Transitioning Resolution Responsibility - Controller/Automation Interaction Styles in NextGen Separation Assurance

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Outline

- **Who**
  - AOL and HITL experiments
- **Where**
  - Simulation environment, airspace, layout etc.
- **What**
  - Separate side study taken out of larger research experiment
  - “Max NextGen” timeframe technologies and operational procedures
- **How**
  - Did ATC perform?
  - Did automation interaction styles differ?
- **Why**
  - might this be important?

Airspace Operations Laboratory

Research Mission

(1) provide a better understanding of roles, responsibilities, and requirements for human operators and automation in future air traffic management (ATM) systems

(2) develop, evaluate, and integrate operational concepts and technologies for the near-, mid-, and far-term Next Generation Air Transportation System (NextGen) in high-fidelity human-in-the-loop (HITL) environments.

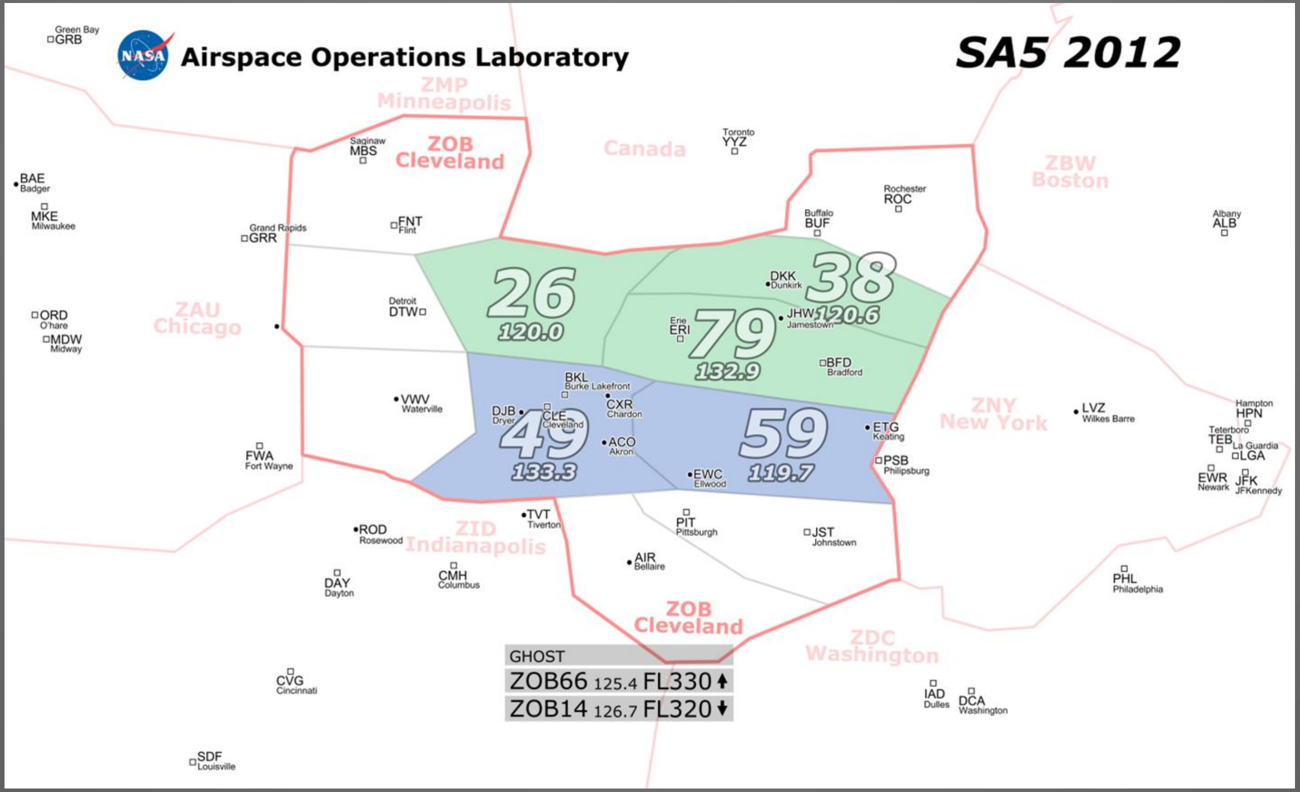
Human Systems integration division

NASA Ames Research Center

Test Airspace (SA5, August 2012)

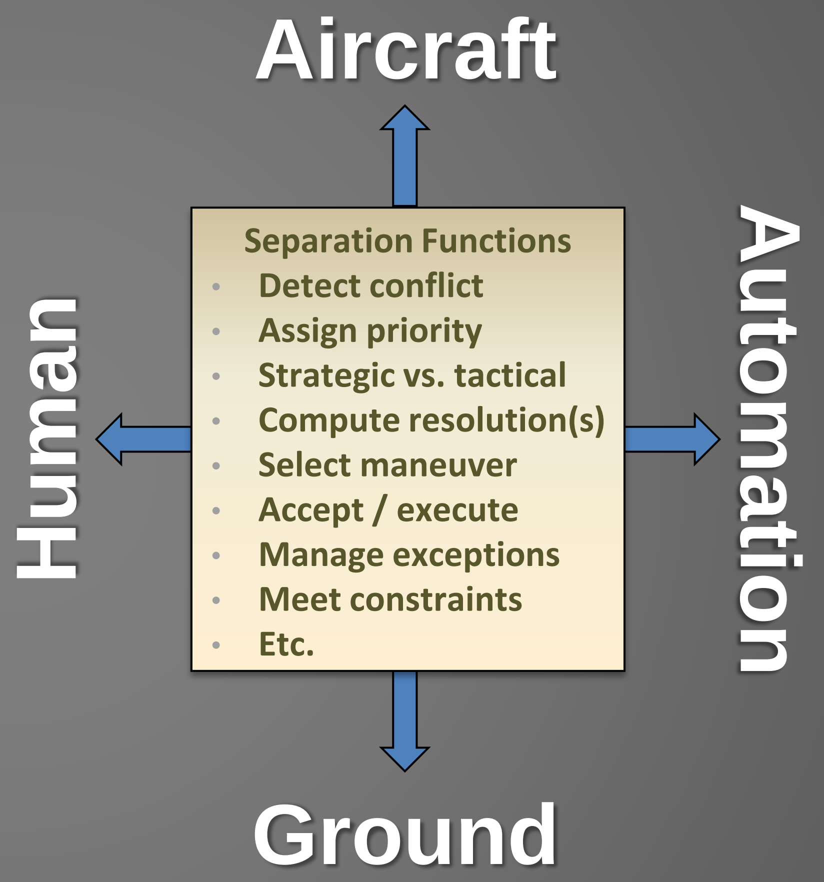
Cleveland Center (ZOB) High altitude (FL 330 and above)

- two areas, five sectors staffed with R-Side and D-Side on-demand
- area supervisors manage staffing



Function Allocation Research

- **Function Allocation in Separation Assurance**
  - improve the air/ground and human/automation function allocation
  - achieve significant capacity and efficiency gains for NextGen and beyond.
  - cooperation between NASA Ames and NASA Langley
- Ground-based and airborne concepts, as ongoing subjects of research
- Series of coordinated air/ground function-allocation HITL experiments
  - Homogeneous operations, normal conditions
  - ***Mixed Operations, normal conditions***
  - Non-normal conditions



Function Allocation Research

- **Function Allocation in Separation Assurance**
  - improve the air/ground and human/automation function allocation
  - achi… effic… beyo…
  - coop… NAS…

- Ground-… concept… research…

- Series o… function-allocation experiments

Aircraft

Ground

"Mixed Operations with Flight-Crew and Controller -Managed Aircraft in Different Stages of NextGen"

Tenth USA/Europe Air Traffic Management Research and Development Seminar (ATM2013)

The Team:

Ames: Tom Prevot (PI)
Connie Brasil, Chris Cabrall, Patrick Cravalho, Ashley Gomez, Sarah Gregg, Jeff Homola, Lynne Martin, Joey Mercer, Susan Morey, Faisal Omar, Natalia Wehrle

Langley: David Wing (PI)
Cathy Adams, Kelly Burke, Bill Cotton, Sheri Hoadley, Clay Hubbs, Sally Johnson, Tim Lewis, Nipa Phojanamongkolkij

  - Homogeneous operations, normal conditions
  - ***Mixed Operations, normal conditions***
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Mixed Operations

- **Role of Automation**
  - Introduction of automation leads to different **stages of NextGen**
  - Function allocation between controllers and automation changes

- **Role of Flight Crew**
  - Introduction of new technologies enables new airborne capabilities
  - Flight crews can participate in separation assurance process
  - Flight crew/controller responsibility varies

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"Maximum NextGen"

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Experimental Design

- Air/Ground function allocation:
  - 2 test conditions (Mixed Ops, Ground-based Ops)
- Human/Automation function allocation:
  - 4 NextGen phases: baseline, minimum, moderate, maximum

Air/ground function allocation	Mixed Ops AFR/IFR				
	Ground-based Ops IFR only				
		Baseline	Minimum NextGen	Moderate NextGen	Maximum NextGen
		Human/Automation function allocation NextGen Maturation level of automation increases →			

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Air/ground function allocation	Mixed Ops AFR/IFR	✗	✗	✗	✗
	Ground-based Ops IFR only	✗	✗	✗	✓
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Controller/Automation: Major Paradigm Shift

- **Conflict Detection**
  - Automation responsible for conflict detection, not the controller
- **Conflict Resolutions**
  - Automation issues strategic conflict resolutions when within limits and alerts controllers to the ones that are out of bounds
    - Increased “out of bounds” limits from prior studies:
      - 90 seconds or more for delay change
      - 60 degrees or more for heading change
      - 50 knots or more for speed change
      - 2,200 feet or more for altitude change
  - Automation issues tactical heading advisories

Controller/Automation: Timing and Transitions

>10 mins to go until Loss of Separation (LoS)

- does not alert
- conflict countdown (white number)

10 mins

- begins to alert
- no resolution automation action yet (blank box)

10 to 8 mins

- computes resolution clearances
- thinking (white box)
- resolution found (blue box)

8 mins

- checks the found resolutions against limits
- if within limits, uplinks direct to aircraft (MAJORITY)
- informs ATC (green box, DataLink status list)
- if not within limits, defers to ATC (yellow box, yellow callsign)

Maximum NextGen: Controller/Automation

5 mins

- conflict countdown (yellow number)

3 mins

- alerts short term tactical (red callsign, red altitude)
- conflict countdown (red number)

2.5 mins

- displays auto generated tactical heading resolution

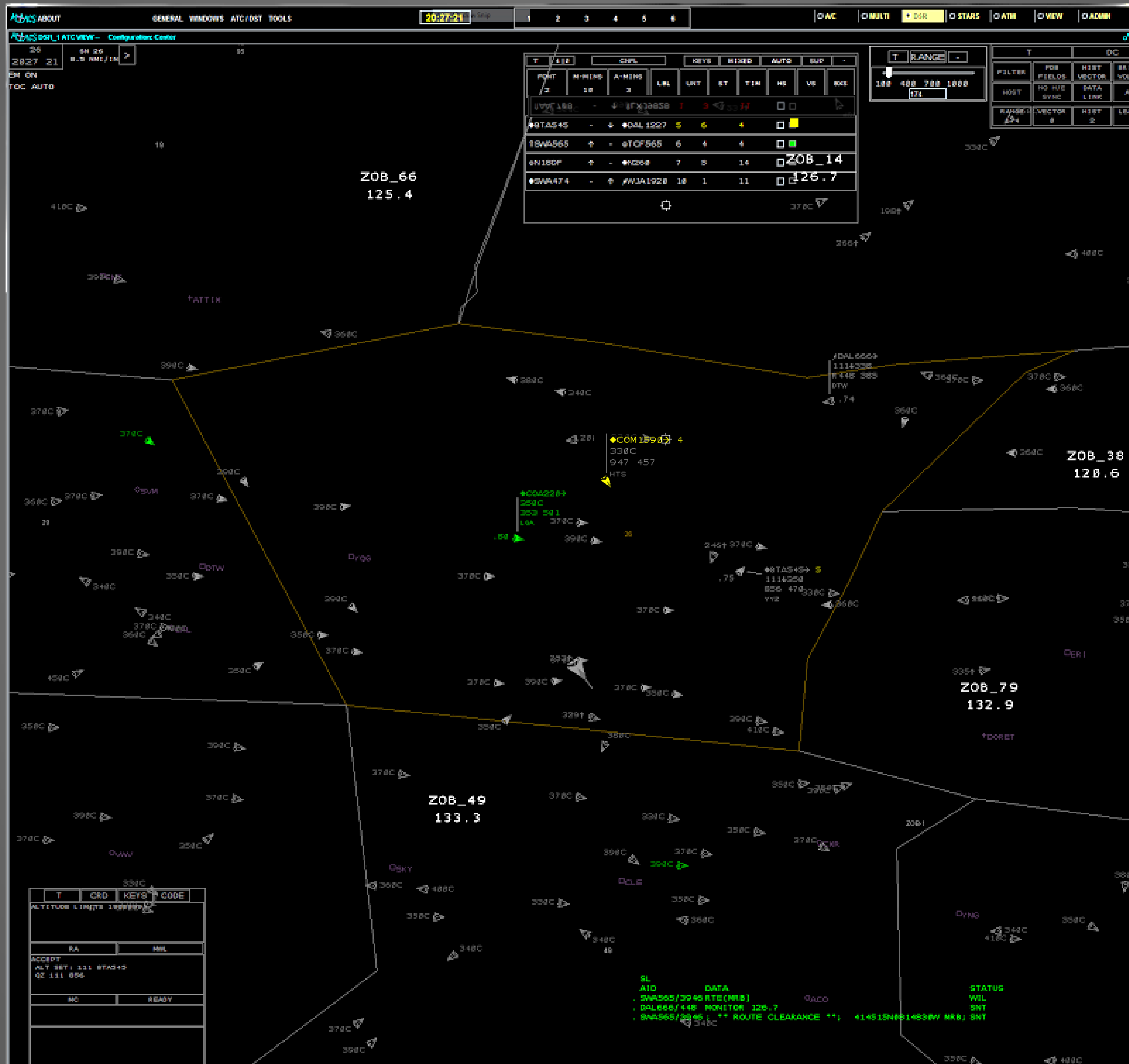
2 mins

- uplinks tactical heading resolution

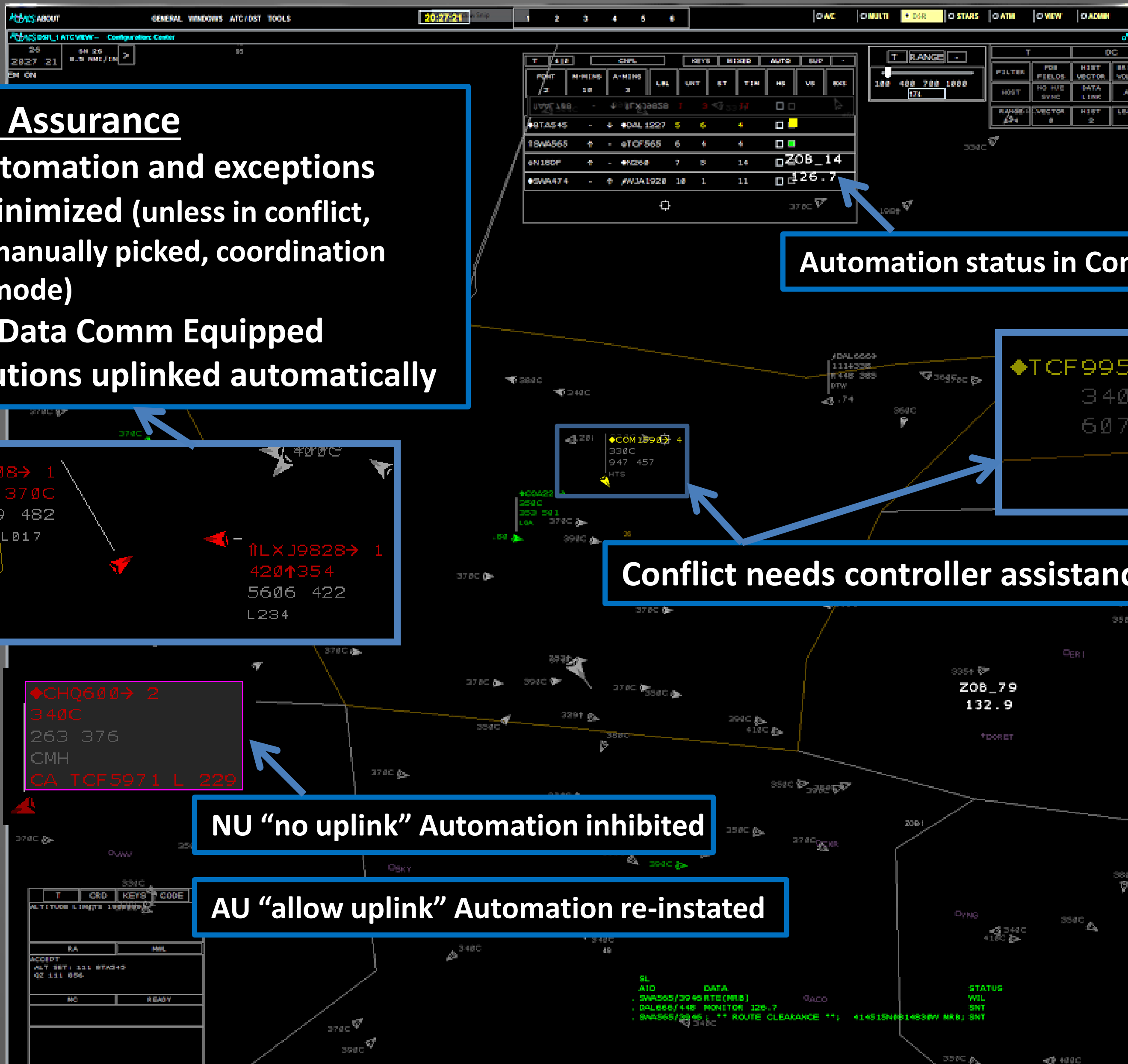
~1 min?

-TCAS (not simulated)

DSR for Maximum NextGen



DSR for Maximum NextGen



Separation Assurance

- Manage Automation and exceptions
- All FDB's minimized (unless in conflict, pointed out, manually picked, coordination pending, NU mode)
- All Aircraft Data Comm Equipped
- Most resolutions uplinked automatically

Automation status in Conflict List

Conflict needs controller assistance

NU "no uplink" Automation inhibited

AU "allow uplink" Automation re-instated

Results (old)

Human-Automation prototype:

-flexible
-layered
-informed by users
-iterative test/design
-principles from HF, UX, psychology, etc.

→

Far-term gains:

-Safe operations (minimal LoS)

-Forecast traffic densities (e.g. 2x current day)

-Acceptable/low workload

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Subjective
Interaction
Accounts
Observation

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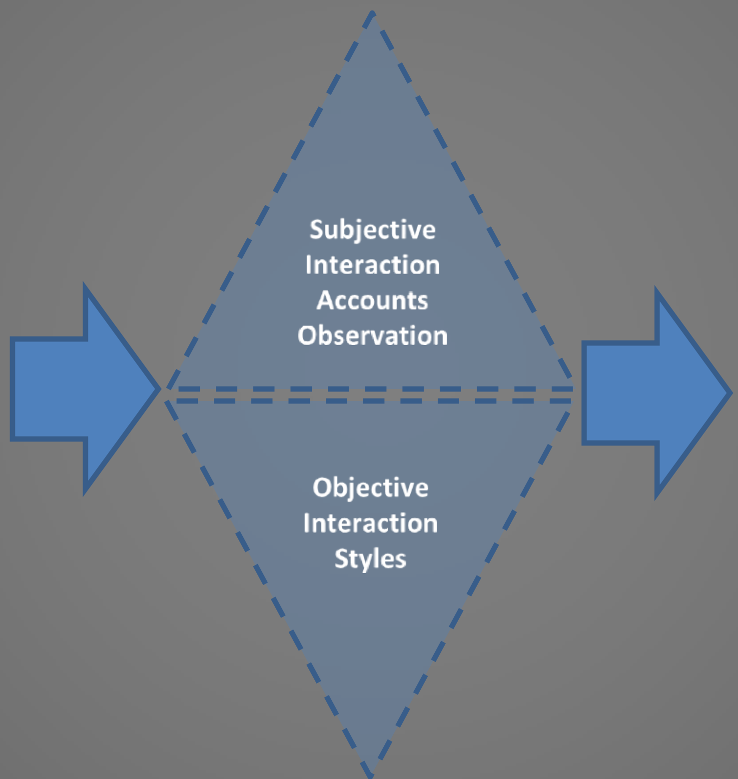

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Contextual and Individual Differences of Styles of Automation Trust and Use

→

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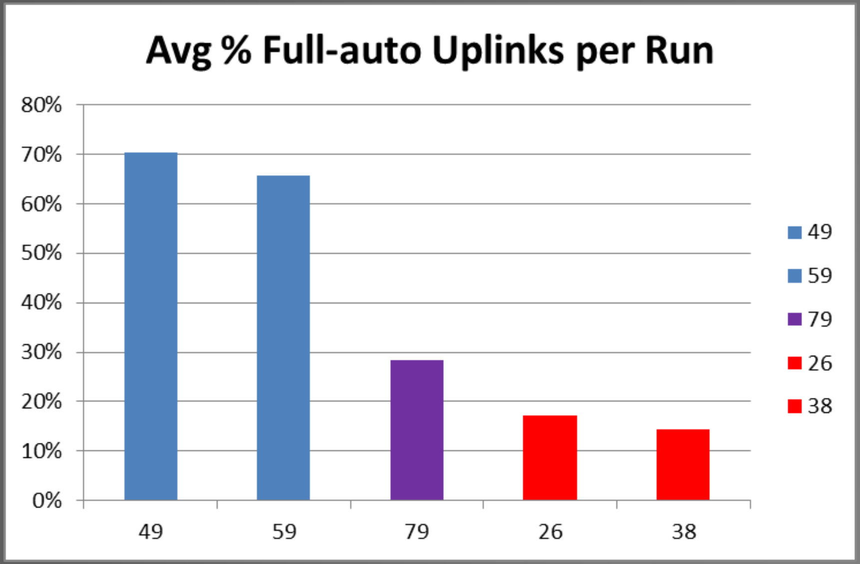
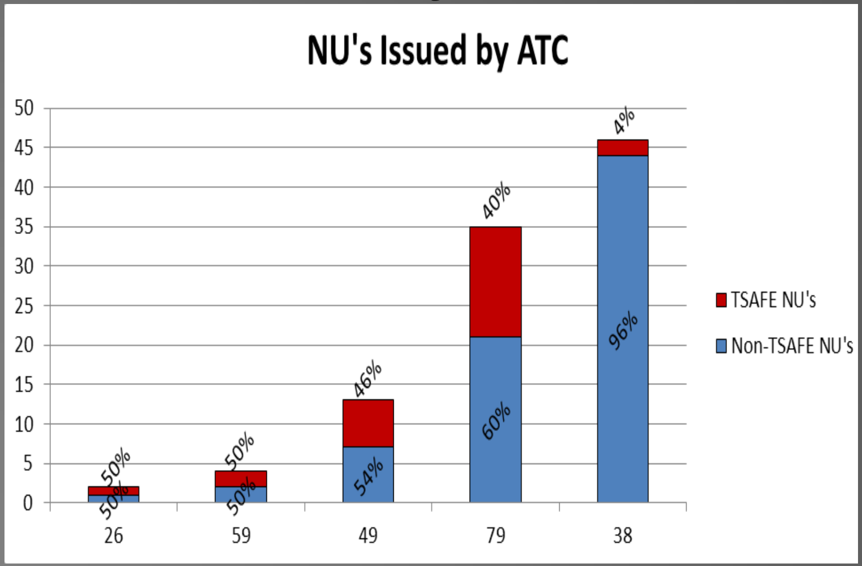
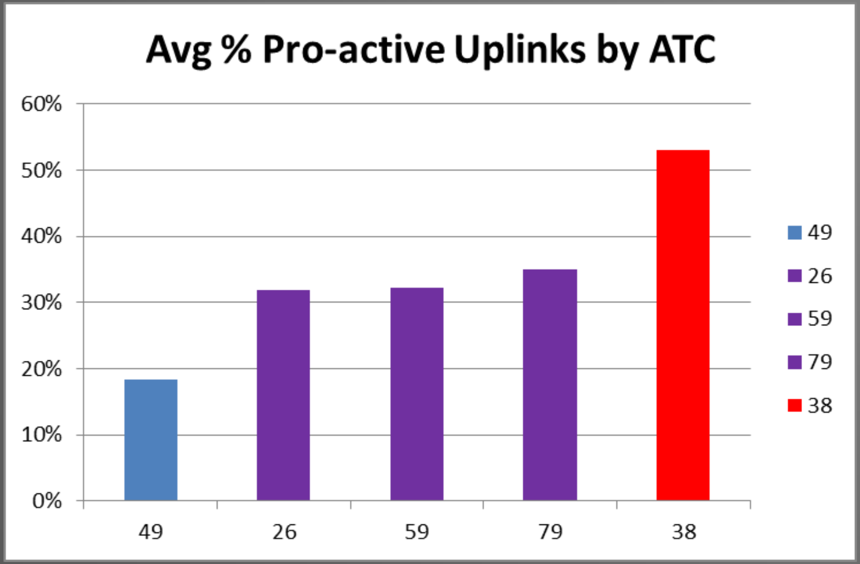
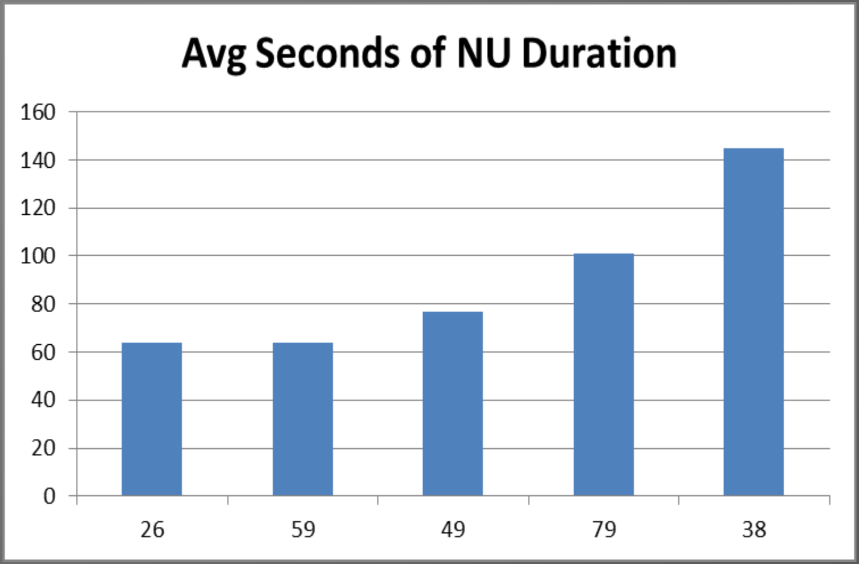
Automation Interaction Styles









Automation Interaction Styles

- Controllers **divided themselves** along a spectrum
  - 38 more towards a more manual/active end
    - Greatest % of pro-active (non-conflict uplinks)
    - Lowest % of full-auto uplinks
    - Highest number of NU's and non-tactical NU's
    - Greatest average NU status durations
    - "I don't always trust the solutions the computer comes up with, and never like the tactical resolutions"
    - Only one to select
      "moderate compensation required to maintain adequate performance" vs.
      "minimal compensation" or "no controller correction" (other ATC answers)
  - 49 more towards a more automated/passive end
    - Lowest % of uplinks without automation involvement
    - Highest % of full-auto uplinks
    - Relatively low number and durations of automatic uplink interventions
    - Exclusively selected: "reduced my workload" or "increased my awareness"
      (when asked about automation)
    - Every time marked: "1 – very low time pressure"

Possible Contributing Factors to Interaction Differences

- **Time and space**
  - Highest average cross sector flight times (secs) (49)
  - Highest average flight distances (nm) (49)
- **Traffic flow characteristics**
  - Higher % of transitioning aircraft for 38 than for 49
  - Largest % of overflights (49)
- **Co-location (local attitude/chances for observation)**
  - 59 had similar sector characteristics to 38, but shared "south area" with 49.
  - Provided more opportunity for 59 to observe and be influenced by a functional passive approach than perhaps afforded to himself alone

Importance/Soapbox

- **The things I learned in school -> real-life (simulated) achievement.**
  - General tenets
    - Machines are great at serial, computation, routines, logic
    - People are great at parallel processes, flexibility, counter-factuals, exceptions
  - Academically instructed principles evident in automation design/implementation
  - Future traffic densities, safe operations, manageable workload, user acceptance
- **Automation interaction is not black and white**
  - Need not nor shouldn’t be, in my opinion
  - Turing Test (a machine’s ability to exhibit intelligent behavior equivalent/indistinguishable from that of a human being)
    - Build trust through observation of simple tasks prior to complex tasks
    - Encourage teamwork through informed sharing of tasks at different times/contexts

Questions?

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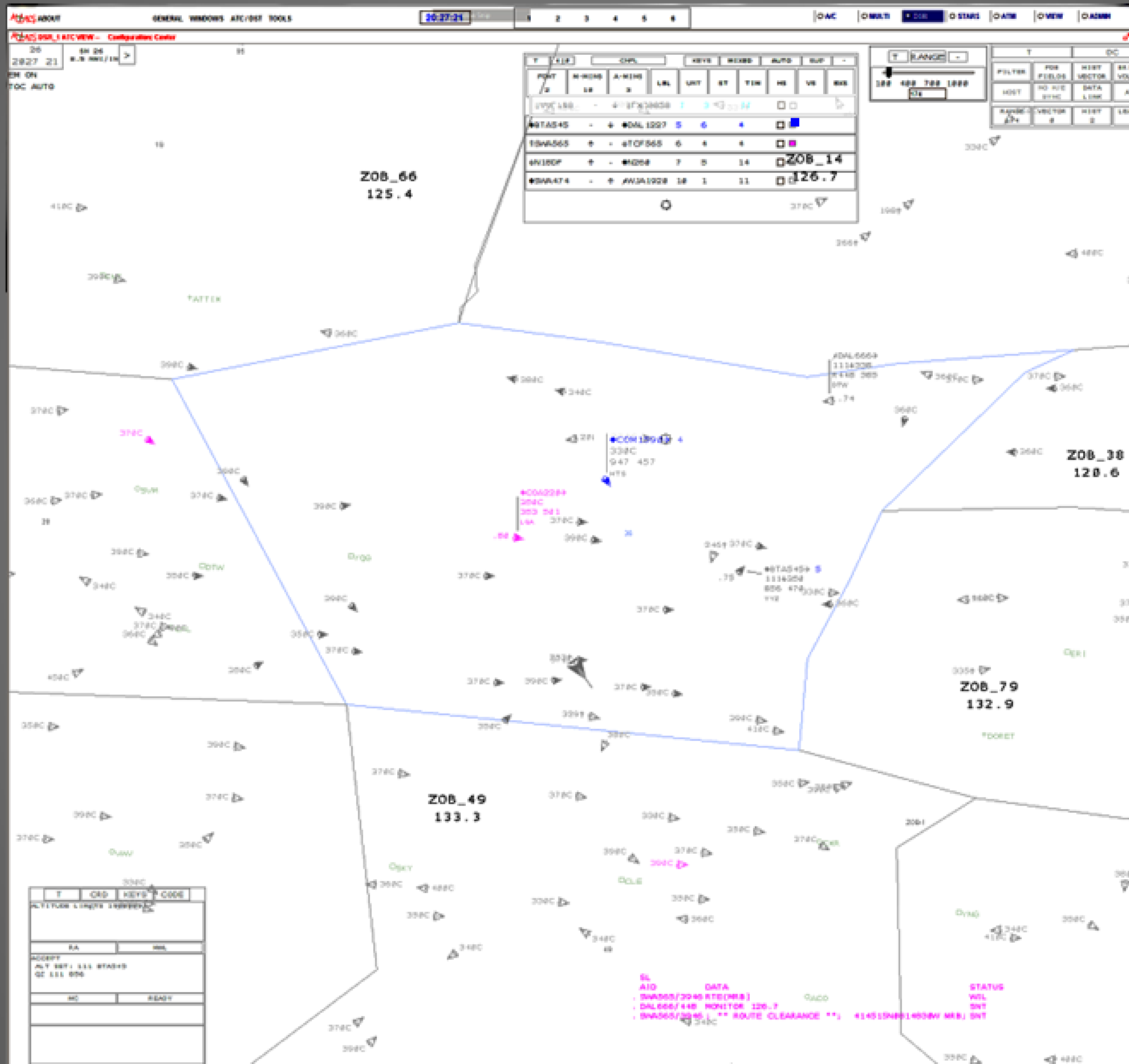
BACK UP SLIDES

Data Tag Display

Figure 3. Expanded data tag examples.

looked like: A) highlighted when manually expanded by the controller, B) a "long-term" seven mins to LOS conflict number in gray C) a "medium-term" five mins to LOS conflict number in yellow, D) a "short term" three mins to LOS with target symbol, data tag, and conflict number in red, E) an auto-generated short term conflict resolution advisory in red, F) a conflict deferred by the automation to the controller in yellow, G) a conflict that the automation is still "thinking" about, and H) an aircraft placed in an auto-uplink inhibited status by a controller.

MACS DSR Maximum NextGen



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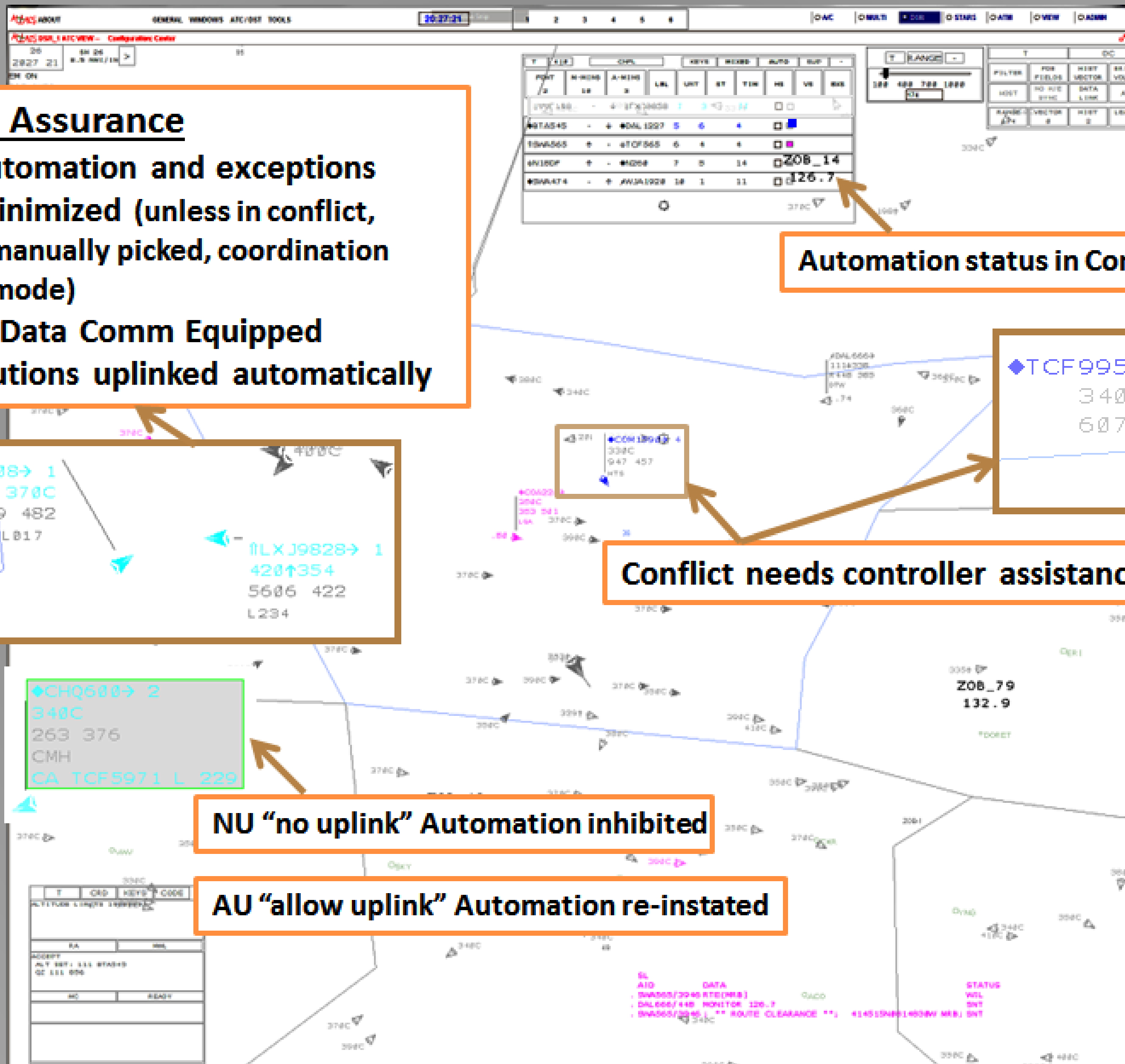

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Levels of Automation - Sheridan

B. Level of Automation

Much of the aforementioned adaptive automation work considers adaptation as changes in what has come to be called the *level of automation* or LOA. Sheridan *et al.* [14] proposed one such scale:

1) The computer offers no assistance: Human must take all decisions and actions.
2) The computer offers a complete set of decision/action alternatives, or
3) narrows the selection down to a few, or
4) suggests one alternative;
5) executes that suggestion if the human approves, or
6) allows the human a restricted time to veto before automatic execution, or
7) executes automatically, then necessarily informs the human, and
8) informs the human only if asked, or
9) informs the human only if it, the computer, decides to.
10) The computer decides everything and acts autonomously, ignoring the human.

Correspondingly, Endsley [15] discriminated the five LOA levels:

1) manual control with no assistance from the system;
2) decision support by the operator with input in the form of recommendations provided by the system;
3) consensual artificial intelligence (AI) by the system with the consent of the operator required to carry out actions;
4) monitored AI by the system to be automatically implemented unless vetoed by the operator;
5) full automation with no operator interaction.

Adaptive automation has also been defined in terms of what the LOA is at different successive *information processing stages* of performing a task, [16], namely:

1) acquisition of information needed to do the task;
2) analysis of that information;
3) decision of what action to take;
4) execution of that action.

[14] T. B. Sheridan, W. L. Verplank, and T. L. Brooks, "Human/computer control of undersea teleoperators," in *Proc. IEEE Int. Conf. Cybern. Soc.*, Tokyo, Japan, 1978.

[16] R. Parasuraman, T. B. Sheridan, and C. D. Wickens, "A model for types and levels of interaction with automation," *IEEE Trans. Syst., Man, Cybern. A, Syst., Humans*, vol. 30, no. 3, pp. 286–297, May 2000.