What's it doing now?
Understanding automation confusion

Randy Mumaw

Boeing Commercial Aviation
Aviation Safety
Human Factors

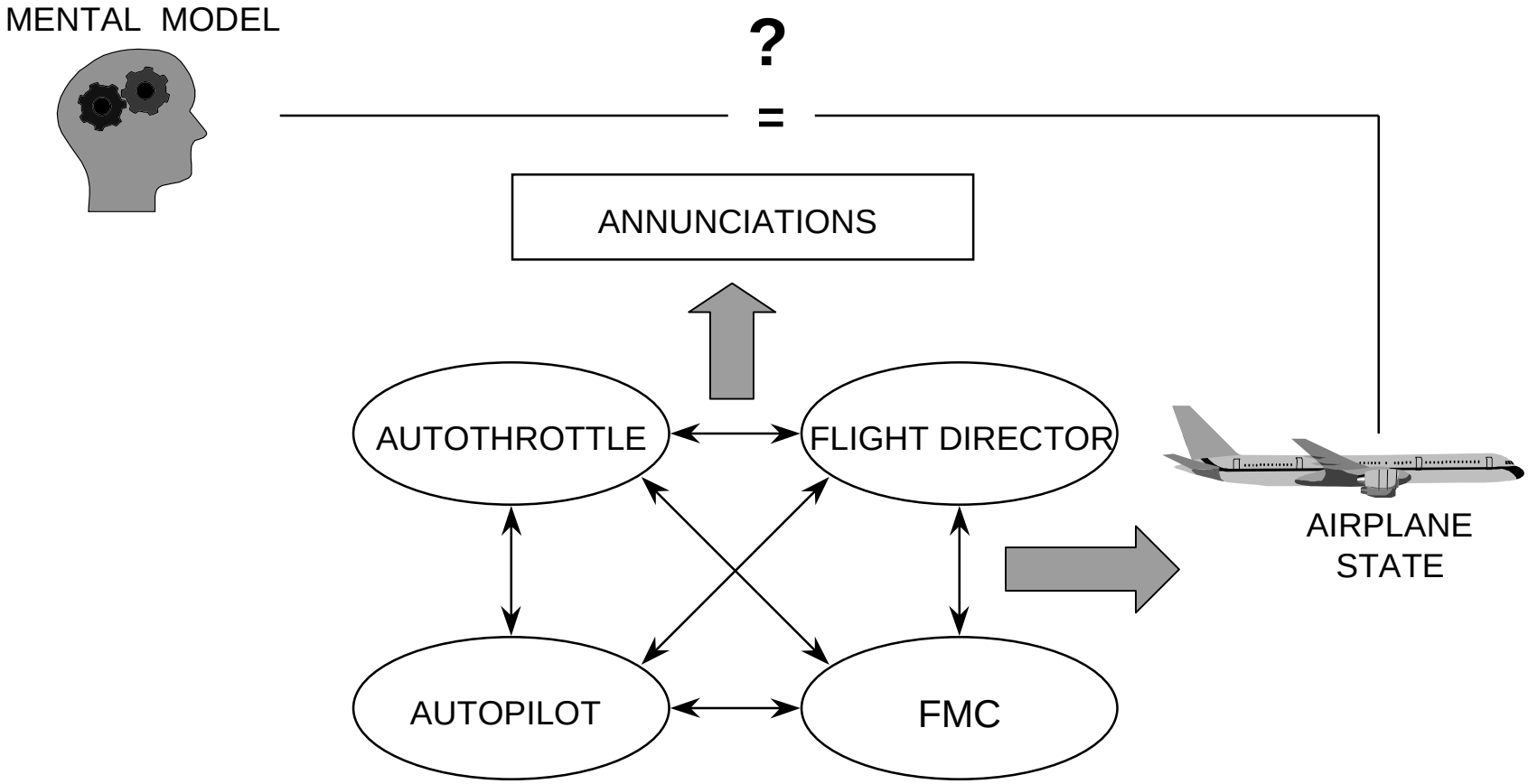
Symposium on
Situation Awareness in the Glass Cockpit

Royal Aeronautical Society
London
February 23, 2000

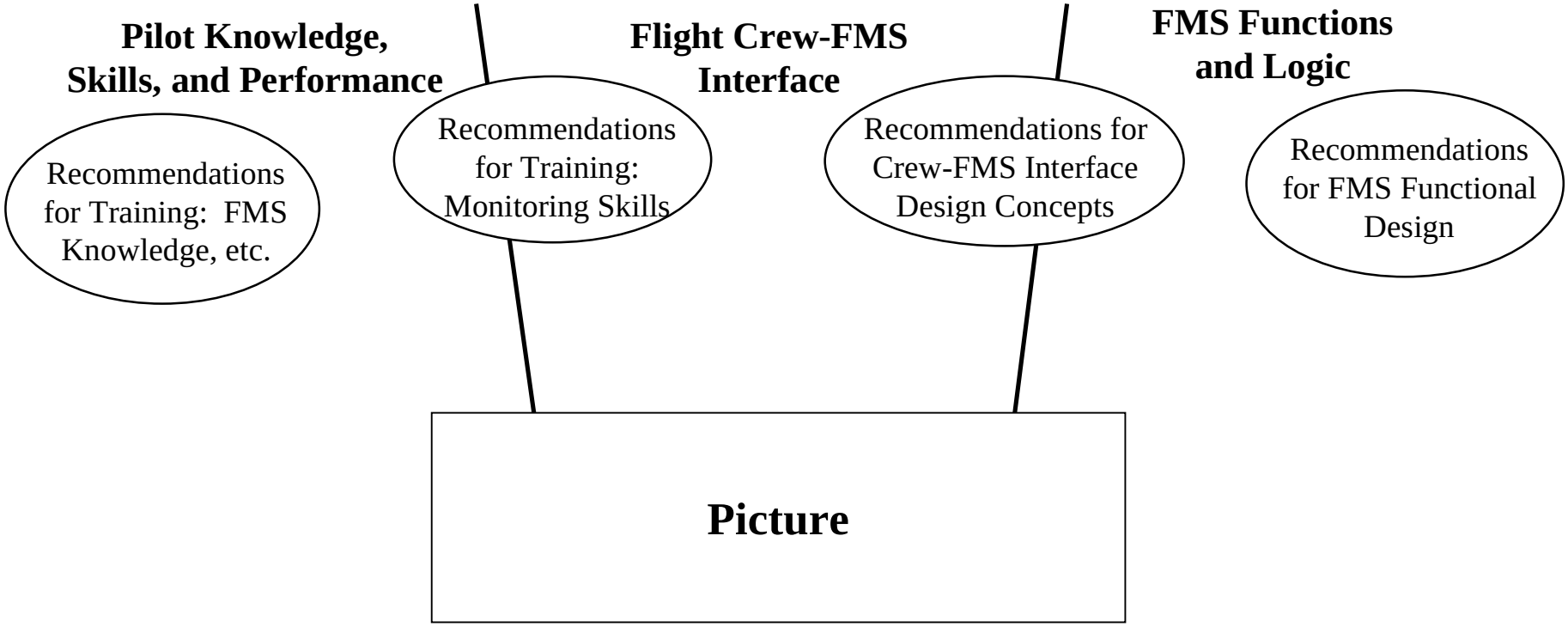
Overview

- **Boeing's Mode Awareness Program**
- **Training an automation "mental model"**
- **Understanding pilot monitoring**

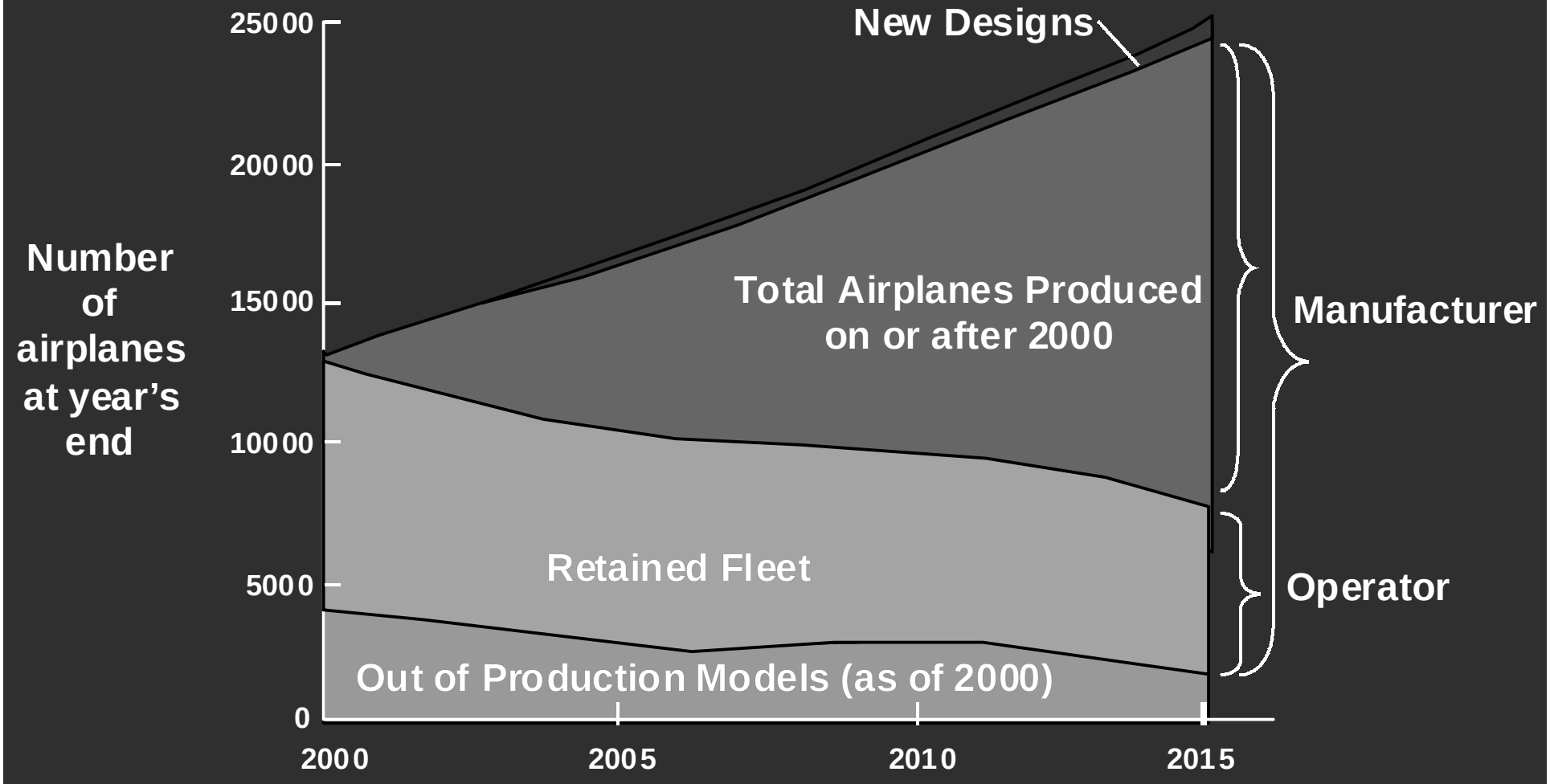
Mode/Automation Awareness



Recommendation Areas



To Affect Safety, Design Enhancements Must Be on Current Production Airplanes



Evidence that Concern Exists in Industry

- **FAA Human Factors Team Report (1996)**
- **Pilot Surveys, Instructor Interviews**
- **Simulator Studies**
- **Jumpseat Observations**
- **Incident/Accident Reports**

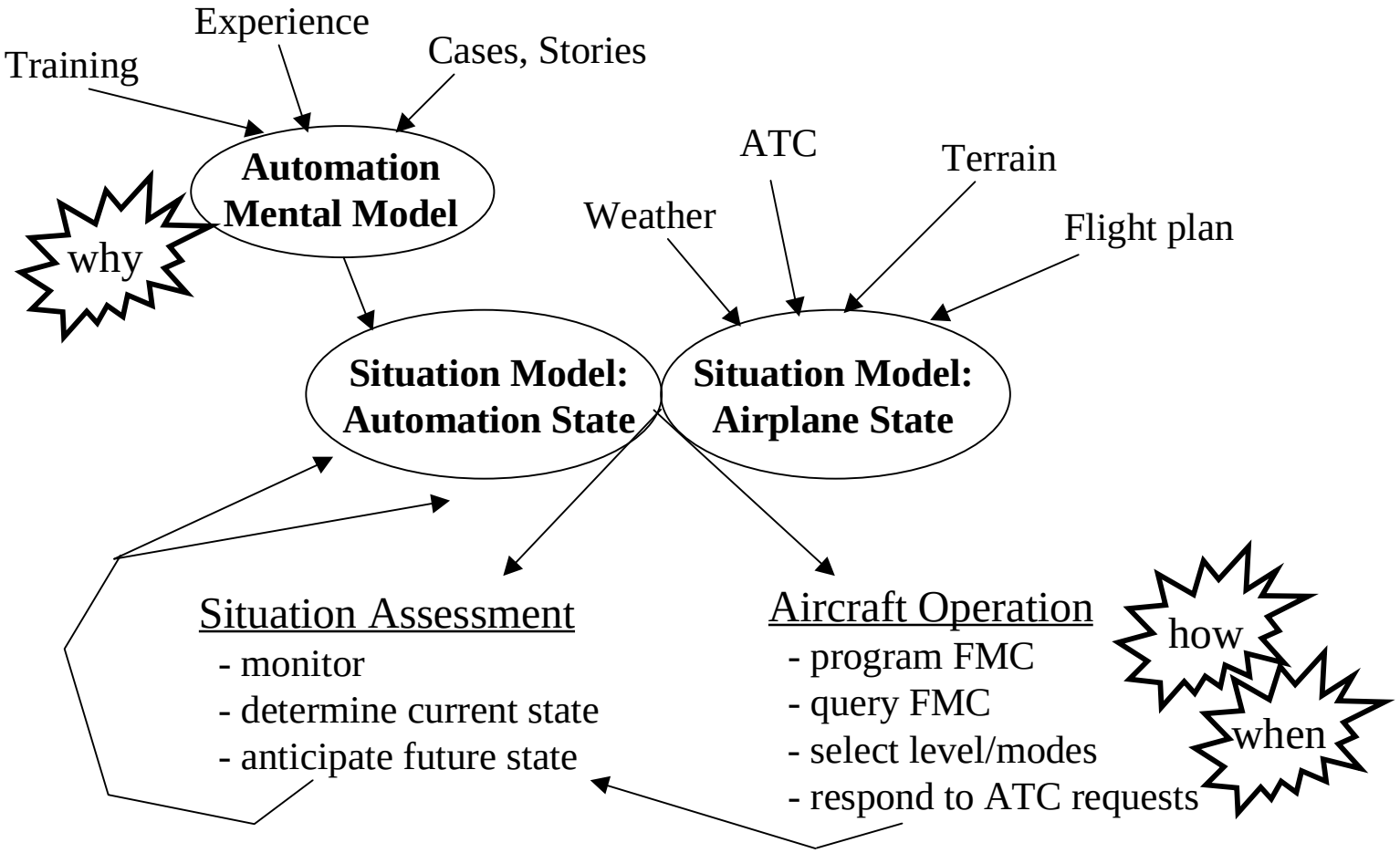
While pilots are generally familiar with and skilled in using basic automation features . . .
Some pilots lose their awareness of what control actions have been given to the automation; and sometimes pilots configure the automation incorrectly.

Established Knowledge/Skill Gaps

- **Poor understanding of "how," especially vertical path.**
- **Poor understanding of assessing automation state.**
- **A lack of operational strategy: What mode or level of automation should I use now?**
- **Poor understanding of energy management.**
- **Weak understanding of where the "traps" lie.**

Pilots seem to develop a limited repertoire of automation procedures, but they have no underlying framework (mental model) that allows them to reason about system behavior.

Pilot Automation Skills and Knowledge



Common Barriers to Gaining Expertise

- **Transition training covers only automation basics; pilots are expected to learn on the job.**
- **Task orientation excludes system knowledge.**
- **Training does not address “why” or “when.”**
- **It’s difficult to learn on the line:**
  - **insufficient feedback on system state; underlying system structure is unknown; hard to infer**
  - **no mentor/teacher available**
  - **system behavior can seem inconsistent due to complexity**

What's Needed?

Pilots need a more conceptual framework to support
- reasoning about system behavior
- learning advanced skills through system use

Pilots need a "simple but complete" mental model.

Boeing is working to support airlines in achieving this objective

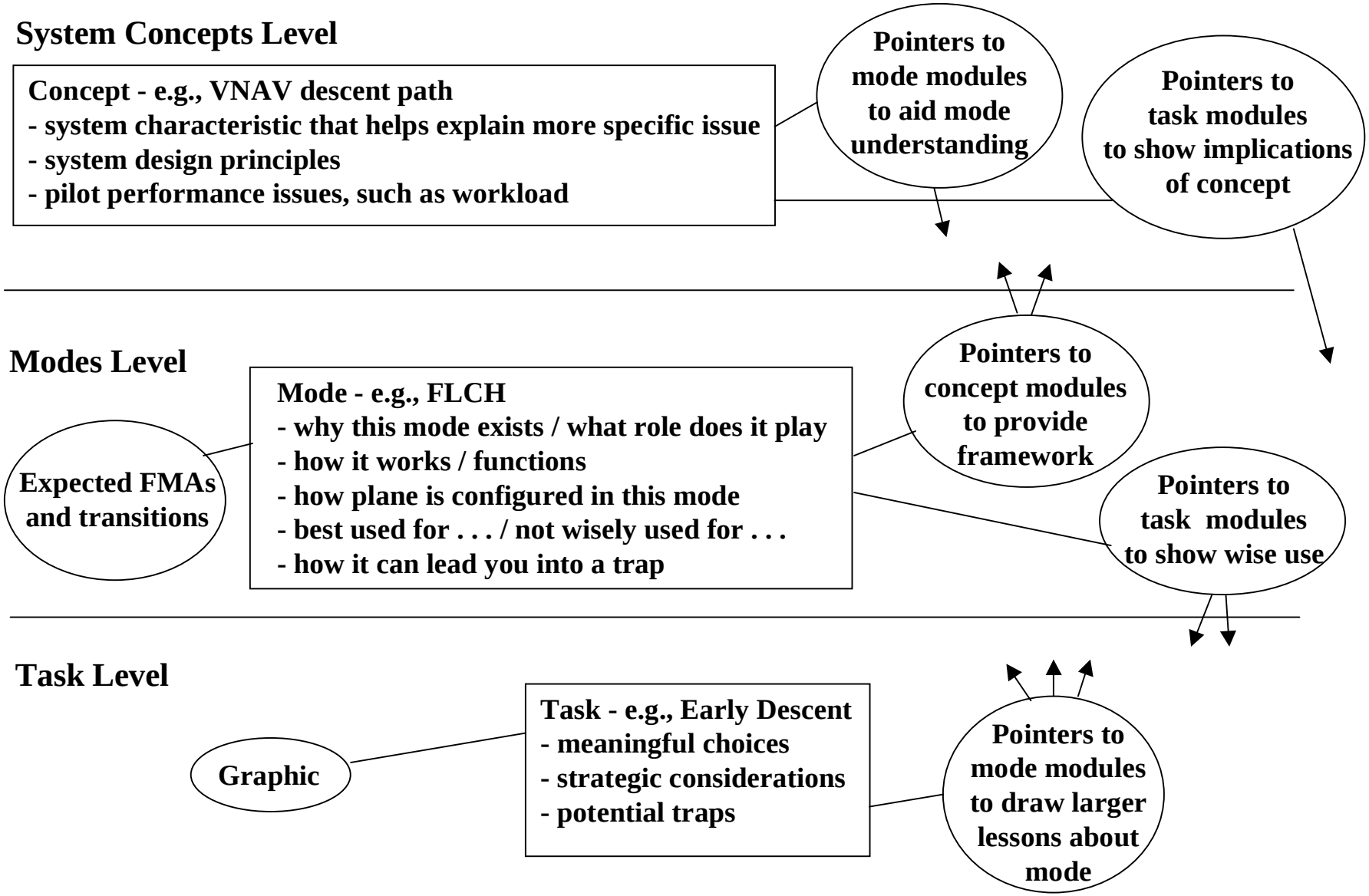
Boeing's Mental Model Objectives

Develop appropriate materials to support better training:

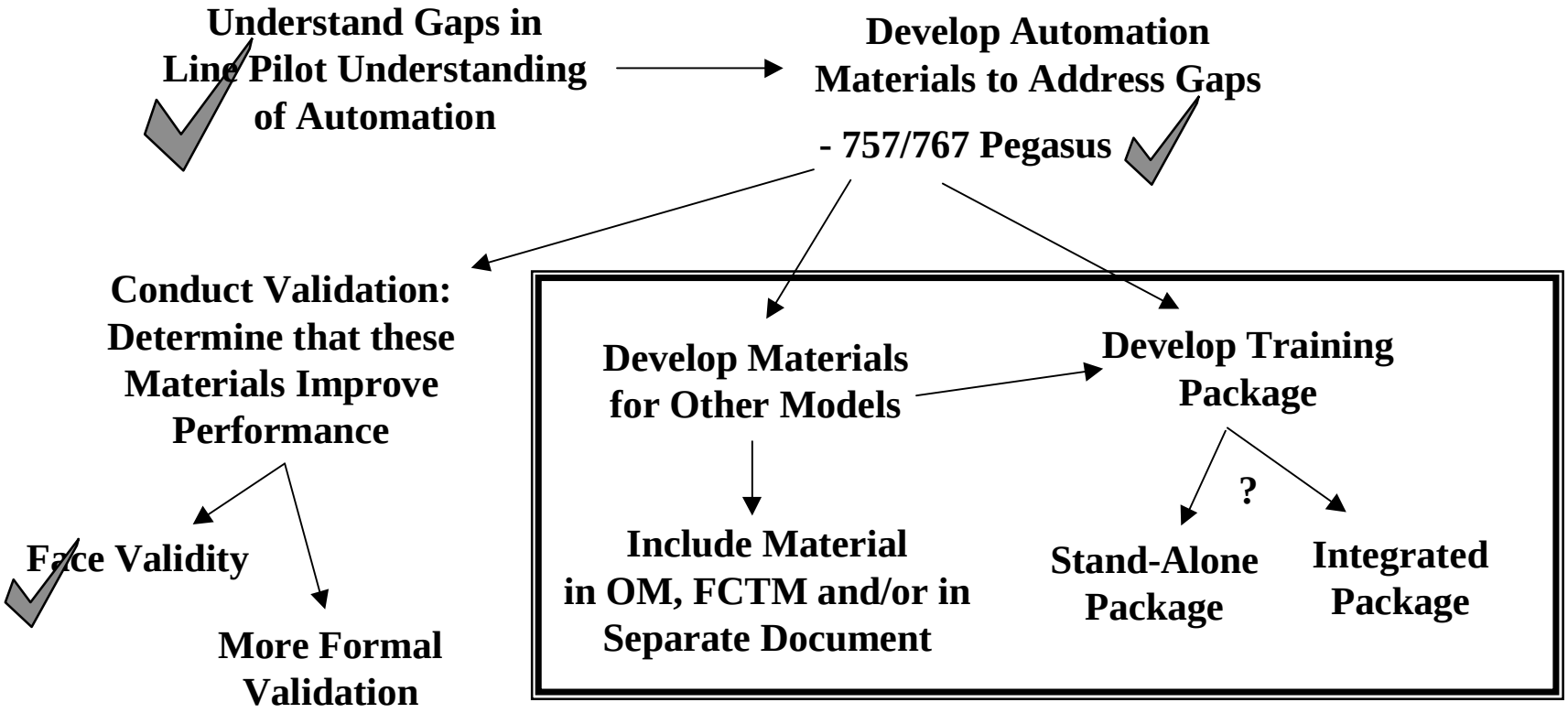
- **Focus on vertical path management.**
- **Focus on a single aircraft (757/767) and FMS version (Pegasus).**
- **Explain "why"**
- **Explain "when"**
- **Begin with guidance in an operational context then link to more abstract knowledge.**

We are NOT creating training.

Conceptual Framework Document



Research Activities and Follow-on Activities



Recommended Training Technique

Context	Need to Understand	Decision-Making	Execution	Integration
↓	↓	↓	↓	↓
Operational Situation	Opportunity for Tutorial	Application to Operational Situation	Guidance on Execution	Feedback/ Review/ Discussion

Example

Desk-Top Simulation: Automation Interface and Vertical Profile and Operational Task	Information on Task, Modes, System, and Strategic Use	Select Appropriate Automation Tools	Set up Automation with Guidance	Discuss; Review Larger Lessons

Summary:
Mental Model Training

- **Transition to glass training is focusing primarily on "how" and needs more of "why" and "when."**
- **Pilots need a "simple but complete" mental model of the automation to support**
  - **reasoning about system behavior**
  - **learning advanced skills through system use**
- **Our objective is to capture and document important information about Boeing automation.**
- **We are NOT developing training, but inputs to training.**
- **We have some strong ideas on the types of training that are likely to be most effective.**
- **We are working with U.S. airlines to develop and evaluate training solutions.**

Automation Monitoring

- **Concerns**
  - **separation of MCP and FMA can lead to inadequate monitoring of automation state.**
  - **some mode transitions occur without pilot input.**
  - **no clear guidance is given for monitoring glass cockpits.**

We know that pilots can lose awareness of automation state, leading to automation surprise.

Automation Monitoring

- **Questions**
  - **where do pilots monitor when using automation?**
    - **which indications do they rely on most?**
    - **which indications should get more attention?**
  - **how does monitoring break down**
    - **poor scanning strategies? OR**
    - **inadequate knowledge/expectations of system behavior?**

Study Overview

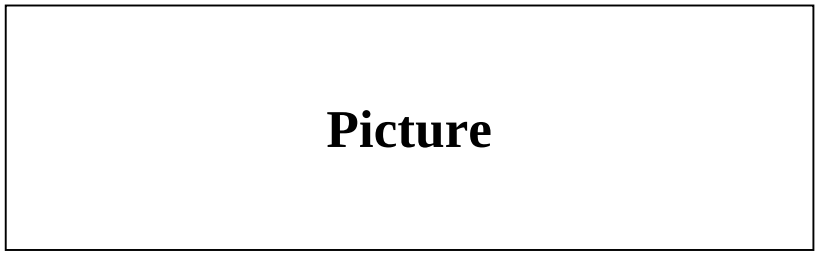
- **Study Team**
  - **NASA-Ames**
  - **University of Illinois (Wickens, Sarter)**
  - **Boeing**

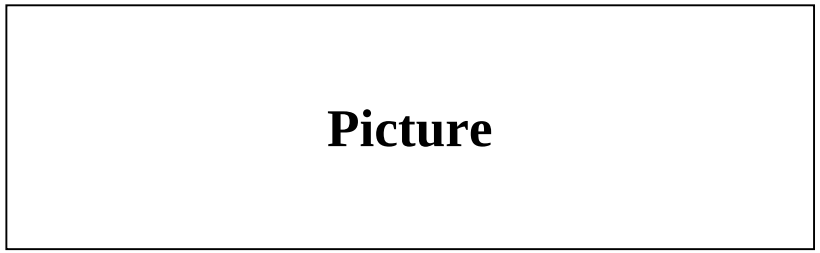
- **Study Setting**
  - **747-400 fixed-base simulator**
  - **1-hour flight: San Francisco to LA**
  - **several “events” tied to monitoring**
  - **both Captains and FOs**
  - **PNF takes an “experimenter” role**
  - **ATC input from another location**
  - **actual airline checklists, SOPs, dispatch**

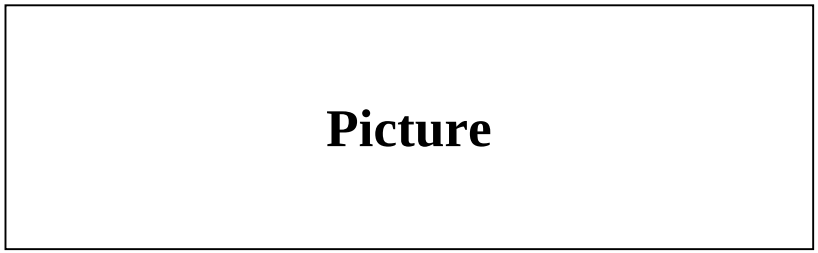
Study Overview

- **Subjects**
  - **20 747-400 line pilots (10 Capt / 10 FO)**
  - **representing 2 U.S. airlines**
  - **exclusively flying 747-400**

- **Data Collected**
  - **pilot demographics**
  - **scenario performance**
  - **eye fixations**
  - **mental model test (after scenario)**


Picture


Picture


Picture

Scenario Details

Clearance:
SFO 28R; PORTE3 departure; AVENAL transition; to LAX via SADDE6 arrival, DERBB transition; landing 25R.

Events:

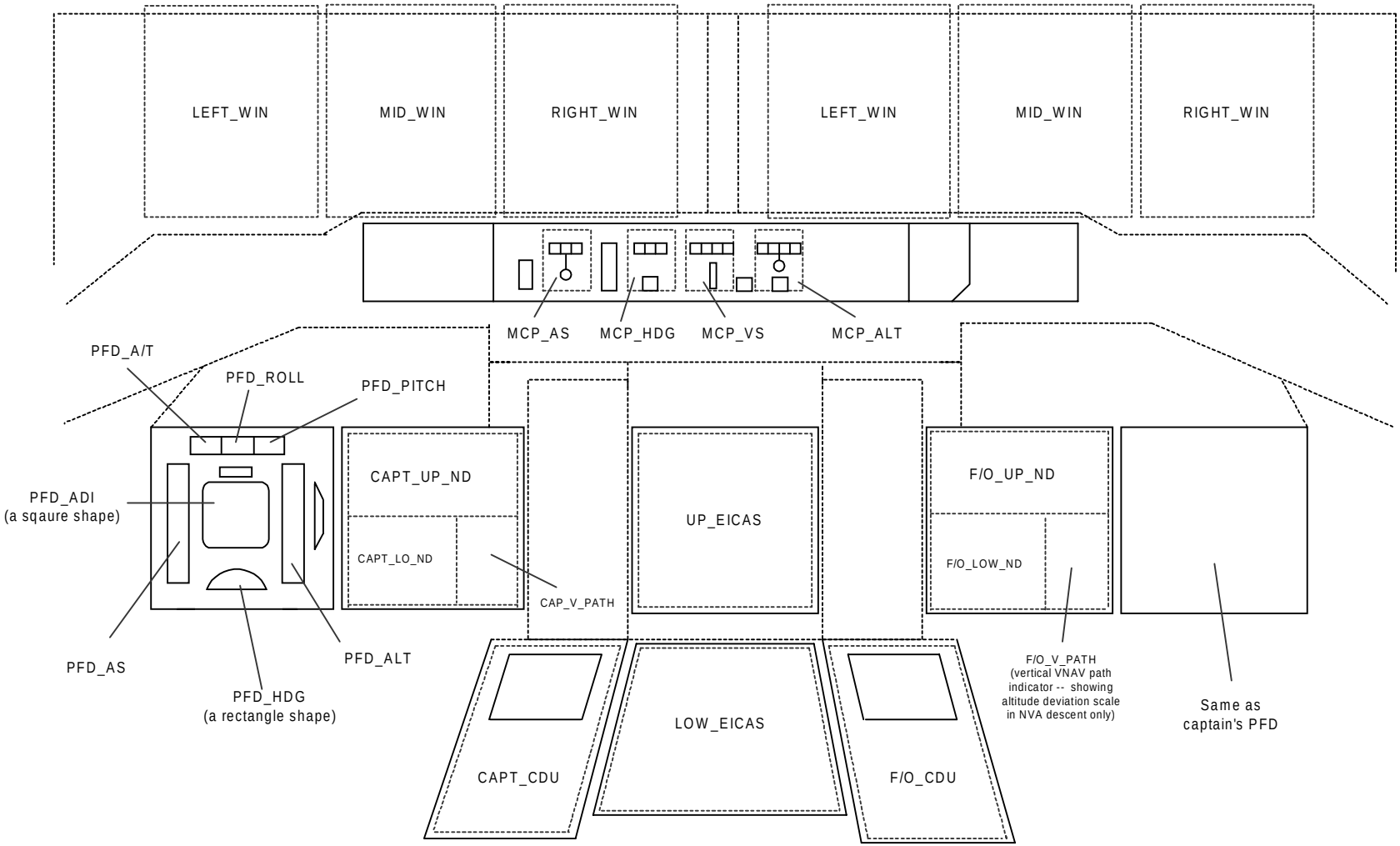
- **Runway change - takeoff speeds deleted; discontinuity created; restriction at PORTE reverts to 9000A from 9000**
- **Departure altitude restriction change - lose MCP altitude restriction; leave VNAV; need to recapture VNAV**
- **Pitch mode FMA artificial change - does pilot notice?**
- **ATC vectors plane off of VNAV/LNAV - need to recover VNAV and LNAV**

Scenario Details

Events continued:

- **CRZ altitude change - need to recover VNAV PTH and T/D**
- **Speed and altitude restrictions on arrival - creates need to maintain VNAV PTH**
- **Airspeed reduction - need to manage speeds across cruise and descent**
- **Pitch mode FMA artificial change - does pilot notice?**
- **Autothrottle mode FMA artificial change - does pilot notice?**
- **Loss of glideslope diamond and glideslope - failure by loss of indication**

Areas of Interest (AOIs)



Eye-Fixation Analysis

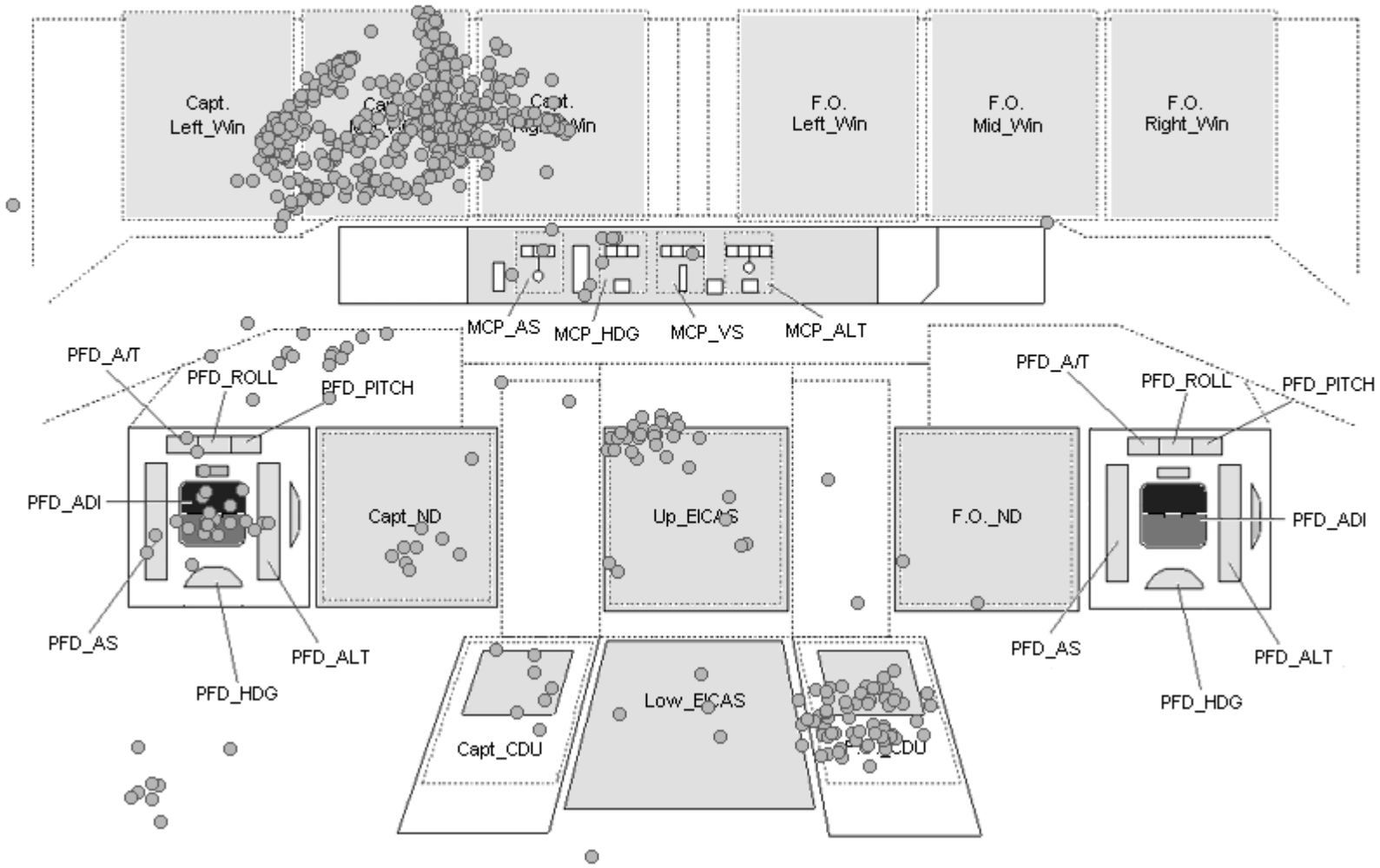
<u>Level 1</u> - Global analysis: fixations averaged within phases of flight (e.g., take-off, cruise, descent)

<u>Level 2</u> - Specific targeted hypothesis for contingency analysis (e.g., pilot should scan A and B in the sequence A, then B).

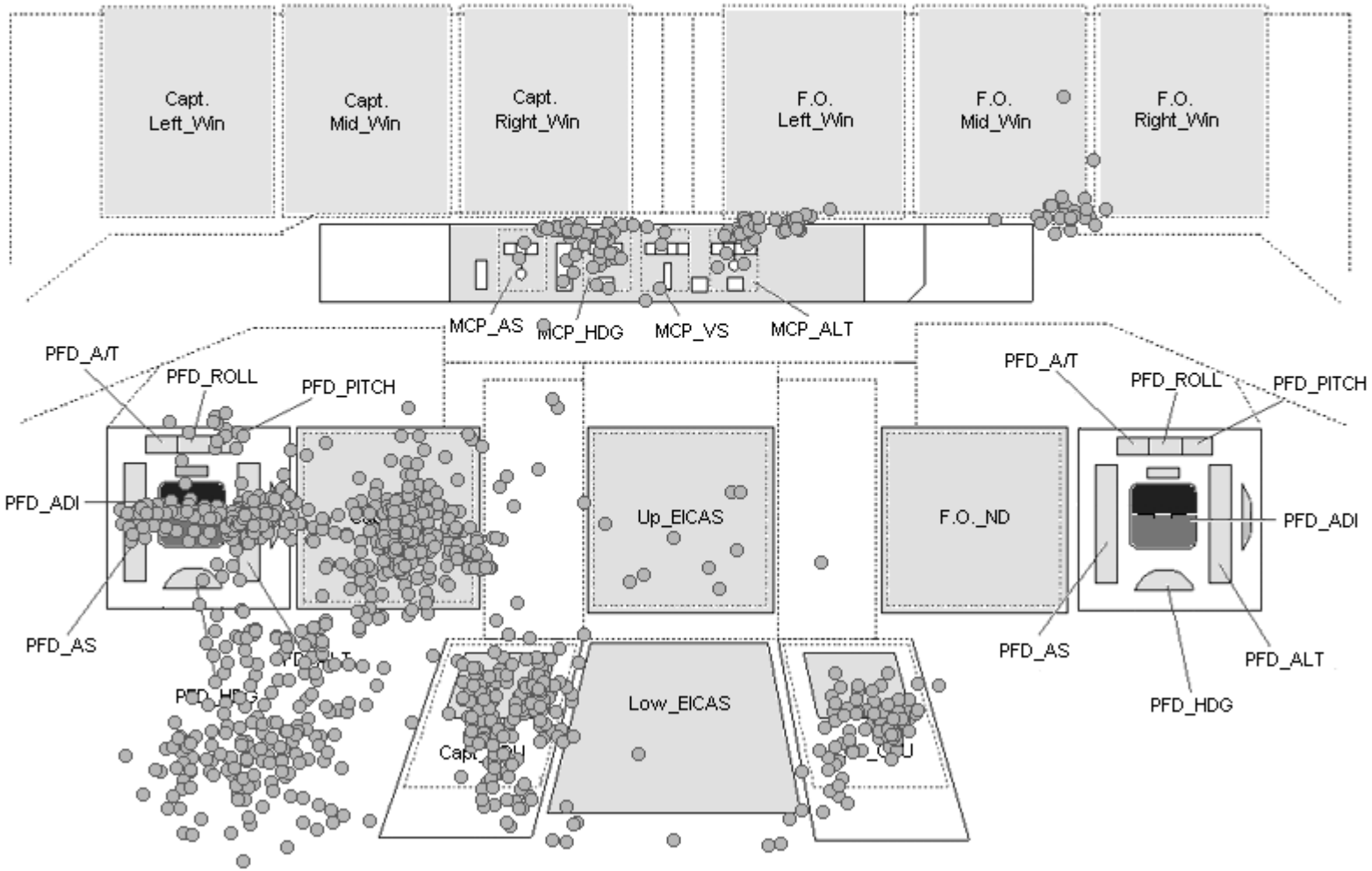
<u>Level 3</u> - Scanning behavior following simulator "events."

- **stimulus contingent scanning**
- **response contingent scanning**

FixFile= Am111817.fix Subject:#17 (Capt)
FlightLegMarks= (1-2)
ATC Runway Change Req -TO- Throttles For Take-Off
SecsDrawn= 279.69 FixesDrawn=605



FixFile= Am111817.fix Subject:#17 (Capt)
FlightLegMarks= (10-11)
A/T Mode Changes To THR -TO- ATC Init Clearance Vectors
SecsDrawn= 552.40 FixesDrawn=1149



Summary:
Automation Monitoring

- **Pilots can lose awareness of automation state.**
- **Pilot scanning patterns for glass cockpits have not been documented. One objective of our work is to document "routine" behavior.**
- **Monitoring is intimately tied to knowledge of system behavior. Knowledge-driven monitoring is a critical element of automation awareness.**

- **We have completed data collection on 20 747-400 pilots.**
- **Data analysis is just beginning. Report should be complete by late summer, 2000.**

Summary and Conclusions

- **Boeing sees automation awareness as an important element of improved safety and accident reduction.**
- **In the short term, enhanced pilot training--mental model and monitoring--is needed for enhancing crew performance.**
- **New flight deck interface designs are also an important element for enhancing automation awareness, but there is a longer time line for implementing these.**
- **We are working with U.S. airlines currently on enhancing pilot training, but will also look for solutions that may be more appropriate for other cultures.**