Analyzing Air Traffic Management Systems Using Agent-based Modeling and Simulation

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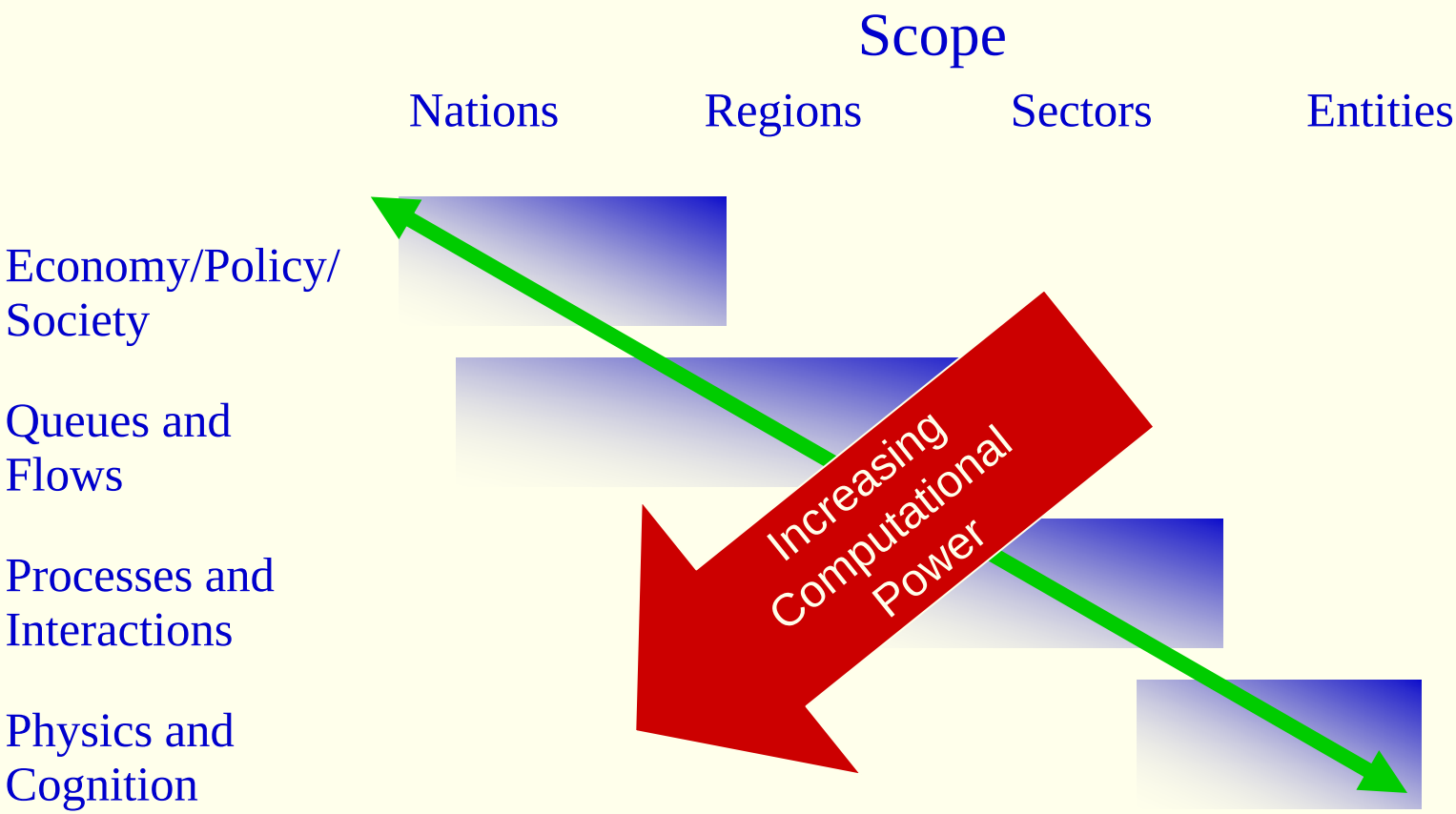
What is the Appropriate Decomposition?



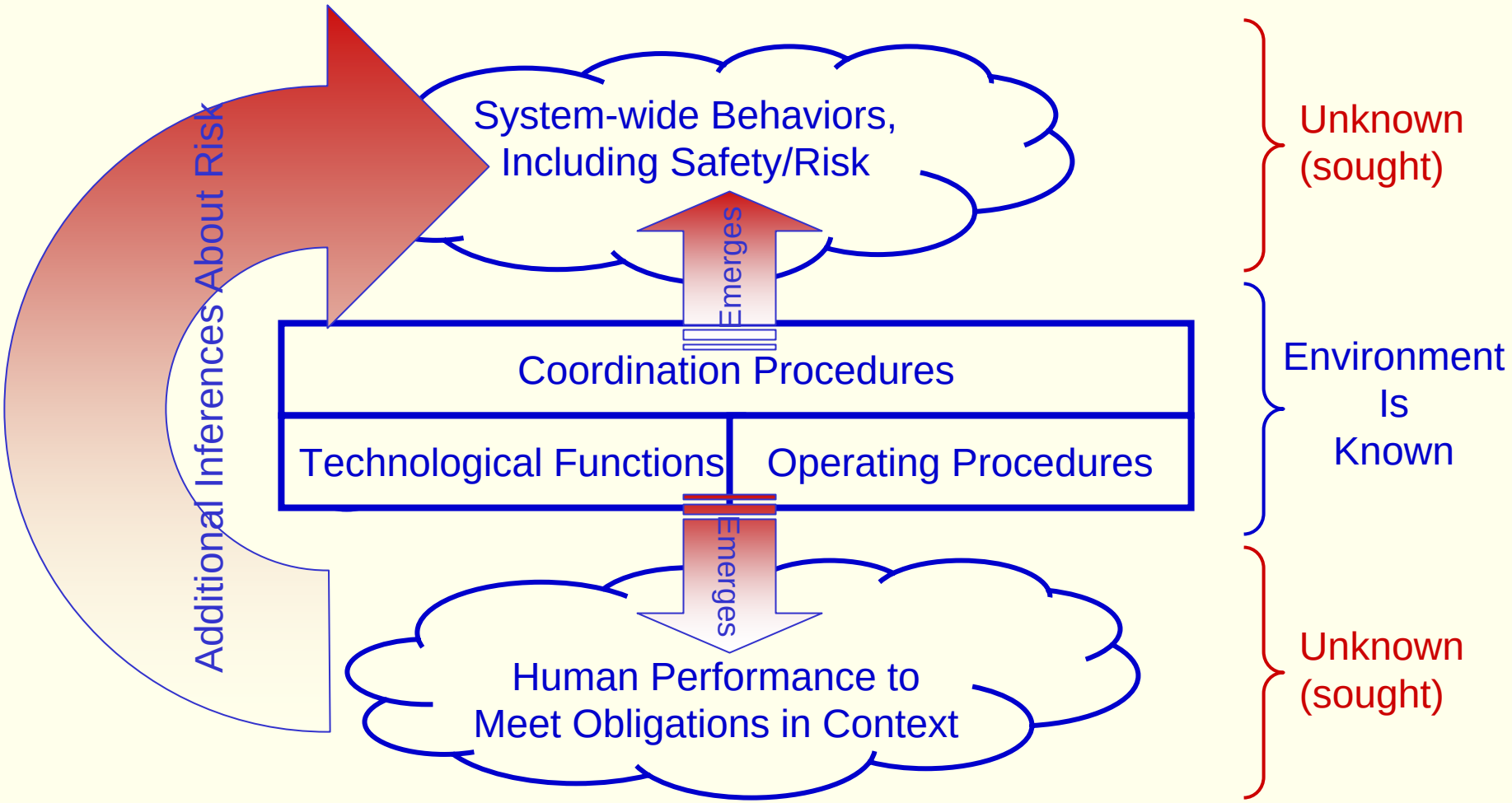
Key Concept: Emergence

- "Emergent Behavior" – a behavior at one level of abstraction that can not be predicted from another level of abstraction
  - Needs simulation to predict!
- Thought question: If we simulated the national airspace system with every "agent" exactly following procedures, would it be safe?
  - *And then throw in impact of human performance of context on top of it!*

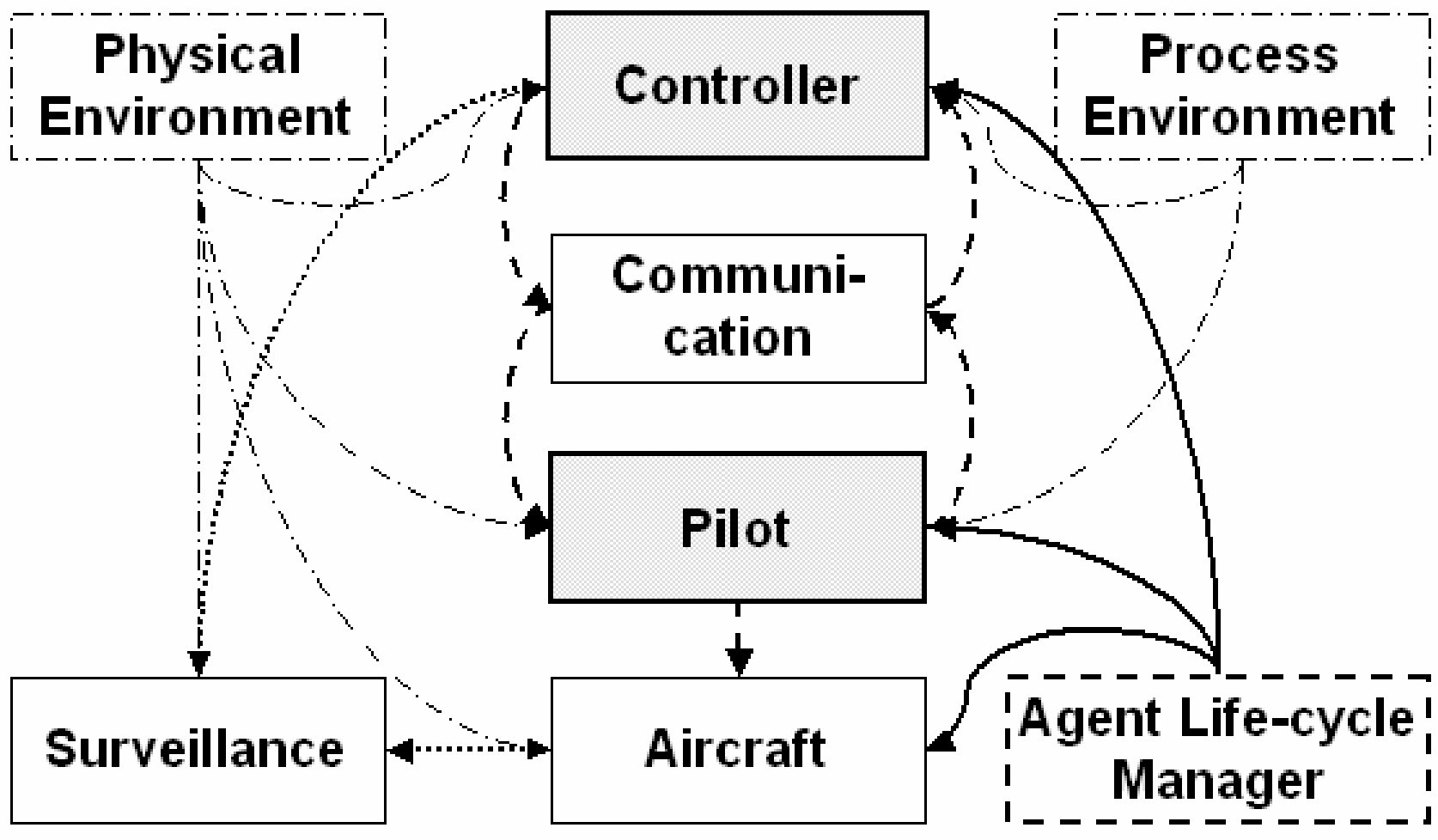
Key Concept: Structure Preserving

- Model maintains the form of reality
  - E.g., directly represent “knowns” in the world in same form as they are designed / implemented
  - Stream-lines all aspects of the process by minimizing translation and abstraction
    - Less model translation
    - Direct comparisons for validation
    - Direct applicability to implementation

Known and Unknown



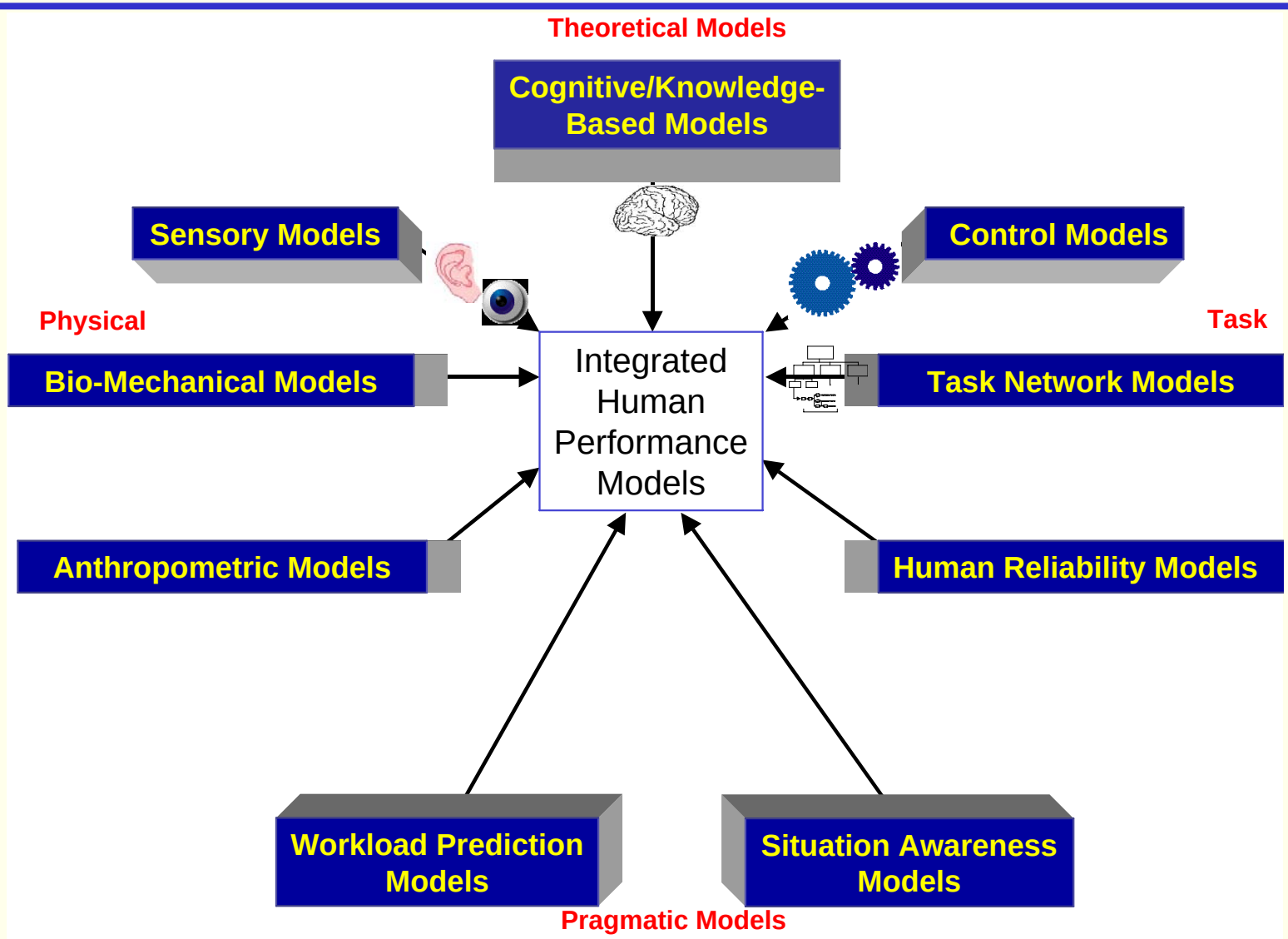
Agent-Based Simulation of Arrival Streams



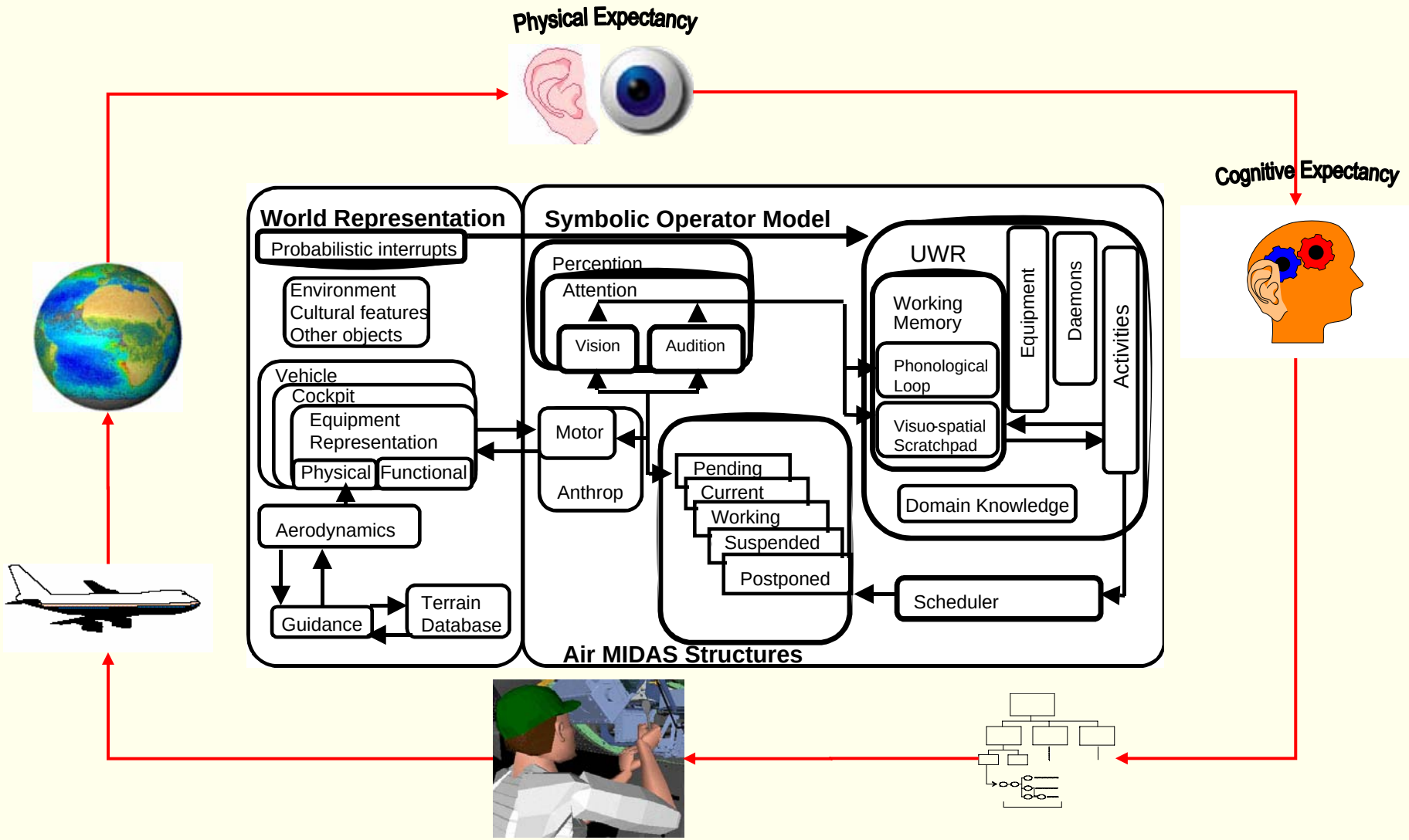
Time-based and Miles-in-trail Metering

- Control Runs Compared
  - Actual PDARS data flight profiles from human ATC
  - Generated data
    - Resultant from injecting the flights into the upstream sectors and the actions of the simulated air traffic controllers
  - Nominal or reference data
    - Profiles generated by taking averaged flight parameters (lat, long, alt & speed) at fixes and entry/exit points in the sectors
- Type of Control
  - Time Based Metering or Miles In Trail Metering

Integrated Models - Composition

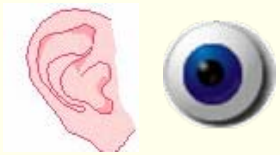


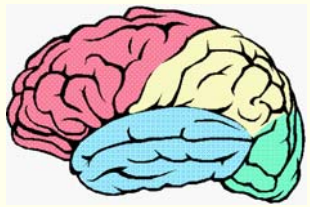
Air MIDAS Integrated Representation

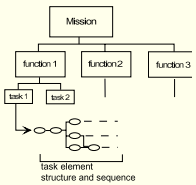


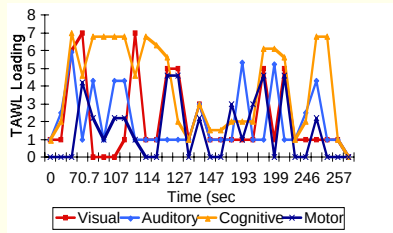
Air MIDAS Output

- Human performance values for the interaction between multiple human agents, the system and the environment:
  - Perceptual demands
  - Operator attention demands
  - Cognitive loading
  - Context-Control Switching
  - Memory representations
  - Task-related information
    - Scheduling, degradation, shedding
    - Task time to complete
    - Timeline information

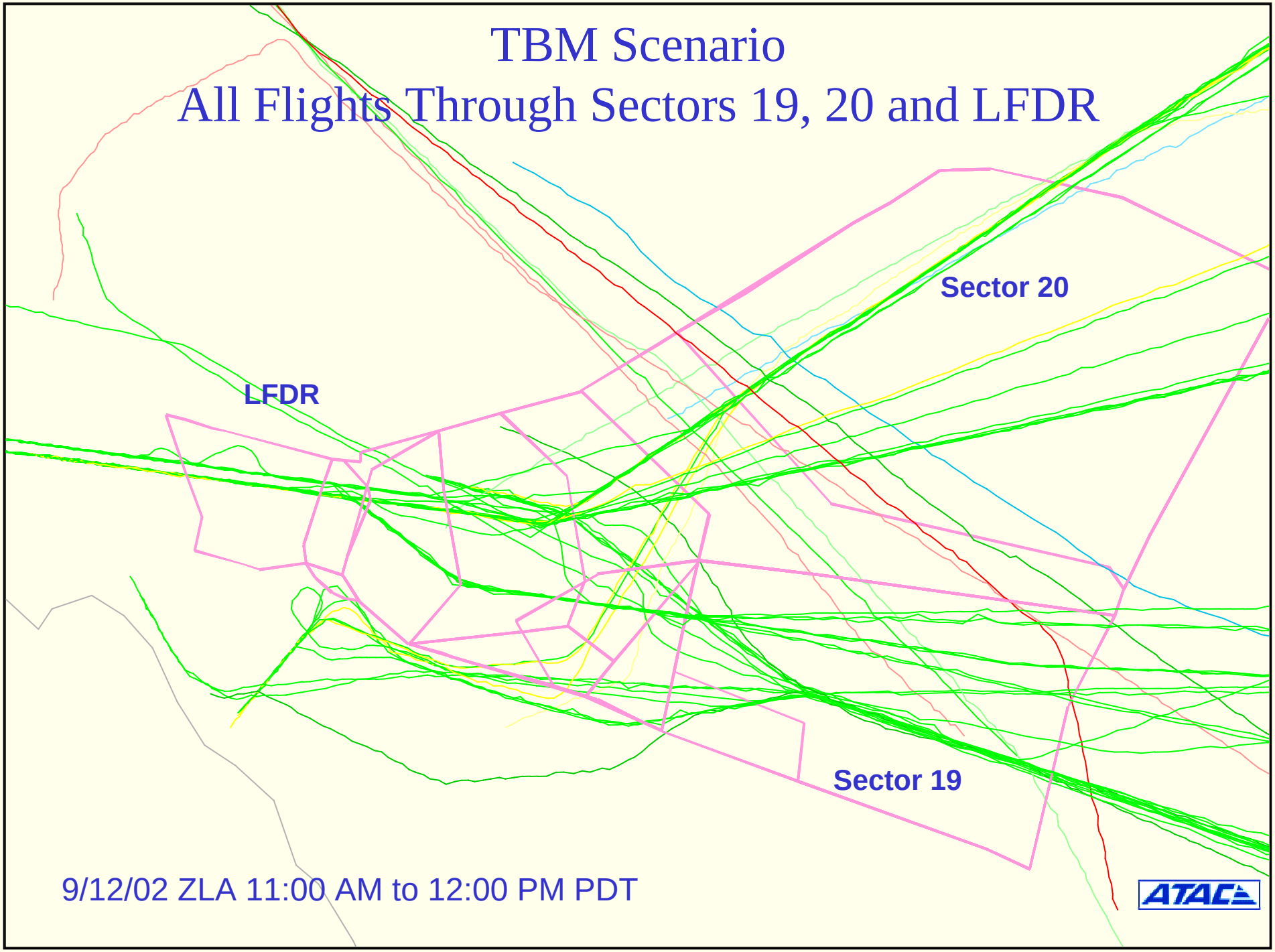








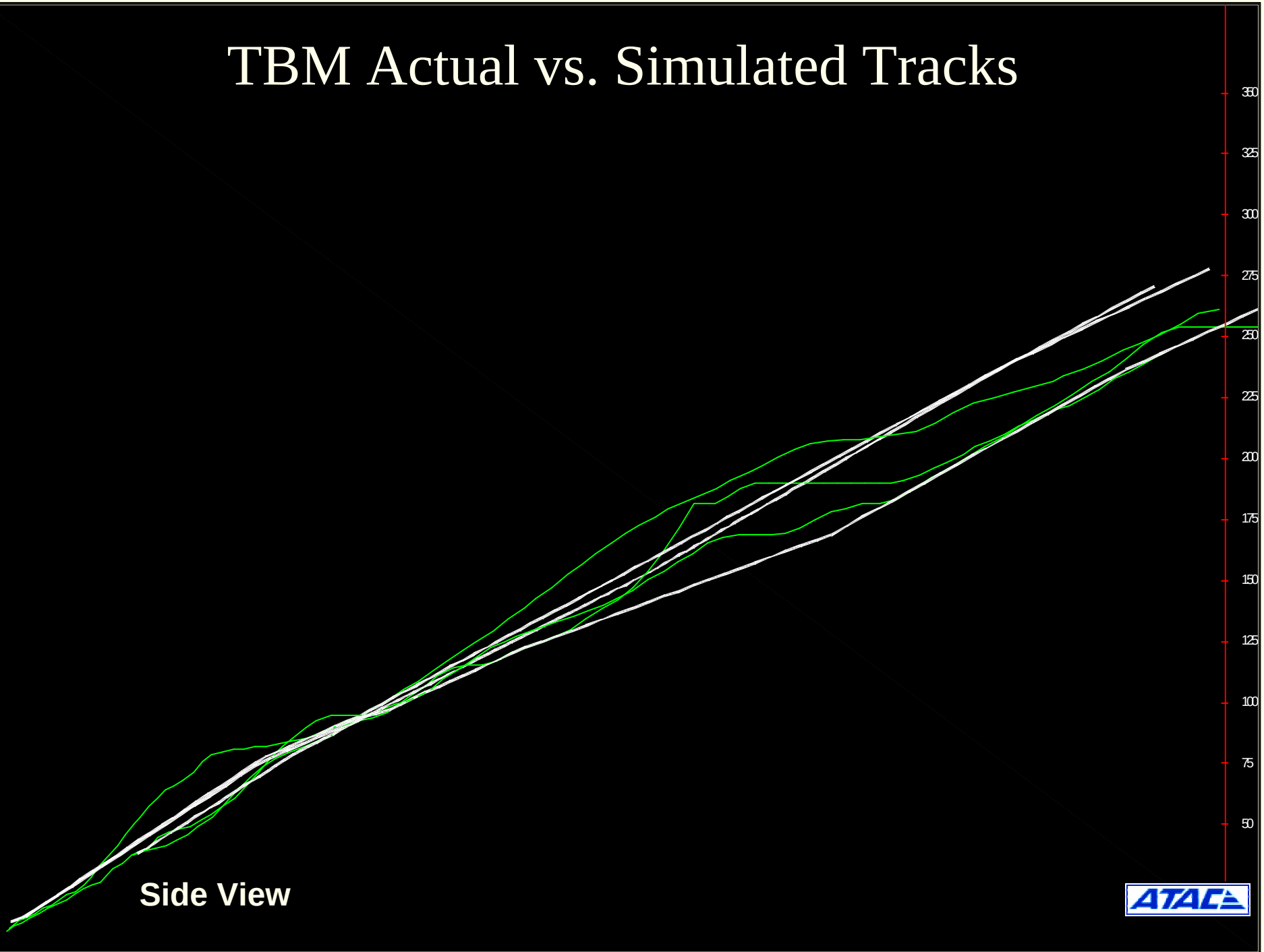
TBM Scenario
All Flights Through Sectors 19, 20 and LFDR



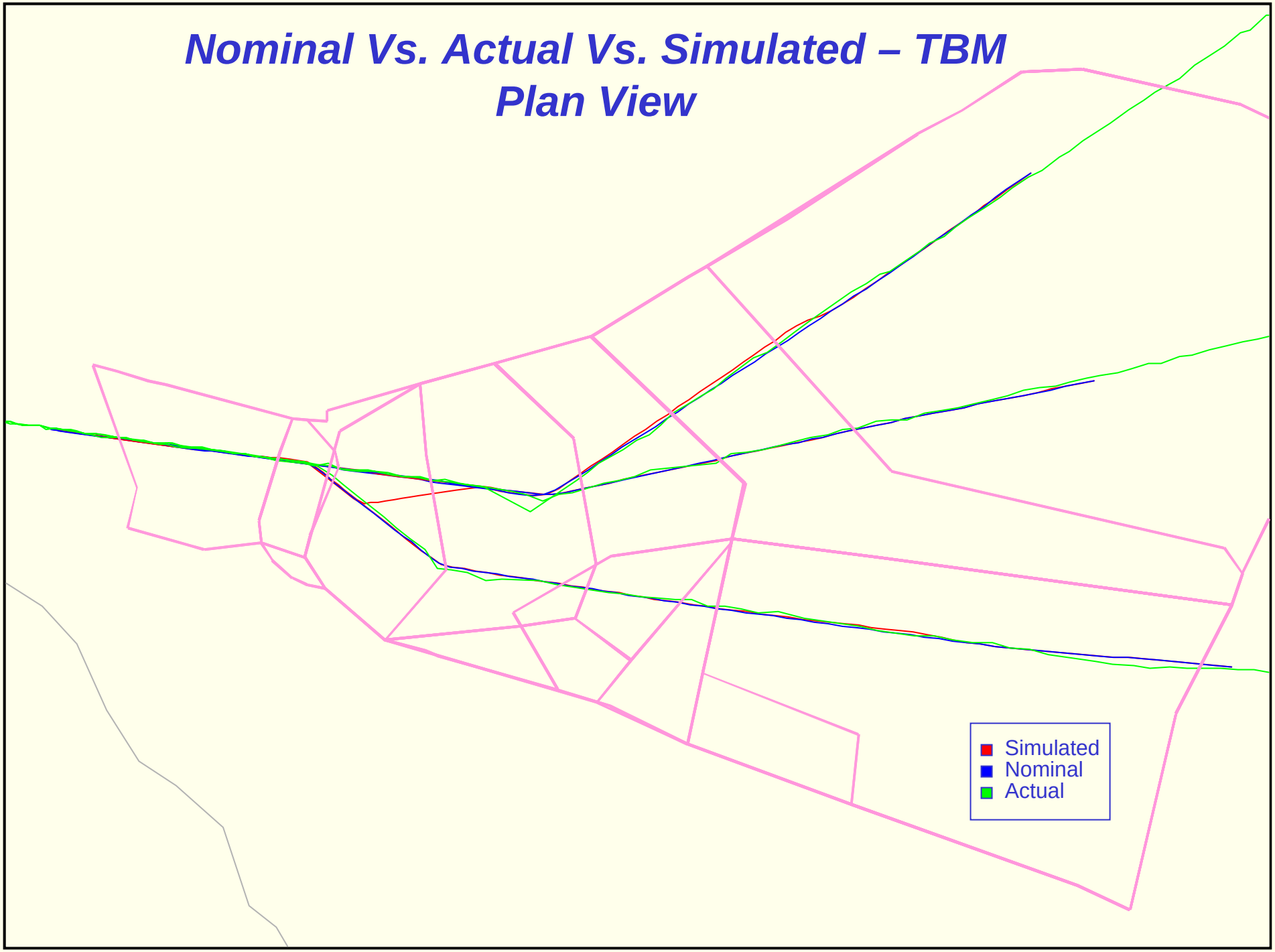
9/12/02 ZLA 11:00 AM to 12:00 PM PDT

ATAC

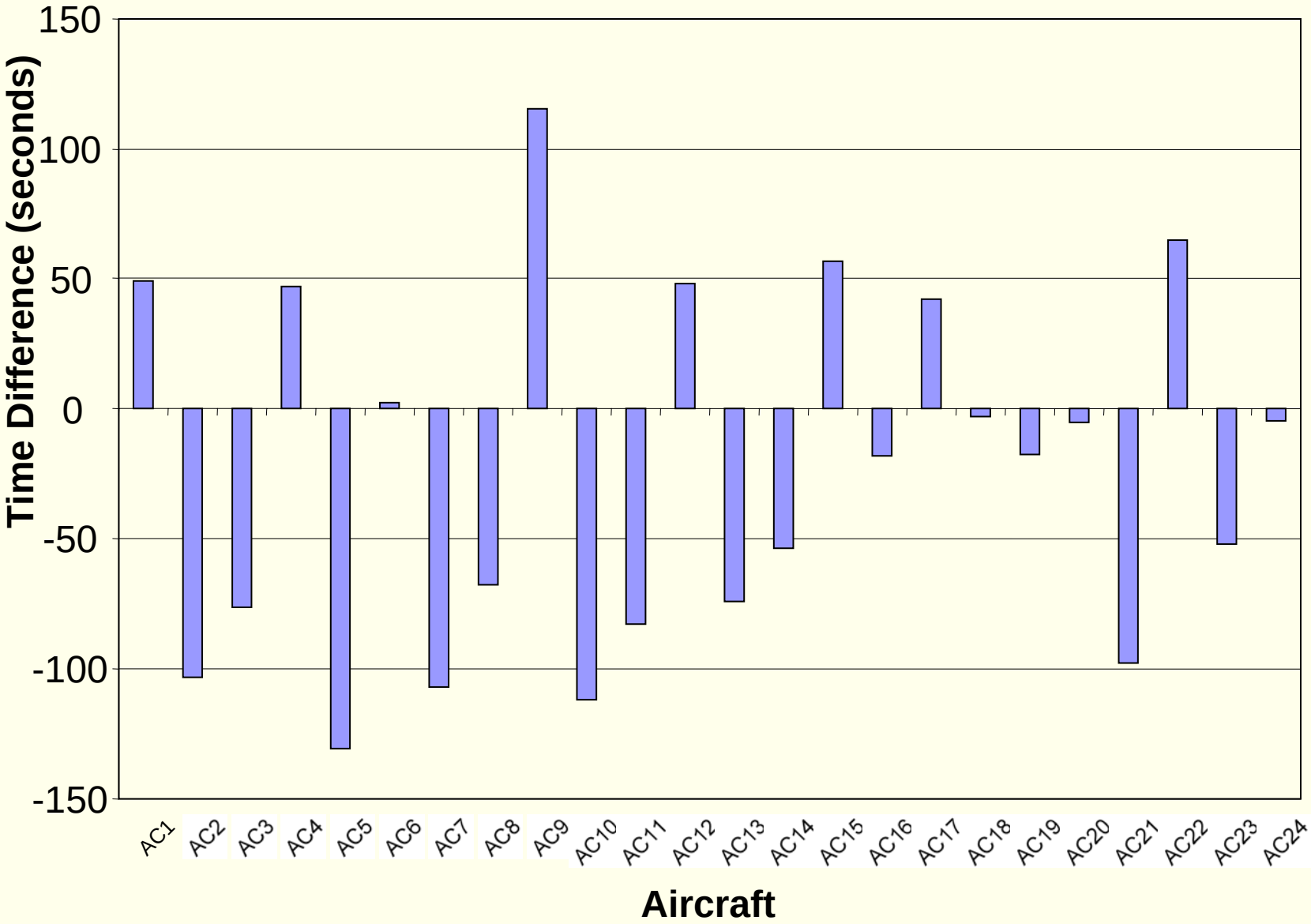
TBM Actual vs. Simulated Tracks



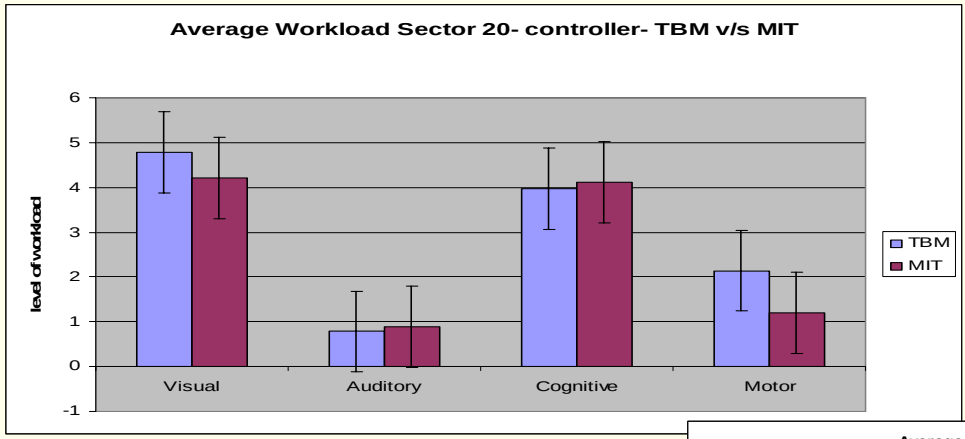
Nominal Vs. Actual Vs. Simulated – TBM
Plan View

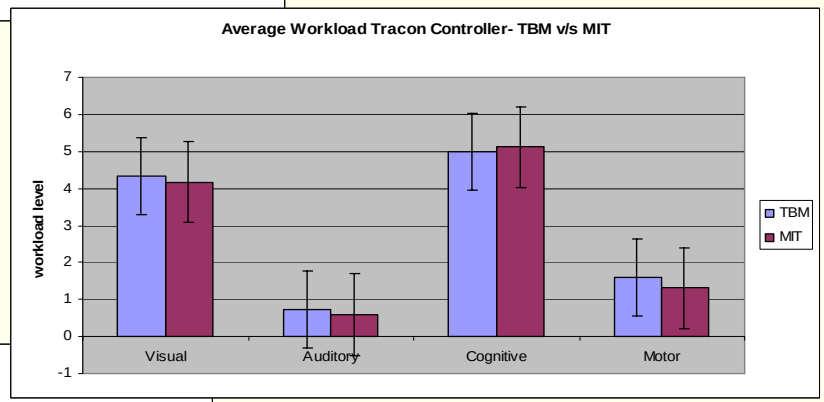


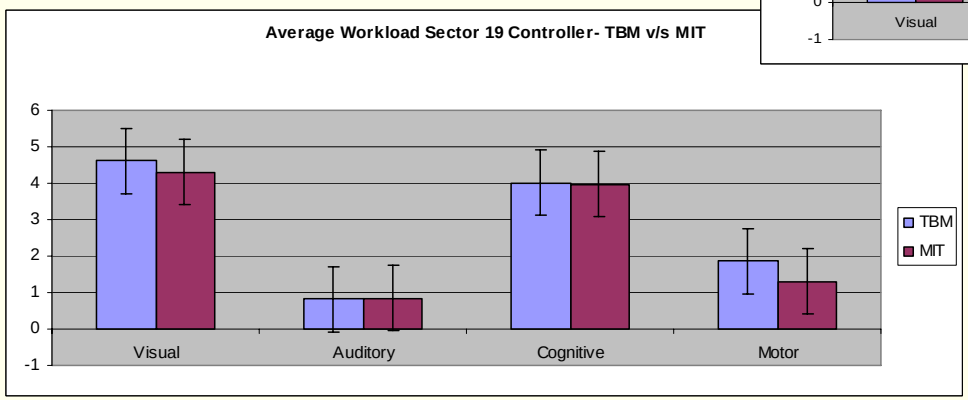
Means of Time Difference between Simulated and Actual Tracks at Sector Exit Points - TBM



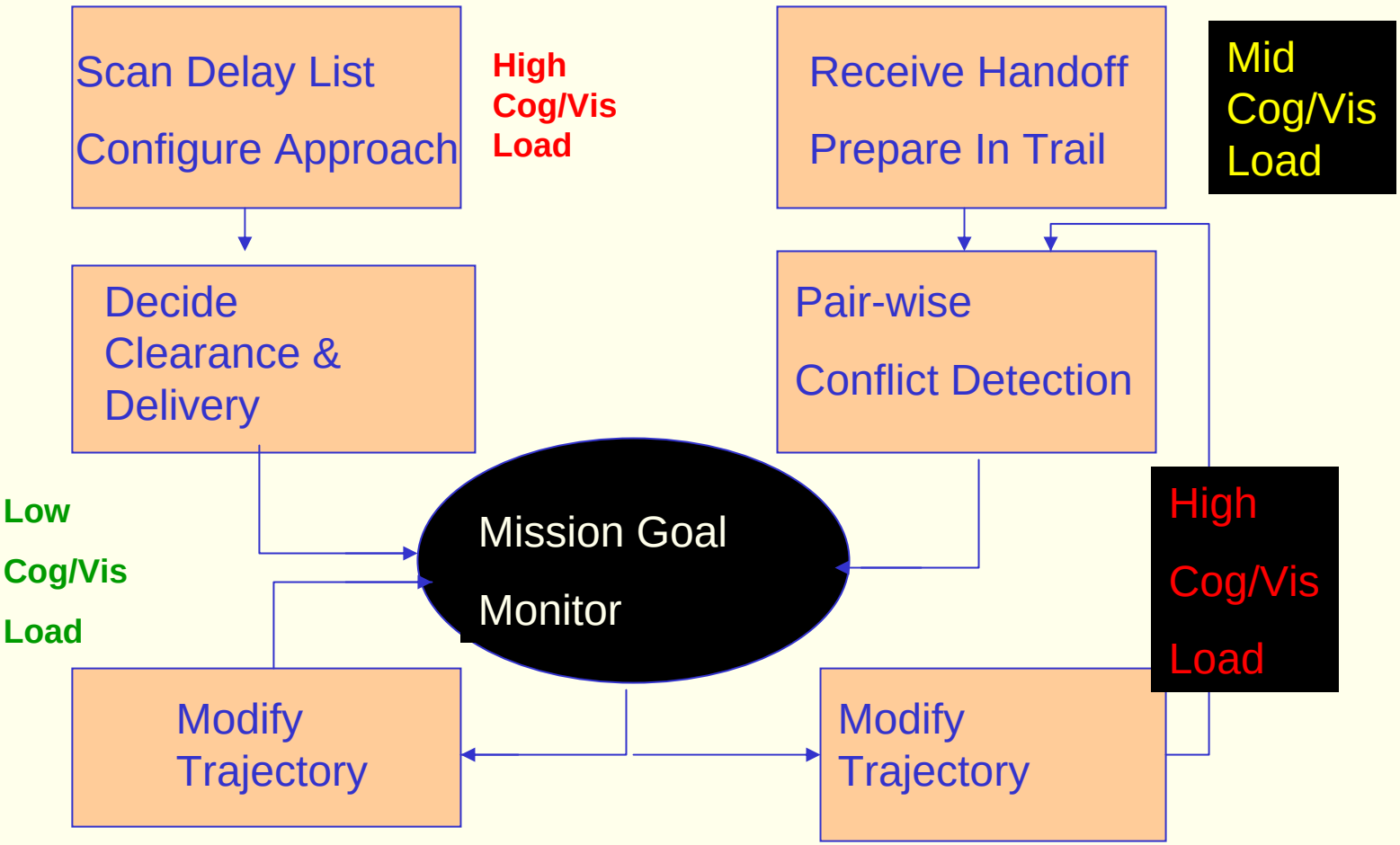
Workload Averages TBM and MIT



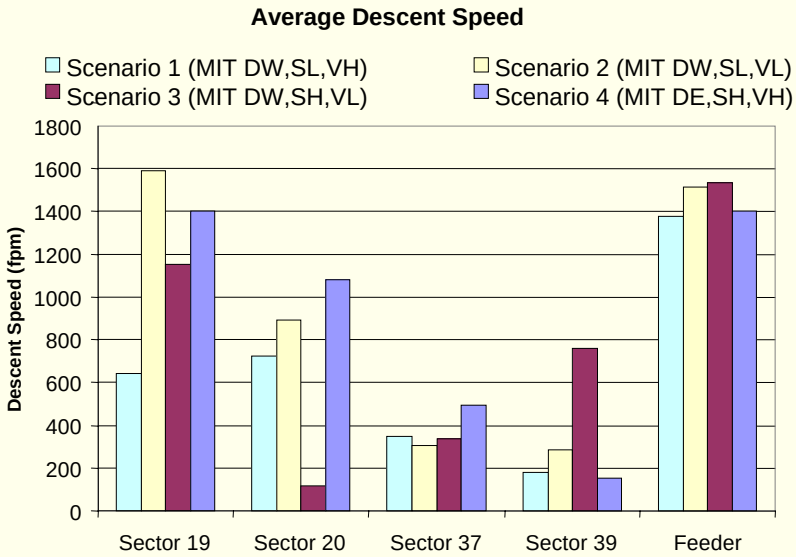


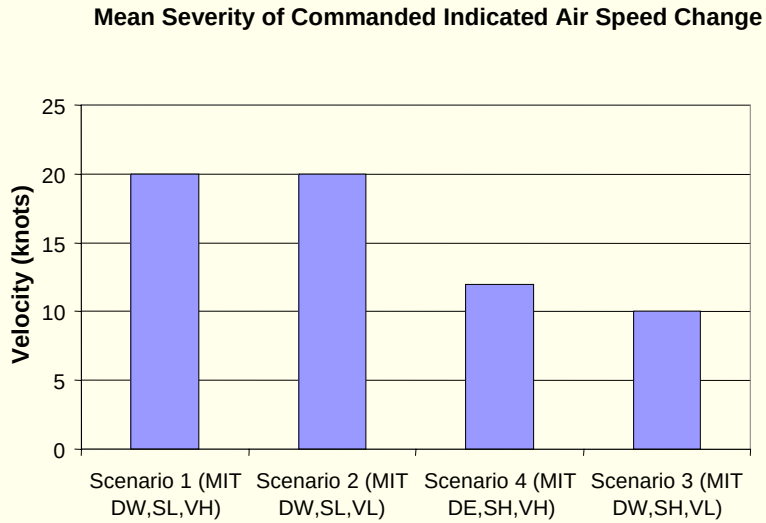


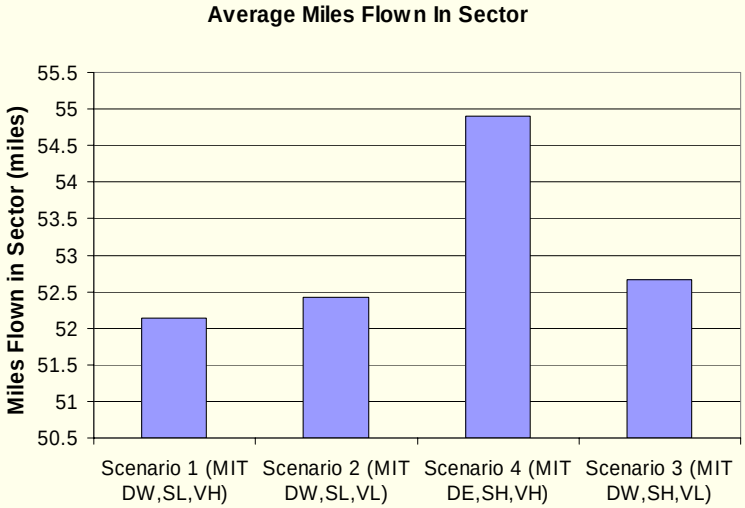
Workload Source Analysis

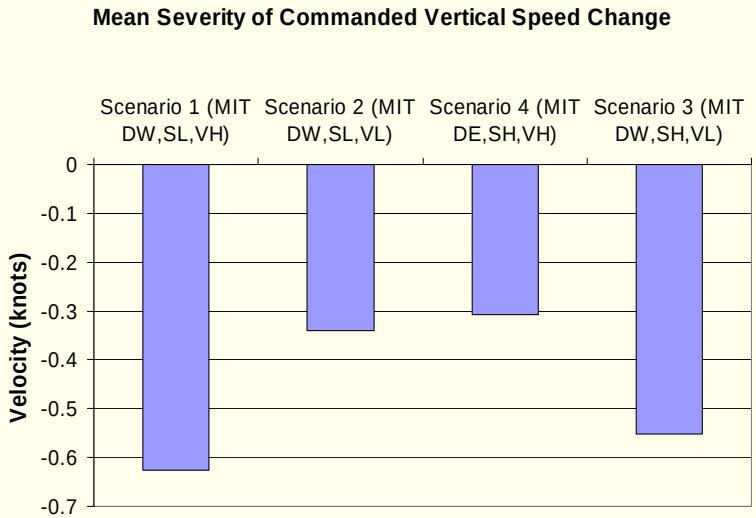


Measures of System Performance

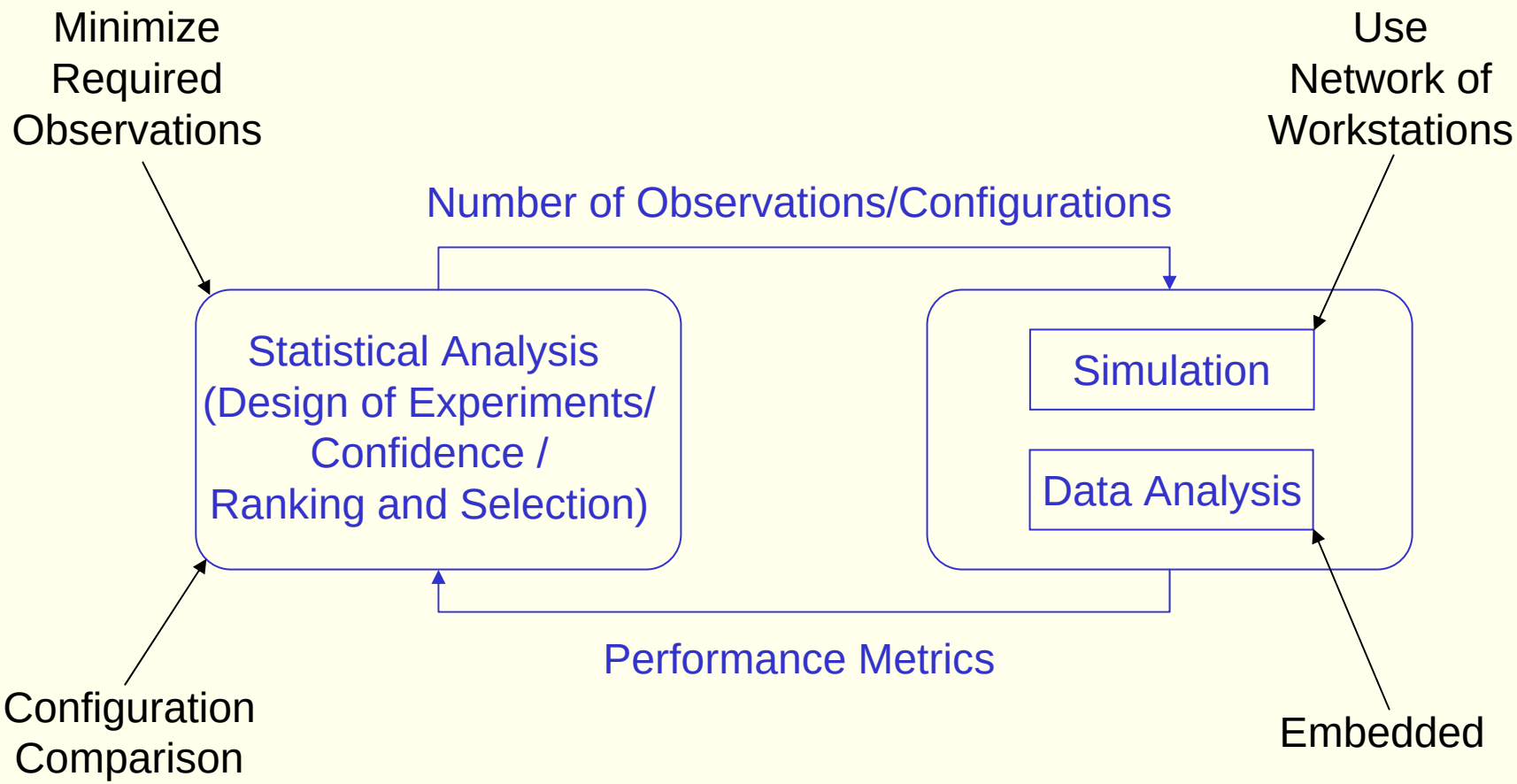






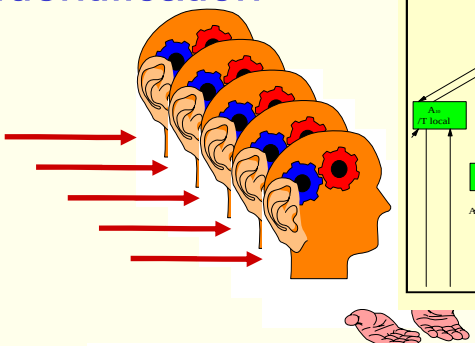


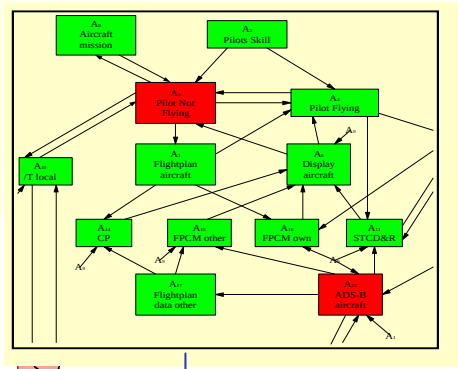
Maximizing the Utility of Simulations

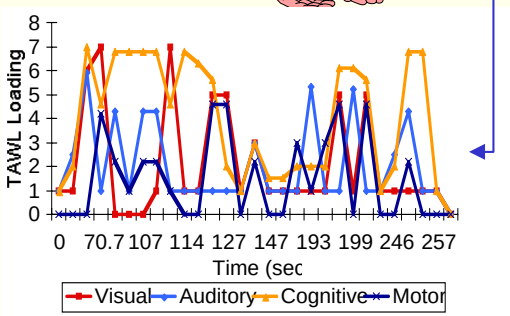


Two-Phase Predictive Risk Assessment

Phase 1: Parameter Identification



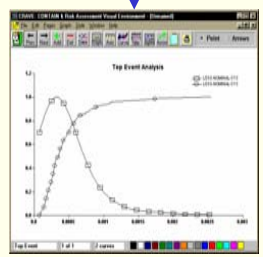




Run detailed simulations to identify and evaluate critical performance parameters (~ 100 runs)

Run streamlined model many times (~1,000,000runs)

Assess risk



Phase 2: Formulation

On-Going Questions for Discussion

- Potential applications of agent-based simulation: emergent effects could be anticipated in:
  - Safety
  - Efficiency / throughput
  - Others? (Demand/scheduling...)
- Translation between 'micro' and 'macro' viewpoints
  - Are there other/complementary methods?
- 'Emergent error' as well as 'emergent behavior'?

Thank You!

Questions?