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Modeling for Future Command and Control Architectures

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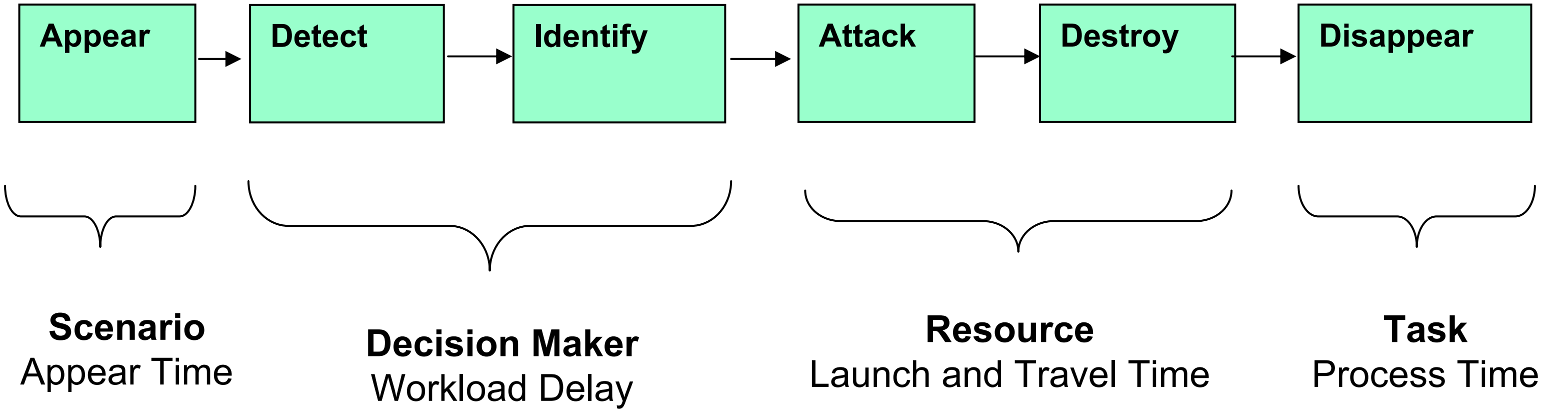
Introduction

- Models can be used to predict and evaluate the behavior and performance of proposed command and control architectures
    - Arrangement of resources, decision makers, and responsibilities.
- A previously developed Decision Maker model focused on the interactions of decision makers required to complete tasks
    - Information on how specific decision makers behaved during task completion.
- A Task Process model was developed for a recent subject experiment that focused on the stages of a task as it was completed
    - Information on how specific tasks were completed by different architectures.
- Combining these models results in a more sophisticated model that allows complex tasks requiring multiple decision maker interactions
    - Develop surrogates for current metrics of interest
        - Speed of Command and Shared Situation Awareness.

Task Process Model

- The Task Process model explicitly represents the stages of the task process
  - Each task is represented and evaluated separately.
- The model was developed to exploit the data recorded by a simulator used for subject experiments
  - The stages are from Dynamic Distributed Decision-Making Simulator
  - The simulator records task timing information for each task at different task stages.
- Each stage of the sequential model has a delay determined by the attributes of the task, decision maker, or resource.
- The output of the model is a task completion time for every task in the scenario.
- The model was developed and validated using experimental data.

Task Process Model



Appear → Detect → Identify → Attack → Destroy → Disappear

Scenario
Appear Time

Decision Maker
Workload Delay

Resource
Launch and Travel Time

Task
Process Time

<u>Task Completion Time:</u>

$$t_{output} = t_{appear} + t_{detect} + t_{identify} + t_{attack} + t_{destroy} + t_{disappear}$$

<u>Task Delay Time:</u>

$$t_{delay} = t_{output} - t_{appear}$$

Limitations of the Single Task Model

- The performance of the model was validated by correlating the model output to the experimental output
  - The average correlation between the model data and the experimental data was .86.
- However, there was a discrepancy between the model data and the experimental data for some of the results
  - The experimental data indicated that often tasks were interrupted in the middle of the process, and then resumed later on,
  - The model, once initiated, continued uninterrupted through the process.
- Secondly, many of the tasks in the scenario required the interaction of one or more decision makers in order to execute
  - These were not included in the model simulation.

Task Process Interruption: Sample Experimental Data

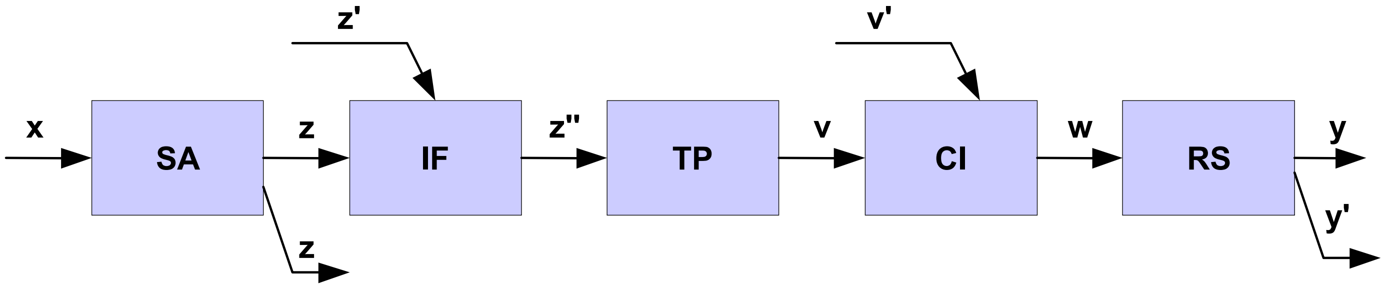
	Arrive	**Detect**	**Identify**	***Select***	**Attack**	**Destroy**
Patrol Boat #218						
Team MA	370	371	372	430	434	439
Team MC – Interruption	370	371	372	584	588	593
Air Attack #406						
Team SA	1251	1254	1322	1340	1342	1347
Team SE – Interruption	1251	1254	1322	1380	1389	1394

Decision Maker Synchronization: Sample Experimental Data

Stage	Time	DM	Resource
04-Select	1726	2	
04-Select	1756	3	
11-Attack	1759	2	SOF-500
12-Assist	1761	3	SOF-501
18-Destroy	1789	2	

Five Stage Interacting Decision Maker

- The Decision Maker model explicitly depicts the stages at which a decision maker can interact with other decision makers or the environment while processing a task.
- A decision maker need not exercise all five stages when performing a task
  - Depending on the inputs and outputs required, a decision maker can instantiate different subsets of the five stage model.

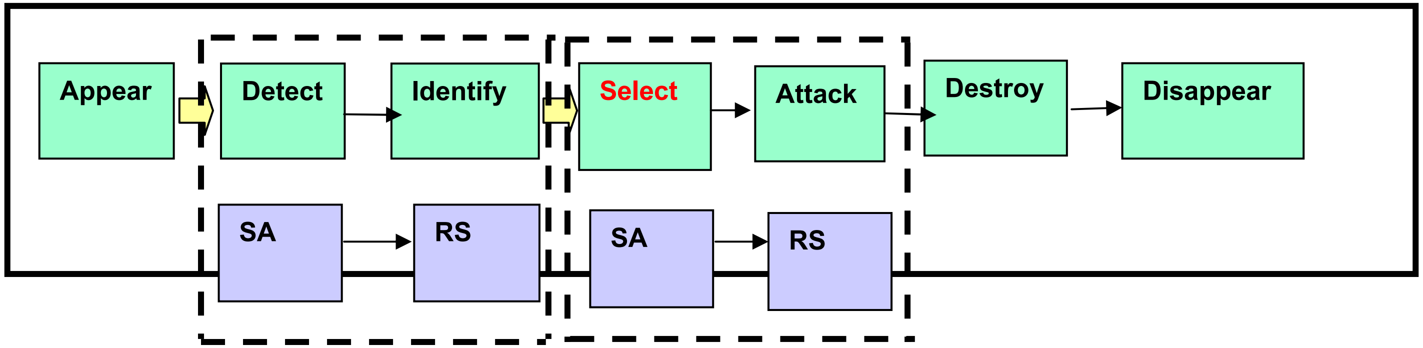


Modeling Task Interruption

- In order to represent task interruption in the model the relationship between the decision maker model and the task process model must be made explicit
  - It is the decision maker that causes the interruption.
- Associate the Task Process *Detect – Identify* stages
  - ➢ with the Decision Maker *Situation Assessment – Response Selection* stages
- Associate the Task Process *Select – Attack* stages
  - ➢ with the DM *Situation Assessment – Response Selection* stages

- Note that the Select stage was identified in the empirical data.
- Allows for two opportunities for variability based on Decision Maker workload.

Single Task Coupled with Decision Maker



Task Completion Time:

$t_{finish}` = t_{appear} + t_{detect} + t_{identify} + t_{select} + t_{attack} + t_{destroy} + t_{disappear}$

Task Delay Time:

$t_{delay}` = t_{finish}` - t_{appear}$

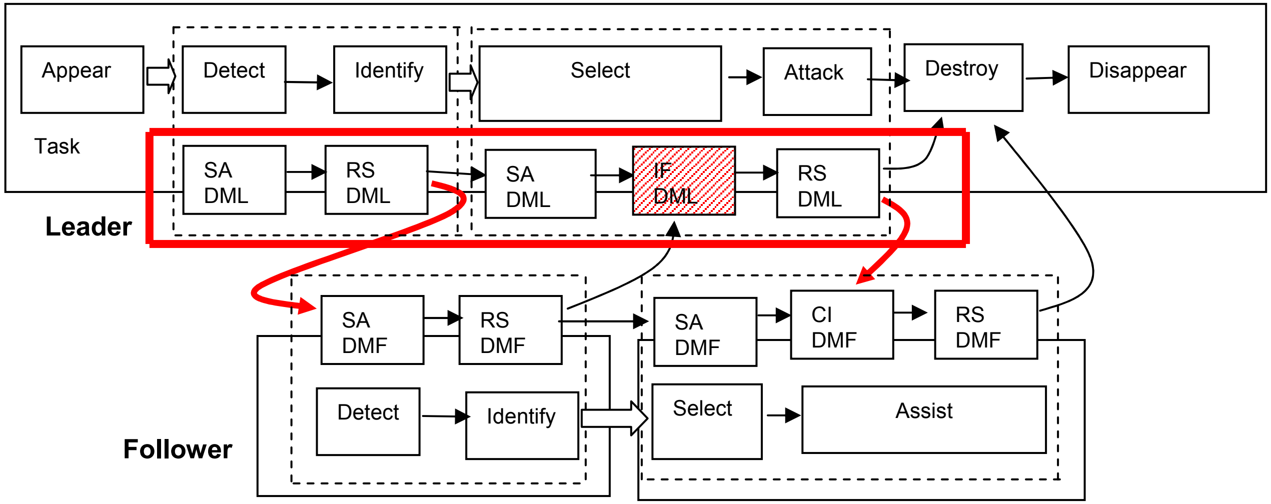
Decision Maker Synchronization

- In order to represent decision maker synchronization in the model the different *roles* a decision maker assumes in terms of the decision maker model must be made explicit.
- Independent Role – a decision maker acting on a task that he can execute without interacting with other decision makers.
  - Current Task Process Model

➢ Leader Role – a decision maker needs to interact with other decision makers to execute a task, however this decision maker sends the synchronization signal.

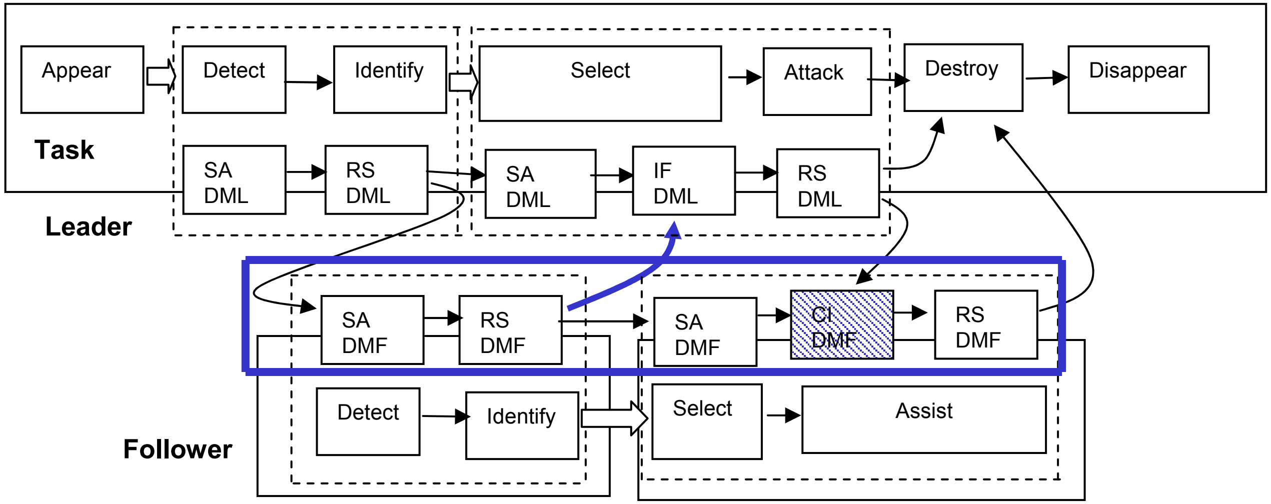
➢ Follower Role – a decision maker needs to interact with other decision makers to execute a task, however this decision maker waits for the synchronization signal.

Leader Role



- Leader Role – a decision maker needs to interact with other decision makers to execute a task, however this decision maker sends the synchronization signal
  - Detect – Identify => Situation Assessment – Response Selection w/ y' output
  - Select – Attack => Situation Assessment/Information Fusion – Response Selection w/ y' output

Follower Role

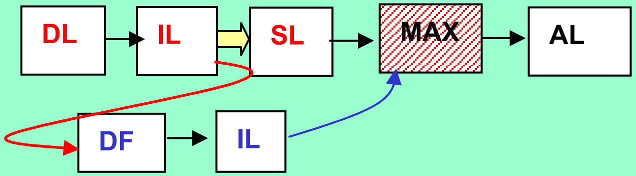


- Follower Role – a decision maker needs to interact with other decision makers to execute a task, however this decision maker waits for the synchronization signal
  - Detect – Identify => Situation Assessment – Response Selection w/ y' output
  - Select – Attack => Situation Assessment – Command Interpretation/ Response Selection

Speed of Command

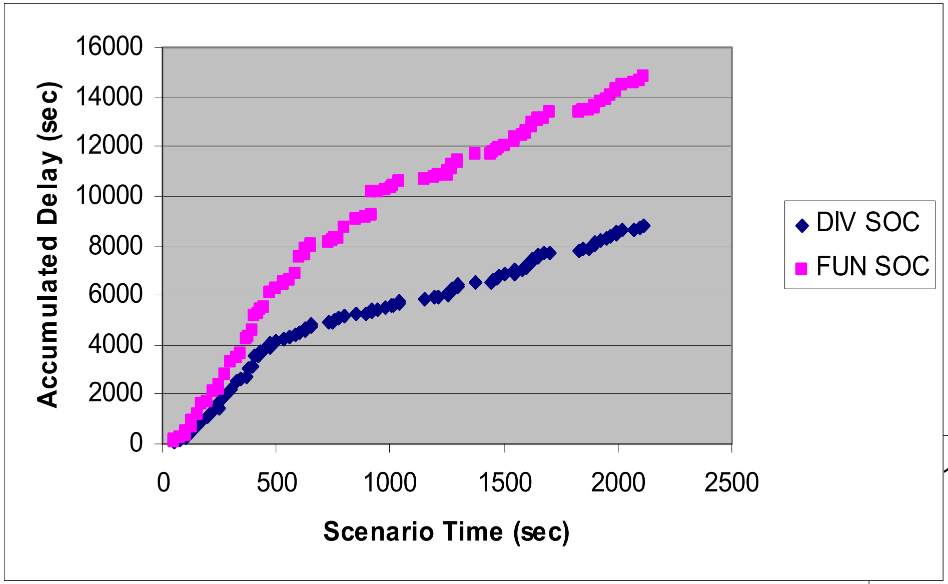
- Defined as the time from when a threat is detected until it is engaged.
- Surrogate measure is the task delay
  - The time from the detect stage to the attack stage.
- Use measure to evaluate different architectures in same scenario.

Task Completion Time:



$$t_{finish}{}^{``} = t_{appear} + \{t_{detectL} + t_{identifyL} + t_{selectL} + \max[0, (t_{detectF} + t_{identifyF}) - t_{selectL}] + t_{attackL}\} + t_{destroy} + t_{disappear}$$

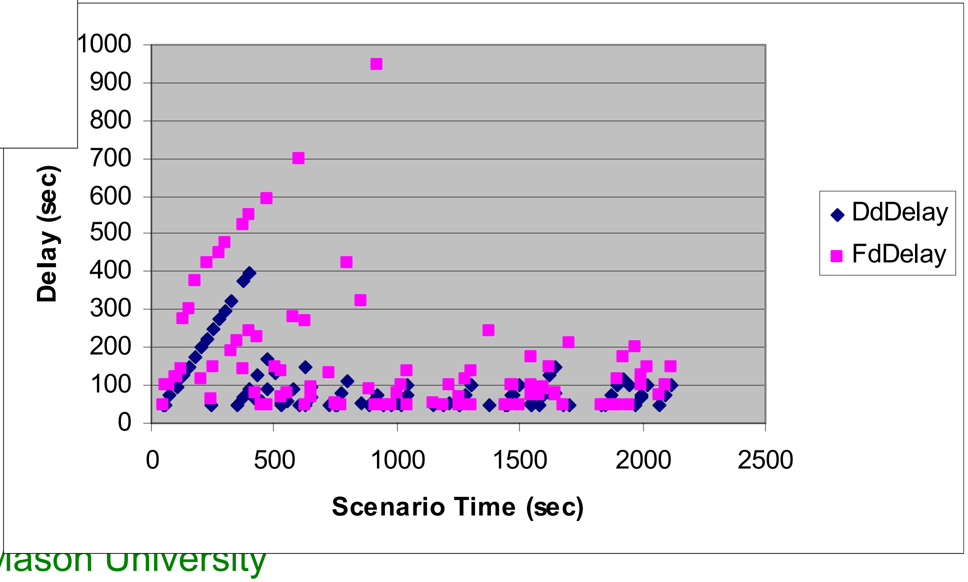
Speed of Command Results



Accumulated SOC (sec):

DIV = 9000

FUN = 15000



Average SOC (sec):

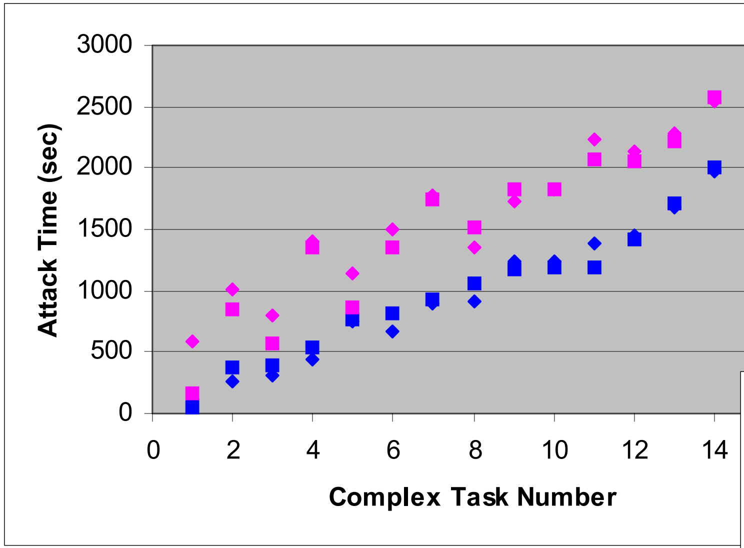
DIV = 95

FUN = 159

Shared Situation Awareness

- Defined as the ability of a team of decision makers to perceive and understand a tactical picture that is complete and consistent across the team.
- Complex tasks that require multiple decision makers have a time window in which all required resources must be fired: *Window of Attack*
  - The time difference between the launch of the first resource to the launch of the last resource must be less than the Window of Attack.
  - $t_{assistF} - t_{attackL} < \Delta t_{attack}$
- Window of Attack can represent a surrogate measure for Shared Situation Awareness for the decision makers participating in the task
  - As the number of decision makers who participate in an attack increase, this metric becomes more meaningful.

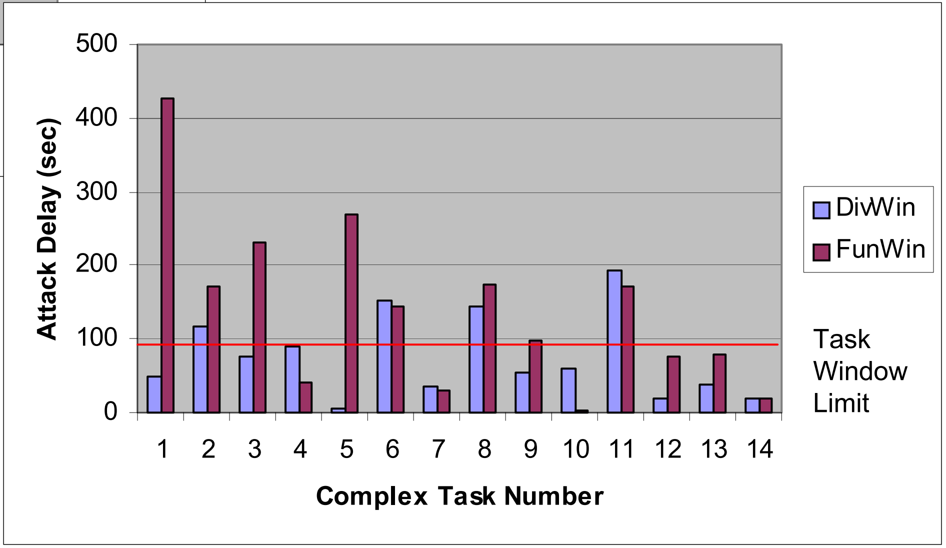
Shared Situation Awareness Results



Average Window of Attack:

DIV = 74 (77) sec

FUN = 136 (114) sec



Window of Attack = 100 (sec):

DIV = 4 missed tasks

FUN = 7 missed tasks

Conclusions

- Limitations of the current Task Process model suggested a coupling with a Decision Maker model:
  - Inability to allow a decision maker to disengage from a task mid-process,
  - Inability to represent a synchronized attack of multiple decision makers.
- The relationship between the models was made explicit by associating the *Detect – Identify* and *Select – Attack* stages of the Task Process model with the *Situation Assessment – Response Selection* stages of the Decision Maker model.
- This Enhanced Task Process model allows the definition of surrogate measures for
  - Speed of Command – accumulated delay time,
  - Shared Situation Awareness – task window limit.
- This model can now be used to evaluate alternative architectures on performance measures of current interest.