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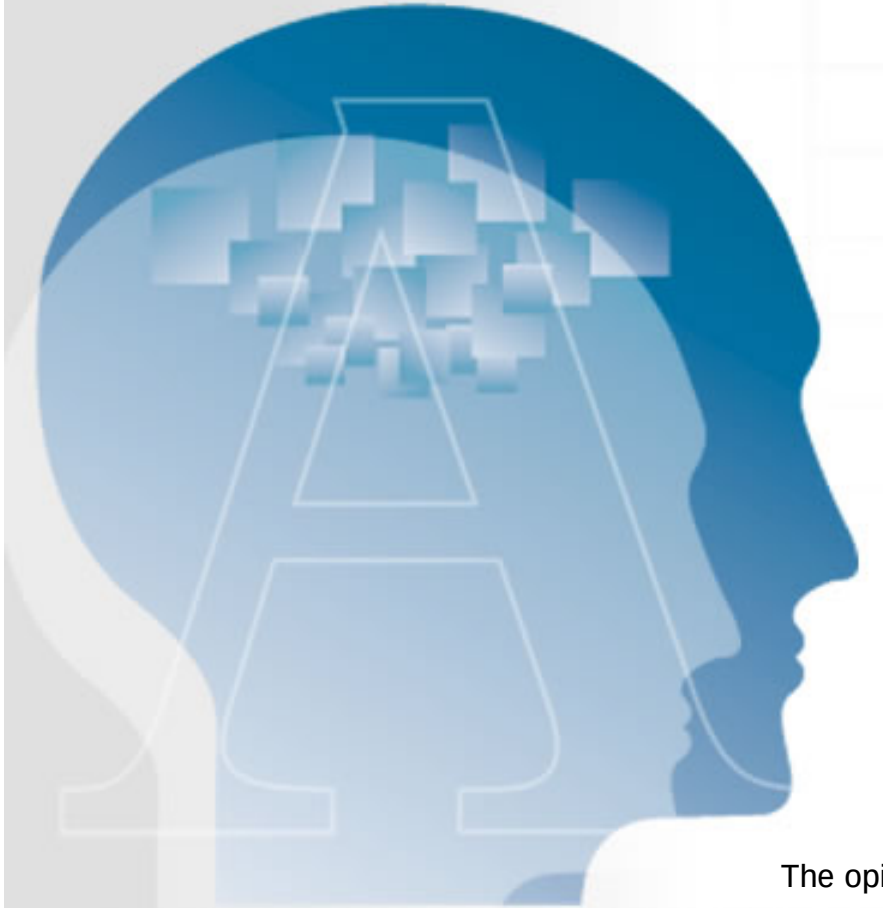

Collaborative Critical Thinking

Jared Freeman, Ph.D., Daniel Serfaty, Jean MacMillan, Ph.D., Kathy Hess, Ph.D., Beth Littleton, Ph.D., **Aptima**

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Pacific Science & Engineering

Collaboration and Knowledge Management Workshop

January 14 – 16 2003

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Agenda

- Motivation & Objectives
- Collaborative Critical Thinking (CCT) defined
- Conceptual Model
- Experiments
- Planned CCT Technology and Training Products

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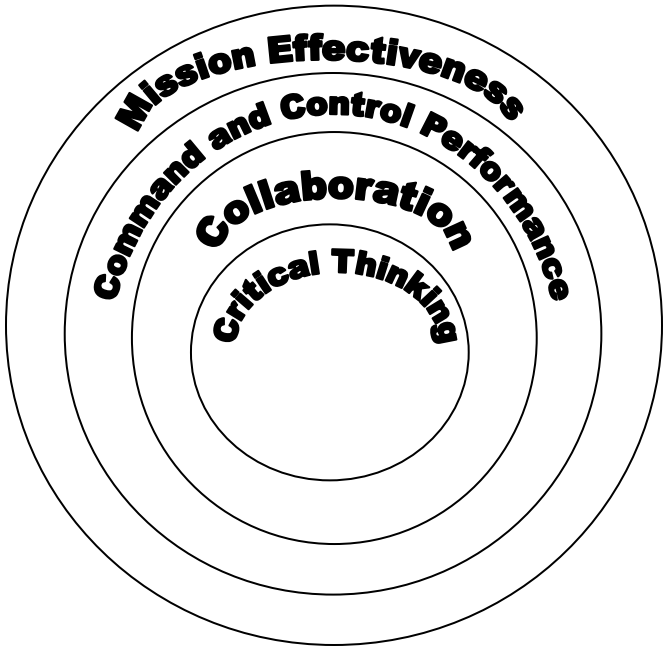
Motivation & Objectives

- Goal: effective collaboration
  - Collaboration at a distance—enabled by network connectivity— is central to 21st century Command and Control
- Collaboration technology capabilities have outpaced understanding of collaboration
- Need insight into the cognitive processes involved in effective collaborative in order to best design and use the technology
- Our focus: collaborative critical thinking.
- Our objectives:
  - Define,
  - Measure, and
  - Strengthen CCT w/ tools and training



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Examples

- Template
  - Team Member A: **States assessment**
  - Team Member B: **Proposes alternative assessment**

- Transcript:
  - Mike: **Study Thomas's use of the US Calvery with repeating firearms** in the battle of Nashville. Especially the follow-up where Hood's army was totally destroyed as a fighting force.
  - Robert: As for the Battle of Nashville, a much better point is **don't let your commander become a opium addict**. Much of what was left of the Army of Tennessee had already been squandered on the useless assualts at Franklin. While Thomas did a commendable job of defeating the remains, the issue was hardly in doubt.

- Source: sci.military newsgroup

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Examples

- Template
  - Team Member A: **Monitors for risk**
  - Team Member B: **Identifies source of risk**
  - Team Member A: **Concurs**

- Transcript:
  - Harriet: **It looks like one subject was sort of pulling it up there...**
  - Sam: Yeah, there's one slow subject, uh or two at the end.
  - Keith: **Well you could have a selection effect**. In that ...
  - Sam: ... in the examples...
  - Keith: **Slower subjects in the example condition, because they fail.**
  - Sam: That's correct, uh yeah.

- Source: Chris Schunn, Ph.D., LRDC

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Examples

- Template
  - Team Member A: **Monitors for risk**
  - Team Member B: **Identifies source of risk**
  - Team Member B: **Plans investigation of source of risk**
  - Team Member A: **Prompts for contingency plan**
  - Team Member B: **Proposes contingency plan**

- Transcript:
  - Mike: We need to redirect our friendlies to account for **SAM A34's relocation**.
  - Gavan: Ok. **I thought this SAM was fortified, stationary**.
  - Mike: Negative. ComInt has just reported that the SAM is moving.
  - Gavan: I see it. **Didn't ELINT and IMINT report no movement** and no support? Doesn't COMMINT get their information from the other two?
  - Mike: That's my understanding, but I will confirm that.
  - Gavan: So, **we should check back to make certain these reports are correct**. Why don't you check back with IMINT and I'll check back with ELINT to verify this information. We still have a bit of time. Ask them how conclusive their information is. How did they decide this SAM would not move?
  - Mike: **Shouldn't we decide on a time to abort the mission** or at least to make a final call?
  - Gavan: Yes. Probably the safest thing to do would be to **cancel the mission if we aren't certain about that SAM**. We can't reroute. Let's huddle no later than 0500 and make a final call no later than 0600.

- Source: Aptima intelligence scenario

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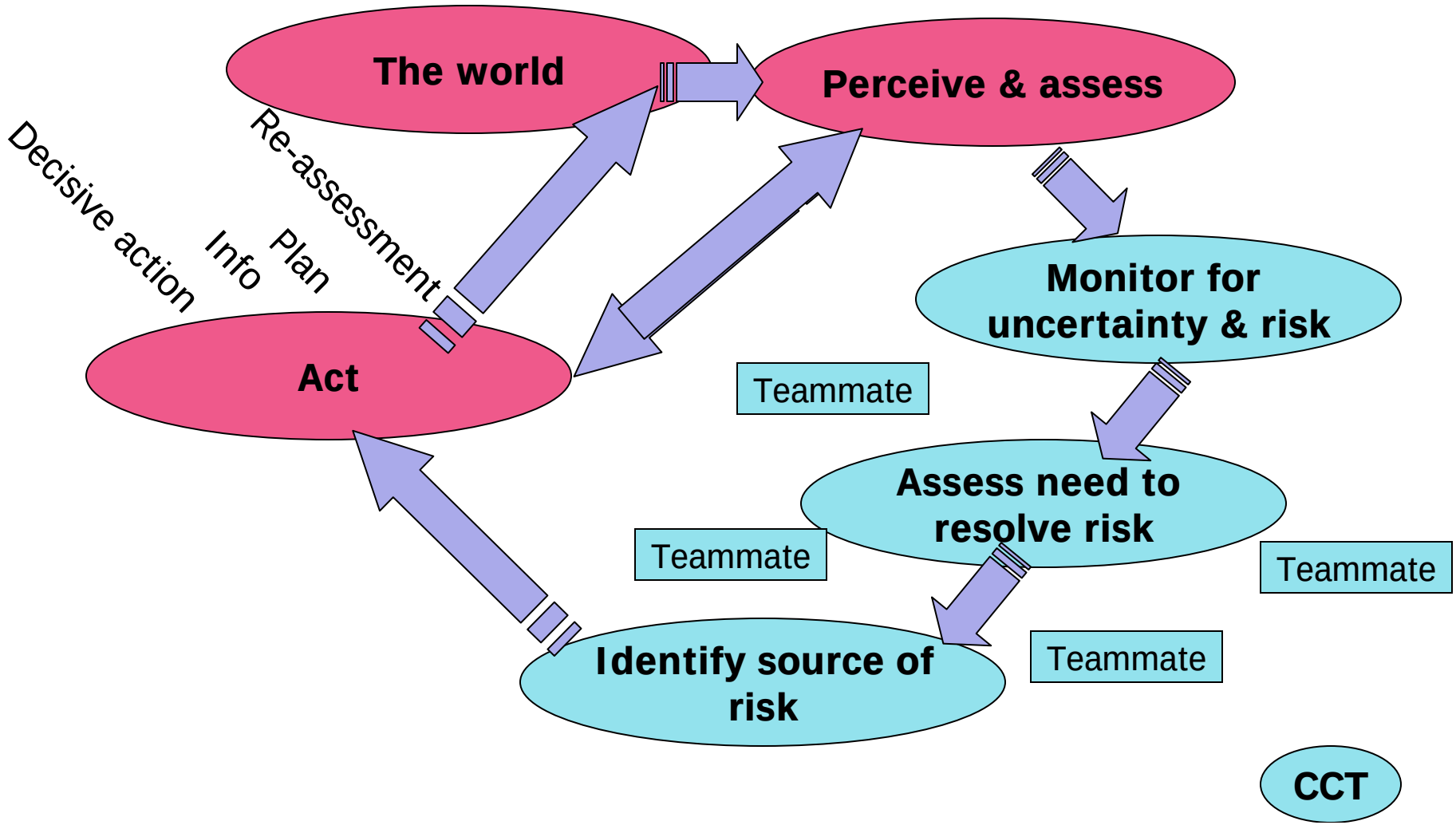
What is Collaborative Critical Thinking?

- Collaborative Critical Thinking (CCT) is an interactive process for evaluating and refining assessments, plans, and teamwork



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Characteristics of Collaborative Critical Thinking

- **Interactive** – CCT is collaborative
- **Evaluative** – CCT involves:
  - Monitoring & perception for risk or uncertainty
  - Assessing the priority of addressing this risk (given other tasks)
  - Identifying source(s) of risk or uncertainty (assumptions, gaps, conflicts)
- **Productive** – Leads to action that bear on:
  - problem assessment ... reframes the problem
  - problem solutions
    - Gathering information by probing, testing, waiting
    - Eliminating the problem (e.g., an enemy outpost)
    - Developing contingency plans
  - team state, process, and structure
  - team CCT skills
- **Distributed** – CCT may be conducted by teams distributed over space or time. Critical factors:
  - Conduits for communication and collaboration
  - Transactive memory (of who said what, did what, can do what)
  - Public representations of problem state and (transaction) history
- Addresses **ill-defined problems** – No agreed upon method or answer

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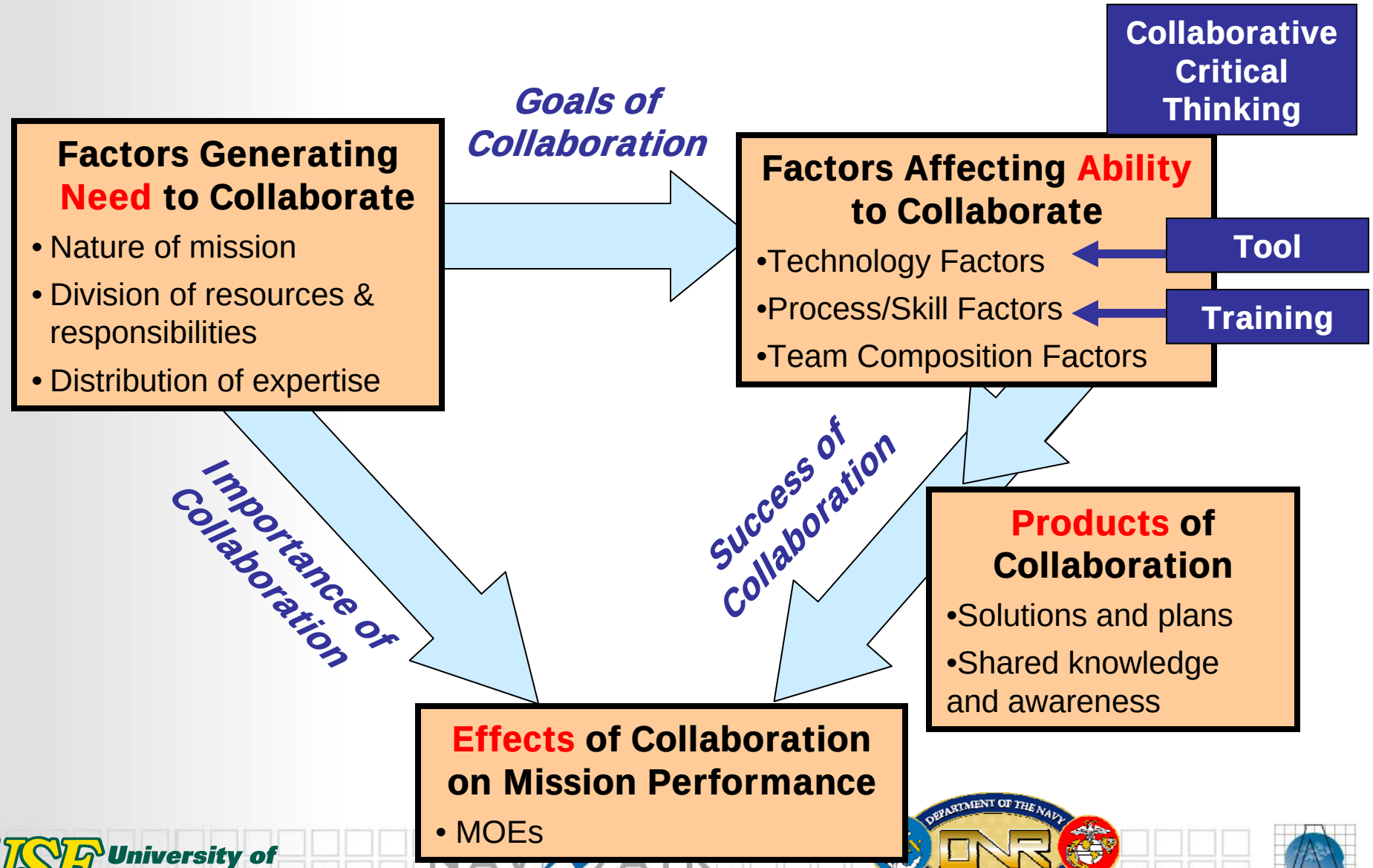
Conceptual Model



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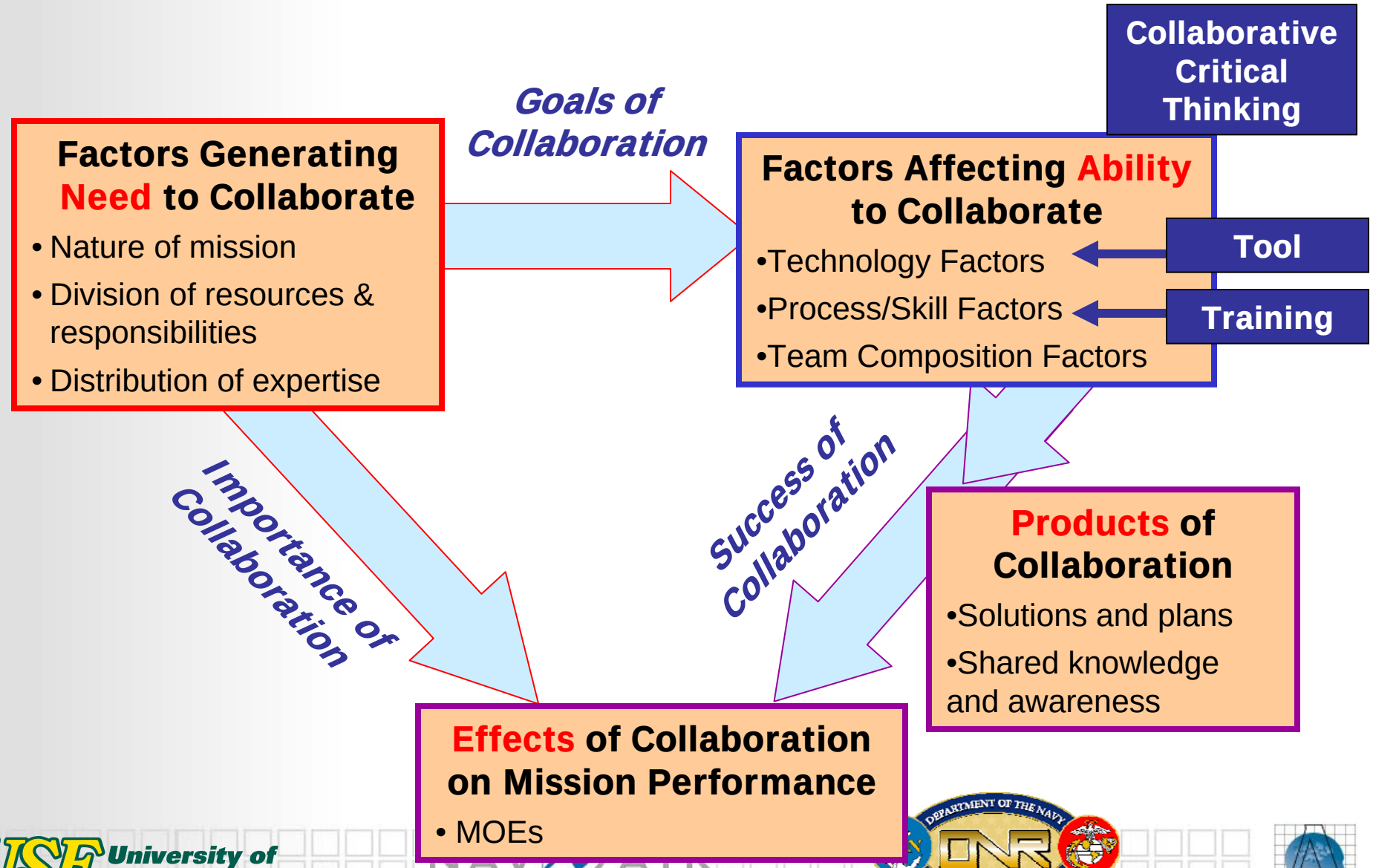

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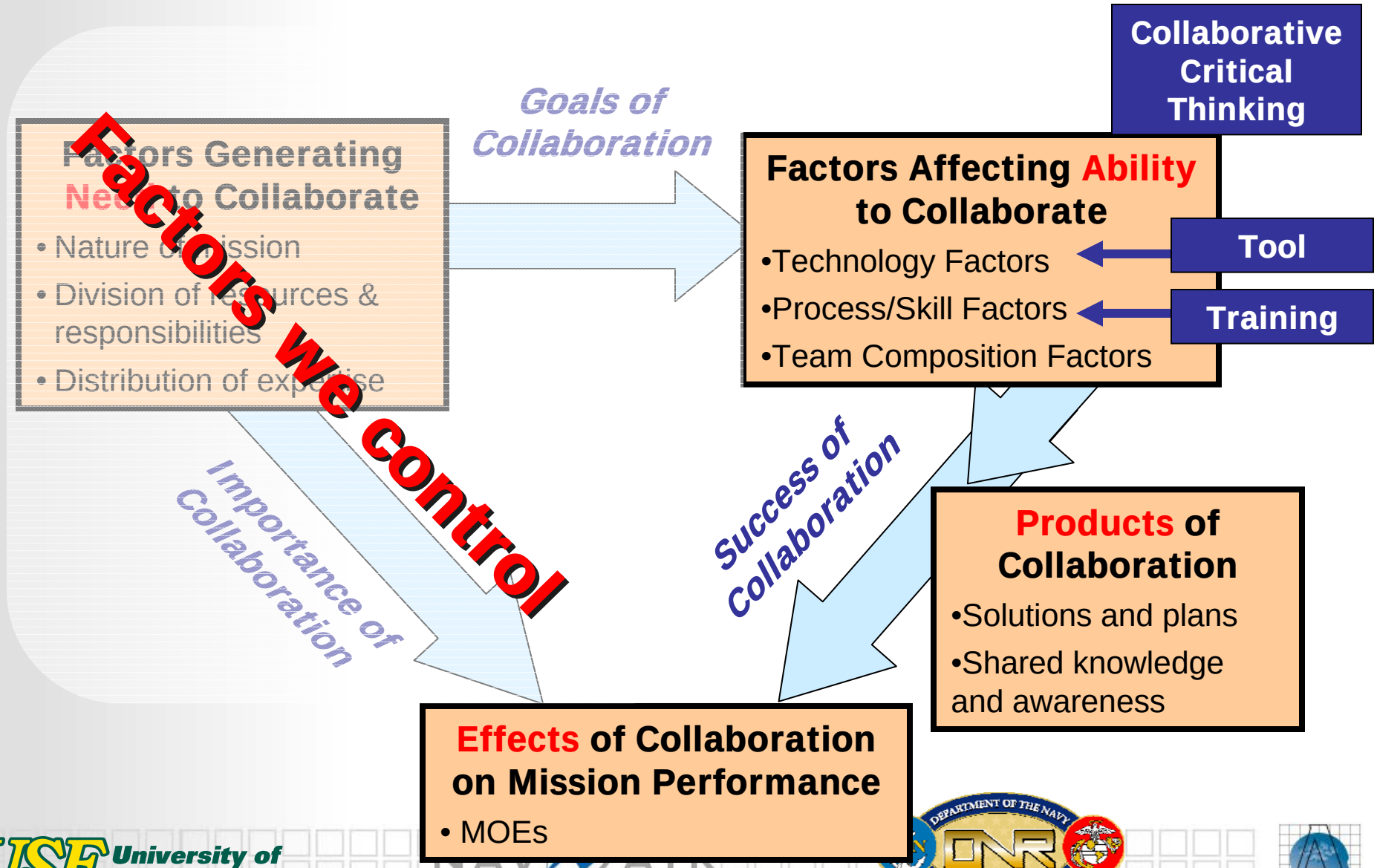

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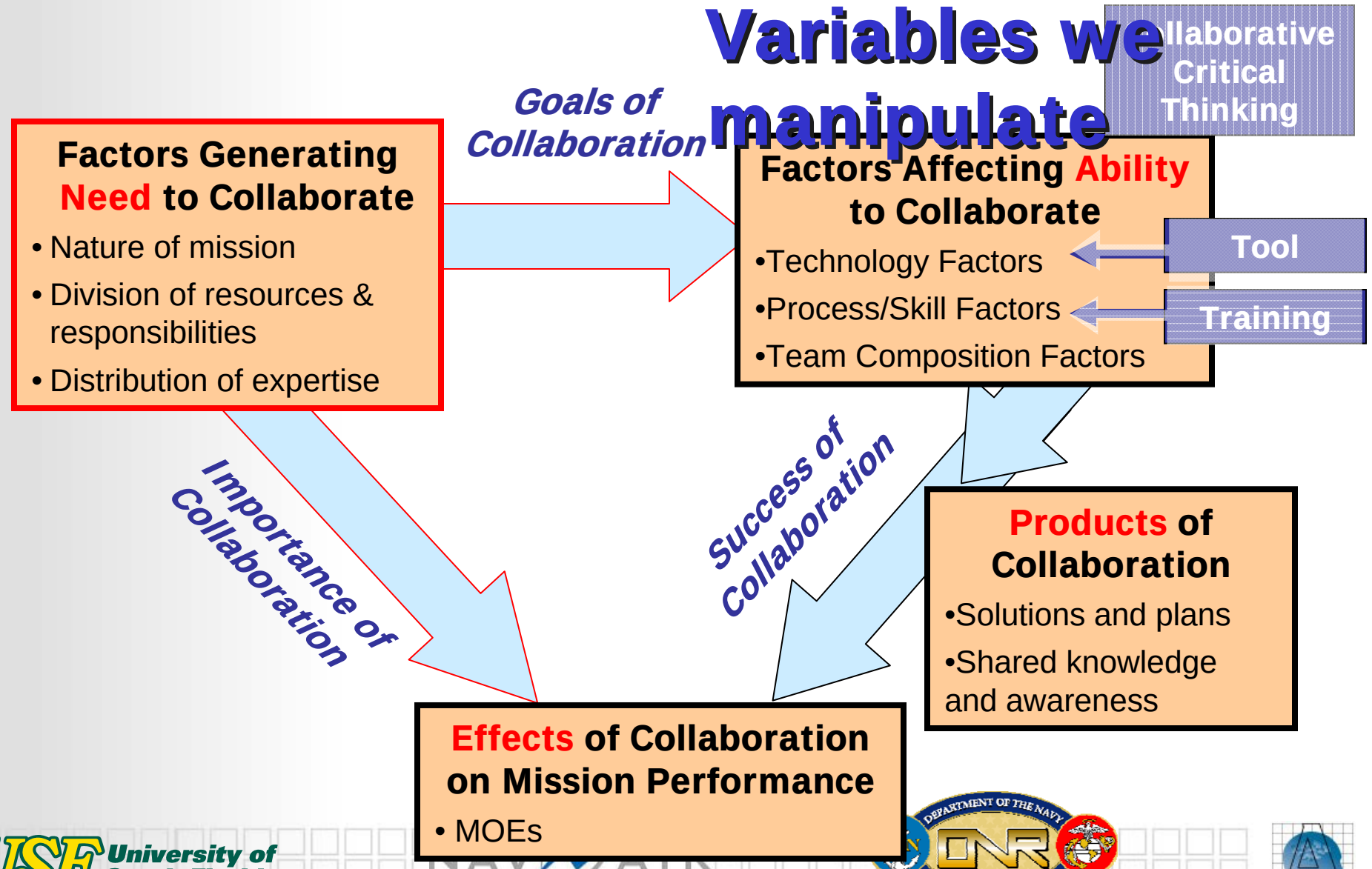

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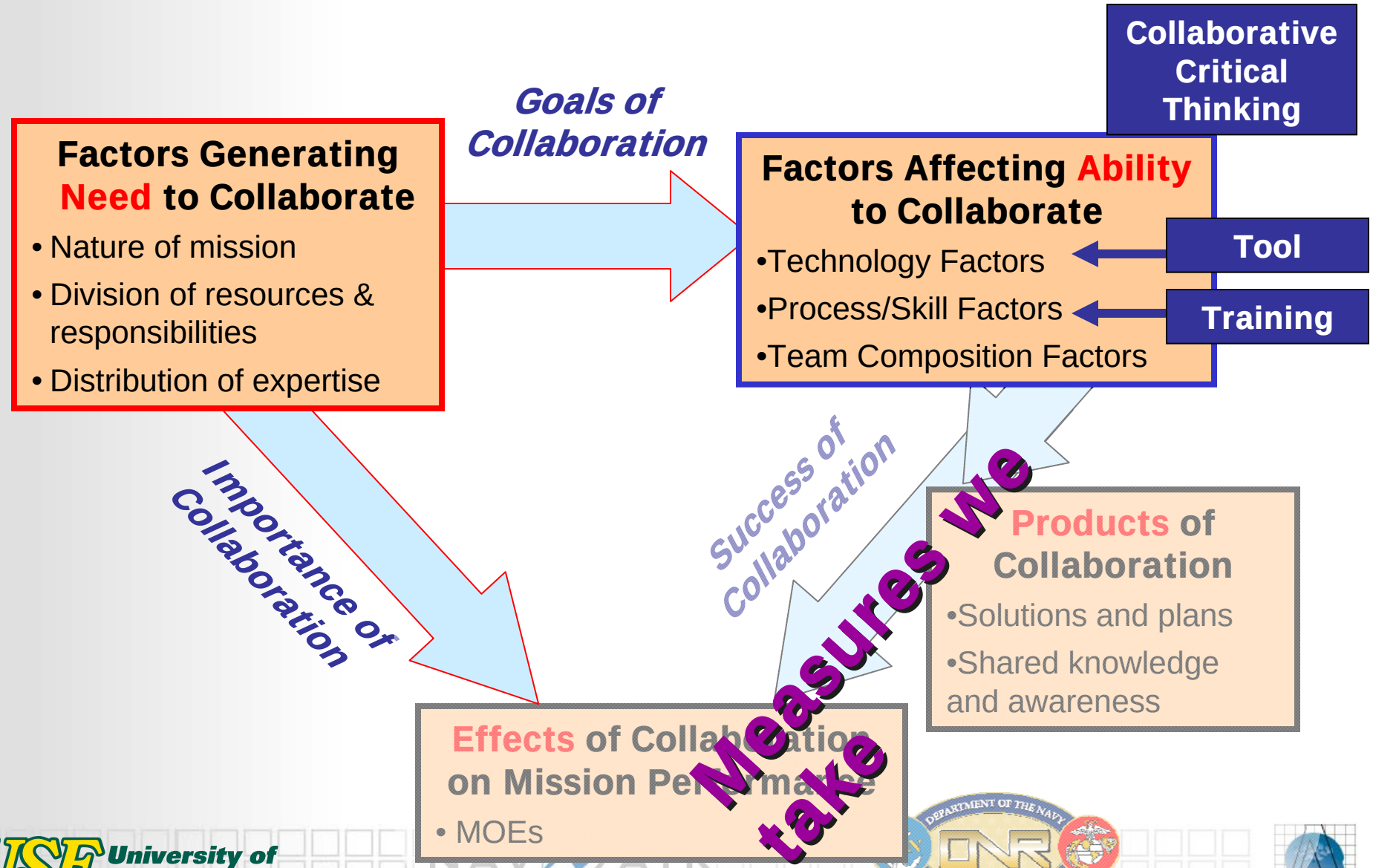

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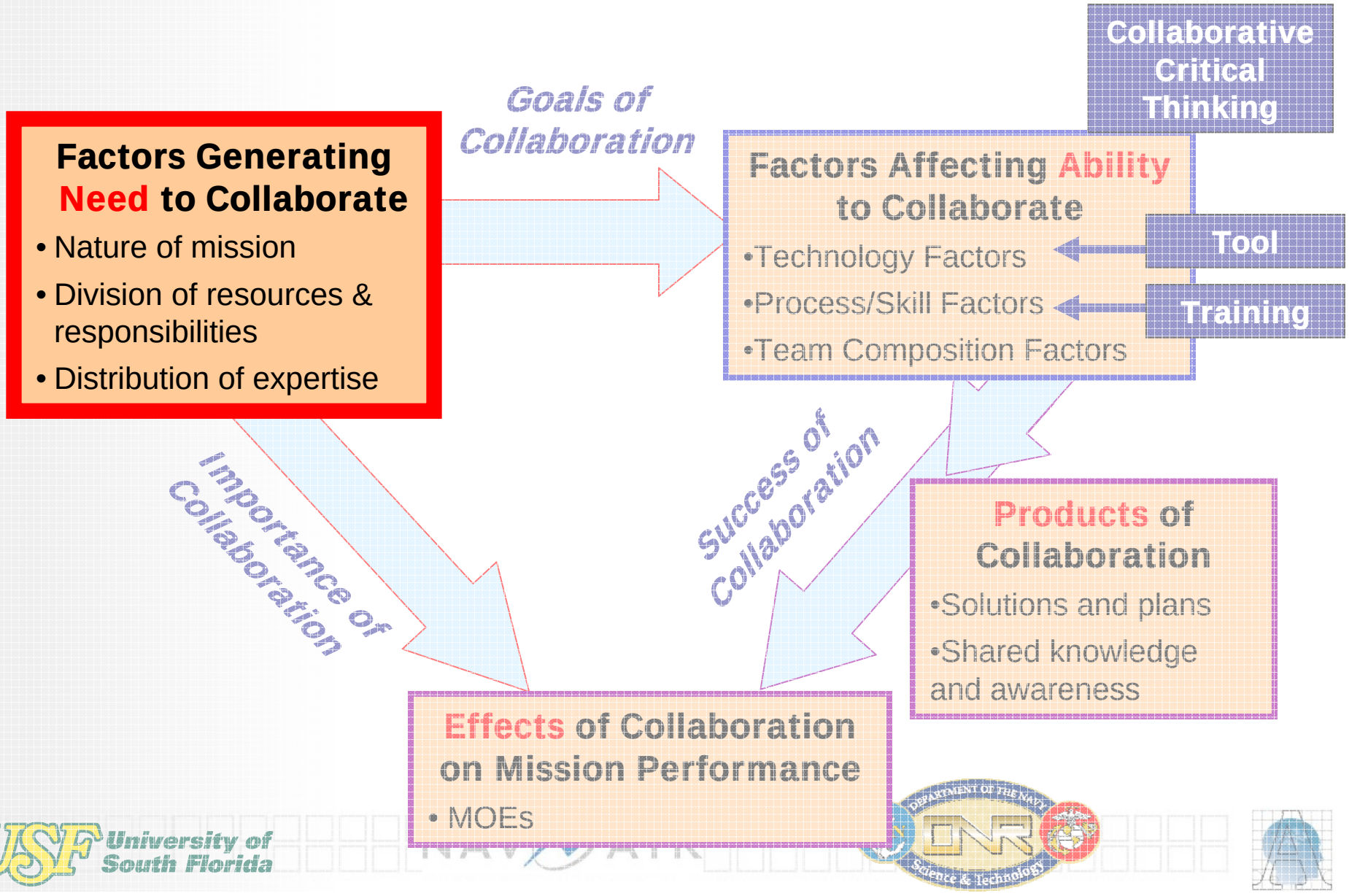
Factors we Control



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Factors We Control

Factors Generating Need to Collaborate

- Nature of mission
- Division of resources & responsibilities
- Distribution of expertise

- Mission is complex and time sensitive
- Resources & responsibilities are divided among team members
- Expertise is distributed between team members

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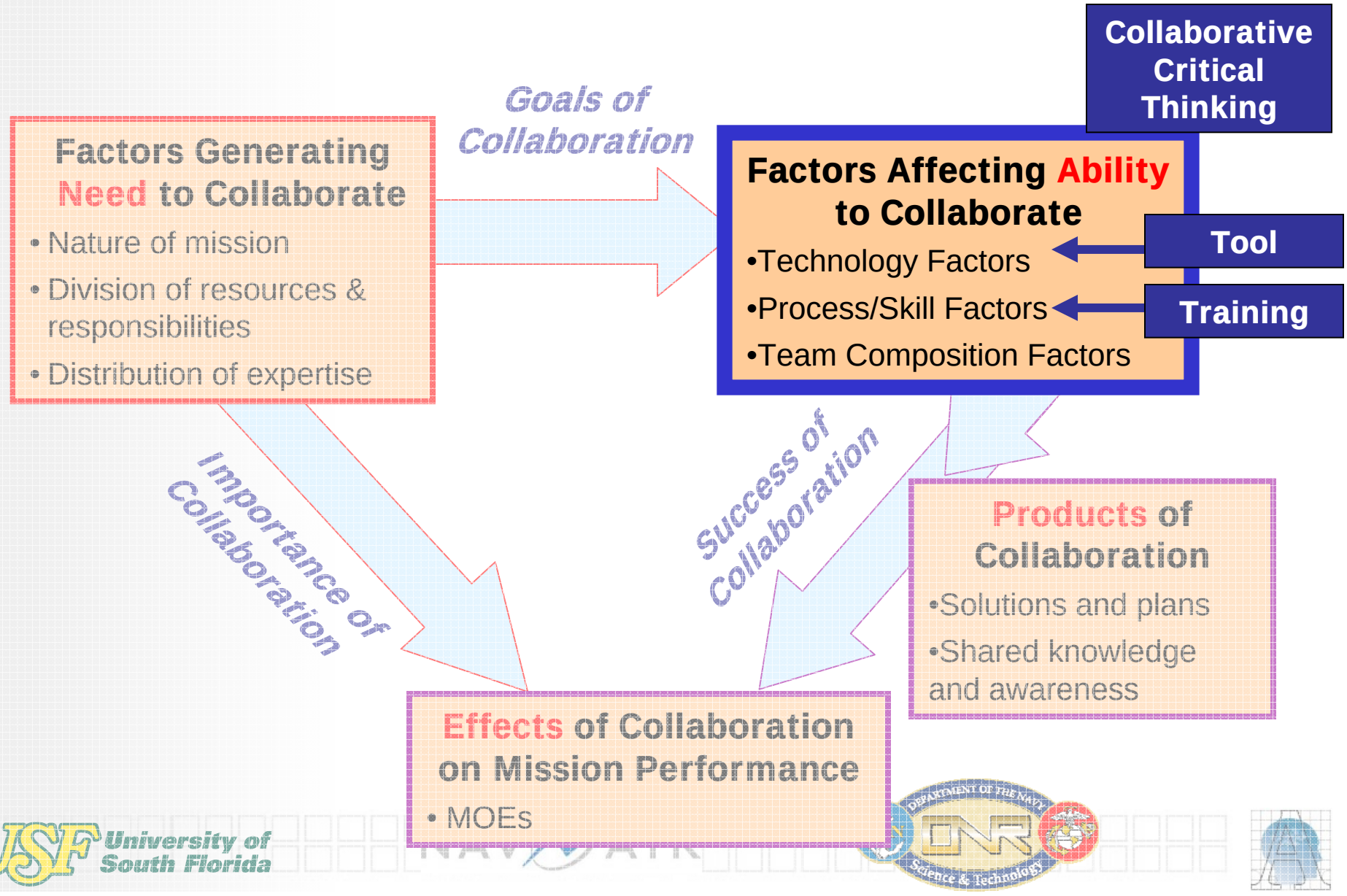
Variables We Manipulate



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Variables We Manipulate – Tool

Factors Affecting Ability to Collaborate

- **Technology Factors**
- Process/Skill Factors
- Team Composition Factors

Collaboration technology measures	Reach: Team connectivity	Interconnectivity of team members to each other ("Communities of interest")
	Reach: Information connectivity	Interconnectivity of team members to information sources ("Information access")
	Reach: Translation	Degree to which tool supports translation between representations, domains, and languages
	Richness: Structured problem representation	Degree to which the tool provides structured representations of the problem at hand
	Richness: Deconfliction	Degree to which the tool supports coordination of activities via a shared workspace

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Variables We Manipulate – Training

Factors Affecting Ability to Collaborate

- Technology Factors
- **Process/Skill Factors**
- Team Composition Factors

CCT process measures	Planning for TC^2T	Collaboration communications (e.g., paraphrasing others, explicit statement of monitoring plans & critieria) during planning stage.
	Monitoring	Number of critiques initiated concerning high priority issues
	Diagnosis	Number of gaps, conflicts, and untested assumptions identified
	Action	Instances of probing own resources for data, testing enemy or environment for data, intentionally waiting out problem

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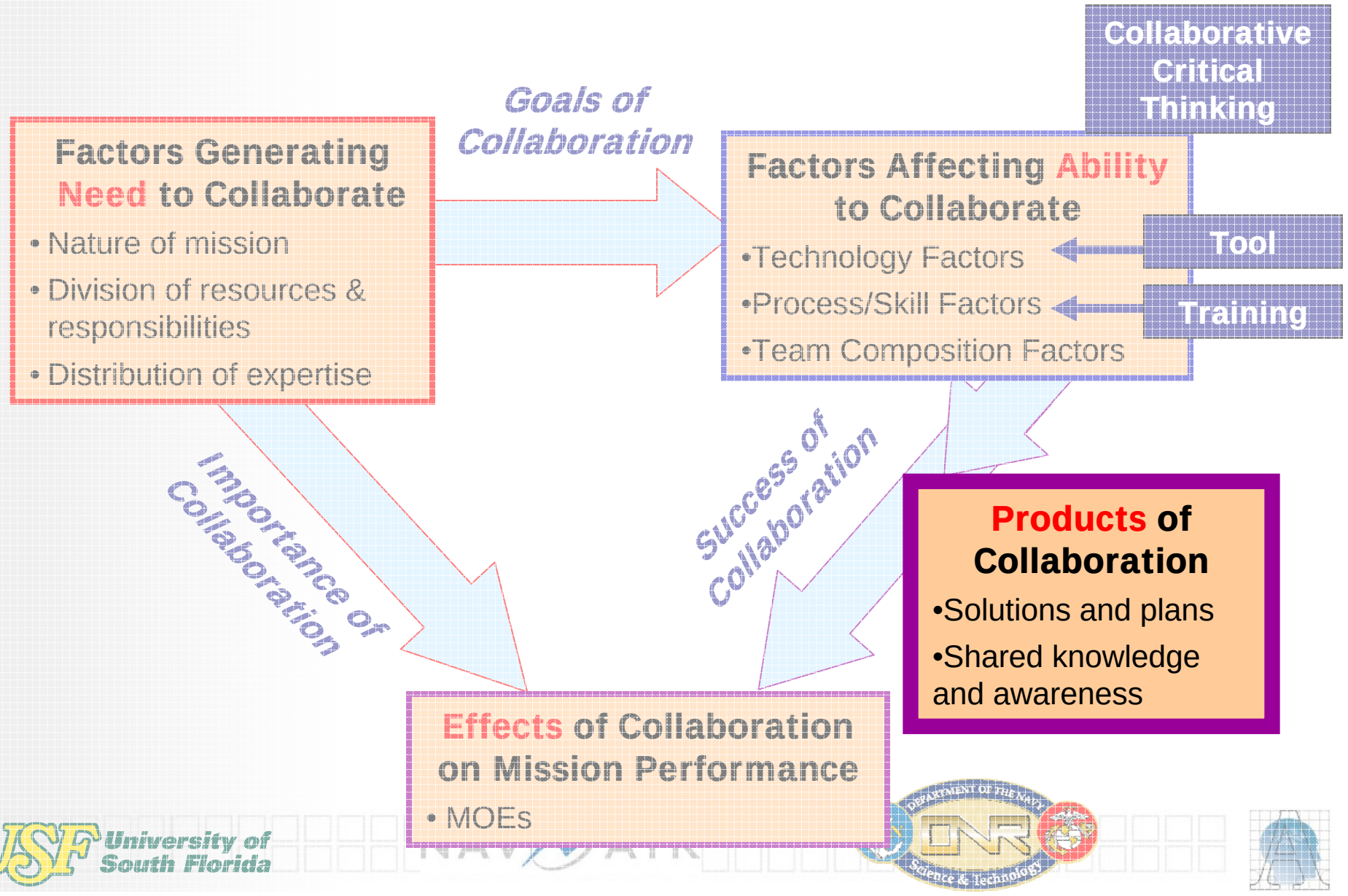
Measures We Take



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Measures We Take

Products of Collaboration

- Solutions and plans
- **Shared knowledge and awareness**

Shared awareness measures	Shared situation awareness	Degree to which team members share memory for current location of objects in the tactical picture
	Shared predictions of future situation	Degree to which team members share predictions of the location of objects in the tactical picture
	Shared situation assessment	Degree to which team members share assessments of the intent of entities of operational interest
	Mutual awareness of goals	Degree to which team members express shared goals
	Mutual awareness of information needs	Degree to which team members anticipate the information needs of teammates
	Mutual awareness of next action(s)	Degree to which team members anticipate the actions of teammates
	Mutual awareness of workload	Accuracy with which team members estimate the subjective workload of teammates

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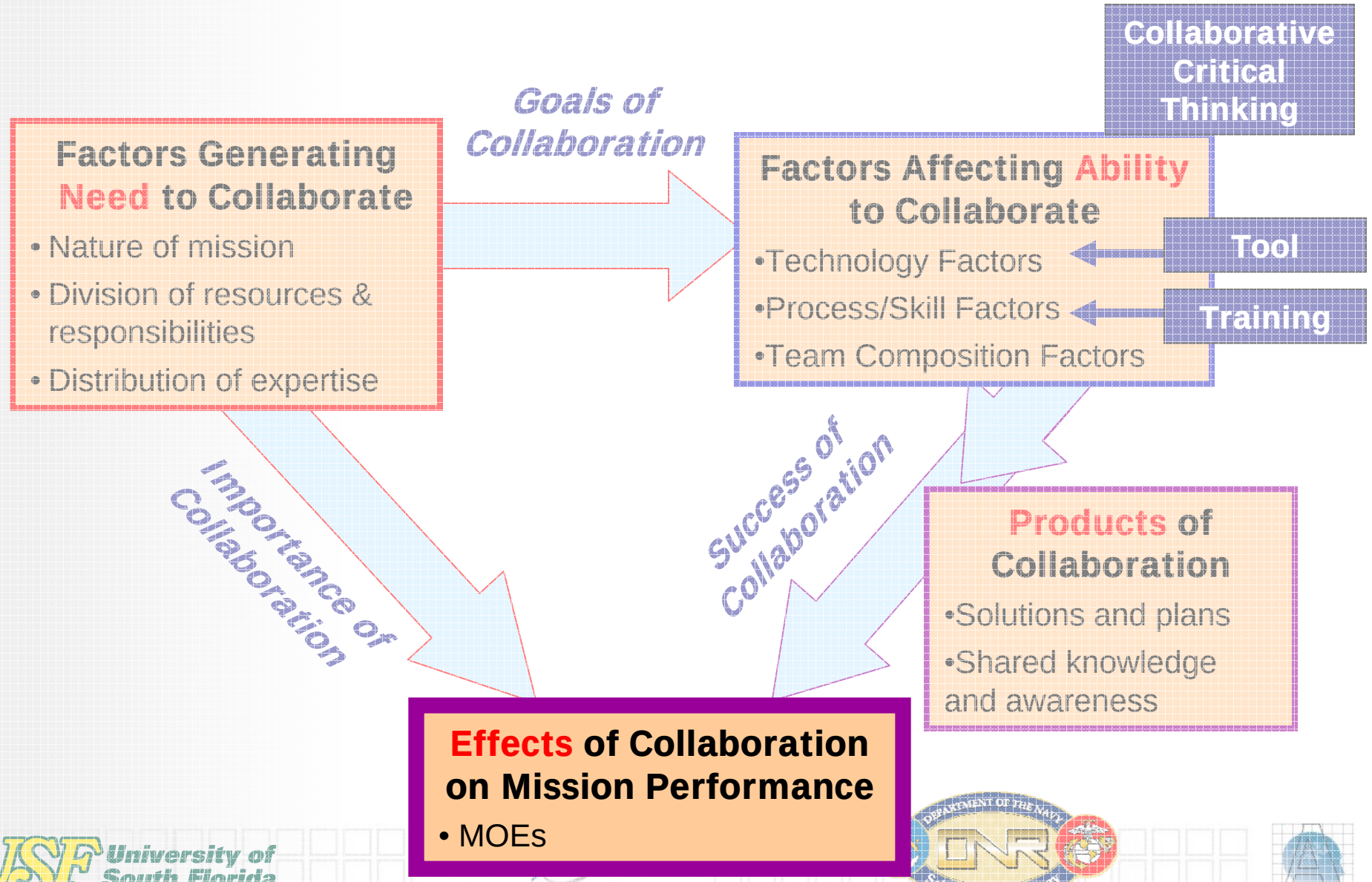
Measures We Take



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Measures We Take

Effects of Collaboration on Mission Performance

- MOEs

MOEs	Synchronization: Allocation	Proportion of tasks executed without conflicts in resource allocation
	Synchronization: Execution	Proportion of tasks requiring coordination that are successfully executed
	Synchronization: Precision	Lag in readiness for execution of synchronized events between first and last operator ready to act.
	Effects: Enemy losses	Proportion of targets or threats destroyed
	Effects: Friendly losses	Proportion of friendly forces destroyed or lost
	Effects: Delay in enemy ops	Latency in enemy maneuvers or actions (e.g., bombing targets) due to friendly actions
	Effects: Team process	Average delay in task execution relative to optimal task execution schedule

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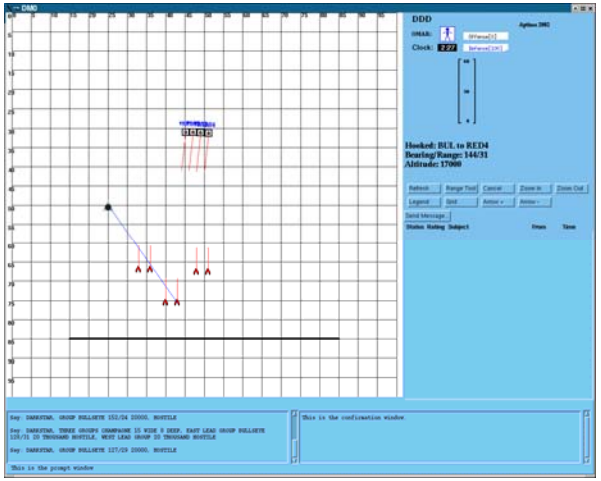
Draft Experiment

- Hypotheses
  - H1: CCT tools and/or training **improve shared awareness of uncertainty and risk**. (Ability/Process)
  - H21: CCT tools and/or training **increase the incidence of CCT behaviors.** (Ability/Process)
  - H3: CCT tools and/or training **improve the team plans**. (Products)
  - H4: CCT tools and training **improve mission execution and outcomes**. (Effects)
- Materials: Military scenario in which
  - some aspects of the situation are well defined, others are not.
  - some risks can be reduced by information gathering or probing
  - some risks cannot be reduced and require contingency plans
- Testbed: Distributed Dynamic Decision-making (DDD) Simulation
  - Team research testbed
  - Collaboration measurement capability
  - Developed at U.Conn, freely available, used at 25 labs
- Subjects: ROTC and undergraduate students
- Method:
  - Pretest domain knowledge & critical thinking ability
  - Scenario (re)planning phase ←→ execution phase
  - Real time measures of CCT
  - Posttest measures of CCT
- Analysis: Multi level modeling supports analysis of group, individual, their interaction (individual on this team), and error for group and individual



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Tool Development

- Hypothesis:
  - Team awareness of deficits in shared awareness (regarding, e.g., risk involved and predicted outcomes) enable teams to improve awareness and mission effects.
- Tool will help the team evaluate its state and identify opportunities for critical thinking
  - Each team member will answer questions about the risk involved and the predicted outcomes
  - These values will be combined to calculate the team's mutual awareness of risk and predicted outcomes

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Is target localized?

|1|------|2|------|3|------|4|------|5|

Is target identified?

|1|------|2|------|3|------|4|------|5|

Are munitions correct for given target?

|1|------|2|------|3|------|4|------|5|

Is airspace deconflicted?

|1|------|2|------|3|------|4|------|5|

What is the probability that we will kill?

|1|------|2|------|3|------|4|------|5|

What is the probability that we will lose one of our assets?

|1|------|2|------|3|------|4|------|5|

Is target localized?
|1|------|2|------|3|------|4|------|5|
Is target identified?
|1|------|2|------|3|------|4|------|5|
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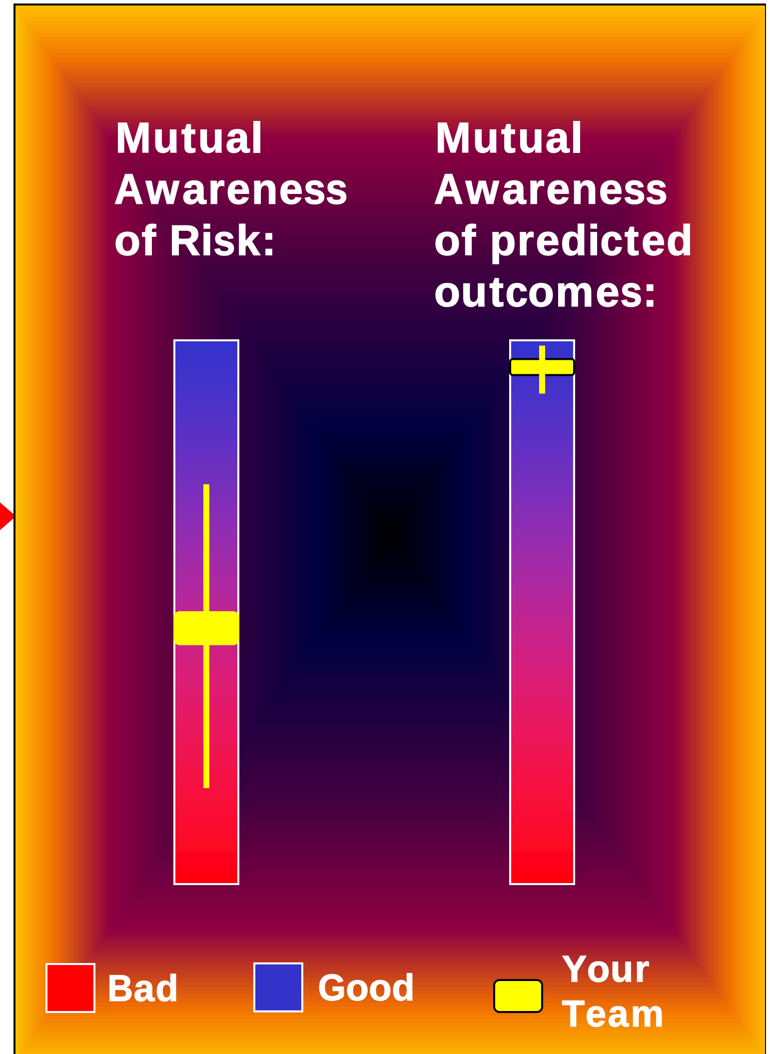

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Training Development

- Hypothesis: CCT training will help teams to:
  - Identify the triggers in the situation that require CCT
  - Weigh benefits of engaging in CCT across all priorities
  - Exercise their CCT faculties to improve plans
- Possible training topics:
  - Domain-independent CCT
    - Training in devil's advocate strategies
    - Training in appropriate situation for CCT (e.g., need for high quality, with relatively little time constraints)
  - Domain-specific CCT – Train to identify and critically evaluate problem. E.g., determine why there are problems localizing enemy. Is it caused by:
    - deliberate deception by enemy
    - Reliability of source
    - Stale data

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Project Timeline

28 August 2002 through 27 August 2004

				Schedule							
Task Type	**Task ID**	**Task Name**	**Sponsor**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
Main	1	**Develop model**	ONR								
Option	2	**Develop measures**	ASD (C3I)								
Option	3	**Prototype assessment tool**	ASD (C3I)								
Main	4	**Design TC2T intervention**	ONR								
Main	5	**Experimental validation**	ONR								
Option	6	**Visualization/assessment tool**	ONR								
Option	7	**TC2T Training tool**	ONR								
		Briefings to the clients									
		Progress reports (quarterly)									

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Questions? Comments?

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Background Materials

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Project Summary

- Title: Collaborative Critical Thinking
- Jared Freeman, Ph.D., P.I.
  - Aptima, 1030 15th Street NW, Washington, DC 20005
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- Objectives
  - A fundamental goal of military is to ensure that C2 organizations operate decisively and synchronously in highly uncertain and dynamic settings. Individuals succeed in these settings by thinking critically, that is by critiquing their understanding of the situation at hand, refining their knowledge, and adapting their decision making and planning to the problems at hand. This project proposes that individual team members collaborate in their application of critical thinking in a process called "team critical thinking". The project will develop the concept of collaborative critical thinking within C2 teams from three research threads concerning: individual critical thinking, team process and architecture, and human performance in information age warfare. These research threads will be woven together to create a theory, validated measures, and tools and techniques that help understand and support team critical thinking. The team collaboration and critical thinking theory will help explain how teams critique their understanding of the current situation. It will illustrate how teams incrementally refine their shared assessments and plans or radically revise their beliefs and conceptual frameworks. In addition, the theory will help explain how teams turn their critical faculties on themselves to assess and adapt the fit of team processes and team structure to the situation at hand.
  - Based on these measures, training, tools, procedures and team architectures that improve team critical thinking will be developed. The end product will be a solid foundation in theory, measurement, and practical support for improving C2 teams as they confront the challenging and varied missions of the 21st century.
- Research Questions
  - What are the behavioral markers of collaborative critical thinking?
  - How can CCT behaviors and their effects be reliably measured in a semi- or fully automated fashion?
  - Can we promote CCT behaviors with training and job aids?
- Project Status
  - Two theoretical frameworks have been developed, one concerning collaboration generally, and the other addressing the role of CCT within collaboration.
  - A set of measures has been drafted that addresses several aspects of collaboration and CCT.
  - Design discussions are underway for experiments, tools, and training

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