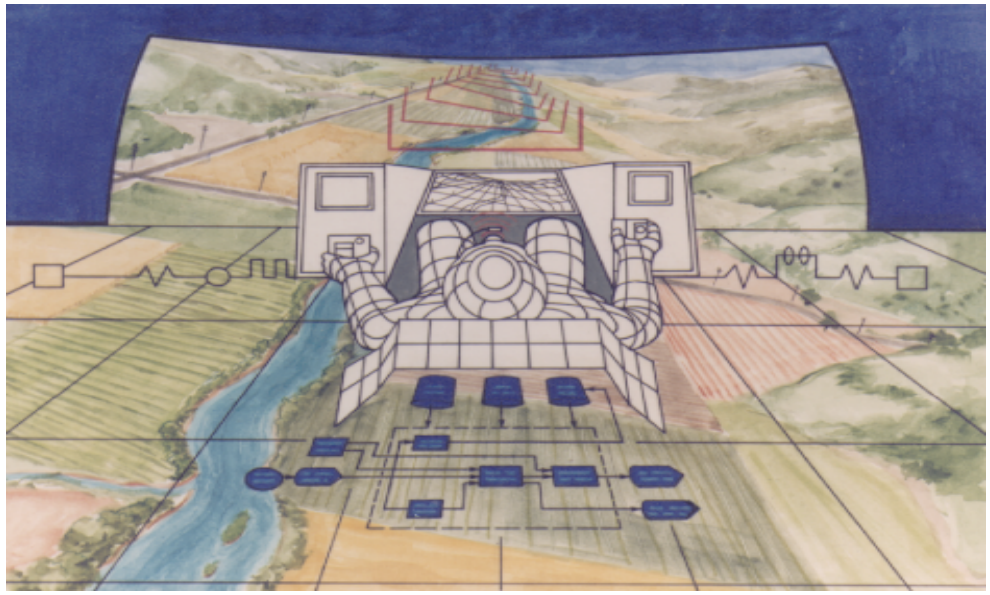
SVS Operator Modeling: Human Performance Modeling Project Overview



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Human Factors research and technology

Outline of Topics

- Problem, Approach and Goal
  - Accidents, errors and error precursors in aviation
  - Model development plan / implementation
- Developing Cognitive Modeling Tools for System Design
  - Overview of five modeling frameworks
  - Application to approach and landing operations with and without augmented displays
- Future efforts
  - Verification and validation
  - Cross-model mechanism analyses

Problem, Approach and Goal

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Problem

- Accident precursors are complex interaction of latent error in a system design or procedure (and dynamic interaction of design, human operation and environment)
- Difficult to observe rare error and error precursors in aviation environment ($1x10^{-n}$)
- Design cycle (design, build, evaluate, field, revise) is difficult, expensive, and time-consuming

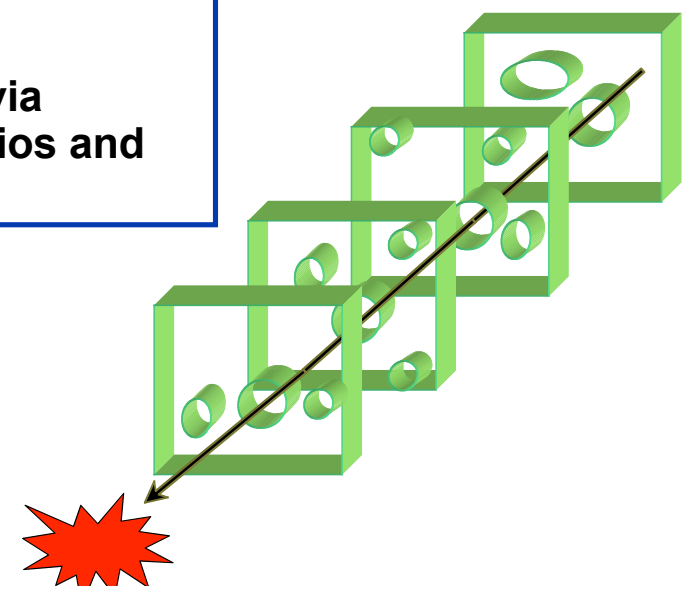
Approach

- Identify scenarios with high probability of human error
- Identify/model precursors to errors
- Assess technological and procedural solutions via development of computational models of scenarios and candidate solutions

Goal

Develop modeling capability to:

- Assess technological and procedural solutions via development of computational models of scenarios and candidate solutions
- Test potential mitigation strategies



Accidents/ Incidents
Error/ Error precursors

Reason 1990

Implementation Plan Status

AvSSP SWAP — **Human Performance Modeling**

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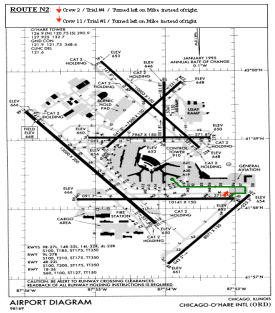
'01 Modeling Taxi-Navigation Errors

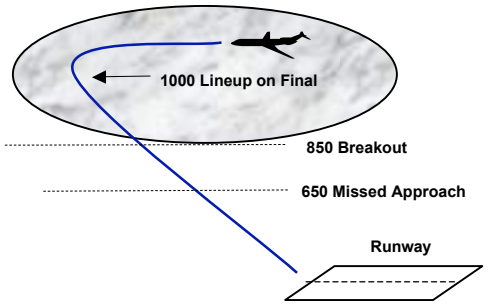
- Technical report on context of aviation errors
- Development of 5 models of surface operations
- Workshop 10/18/01



Proof-of-Concept: replication and causal explanation of various observed pilot taxi-navigation errors committed in high-fidelity simulation

'02-'03 Modeling Nominal Approach/Landing with and without SVS

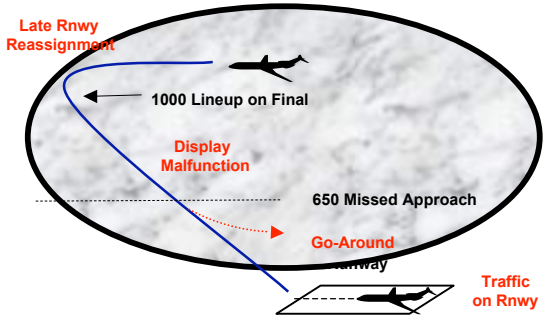
- Cognitive Task Analysis
  - •Baseline approach& landing
  - •Augmented display approach & landing
- Part-task Pilot-in-loop Simulation
  - •Eye-tracking data
  - •Display monitoring/ usage data
  - •Multiple scenarios (late runway reassignment, system failure, etc.)
- Models of Approach / Landing
  - •Initial model development
- Workshop 3/6/03
- Operator model provided to AvSP ASMM project



Demonstrated: 3 working models of pilot performance during nominal approach/landing: good correlations between simulation outputs and observed pilot eye tracking/visual attention allocation

'03-'04 Modeling Multiple Off-Nominal Approach/Landing with and without SVS

- Models of Approach / Landing
  - •Develop advanced models
  - •Investigate off-nominal scenarios
  - •Identify error susceptibilities
  - •Evaluate mitigation strategies
- Model Verification/Validation Approaches
  - •Determine "choke points" (e.g., workload, SA at transition points)
  - •Cross scenario
  - •Cross model
  - •Emergent behaviors



Objective: prediction of pilot attentional allocation, decisions, and actions during off-nominal operations with & without SVS

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Summary of Human Performance Models

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Characteristics of selected models

- Operator level, cognitively oriented
- Generative, stochastic, context sensitive
- Integrative computational frameworks
- Comprehensive, mature, validated systems

Model	Type	Implemented Advances	Error Mechanisms
ACT-R/PM	Cognitive & Statistical Environment Model	Coupling of comprehensive low-level cognitive architecture with a principled methodology for statistically describing information environment	* Time pressure * Misplaced Expectations * Memory retrieval problems
Air MIDAS	Integrative Cognitive & Environment	Demonstrated multiple cognitive agents interacting with each other and to their evolving context	* Workload * Memory Interference
A-SA	Attention & SA	Demonstrated computational algorithms for allocation of attention linked to algorithm assessing level of situational awareness in error generation	* Misplaced Attention * Lowered SA
D-OMAR	Integrative Cognitive & Environment	Provided framework to capture rich multi-tasking world of pilots in this environment for examining error	* Comm errors * Interruption / Distraction * Misplaced Expectation
IMPRINT / ACT-R	Cognitive & Task Network	Coupling of comprehensive low-level cognitive architecture with high-level task network	* Time pressure * Perceptual errors * Memory retrieval * Inadequate knowledge

Modeling Nominal Approach & Landing

Data Set

Part-task Pilot-in-loop Simulation
Performance data and Eye-tracking (3 Current Commercial Transport Pilots)

Other Information Provided Modelers

Detailed Cognitive Task Analysis

Modeling Problem

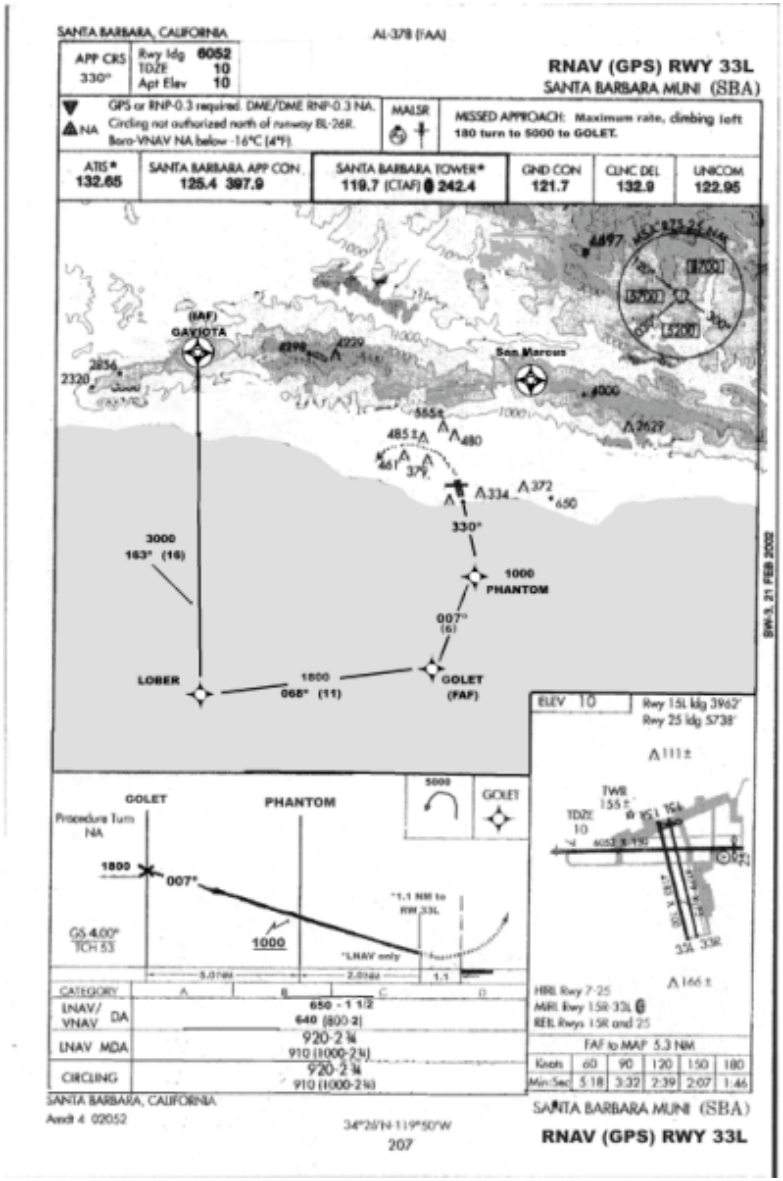
Develop "Normative" Model of Approach & Landing with and without Augmented Display

Scenarios

Display Configuration		Baseline	Baseline	SVS
Visibility		VMC	IMC	IMC
Approach Event	Nominal Approach (nominal landing)	*Scenario #1*	*Scenario #4*	*Scenario #7*
	Late Reassignment (side-step & land)	*Scenario #2*		*Scenario #8*
	Missed Approach (go-around)	*Scenario #3*	*Scenario #5*	*Scenario #9*
	Terrain Mismatch (go-around)		*Scenario #6*	*Scenario #10*

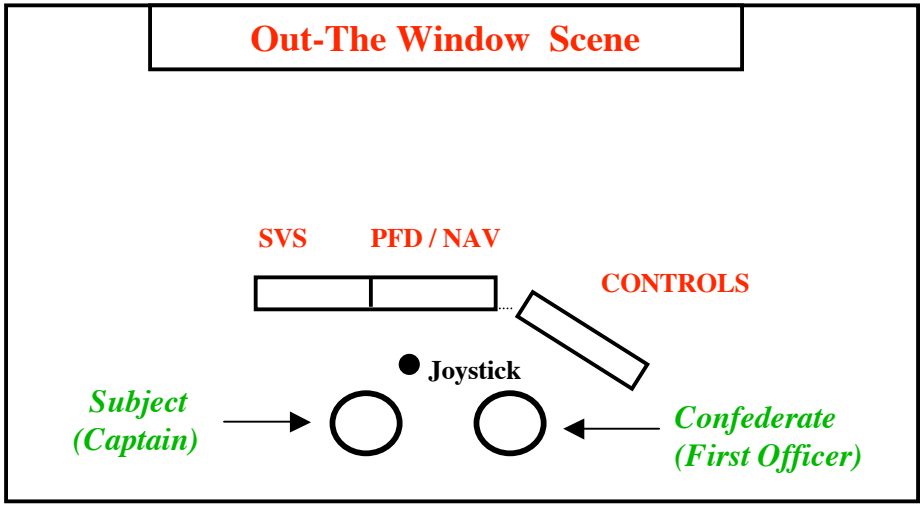
Basic Scenario Description

- RNAV (GPS) approach to Runway 33L
- Daylight operations under calm winds
- Flown fully coupled to autopilot until DH (650')
- Experimenters served as FO and ATC



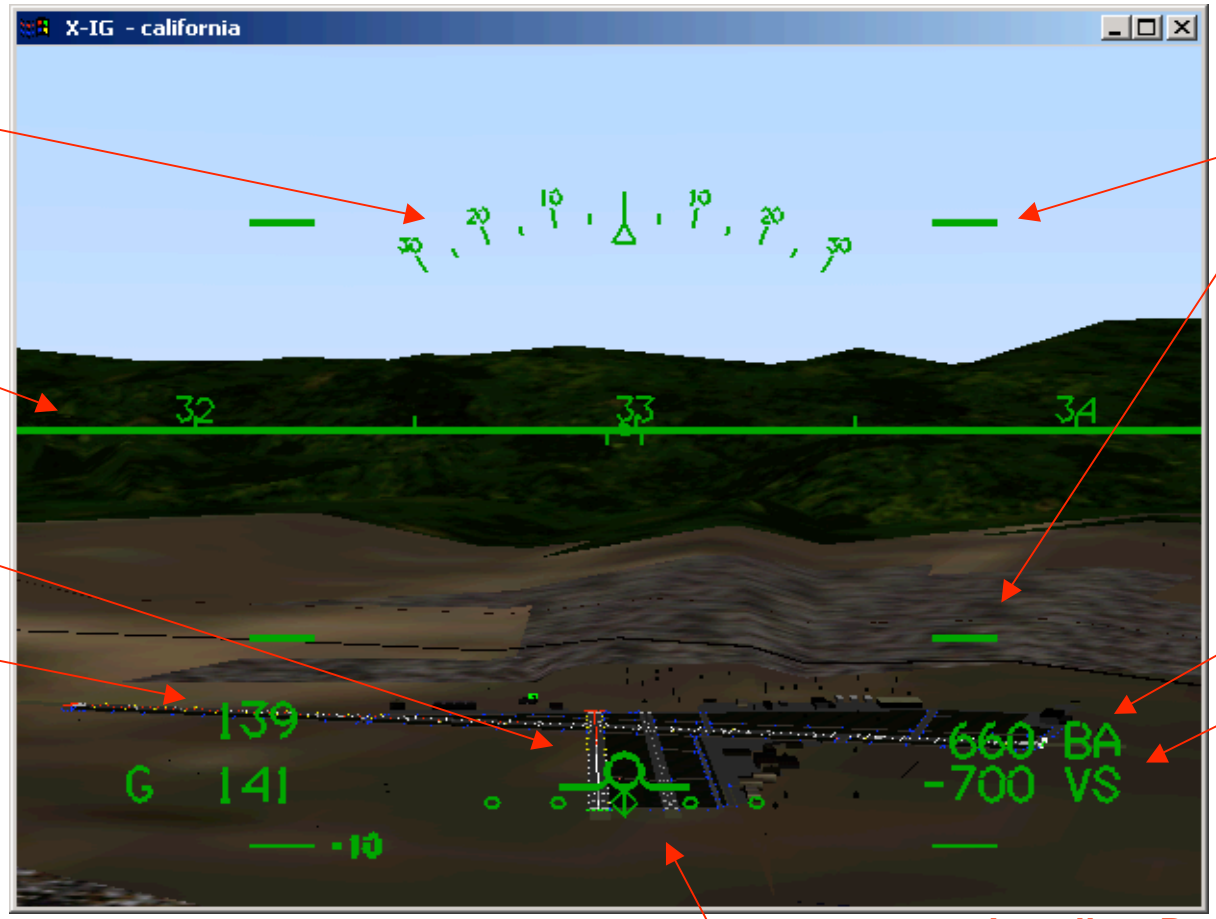
Simulator Configuration

- PC-based simulator approximates instruments and controls B-757
- 4 display components and joystick with throttle
- Visual data base of Santa Barbara Airport with surrounding terrain and cultural features



Generic Synthetic Vision Display

- Head-down SVS display measured 10"x 7.5"
- Display presented terrain imagery overlaid with flight symbology
- Field of view set at 31˚ x 23˚ (provided wide-angle perspective)



Roll Indicator

Heading Tape on Horizon Line

Flight Path Predictor

Air Speed

Pitch Ladder

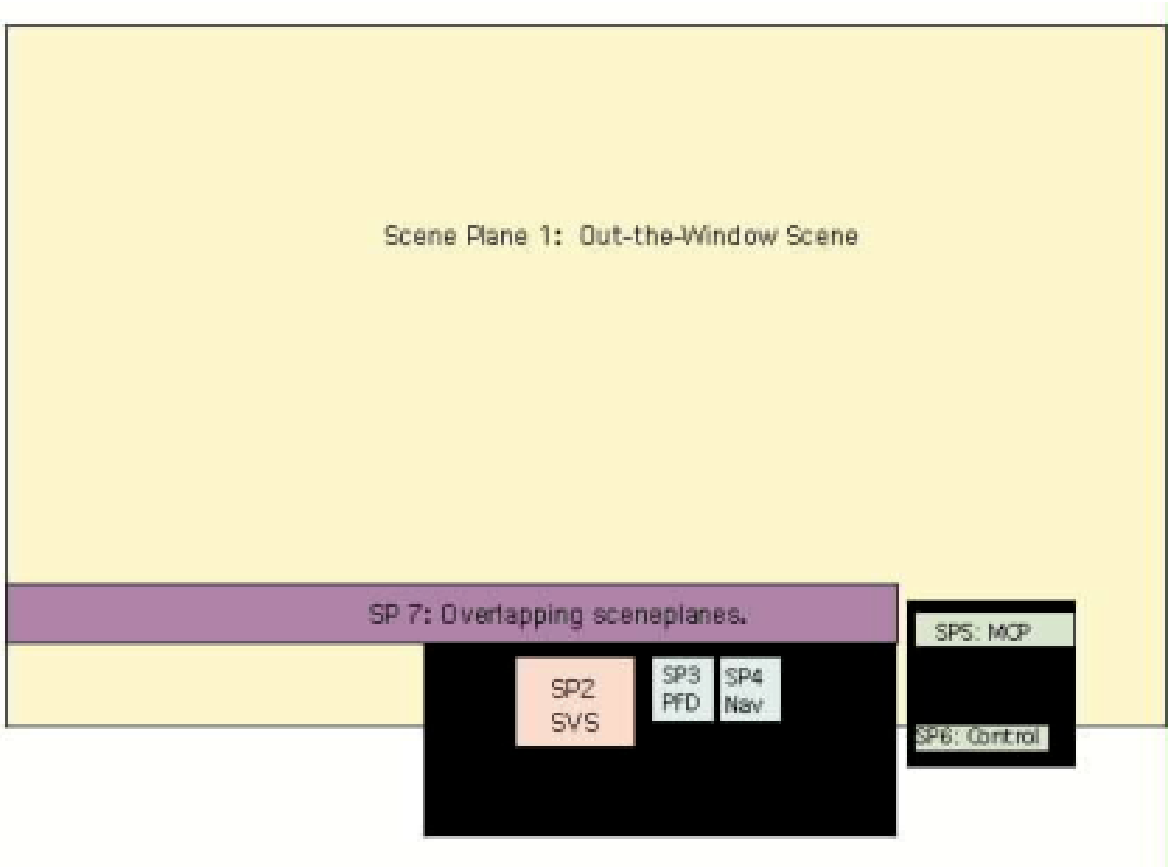
Altitude

Vertical Speed

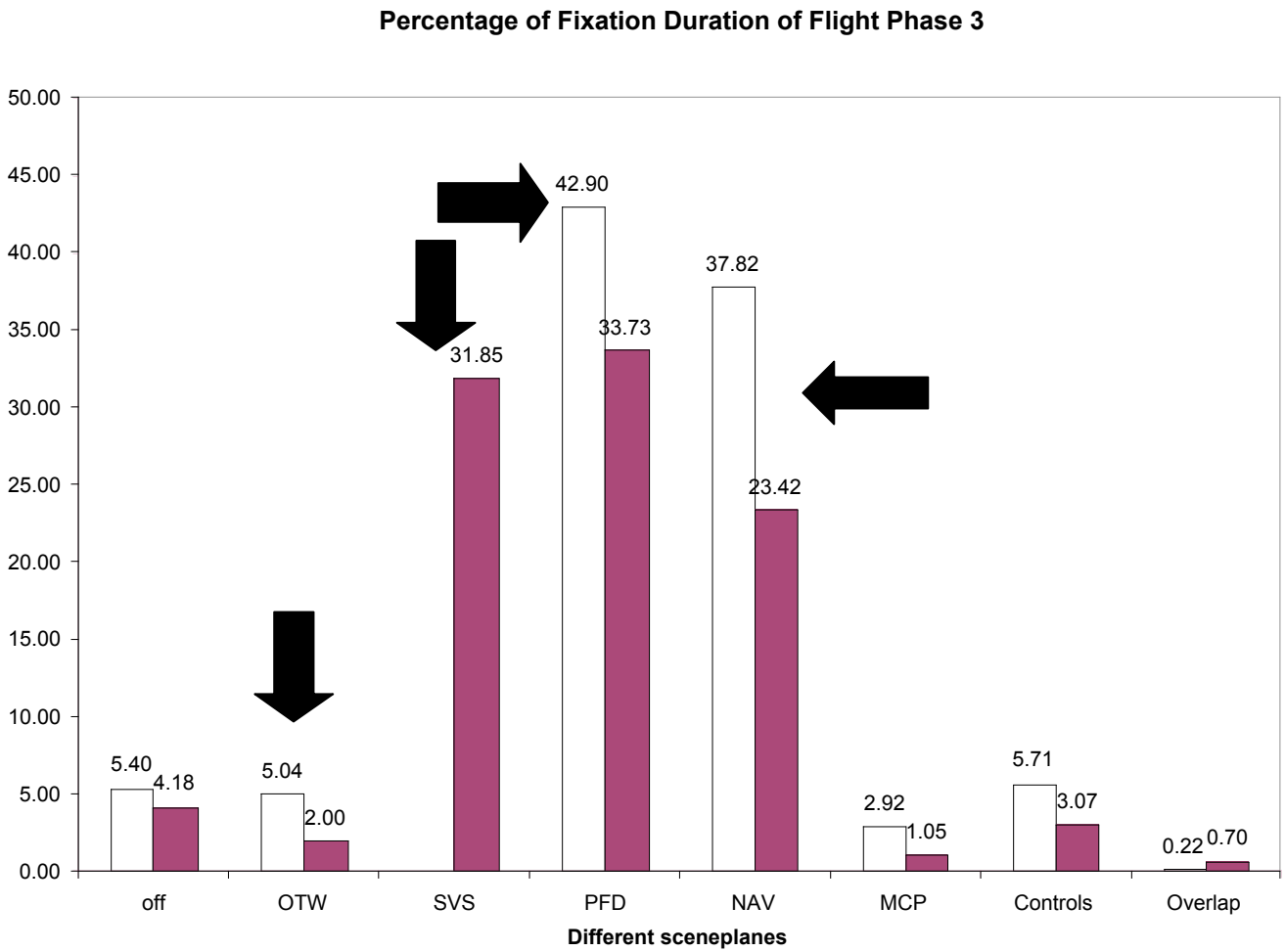
Localizer Dots Non-functional

Eye Tracker Data

6 areas of interest (AOI's)

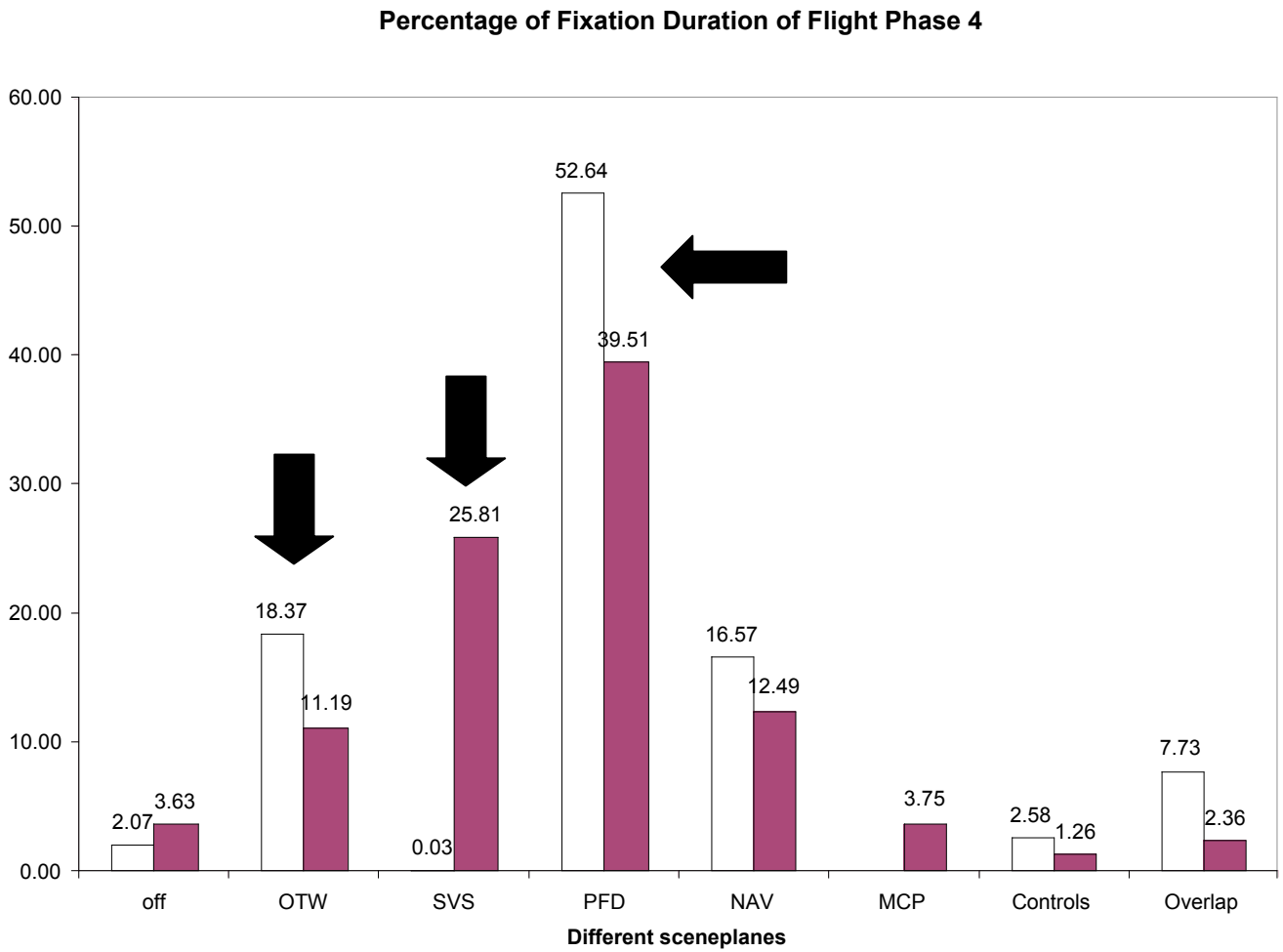


SVS vs. No SVS: FAF to DH



From: Goodman, Hooey, Foyle, & Wilson, 2003
Byrne & Kirlik, 2003

SVS vs. No SVS: DH to 50'



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ACT-R Explanation of Results

- SVS is clearly not just a proxy for OTW
- Appears to take on functionality of PFD and NAV
  - How?
  - Working hypothesis: Symbology overlaid on SVS
- Kirlik & Byrne's ACT-R model suggests a cognitive mechanism for this:
  - SVS contains task-relevant information
  - Local costs of access = more rapid access of nearby visual items
  - SVS information access increases continued SVS viewing, rather than switching to same information on the PFD
- Implications for design, training and procedures
  - Crew monitoring (PFD vs. SVS)
  - Instrument cross check scan
  - Symbology design
  - Switching time between displays

Current Status / Future

- Verification and Validation
  - Wickens (2004) SVS data
  - Mumaw et al (2000) data
  - HPM modeler's new data
- Robustness testing
- Cross-model mechanism evaluation
  - Not evaluate on best correlation (AMBR project)
  - Multiple models on common problem
  - Mechanisms, insights, strengths, weaknesses
- Publications
  - More than 50 papers; 20 downloadable from HCSL website: http:// humanfactors.arc.nasa.gov/ihi/hcsl

Technical Transfers

- A/SA Model (Wickens, U. Illinois)
  - LaRC SVS design recommendations (Prinzel)
  - General Motors "attentional allocation in vehicles" study
  - FAA study on UAV interface designs (upcoming)

- AirMIDAS Model (Corker, SJSU)
  - AvSSP/ASMM simulation

- IMPRINT/ACT-R Model (Archer/Lebiere, MA&D)
  - LaRC AWIN study (Latorella)
  - ONR GPS usage study (Hawkins)
  - ARL UAV Operator Control Unit interface design/eval (Army Research Lab Advanced Decision Architectures Collaborative Technology Alliance-ARLADA CTA)