



Modelling a Network of Decision Makers

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June 2004

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE JUN 2004		2. REPORT TYPE		3. DATES COVERED 00-00-2004 to 00-00-2004	
4. TITLE AND SUBTITLE Modelling a Netowrk of Decision Makers (Briefing Charts)				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Defence Science and Technology Laboratory,Dstl Farnborough,Ively Road, Farnborough,Hampshire GU14 0LX United Kingdom, ,				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES 31	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Acknowledgements

- This work is based on the RAND publication “*Information Sharing in Military Headquarters: the Impact on Decision Making*” by
Dr Walt Perry (RAND) and Prof Jim Moffat (Dstl)
- Funded by Directorate Equipment Plan, Ministry of Defence, UK



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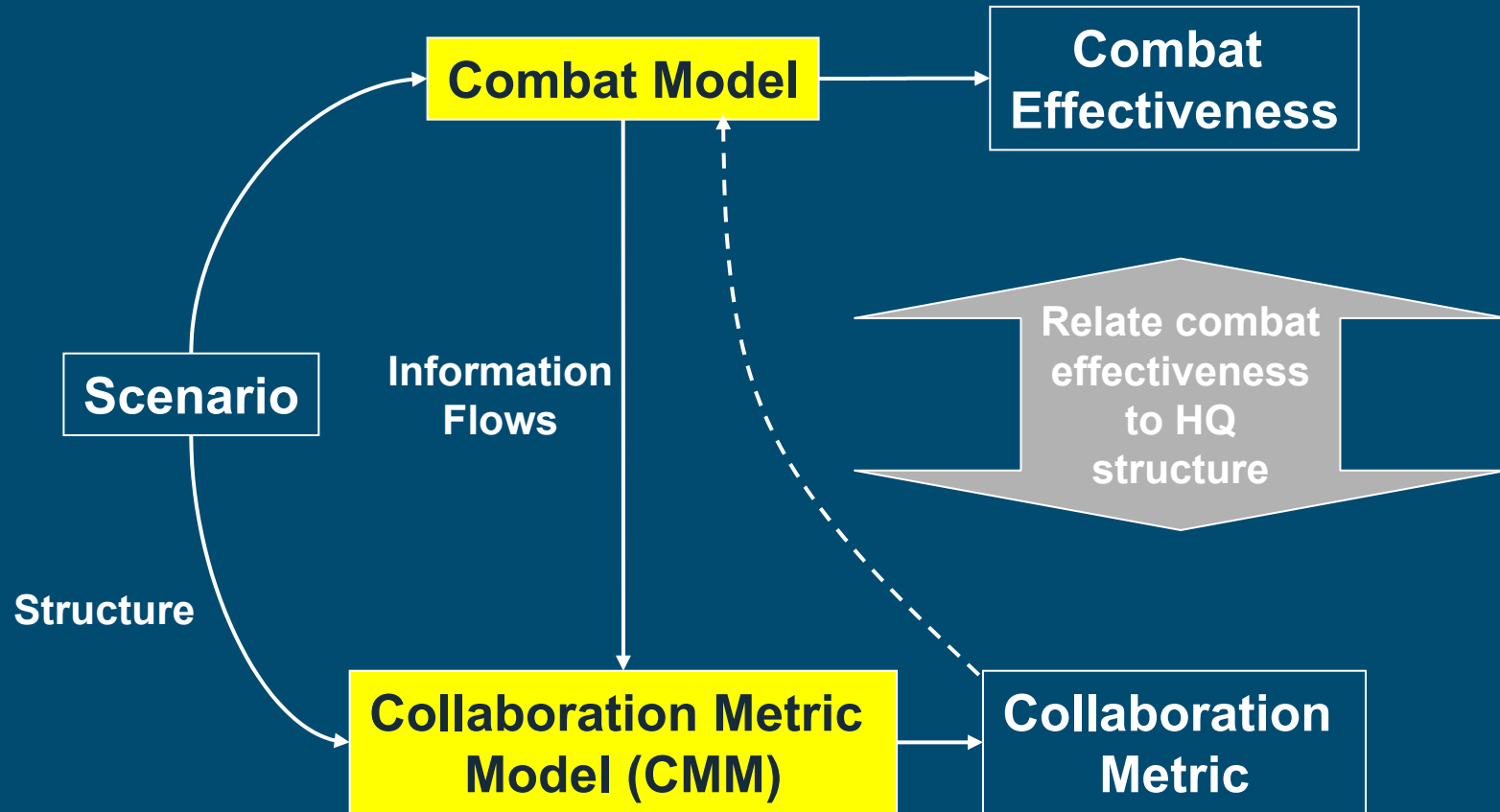
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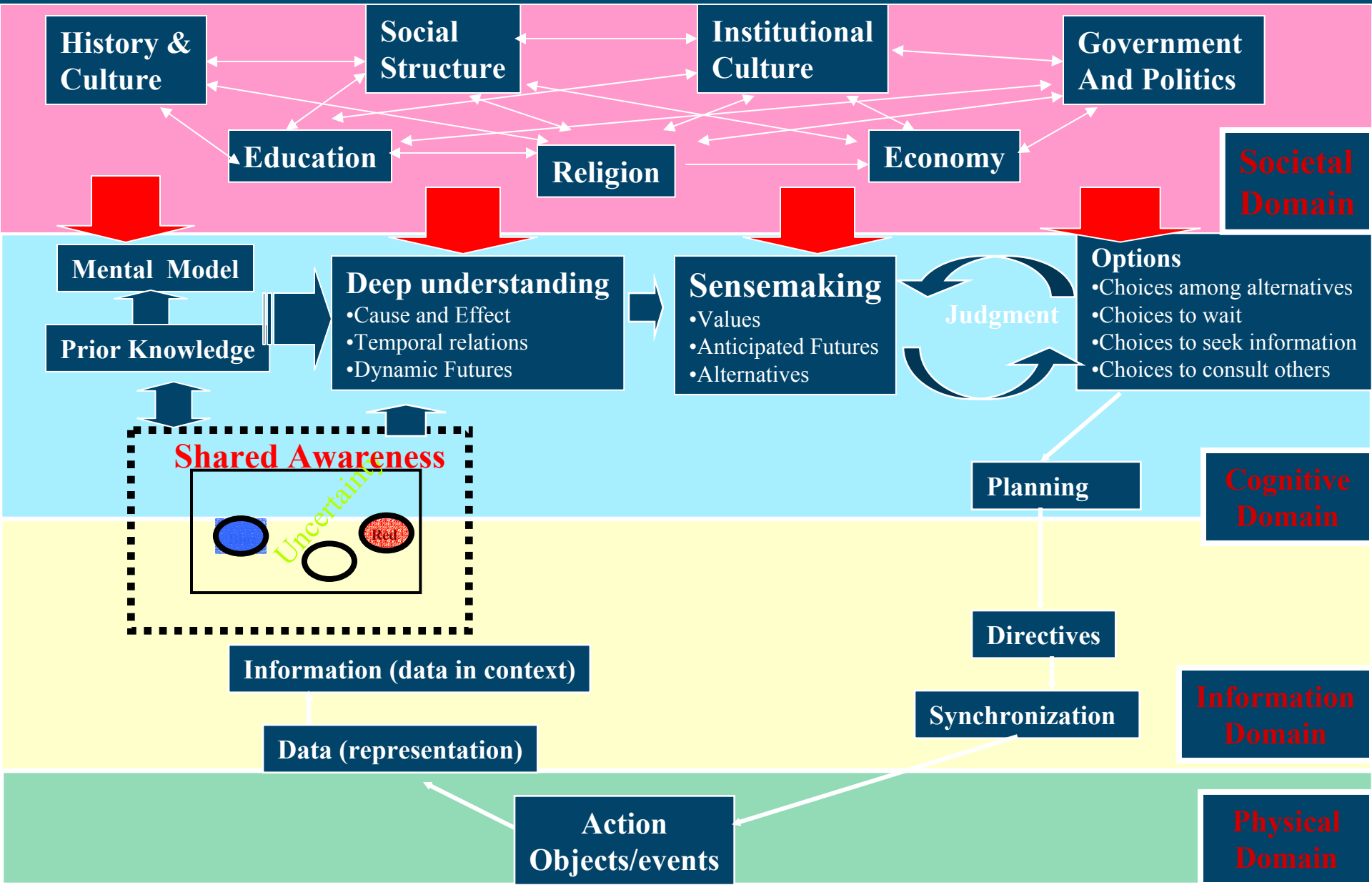
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Testing the impact of shared information on Combat Outcome



Physical - Information - Cognitive - Societal

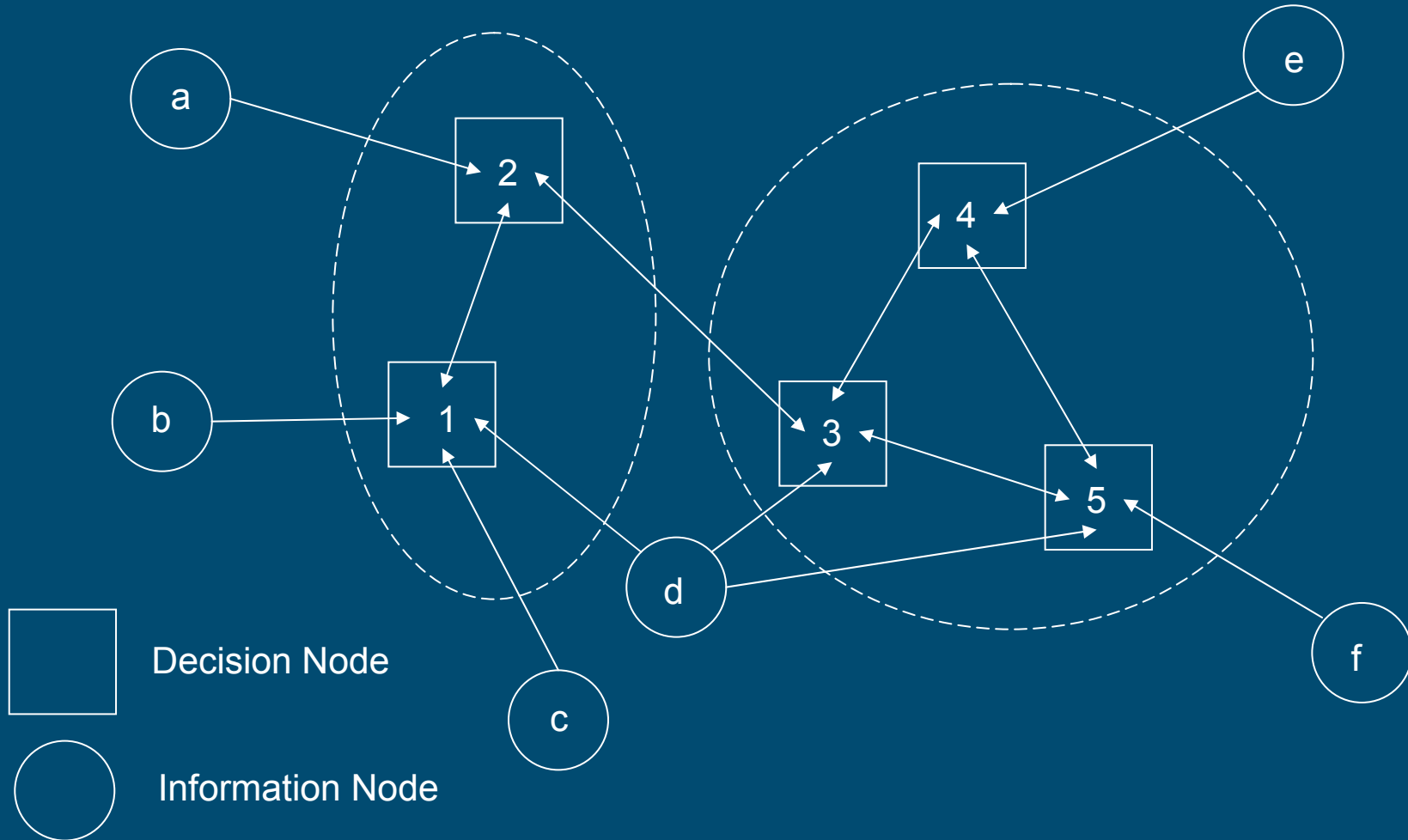
Ed Smith "Effects Based Operations"



Some simplifying assumptions

- Focus on the Information Domain and the Cognitive Domain
- Network comprises nodes and edges between nodes together with flows through the graph
- There are two types of node
 - Decision Making node
 - Information node
- There may be several different flows simultaneously

Network of decision making nodes and Information nodes



Cognitive Domain

The Recognition Primed Decision Model

A decision is simply the selection of a Course of Action in response to a situation



Recognition Primed Decision Model

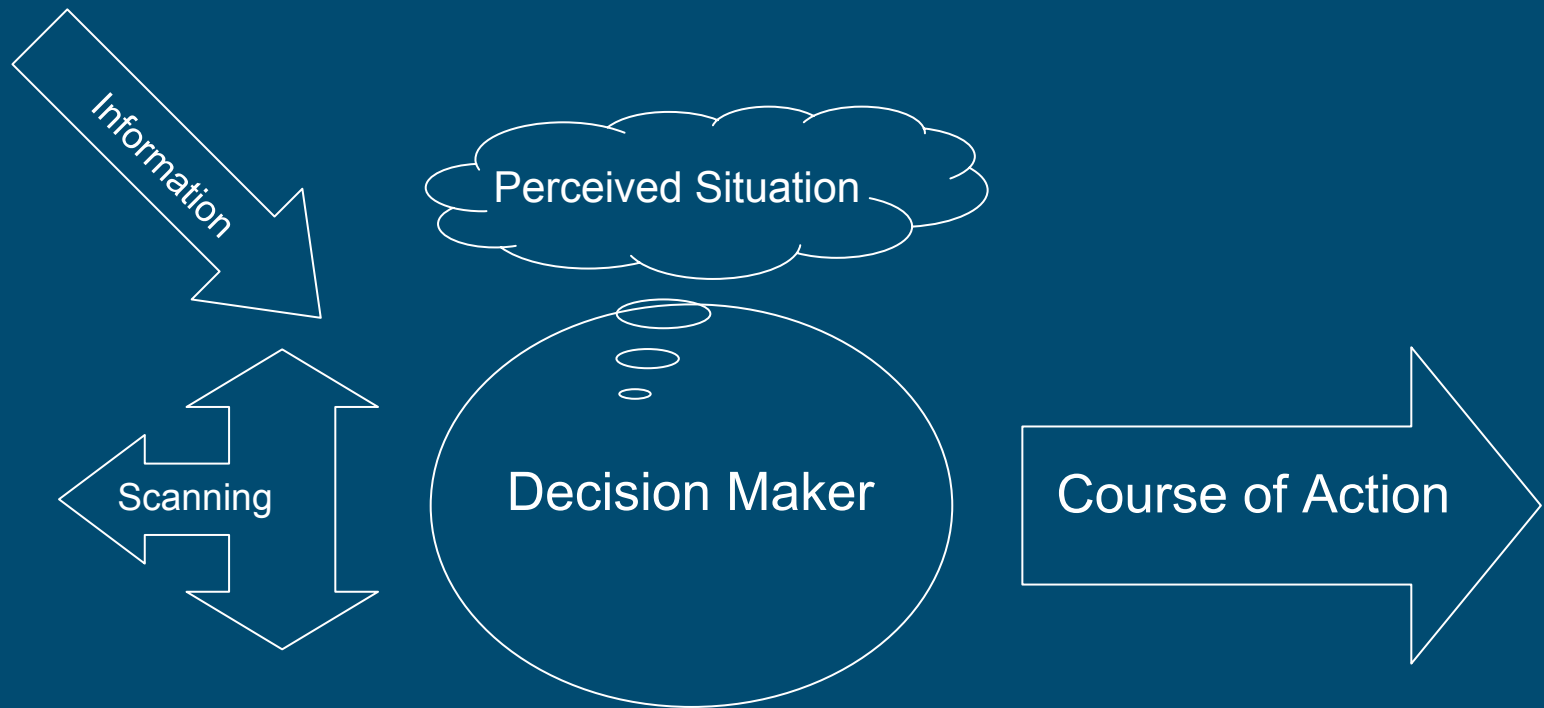
More accurately, the decision maker bases his decision on perception of the situation



Recognition Primed Decision Model

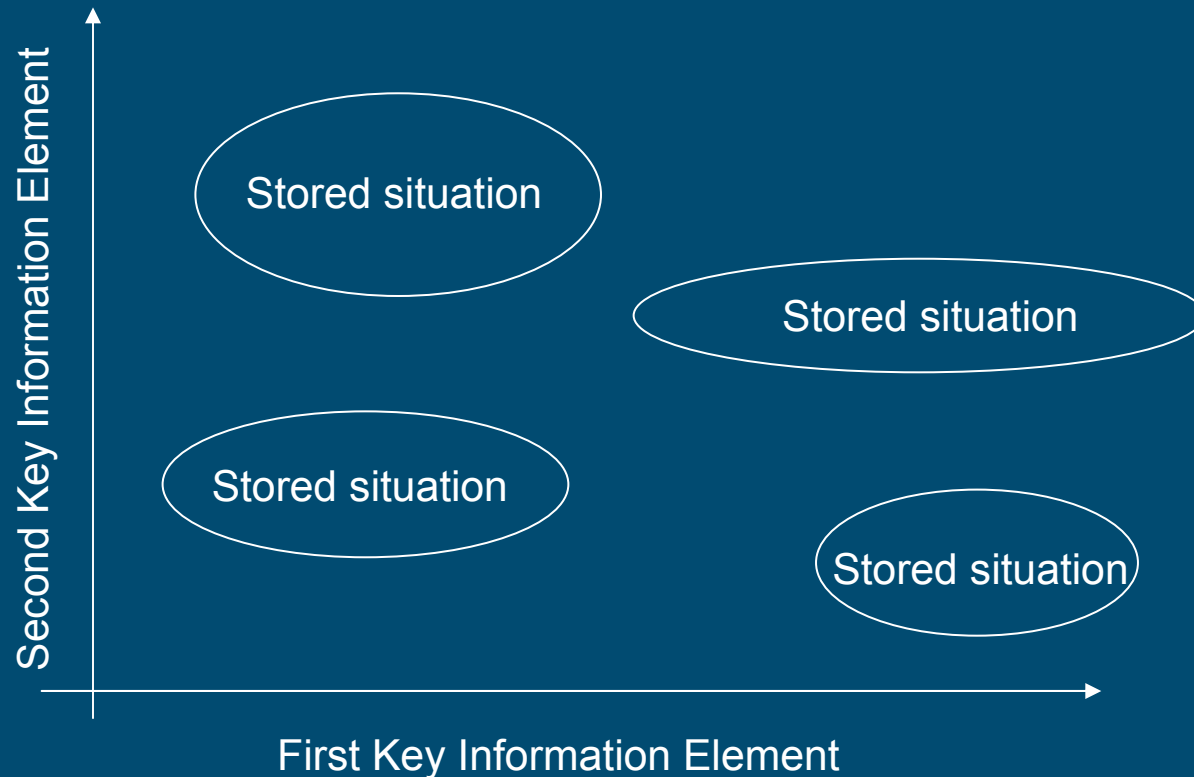
The decision maker scans the environment for clues and cues that might clarify his perception of the given situation

Key Information Requirements



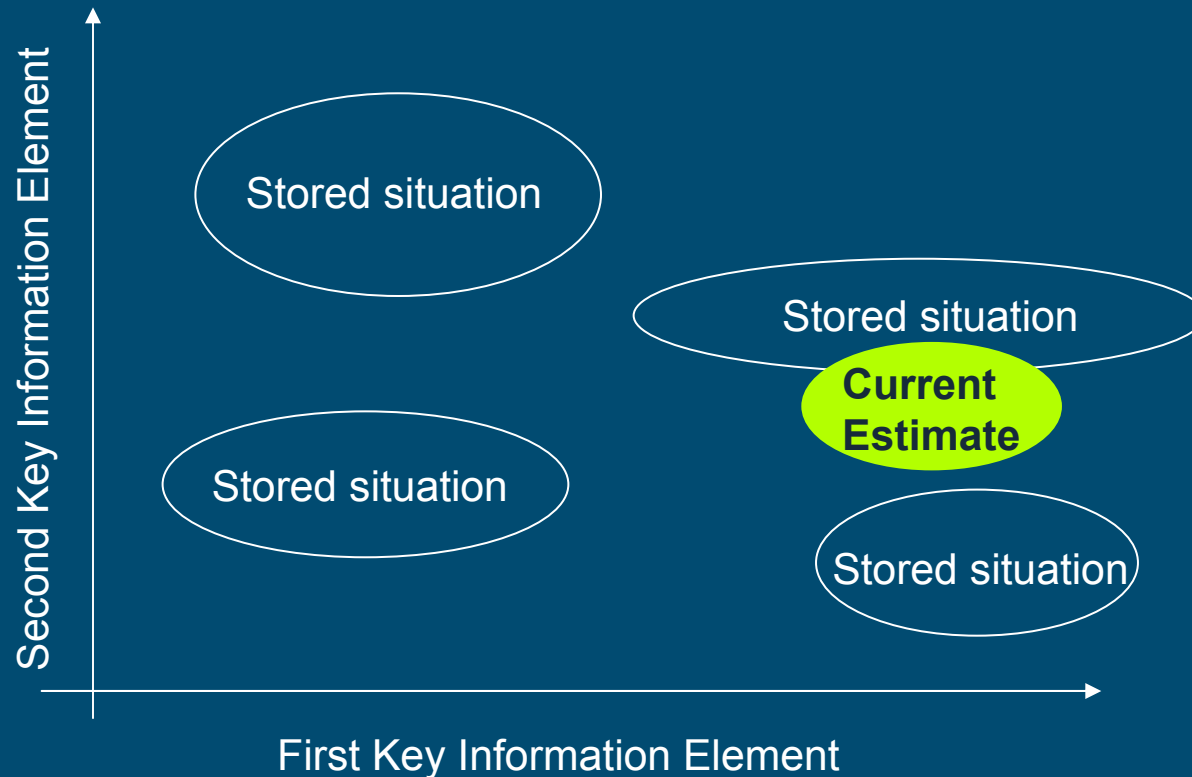
Recognition Primed Decision Model

Situations from experience are stored in the decision maker's mind
Each experience is labelled by a region in the "Information Element Space"
To each stored situation is associated a Course of Action



Recognition Primed Decision Model

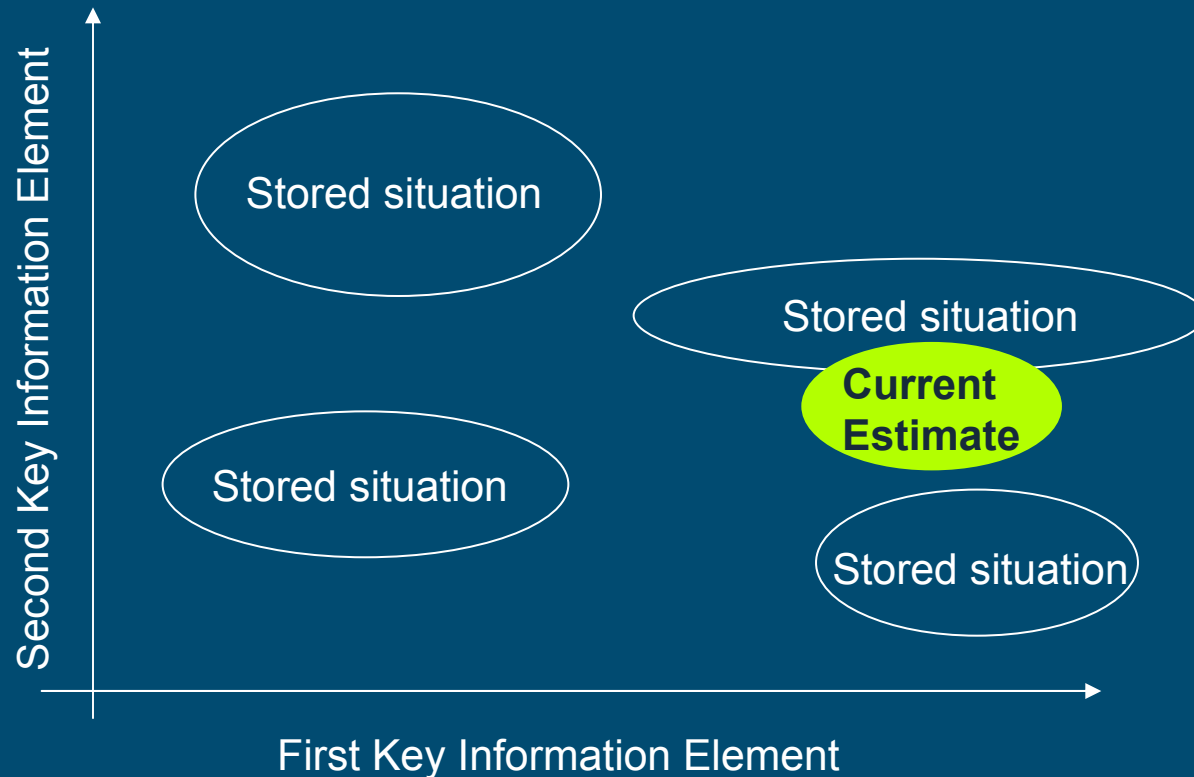
The decision maker's estimate of the current situation is plotted in the Information Element Space - *with a volume of uncertainty*



Recognition Primed Decision Model

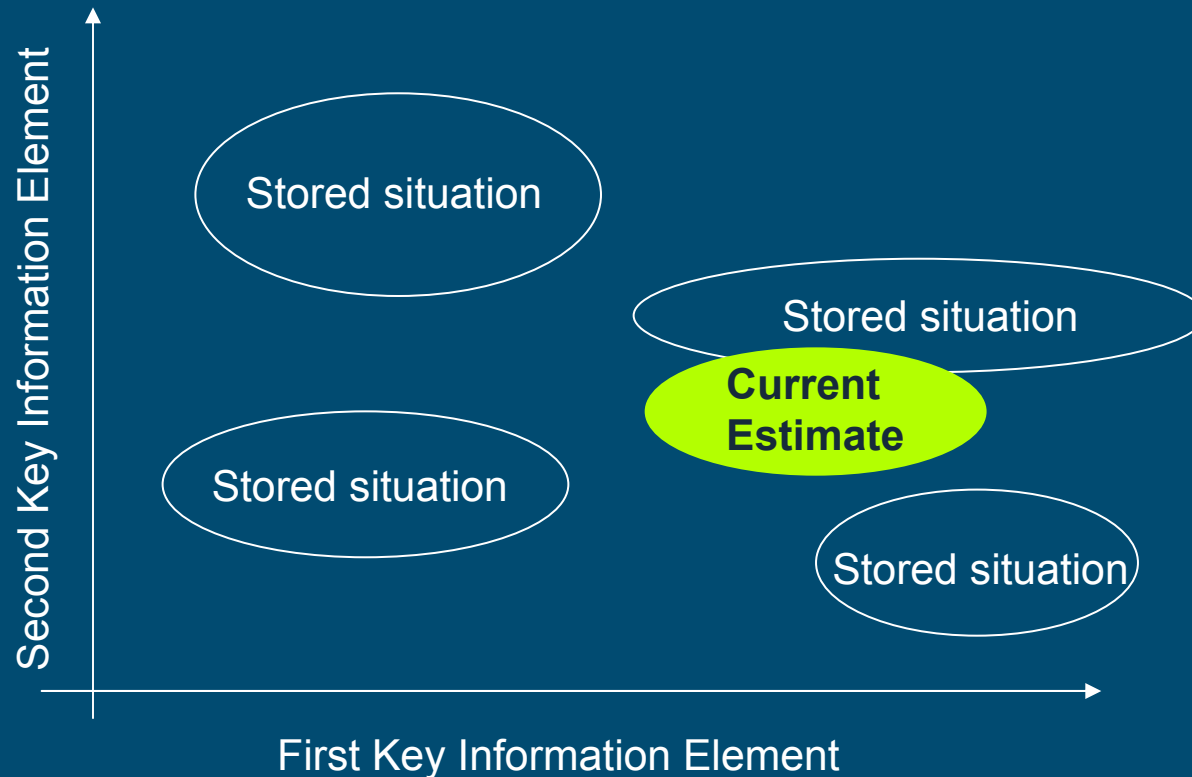
How closely must the perceived situation match a stored situation for the stored Course of Action to be chosen?

Is the decision maker feeling lucky?



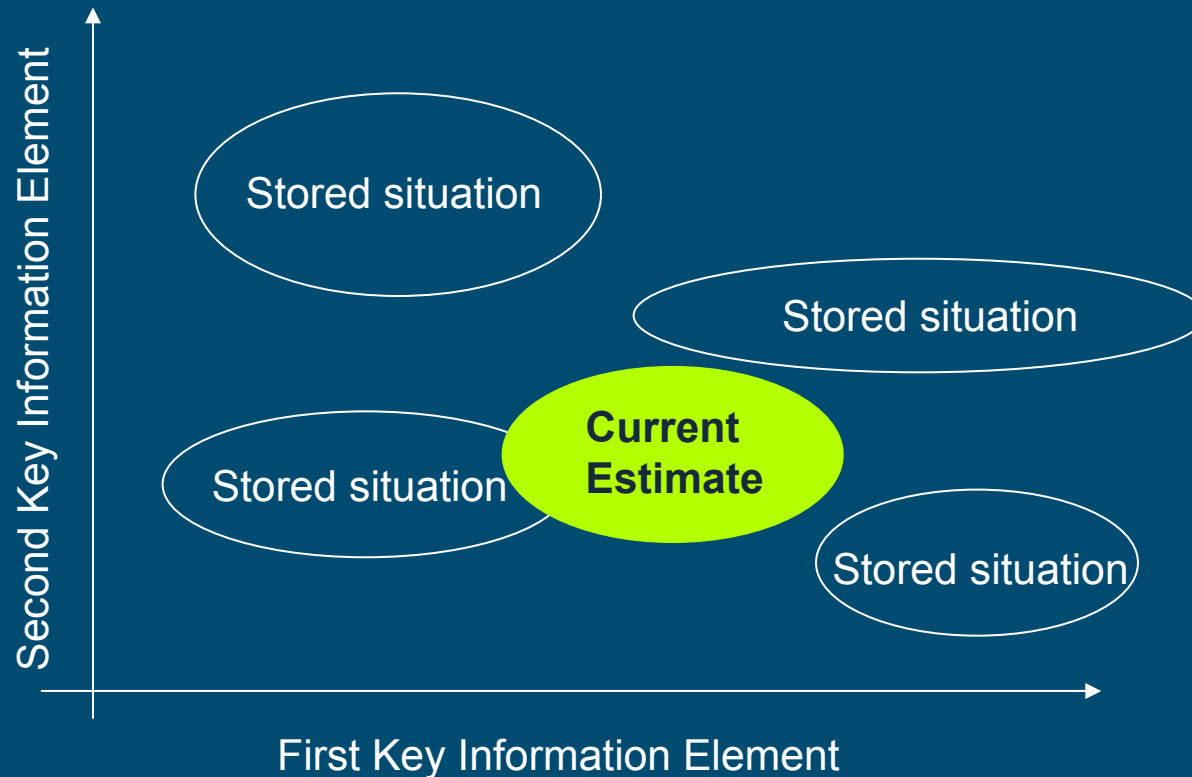
Recognition Primed Decision Model

As time goes by, the estimate will change and the degree of uncertainty may increase



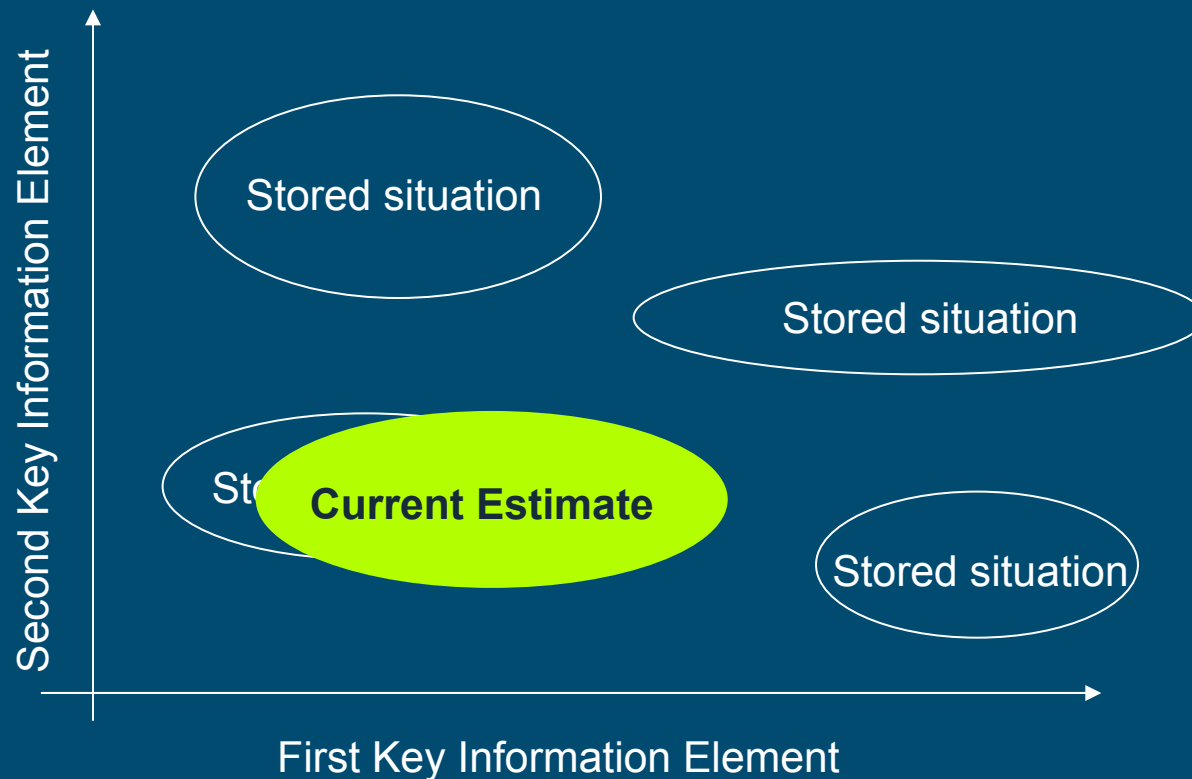
Recognition Primed Decision Model

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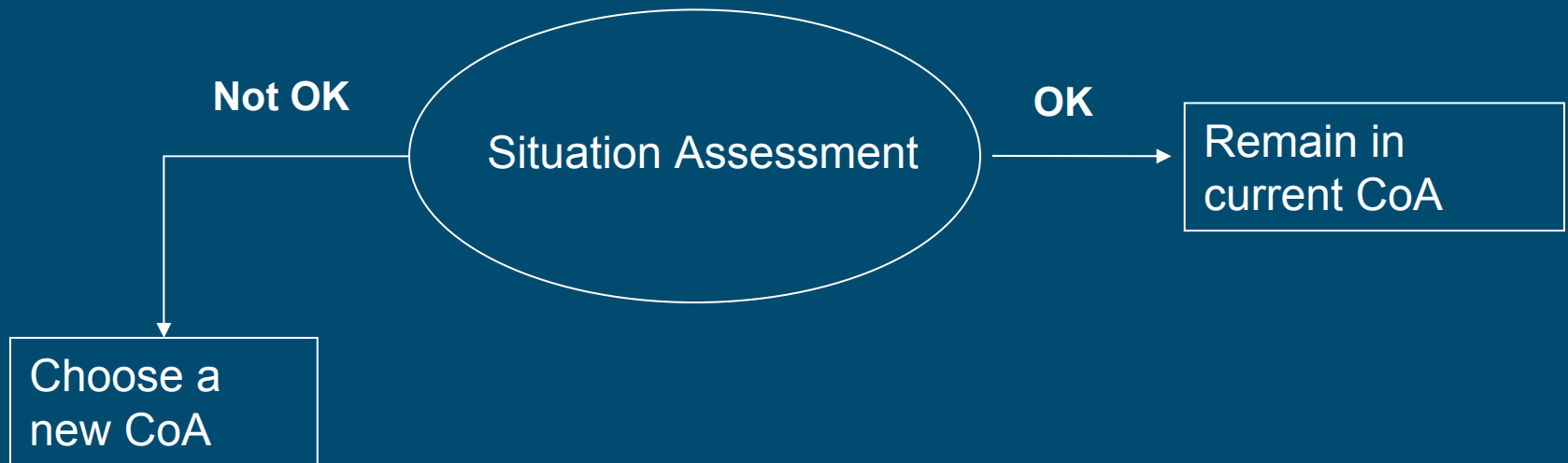
Recognition Primed Decision Model

As time goes by, the estimate will change and the degree of uncertainty may increase - until a change in the course of action is desirable or inescapable



Recognition Primed Decision Model

Situation assessment - OK / Not OK



Information domain - Representing Uncertainty

Information Element Space is spanned by a small number of critical information elements $\mathbf{A} = \{a_1, \dots, a_N\}$

Example: $\mathbf{A} = \{\text{location, altitude, speed, direction, missile type}\} = \{\mathbf{a}_1, a_2, a_3, a_4, a_5\}$

Each of these information elements is given by a probability distribution

The mean vector represents current estimate $\boldsymbol{\mu} = [\mu_1, \mu_2, \dots, \mu_N]$

The covariance matrix of the multivariate distribution represents uncertainty

$$\boldsymbol{\Sigma} = \begin{bmatrix} \sigma_1^2 & \Sigma_{1,2} & \Lambda & \Sigma_{1,N} \\ \Sigma_{2,1} & \sigma_2^2 & \Lambda & \Sigma_{2,N} \\ M & M & O & M \\ \Sigma_{N,1} & \Sigma_{N,2} & \Lambda & \sigma_N^2 \end{bmatrix}$$

Representing Uncertainty

Decisions depend on the confidence of the decision maker in the accuracy of the estimation

A measure of Uncertainty from Shannon's *Theory of Information* is **Information Entropy**

The Information Entropy contained in a joint probability density function $f(\mathbf{X})$ is given by

$$H(\mathbf{X}) = E[-\log f(\mathbf{X})] = - \int_{x_1} \int_{x_2} \int_{x_N} f(\mathbf{X}) \log f(\mathbf{X}) dx_N dx_2 dx_1$$

Representing Uncertainty

Decisions depend on the confidence of the decision maker in the accuracy of the estimation

A measure of Uncertainty from Shannon's *Theory of Information* is **Information Entropy**

The Information Entropy contained in a multivariate normal distribution was calculated by Shannon in 1948.

$$H(\mathbf{X}) = \frac{1}{2} \log(2\pi)^N |\Sigma| + \frac{N}{2} = \frac{1}{2} \log \left[(2\pi e)^N |\Sigma| \right],$$

Metrics - How good is my information?

- Precision - function of the covariance
- Accuracy - function of the mean
- Completeness - measure of how critical are the critical information requirements?

These are combined into one single metric - the **Collaboration Measure**

Some Effects of Collaboration

Sharing information reduces uncertainty and leads to greater precision, greater accuracy

Sharing information $\Longrightarrow$ more complete information

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Sharing information reduces uncertainty and leads to greater precision, greater accuracy

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Sharing information cost - time, volume, disconfirming evidence



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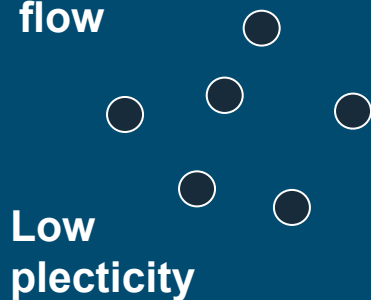


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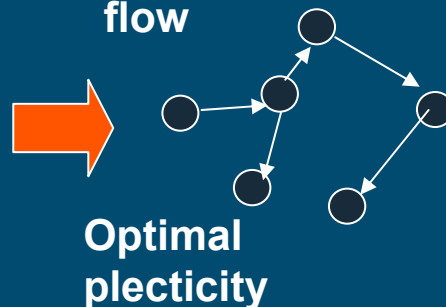
Metrics - How good is my network?

- Network Redundancy - measure of the reliability of the network
 - this is simultaneously a cost and a benefit
- Access Cost - connectivity score based on the distance piece of information must travel from source to decision maker
- Information Overload Cost - measure of the process time required to distinguish between needed and unneeded information

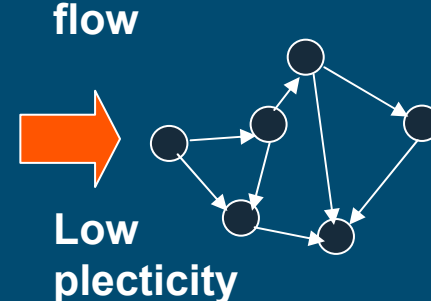
Minimal information flow



Adequate information flow



Excessive information flow



Metrics

Information Metrics

Accuracy
Precision
Completeness

Network Metrics

Information Accessibility
Network Redundancy
Information Overload

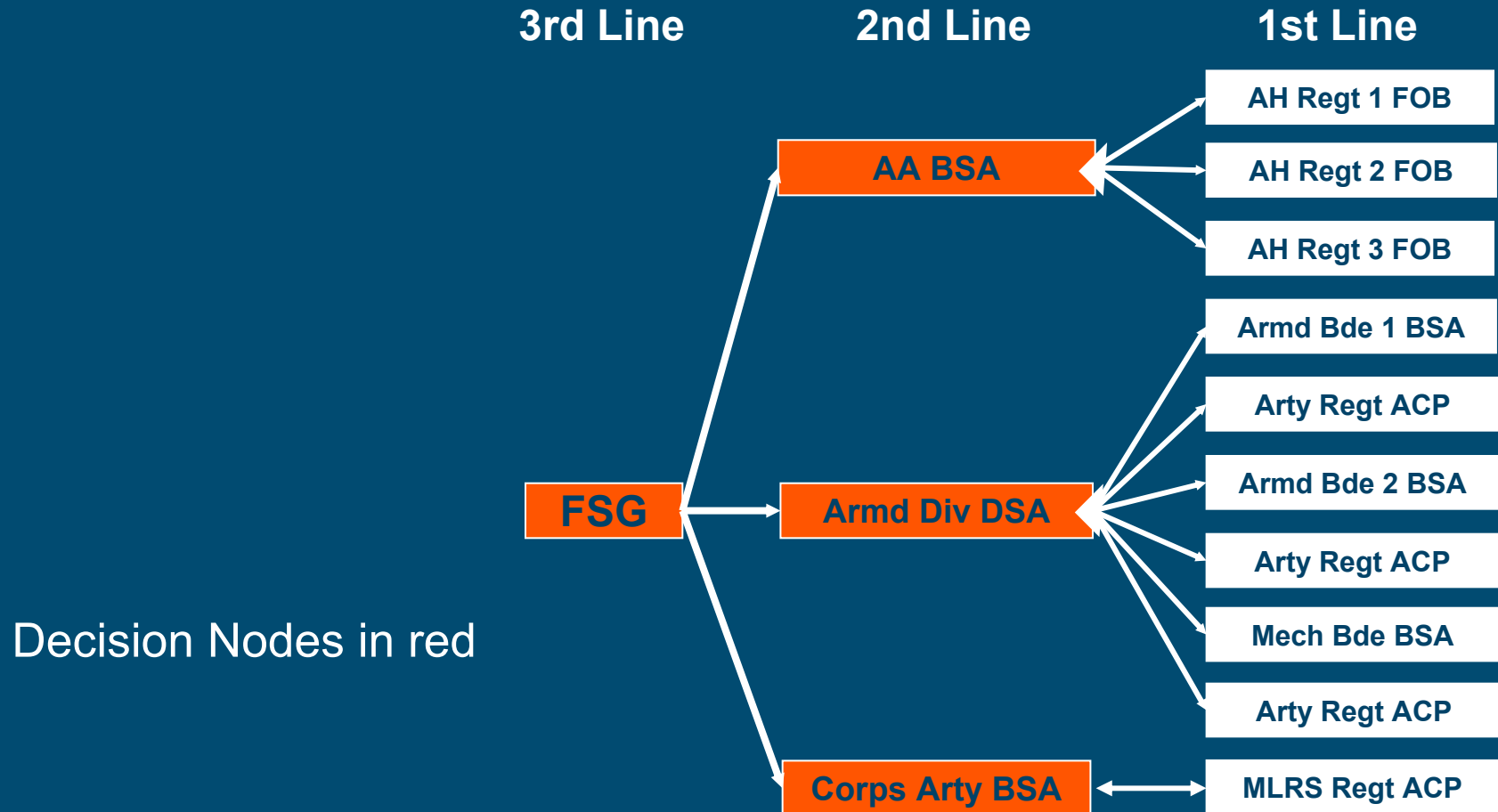
COLLABORATION

PLECTICITY

OVERALL NETWORK
EFFECTIVENESS

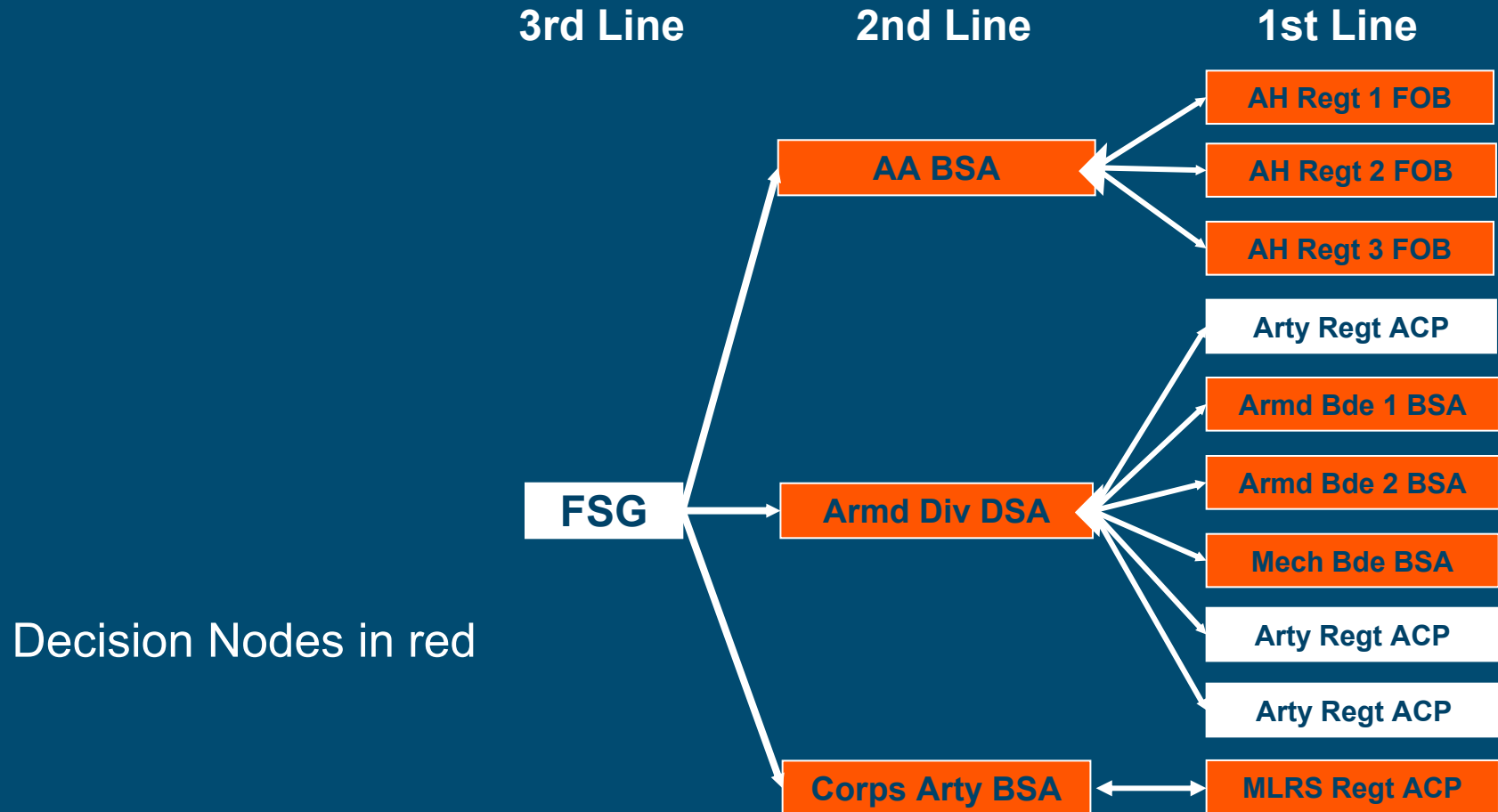
First Network of Decision Makers

Supply Case (S)



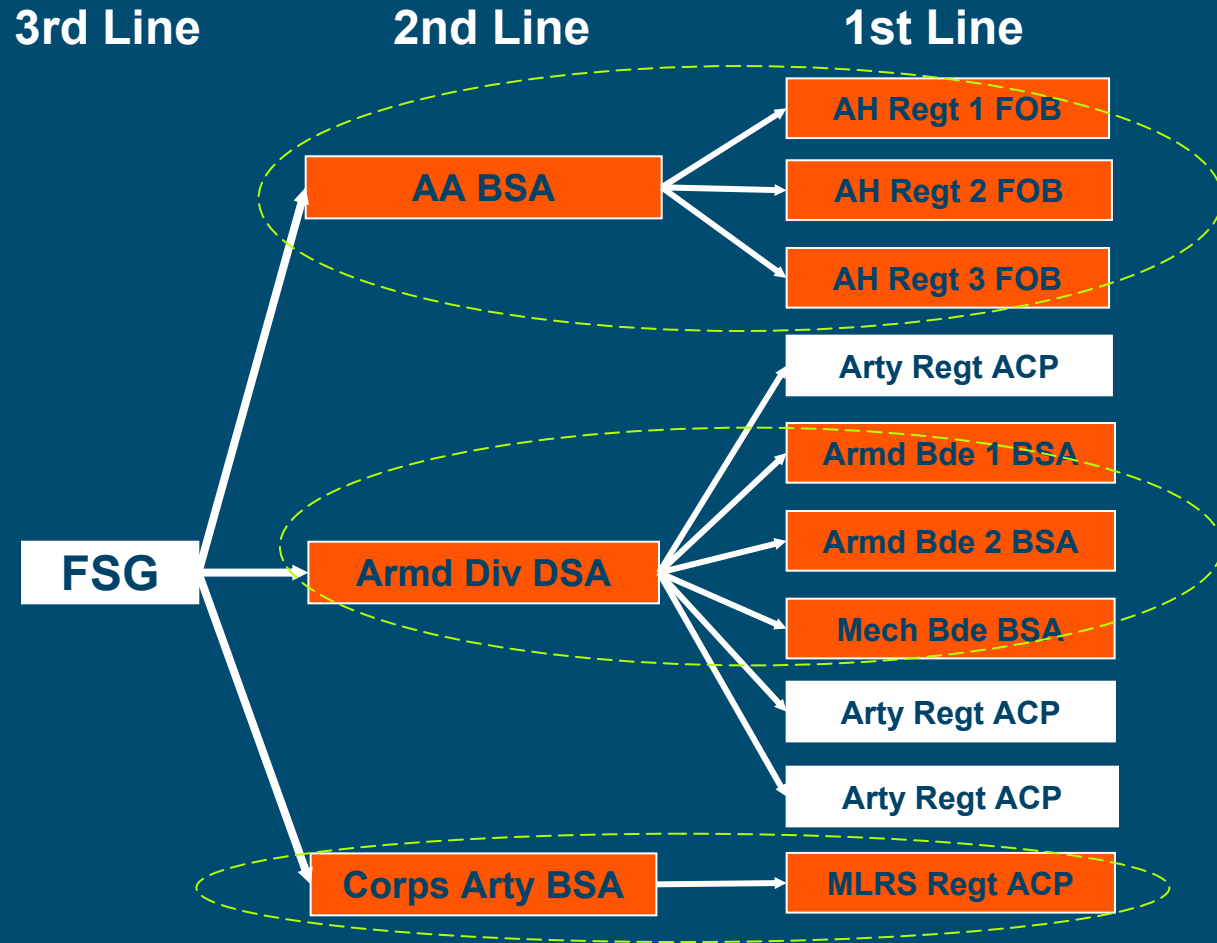
Second Network of Decision Makers

Demand Case (D10)



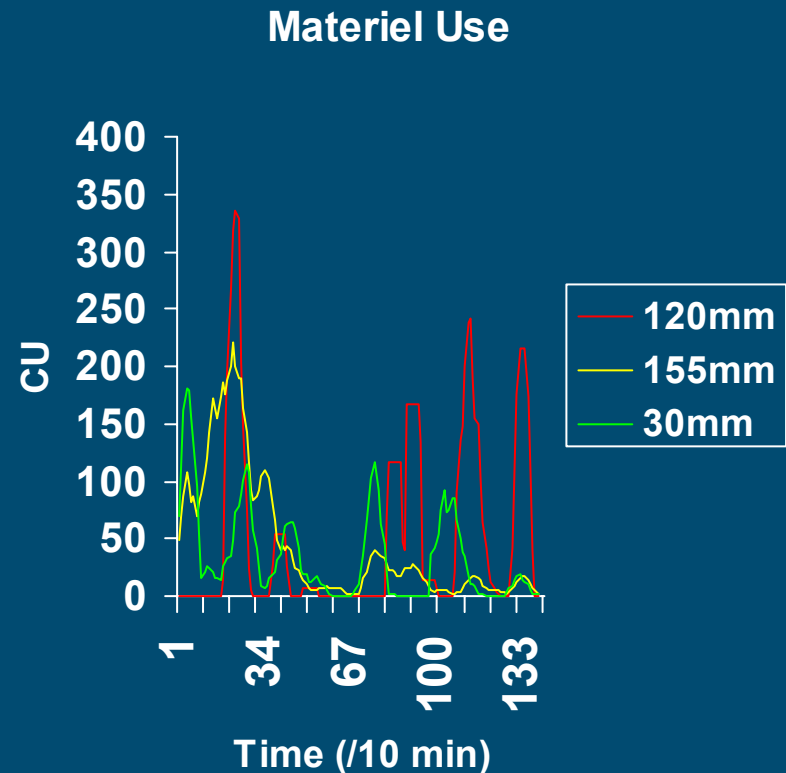
Third Network of Decision Makers

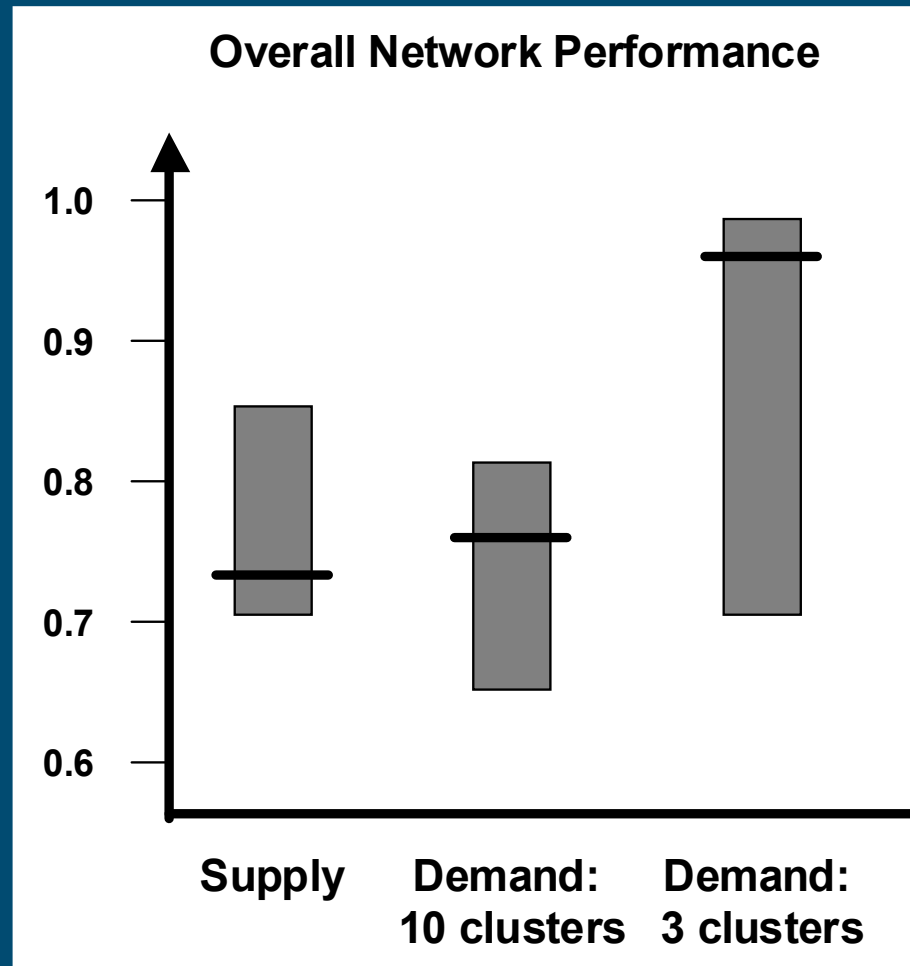
Demand Case (D3)



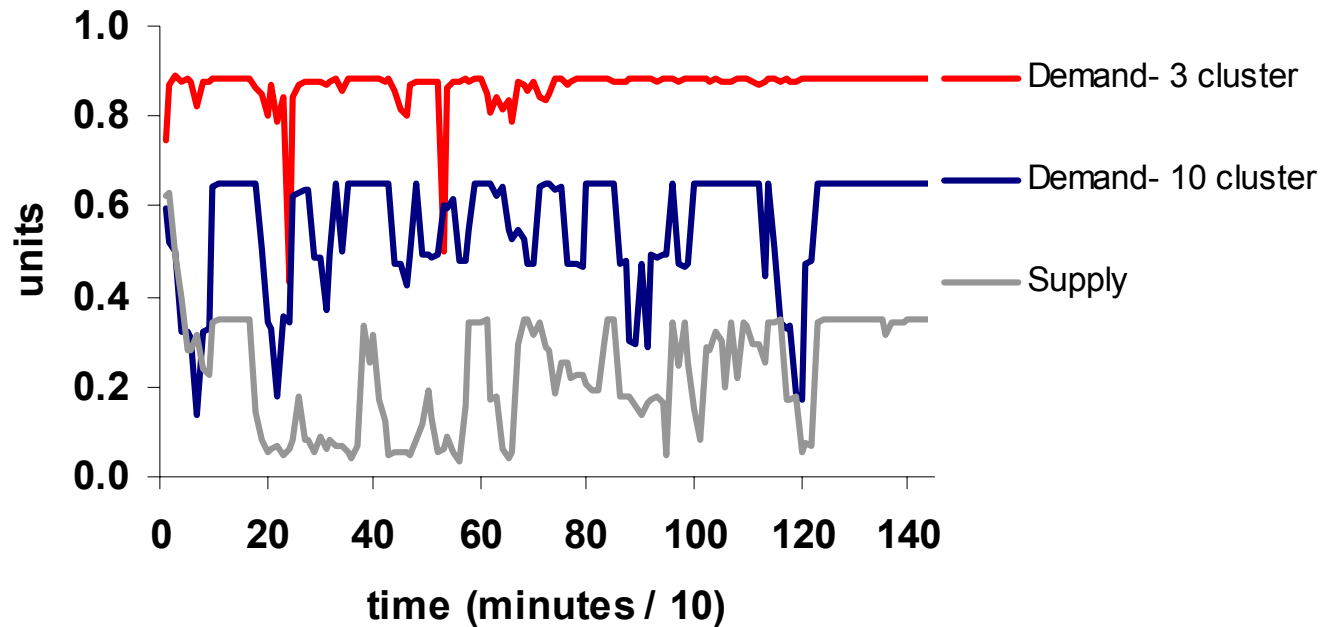
Input data from the combat model

- Actual use and Consumption
Unit data for Ammo and Supplies:
 - 120mm, 155mm, 30 mm, 81mm
 - MLRS, HellFire
 - Fuel, Oil+Lub, PW, Rations, Bulk Water
- Variety of first, second and third line log units
- Time steps from 1 minute increment





Accuracy and Knowledge



Study Diagram

CMM / Combat Model Relationship

