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

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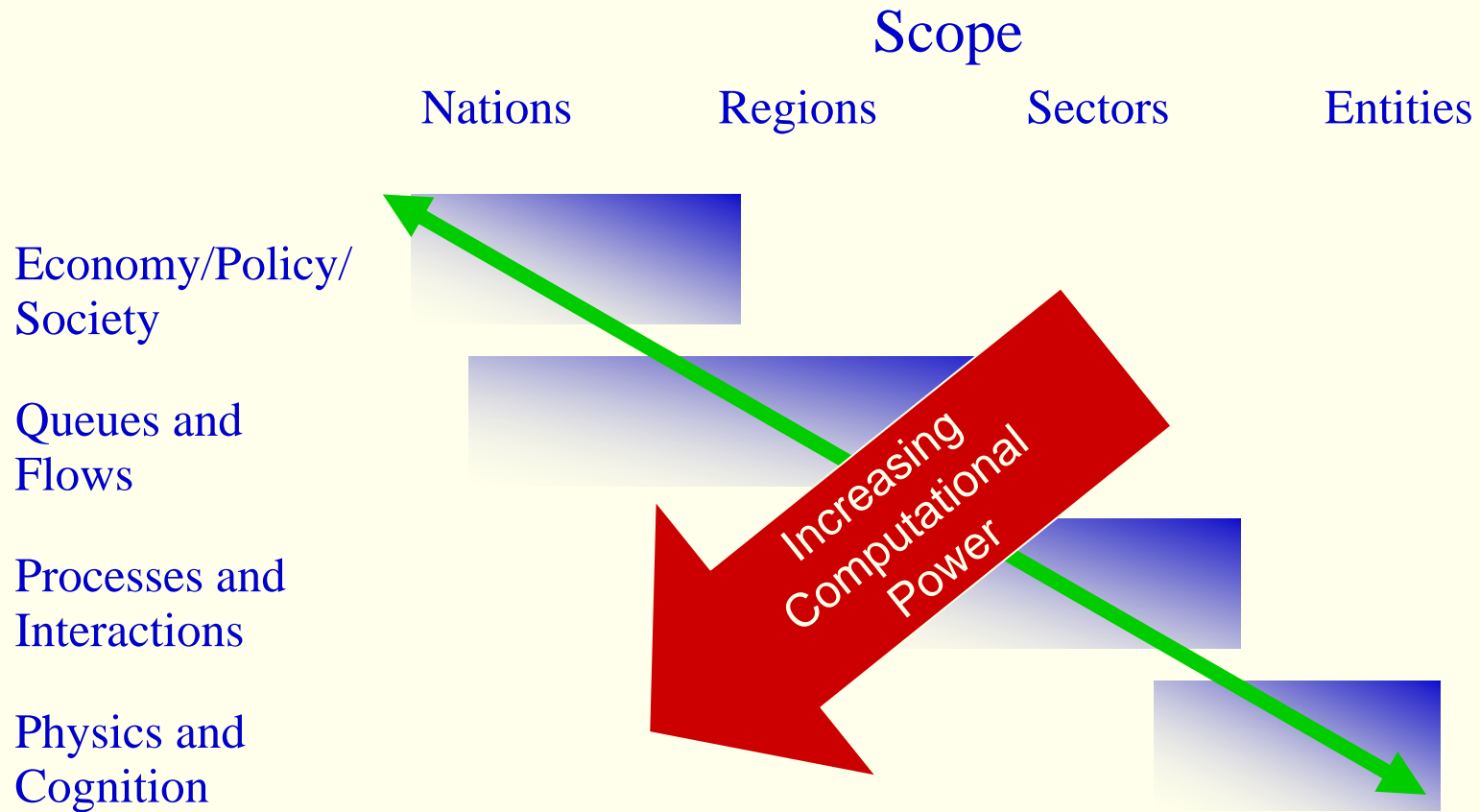
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San Jose State University, San Jose, CA

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ATAC Corporation, Sunnyvale, CA

What is the Appropriate Decomposition?



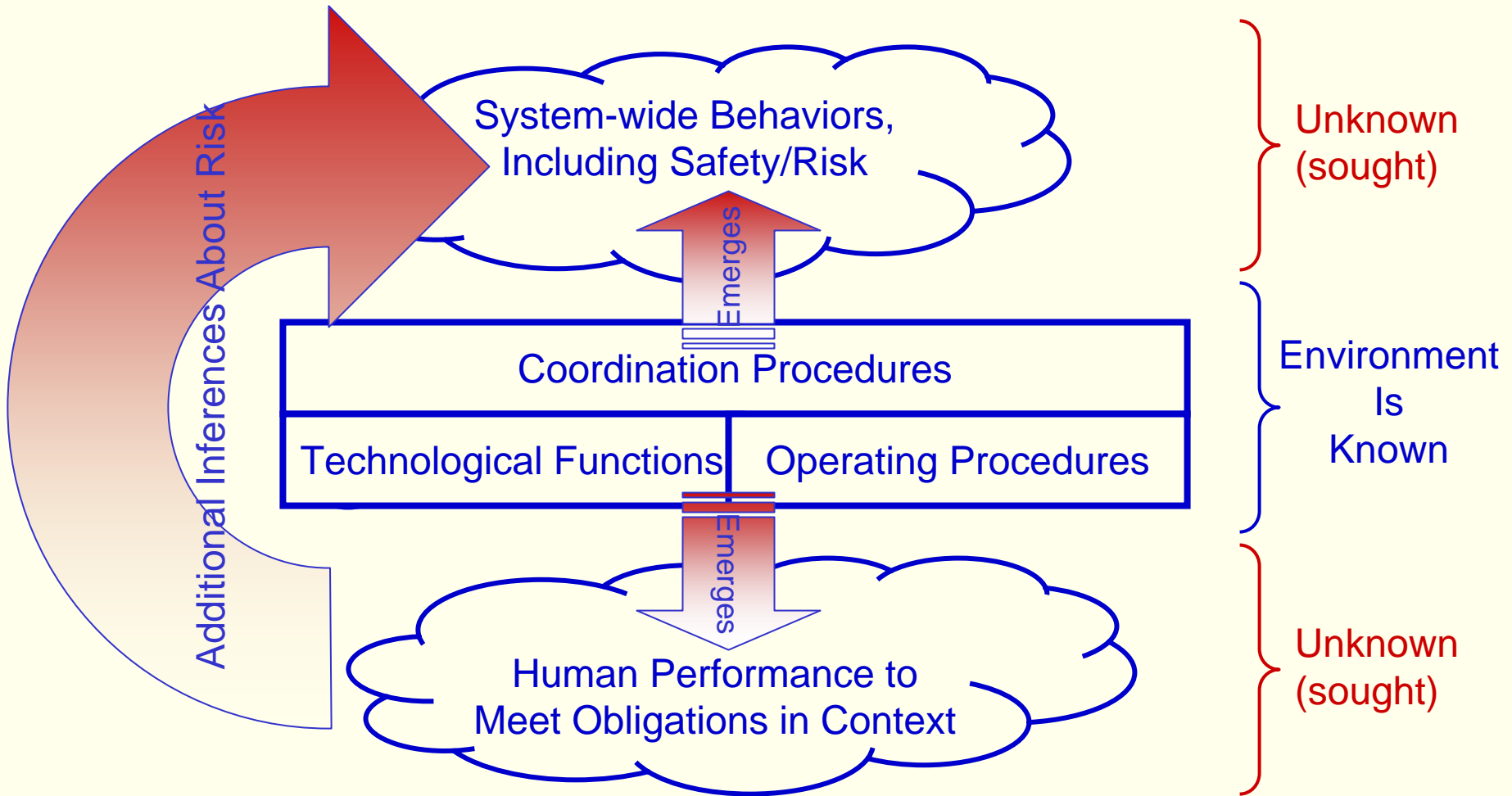
Key Concept: Emergence

- ➔ “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!*

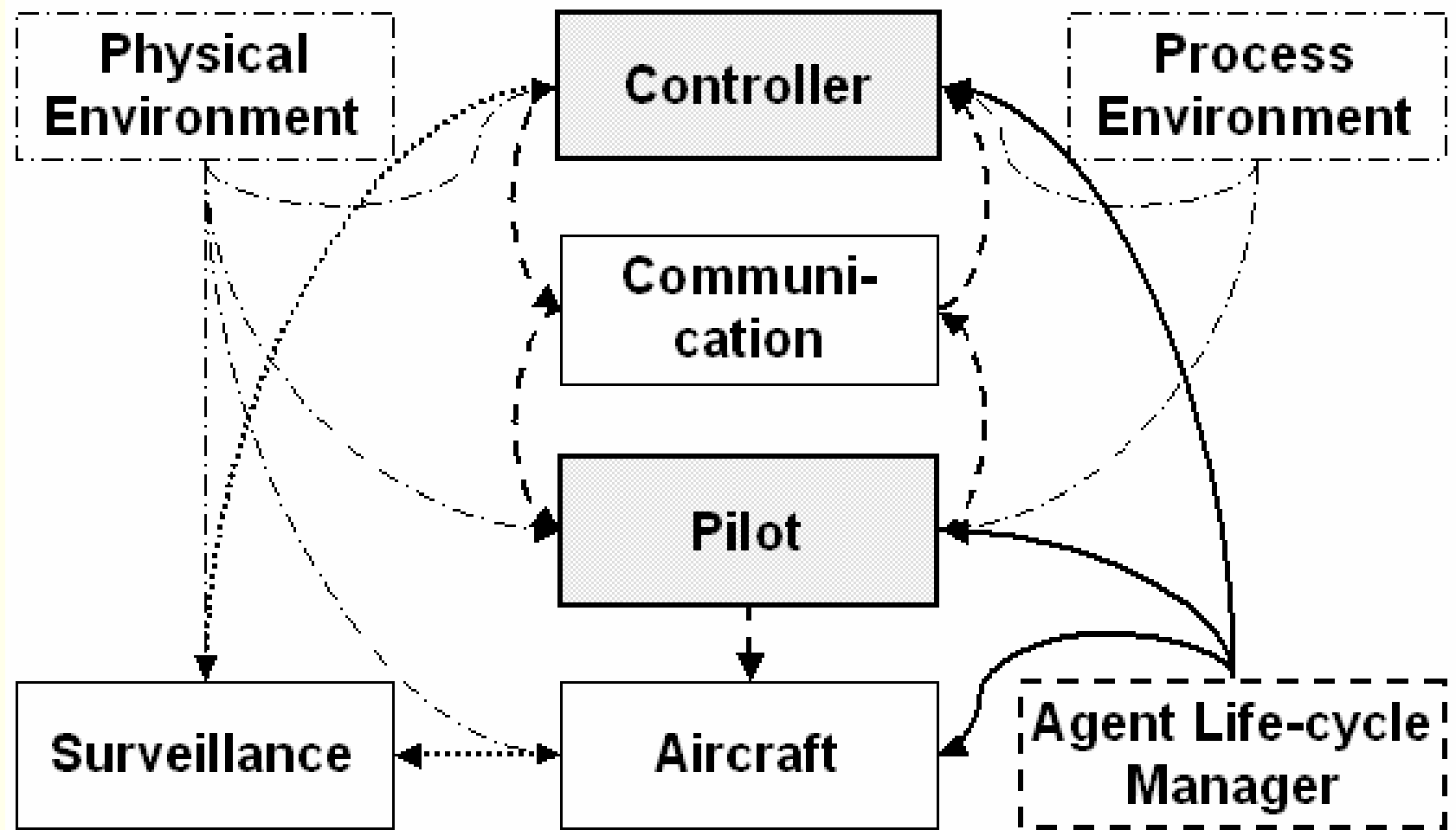
Key Concept: Structure Preserving

- ➔ 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

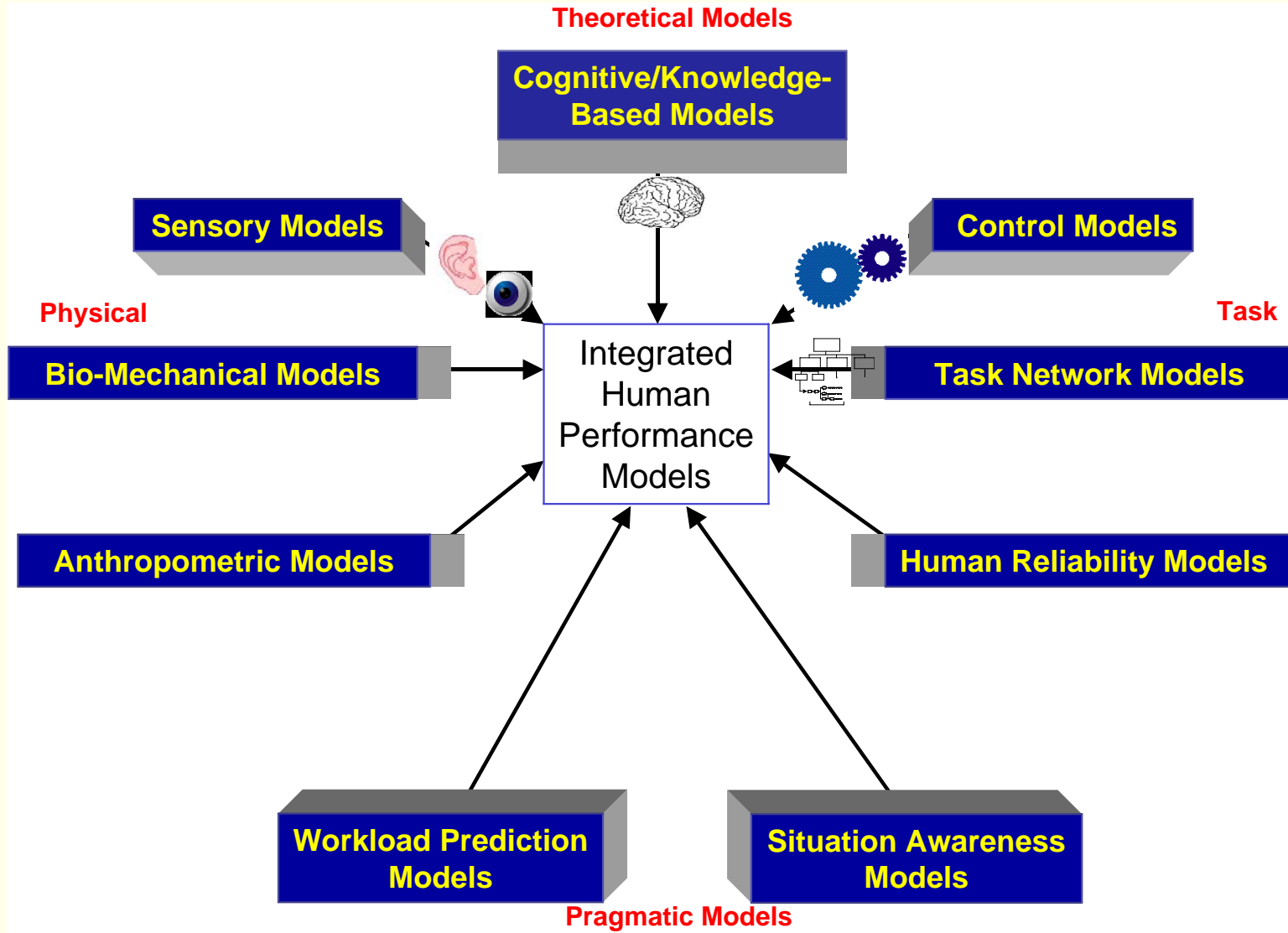
→ Control Runs Compared

- 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

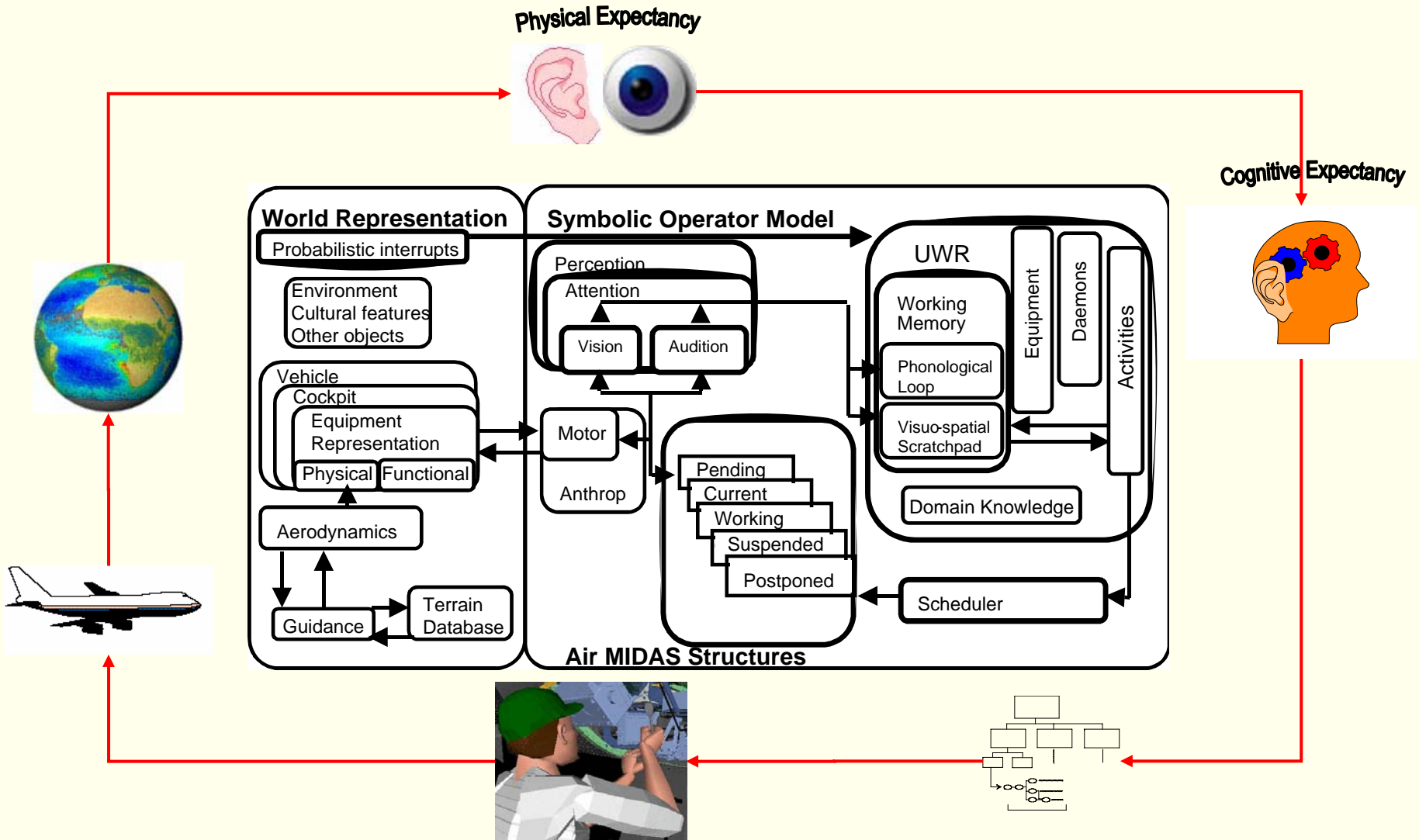
→ Type of Control

- Time Based Metering or Miles In Trail Metering

Integrated Models - Composition



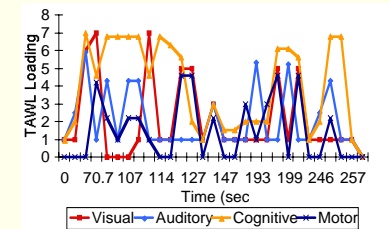
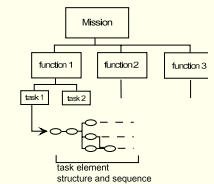
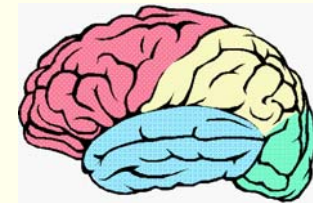
Air MIDAS Integrated Representation



Air MIDAS Output

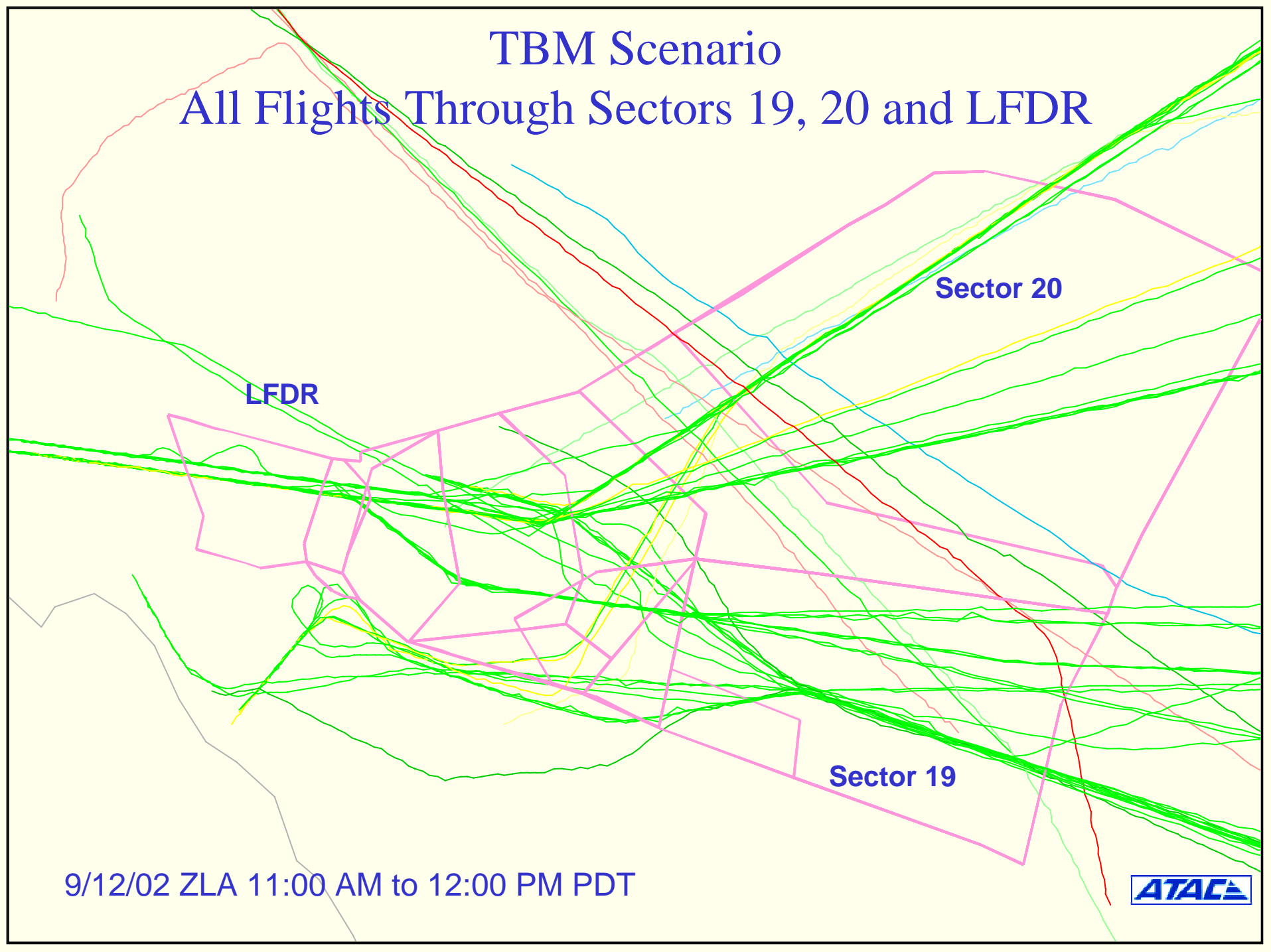
→ Human performance values for the interaction between multiple human agents, the system and the environment:

- 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



LFDR

Sector 20

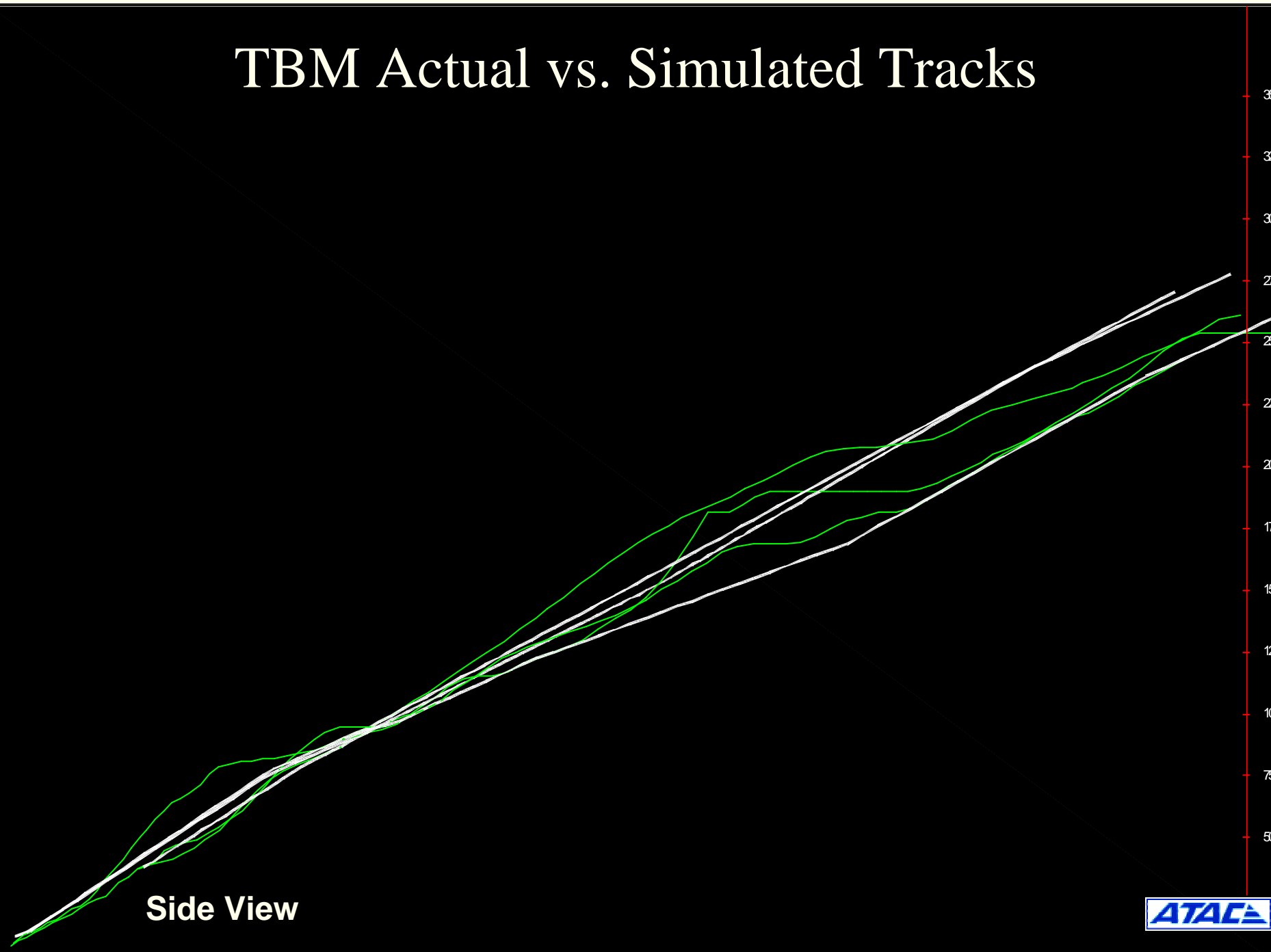
Sector 19

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

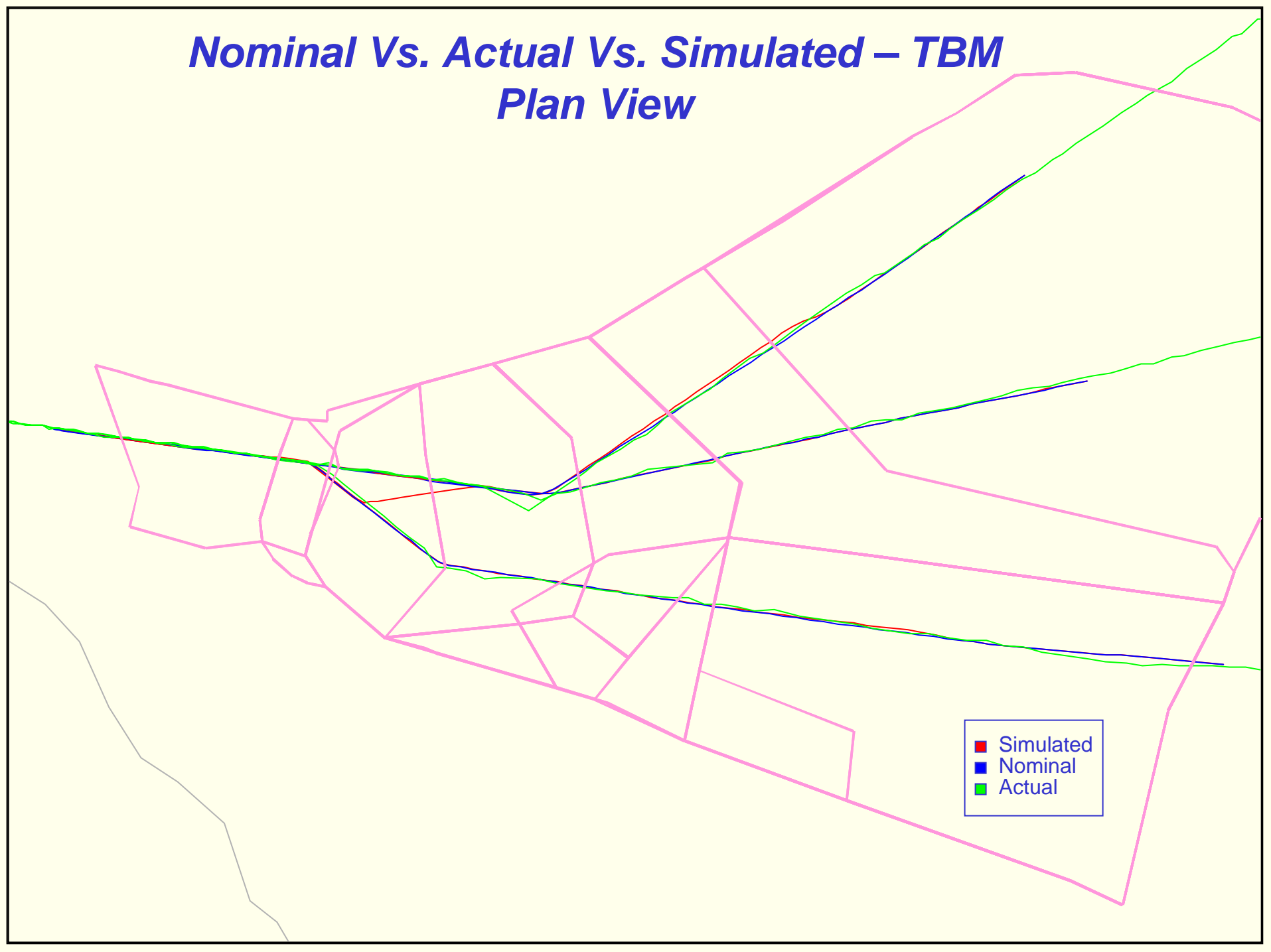


TBM Actual vs. Simulated Tracks

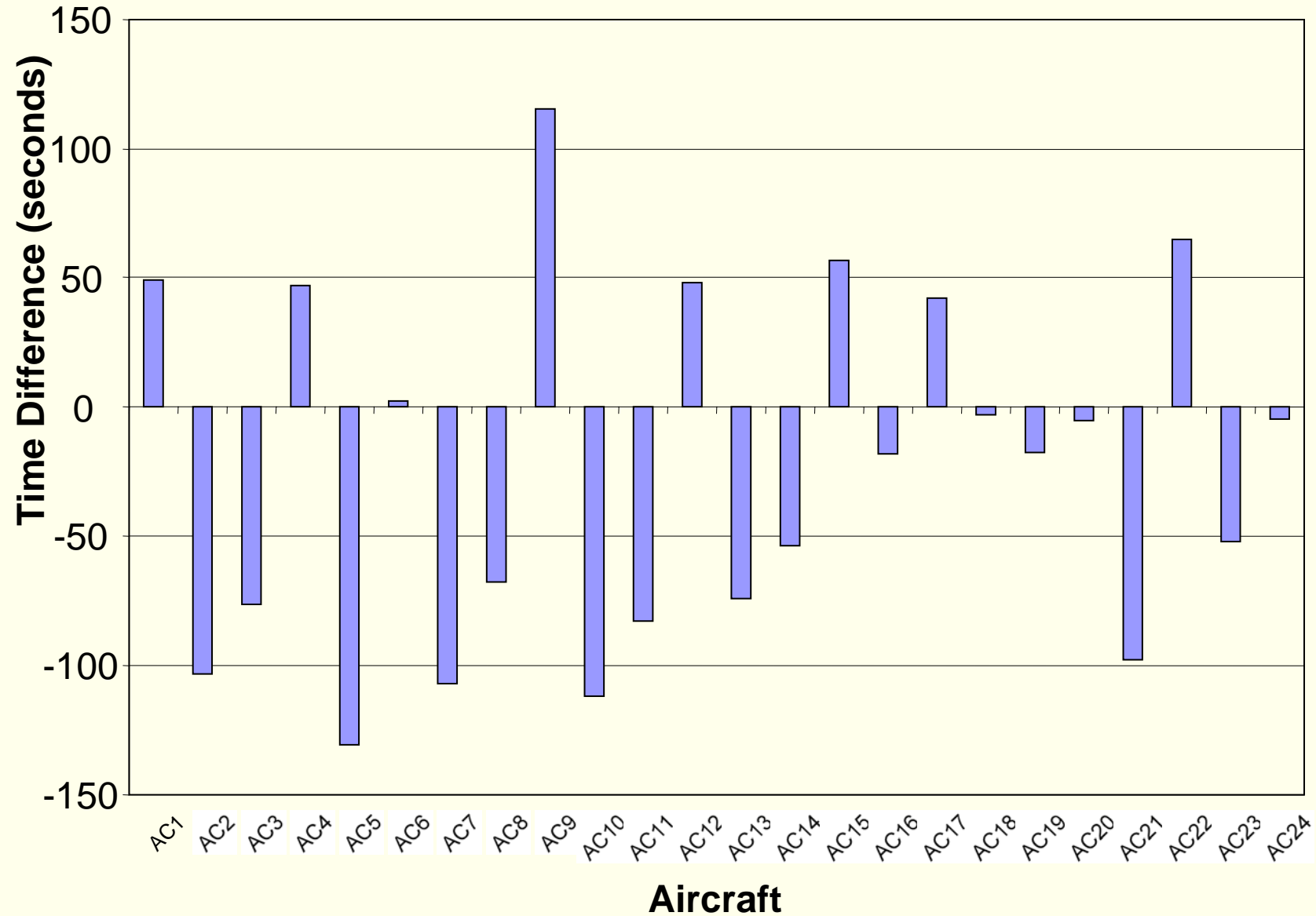
Side View



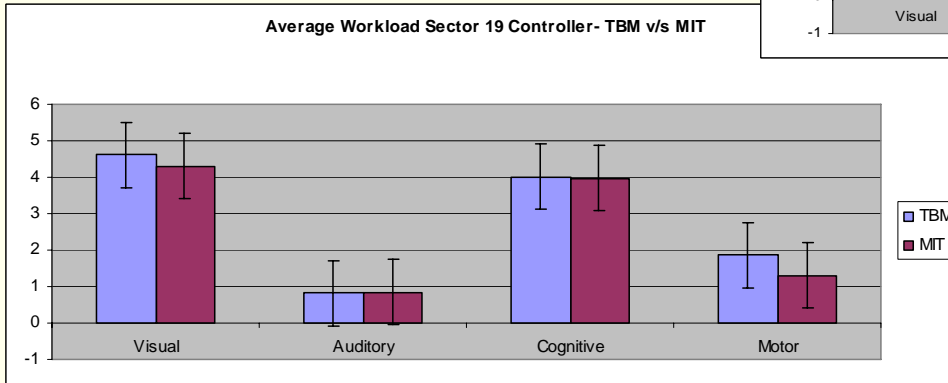
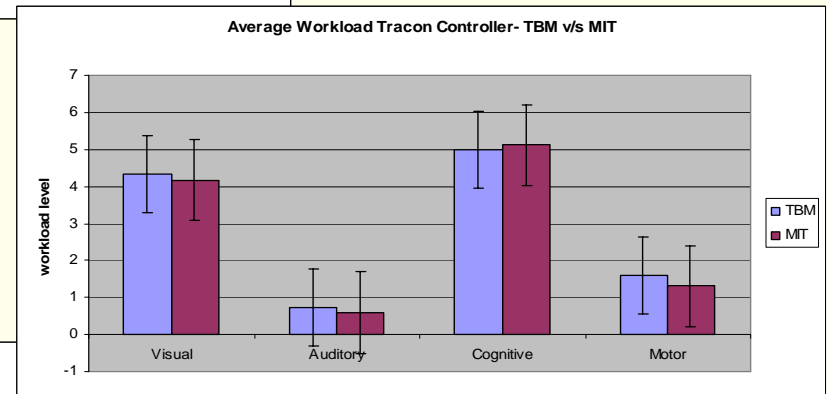
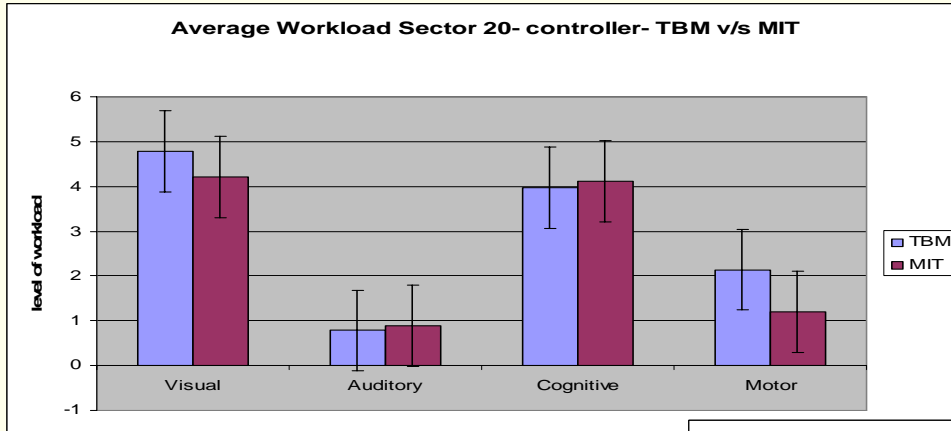
Nominal Vs. Actual Vs. Simulated – TBM Plan View



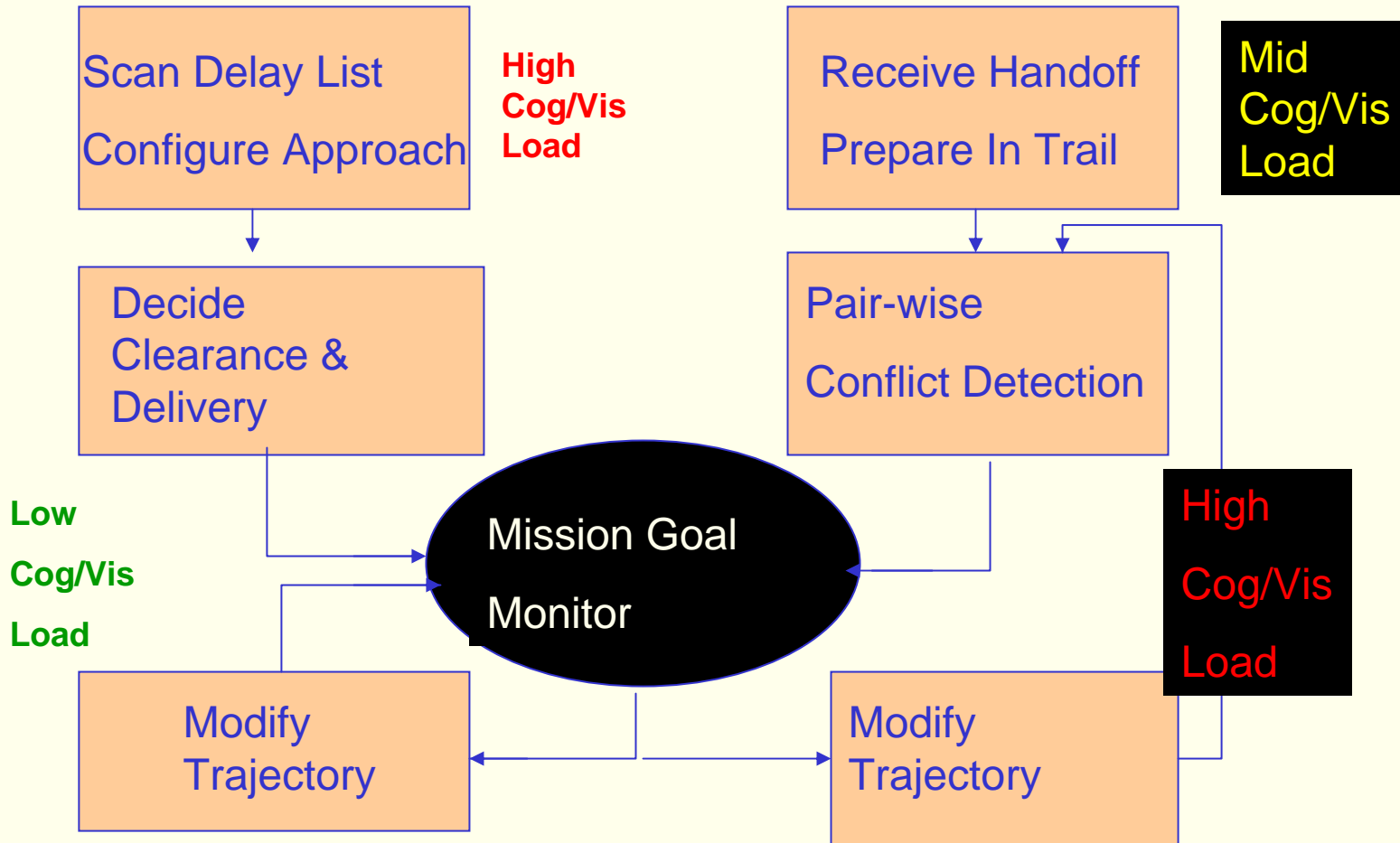
Means of Time Difference between Simulated and Actual Tracks at Sector Exit Points - TBM



Workload Averages TBM and MIT

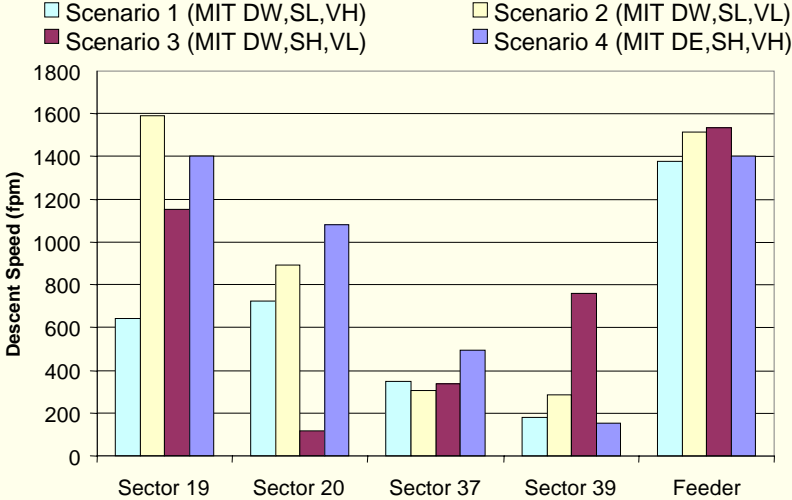


Workload Source Analysis

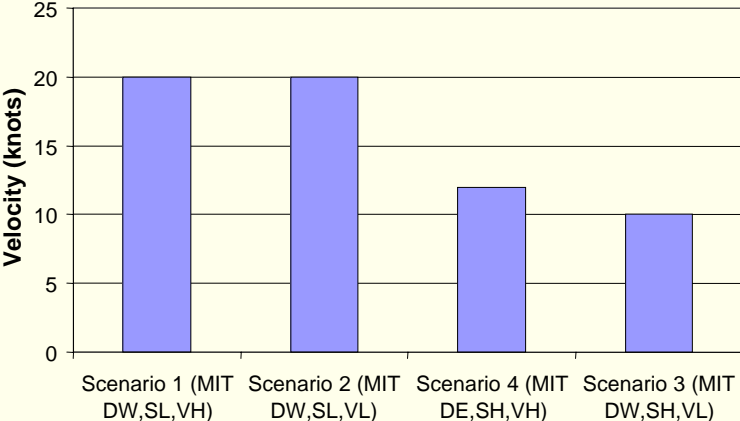


Measures of System Performance

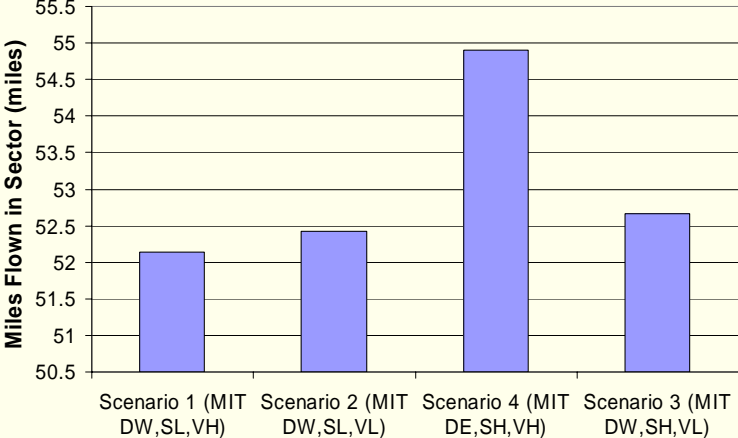
Average Descent Speed



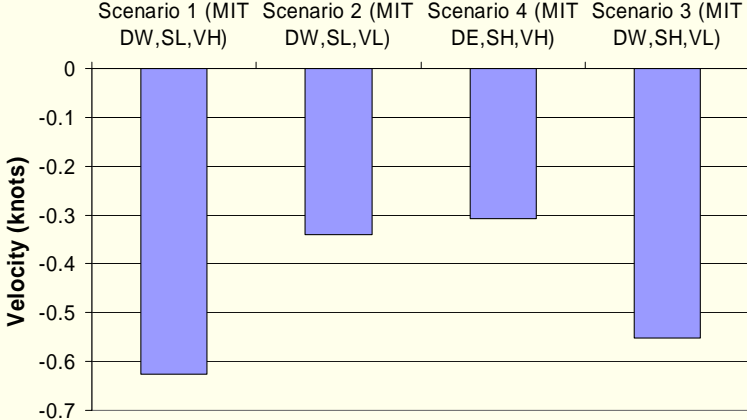
Mean Severity of Commanded Indicated Air Speed Change



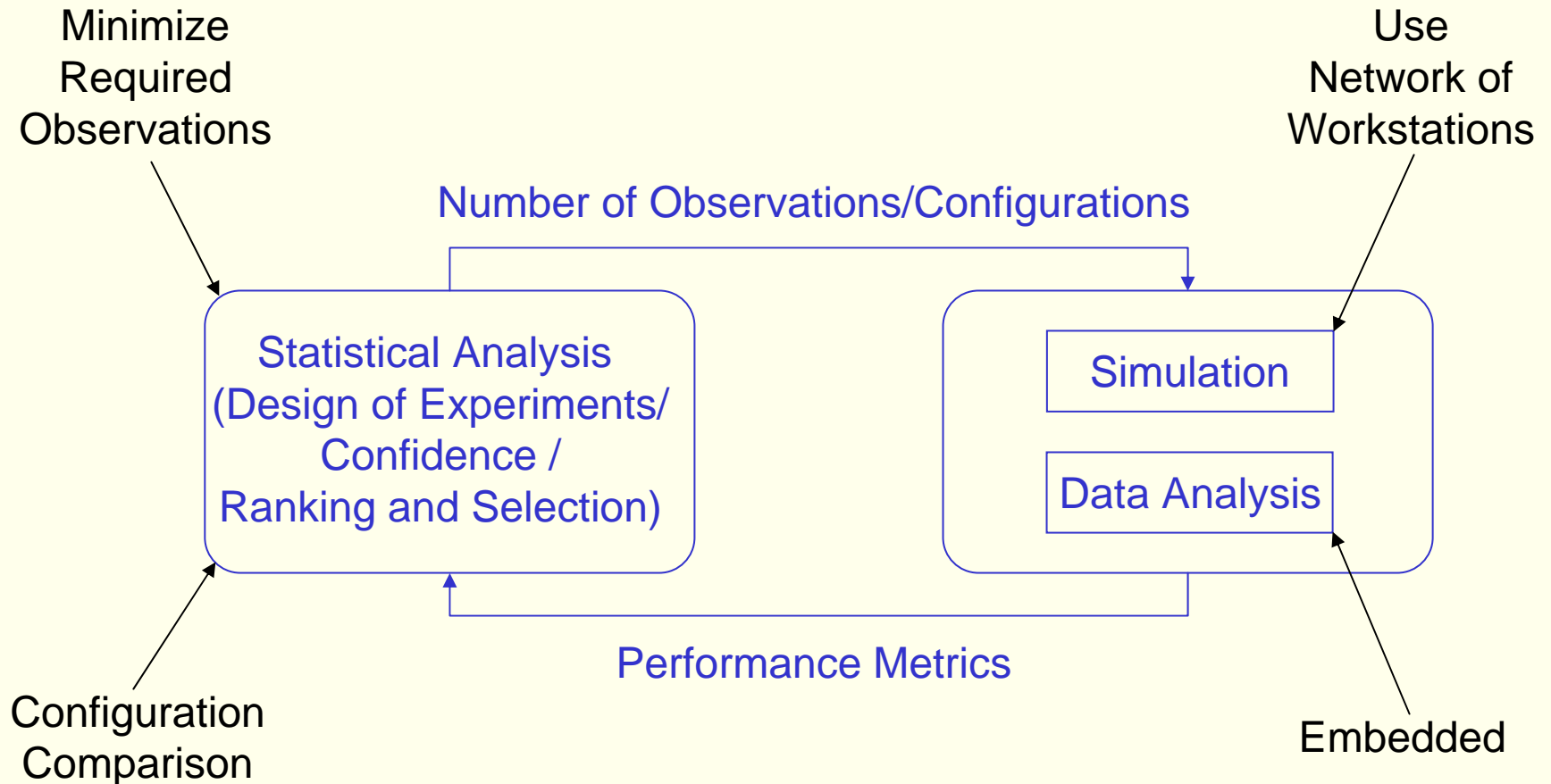
Average Miles Flown In Sector



Mean Severity of Commanded Vertical Speed Change



Maximizing the Utility of Simulations



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?