



# **The Cognitive Processes used in Team Collaboration during Asynchronous, Distributed Decision Making**

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# Presentation Outline



- ✦ **Objective of Presentation**
- ✦ **Major Factors Impacting Team Collaboration**
- ✦ **Impact of Theories of Cognitive Psychology on Team Collaboration Model Development**
- ✦ **Structural Model of Team Collaboration**
- ✦ **Experiment 1: Collaborative Team Problem Solving**
- ✦ **Experimental Results**
- ✦ **Summary Conclusions**
- ✦ **Potential Applications**



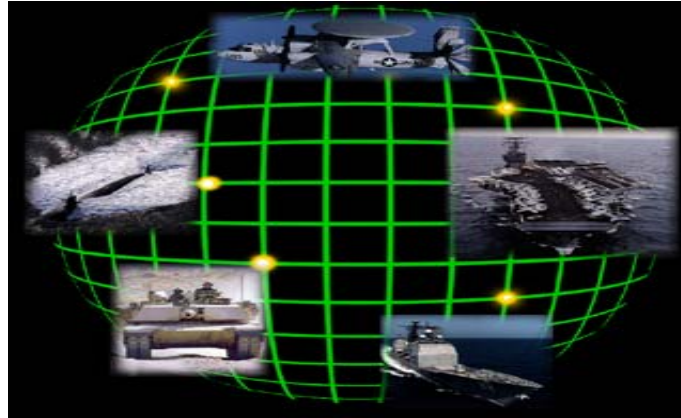
## Objective of Presentation



- **To describe the unique cognitive processes that are employed to optimize collaborative team decision making in a geographically distributed and time delayed situation**
- **To describe an empirically-based structural model of team collaboration that illustrates the respective cognitive processes**

## Collaborative Challenges

- Increasing problem complexity – team effort needed
- IT/Communications technology widening accessibility of contributors
- Problems addressed at international level – coalitions required
- Defense Transformation to agile and coalition operations
- Information overload condition



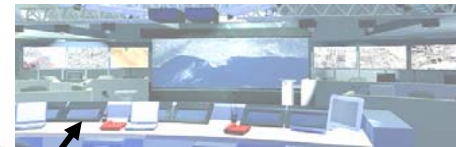
### Operational Tasks:

- \* Team decision making, COA selection
- \* Develop shared understanding
- \* Intell analysis (team data processing)



### Collaborative Situation Parameters:

- \* time pressure
- \* information / knowledge uncertainty
- \* dynamic information
- \* large amount of knowledge (cognitive overload)
- \* human -agent interfaces



### Team Types

- \* asynchronous
- \* distributed
- \* culturally diverse
- \* heterogeneous knowledge

- \* unique roles
- \* command structure (hierarchical vs flat)
- \* rotating team members



# Impact of Theories of Cognitive Psychology on Team Collaboration Model Development



## Theories of Human Cognition

- Origin of Human Thought and Knowledge - Descartes (1641) & Kant (1781)
- Behaviorism - Skinner (1985)
- Information-Processing Model - Turing (1936), Weiner (1948), Shannon (1949)  
Wickens (1992)
- Human Language – Chomsky (1957), Cooke (2003)
- Developmental Biology – Piaget (1970)
- Computer Computational Model – Newell & Simon (1956), Anderson (1993),  
Minsky (1997)
- Physiological Neural Networks – Rumelhart (1990), Churchland (1989)
- Meta-Cognition – Davidson, Deuser & Sternberg (1994)

## Impact on Model Development

- Multi-Disciplinary Approach to Cognition
- No Unified Theory of Human Cognition
- Insufficient Objective Metrics to Measure Human Cognitive Processes

# STRUCTURAL MODEL OF TEAM COLLABORATION

## Problem Area Characteristics

### Collaborative Situation Parameters:

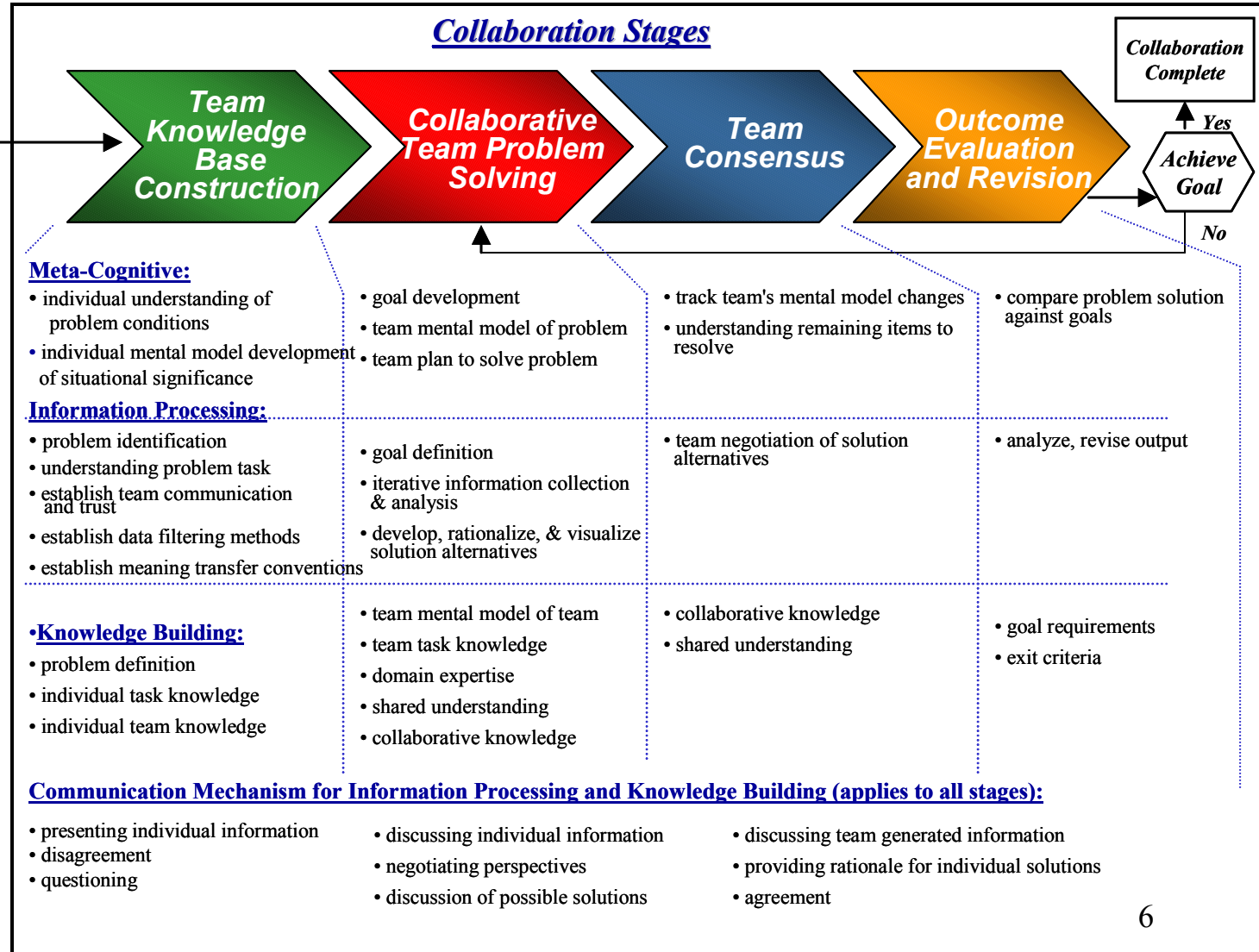
- time pressure
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### Team Types

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# Experiment 1 Collaborative Problem Solving Task

## Murder Mystery



- **The Case of the Fallen Businessman, ( by Dr. Garold Stasser, Miami University, Oxford, Ohio)**

- **Major Characters**

**Robert Gill:** The victim

**Mary Gill:** The victim's wife

**Lt. Mark Moody:** Detective in charge of the investigation

**Sgt. Cassini:** Police officer assisting in the investigation

**\*\*Eddie Sullivan:** Handyman who worked for the Gills

**\*\*Billy Prentice:** Yardman who worked for the Gills

**\*\*Mickey Malone:** Owner of MM Auto Parts; business associate of the victim

**Sam Nietzel:** Parts manager for Gill Lincoln/Mercury

**Dave Daniels:** Owner of Dave's Quick Stop in the Eastwood Shopping Center

**\*\* The ONLY suspects under consideration are: Mickey Malone**

**Billy Prentice**

**Eddie Sullivan**

- **Summary:** Robert Gill, a prominent local businessman was found dead behind his Crestview home this morning. Detective Lt. Mark Moody of the Hilltown precinct reported that Mr. Gill had apparently been assaulted when leaving his home to play golf early this morning. He was struck on the head over the left eye and fell down a flight of stairs leading from a second story deck at the rear of the house. The preliminary coroner's report concluded that death was caused by injuries sustained from the fall and not from the blow to the head. The report estimated that Mr. Gill's death occurred between 6:30 and 7:00 AM. Lt. Moody would neither confirm nor deny rumors that Mr. Gill had been robbed. "We're following all leads. That's all I have to say for now," said Lt. Moody.
- **Team Objective:** Collaborate on the detailed murder information and develop a team consensus on who killed Mr. Gill



# Independent Variables



➤ **Collaboration Mode** (face-to-face vs asynchronous, distributed)

- \* **Face-to-Face** = team interacts synchronously with each other through speech
- \* **Asynchronous, Distributed** = team interacts with each other at different times and from different locations through a text based web forum

➤ **Knowledge Distribution** (homogeneous vs heterogeneous)

- \* **Homogeneous** = the members of the team have all the murder mystery knowledge in common
- \* **Heterogeneous** = the members of the team have some murder mystery knowledge in common and some uniquely held murder mystery knowledge



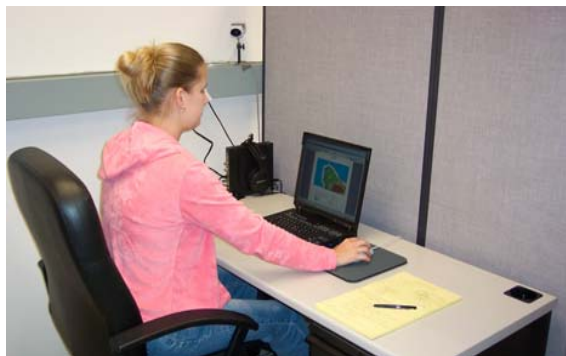
## COGNITIVE AND AUTOMATION RESEARCH LAB (CARL)



### Asynchronous, Distributed Collaboration Stations

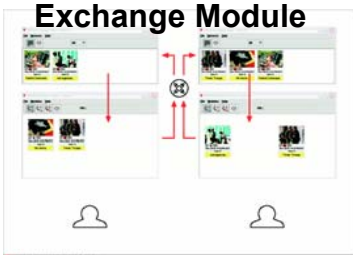
### Face-to-Face Collaboration Area

### Experimenter's Station



Electronic Card Wall Collaboration Tool (Ewall)\*\*

#### Exchange Module



#### Newsview Module

#### Workspace Module



### Experience & Capabilities

### Potential Applications

- Over 25 Years Experience in Decision Making / Automation Research
- Member National & International Research Panels
- **Recent efforts:** CASC, Agent Learning, ADSS, ANGEL, SCC
- **Tools:** local web server, Pathfinder, Agent development toolsets, Statistica
- Joint efforts (e.g. NAVAIR TSD, JFCOM,)

#### Users



• Improved pilot situational awareness resulting in timely mission performance and a significant decrease in aircraft/aircrew accidents

• More timely and accurate mission decisions based on current information achieved through asynchronous, distributed collaboration tools (C2 down to individual warfighter)

• Improved mission planning and execution through networked asynchronous, distributed team collaboration tools.

\*\* Produced by MIT under ONR CKM program



# EXPERIMENTAL DESIGN



( 2x2 randomized factorial)

## Knowledge Distribution

		Homogeneous	Heterogeneous
<b><u>Collaboration Mode</u></b>	Face-to-Face (speech)	Gp 1 * * Gp 7	Gp 15 * * Gp 21
	Asynchronous, Distributed (text)	Gp 8 * * Gp 14	Gp 22 * * Gp 28

### Phase I

- 28 groups total
- 3 subjects / group
- 84 subjects total

## DEPENDENT VARIABLES:

- Forum text and face-to-face audio / video recordings including time stamp per response (I.e. text and speech)
- Thinking Aloud Protocol (concurrent verbalizations) for asynchronous, distributed teams
- Total time to successfully complete the problem-solving task (time from the beginning of the task until task completion)
- Collaboration Maps (post session – subjects construct a map of their view of the stages & cognitive process states of team collaboration)
- Subjective Questionnaire – measuring expertise, trust between team members, and general collaboration opinions among members



# *TYPES OF DATA ANALYSES*



- **Verbal Protocol Communication Analyses**– identification of collaboration stages and cognitive process states compared across collaboration mode and knowledge distribution. Compare results to preliminary structural model of collaboration.
- **Transition State Diagrams** – representation of the *dynamic* team collaborative behavior between collaboration stages and between cognitive process states within each collaboration stage compared across collaboration mode and knowledge distribution. Compare results to preliminary structural model of collaboration.
- **Parametric statistics** for analyzing time, and frequency within each collaboration stage and cognitive process state across collaboration mode and knowledge distribution conditions. Also used for analyzing total time to complete task and questionnaire data.
- **Collaboration Maps** – determine the degree of convergence between individual mental model ‘s regarding collaboration stages and cognitive processes. In addition, compare how an individual thinks a group makes a decision in a collaborative setting and how the group actually performs.



# Results



## Mean % Time by Collaboration Stages Collaboration Mode (CM) vs. Knowledge Distribution (KD)

### Team Knowledge Base Construction:

CM:  $F = 5.51323$ ,  $p = 0.027449$   
 KD:  $F = 170682$ ,  $p = 0.203780$   
 CM\*KD:  $F = 6.02627$ ,  $p = 0.021724$   
 N = 84

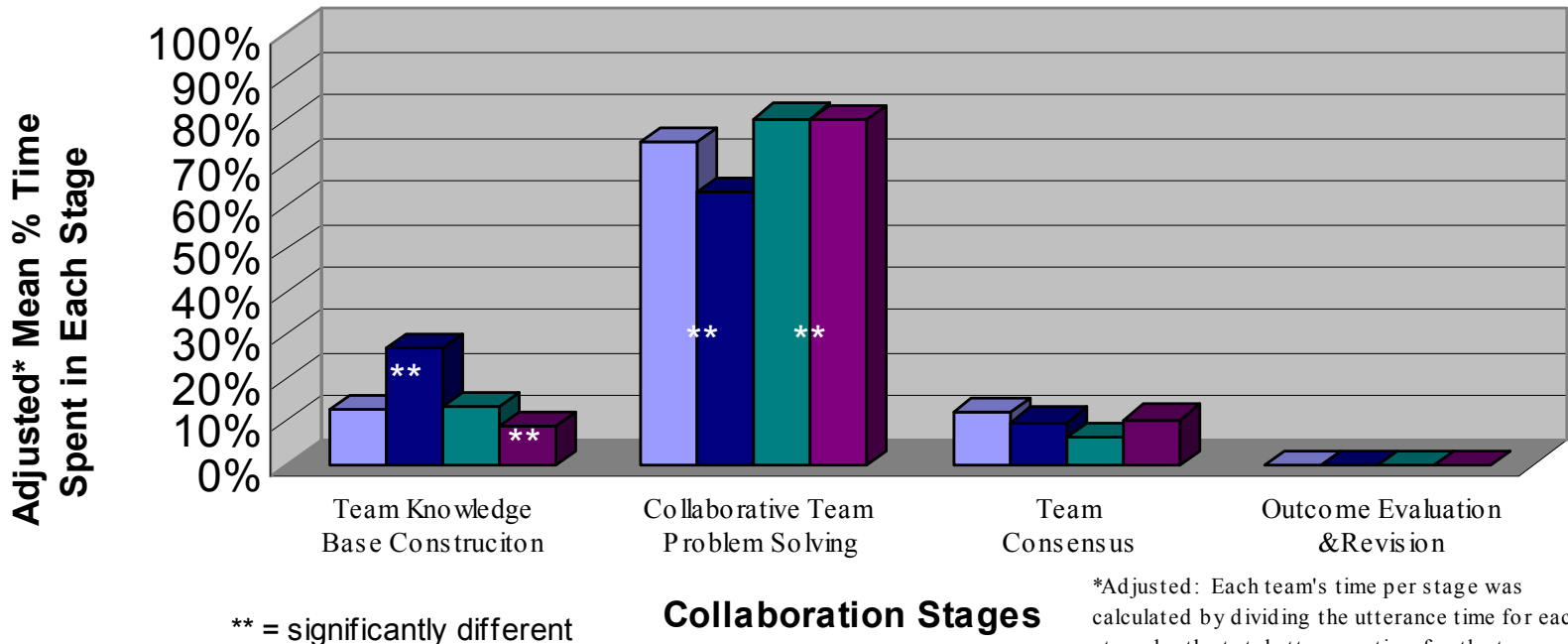
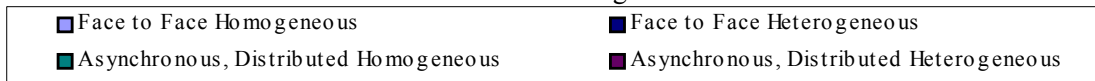
### Collaborative Team Problem Solving:

CM:  $F = 6.944$ ,  $p = 0.014504$   
 KD:  $F = 2.010$ ,  $p = 0.169097$   
 CM\*KD:  $F = 1.876$ ,  $p = 0.183471$   
 N = 84

### Team Consensus:

CM:  $F = 0.51854$ ,  $p = 0.478422$   
 KD:  $F = 3.43855$ ,  $p = 0.07602$   
 CM\*KD:  $F = 0.82967$ ,  $p = 0.371425$   
 N = 84

### Collaboration Mode/Knowledge Distribution:



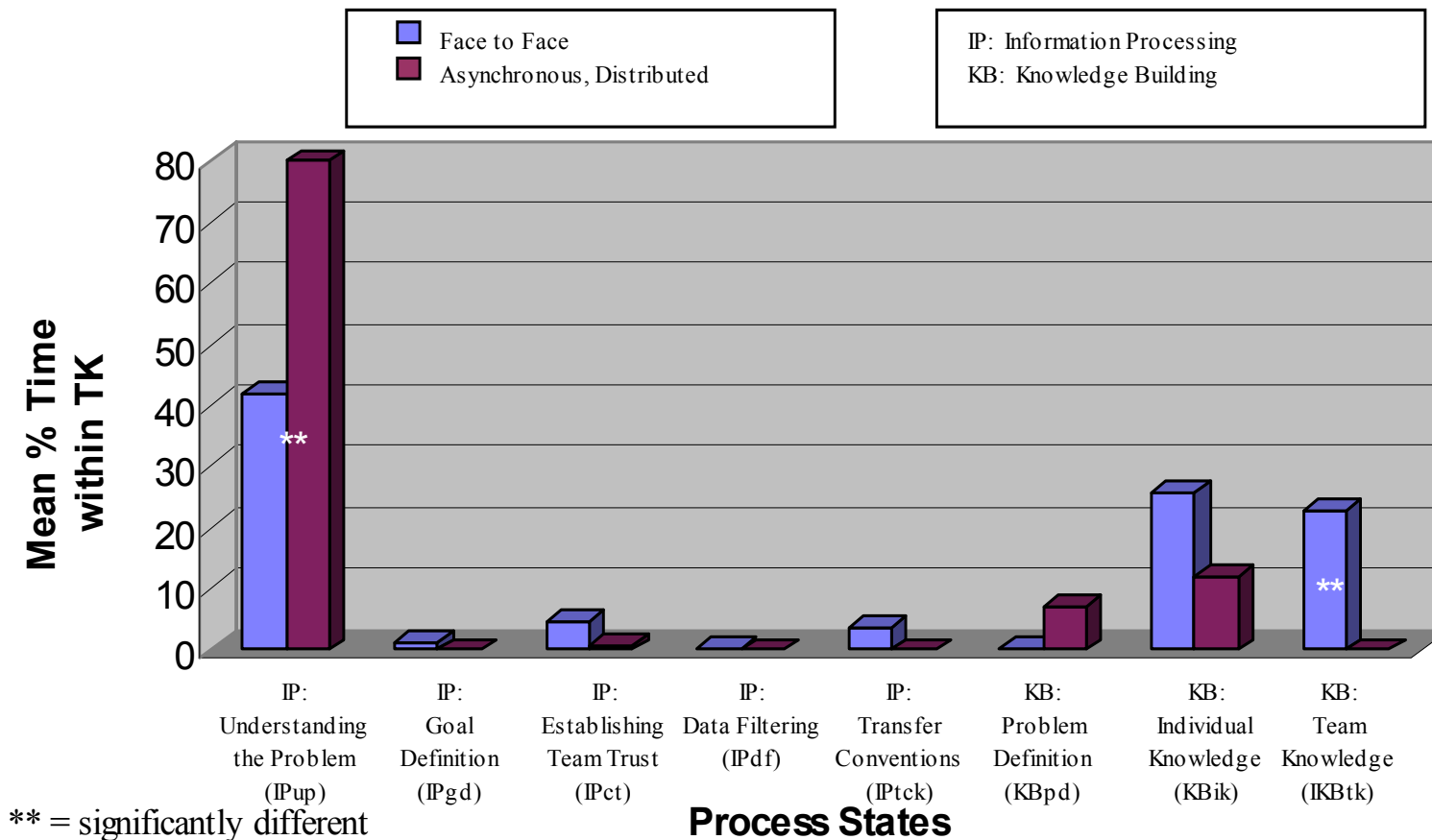
\*\* = significantly different

### Collaboration Stages

\*Adjusted: Each team's time per stage was calculated by dividing the utterance time for each stage by the total utterance time for the team.

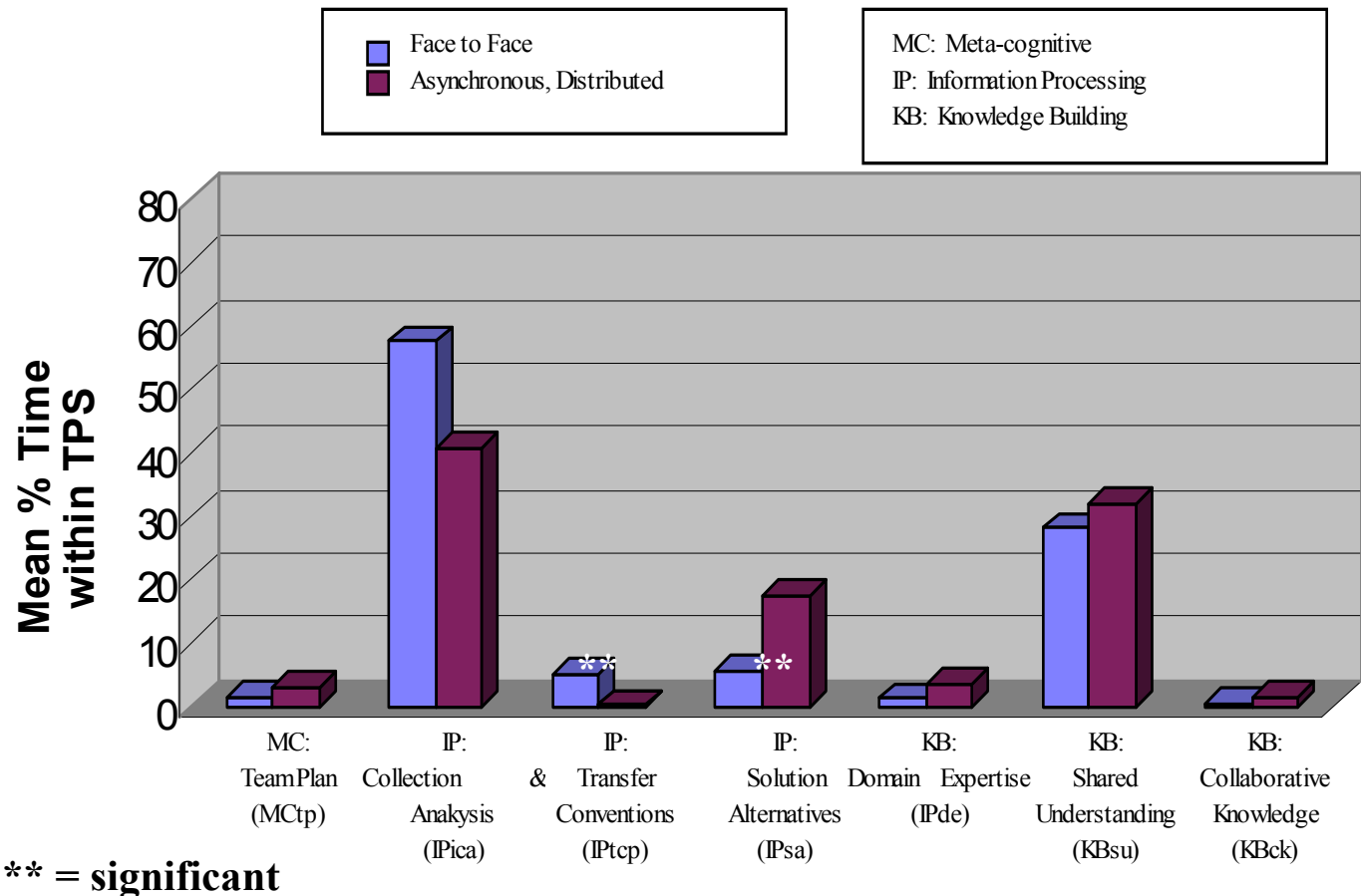
## Mean % Time By Cognitive Process States: Team Knowledge Construction (TK)

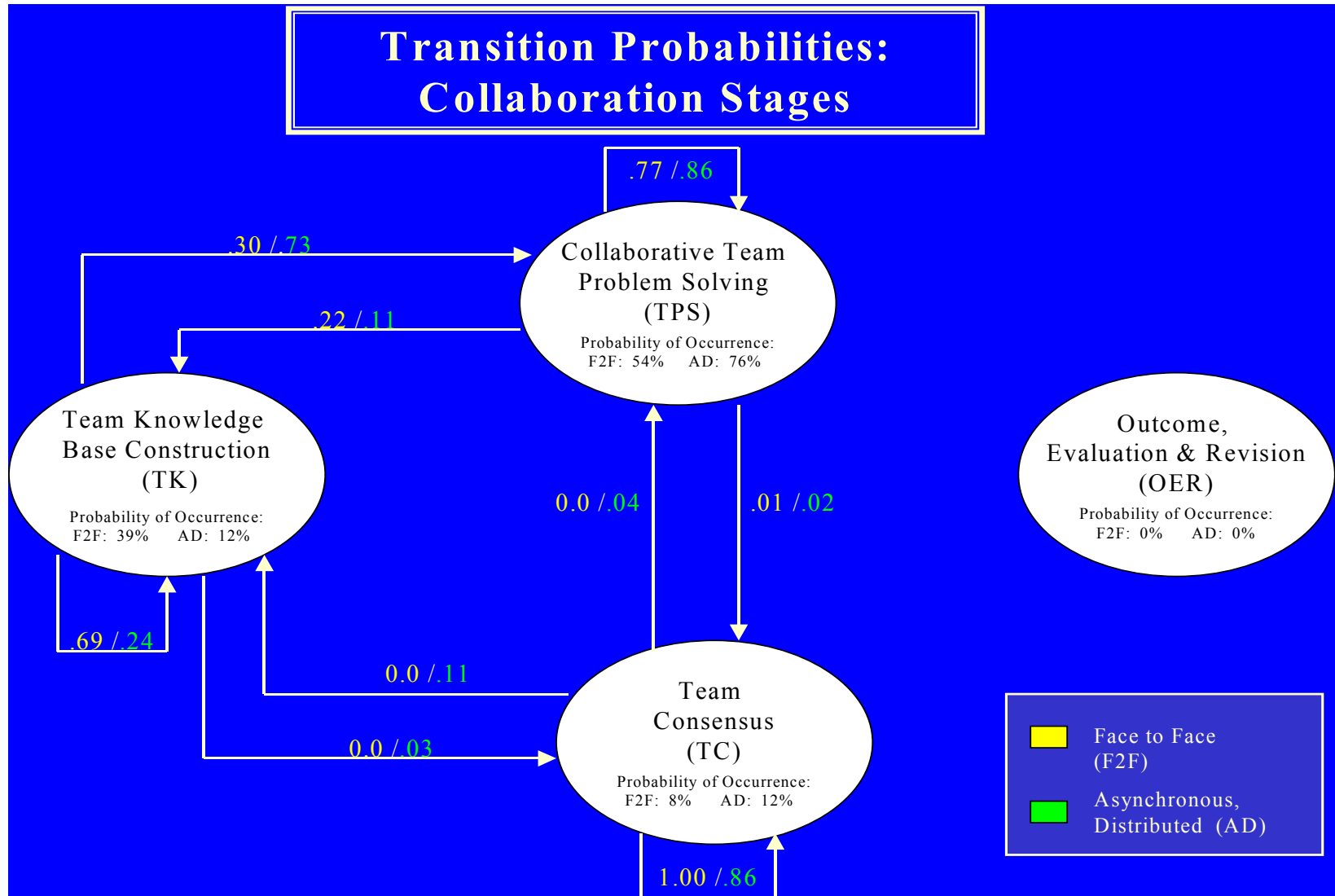
Wilks lambda = 0.402182, F = 3.158681, p = 0.022010



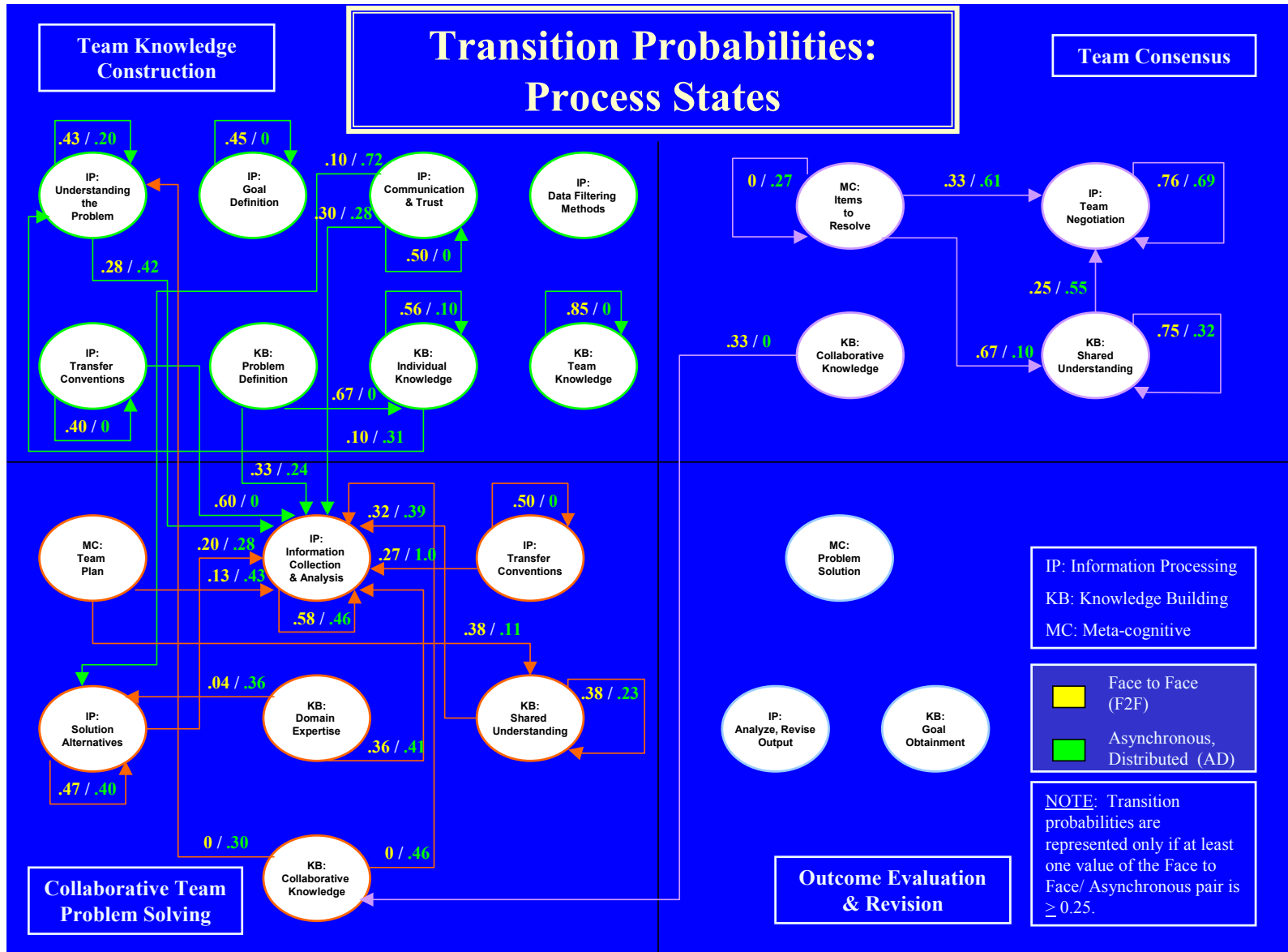
## Mean % Time By Cognitive Process States: Collaborative Team Problem Solving (TPS)

Wilks lambda = 0.00033 F = 9605.498 p = 0.000000













# Summary Conclusions



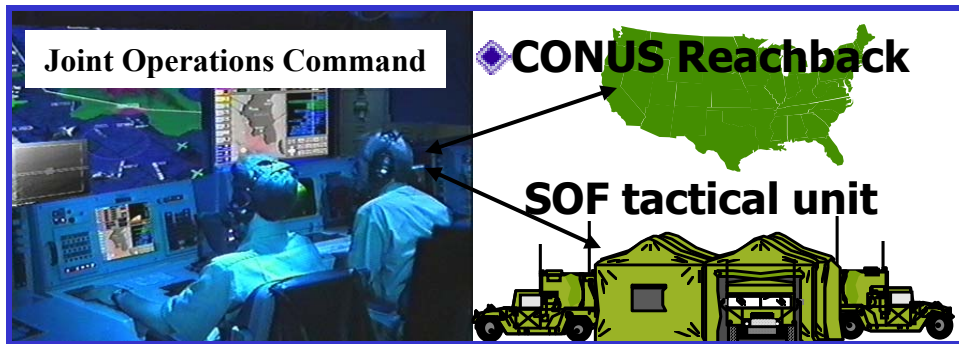
- ✦ Both face-to-face and asynchronous, distributed teams demonstrated behavior that **supports the existence of Team Knowledge Base Construction, Collaborative Problem Solving and Team Consensus** stages during collaborative problem solving. Phase I data showed that the stages are **task dependent** as the Outcome Evaluation & Revision stage was not used
- ✦ The significant cognitive process states were **Understanding the Problem, Team Knowledge development, Conventions for Transferring Meaning, and developing Solution Alternatives**
- ✦ Knowledge Distribution (homogeneous / heterogeneous information) did not make any difference on the **time spent in** each collaboration stage
- ✦ Asynchronous, Distributed teams spent **more time** in Collaborative Problem Solving stage than face-to-face teams. Appears to be more difficult to solve collaborative problems with these types of teams even though collaboration environment is inherently more structured. Need to determine **why these teams spend more time** so collaborative problem solving can be facilitated
- ✦ Face-to-Face teams used **conventions to transfer meaning** (e.g. yellow stickers, maps) whereas asynchronous, distributed teams did not use conventions. Need ways to easily create conventions with asynchronous, distributed teams (area for agent support)
- ✦ Face-to-Face teams demonstrated mostly a **linear path** between team knowledge construction, team problem solving and team consensus whereas asynchronous, distributed teams showed a **non-linear path with feedback loops** (area for agent support)

## Users

## Benefit



- More timely and accurate mission decisions based on current information achieved through asynchronous, distributed collaboration tools (C2 down to individual warfighter)



- Improved mission planning and execution through networked asynchronous, distributed team collaboration tools.