System-wide Human Performance Modeling

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Kevin M. Corker
San Jose State University
San Jose, Ca.

kevin.corker@sjsu.edu

Outline

- Why model human performance at a system-wide level?
- What human performance should be modeled at a system wide level?
- How: What has been the experience of modeling human performance?
  - Team-Group
  - Regional
  - System-wide
- What is to be done next?

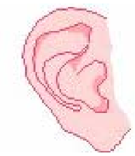
Why?

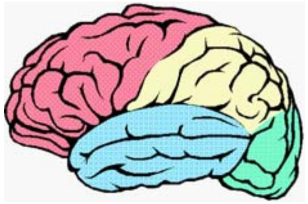
Why do we model human-system behavior ?

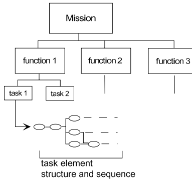
- **Explore Mechanisms of Performance**
  - Establish emergent behavior among the human operators and the system context in which they operate
- **Predict Performance**
  - Establish probabilities of operational goals being met
  - Determine hazard impact of off-nominal ("blunders") operations in human-system interaction
- **Determine Perceptual, Cognitive and Motor Requirements for Task Performance**
- **Explore Augmentation of Performance (aiding)**
  - Exceed limitations of human and system
  - Reduce frequency and impact of errors

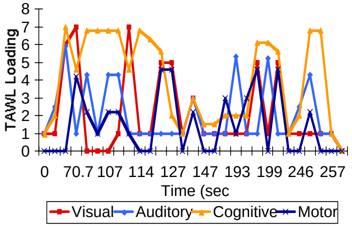
Typical Human Performance Model Output

- **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









Why do we model human-system behavior at a system-wide level?

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What?

1. Predict Performance

- **Determine Hazard Likelihood and Impact:**
- **Human performance contributes to system closed loop response time: noisy, delayed, erroneous, adaptive, anticipatory, predictive**

- **Models of performance can be used to:**
  - **Predict response times to alerts**
  - **Predict visual search times**
  - **Predict the conformance monitoring visual sampling for varied separation standards**
  - **Predict blunder likelihood and response/recovery operations**

2. Examine the Mechanisms of Performance

What mechanisms of human performance scale up to have an effect on system-wide operations?

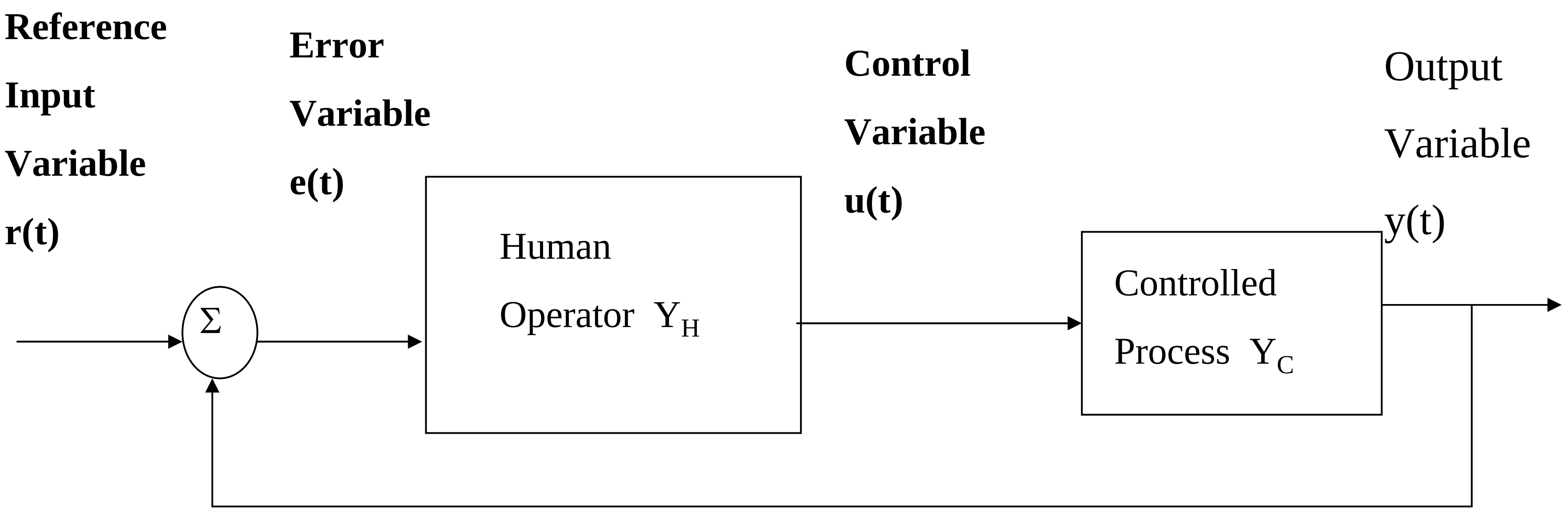
- Closed-loop Operator Loading
  - Feasibility measures
  - Recoverability measures
- Requirement for and effect of Aiding Systems
  - Reduction in demand on operator
  - Reduction in likelihood of or impact of error (human or system)

Workload & Situation Awareness: a note

- **Prediction or Measurement of "subjectively experienced" workload is of NO CONSEQUENCE in system-wide modeling**
- **Prediction or Measurement of Situation Awareness is of NO CONSEQUENCE in system-wide modeling**

Unless these affect performance in a large-scale and in a closed loop model.

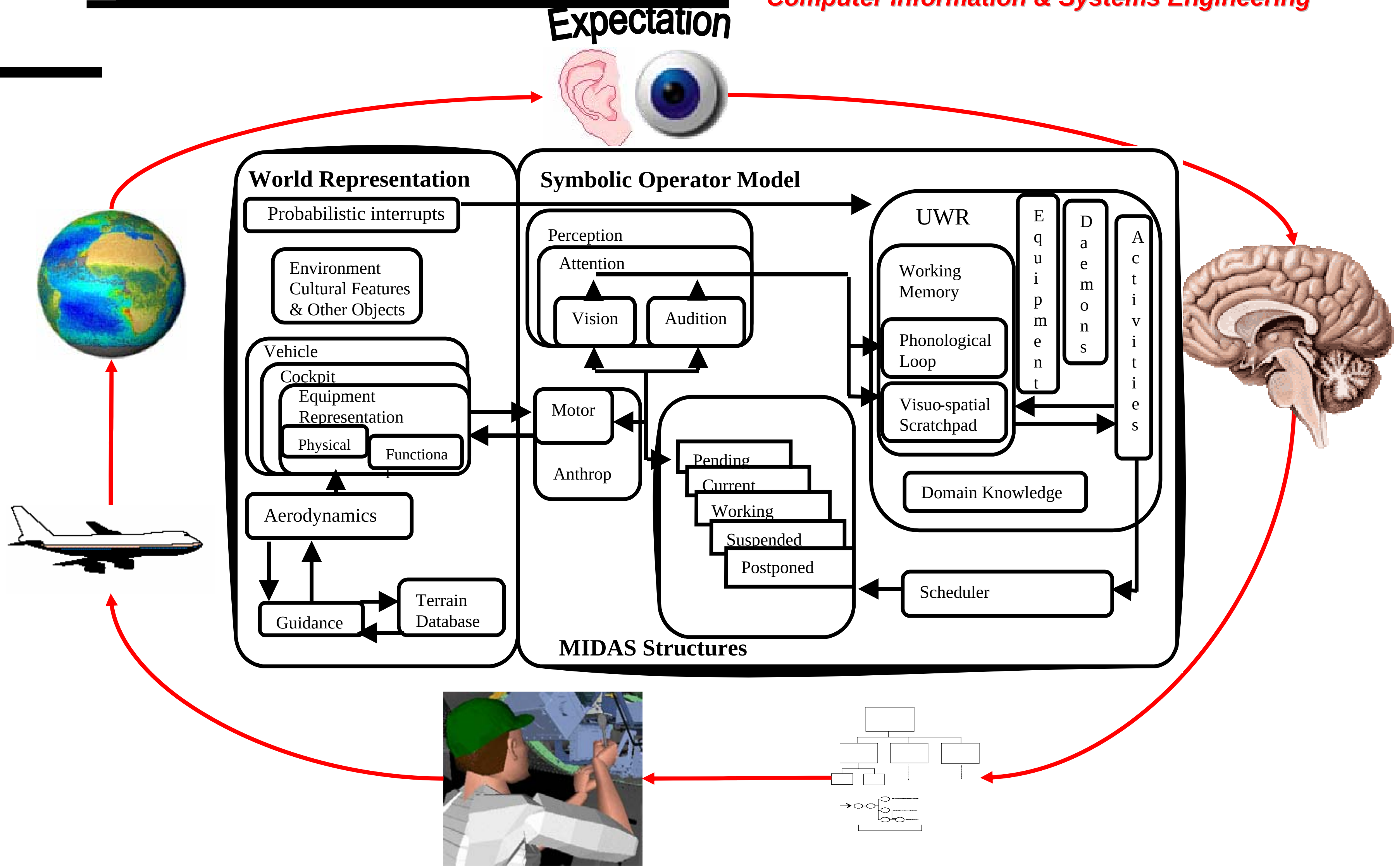
ONLY IF: Human Performance is part of a closed loop process



Where:

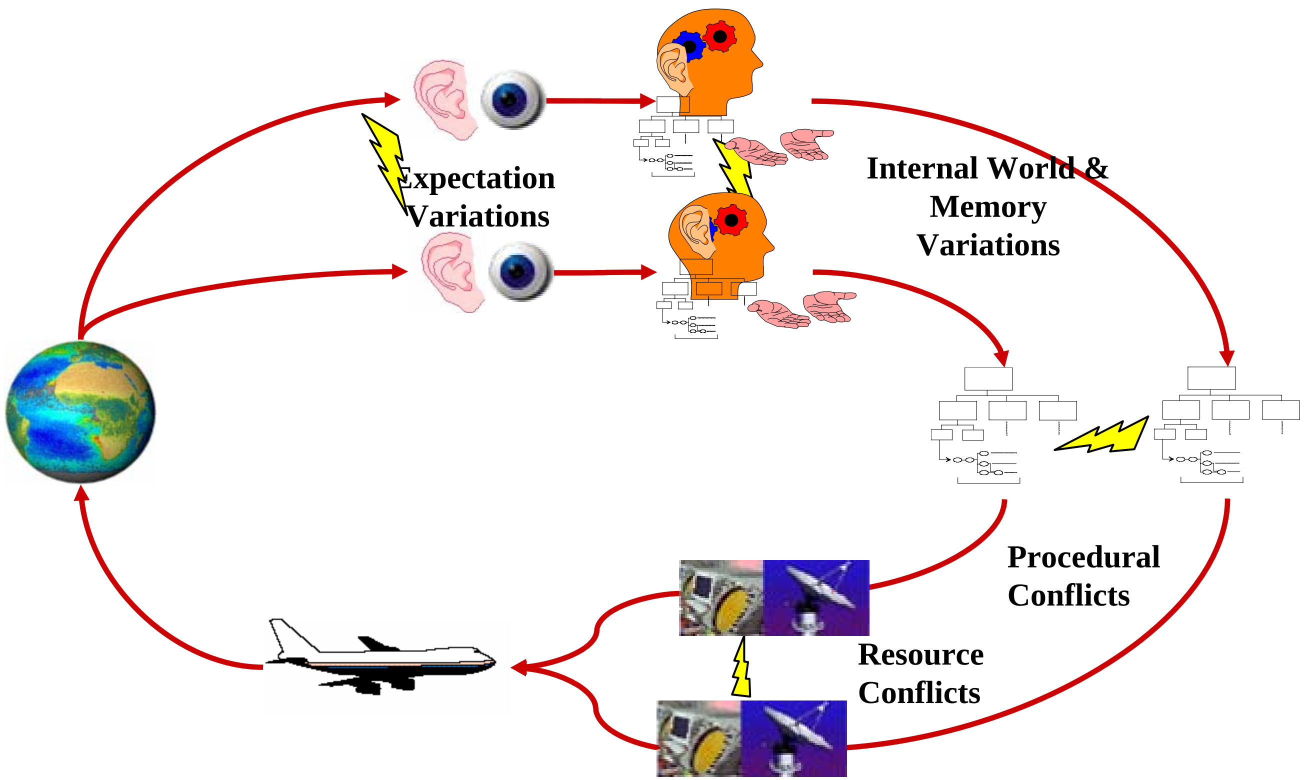
Y_H and Y_c are dynamic operators on time replaceable by Fourier transformed time functions

Air MIDAS Functional Representation



What Else?

- There are the functions of interactions that must be represented– the weak forces interpersonal gravity begin to dominate at larger scales.



How?

Issues for How

1. Level of detail of human performance versus extent of human performance in the NAS.
2. Extent of propagation of an affect versus damping and dead bands
3. Temporal range of System-wide modeling versus operational range of human's in NAS.
   – The human equivalent of good day vs. bad day

1. Level of detail of human performance versus extent of human performance

Two Approaches for HPM

- Take a representative detailed chunk of behavior and distribute it across larger traffic sample or larger airspace

or

- Take a small chunk of behavior :
  - CD&R (ISA: RAMS)
  - Speed-based separation assurance (Mitre-CASSD: TSSIM)

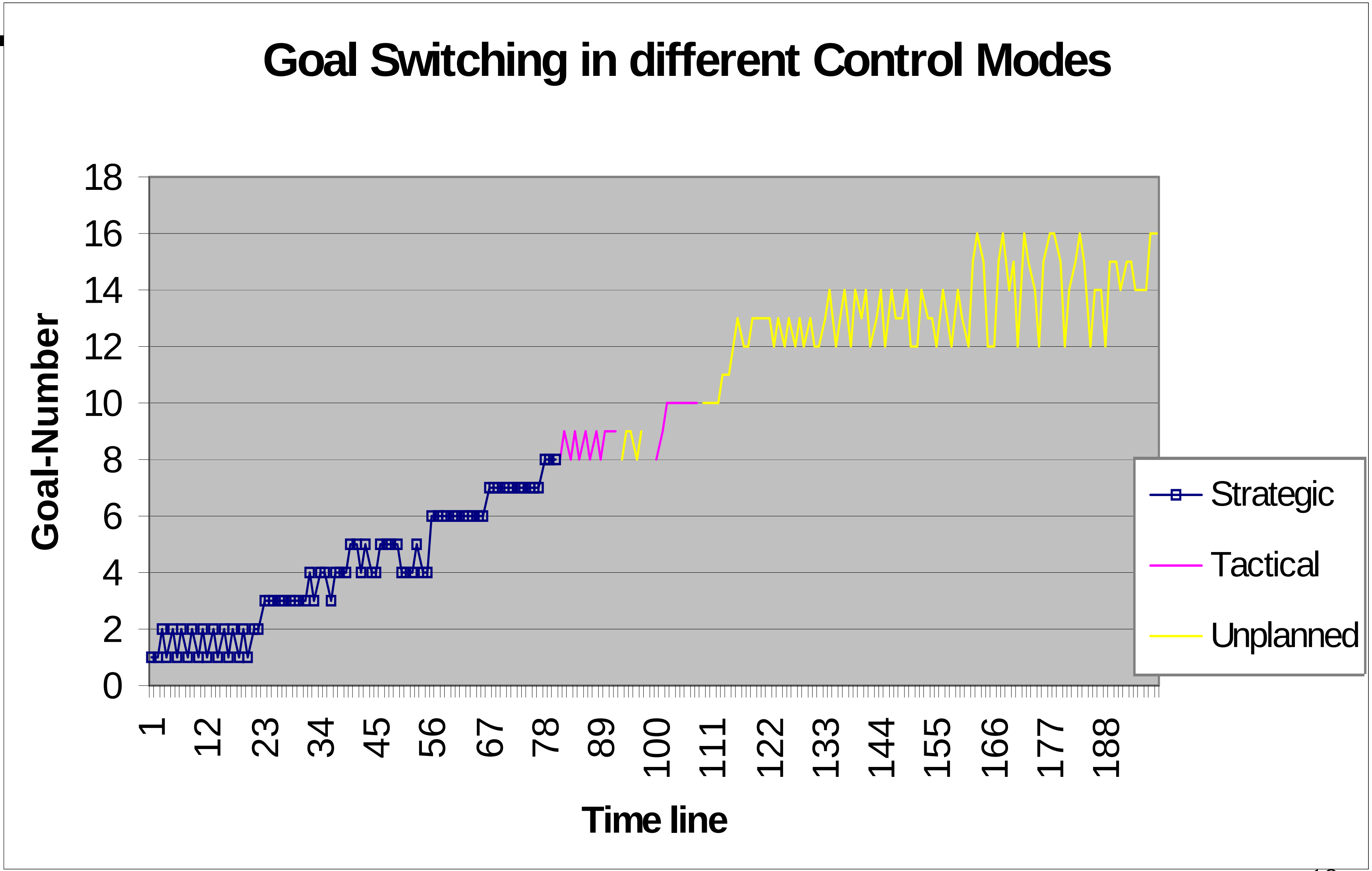
And add it to all operations

Issues:

Detailed chunk may not generalize completely

Small chunk may contain non-linearities

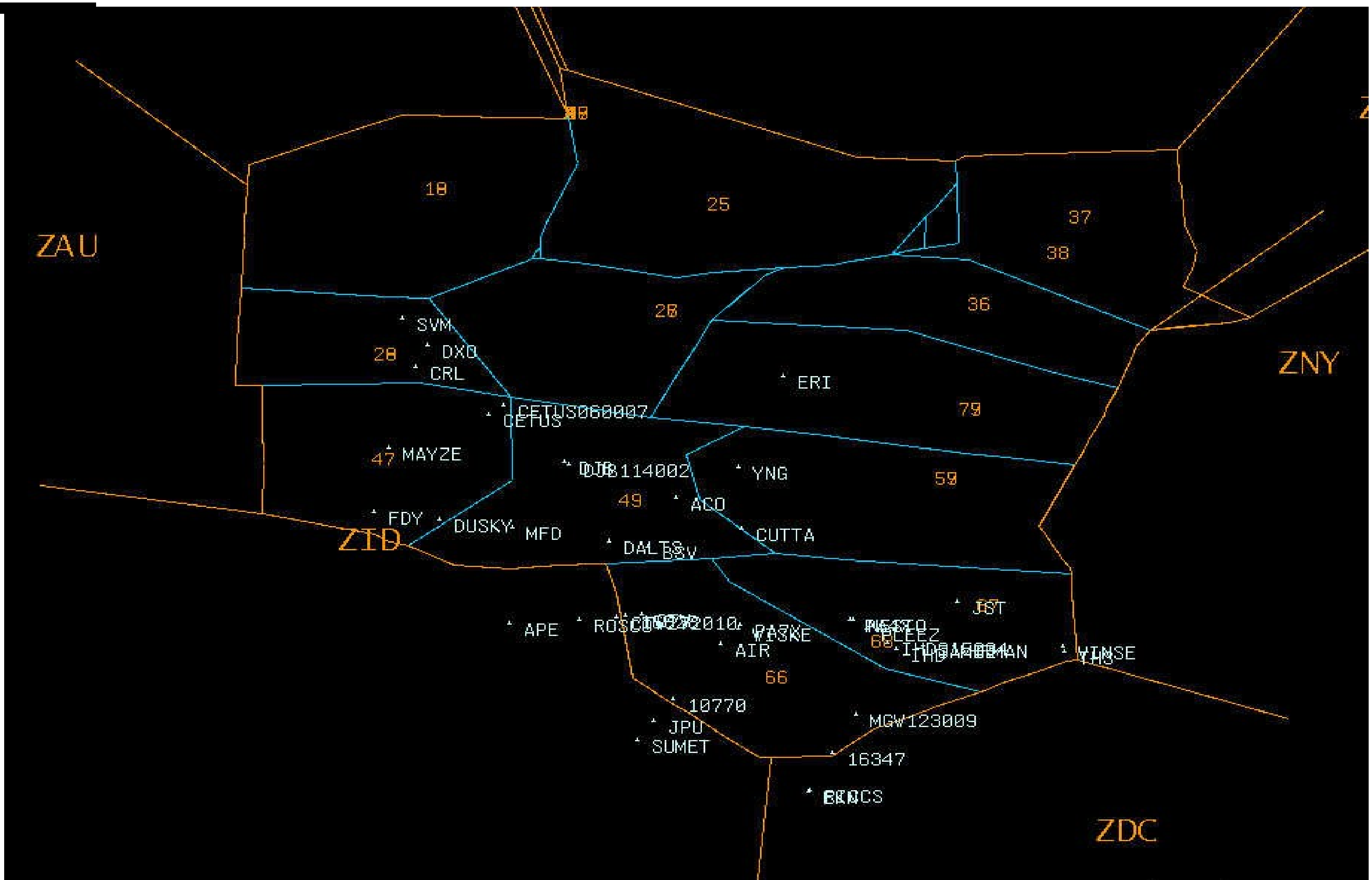
Non-Linearity



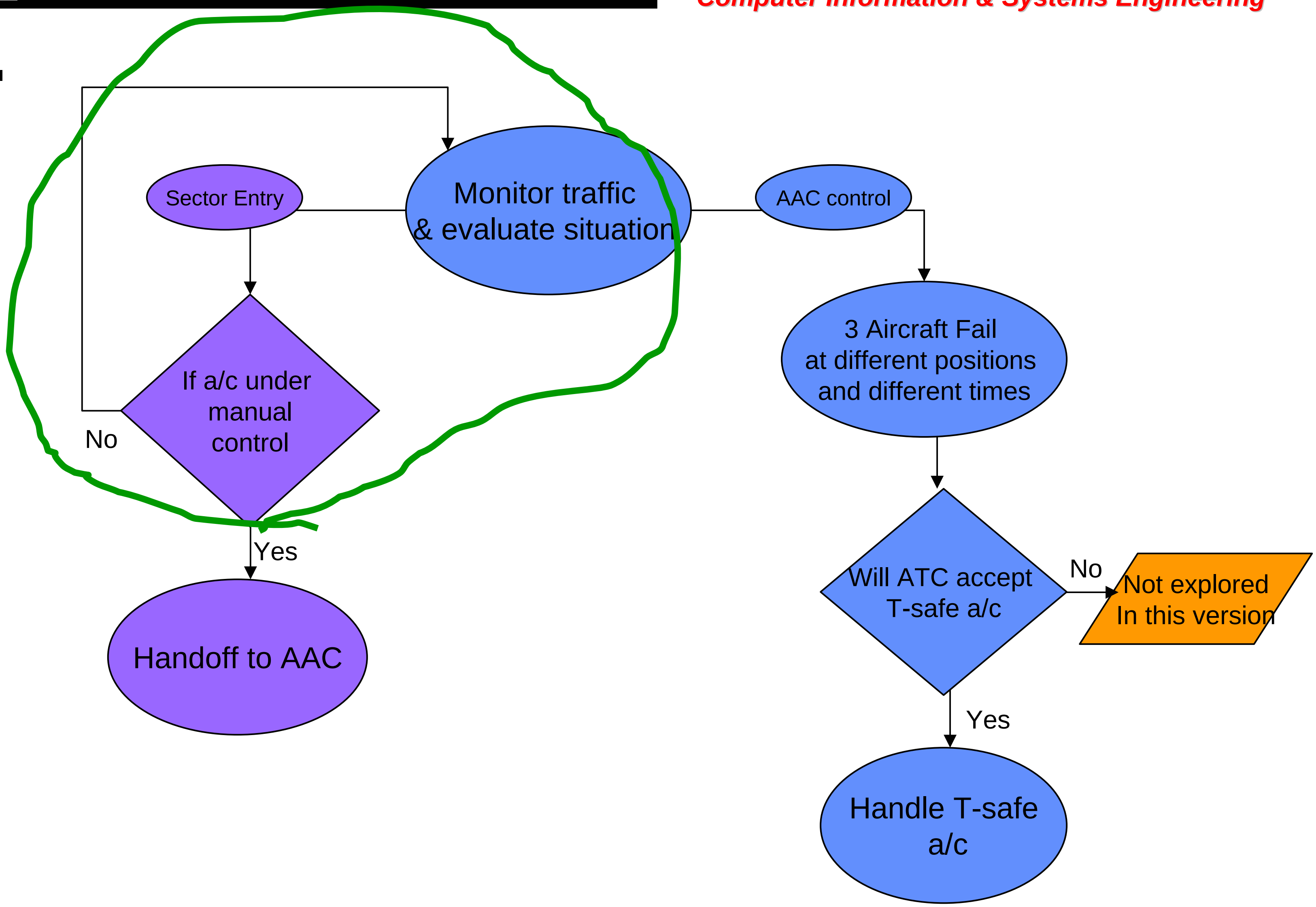
AAC/ACES Analysis

- ACES Simulated ZOB as a single controller airspace
- ACES Simulated 9618 aircraft transiting ZOB in 24 hours under AAC Control
- ATC Agent Communication evens flagged at A/C entry into sector
- Air MIDAS runs the coordination event

Airspace –ZOB sector 47 and 49



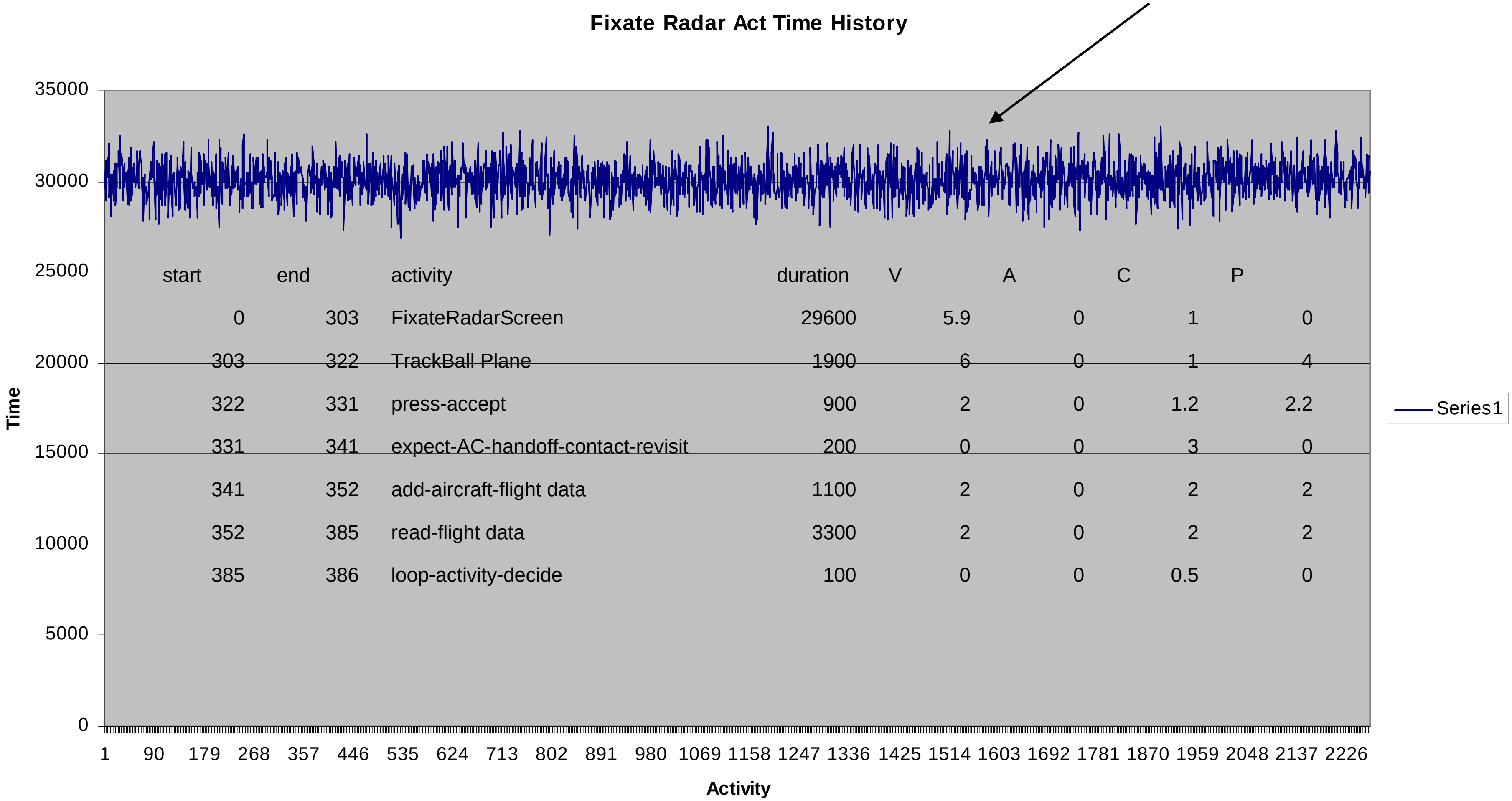
ATC Processes



AAC Analysis

Computer Information & Systems Engineering

stochastic



start	end	activity	duration	V	A	C	P
0	303	FixateRadarScreen	29600	5.9	0	1	0
303	322	TrackBall Plane	1900	6	0	1	4
322	331	press-accept	900	2	0	1.2	2.2
331	341	expect-AC-handoff-contact-revisit	200	0	0	3	0
341	352	add-aircraft-flight data	1100	2	0	2	2
352	385	read-flight data	3300	2	0	2	2
385	386	loop-activity-decide	100	0	0	0.5	0

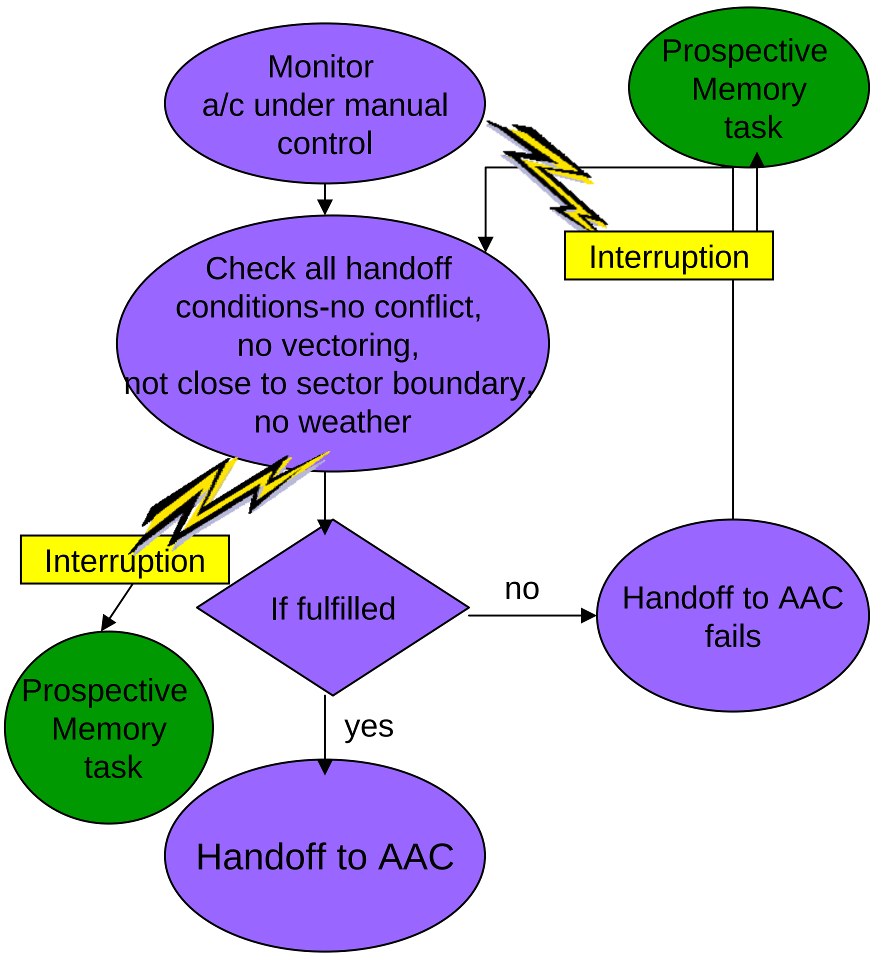
Timing Data

- **Load was not evaluated for schedule**
- **Tasks were serial**

Results-

- **9618 a/c entered ZOB in 24 hours**
- **2269 hand offs managed in 23.16 hours**
- **4.23 days to manage 98618 handoffs as modeled**

Full AAC Protocol

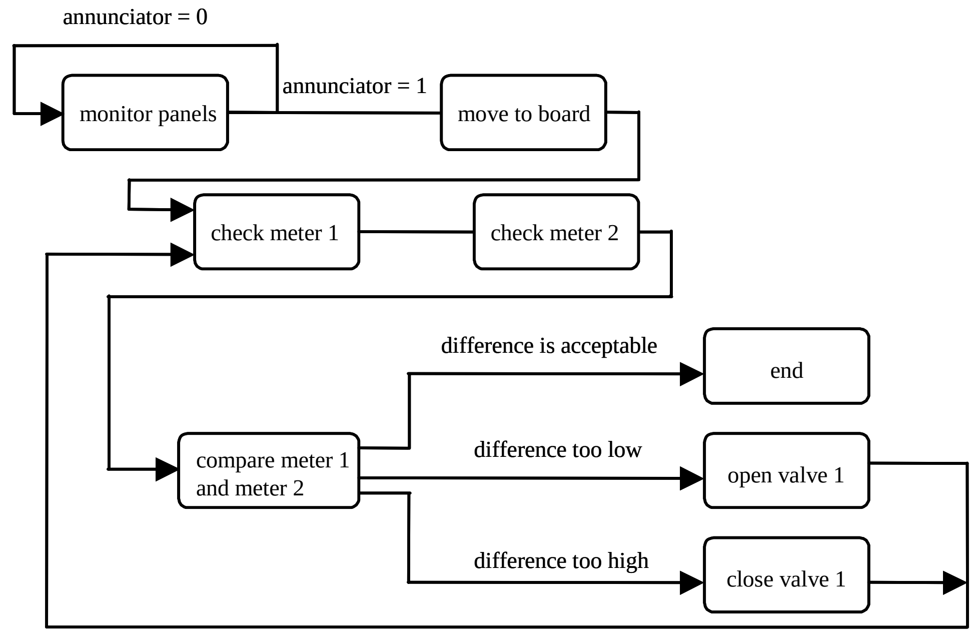


Error Evolution Process System Wide

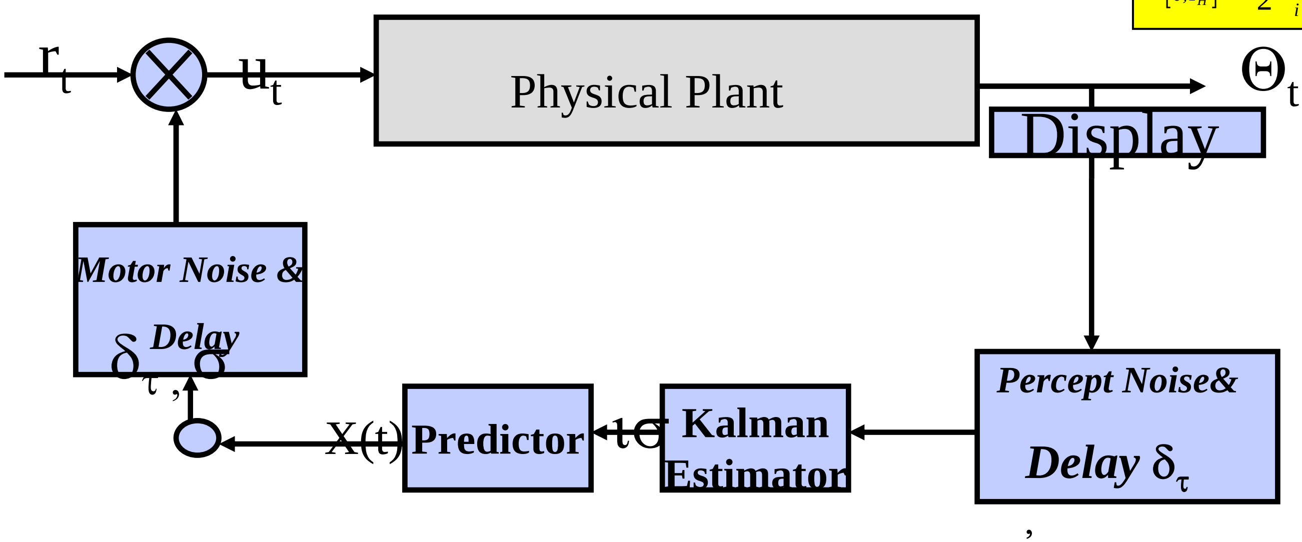
- Two Approaches
  - Mathematical Representation of Distributional Characteristics (TOPAZ)
  - Regional Performance Models run to determine distributional characteristics (RFS-AirMIDAS)

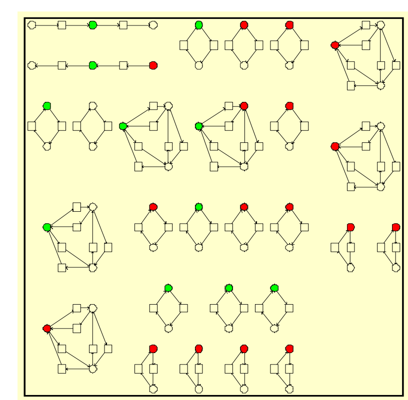
What Methods are Available?

- **Task Analytic**
- **Control Theoretic**
- **Queuing Theoretic**
- **Information Processing**
- **Probabilistic Reliability**
- **Networks**
  - **Neural**
  - **Petri**
  - **DES**



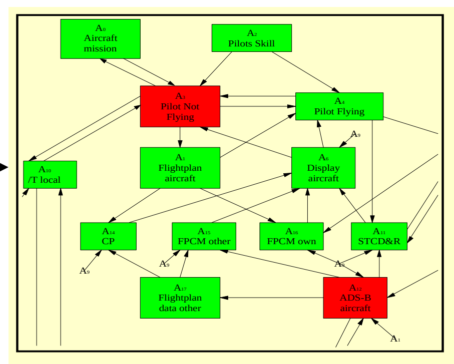
$$\Re_{[0,T_H]} = \frac{1}{2}\sum_i \sum_{j\neq i} \sum_l \int_0^{T_H} \varphi^{ij}\left(t \middle| \kappa_{t*}^{ij} = \kappa^l\right)dt \cdot P\left\{\kappa_{t*}^{ij} = \kappa^l\right\}$$



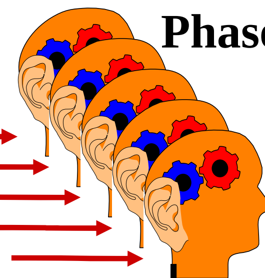


Human-System Performance Assessment

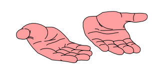
Phase 1:

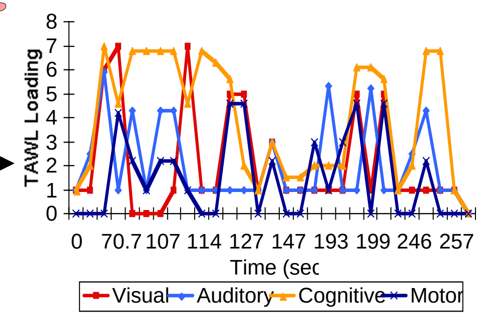


Phase 2:

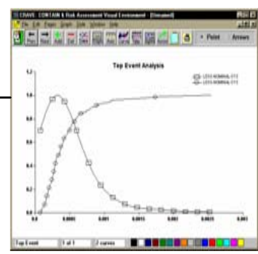


Identify Critical Human Performance Elements





Establish System Performance in Fast time simulation



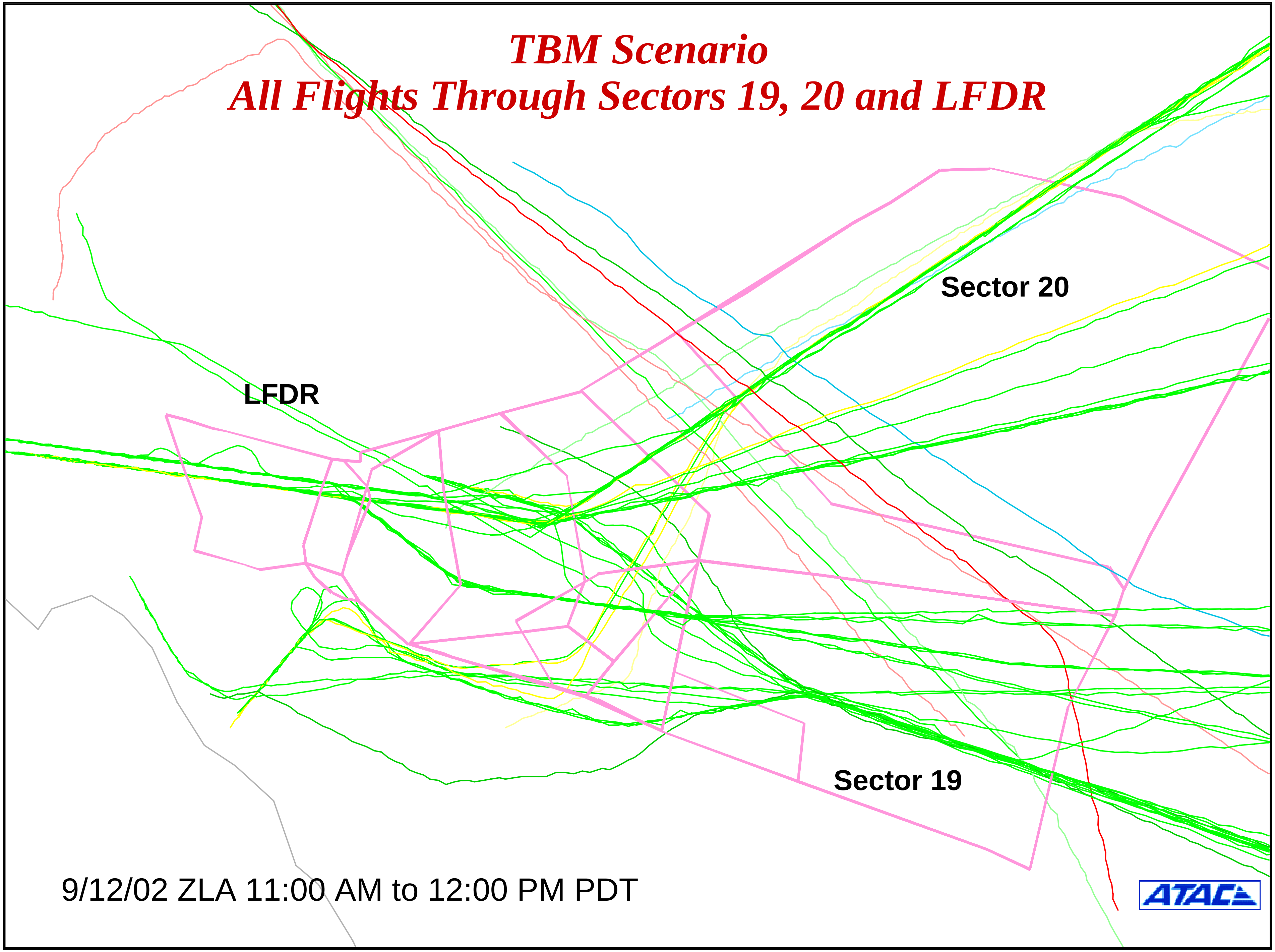
Phase 3:

Run full HPM in parallel scenarios to generate critical performance parameters (> 100 runs)

Run parameterized reduced HPM model integrated into DES (>1,000,000runs)

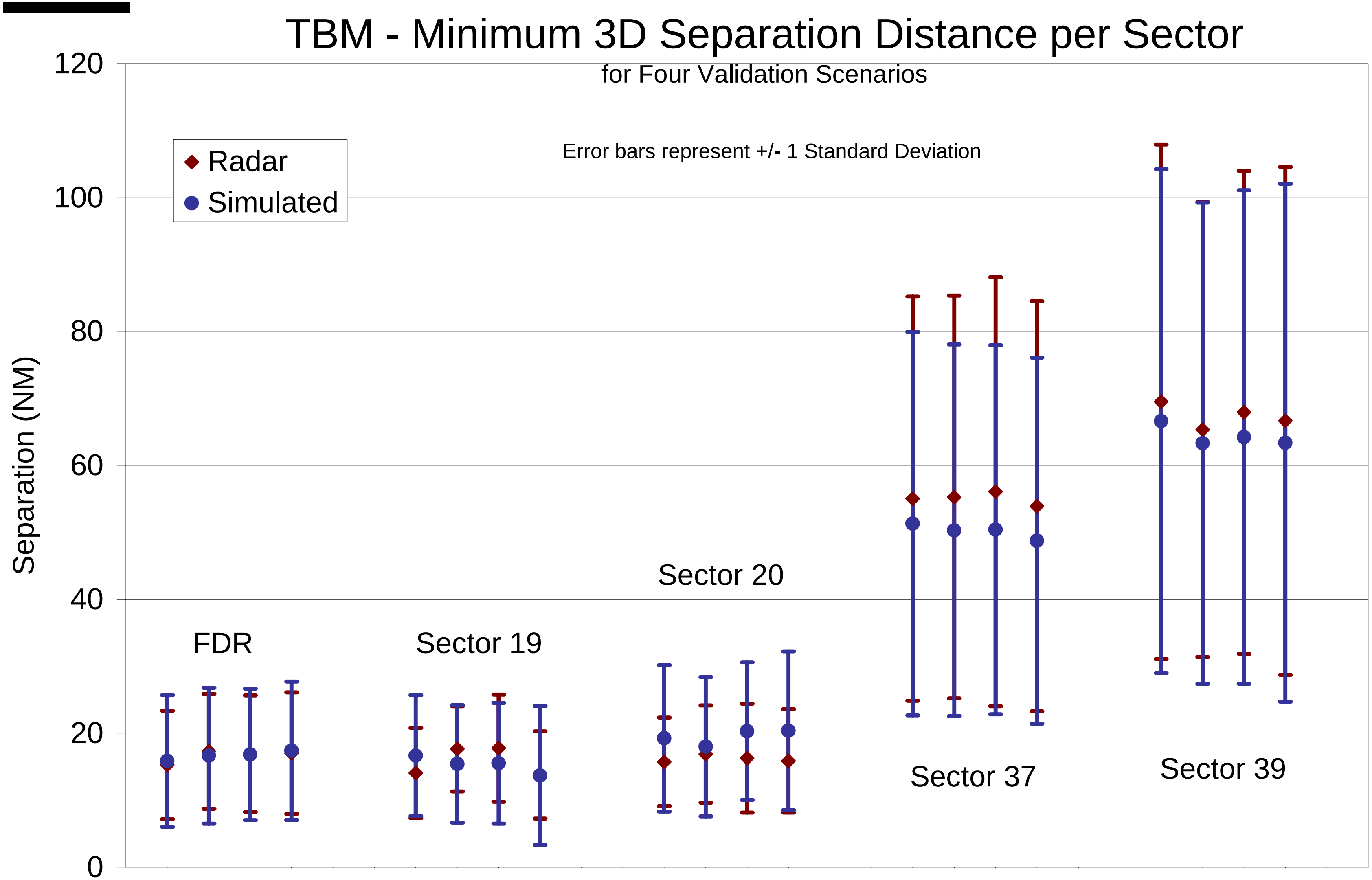
Human-In-Loop

TBM Scenario
All Flights Through Sectors 19, 20 and LFDR



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

Minimum 3D Separation Distance per Sector



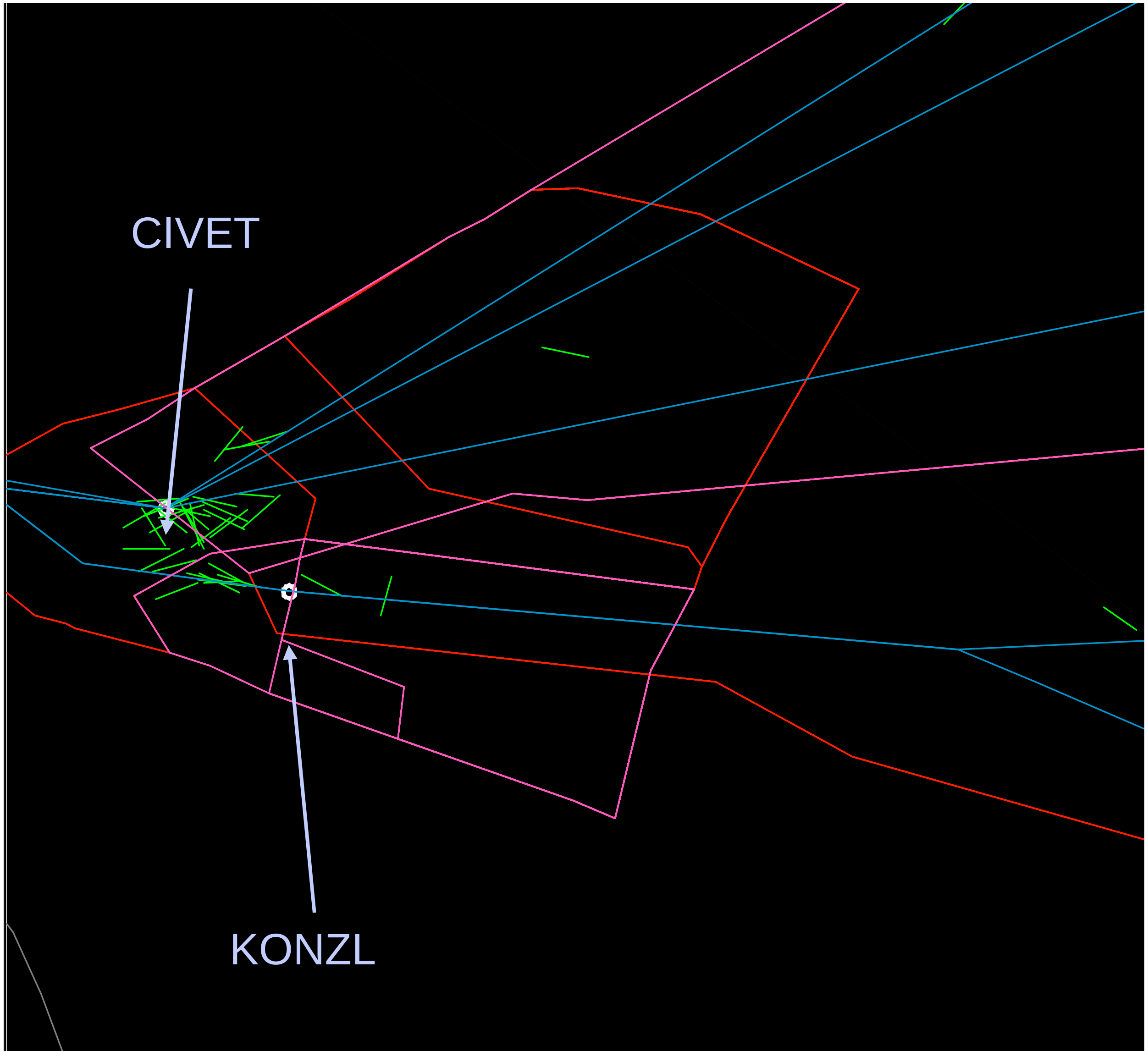
Analyses Results

- F test should no significant difference among the sources of data (simulation, nominal and actual)
- F of $1.648_{(1, 42)}$ non significant difference for the type of control (TBM vs. MIT)
- $R^2 = 0.81$ was found in analysis of all model factors (source and type)
- $R^2 = 0.960$ was found in analysis of the source of data (actual vs. simulated)
- Conclusion:
  - No significant difference between types of control and sources of data were found
- The simulated and actual controller performances are 99.6% in agreement with respect to miles flown in simulation

3. Temporal range of System-wide modeling versus operational range of human's in NAS.

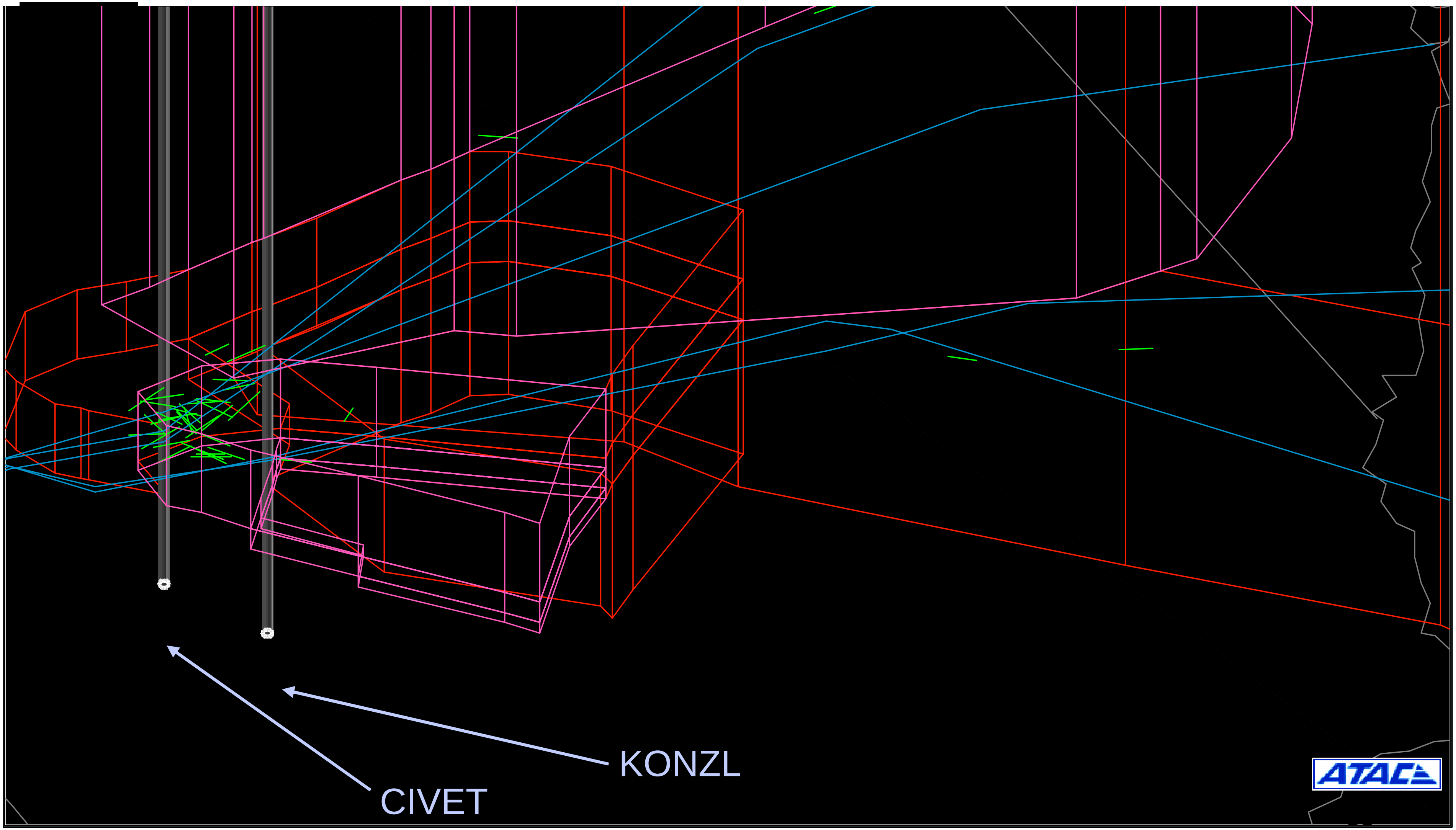
- **Mismatch between human performance scale and analytic scale of interest for System-wide**
  - **Don't mistake the map for the territory**

Modeled Behavior (1 hour of operations)



What is the impact of blunder or human response anomaly at or near convergence points?

Operational Error Traces (10 month)

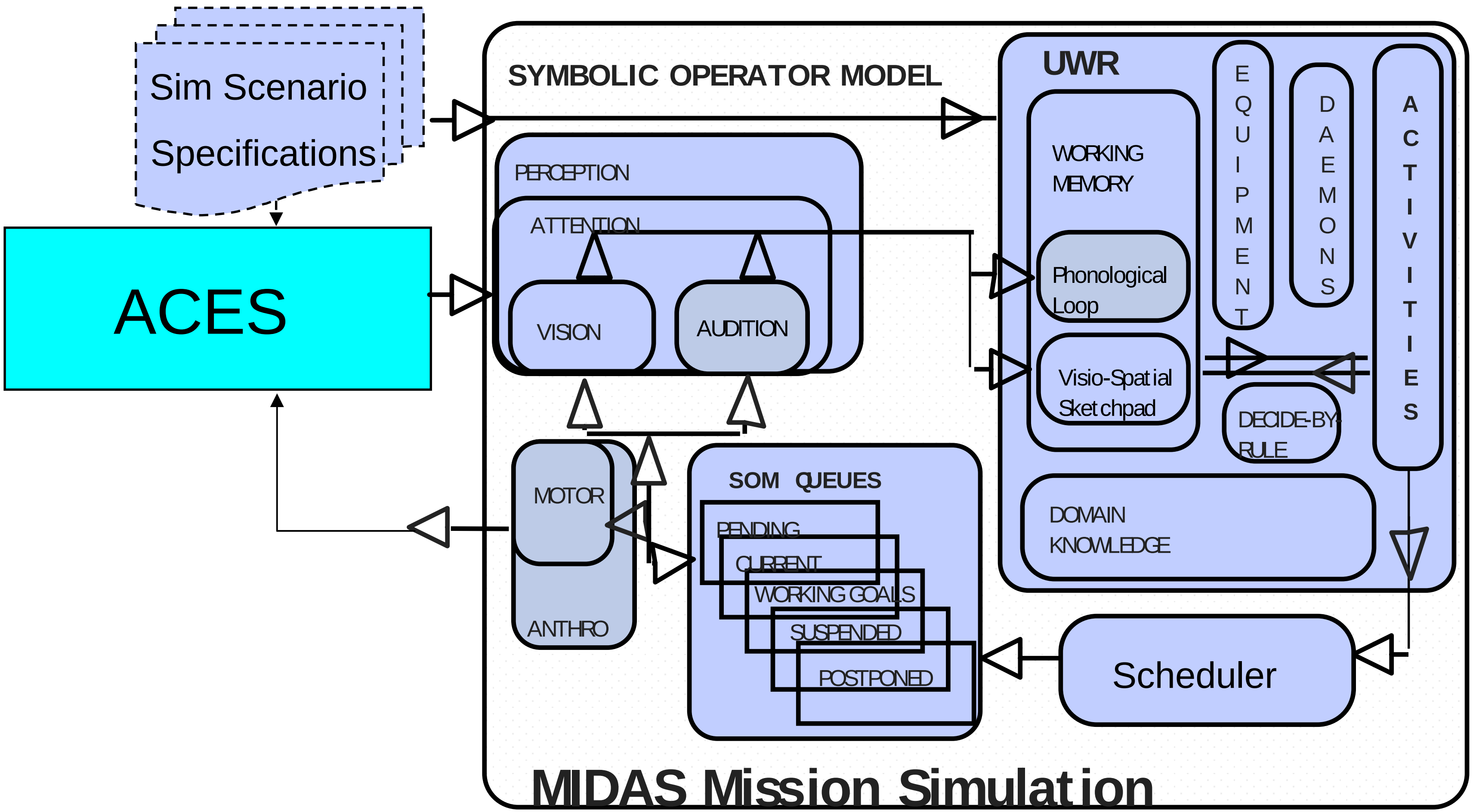


What is to be done next?

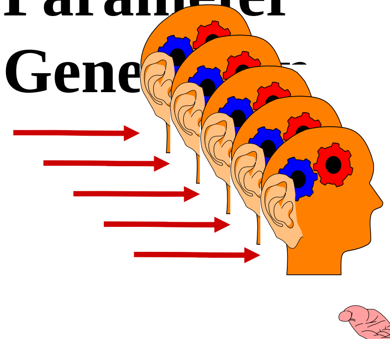
Scalable Human Performance Characteristic for System-wide

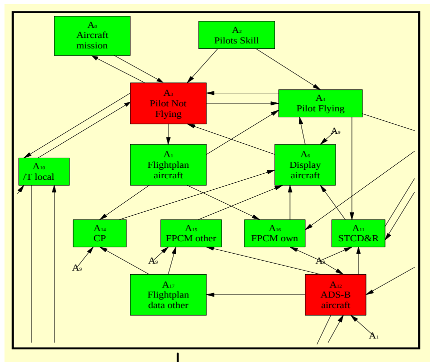
1. **Causal factors that emerge to form human-system behavior**
   - **Factors too complex to address through standard analysis**
2. **Performance Factors**
   - **Taskload**
   - **Error Trends**
3. **Information Exchange**

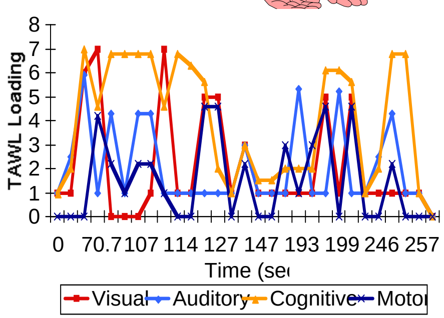
Air-MIDAS INTERACTION WITH ACES



Phase 1: Parameter Gene





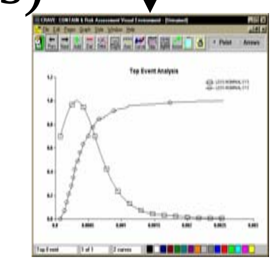


Run full HPM in 5 parallel scenarios to generate critical performance parameters (> 100 runs)

Run parameterized reduced HPM model integrated into RFS

(>1,000,000runs)

Establish Performance Levels and Rare Event Identification



Phase 2: Performance Determination

Conclusions

- There are human performance models available to address the major issues of integrating some human performance characteristics into system-wide assessment.
- What is needed:
  - Demonstration of those integrated capability
  - Validation of results
  - Sensitivity Analyses to human performance inclusion (how much is really needed)
- What is really needed is an agreed upon experimental design approach using the tools described over these two days