Human Error Modeling Predictions: Air MIDAS Human Performance Modeling of T-NASA

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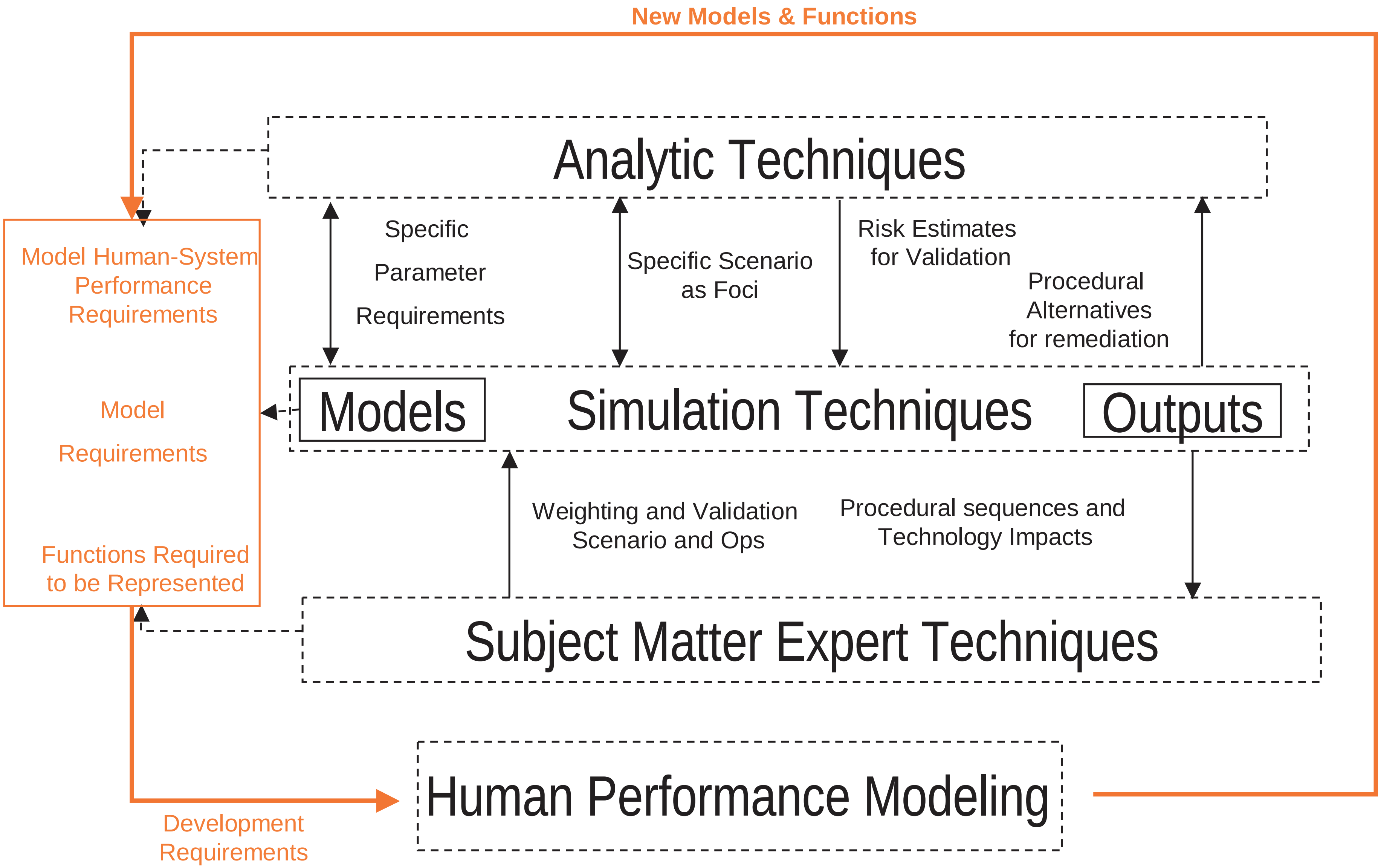
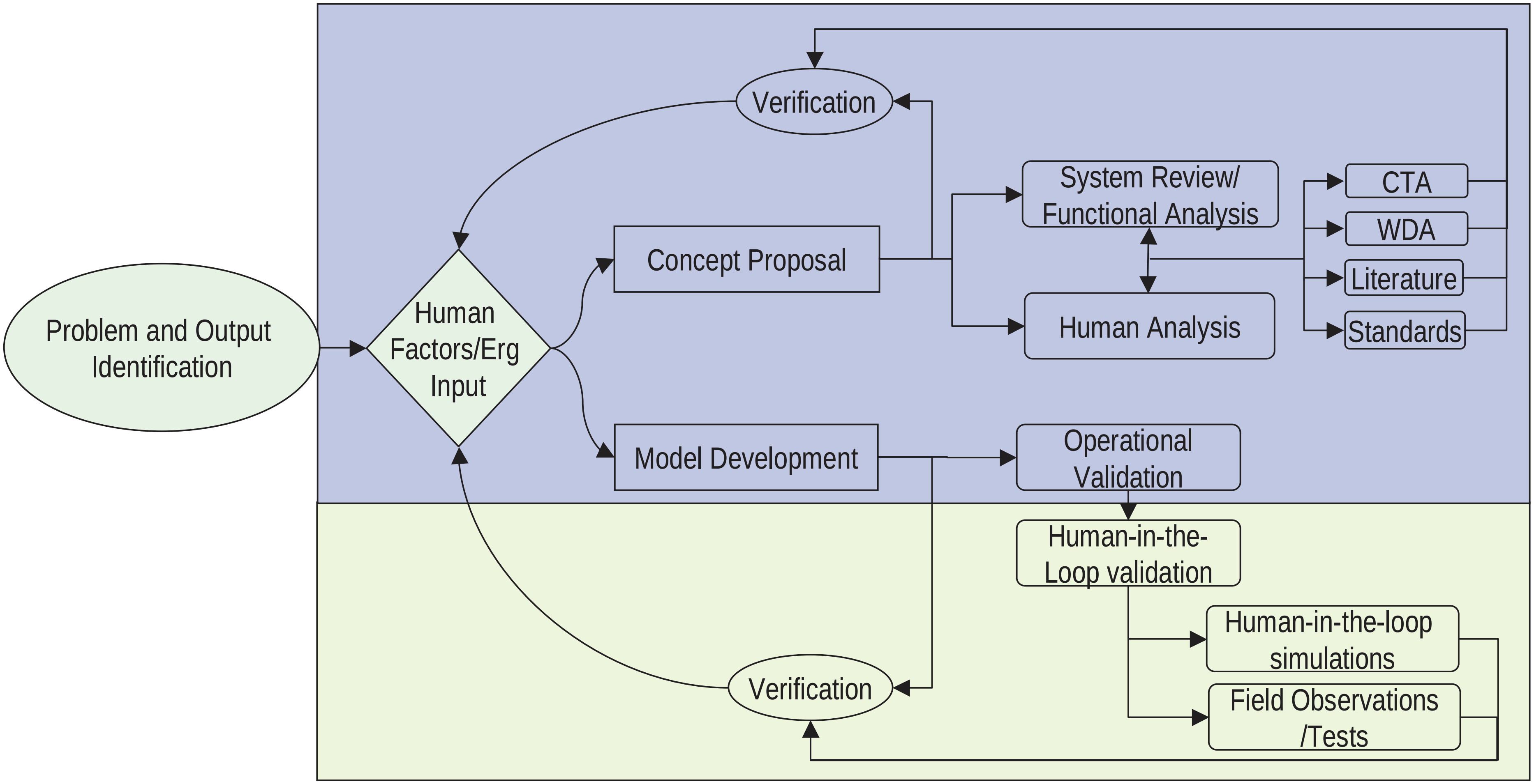
Background

- Striving for:
  - Accurate understanding of human performance, contextual effects and operational safety in complex operating environments (error causation and automation interaction).
  - Accurate behavioral onset description using performance modifiers.
  - Resultant system-safety related effects.
- Supports an understanding of safety-related conceptual mechanisms.
- Application area for the augmentation of existing Human Performance Models.

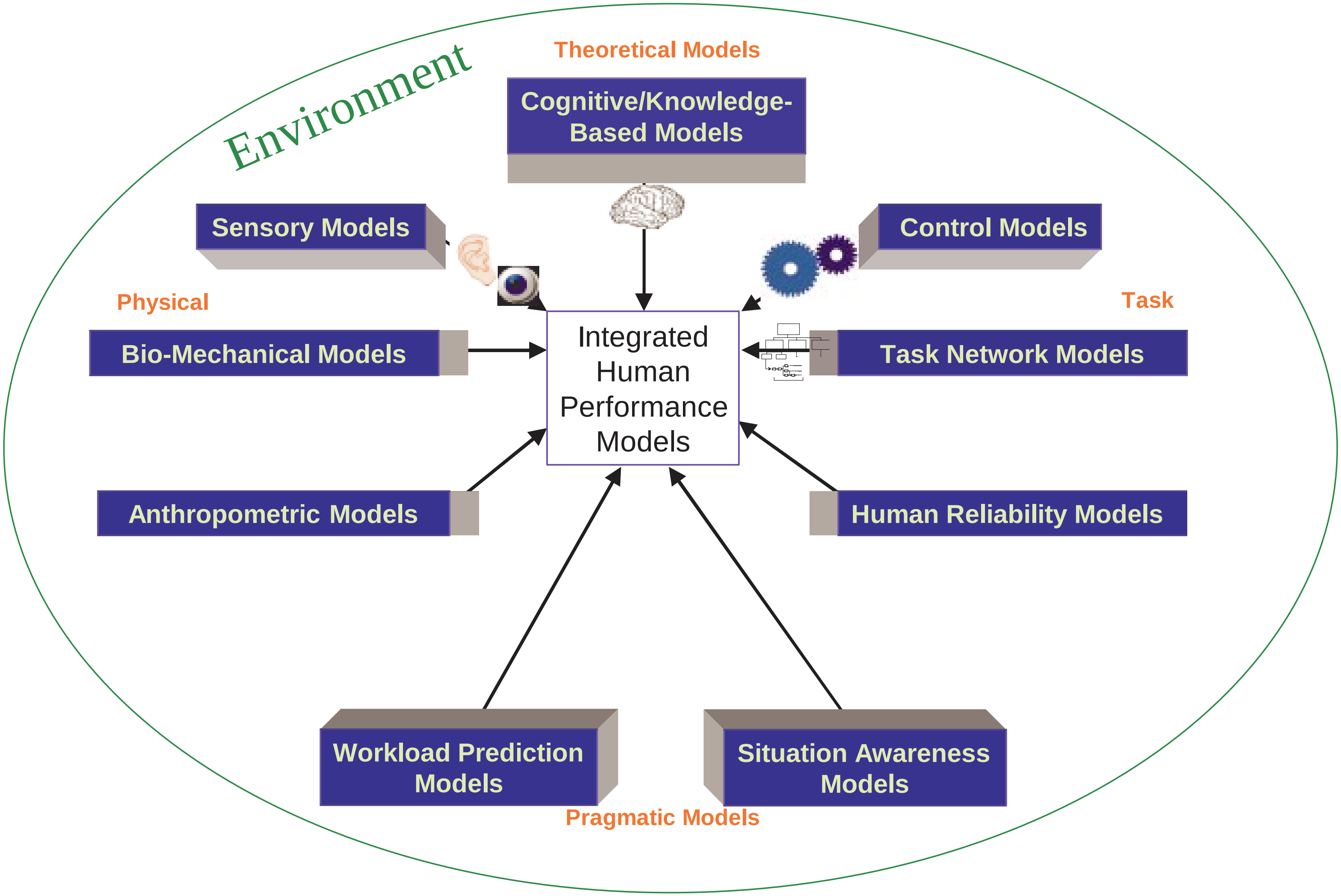
Modeling Interaction Levels of Analyses



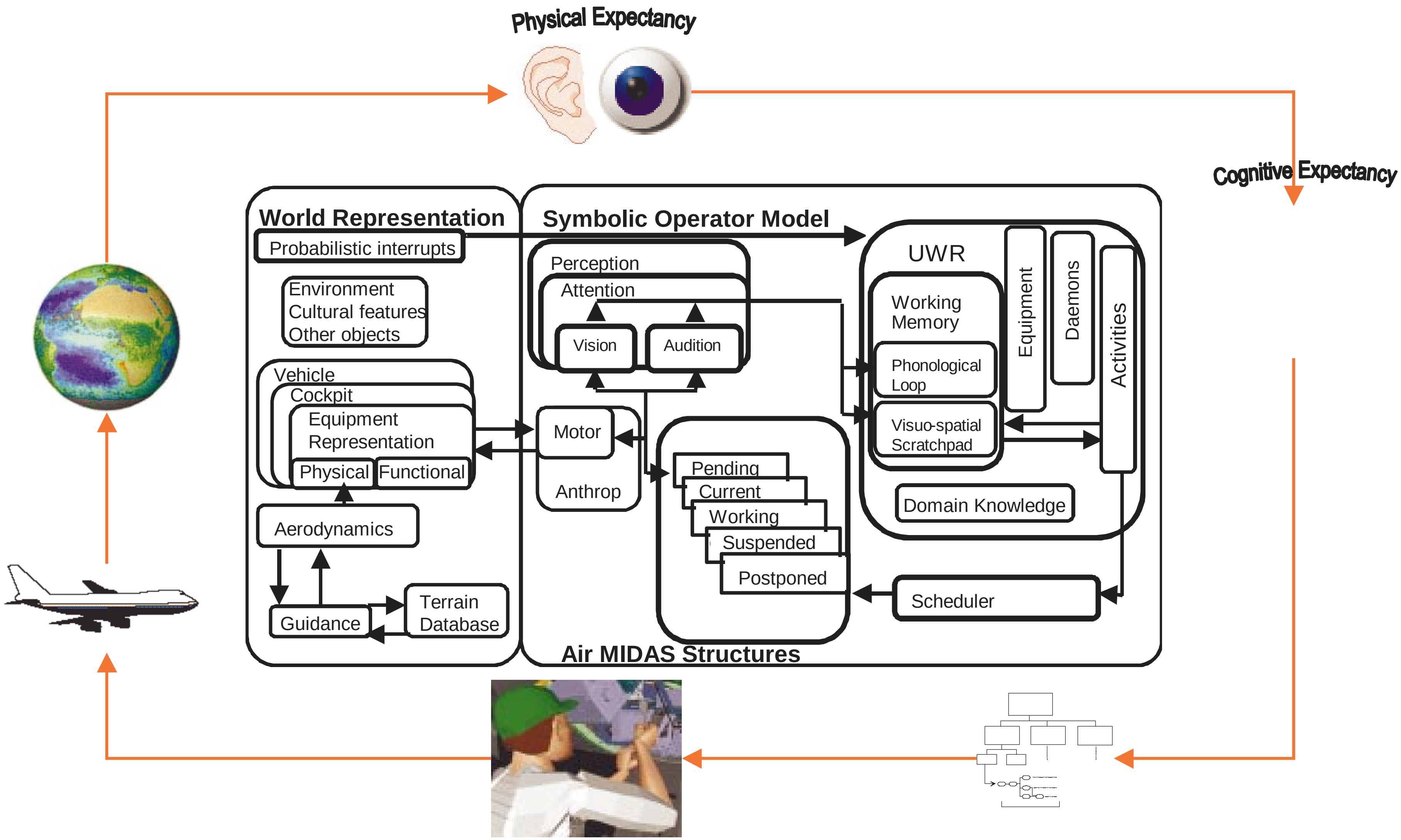
Modeling in System Development Process



Integrated Models - Composition

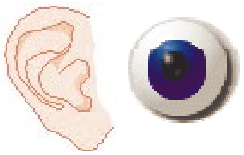


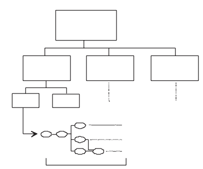
Air MIDAS Integrated Representation

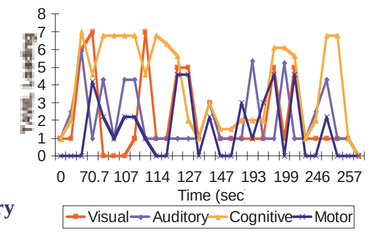


Air MIDAS Output

- Human performance values for the interaction between multiple human agents, the system and the environment (emergent performance):
  - Perceptual demands
  - Operator attention demands
  - Cognitive loading
  - Memory representations
  - Procedural-related information
    - Scheduling, degradation, shedding
    - Time to complete
    - Timeline information







Purpose of HEM Project

- Undertake tasks to develop a validated model of human error behavior applied to surface operations.
- Generate predictions of human performance interacting with advanced technologies designed to improve the safety of surface operations (Taxiway Navigation and Situation Awareness/T-NASA display suite).

Human Error

- Traditionally has been studied in an incidental (reactive) fashion
  - Result - difficulty defining/researching human error.
- Recently human error has been central in much research surrounding human performance.
  - Definition of Human Error has been evolving

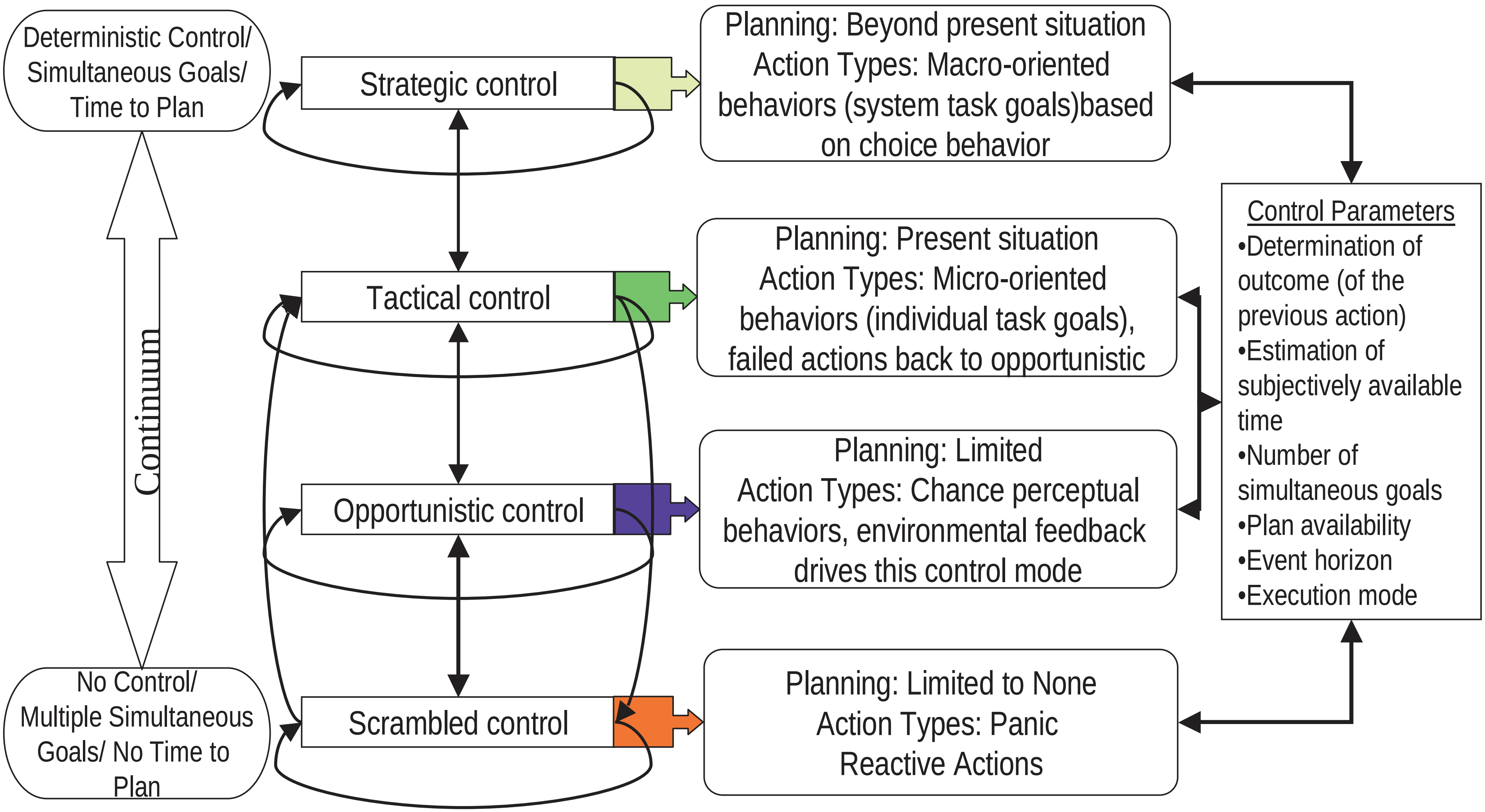
Evolution timeline

- 1920's – Mechanistic - view of simply being the output of incorrect performance.
- 1960's – Cognitive - being the result of more detailed cognitive factors
- 1970's – Information processing - An interaction between the physical and cognitive worlds.
- Current – Information processing from a system perspective, context effects.

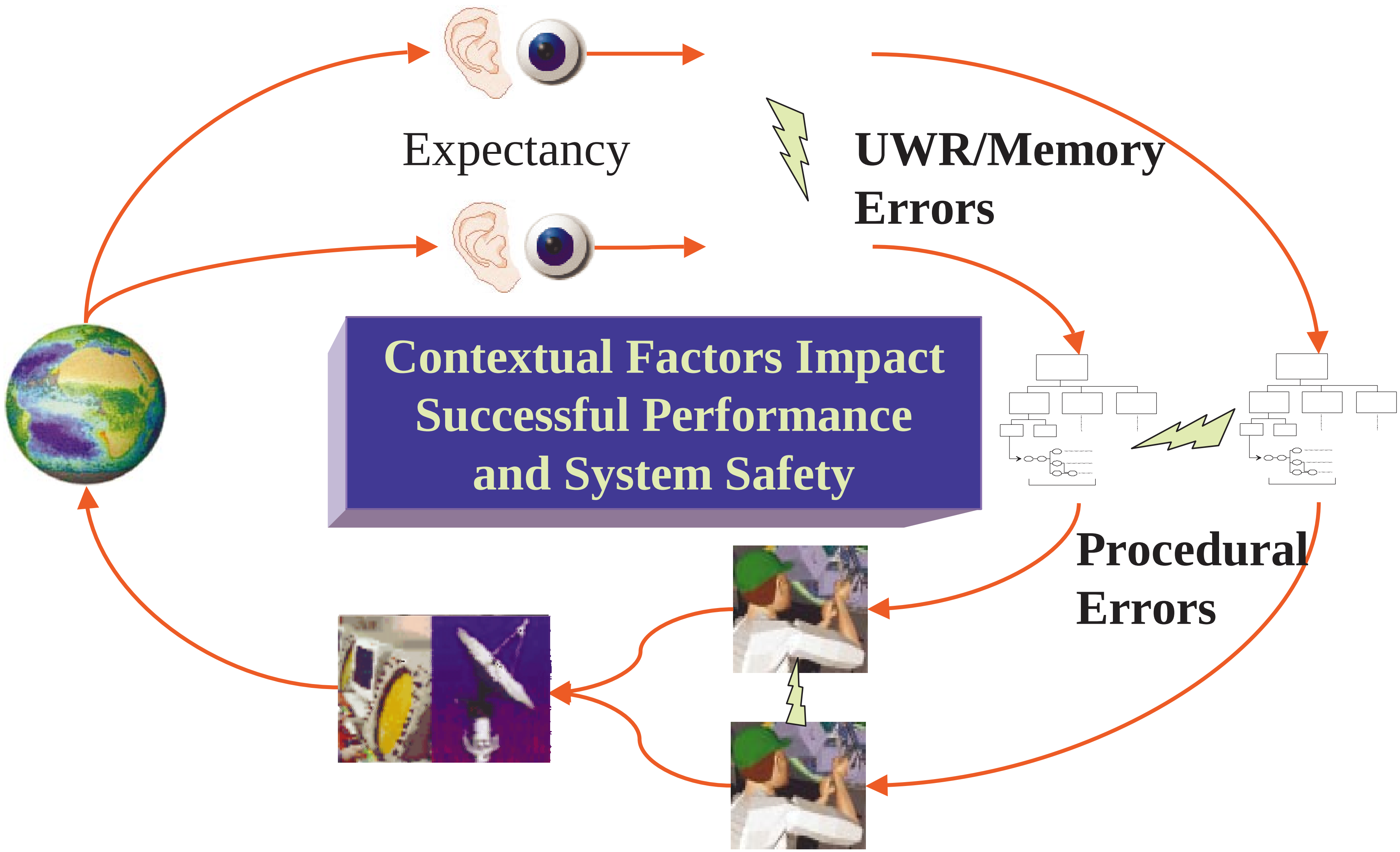
Human Error - Definition

- Situations or events where undesirable consequences occur and where the cause can be attributed in whole or in part to human action (Hollnagel, 1993).
- Augmented to include the contextual components behind human action and human cognition as opposed to solely referring to incorrect human actions (Hollnagel, 2000).

Contextual Control Theory Modes



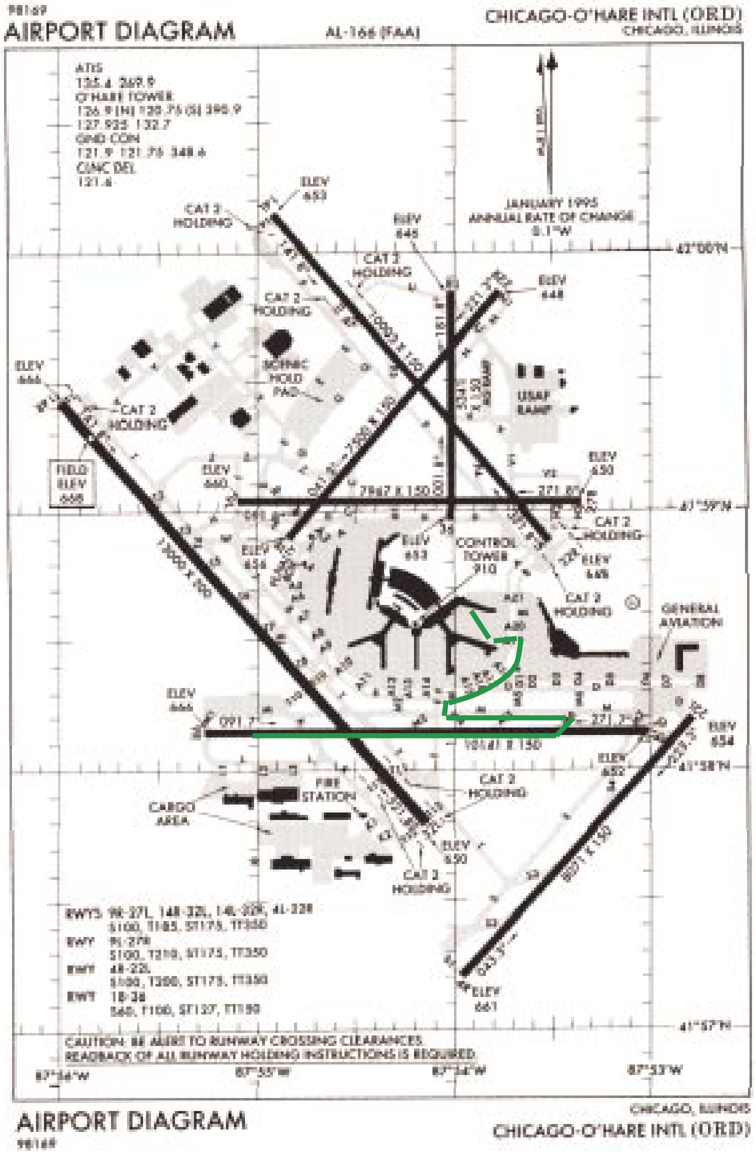
Human Error Modeling System Vulnerabilities



T-NASA Error Types (Hooey & Foyle, 2001)

- Planning Errors:
  - Incorrectly writing down.
  - Reading back clearance.
- Decision/Execution Errors:
  - Time pressure: FO head down (Jepp chart), Captain continues navigation from Captain's incorrect mental map.
  - Interruptions: FO head down leaving one agent responsible for correct local guidance, navigation is affected when interrupted.

Model Operational Environment



- Single scenario.
- Baseline operations.
- Chicago O'Hare.
- Route - NH3.
- Other Traffic - None.
- Communication - Voice.
- "Major Errors" types.

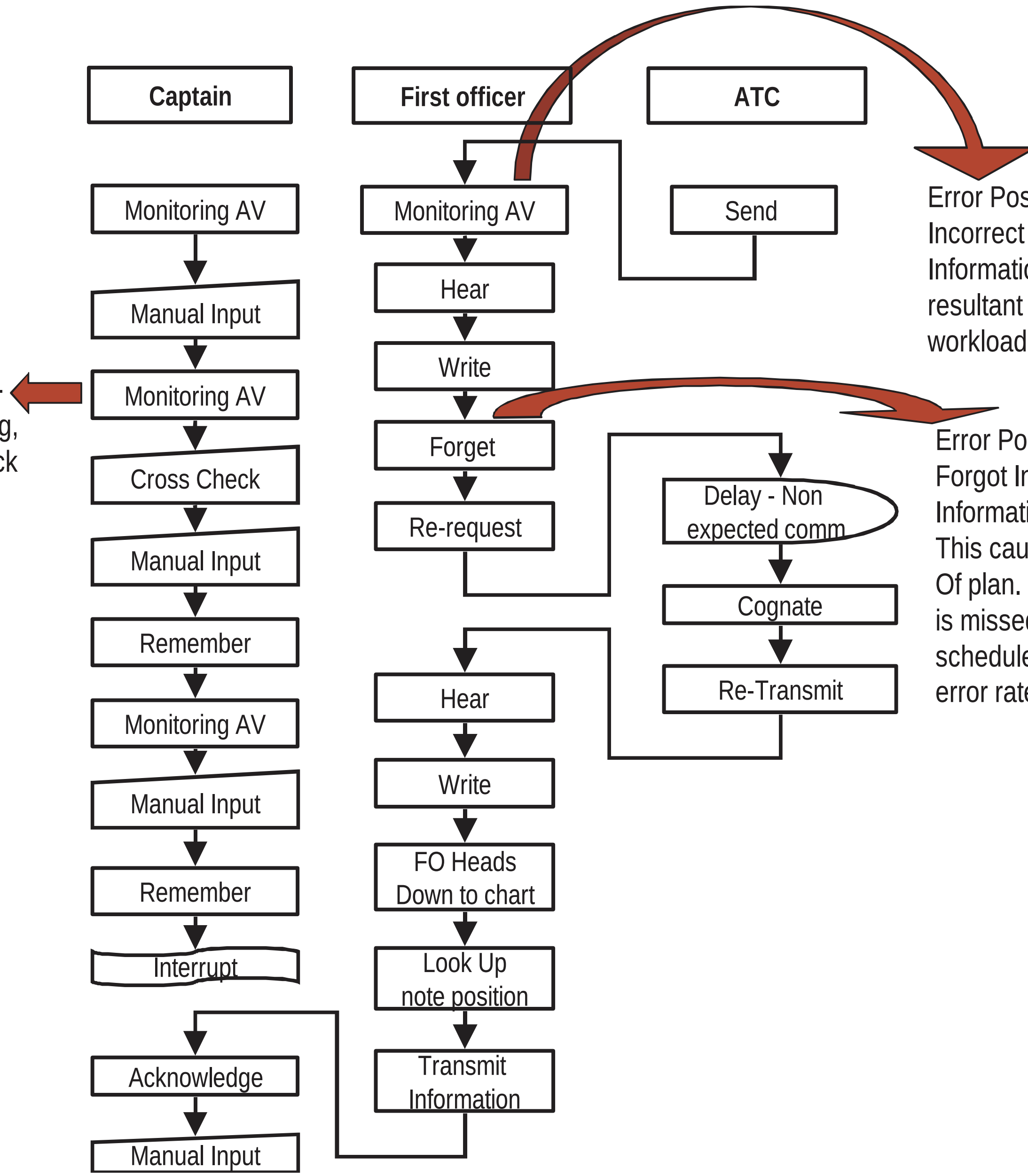
Procedural Overview

Captain	First Officer	ATC (Tower&Ground)
Based on the turn-off instruction, the Captain might have expectations regarding their taxi route, which might influence his/her decisions later i.e. confirmation bias, heuristic—same for FO	*Before all of this (in the air), the FO was supposed to refer to the taxi chart to gain an awareness of where the expected turn-off was situated in relation to the airport configuration*	
While navigating turn-off	Do: (order depends on time, A/C positioning i.e. whether still approaching HS bar or not or whether ATC responded yet)	
❑ Keeps navigating or is waiting on HS bar by now ❑ Listens to taxi route clearance (depending on load)	❑ Contacts Tower of clearing runway and location ❑ Switches frequency to Ground ❑ Contacts Ground regarding clearing runway and location ❑ Waits for a response (clearance)	❑ Tower ATC gives frequency for Ground ATC ❑ Ground ATC gives taxi route when ready (*this message might be given right away or it might take them longer)*
❑ Keeps navigating or is at HS bar by now ❑ Listens to taxi route clearance (depending on load)	❑ Writes down taxi route ❑ Reads back taxi route to Ground	❑ Ground ATC might acknowledge the confirmation, but might not
❑ If already stopped, may start on taxi route *while* discussing with FO (*this would probably mean that the Captain had heard the first route instructions and thought s/he knew how to start off—and was probably under time pressure to do so)*	❑ Discusses taxi route with Captain	
❑ Visually reference chart if unsure/lack of local and/or global awareness	❑ Visually references chart	

Scenario - Operational Environment

Human Performance Decision Error (Hooey & Foyle 2001)/ Opportunistic Errors (Hollnagel, 1993) Model Specification

Error Possibility #3 -
Contextual Switching, hear and cross check versus hear and go.



Error Possibility #1 -
Incorrect auditory registration = lost Information by the FO, WM load, resultant effect is increased turns, workload increases, increased error.

Error Possibility #2 -
Forgot Information due to subsequent Information pushing first info. This causes incorrect formulation Of plan. Out of memory effect is missed turns, workload increases, scheduler activation, increased error rate.

Output: Analytic Model Subset

- Captain Specification
- First Officer Specification
- Air Traffic Control Specification

Agent:	Captain
Initiated by:	Simulation Initiation
Priority:	
Goal:	Navigate Turn-off
Tasks:	monitor OTW scene for preferred turn-off, disengage autopilot, initiate runway turn-off, slow down A/C, monitor ATC-FO radio communication--passive
Interruptable:	no

Control Activity	sub-Control	Leaf Activity	sub-Leaf	V	A	C	M	Mean	SD
Parallel All	VISUAL-MOTOR-ACTIVITY								
Sequential Activity	RADIO-MESSAGE								
		Communication	SAY-RADIO-MESSAGE	0	4	4	2	2	1
		Expectations	COMM-EXPECTATION	0	0	1	0	5	3
		Communication	HEAR-RADIO-MESSAGE	0	5	4	2	2	1

Agent:	First Officer
Initiated by:	Simulation Initiation
Priority:	
Goal:	Monitor Ground Environment
Tasks:	scan OTW scene for possible incursions, exit path
Interruptable:	yes

Control Activity	sub-Control	Leaf Activity	sub-Leaf	V	A	C	M	Mean	SD
Loop	MONITOR								
		General	AM-VISION-ACTIVITY	5	0	3	0		

Agent:	ATC Tower
Initiated by:	
Priority:	
Goal:	Communicate with ATC Tower
Tasks:	Communicate Preferred Exit to First Officer; send preferred exit -M6, expect a response, receive a response from First Officer
Interruptable:	yes

Control Activity	sub-Control	Leaf Activity	sub-Leaf	V	A	C	M	Mean	SD
Sequential Activity	SEQUENTIAL-ACTIVITY								
		General	AM-VISION-ACTIVITY	2	1	2	1		
		General	AM-MOTOR-ACTIVITY	1	0	1	5	3	1
		General	FIXED-DURATION-ACTIVITY						
		General	AM-MOTOR-ACTIVITY	1	1	1	5		
		General	WAIT	1	1	1	1		

Agent:	First Officer
Initiated by:	Simulation Initiation
Priority:	
Goal:	Support Roll-Out Performance
Tasks:	verify thrust levers are closed, speedbrakes are up
Interruptable:	yes

Control Activity	sub-Control	Leaf Activity	sub-Leaf	V	A	C	M	Mean	SD
Sequential Activity	SEQUENTIAL-ACTIVITY								
		General	AM-VISION-ACTIVITY	4	0	2	0	4	2
		General	AM-VISION-ACTIVITY	4	0	2	0	4	2

Communicate Ground Frequency to First Officer: receive exit location of A/C from First Officer, acknowledge and send ATC Ground radio frequency

Agent:	Captain
Initiated by:	
Priority:	
Goal:	Co-ordinate A/C Ground Manuevering
Tasks:	control speed, direction, braking; monitor ground environment (traffic and taxiways); scan OTW for centerline tracking, possible incursions
Interruptable:	no

Control Activity	sub-Control	Leaf Activity	sub-Leaf	V	A	C	M	Mean	SD
Sequential Activity	RADIO-MESSAGE								
Parallel All	VISUAL-MOTOR-ACTIVITY								
		Expectations	COMM-EXPECTATION	0	0	1	0	5	3
		Communication	HEAR-RADIO-MESSAGE	0	5	4	2	2	1
		Communication	SAY-RADIO-MESSAGE	0	4	4	2	2	1
		General	CONTINOUS-ACTIVITY	4	1	0	7	6	3
		General	AM-VISION-ACTIVITY	1	1	1	1		
		General	AM-VISION-ACTIVITY	6	0	6	0	1	
								4	2
								10	3

Agent:	First Officer
Initiated by:	
Priority:	
Goal:	Ground Speed Call-Outs
Tasks:	initiate ground speed call-outs @100, fixate on indicator, identify reading, call-out ground speed 100, *repeat by increments of 10 until 60 reached
Interruptable:	no

Control Activity	sub-Control	Leaf Activity	sub-Leaf	V	A	C	M	Mean	SD
Sequential Activity	SEQUENTIAL-ACTIVITY								
		General	WAIT	1	1	1	1		
		General	CONTINOUS-ACTIVITY	4	0	3	0		
		Perception	FIXATE-LOCATION	6	0	4	0	3	1
		General	UPDATE-UWR					1	
		Communication	SAY-MESSAGE	0	4	4	2	4	2
		Perception	FIXATE-LOCATION	6	0	4	0	3	1
		General	UPDATE-UWR					1	
		Communication	SAY-MESSAGE	0	4	4	2	4	2
		*							

Agent:	ATC Ground
Initiated by:	
Priority:	
Goal:	Communicate with ATC Ground
Tasks:	Communicate Clearance to First Officer: receive position of A/C from FO, cognate on taxi route, send taxi route and clearance, expect response, receive response and read-back
Interruptable:	yes

Control Activity	sub-Control	Leaf Activity	sub-Leaf	V	A	C	M	Mean	SD
Sequential Activity	RADIO-MESSAGE								
		Communication	HEAR-RADIO-MESSAGE	0	5	4	2	2	1
		General	FIXATE-DURATION-ACTIVITY	0	5	4	2	15	2
		Communication	SAY-RADIO-MESSAGE	0	4	4	2	2	1
		Expectations	COMM-EXPECTATION	0	0	1	0	5	3
		Communication	HEAR-RADIO-MESSAGE	0	5	4	2	2	1

Agent:	Captain
Initiated by:	
Priority:	
Goal:	Complete Checklists
Tasks:	communicate/respond to First Officer reading off the checklist
Interruptable:	yes

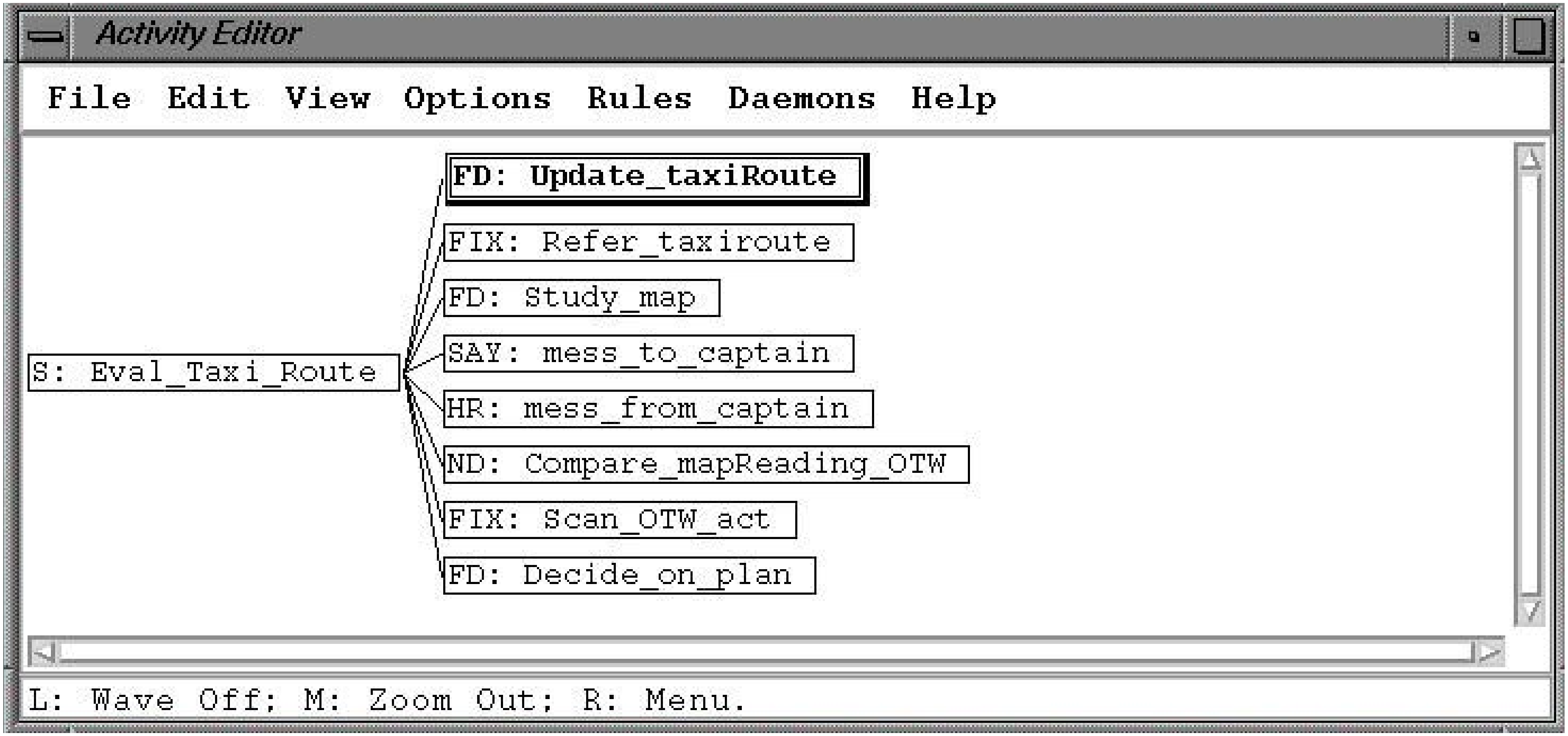
Control Activity	sub-Control	Leaf Activity	sub-Leaf	V	A	C	M	Mean	SD
Sequential Activity	Parallel All								
		Communication	HEAR-MESSAGE	0	5	4	2	2	1
		Communication	SAY-MESSAGE	0	5	4	2	2	1
		Communication	HEAR-MESSAGE	0	5	4	2	2	1
		Communication	SAY-MESSAGE	0	5	4	2	2	1
		Communication	HEAR-MESSAGE	0	5	4	2	2	1
		Communication	SAY-MESSAGE	0	5	4	2	2	1
		Communication	HEAR-MESSAGE	0	5	4	2	2	1
		Communication	SAY-MESSAGE	0	5	4	2	2	1
		Communication	HEAR-MESSAGE	0	5	4	2	2	1
		Communication	SAY-MESSAGE	0	5	4	2	2	1

Agent:	First Officer
Initiated by:	Decide by Rule
Priority:	
Goal:	Complete Checklists
Tasks:	read off each item from list, communicate with Captain
Interruptable:	yes

Control Activity	sub-Control	Leaf Activity	sub-Leaf	V	A	C	M	Mean	SD
Sequential Activity	SEQUENTIAL-ACTIVITY							30	5
		General	FIXED-DURATION-ACTIVITY	4	0	2	1		
		Communication	SAY-MESSAGE	0	5	5	0	4	2
		Communication	HEAR-MESSAGE	0	4	4	0	4	2
		*							

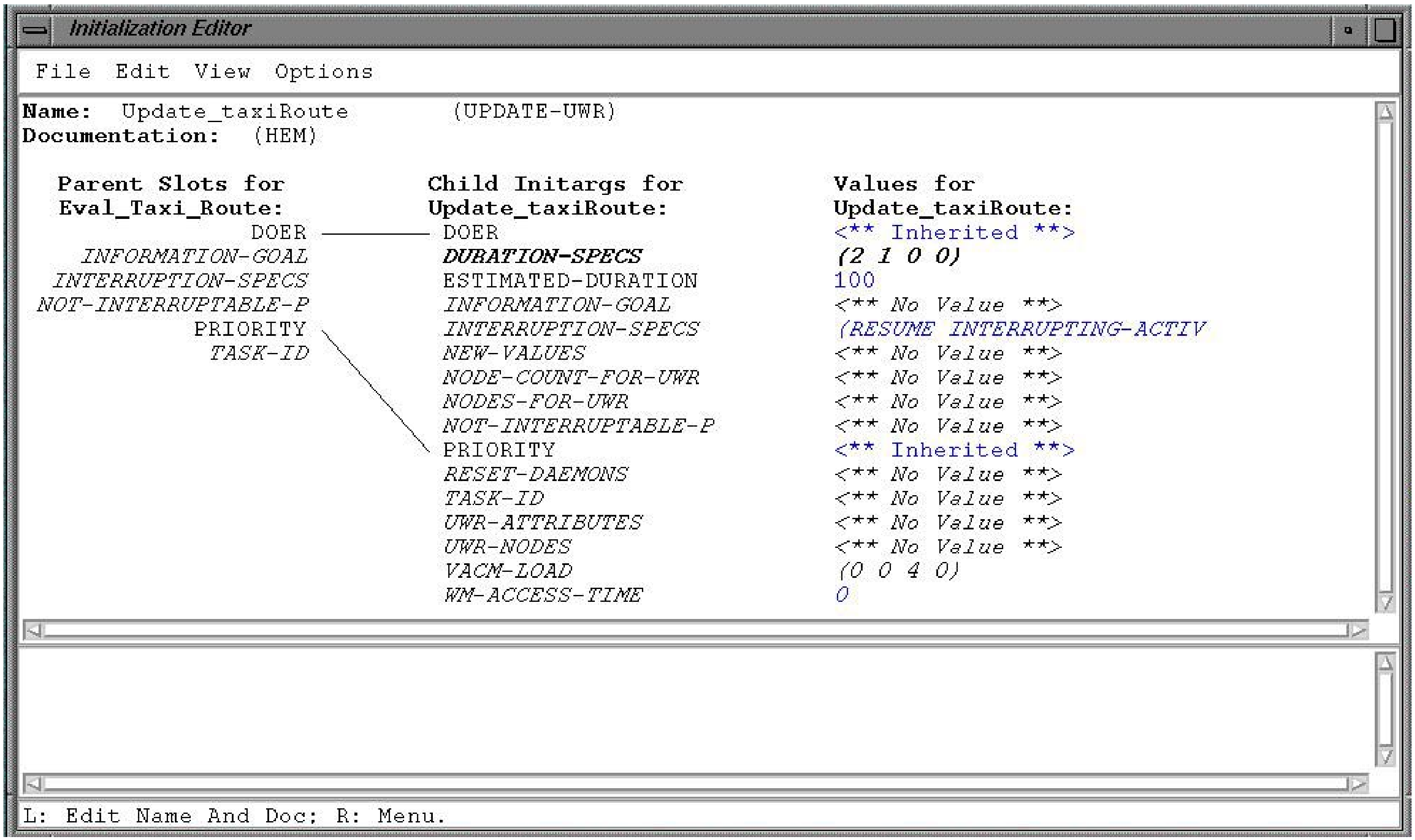
Air MIDAS Activity Input

- A procedural example: The parent activity



Air MIDAS Initialization Input

- Sub activities (child activities) of parent



Error Structures: Expected Results

- Error 1: Memory loss due to timing:
  - Memory decays as time increases at each node level.
  - If no recovery from scrambled mode, strategic mode intervention from ATC agent occurs. If late, simple heuristic 1 straight line to gate is enacted by FC.

Example of Code

```
(defmethod forget-node-attributes ((node uwr-node) current-time
                                   reason-for-forgetting)
 "Forget all data attributes of node and put reason in forgotten datums."
 (when (attributes node)
  (display-debug *sim-exec* #'format
         "~%~% In FORGET-NODE-ATTRIBUTES: node ~a is being ~
        forgotten at time ~a with reason = ~a~%~%"
         (get-node-name node)
         current-time
         reason-for-forgetting)
  (loop for datum in (attributes node) do
     (setf (datum-forgotten datum)
      (cons current-time reason-for-forgetting)))
  (setf (forgotten-data node)
   (append (attributes node) (forgotten-data node))
   (attributes node) nil)))
```

- Mechanism - temporal and capacity constrained Working Memory (WM) buffer.

Error Structures: Expected Results

- Error 2: Memory Loss due to overload:
  - Primacy effect - not writing the information down, causes the first bit of information to be forgotten, results in "planning error".
  - Confusion/loss of SA activates respective heuristic (depending on the conditions/rules).

Example of Code

```
(defun compute-decayed-activation-level (current-activation-level
                                         elapsed-time-in-secs
                                         decay-rate-in-secs)
  "Compute new activation level based on current level, time elapsed ~
   in secs and per-second decay rate."
  (- current-activation-level (* decay-rate-in-secs elapsed-time-in-secs)))
```

- HEM application of the Air MIDAS heuristic of shared intent failure.

Error Structures: Expected Results

- Error 3: Time pressure and COCOM switch
  - Heuristic 1 (uncertainty, crew does a cross check) and heuristic 2 (time pressure and uncertainty crew takes immediate action).
  - Situation: Pilot moves aircraft immediately without fully understanding the direction.
- Mechanism - COCOM switching - ratio of number of goals:time available

Air MIDAS Contextual Parameters

- Planning mode switching ratio (# of simultaneous goals:time available).
  - < 37 secs/goal: unplanned
  - 37 - 52 secs/goal: tactical
  - > 52 secs/goal: strategic
- Rules
  - **strategic mode performance -** Captain performs a cross check with First Officer
  - **scrambled mode performance -** Captain hears information and performs an action without a full understanding of the direction selected.

Error Structures: Expected Results

- Confirmation Bias
  - – Flight crew default uncertainty = taking direct routing to goal location.
  - – Confirmation bias - Pilot receives confirmation from the environment (hits Delta taxiway this acts to confirm the direction chosen).
- Mechanism - supported by the ability to add probabilistic decision making.

Error Structures: Generalizability

- Team Air MIDAS has been working to create a generalizable generative function allowing emergence across different scenarios.
- NH3 results will be generalizable to other "major errors" in the environment.
  - Flight crew went directly to the gate with fewer turns on 83% of the time across all T-NASA scenarios.
  - Suggested that when major errors were made and crew lost SA, and reverted to going directly to their goal location.

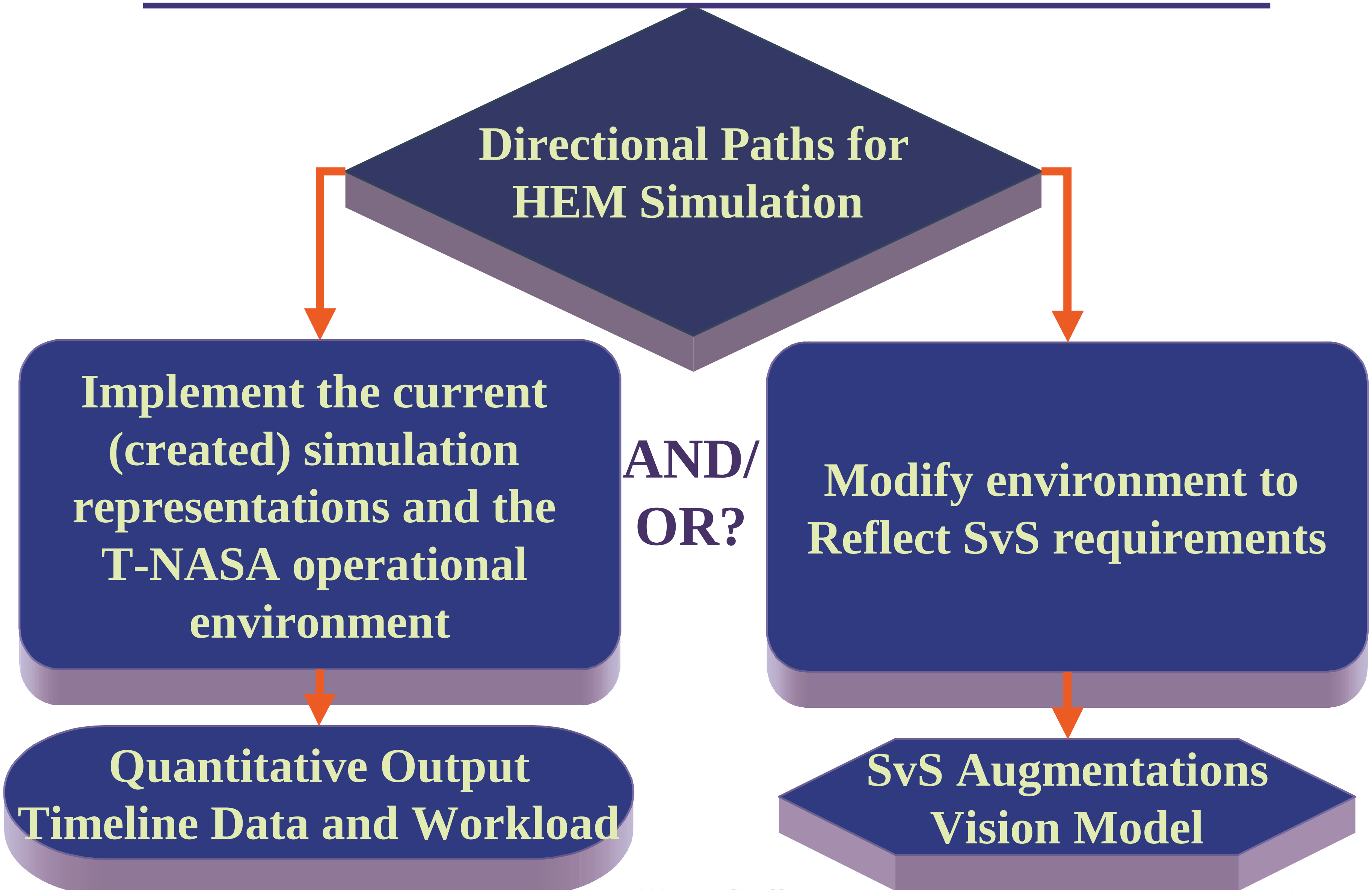
Air MIDAS Optimization

- Memory Buffer and Scheduler within Air MIDAS
  - Significant programming issues - legacy code:
    - Low level, very detailed programming required.
    - Desire for higher level, less detailed but equally valid output.
  - Software/structural modifications made to:
    - Allow multi-programmer.
    - Permit ease of use.
      - Increase ease of validation efforts.
      - Increase usability of the software.
    - LISP-LINUX finished, LINUX-Windows Commenced

Status Update

Description	Commenced	Completed
Scenario identification	✓	✓
Scenario specification	✓	✓
Procedural specification	✓	✓
Procedural coding	✓	✓
Equipment coding	✓	✓
Environmental coding	✓	
Analytic model	✓	✓
Implementation of model	✓	

Conclusion: Development Path Guidance



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Questions/Discussion

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