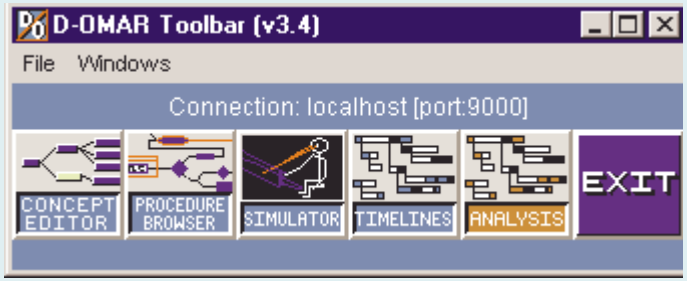


Modeling Human Error in D-OMAR

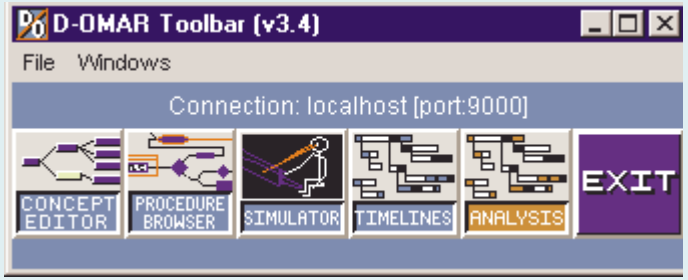
Steve Deutsch
Dick Pew, PhD
BBN Technologies
10 Moulton Street
Cambridge, MA 02138
(617)873-3168
sdeutsch@bbn.com
pew@bbn.com

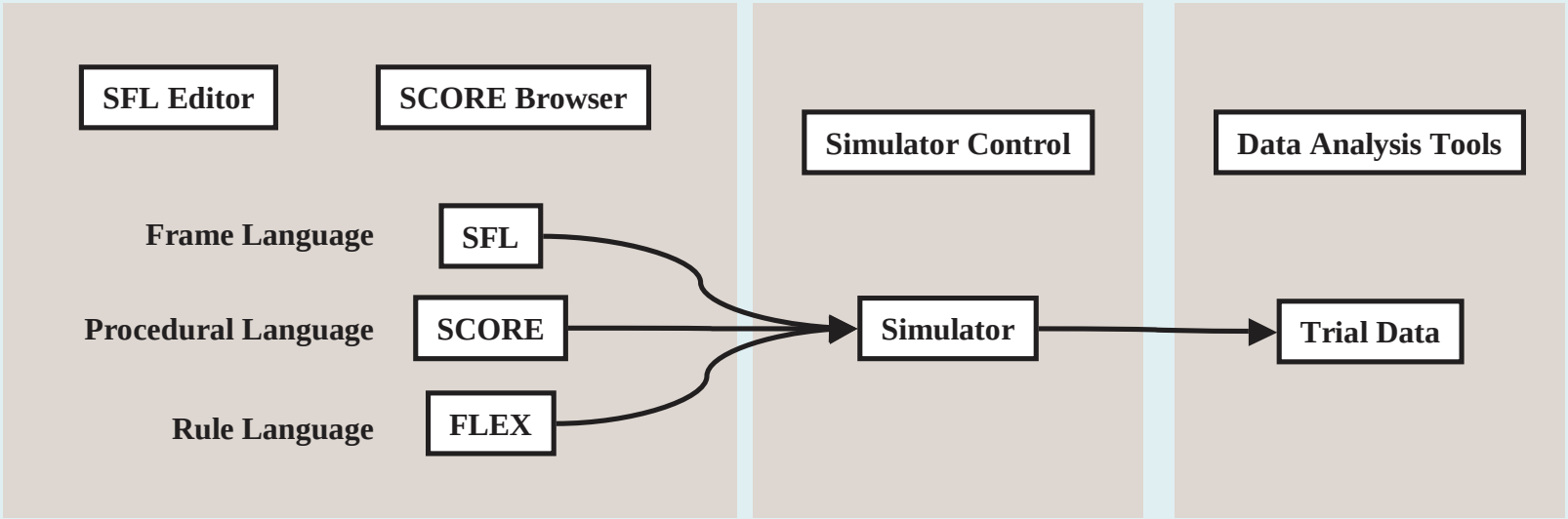
NASA Ames Research Center
Human Error Modeling Workshop
October 18-19, 2001

Outline

- **Introduction to D-OMAR**
- **The Approach&Landing / Taxi Scenario**
- **Human Performance Modeling in D-OMAR**
- **Human error modeling concepts**
- **Human error modeling applied to taxi operations**

D-OMAR Simulation Environment





D-OMAR Applications

- **Distributed real-time and fast-time simulation**
- **Human performance modeling**
- **Agent-based systems**

Scenario Components

- **Aircraft models - approach, landing, and taxi**
- **Aircraft and ATC workplace models**
- **Human Performance Models**
  - **Flight crew (Captain and First-officer) and ATC (approach and ground controller) models**
  - **Flight crew (aviate, navigate, communicate) and ATC procedures**
  - **Communication:**
    - **party-line radio**
    - **in-person**
    - **telephone**

Flight Crew Models

Domain-specific capabilities:

- **Pilot-flying**
  - **aviate--approach, landing, and taxi operations**
  - **execute ATC directives**
  - **monitor ATC radio communication**
  - **maintain dialog with PNF**
- **Pilot-not-flying**
  - **support approach, landing, and taxi operations**
  - **handle ATC radio communication**
  - **cross check pilot-flying on ATC directives**
  - **maintain dialog with PF**

Basic-person proactive and reactive capabilities:

- **Intentions grounded in a mix of habit, expectations, and ongoing events**
- **The ability to cope more or less well with interruption**
- **Supporting cognitive and perceptor / effector capabilities**

Complex multi-tasking behaviors

Contrasting Crew Awareness

Captain

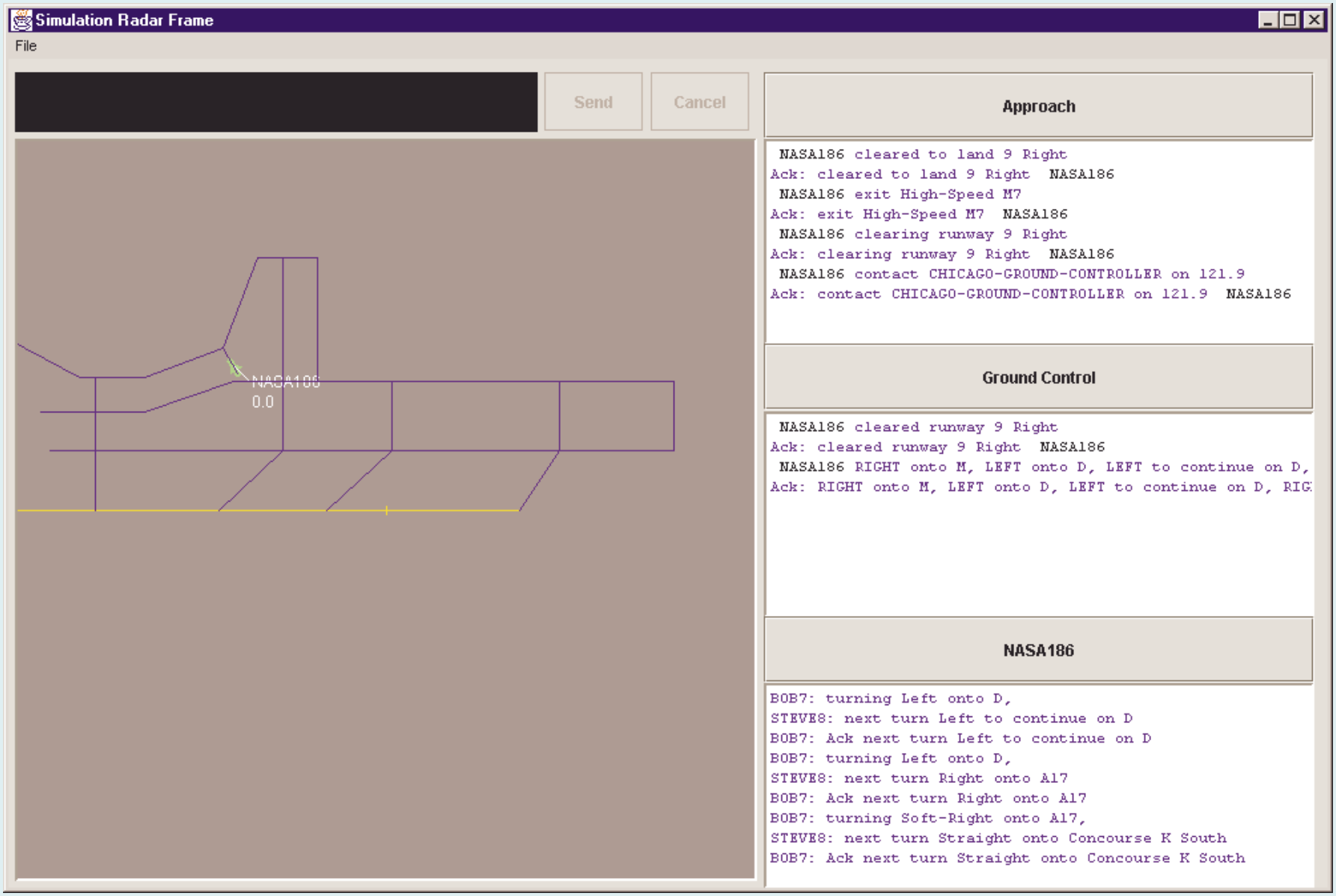
- **active control of aircraft**
- **continuous visual scene input**
- **supplemented by instrument scan of heading and speed**
- **strong local SA**

First-officer

- **passive presence on aircraft (e.g., notice initiation of turns)**
- **visual scene input, but interrupted**
- **map/notepad supported route memory**
- **strong global SA**

Teamwork Skills

- **There are multiple teams:**
  - **flight crews**
  - **ATCs**
  - **flight crews / ATCs**
- **Team members as a source of:**
  - **support to accomplish a task**
  - **interruption to work in progress**
- **Communication plays a major role in team activities**
- **The workplace(s) plays a supporting role for team members**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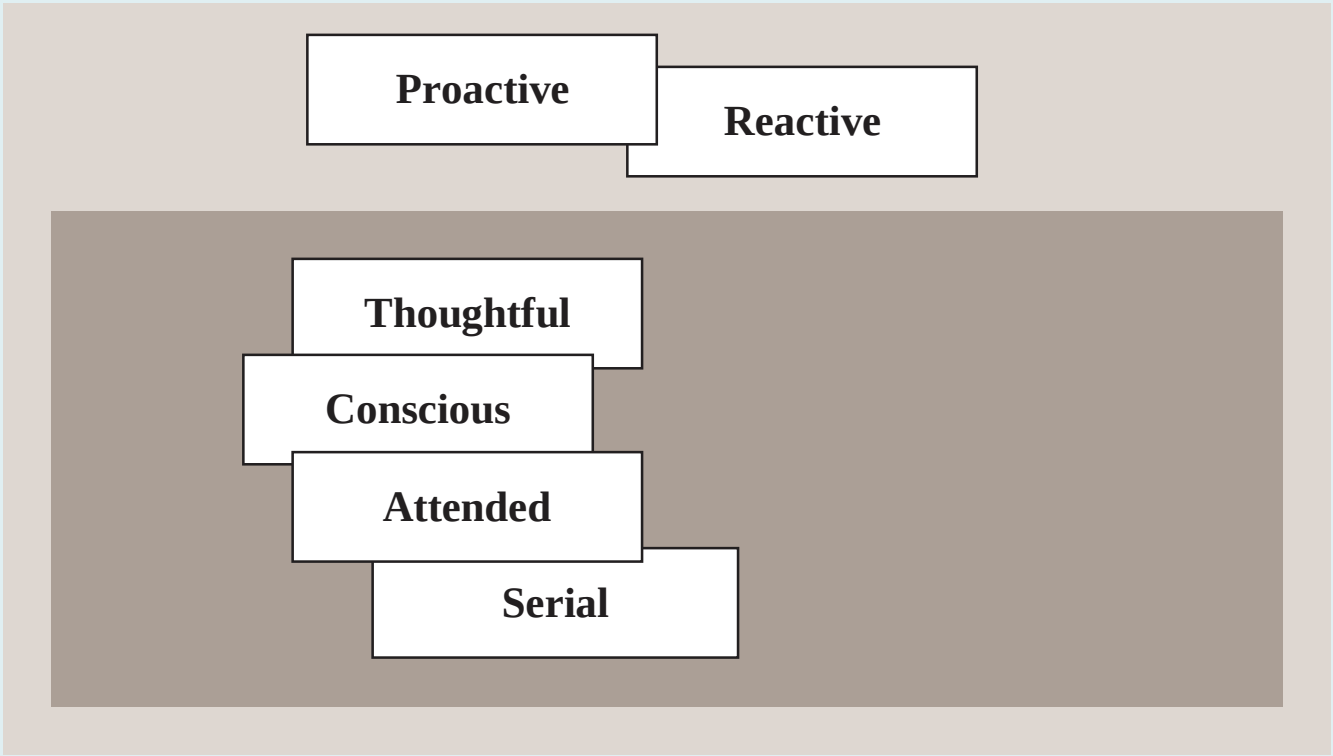
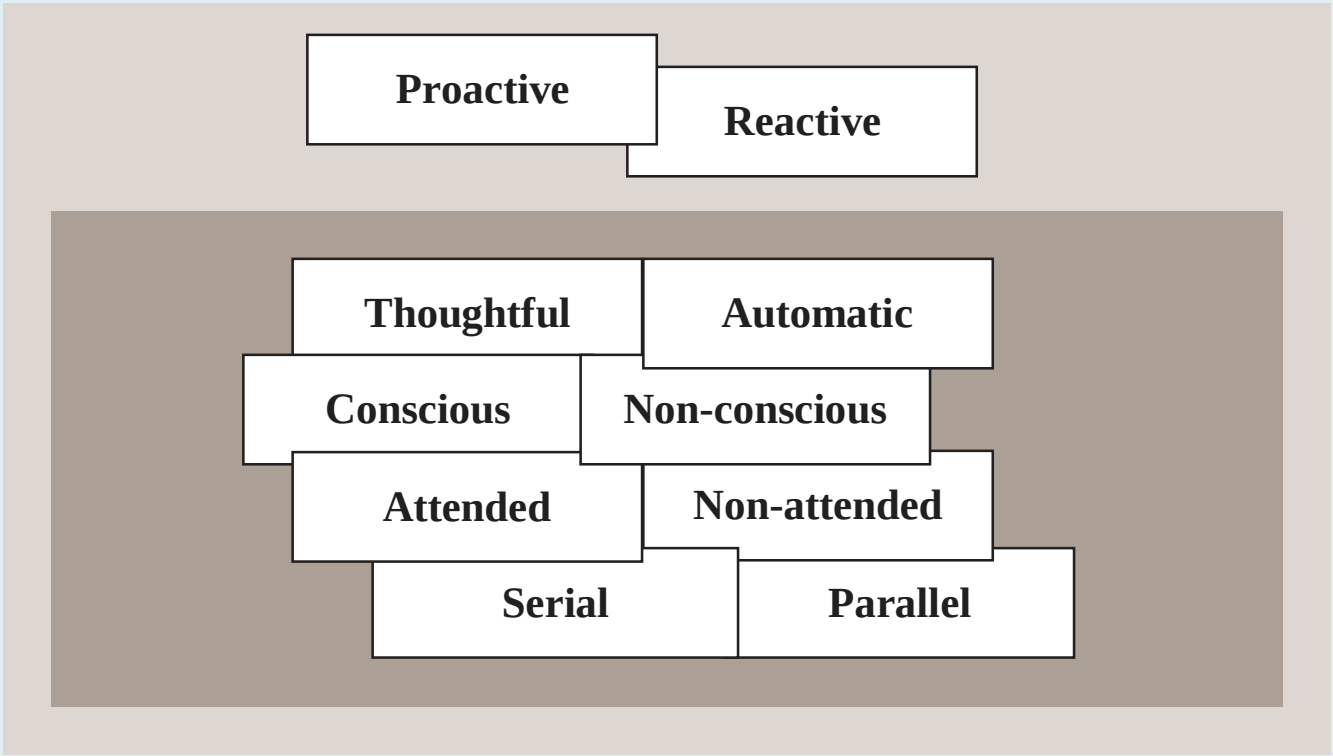
File
Send
Cancel
NASA186
0.0
Approach
NASA186 cleared to land 9 Right
Ack: cleared to land 9 Right NASA186
NASA186 exit High-Speed M7
Ack: exit High-Speed M7 NASA186
NASA186 clearing runway 9 Right
Ack: clearing runway 9 Right NASA186
NASA186 contact CHICAGO-GROUND-CONTROLLER on 121.9
Ack: contact CHICAGO-GROUND-CONTROLLER on 121.9 NASA186
Ground Control
NASA186 cleared runway 9 Right
Ack: cleared runway 9 Right NASA186
NASA186 RIGHT onto M, LEFT onto D, LEFT to continue on D,
Ack: RIGHT onto M, LEFT onto D, LEFT to continue on D, RIG
NASA186
BOB7: turning Left onto D,
STEVE8: next turn Left to continue on D
BOB7: Ack next turn Left to continue on D
BOB7: turning Left onto D,
STEVE8: next turn Right onto A17
BOB7: Ack next turn Right onto A17
BOB7: turning Soft-Right onto A17,
STEVE8: next turn Straight onto Concourse K South
BOB7: Ack next turn Straight onto Concourse K South

Modeling Surface Behaviors



Components of Multiple Task Behaviors



- **Long-term and working memory**
- **Control: central executive versus distributed**

Expertise in Human Performance

- **Problem spaces and rules - Alan Newell**
- **Skills, rules, and knowledge - Jens Rasmussen**

- **Proficiency and expertise - Hubert Dreyfus and Stuart Dreyfus**

- **"... look more broadly for automatic processes. They need not be restricted to procedural knowledge or perceptual motor skills but may permeate the most intellectual activities in the application environment." - Gordon Logan**

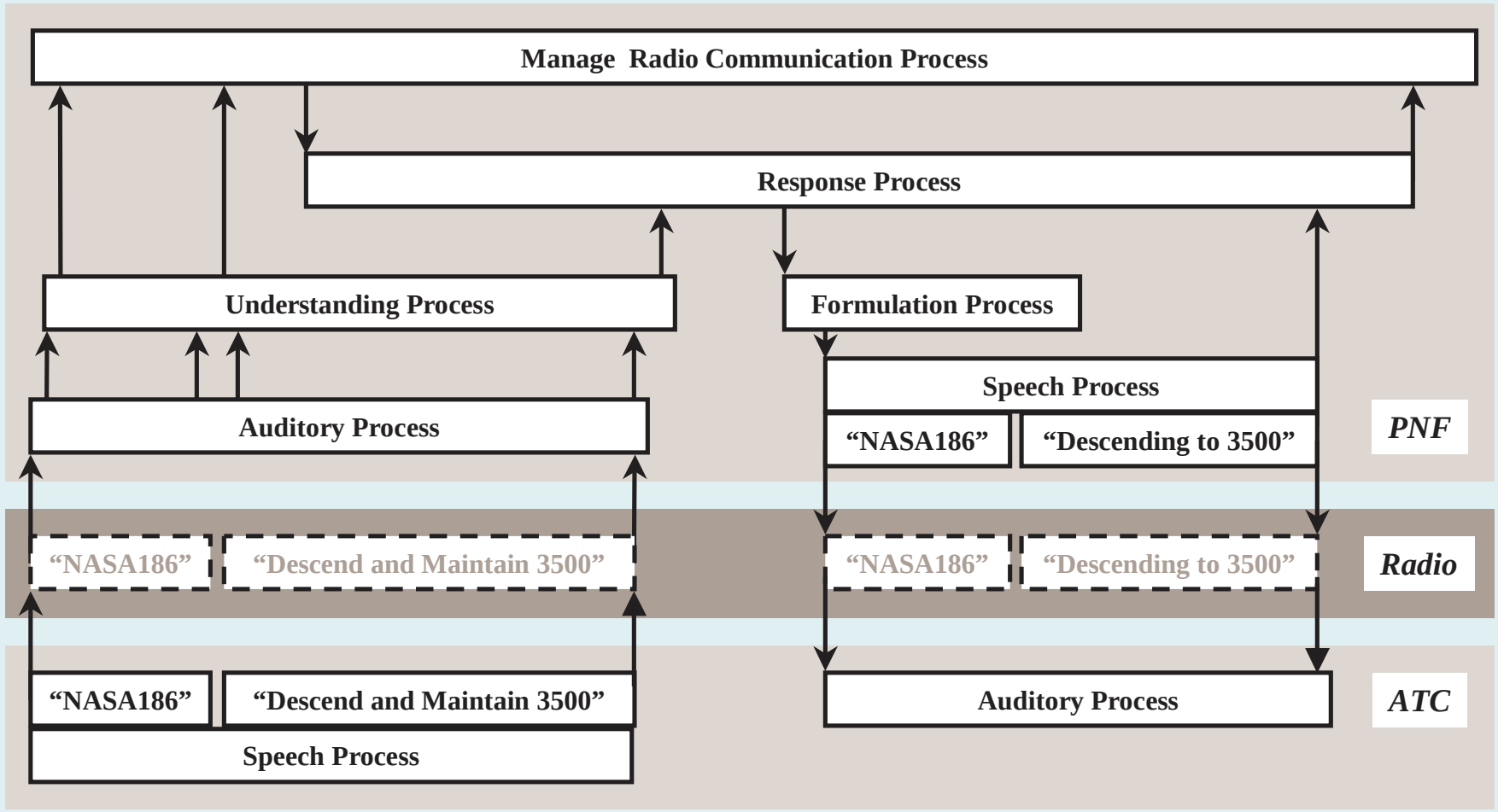
Expertise as skill-based interactions with patterns of events evolving in time

Multi-tasking from a Functional Perspective

- **Tasks operate as a network of functional components that coordinate their activities to accomplish their purposes**
  - **there is concurrent processing at widely distributed centers**
  - **network interconnections coordinate execution at the centers**
  - **processing time frames may vary from center to center**

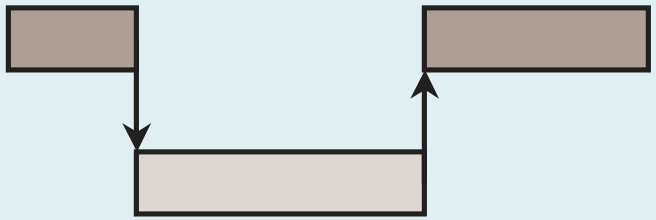
- **Motivation for the functional approach:**
  - **reentrant and degenerate maps - Gerald Edelman**
  - **multiple centers of attention, localization of cognitive operations - Michael Posner**
  - **instance theory of automaticity - Gordon Logan**
  - **intermediate level theory - Ray Jackendoff**
  - **PET, CAT, and recent fMRI studies**

Coordination Among Functional Capabilities
An Example



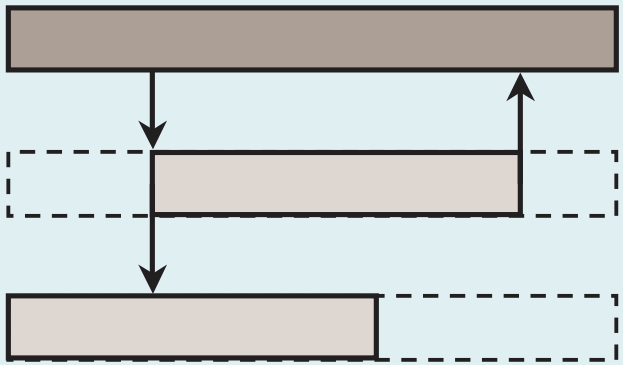
Contrasting
Publish / Subscribe and Message Passing

Message passing



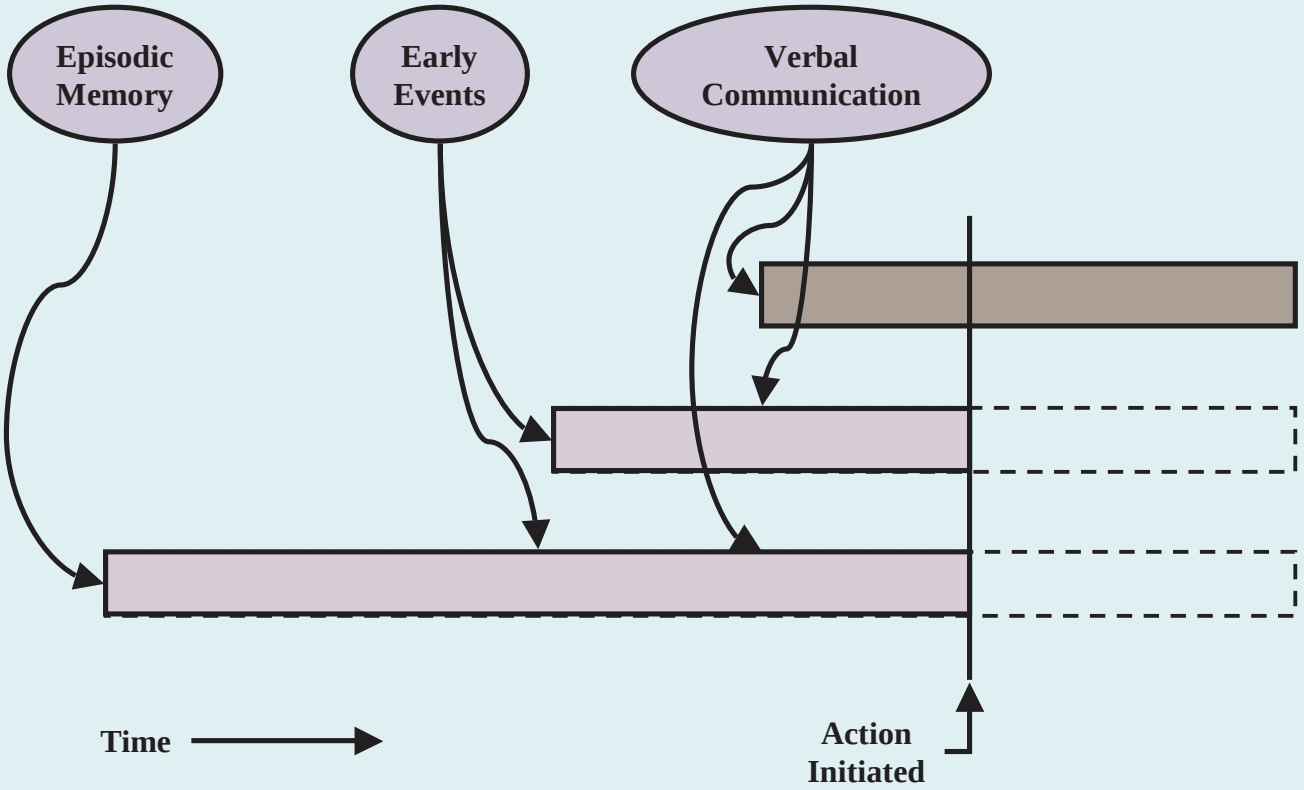
- **single named target routine**
- **processing interrupted and resumed**
- **values are returned**

Publish / subscribe protocol

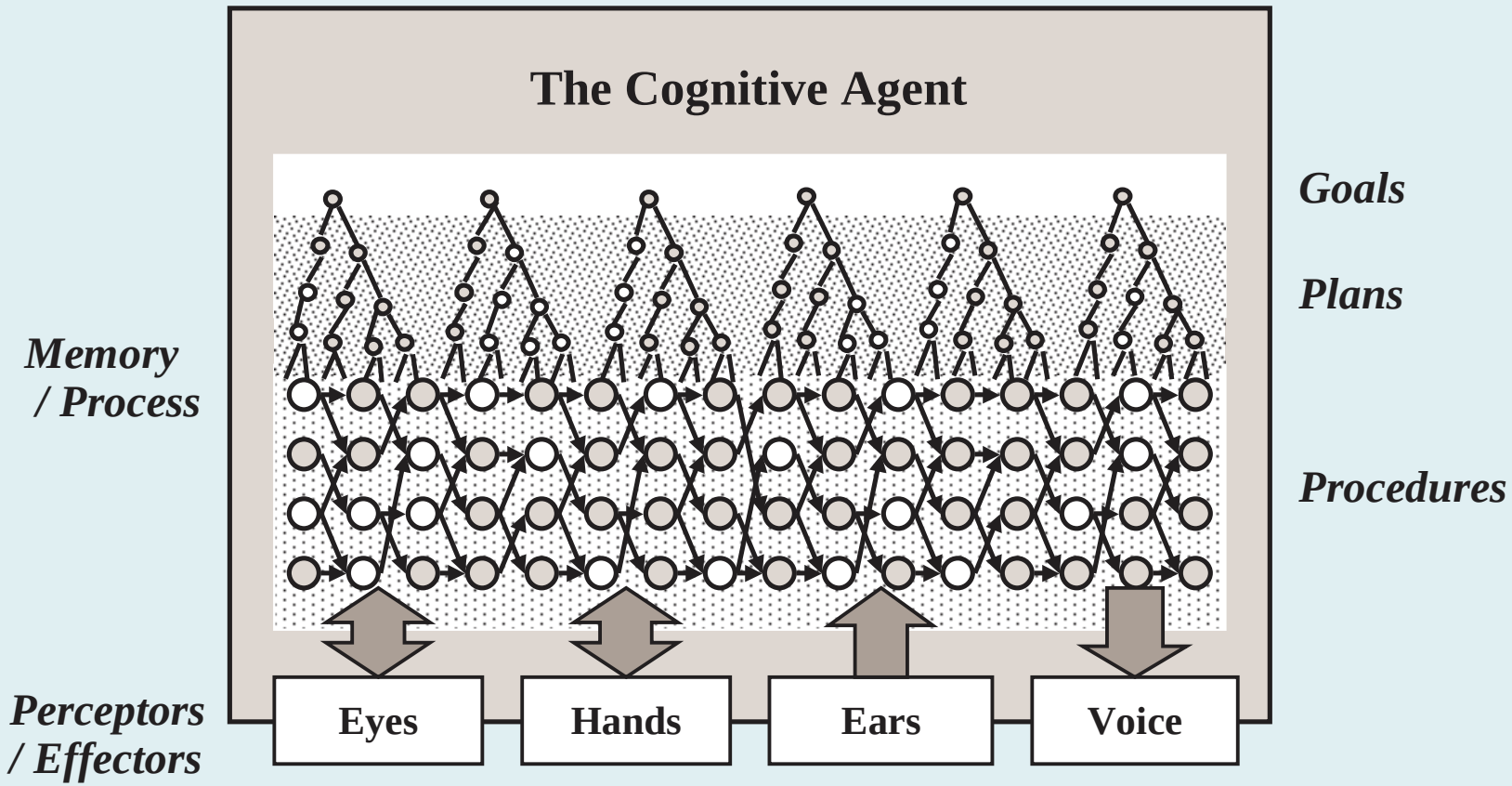


- **zero or more receiving routines**
- **signal may be evaluated prior to acceptance**
- **processing is concurrent**
- **no returned values**

Competing Intentions Mediated by Priority



A Multiple Task Framework



Behaviors as the Product of Goal-directed, Context Sensitive Procedures

- ***Tasks*** **are structured as goals and the plans and procedures that activate the distributed functional capabilities necessary to accomplish the task**
  - ***situation-specific*** **goals and their plans set up proactive procedures associated with the task**
  - **task execution is supported by *basic-person* goals and plans that activate cognitive and perceptor-effector procedures**
- **Task *procedures* form a network whose connectivity adapts in response to evolving situations**
  - **individual procedures represent particular functional capabilities**
  - **procedures operate on distinct individual time frames**
  - **parallelism in procedure execution is the norm**
- **Agent *behaviors* are the product of the activated nodes of the procedure network**

Distributed Situational Pattern Matching

- **A broad range of capabilities may be established to respond to evolving situations proactively channeling the response**
  - **pattern matching on individual signals be can arbitrarily complex**
  - **related signals can be designated as ordered or arbitrary in order, required or optional, and time-out conditions may be specified**

- **The selection of the attended task and that task's response to the situation emerges from the network's classification and prioritization of the elements of the situation as it unfolds**

The same features of human performance that lead to robust, intelligent behavior, can also induce error

- **Behaviors that are appropriate in one context are errors in another**
  - **Expectancies**
  - **Situation awareness**
  - **Intention formation**
  - **Competition among intentions based on situation and expectancy**
  - **Execution**

- **Failures of elemental information processing operations can intrude**
  - **Perception/discrimination**
  - **Memory/forgetting/interference**

Given a context, human errors are not statistically random events

- **Human performance as highly practiced intellectual and physical skills is context dependent**
  - **Each context constrains behavior to a particular "family" of task choices--specific contexts induce specific types of errors**
  - **Each task in each context has a window of opportunity; a time when it becomes relevant and a time when it is too late**
- **Strategic workload management -- priority "churn"**
- **Communication -- misinterpretation**

Sources of overload and stress amplify error tendencies

- **Too many tasks competing for the same time window--aggregate time required exceeds time available**
  - **Error depends on whether the context is forgiving**
    - » **Can tasks be cued?**
    - » **Can tasks be partially completed without penalty**
- **Fatigue**
  - **Mental blinks**
  - **Narrowing of focus**
- **External sources of stress; task criticality; fear of retribution for error; personal non-job-related stress**

Each of these "stresses" increases probability of "resident pathogens" leading to error

Errors are more likely in tightly coupled systems

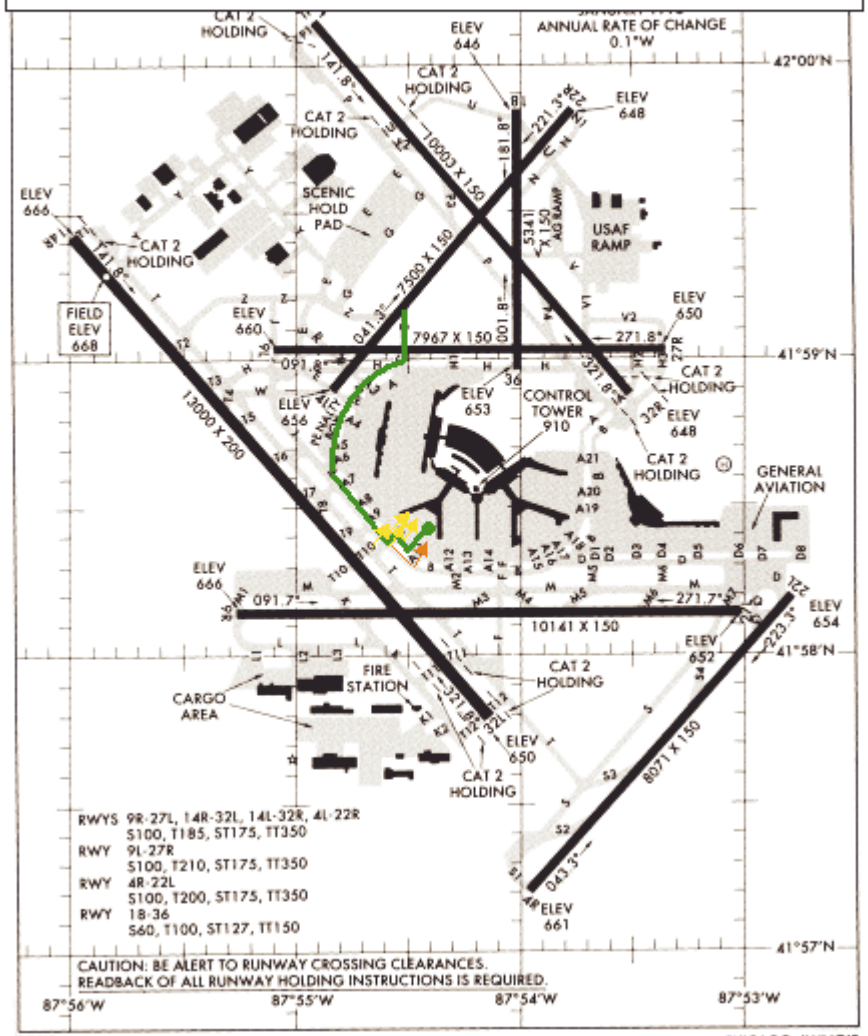
- **Task dependencies are more complex**
- **Time windows are more constrained**
- **Sequences are more constrained**
- **Procedural mistakes combine to cause error**

When viewed from these perspectives, human error can be discovered in thoughtful, detailed models of robust, successful human performance!

Problems Areas Identified in the T-NASA Experiments

- **Turns to the lead-ins in the concourse area:**
  - **NH2, NH3, RC1, RC2, RC3**
- **Pertinent error factors singly and in combination:**
  - **Second turn in rapid turn sequence:**
    - » **N2, N3, NH1, NH2, NH3, RC1, RC2, RC3**
  - **Turns away from the concourse in the taxi sequence:**
    - » **N2, N3, NH2, NH3**
- **Difficult to explain errors:**
  - **missed turn**
    - » **NH2 (concourse), NH3 (time pressure), RC1 (lots of time), RC3 (concourse)**
  - **left-right mix up**
    - » **NC2, N3, NH1, RC2**
  - **turns away from the concourse that are errors**
    - » **NH1, RC2**

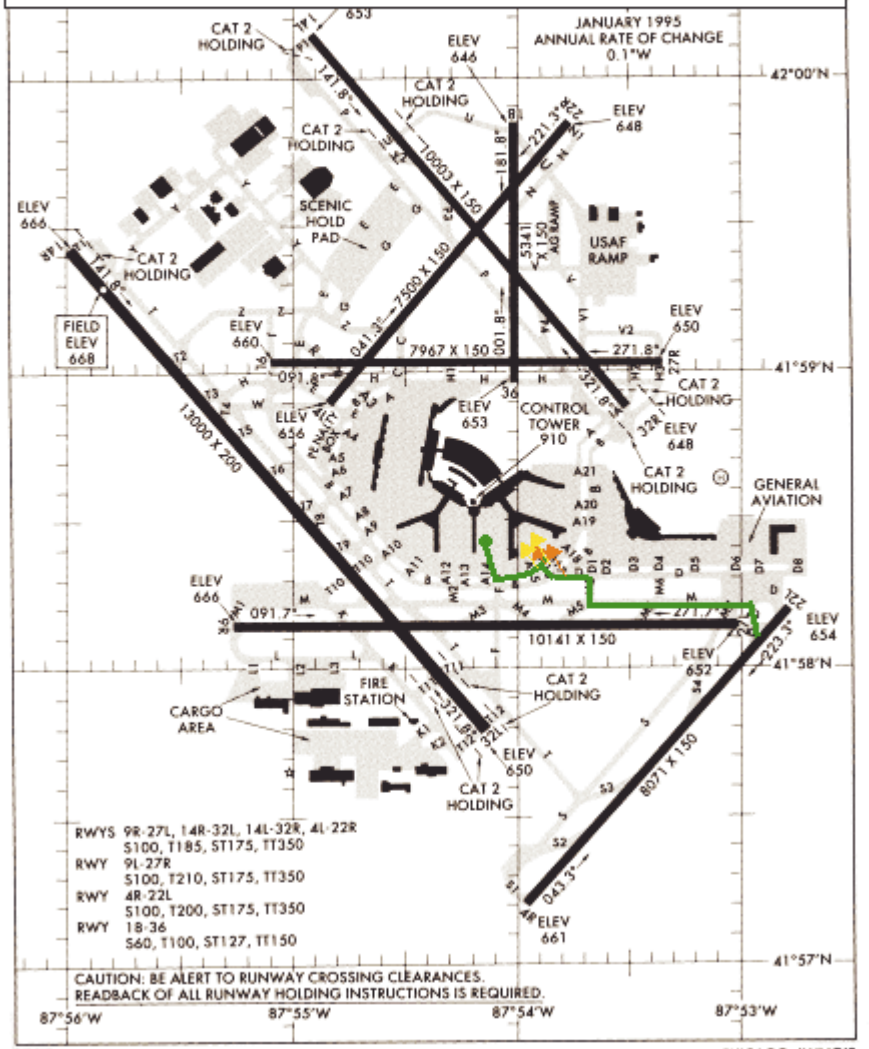
ROUTE RC1:
- Crew 13 / Trial 12 / Failed to turn left at A10 -- controller had them turn at A11
- Crew 1 / Trial 3 / Followed wrong lead line into Cncs E -- recovered
- Crew 10 / Trial 3 / Followed wrong lead line into Cncs E -- recovered
- Crew 7 / Trial 7 / Followed wrong lead line into Cncs E -- recovered
- Crew 4 / Trial 12 / Followed wrong lead line into Cncs E -- recovered



AIRPORT DIAGRAM
98169

CHICAGO, ILLINOIS
CHICAGO-O'HARE INTL (ORD)

ROUTE RC3:
- Crew 6 / Trial #13 / Continued straight off of A16 instead of transitioning to A
- Crew 12 / Trial #4 / Turned right onto A17 instead of A16
- Crew 9 / Trial #8 / Continued straight off of A16 instead of transitioning to A -- recovered
- Crew 3 / Trial #4 / Continued straight off of A16 instead of transitioning to A -- recovered



AIRPORT DIAGRAM
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CHICAGO, ILLINOIS
CHICAGO-O'HARE INTL (ORD)

Turns in the Concourse Area

- **Turns to the lead-ins in the concourse area produced errors in trials:**
  - **NH2, NH3, RC1, RC2, RC3**

- **Observations:**
  - **signage to lead-ins is limited**
  - **poor visibility conditions and nighttime exacerbate the problem**
  - **approach to a lead-in along taxiway A lead to more frequent errors than approaches along taxiway B and A*n***
  - **there appears to be an expectation that the lead-in is close to the arrival point at taxiway A**

- **Motivates the suggestion that outbound traffic be routed along A and inbound traffic be routed along B and A*n***

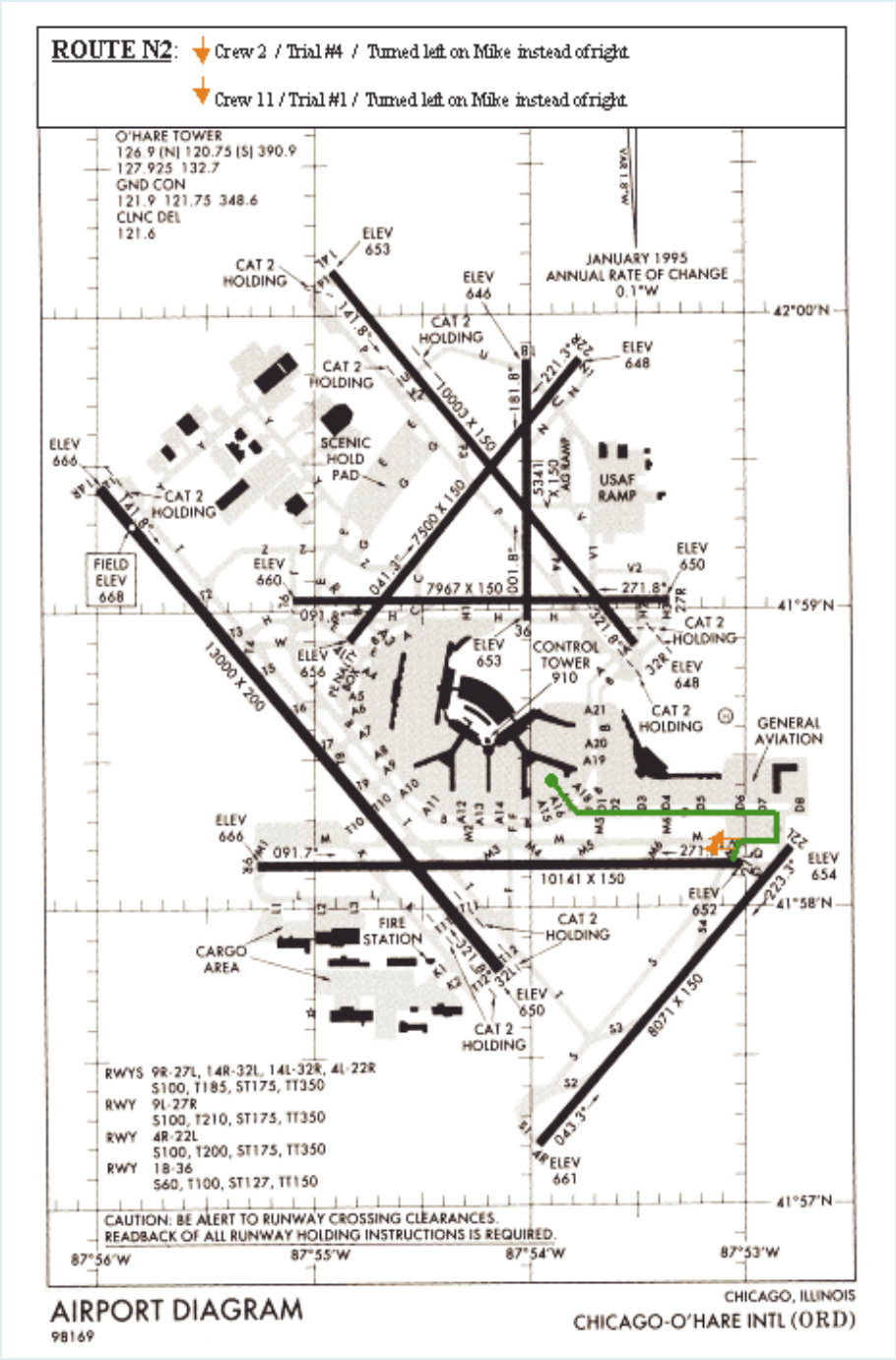
Combinations of Error Factors

Second turn in rapid turn sequence

- **N2, N3, NH1, NH2, NH3, RC1, RC2, RC3**

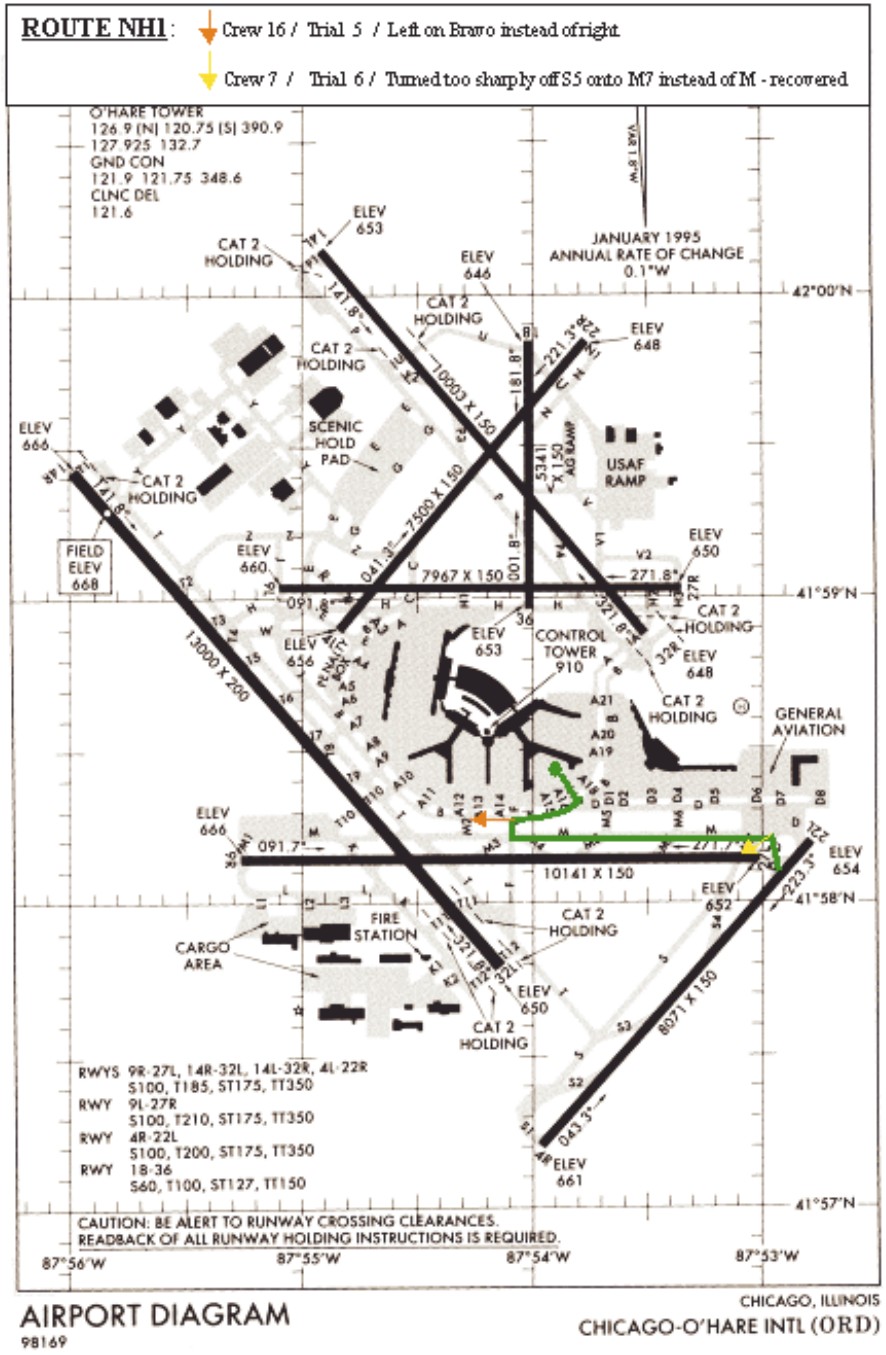
Turns away from concourse in the taxi sequence

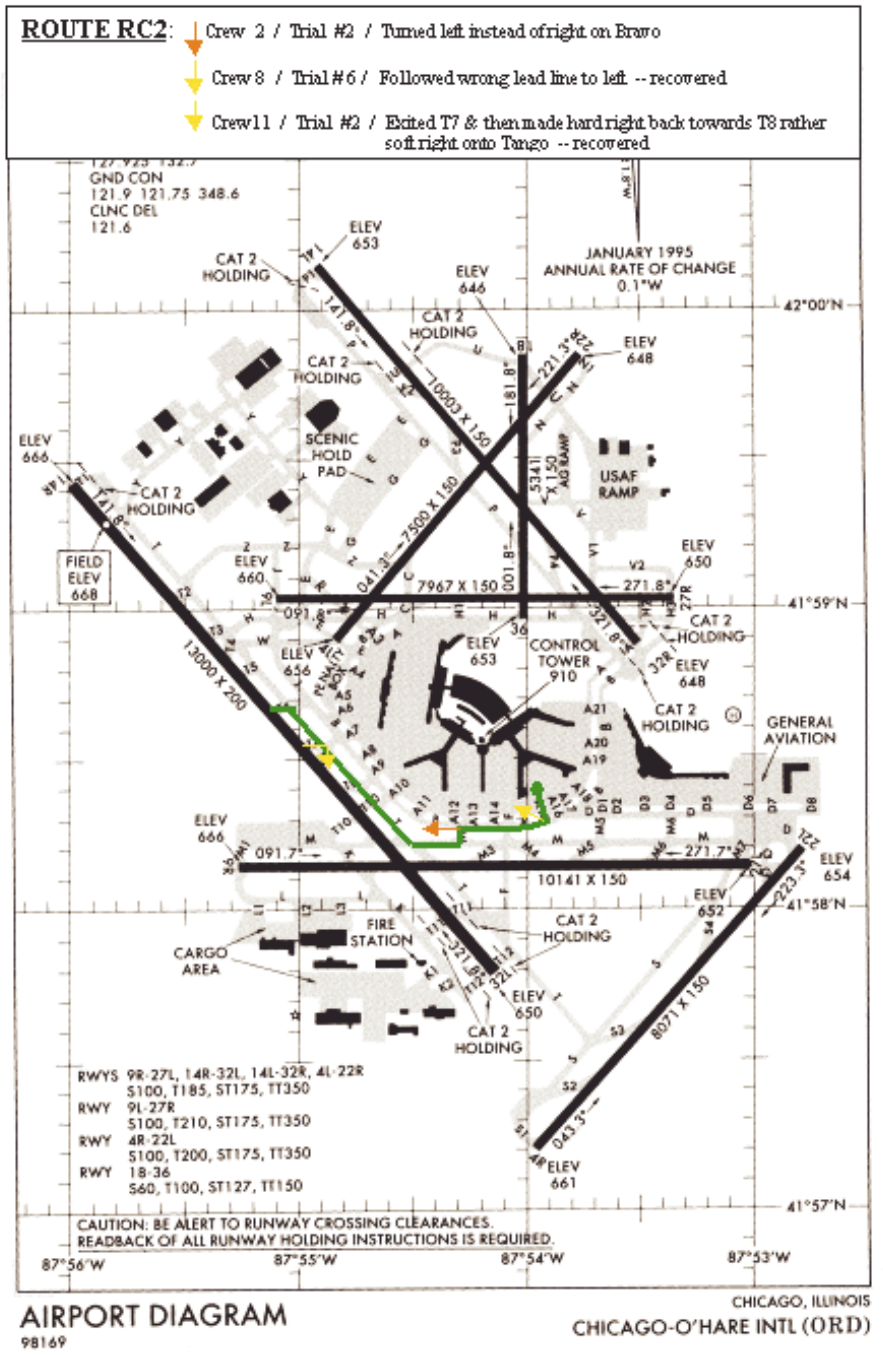
- **N2, N3, NH1, NH2, NH3**


ROUTE N2:
Crew 2 / Trial #4 / Turned left on Mike instead of right
Crew 11 / Trial #1 / Turned left on Mike instead of right
O'HARE TOWER
126.9 (N) 120.75 (S) 390.9
127.925 132.7
GND CON
121.9 121.75 348.6
CLNC DEL
121.6
JANUARY 1995
ANNUAL RATE OF CHANGE
0.1°W
CAT 2 HOLDING
ELEV 653
ELEV 646
ELEV 648
ELEV 666
ELEV 660
ELEV 650
ELEV 656
ELEV 654
ELEV 652
ELEV 661
SCENIC HOLD PAD
USAF RAMP
FIELD ELEV 668
CONTROL TOWER 910
GENERAL AVIATION
FIRE STATION
CARGO AREA
10003 X 150
7500 X 150
7967 X 150
13000 X 200
10141 X 150
8071 X 150
5341 X 150
AG RAMP
42°00'N
41°59'N
41°58'N
41°57'N
87°56'W
87°55'W
87°54'W
87°53'W
RWYS 9R-27L, 14R-32L, 14L-32R, 4L-22R
S100, T185, ST175, TT350
RWY 9L-27R
S100, T210, ST175, TT350
RWY 4R-22L
S100, T200, ST175, TT350
RWY 18-36
S60, T100, ST127, TT150
CAUTION: BE ALERT TO RUNWAY CROSSING CLEARANCES.
READBACK OF ALL RUNWAY HOLDING INSTRUCTIONS IS REQUIRED.
AIRPORT DIAGRAM
98169
CHICAGO, ILLINOIS
CHICAGO-O'HARE INTL (ORD)

Example 1: Route N2 Error #8

- **Immediate turn after high-speed runway exit**
  - **Time window to prepare for it very short**
- **Terminal control communication**
  - **Lengthy and complex**
- **First-officer delayed in communicating with Captain**
  - **Writing instructions competed with communicating**
- **Captain turns left instead of right**
  - **Expectancy based on knowledge of gate location leads to left turn instead of right turn**





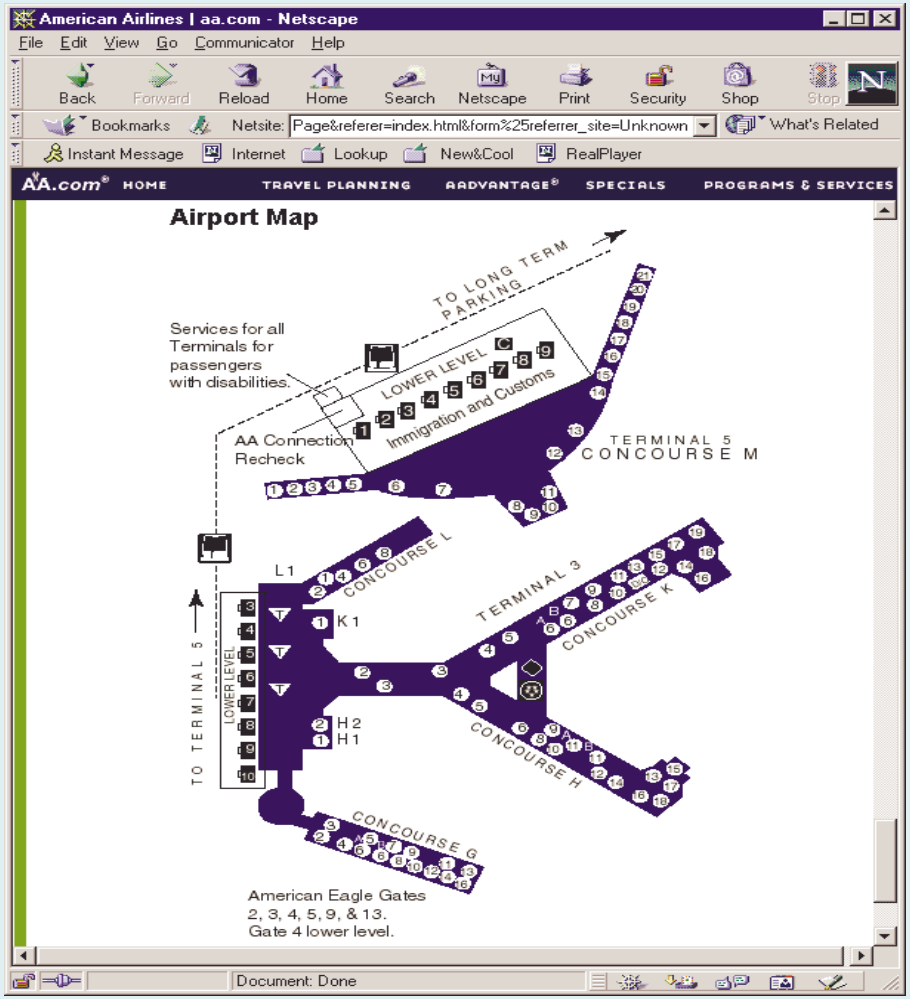
Steve Deutsch & Dick Pew, NASA HEM Workshop, October 18-19, 2001

Turns Away From the Concourse That Are Errors

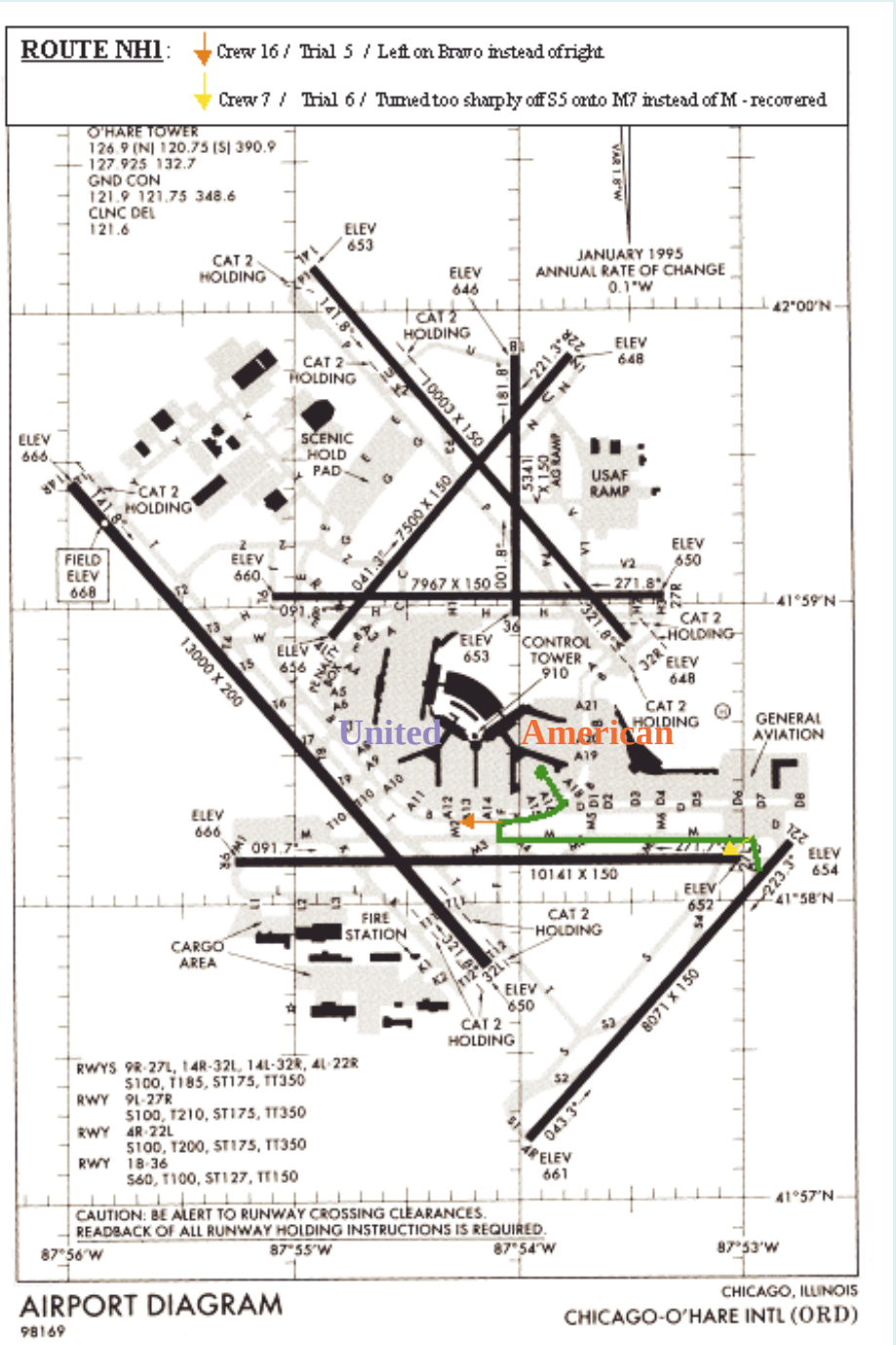
Examples:

- **Route NH1 Error #11 -- left on Bravo rather than right**
  - **turned away from concourse rather than toward it**
- **Route RC2 Error # 2 -- left on Bravo rather than right**
  - **turned away from concourse rather than toward it**

- **Two turns in immediate succession**
  - **Abbreviated time window in which to decide next move**
- **First-officer head down at time of second turn**
  - **Delayed instruction to Captain**


American Airlines | aa.com - Netscape
File Edit View Go Communicator Help
Back Forward Reload Home Search Netscape Print Security Shop Stop
Bookmarks Netsite: Page&referer=index.html&form%25referrer_site=Unknown What's Related
Instant Message Internet Lookup New&Cool RealPlayer
AA.com® HOME TRAVEL PLANNING AADVANTAGE® SPECIALS PROGRAMS & SERVICES
Airport Map
TO LONG TERM PARKING
Services for all Terminals for passengers with disabilities.
LOWER LEVEL
Immigration and Customs
AA Connection Recheck
TERMINAL 5
CONCOURSE M
L1
CONCOURSE L
TERMINAL 3
CONCOURSE K
K1
TO TERMINAL 5
LOWER LEVEL
H2
H1
CONCOURSE H
CONCOURSE G
American Eagle Gates
2, 3, 4, 5, 9, & 13.
Gate 4 lower level.
Document: Done


UNITED
Planning travel
Travel support
Mileage Plus
About United
Chicago O'Hare International Airport
CONCOURSE F
CONCOURSE E
CONCOURSE C
CONCOURSE G
CONCOURSE B
CONCOURSE H
CONCOURSE K
CONCOURSE L
Parking Garage
LOT A



Pilot turns left instead of right *and* away from the concourse

- **Strong habit pattern based in episodic memory might well lead a United pilot to turn towards the United concourses**

Status of the Model

- **Representative mistake-sources are being developed**
- **Sample errors are being generated**
- **Preparations are being made for stochastic exploration**
  - **execution times**
  - **contending intentions (priorities, values, timing)**
- **Preparations are being made for a guided heuristic exploration of the mistake-space seeking paths to errors**
  - **straightforward stochastic exploration in an enormous search space, even with exceptionally fast models, may yield little of interest**
  - **we are looking at selectively forcing combinations of off-nominal values that produce mistakes with the expectation that they will identify error sources**