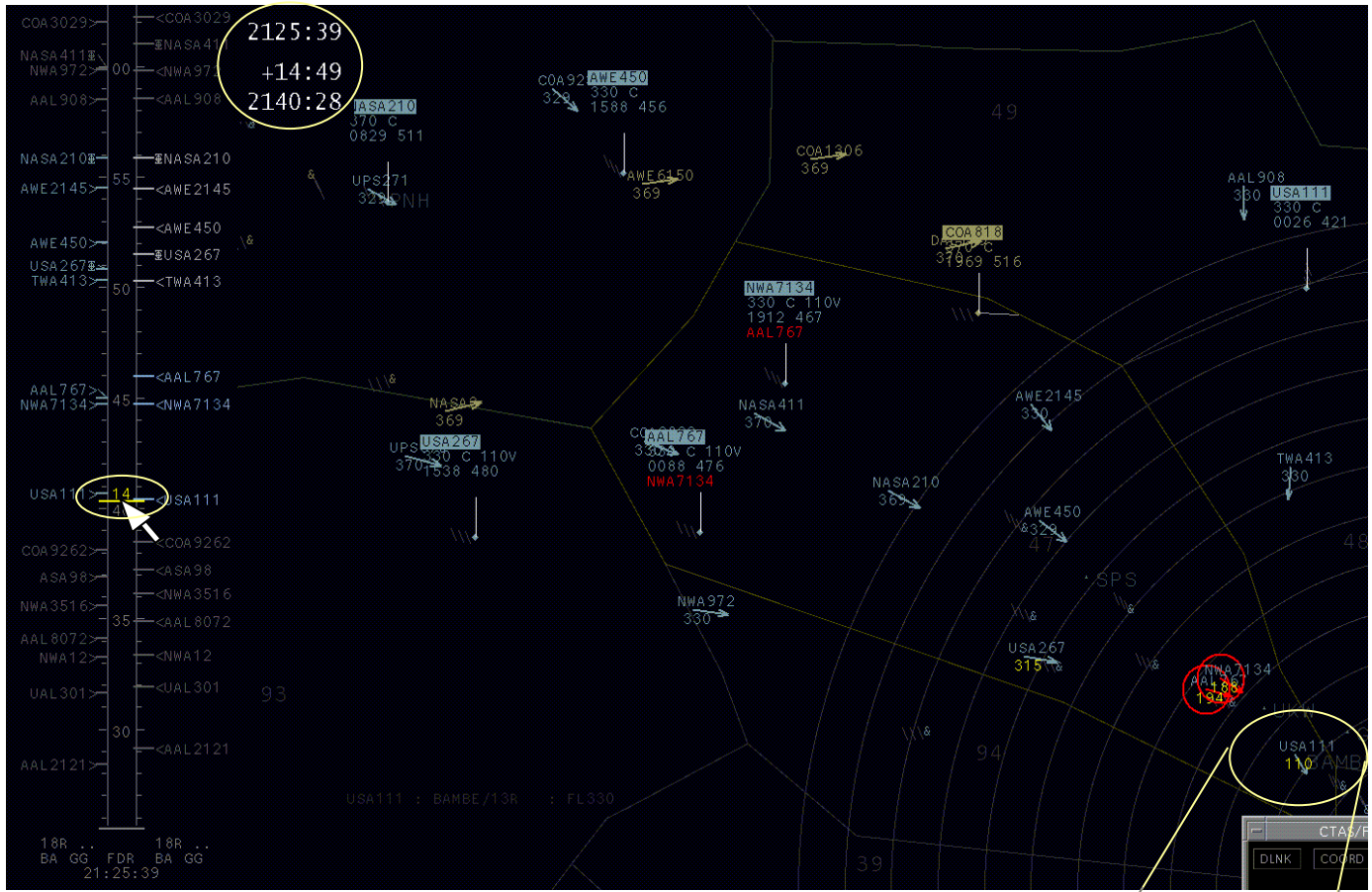
- CTAS Traffic Management Advisor (TMA)
- Descent Advisor (DA)
- Final approach spacing tool (FAST)
- Include:
  - Scheduling and sequencing support
  - Conflict probe
  - Trajectory visualization tools
  - Trial Planning and Advisories on controller request
- Controller Pilot Data Link Communication (CPDLC)
- ADS(B) state and trajectory intent information

ATC Automation examples





ATC Automation examples

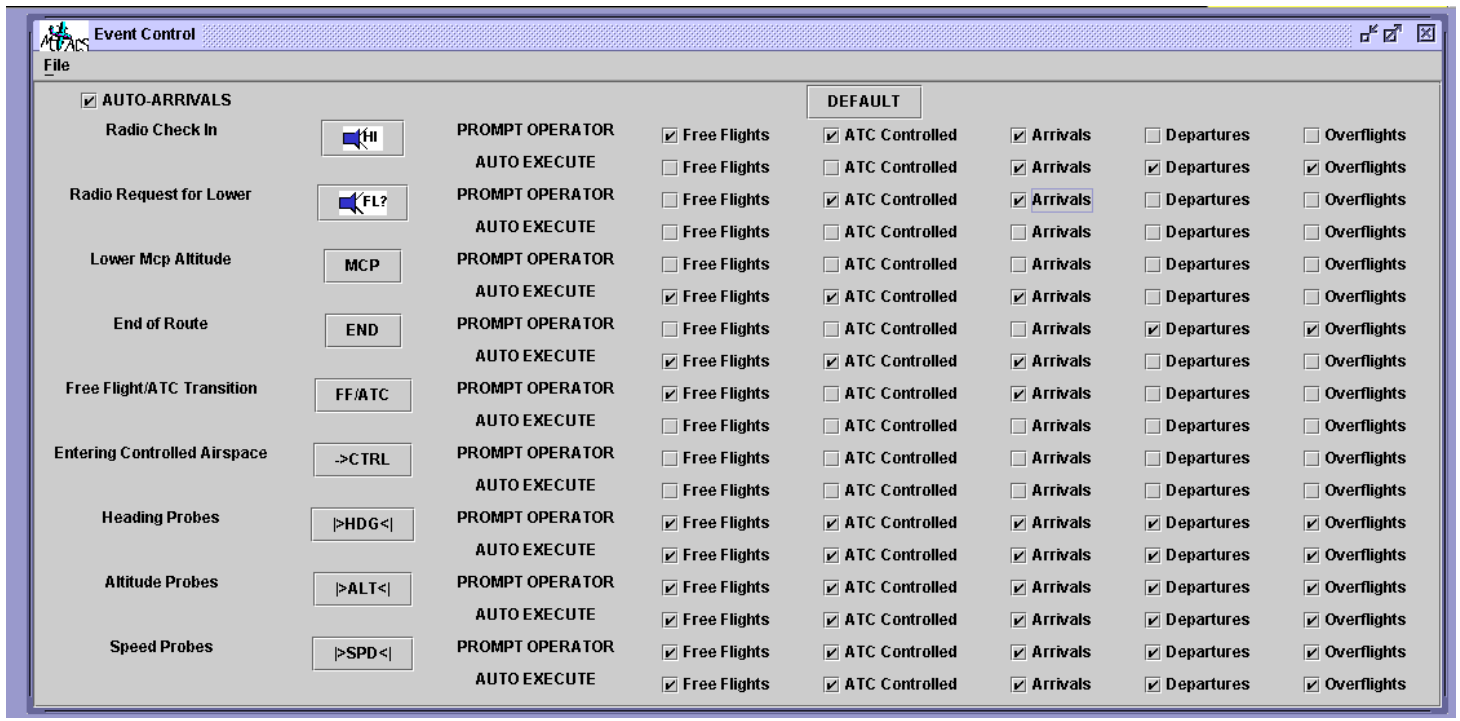


Operator Tracking

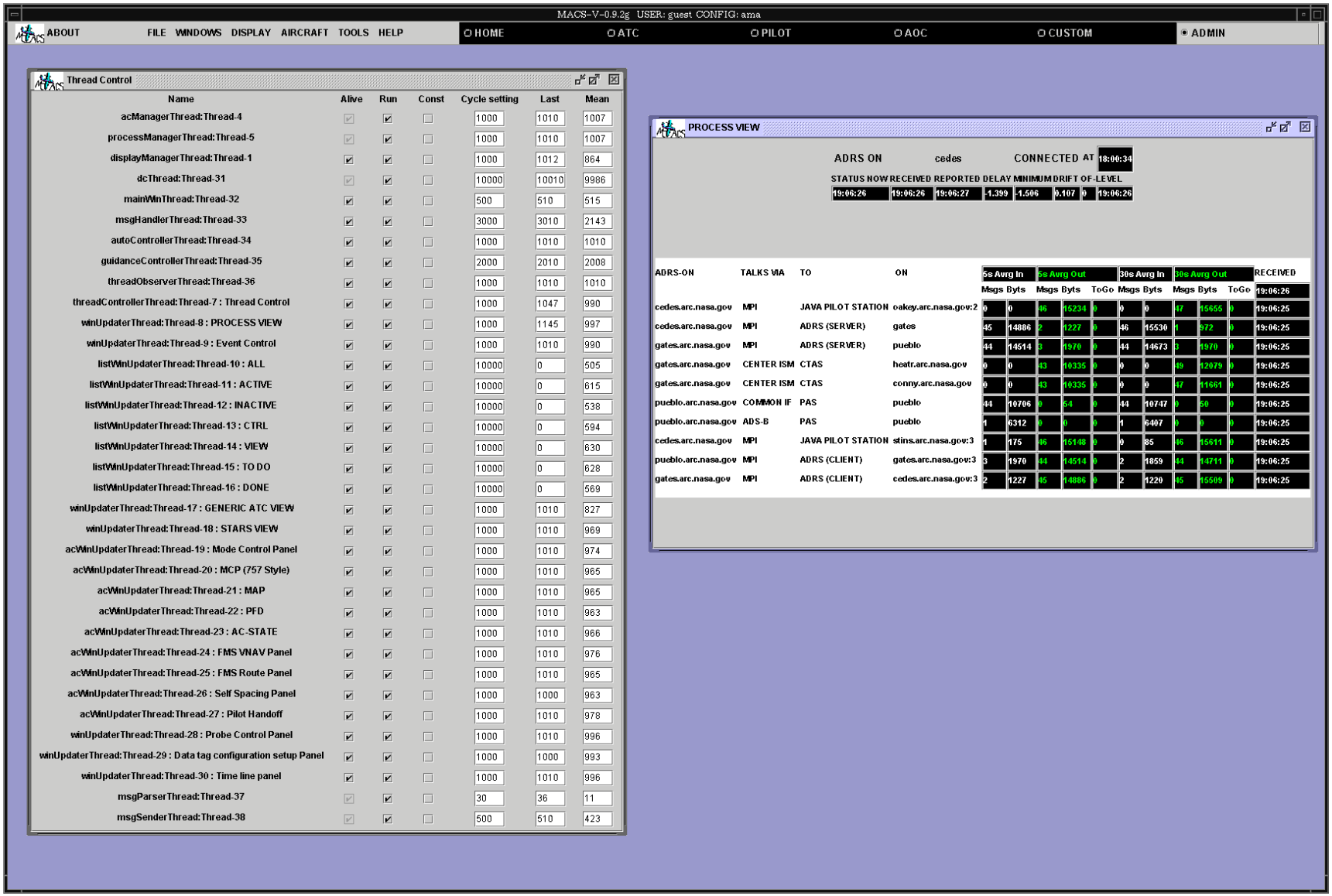
- Crew Activity Tracking System (CATS)
  - Model-based tool capable of analyzing subject activities in real-time
  - Compares expected to actual behavior and detects deviations
  - Produces visualizations of salient operator-automation interactions
  - Data replay for Post-run debriefings

Automated Agents

- CATS can act as model-based agent for certain aspects of the simulation
- MACS can be configured for automatically performing tasks or prompting operators



Experiment control and management



Name	Alive	Run	Const	Cycle setting	Last	Mean
acManagerThread:Thread-4	✓	✓		1000	1010	1007
processManagerThread:Thread-5	✓	✓		1000	1010	1007
displayManagerThread:Thread-1	✓	✓		1000	1012	864
dcThread:Thread-31	✓	✓		10000	10010	9986
mainWinThread:Thread-32	✓	✓		500	510	515
msgHandlerThread:Thread-33	✓	✓		3000	3010	2143
autoControllerThread:Thread-34	✓	✓		1000	1010	1010
guidanceControllerThread:Thread-35	✓	✓		2000	2010	2008
threadObserverThread:Thread-36	✓	✓		1000	1010	1010
threadControllerThread:Thread-7 : Thread Control	✓	✓		1000	1047	990
winUpdaterThread:Thread-8 : PROCESS VIEW	✓	✓		1000	1145	997
winUpdaterThread:Thread-9 : Event Control	✓	✓		1000	1010	990
listWinUpdaterThread:Thread-10 : ALL	✓	✓		10000	0	505
listWinUpdaterThread:Thread-11 : ACTIVE	✓	✓		10000	0	615
listWinUpdaterThread:Thread-12 : INACTIVE	✓	✓		10000	0	538
listWinUpdaterThread:Thread-13 : CTRL	✓	✓		10000	0	594
listWinUpdaterThread:Thread-14 : VIEW	✓	✓		10000	0	630
listWinUpdaterThread:Thread-15 : TO DO	✓	✓		10000	0	628
listWinUpdaterThread:Thread-16 : DONE	✓	✓		10000	0	569
winUpdaterThread:Thread-17 : GENERIC ATC VIEW	✓	✓		1000	1010	827
winUpdaterThread:Thread-18 : STARS VIEW	✓	✓		1000	1010	969
acWinUpdaterThread:Thread-19 : Mode Control Panel	✓	✓		1000	1010	974
acWinUpdaterThread:Thread-20 : MCP (757 Style)	✓	✓		1000	1010	965
acWinUpdaterThread:Thread-21 : MAP	✓	✓		1000	1010	965
acWinUpdaterThread:Thread-22 : PFD	✓	✓		1000	1010	963
acWinUpdaterThread:Thread-23 : AC-STATE	✓	✓		1000	1010	966
acWinUpdaterThread:Thread-24 : FMS VNAV Panel	✓	✓		1000	1010	976
acWinUpdaterThread:Thread-25 : FMS Route Panel	✓	✓		1000	1010	965
acWinUpdaterThread:Thread-26 : Self Spacing Panel	✓	✓		1000	1000	963
acWinUpdaterThread:Thread-27 : Pilot Handoff	✓	✓		1000	1010	978
winUpdaterThread:Thread-28 : Probe Control Panel	✓	✓		1000	1010	996
winUpdaterThread:Thread-29 : Data tag configuration setup Panel	✓	✓		1000	1000	993
winUpdaterThread:Thread-30 : Time line panel	✓	✓		1000	1010	996
msgParserThread:Thread-37	✓	✓		30	36	11
msgSenderThread:Thread-38	✓	✓		500	510	423

STATUS NOW	RECEIVED	REPORTED	DELAY	MINIMUM	DRIFT	OF-LEVEL
19:06:26	19:06:26	19:06:27	-1.399	-1.506	0.107	0

ADRS-ON	TALKS VIA	TO	ON	5s Avrg In		5s Avrg Out			30s Avrg In		30s Avrg Out			RECEIVED
				Msgs	Byts	Msgs	Byts	ToGo	Msgs	Byts	Msgs	Byts	ToGo	19:06:26
cedes.arc.nasa.gov	MPI	JAVA PILOT STATION	oakey.arc.nasa.gov:2	0	0	46	15234	0	0	0	47	15655	0	19:06:25
cedes.arc.nasa.gov	MPI	ADRS (SERVER)	gates	45	14886	2	1227	0	46	15530	1	972	0	19:06:25
gates.arc.nasa.gov	MPI	ADRS (SERVER)	pueblo	44	14514	3	1970	0	44	14673	3	1970	0	19:06:25
gates.arc.nasa.gov	CENTER ISM	CTAS	heatr.arc.nasa.gov	0	0	43	10335	0	0	0	49	12079	0	19:06:25
gates.arc.nasa.gov	CENTER ISM	CTAS	conny.arc.nasa.gov	0	0	43	10335	0	0	0	47	11661	0	19:06:25
pueblo.arc.nasa.gov	COMMON IF	PAS	pueblo	44	10706	0	54	0	44	10747	0	50	0	19:06:25
pueblo.arc.nasa.gov	ADS-B	PAS	pueblo	1	6312	0	0	0	1	6407	0	0	0	19:06:25
cedes.arc.nasa.gov	MPI	JAVA PILOT STATION	stins.arc.nasa.gov:3	1	175	46	15148	0	0	85	46	15611	0	19:06:25
pueblo.arc.nasa.gov	MPI	ADRS (CLIENT)	gates.arc.nasa.gov:3	3	1970	44	14514	0	2	1859	44	14711	0	19:06:25
gates.arc.nasa.gov	MPI	ADRS (CLIENT)	cedes.arc.nasa.gov:3	2	1227	45	14886	0	2	1220	45	15509	0	19:06:25

TAP ATM Simulations (1997-2000)

CTAS/ FMS Integration studies conducted in this environment:

- Full mission study of flight deck human factors using the Advanced Concepts Flight Simulator (ACFS) at Ames
  - Data link interfaces, FMS usage in terminal area, Vertical Situation Display
- Initial demonstration with pilots and controllers using the Airspace Operations Lab (AOL) at Ames
  - Operational concept, Controller automation interaction
- Main demonstration with pilots and controllers using the ACFS and AOL at Ames and the Research Flight Deck at Langley
  - Operational concept, Controller automation interaction, Pilot/controller interactions, Flight crew factors

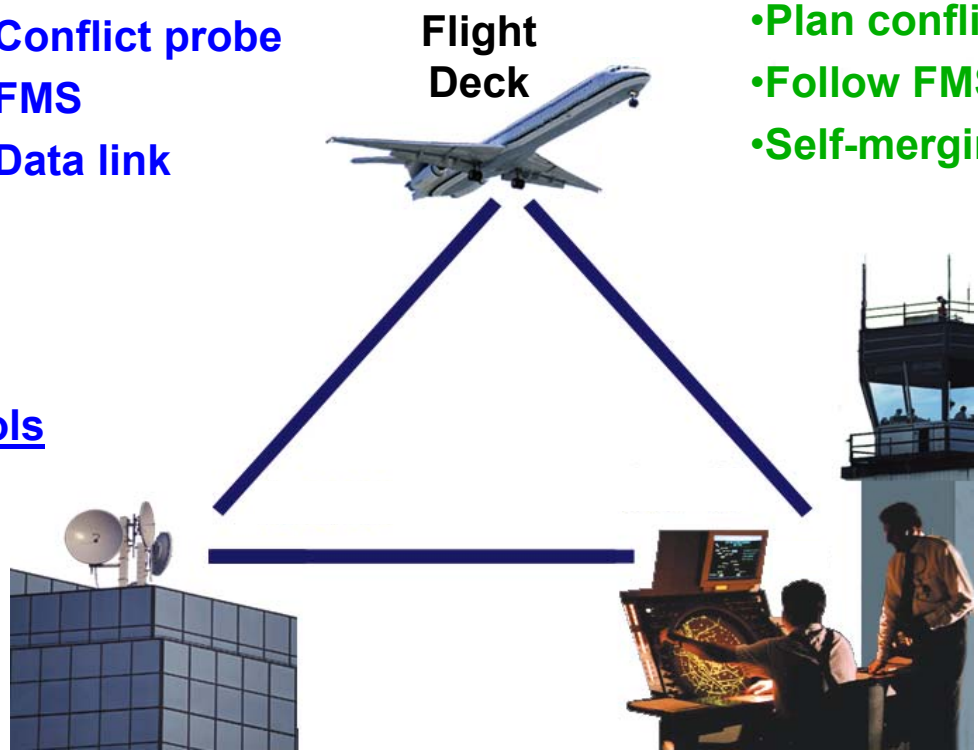
DAG Simulations (Ongoing)

- CTAS/FMS 2002 data collection. Evaluation of trajectory based vs. sector based concepts of managing arrival traffic with FPL controllers and air traffic managers.
  - AOL, MACS, PAS, CTAS
- Frequent workshops, demonstrations and evaluations of distributed concepts that investigate free-flight concepts with airborne and ground-based concept resolution techniques, new separation responsibilities and airspace restructuring with Controllers, pilots, dispatchers and researchers.
  - AOL, ACFS, PC-Plane, MACS, CDTI, PAS, CTAS

Distributed Concept (DAG)

Automation:
- CDTI
- Conflict probe
- FMS
- Data link

Flight Crew Role:
- Assure separation en route
- Plan conflict free flight paths
- Follow FMS flight paths precisely
- Self-merging and spacing



Automation tools
- Planning
- Scheduling
- Data link

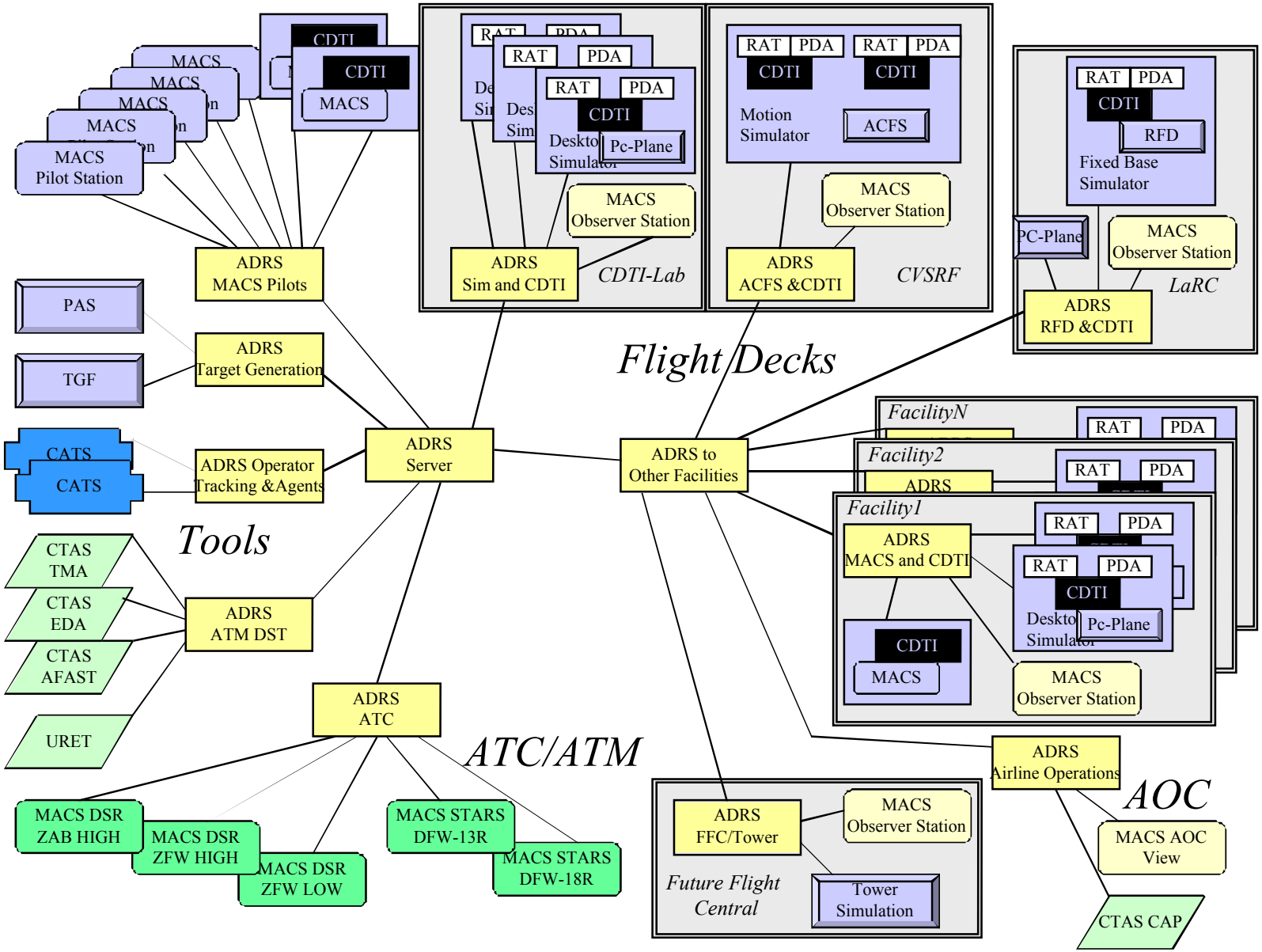
Automation
- Traffic Management
- Conflict probe
- Descent Advisor
- Data link

AOC Role:
- Determine preferences
- Coordinate

Planner Role:
- Generate Schedule
- Assist flight crews and ATC

Controller Role:
- Assure separation in Terminal area
- Adjust flight paths

Upgrading and Expanding



Concluding remarks

- Realistic human-in-the-loop simulations of future distributed air traffic management will require participation of numerous pilots, controllers, airline dispatchers, researchers and the operational community alike
- The multi-fidelity simulation environment at NASA Ames has been successfully used for many demonstrations and evaluations
- The simulation will be upgraded and expanded to include more research facilities on and off-site as active participants, observers, or data analysts.
- We have not yet discovered architectural limitations on the number of involved facilities in any given simulation.

Information on the World Wide Web

http://human-factors.arc.nasa.gov/ihi/research_groups/air-ground-integration

http://human-factors.arc.nasa.gov/ihh/cdti/DAG_TM_WEB/dag2001.html

http://www.arc.nasa.gov/aatt