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Automated Air Traffic Control

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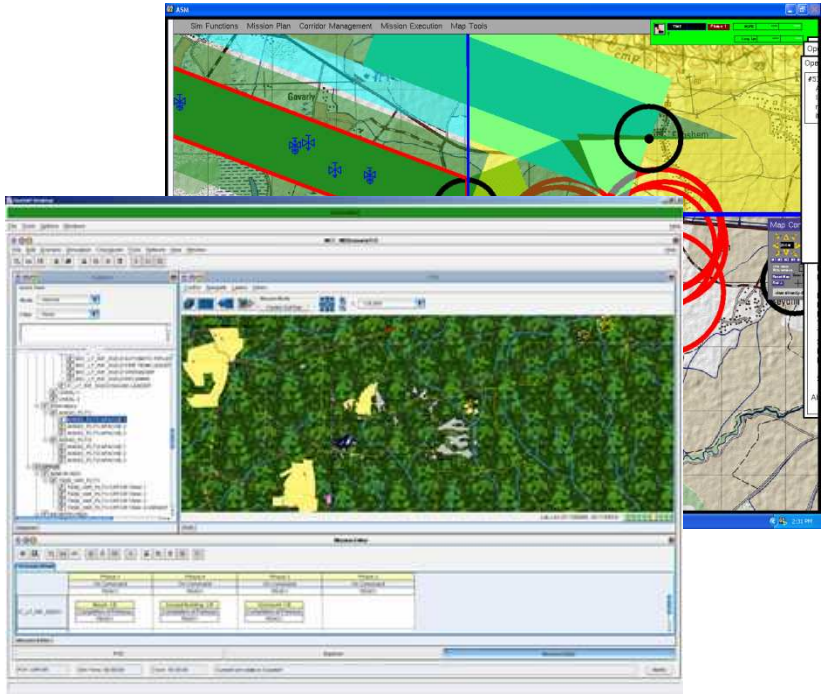
Project Objectives

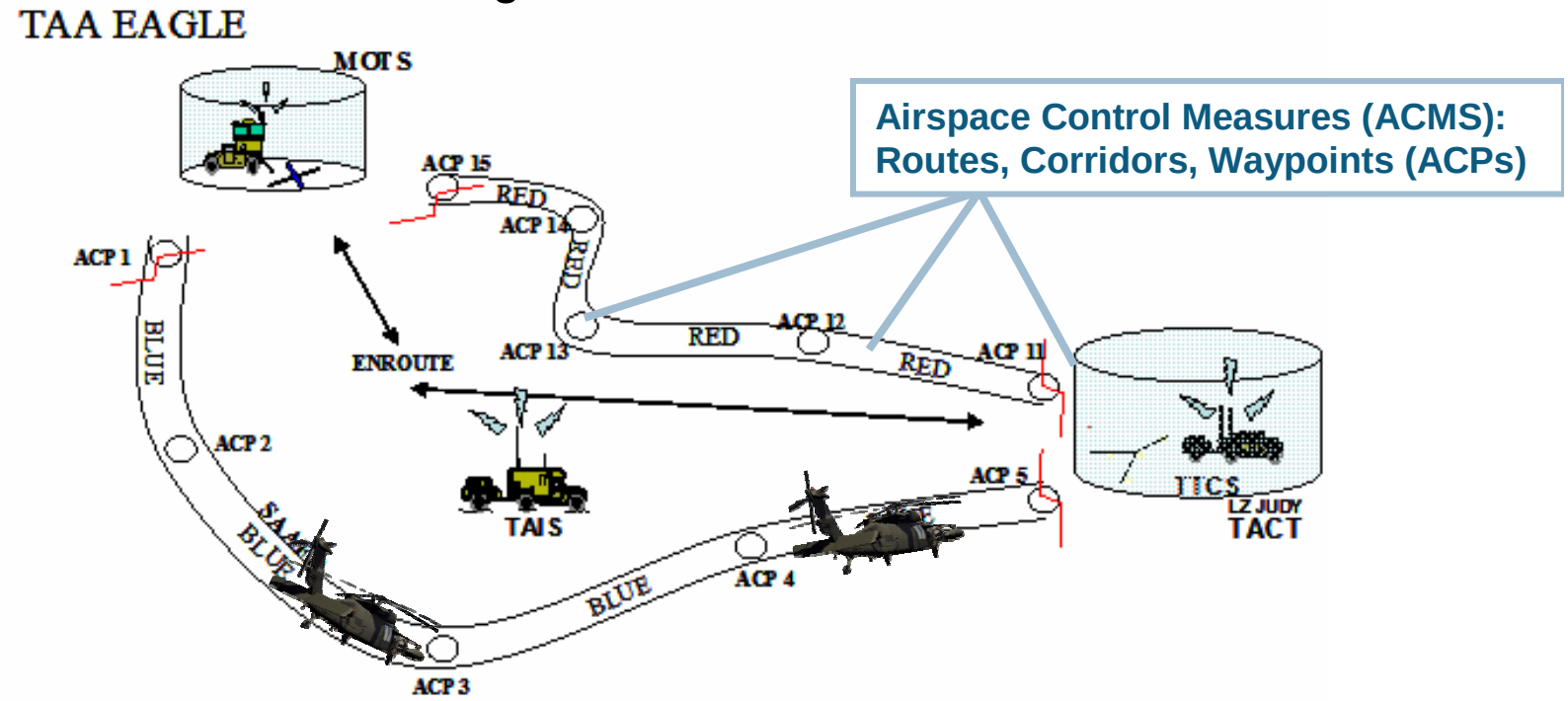
- **Problem:** ATC is not played much in simulation
  - reduces realism
  - where it is, it's played by humans - increasing expense of simulation
- **Goal:** To automate ATC within simulation
  - Increase realism
  - reduce costs of playing
  - interact transparently with human and synthetic pilots alike.



military simulation environments

Army Air Traffic Services – Background

- Army Air Traffic Services (ATS)
  - Part of overall airspace management (ASM)
  - **Procedural Control** – using airspace control measures (ACMs), agreed-upon rules
  - **Positive Control –** using direct id/interactions with aircraft



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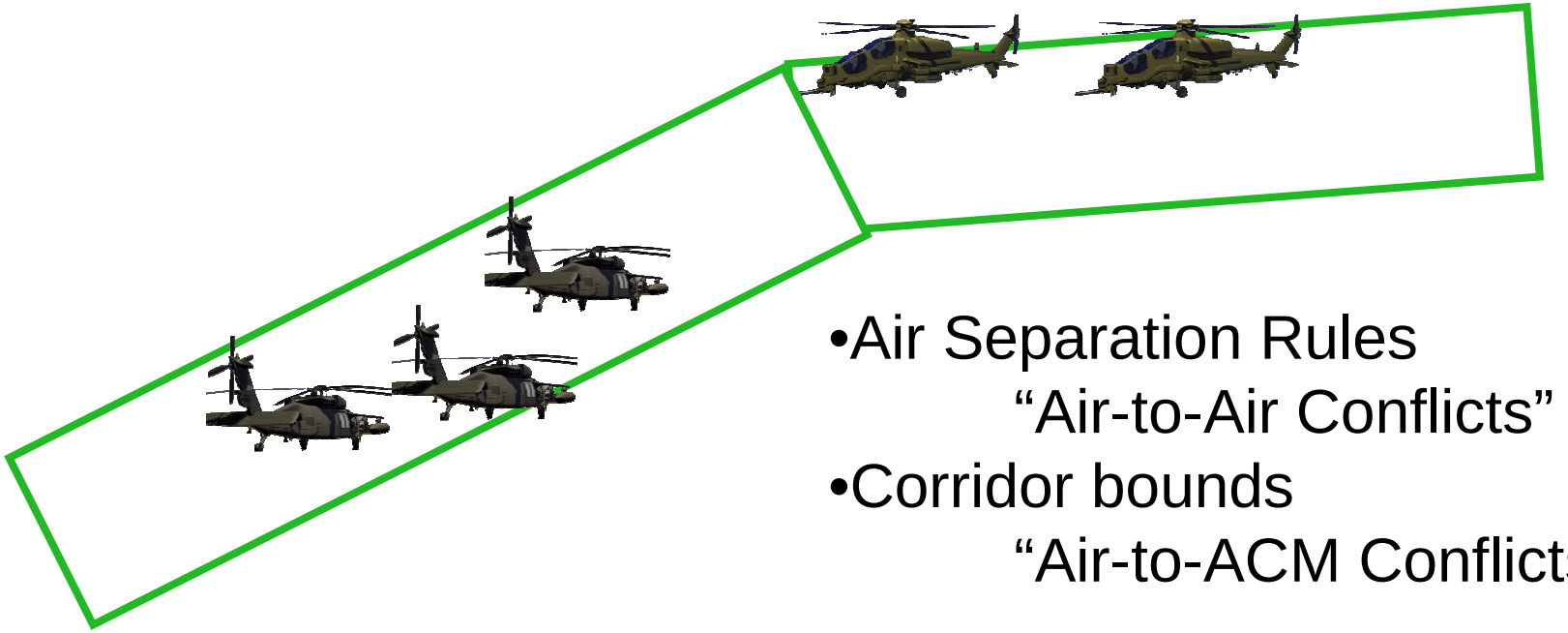
Sub-problem Focus:
Conflict Detection and Advisory Generation



- Air Separation Rules
  - "Air-to-Air Conflicts"
- Corridor bounds
  - "Air-to-ACM Conflicts"

When conflict detected, generate an advisory:

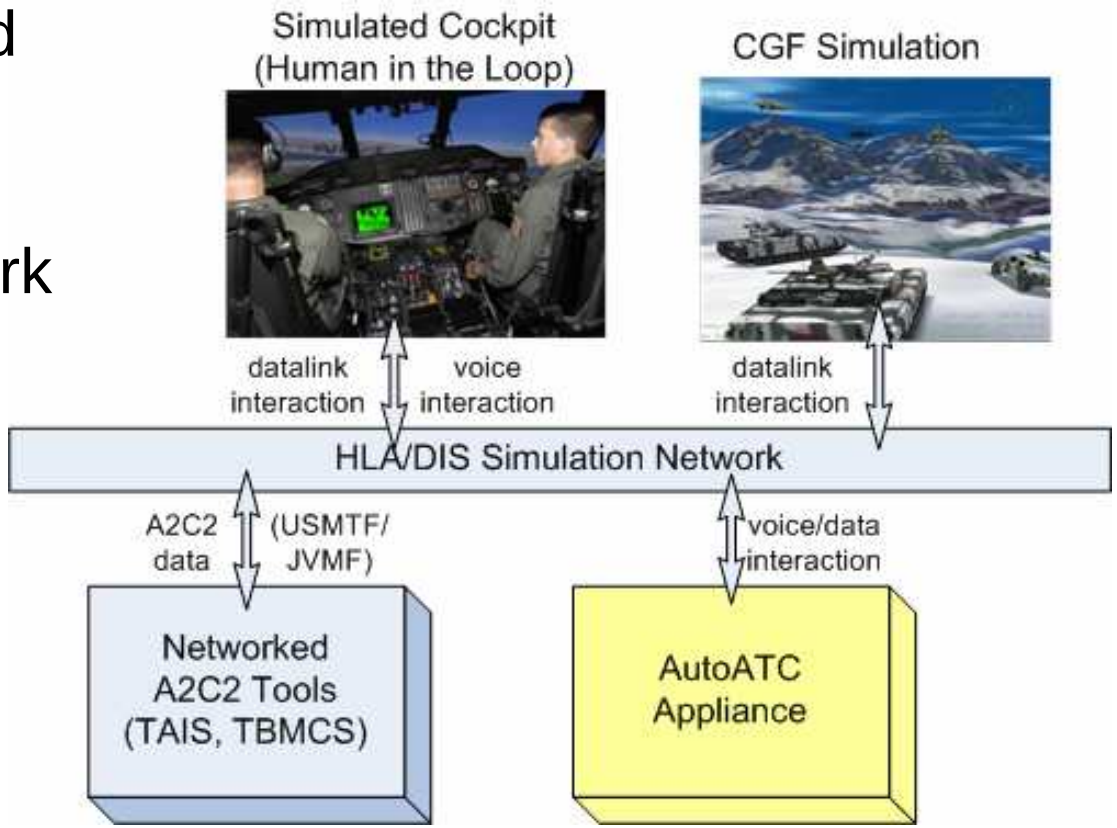
Air-Air: "Eagle01 this is Alpha15 be advised AH-60 flight coming inbound on SAAFR7"

or

Air-ACM: "Eagle01 this is Alpha15 you are right of course, correct to heading 080"

High-Level Approach

- Develop network-based "appliance" ATC
- Use existing sim network technologies/protocols
- Incorporate human language interactions
- Incorporate knowledge about how to do ATC



Detailed Approach

- "Human Behavior Model" of task performance
  - Explicit model of situational awareness
  - Explicit encoding of domain, task knowledge
  - Goal-directed ATC behavior
  - Explicit interaction with aircraft via simulated radio
  - Model of decision making regarding conflicts and advisory generation

Situation Awareness (from Endsley)

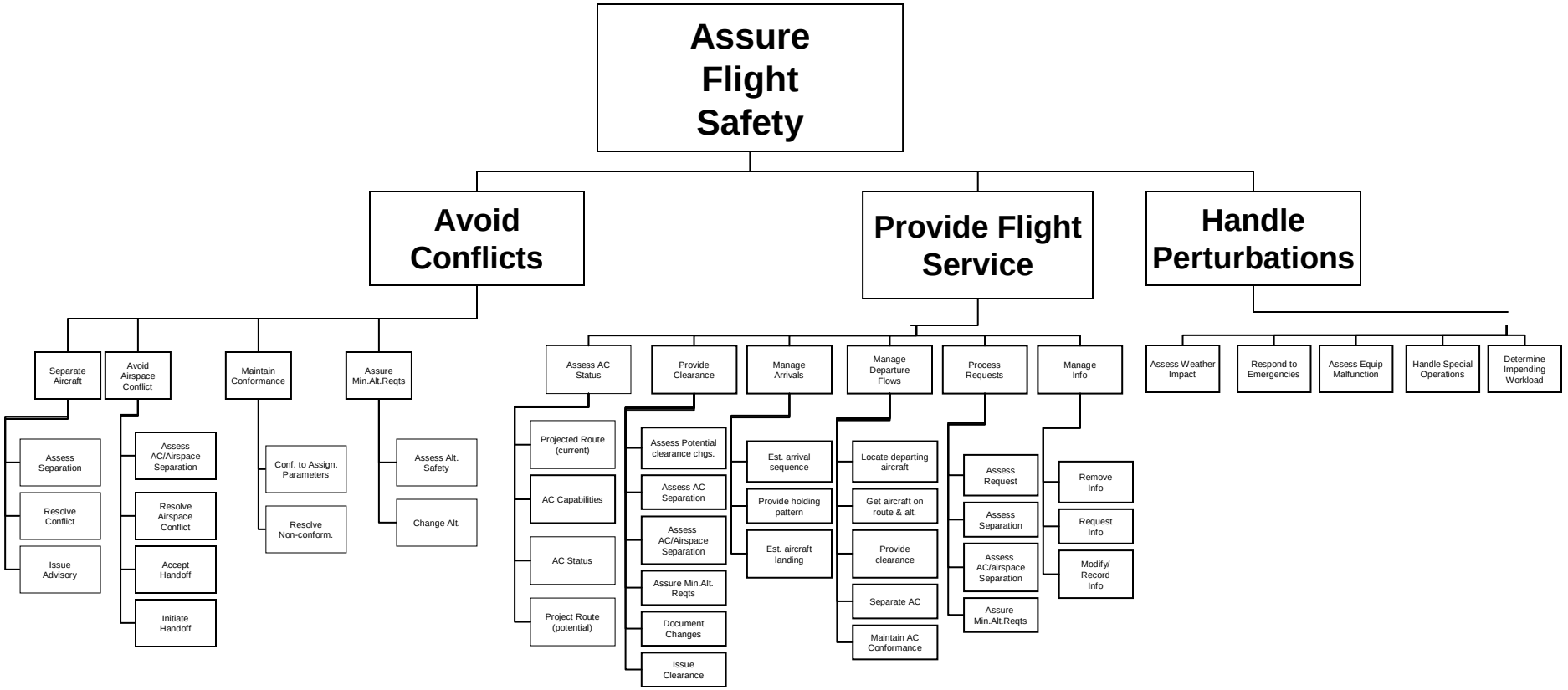
- Level 1: the perception of the elements in the environment within a volume of time and space (current picture)
- Level 2: the compression of their meaning (understanding wrt goals)
- Level 3: projection into the future

Controllers: “The Picture”

Perceive – Decide – Act

Situation Assessment

Goal-Directed Task Analysis of ATC (Endsley)



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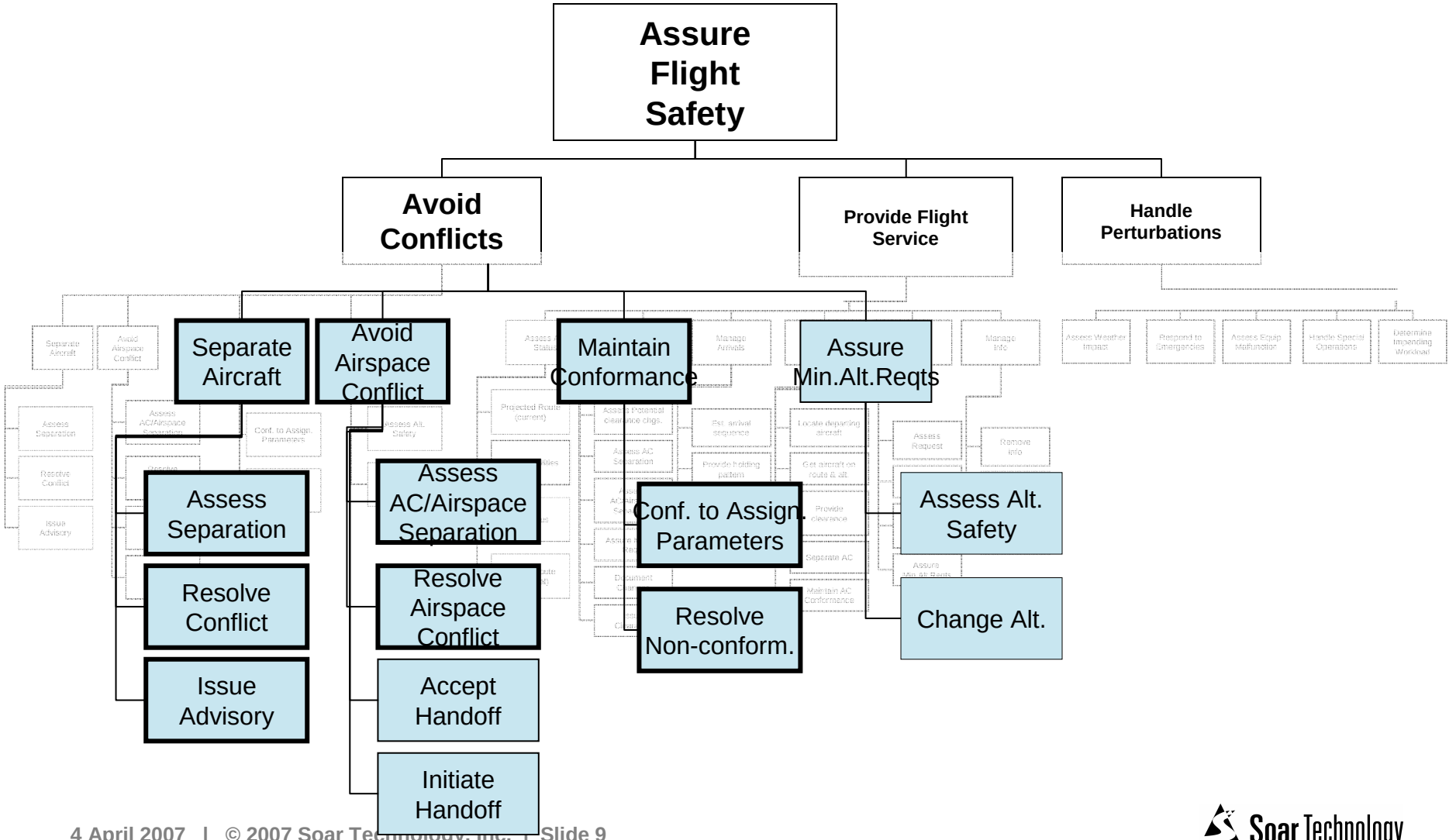
Avoid Conflicts Task Decomposition

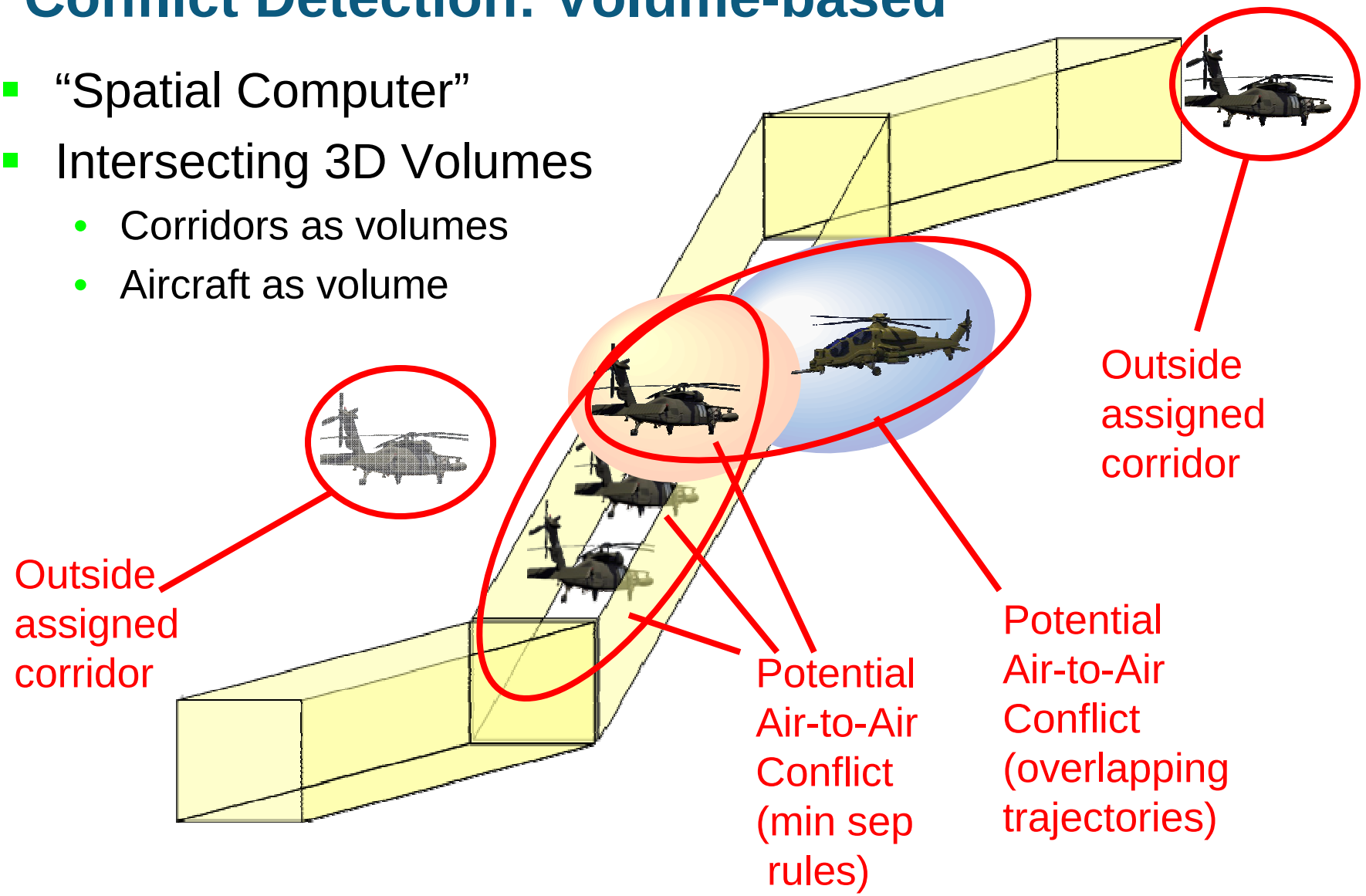


Situational Awareness Goals

- Maintain Level 1 Situational Awareness
  - Export ACM, ACP and aircraft data to external spatial computer
- Maintain Level 2 Situational Awareness
  - Query the spatial computer about the state of the battlespace
  - Identify current potential conflicts
- Maintain Level 3 Situational Awareness
  - Identify possible future conflicts by projecting the current state of the battlespace

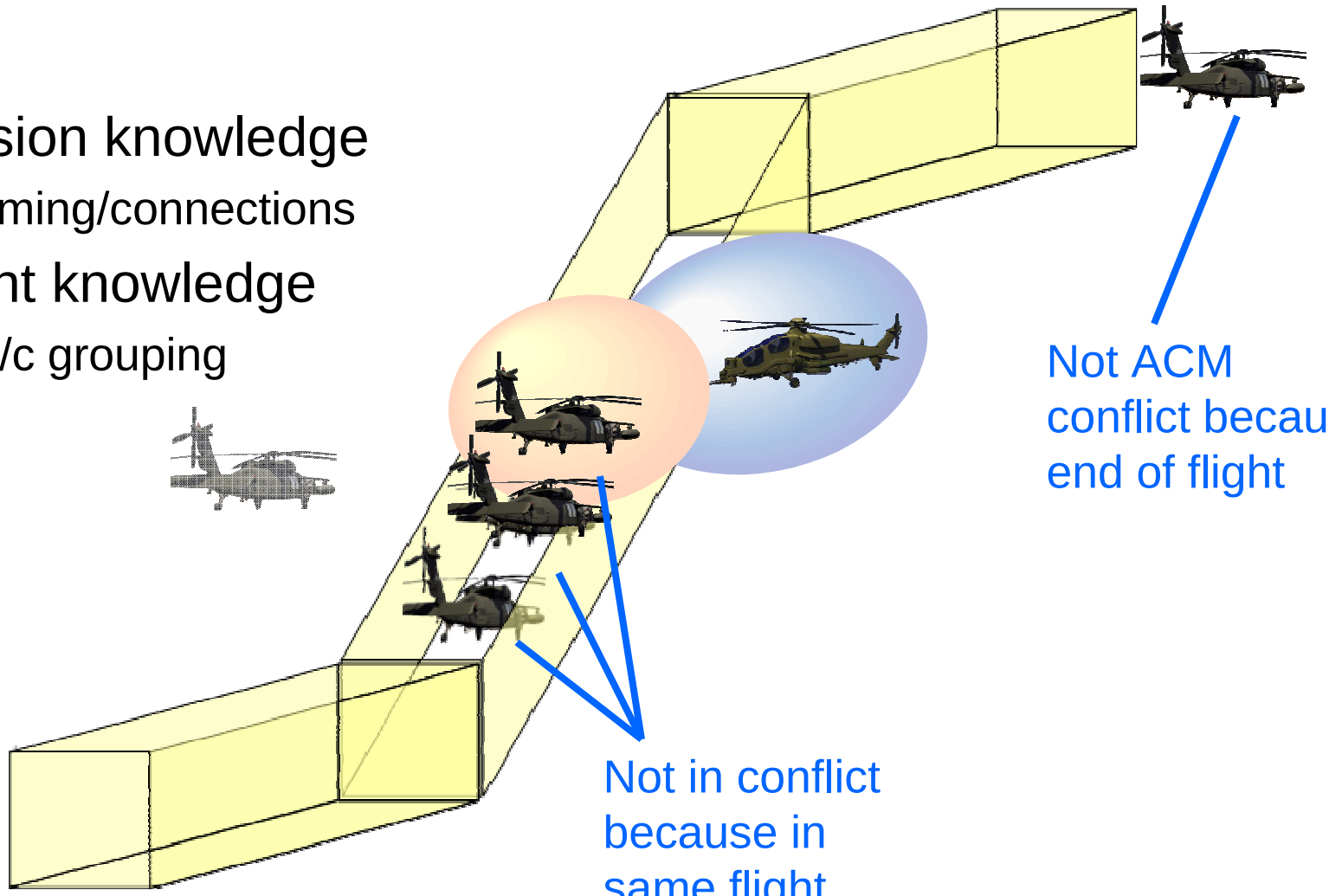
Conflict Detection: Volume-based

- "Spatial Computer"
- Intersecting 3D Volumes
  - Corridors as volumes
  - Aircraft as volume



Conflict Detection: Knowledge-based

- Mission knowledge
  - timing/connections
- Flight knowledge
  - a/c grouping



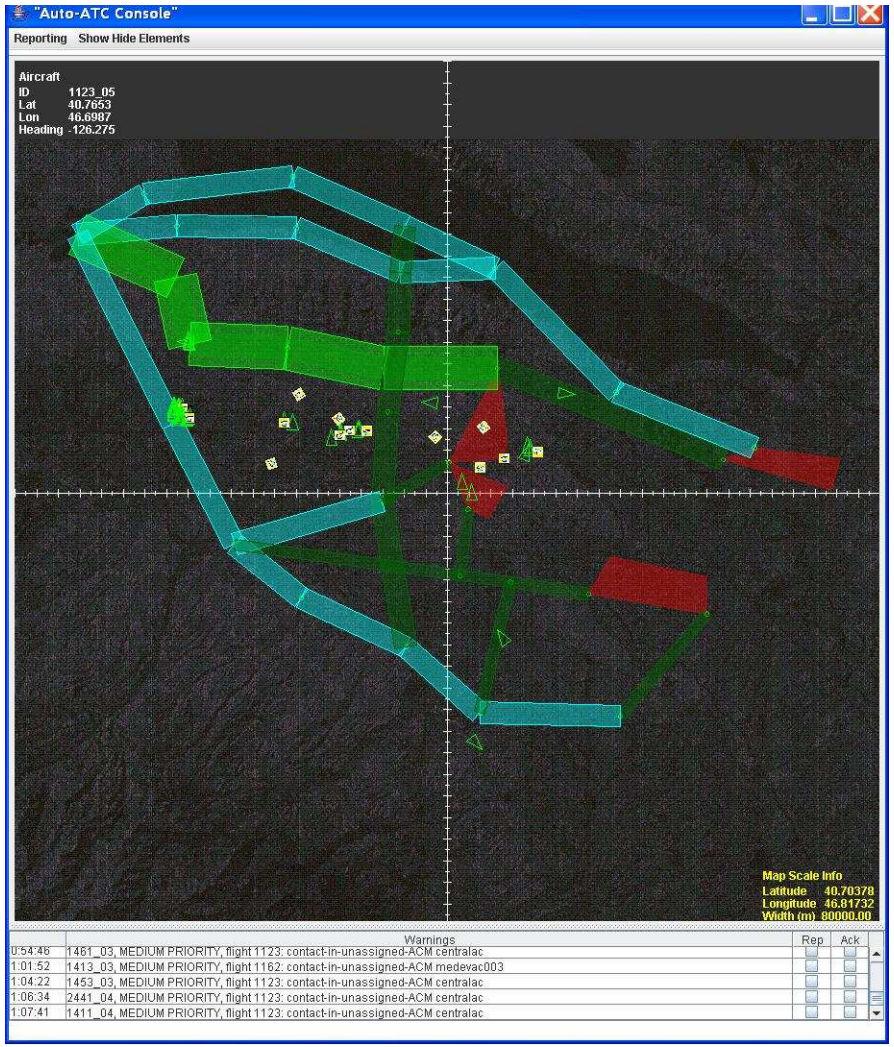
Advisory Generation

- Of the valid conflicts detected, generate advisory based on known data
  - A “heads-up” kind of advisory
  - Generic suggestions about mitigation
  - No detailed flight changes or replanning
    - not much required for RWA aviation (extra SA: see-and-be-seen)
- Here: Semantic content generated, not surface forms
  - i.e., who-what-where, rather than “Mike95 this is Alpha15…”

AutoATS Console

- Display Airspace Control Measures (corridors, routes, points, ROZs)
- Display aircraft/details
- Display conflicts (visual icon and rough advisory text)

- Essentially agent's Levels-1&2 SA picture



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Model-Building Process

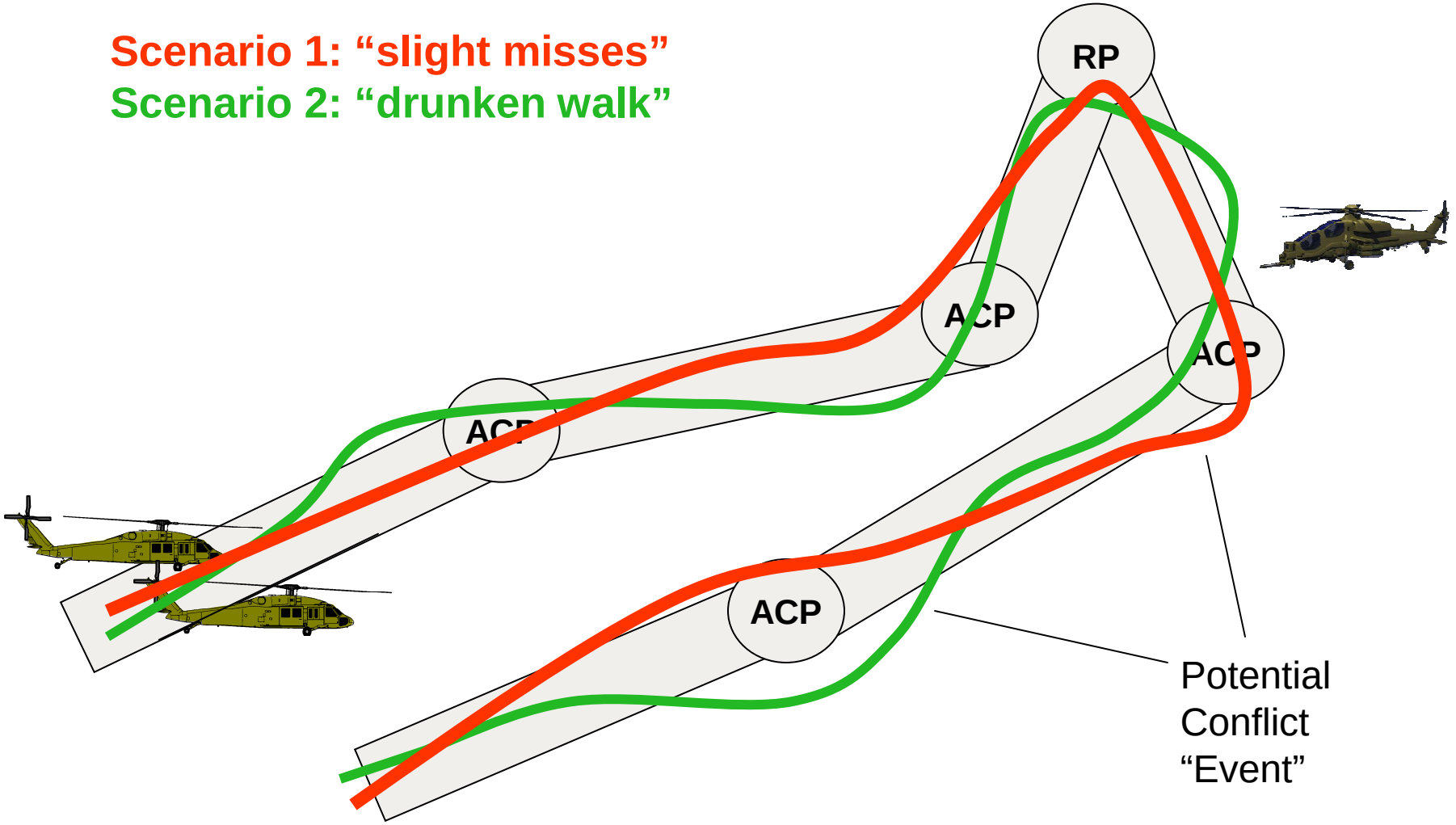
- SME/Knowledge Acquisition
  - acquire basic rules of operation
- Knowledge Engineering
  - code rules, build system
- Evaluate
  - side-by-side comparison with collected human data
- Iterate
  - revise strategies for decision-making

Evaluation

- How well does AutoATS do in conflict detection and advisory generation
  compared to a human performing same task?

Evaluation Scenarios

Scenario 1: “slight misses”
Scenario 2: “drunken walk”



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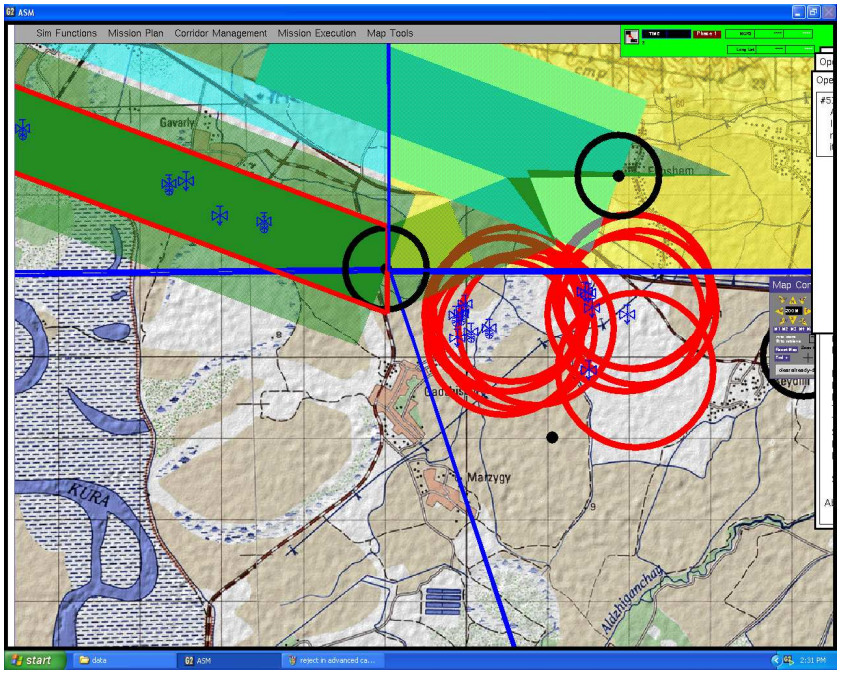
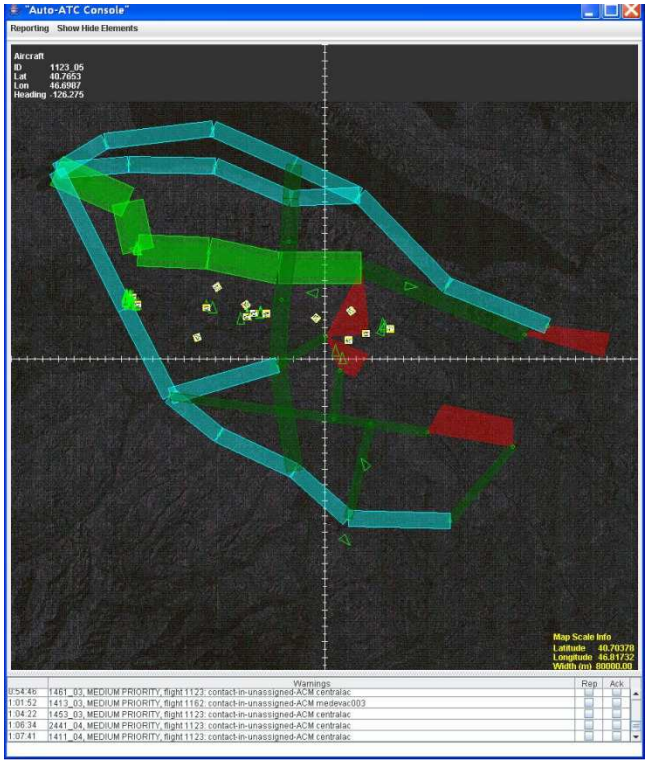
Evaluation Setup

- Human ATC detecting conflicts (via ASM) and generating advisories (to non-responsive aircraft)



- AutoATS detecting conflicts and generating advisories (to non-responsive aircraft)



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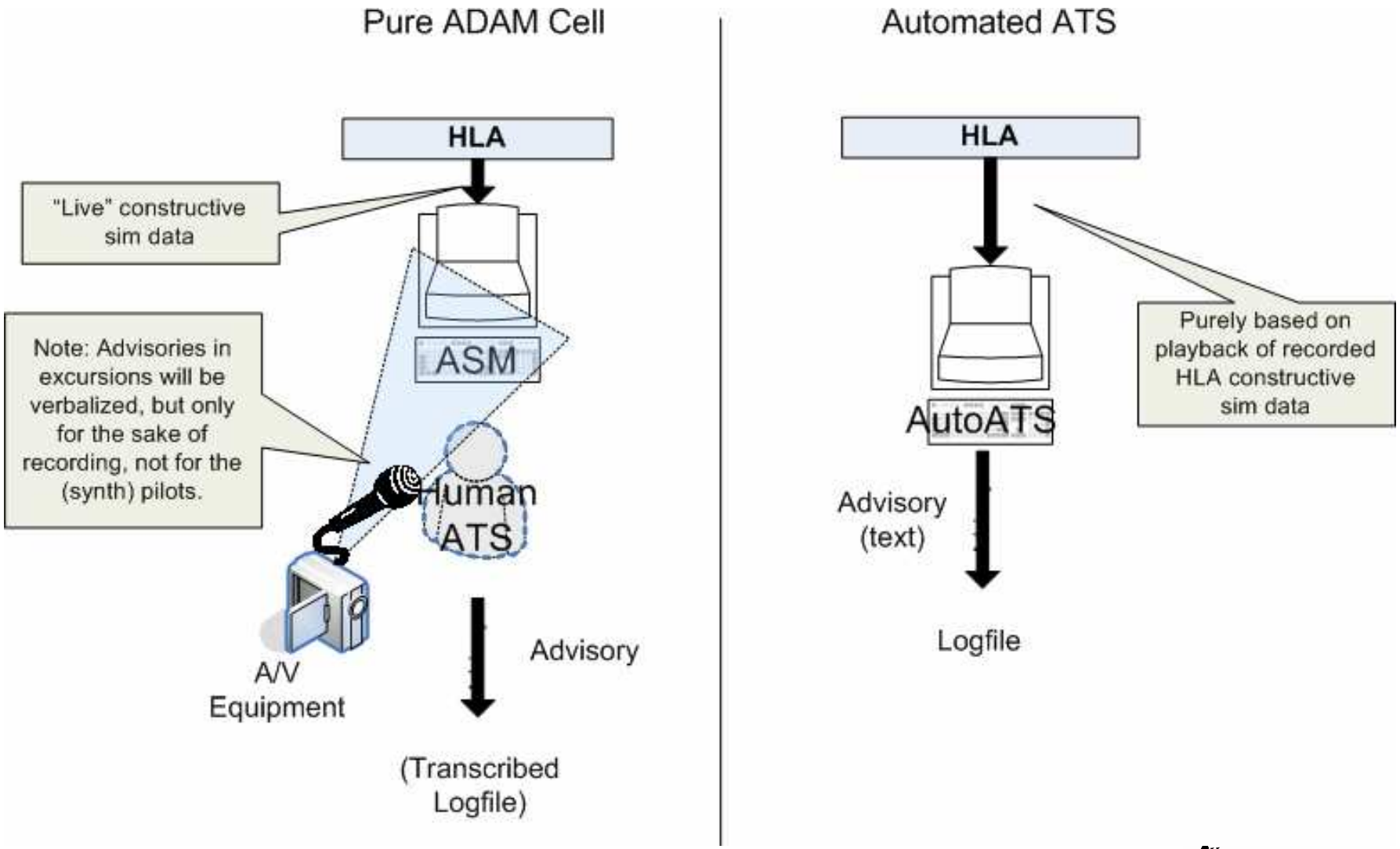
Experiment Setup



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Results Discussion

- Strategy differences
  - re-reporting of advisories after timeout (AutoATS fixed; human based partly on re-scan time)
  - intent recognition: if aircraft looked to be going in right direction, human would not report; AutoATS didn't take into account
  - reporting of multiple infractions per detection (e.g., altitude and lateral conflict) – human reports all; AutoATS reports first
- Geometry differences
  - One corridor represented differently in two systems (accounts for 1 AutoATS "error" in each scenario)
- Perceptual misses (some difference in approach to task)
  - Human scans, zooms console, causing misses
  - AutoATS sees everything
- Human reaction time (likely partially result of increasing load)
  - Scenario 1: 16 seconds from infraction to report
  - Scenario 2: 34 seconds from infraction to report
  - (AutoATS fixed immediate reaction)
- Bugs
  - 1 unknown data difference

Nuggets/Coal

- Development and evaluation of prototype AutoATS system in Army exercise
  - Favorable comparisons to human performance in narrow task

- Despite small amount of data, utility in analyzing and comparing at the level of individual human's decision-making strategies

- Evaluation generated new hypotheses about kinds of knowledge and info processing required to do these tasks in human-like ways
  - e.g., intent inferencing, soft constraints

- Comparison against very limited human data

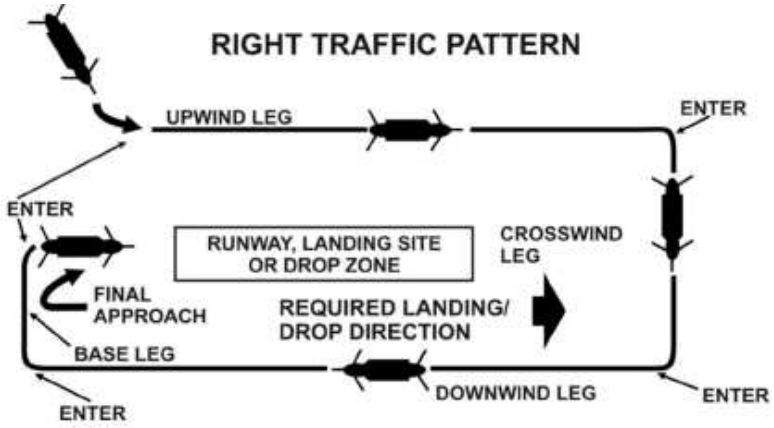
- Somewhat contrived environment
  - Aircraft unable to respond to advisories

- Several discrepancies of AutoATC vs. human performance (strategic, geometric, simple bugs)

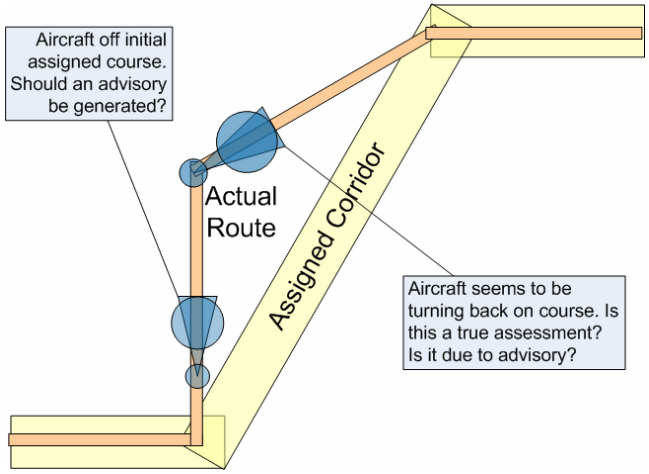
- Need to look more deliberately at pilot interface level
  - e.g., generating 'real' advisories

Backup slides

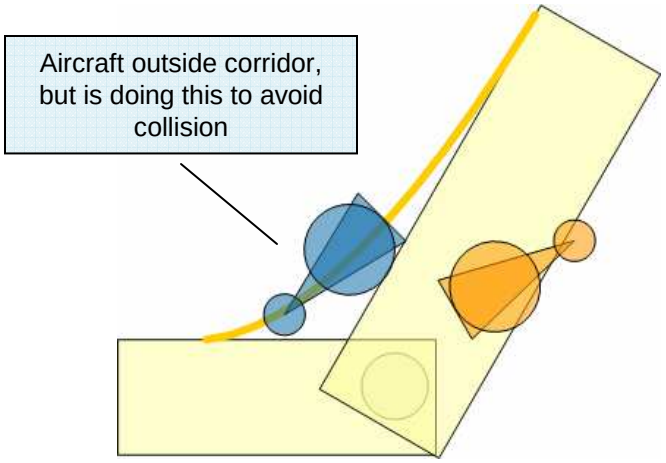
Intent Recognition in ATC



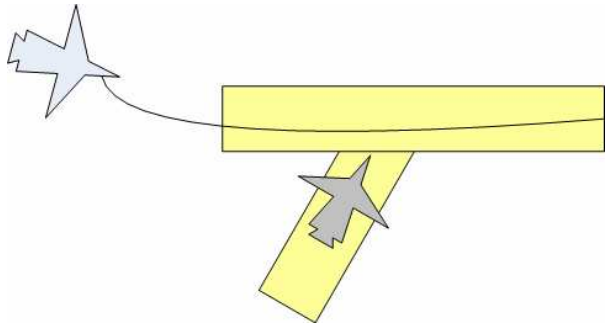
Is aircraft correctly following procedures?



Is aircraft following ATC request?



Is aircraft outside corridor to avoid other?



Is aircraft going to stop in time?

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Challenges

- How to deal with mission timing?
  - Aircraft expected at location at a given time – if they don't make it, how to adjust cascading expectations?
- Intent recognition
  - Once advisory (or command) given, how to judge if aircraft is doing what it was told?
  - Likely approach: Heuristics
- Performance –
  - currently looking at (lead) aircraft only, not munitions, etc.
  - what happens if we pay attention to everything?
- Spatial-temporal reasoning
  - currently brute-force – clearly not what human is doing much more efficiently; what tradeoffs?

ATC Situation Awareness Requirements

- What knowledge is required to effectively perform ATS? (from Endsley et al):

Level1 = Current Situation	Level2 = Understanding	Level3 = Future
•Aircraft	**•Conformity**	**•Projected AC Route (current)**
•Emergencies	**•Current Separation**	•Projected AC Route (potential)
•Requests	**•Timing**	•Projected Separation
•Clearances	**•Deviations**	•Predicted Changes in Weather
•Sector	•Other Sector/Airspace	•Impact of Potential Route Changes
•Special Operations	•Significance	
•ATC Equipment malfunctions	•Confidence Level/Accuracy of Info	
•Airports		
•Weather		