



# **Modelling Information Age Warfare:**

## ***Remaining Challenges***

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| Report Documentation Page                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |                                     |                                            | Form Approved<br>OMB No. 0704-0188          |                                    |
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# *Challenges for the information age*

- Quantifying the benefit of good Command
  - command effectiveness/force effectiveness
- Understanding Emergent Behaviour
  - local collaboration/force level effects
- Modelling the clustering of decision makers across an information network
  - local information sharing/collaboration

[dst1]

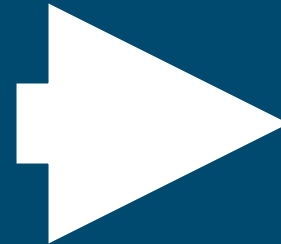
*Challenge 1 - quantifying  
the benefit of good  
command*

# Research Agenda

**Develop metamodels of understanding of behaviour**

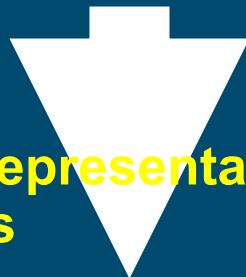


**Baseline enabling capability to represent Command in aggregate fast running models**



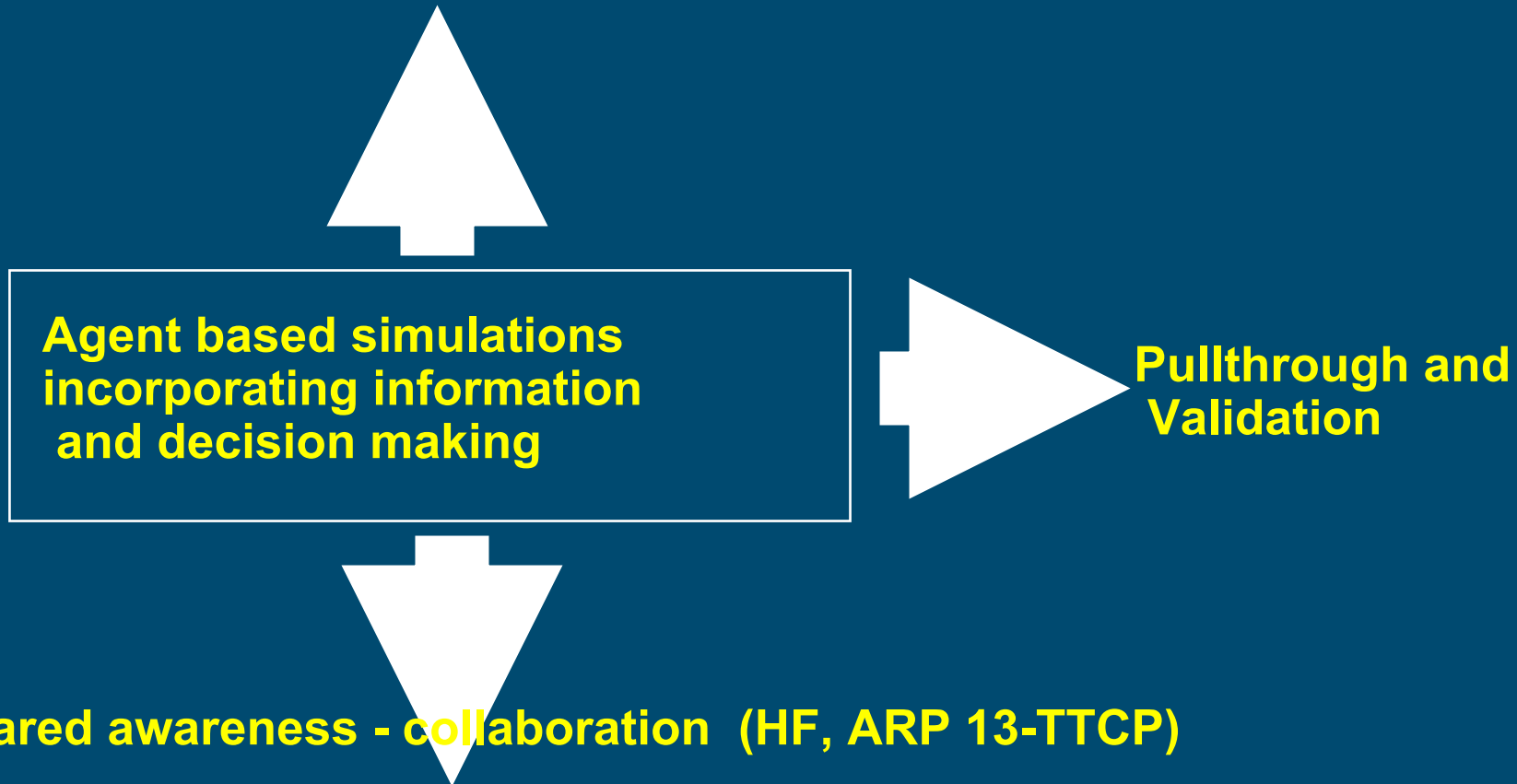
**Pullthrough and Validation**

**Develop deeper representation of C2 specific human processes**



# Network Enabled Capability (NEC) Implications

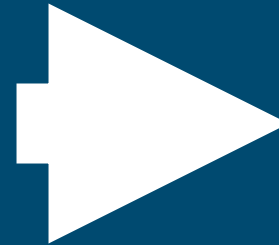
**Analytic Models for Future loosely coupled structures (e.g NEC)**



**Develop metamodel of understanding  
of behaviour**



**Baseline enabling capability  
to represent C2  
in aggregate fast running models**



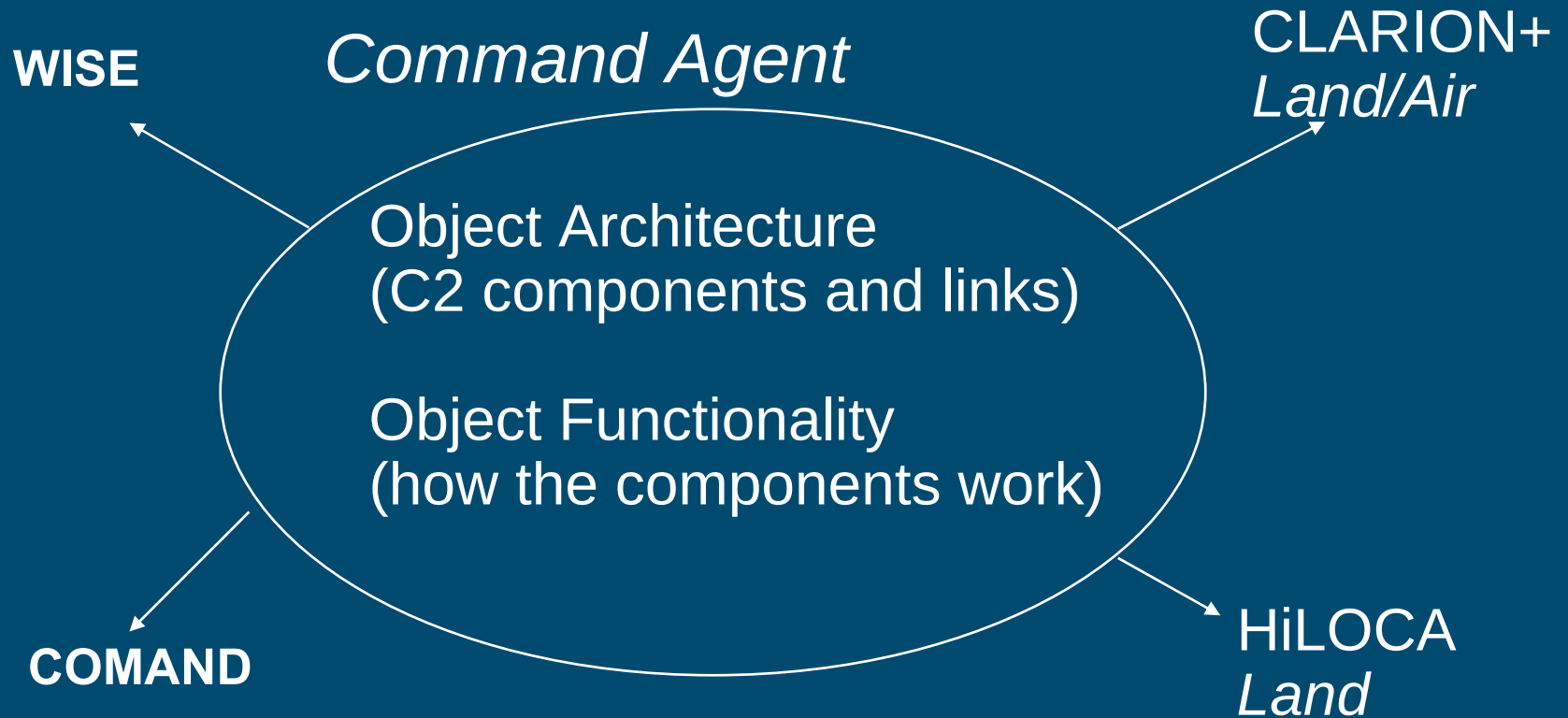
**Pullthrough and  
Validation**

**Develop deeper representation of C2 specific  
human processes**

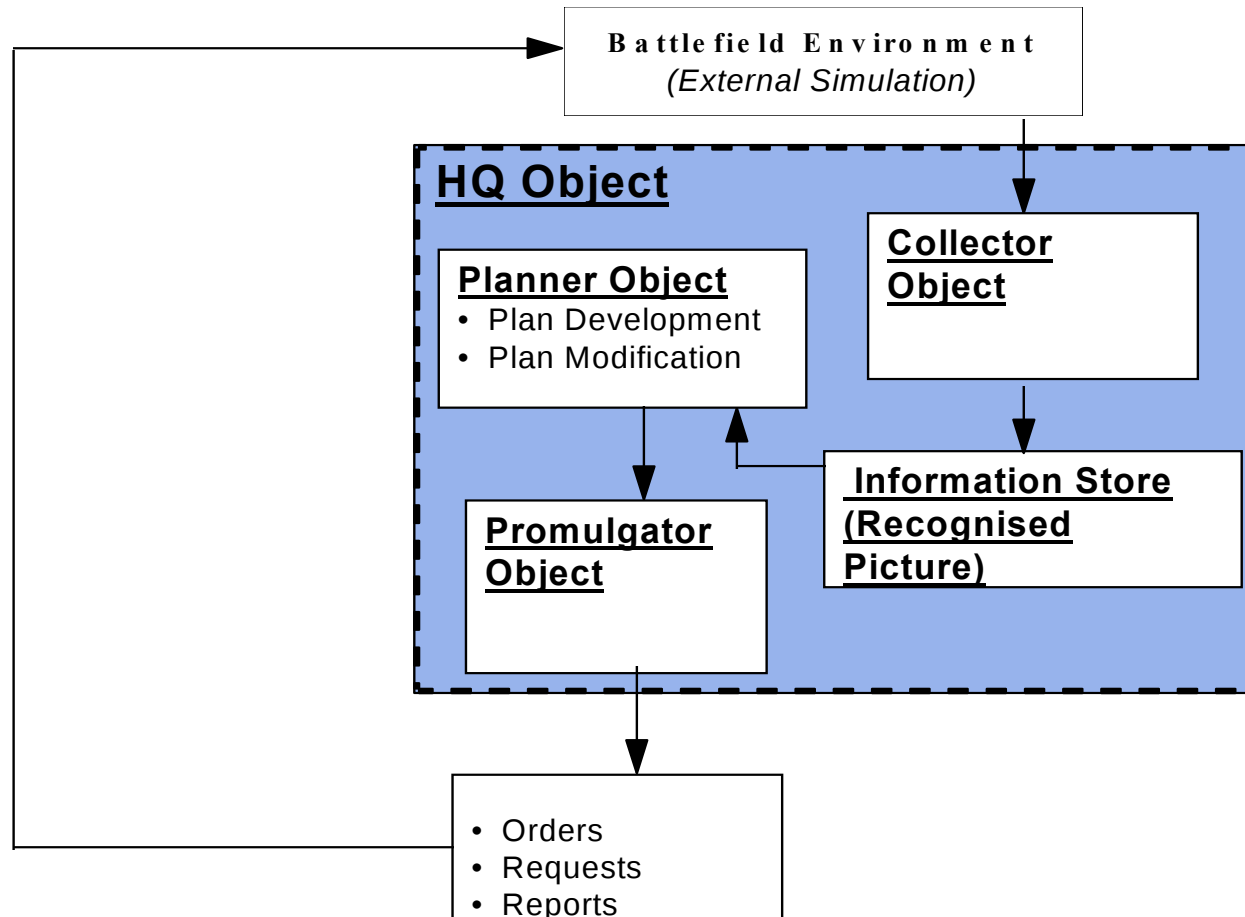


# Research Principles

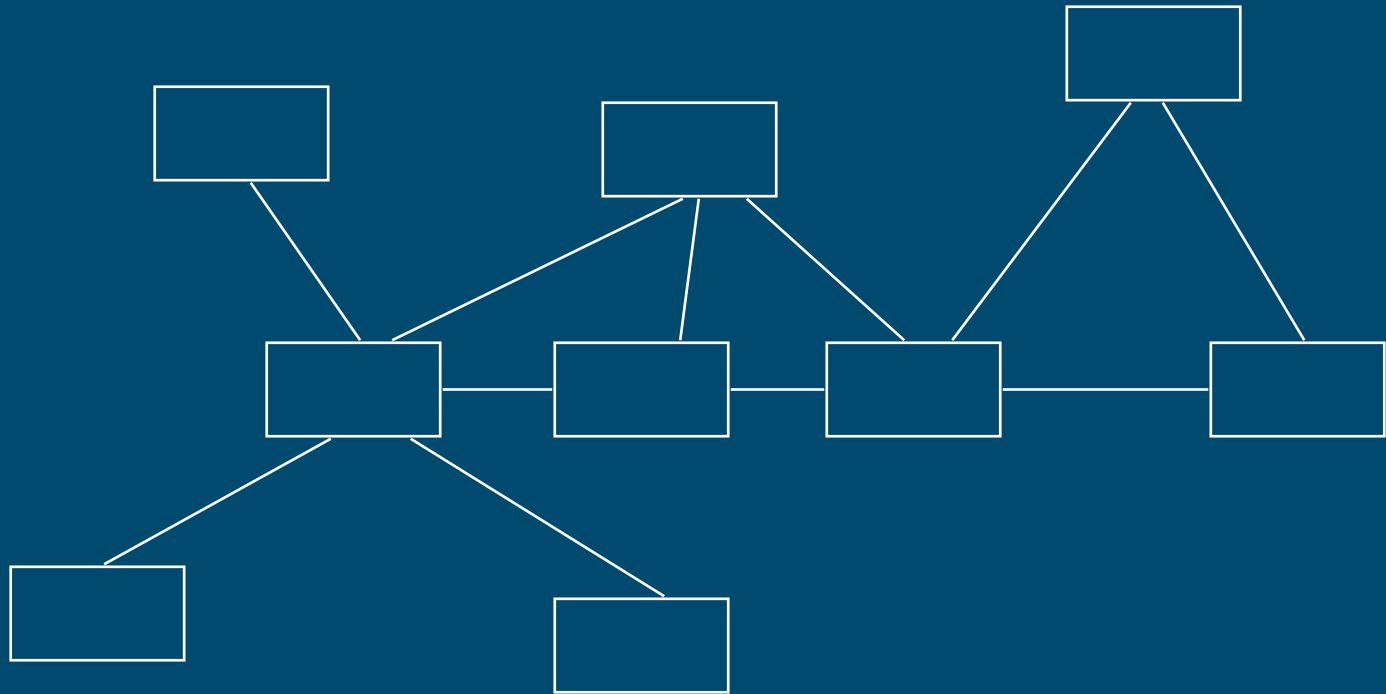
- evolutionary development
- frequent progress demonstrations
- model components complete (holistic)
- **agile, very fast running models**



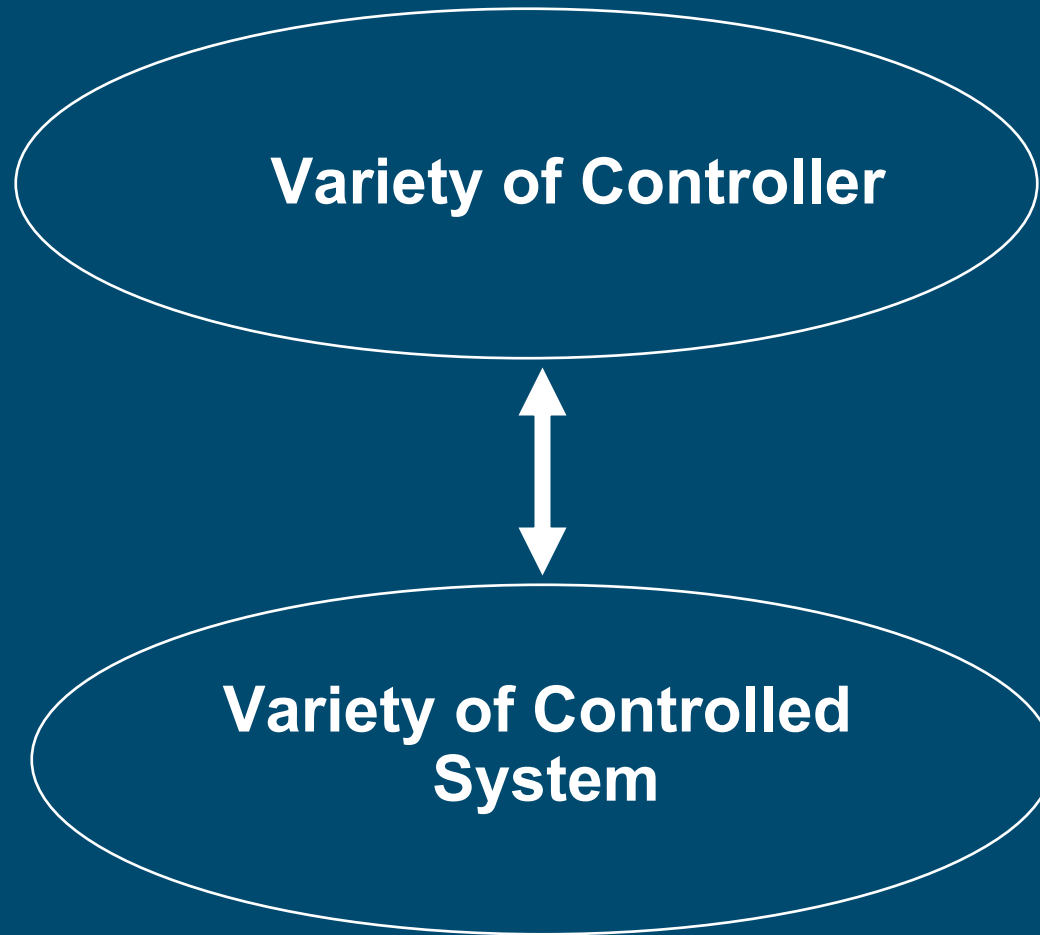
# Command Agent



# C2 is a network of Generic HQs/Command Agents



# Ashby's Law of Requisite Variety



# Possible C2 'Styles' (Alberts and Hayes)

- Order Specific
  - Soviet Union
  - Chinese army
- Objective specific
  - UK/US
- Mission specific
  - WW2 Germany
  - Israeli army

Top Down



Bottom up

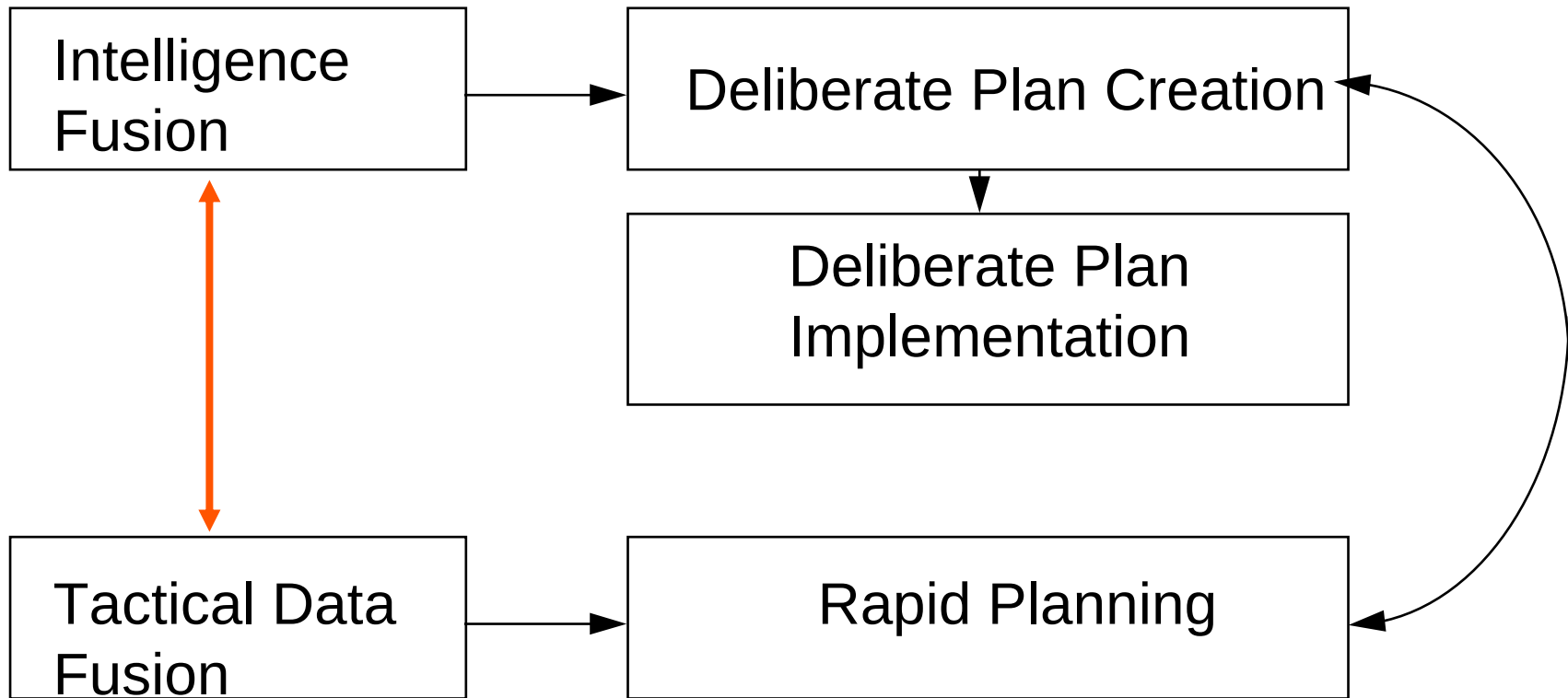
# **Deliberate Planning 'High Command'**

*top down planning (Formal Estimate)*



# **Rapid Planning 'Battle Command'** (Combat Estimate)

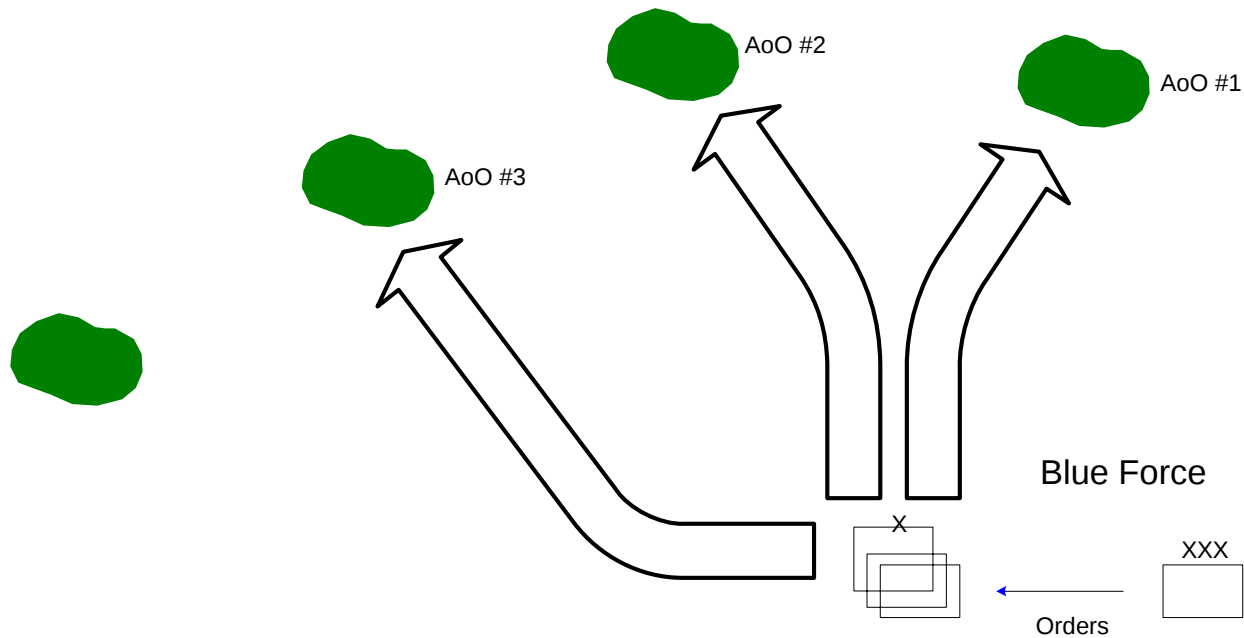
*creates cybernetic variety/complexity*

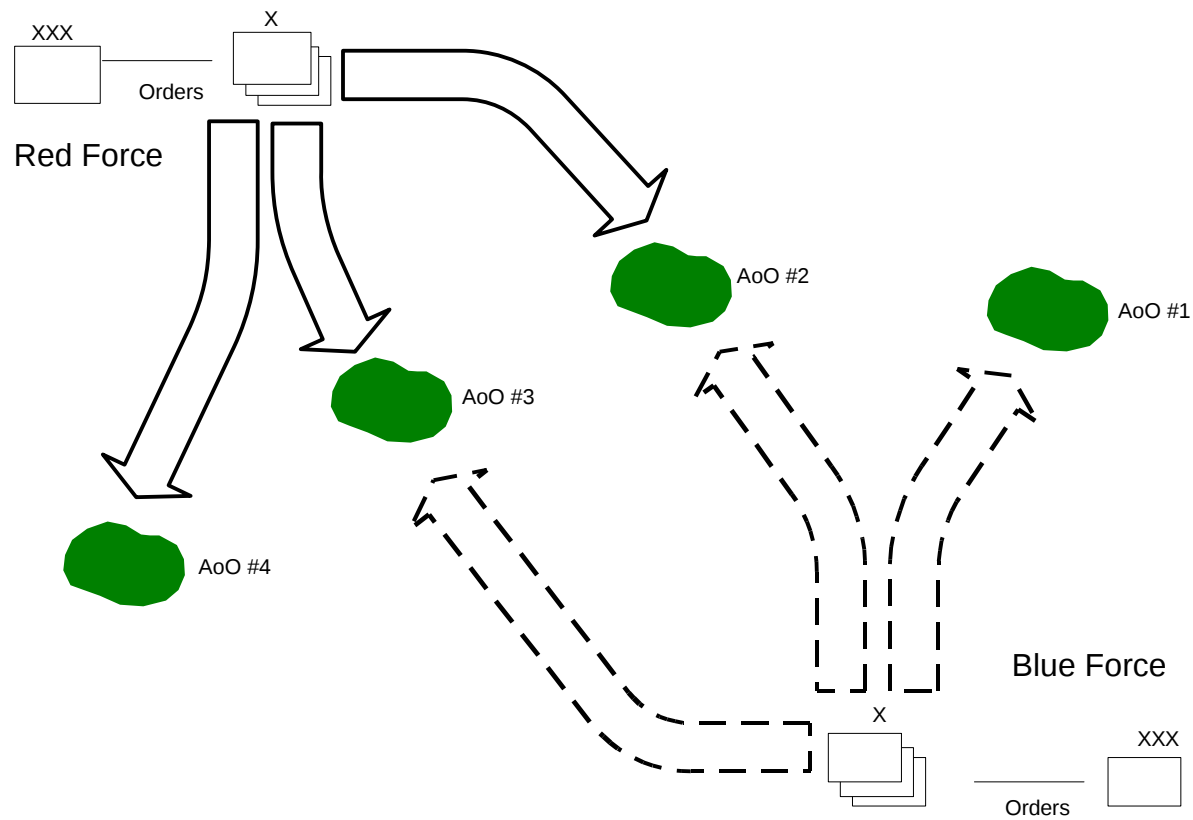


# Deliberate Planning

- New scenarios currently require extensive wargame analysis to represent this level of C2
- The aim is to let the model
  - create the overall plan
  - lay out the forces
  - prosecute the plan automatically

# IPB Process/ Mobility Corridors/Objectives





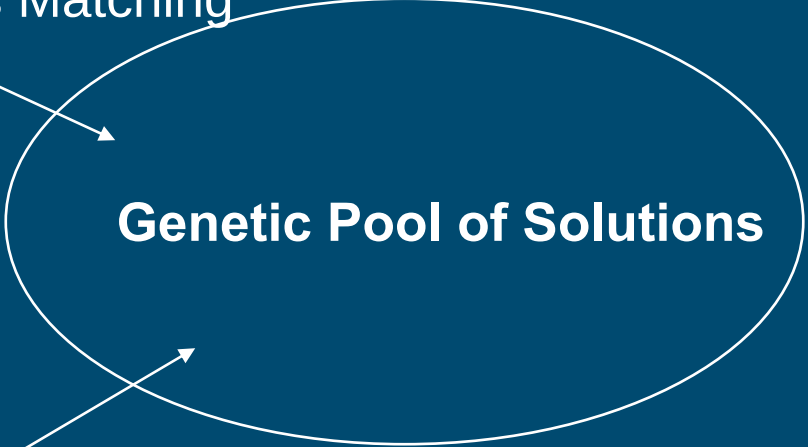
# ‘Wargaming’ of Options

|       | $E_1$    | $E_2$    | ... | $E_N$    |
|-------|----------|----------|-----|----------|
| $O_1$ | $P_{11}$ | $P_{12}$ | ... | $P_{1N}$ |
| $O_2$ | $P_{21}$ | $P_{22}$ | ... | $P_{2N}$ |
| :     | :        | :        | :   | :        |
| $O_M$ | $P_{M1}$ | $P_{M2}$ | ... | $P_{MN}$ |

- Allows representation of both **Bold** and **Cautious** command

# Innovative Deliberate Planning - Genetic Algorithm

Mutation and Cross Matching



The diagram features a large white oval on a dark blue background. Inside the oval, the text 'Genetic Pool of Solutions' is written in white. Two white arrows point towards the oval: one from the top-left text 'Mutation and Cross Matching' and another from the bottom-left text 'Fitness Function (Historical Analysis)'.

**Genetic Pool of Solutions**

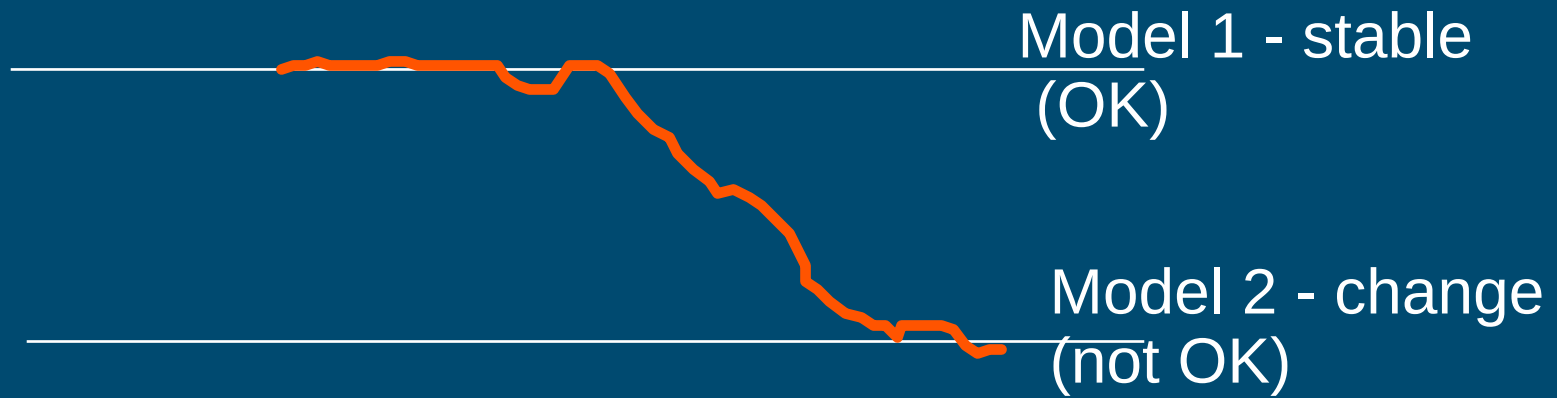
Fitness Function  
(Historical Analysis)

# Rapid Planning (Combat Estimate)

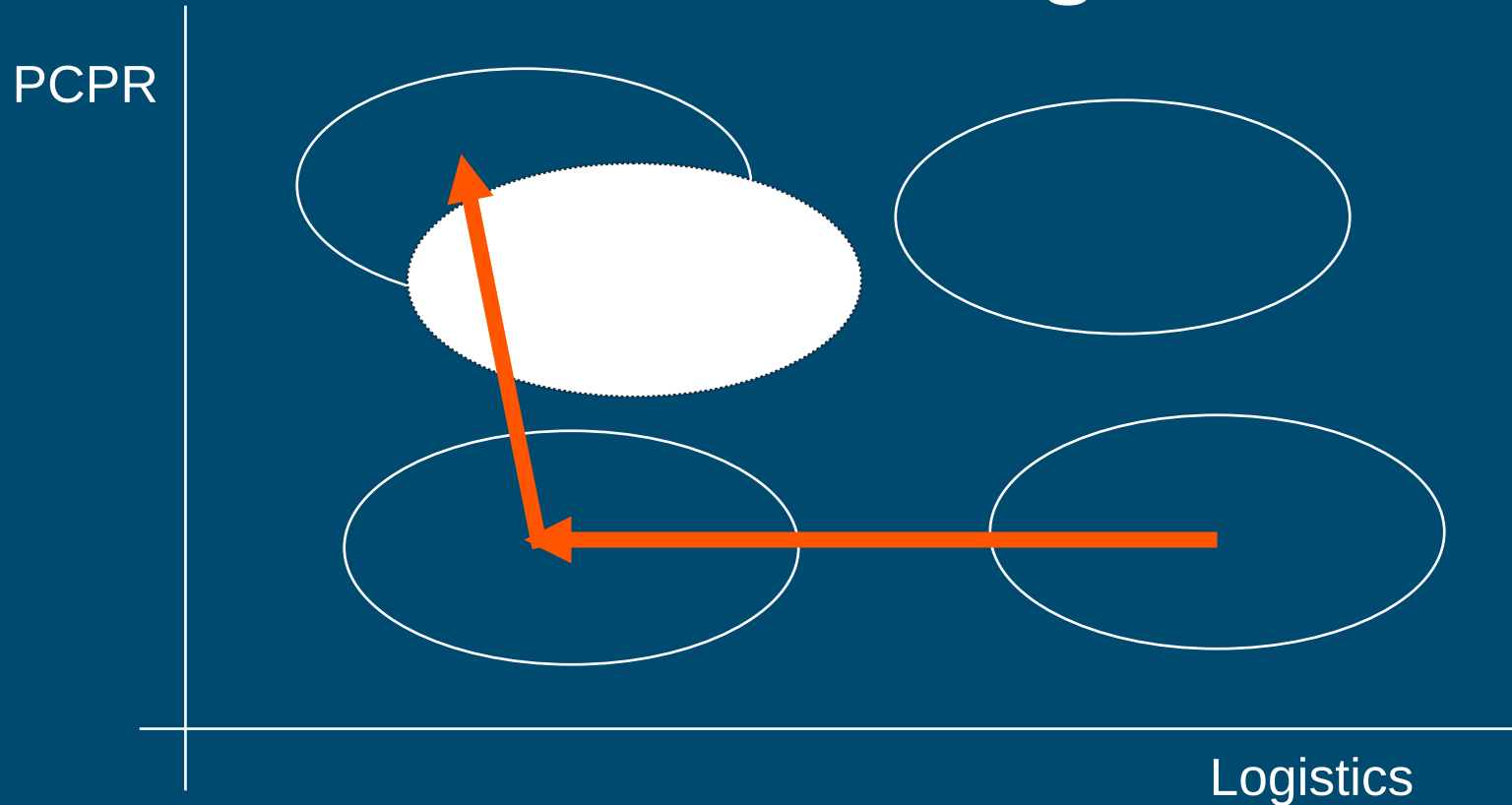
## some key human features

- Mission based
- Effect of stress
- Based on own perception and local circumstance
- Intuitive in nature
- Desired mission might be a 'fuzzy' construct

# Dynamic Linear Model- *Story Telling - have things changed?*



# Situation Assessment- Klein Pattern Matching/RPDM



# Key Dstl models entering study programme

## COMAND

joint campaign level  
warfighting

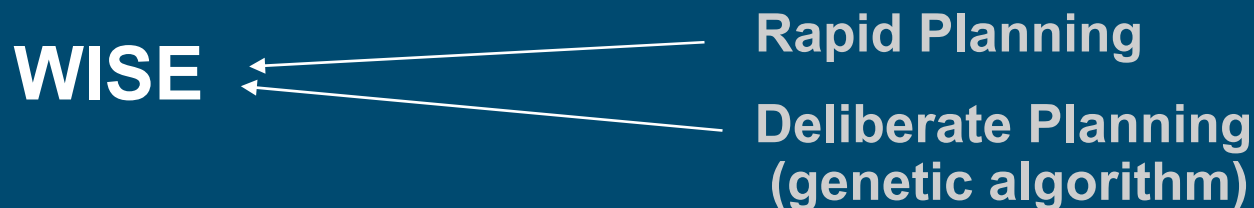
## DIAMOND

joint campaign level  
peacekeeping

## WISE

Land formation level game/simulation  
warfighting/peacekeeping

# All these models are C2 centred, based on our approach to C2 representation

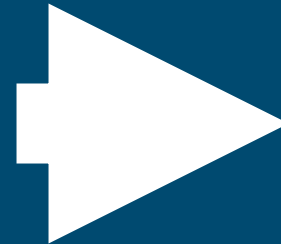


# Validation

Develop metamodel of understanding  
of behaviour



Baseline enabling capability  
to represent C2  
in aggregate fast running models

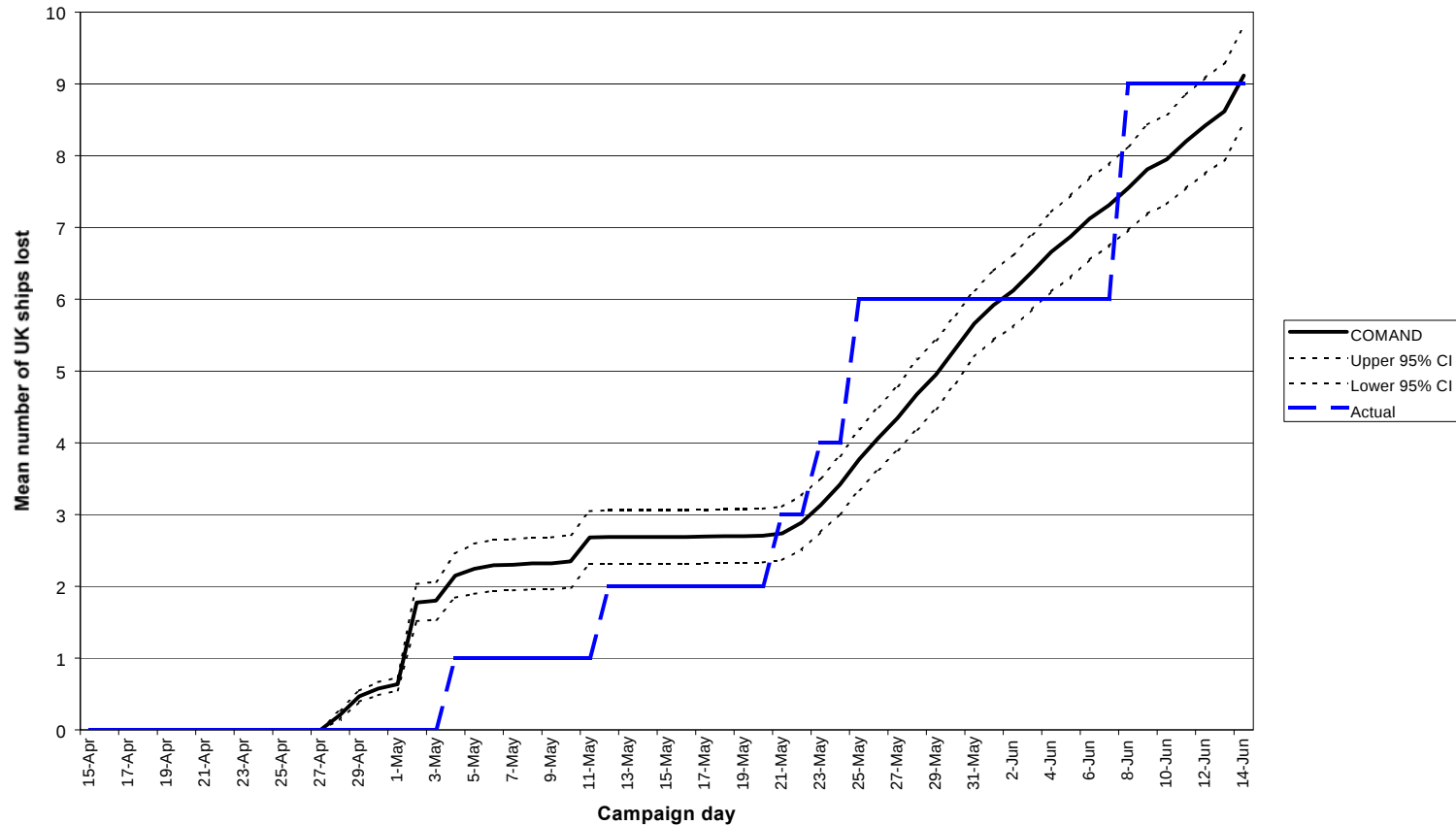


**Pullthrough and  
Validation**

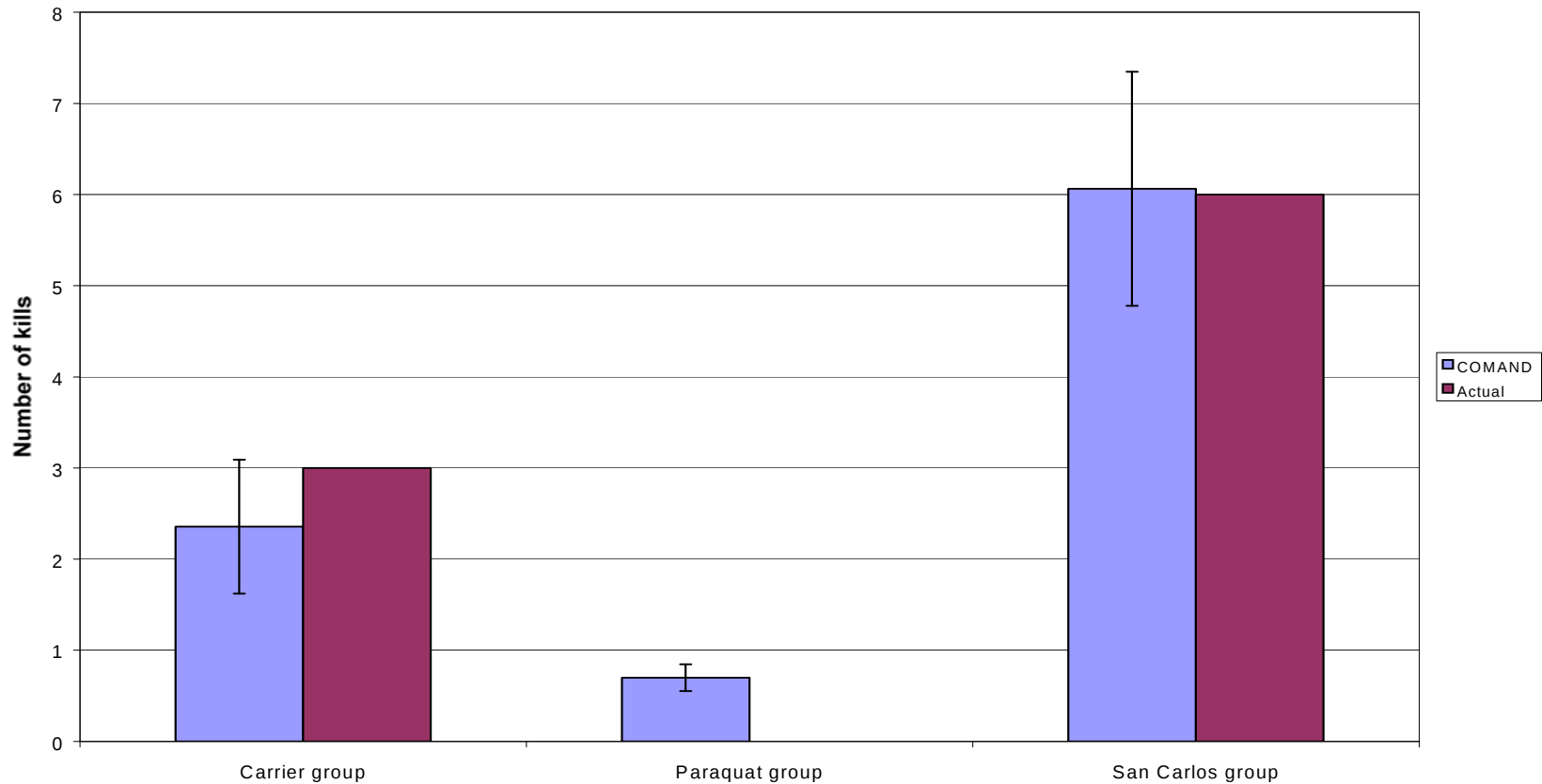
Develop deeper representation of C2 specific  
human processes



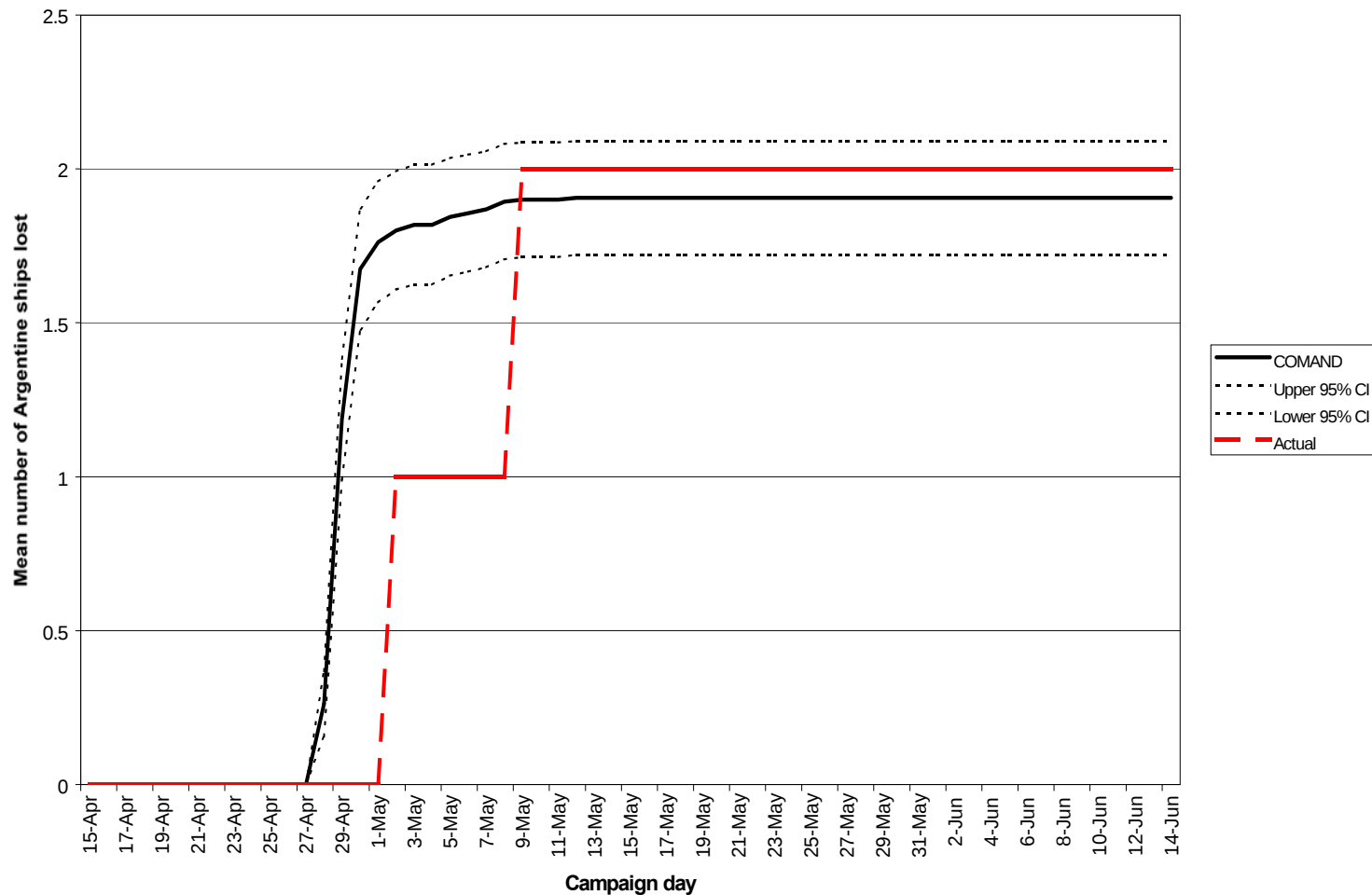
# Validation in COMAND - UK ships lost over time



# UK losses by type



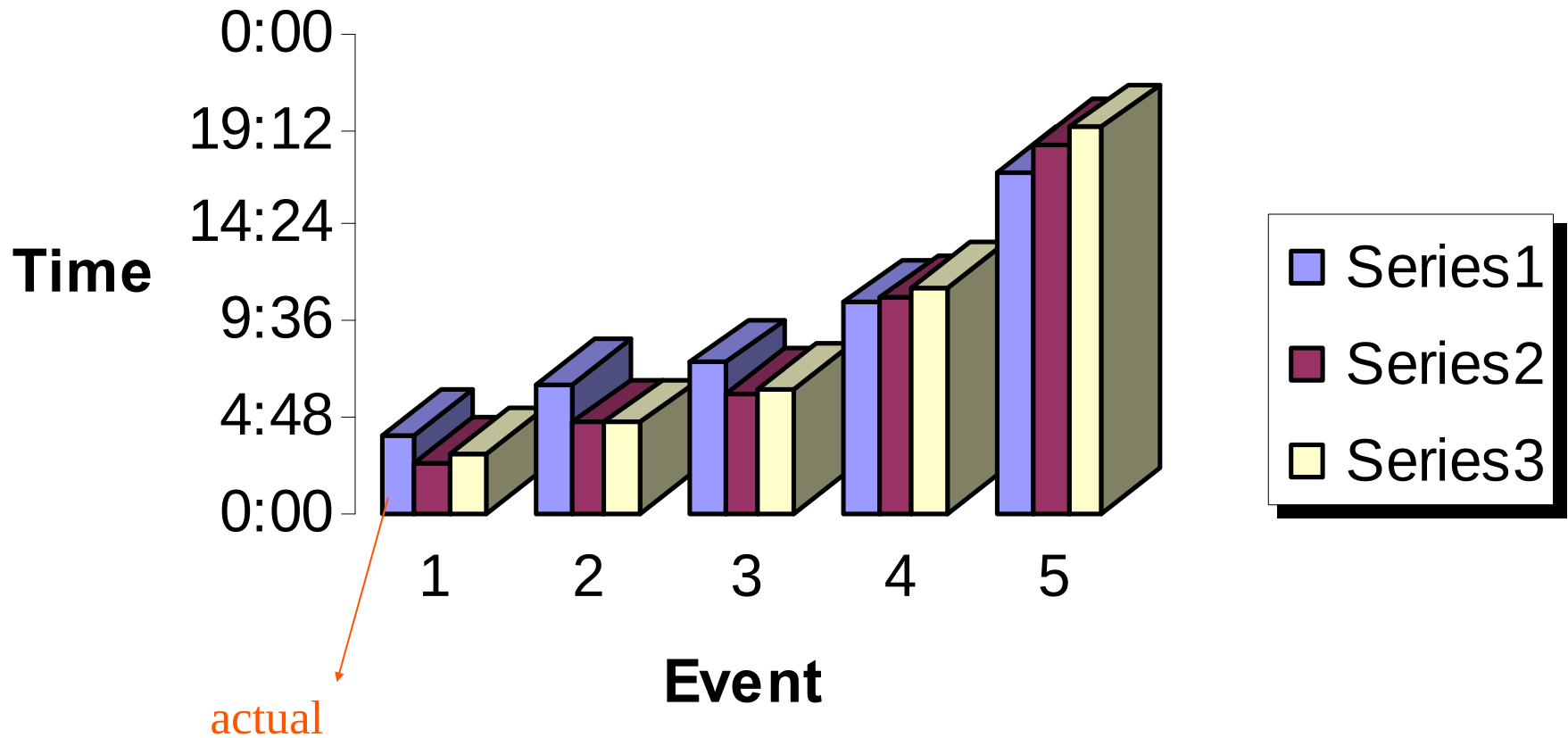
# Argentinian ship losses



# Validation of SIMBAT

- Battle of Goose Green 1982
- Operation Epsom 1944
- Brigade level operations 1944-45
- Comparison with CAEN
- Comparison with BATUS trials

# Goose Green Battle Dynamics



**[dst1]**

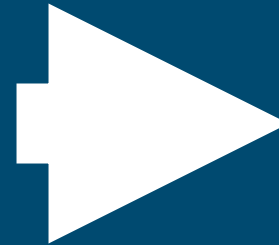
***Challenge 2 -  
understanding emergent  
behaviour***

# Research Agenda

**Develop metamodel of understanding of behaviour**



**Baseline enabling capability to represent C2 in aggregate fast running models**

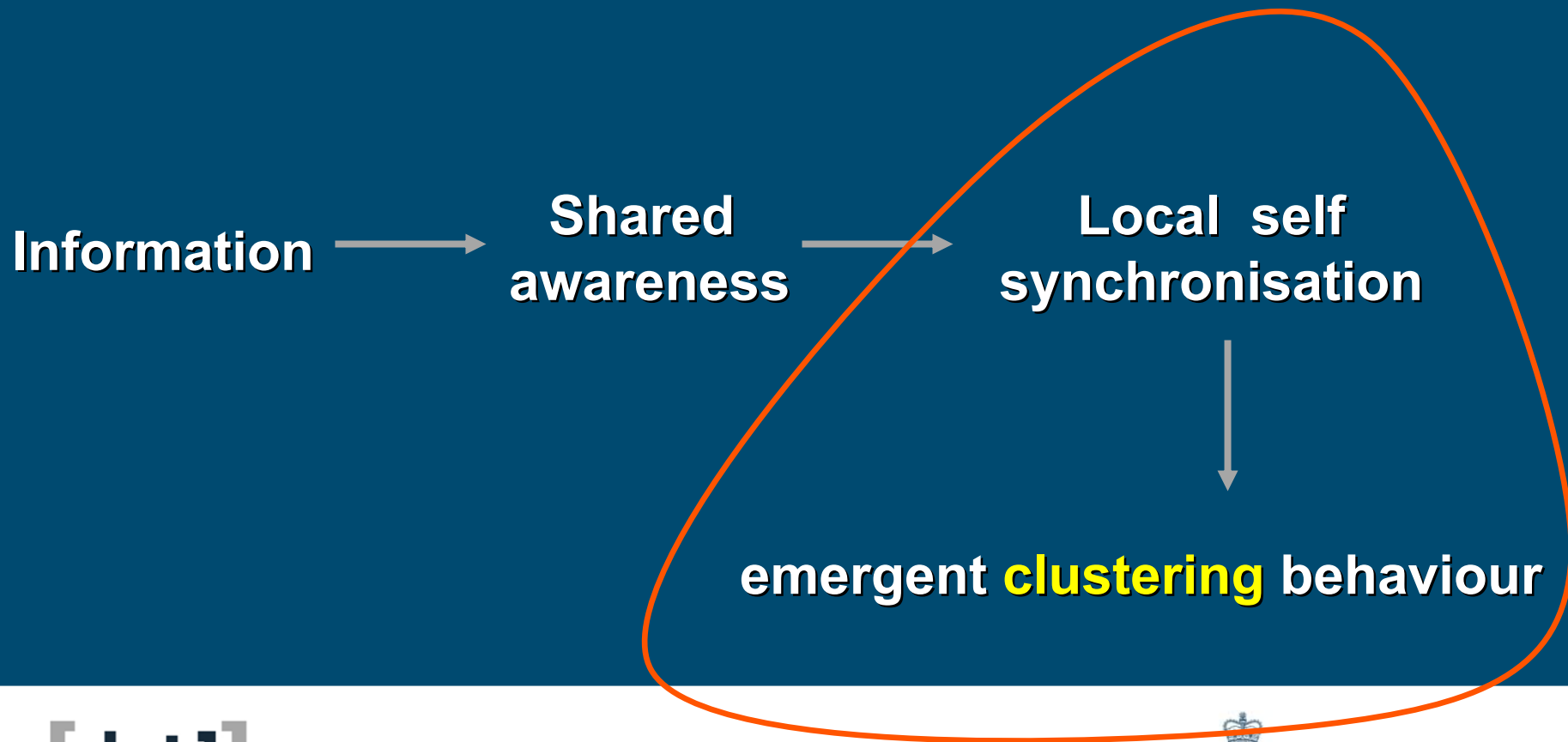


**Pullthrough and Validation**

**Develop deeper representation of C2 specific human processes**



# network enabled warfare/Information age warfare

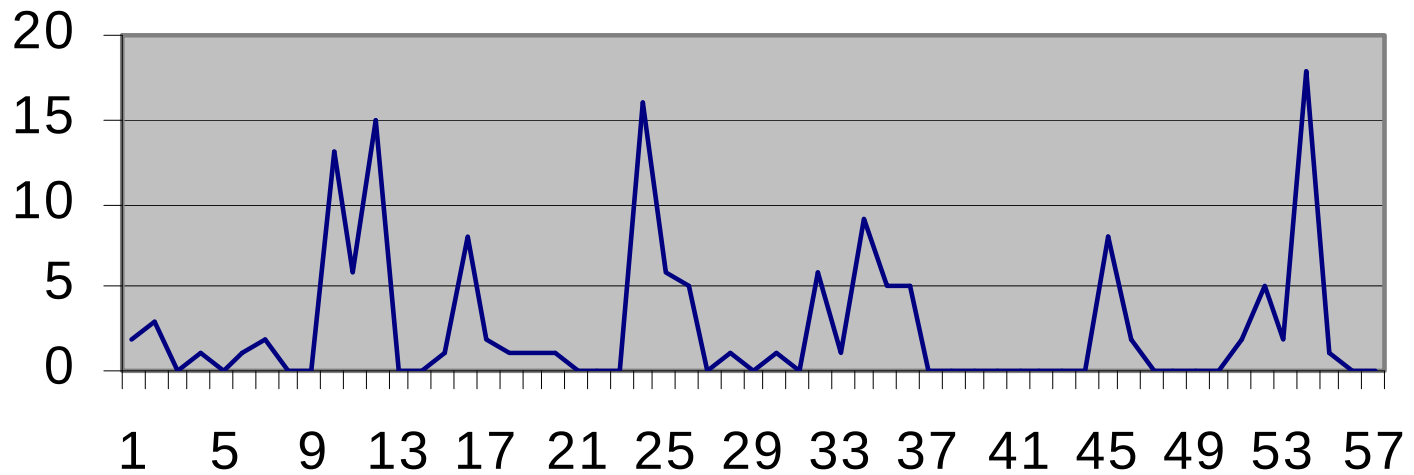


# Roberts and Turcotte data

- Real forest fires (4 data sets 4284, 120, 164, 298)  
power law with slope 1.3-1.5
- Real wars (2 data sets: 119, 1495 - 1973; 118, 1816 - 1980) power law with slope 1.3-1.4

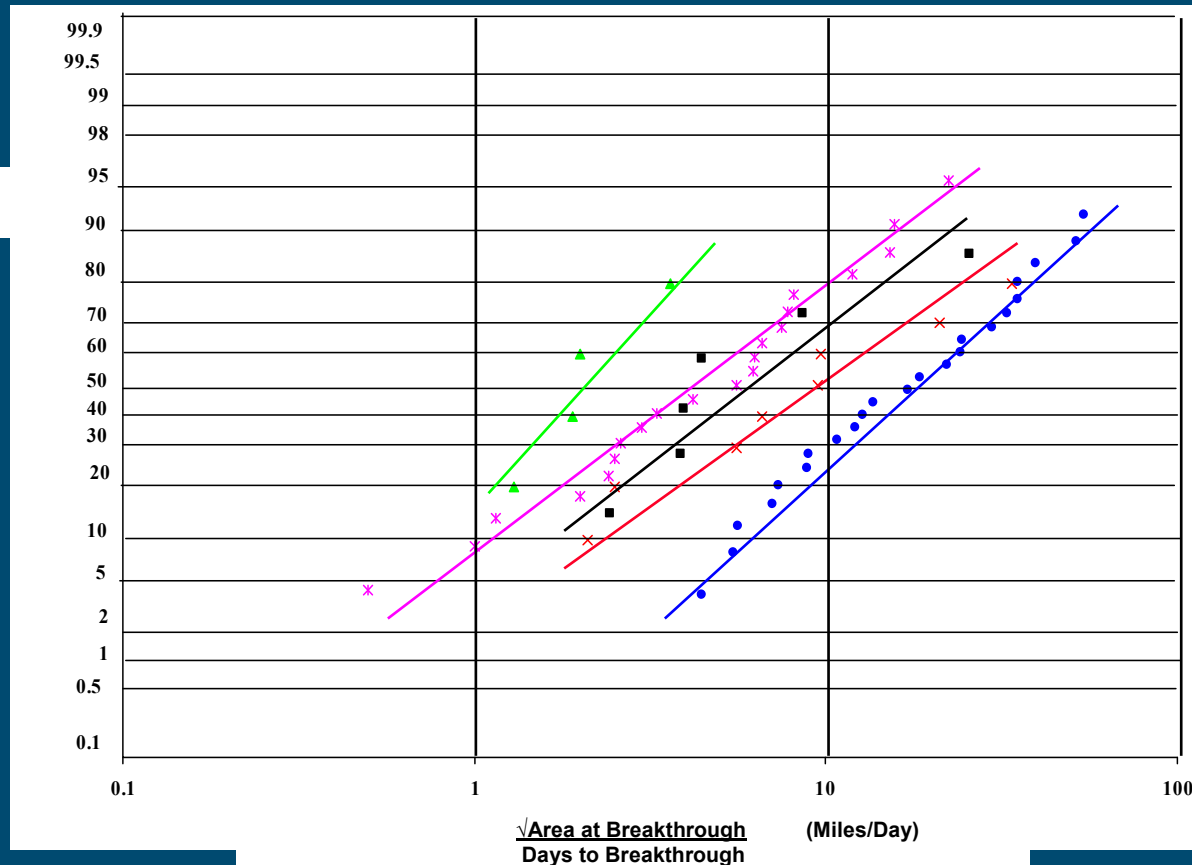
# US WW2 data on casualties suffered

## 2nd Armoured Division data



# Irruption as complex process

Fig 2: Cumulative Distributions of  $\sqrt{\text{Area}/\text{Duration}}$  at Breakthrough



# General Form of a Metamodel -similarity parameter b (e.g Fluid Dynamics)

$$a = f(a_1, \dots, a_k, b_1) = a_1^p \dots a_k^r \Phi \left( \frac{b_1}{a_1^{p_1} \dots a_k^{r_1}} \right)$$

Casualties or Control

Unit effectiveness

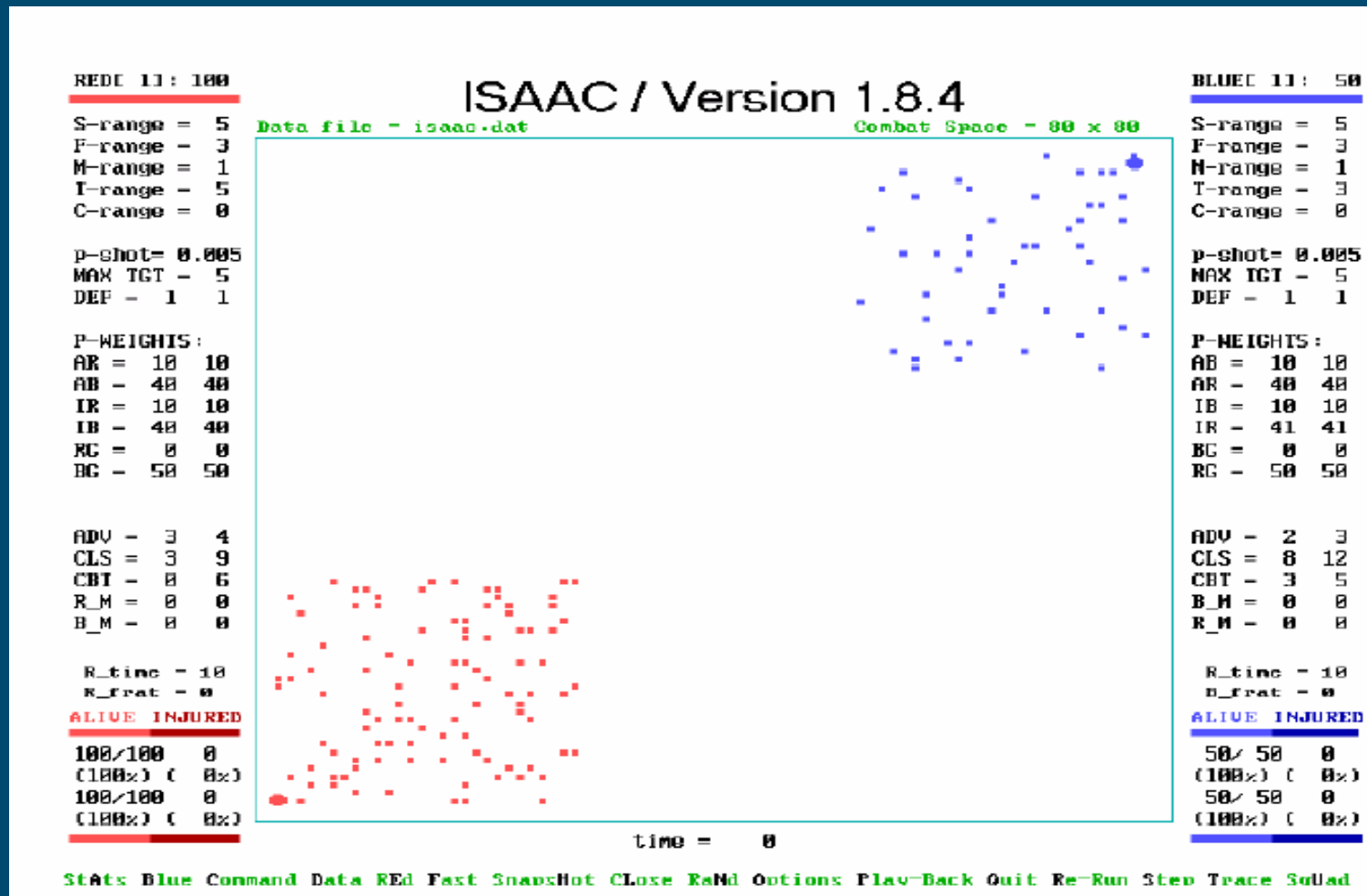
Clustering of forces or effects

# Fractal Dimension - 'Similarity'

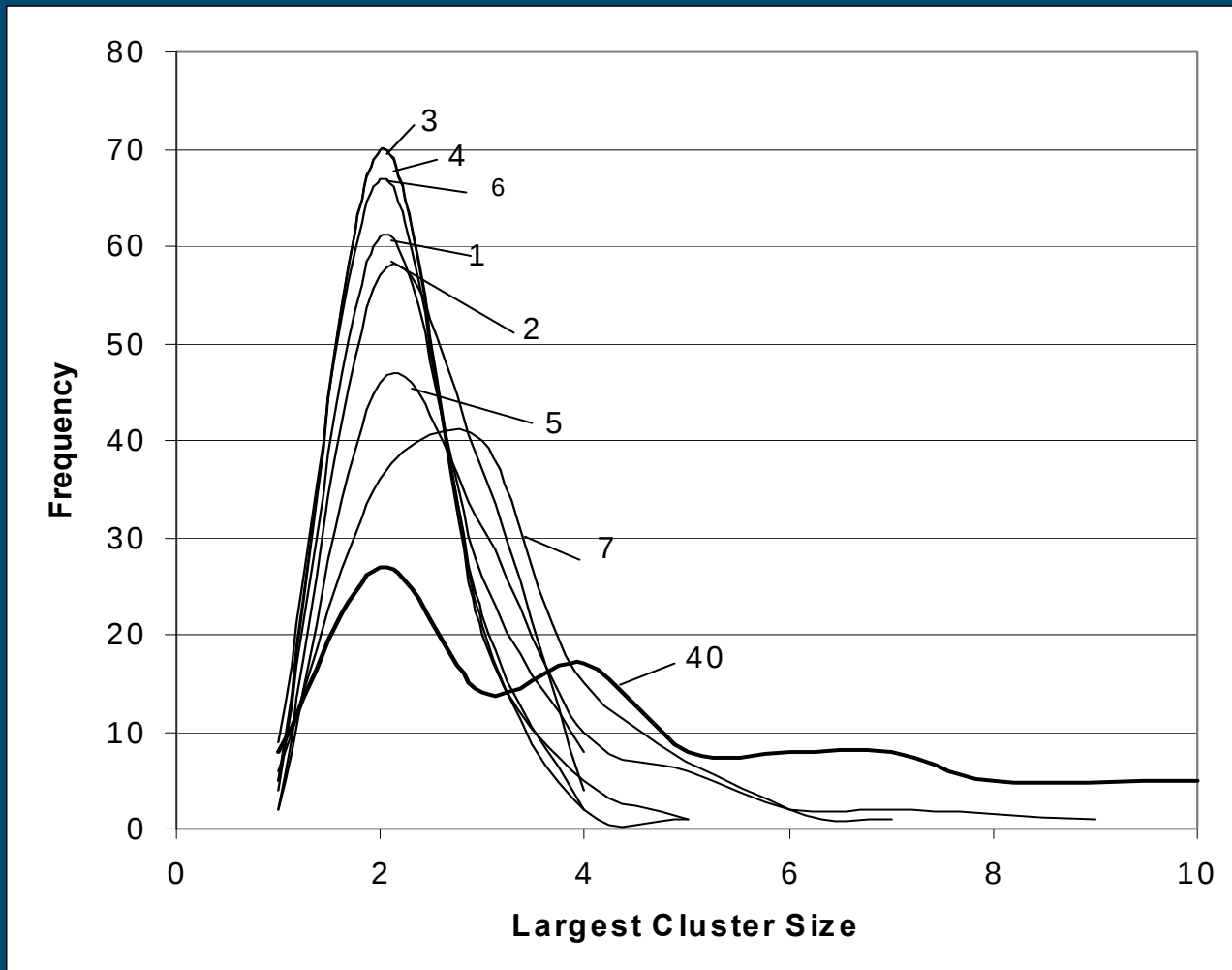
| Case (requirement is for Blue to reach 25% casualty level). | Red Fractal Dimension $D$ |
|-------------------------------------------------------------|---------------------------|
| 'Dispersed'                                                 | 0.7                       |
| 'Linear'                                                    | 1.7                       |
| Stochastic Lanchester                                       | 2                         |
| Recce                                                       | 0.8                       |
| 'Dispersed'                                                 | 0.9                       |
| 'Dynamic'                                                   | 1.0                       |
| 'Fluid'                                                     | 1.1                       |
| 'Classic Fronts'                                            | 1.7                       |

Table 6.1 ISAAC mean fractal dimensions

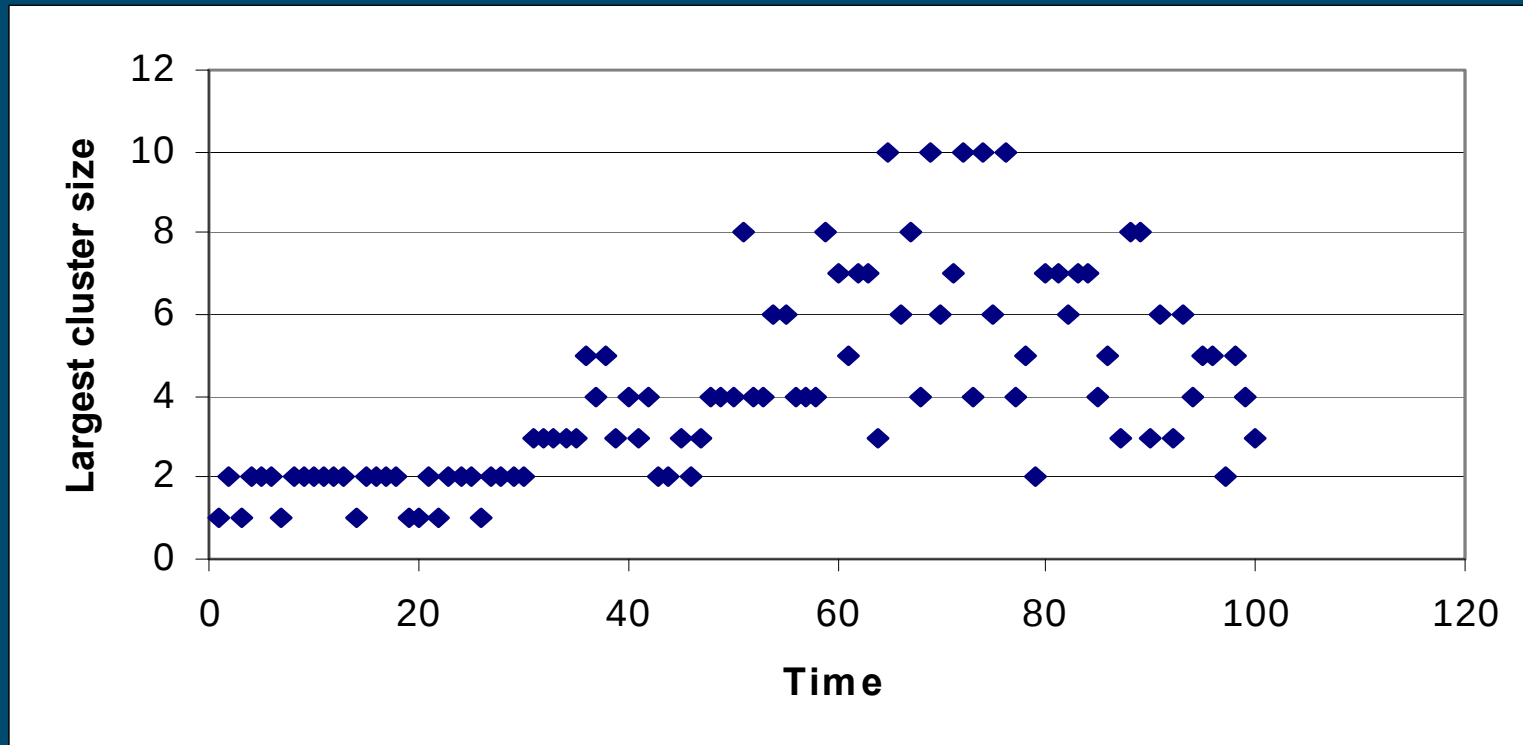
# Example of ISAAC start condition



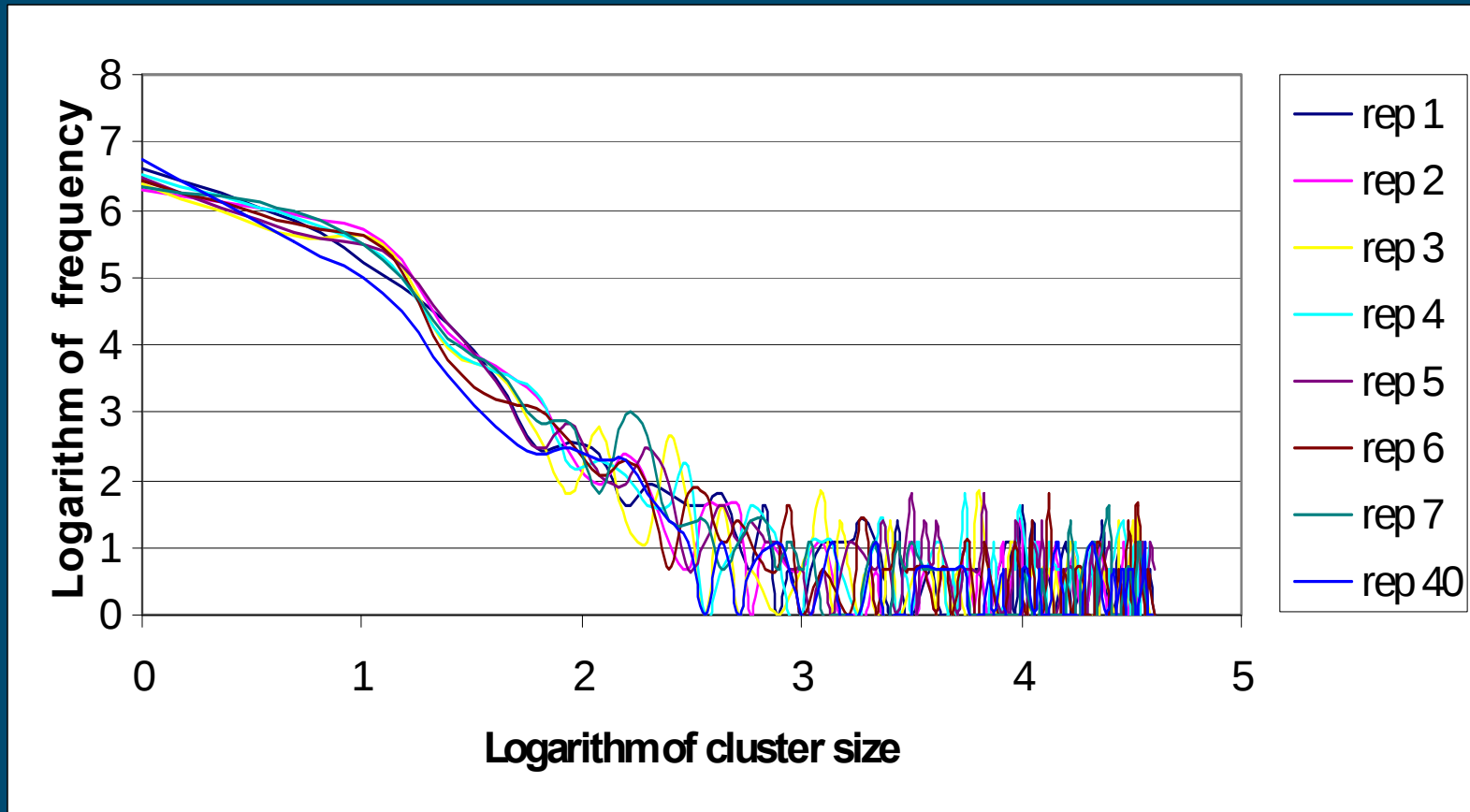
# Blue cluster size distribution



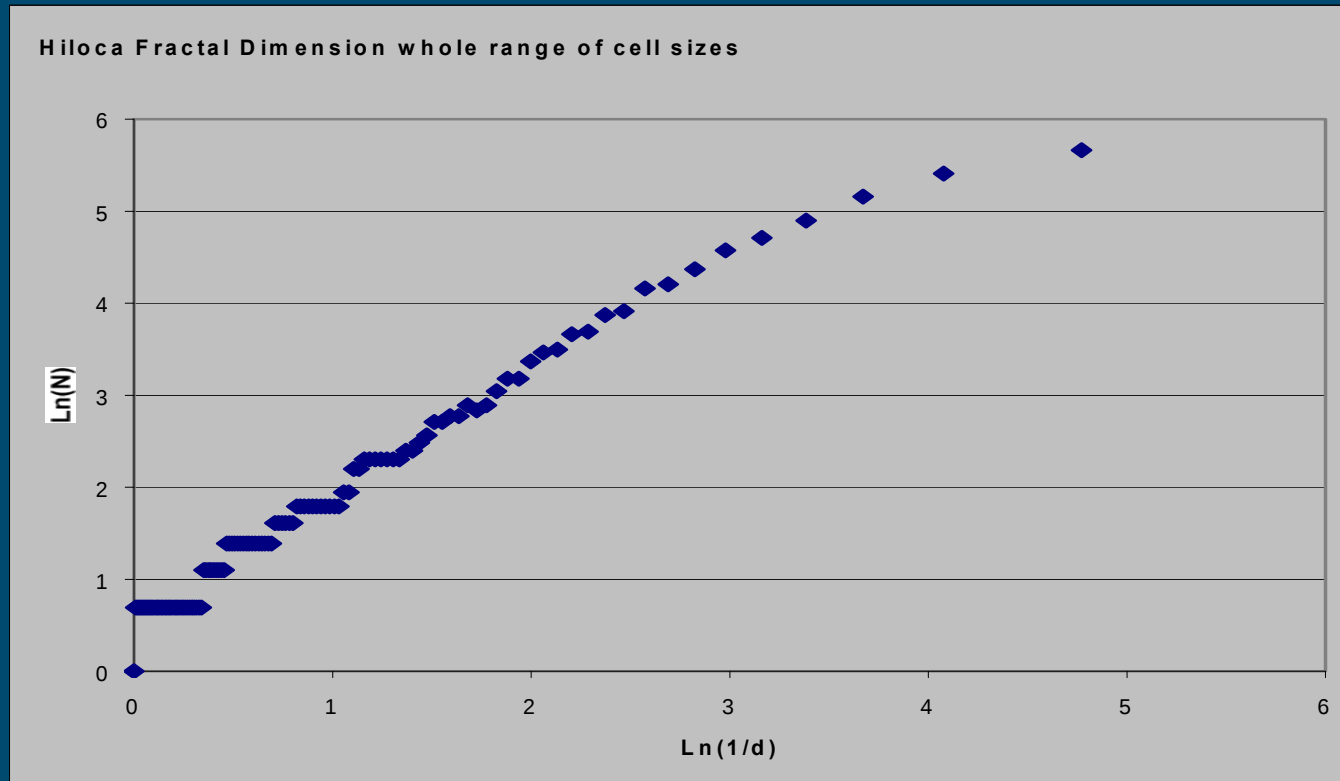
# Blue largest cluster size over time



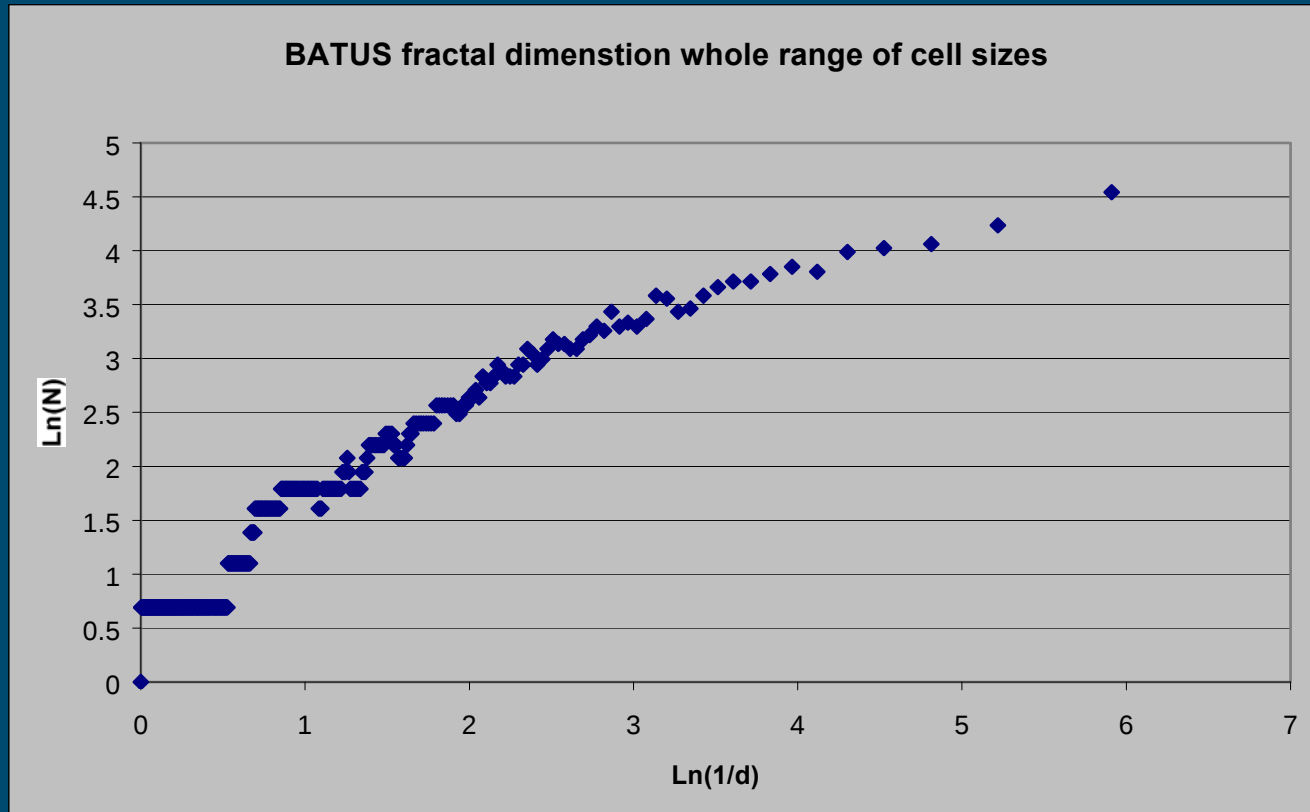
# Red distribution of cluster size



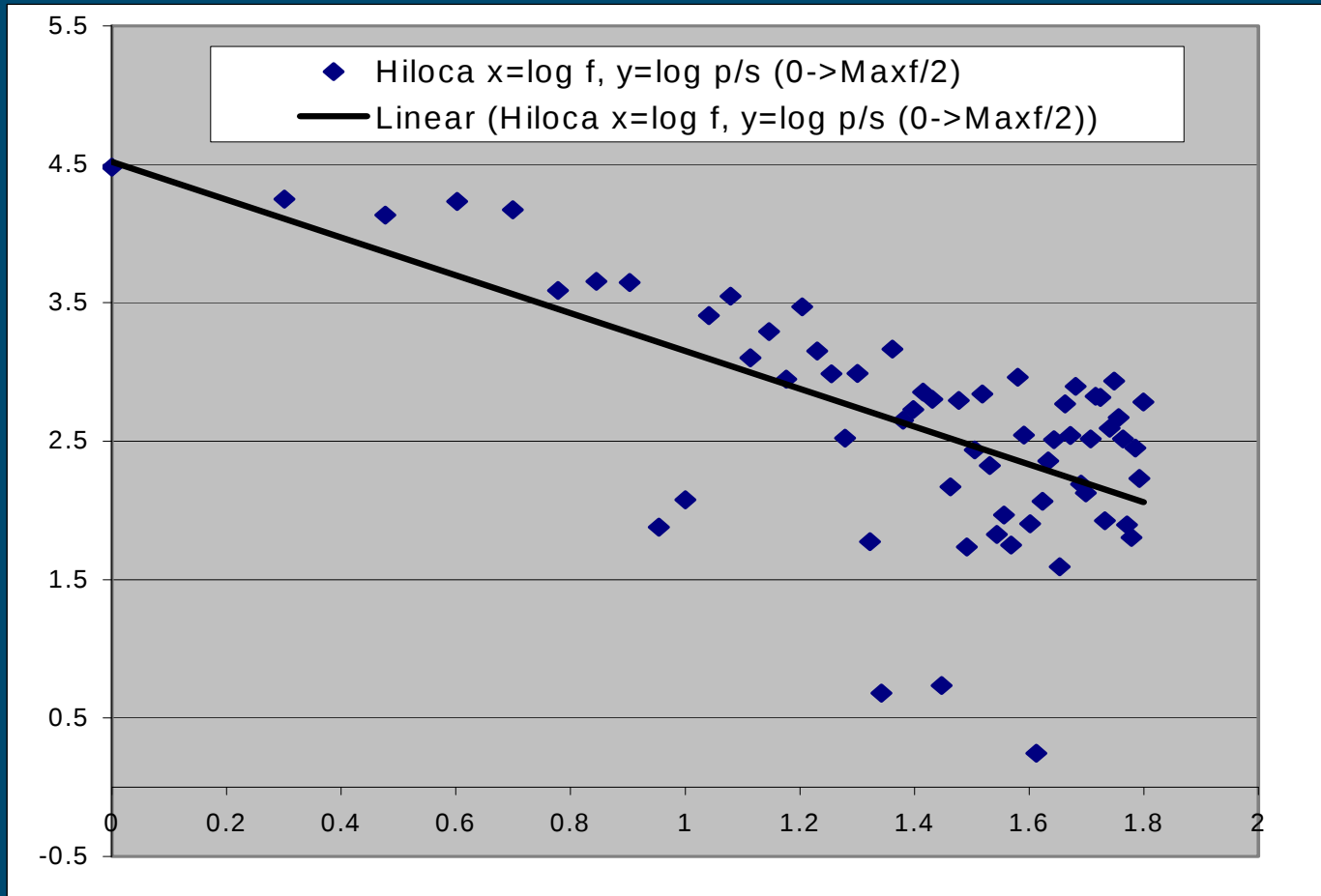
# Agent simulation force fractal dimension



# BATUS experimental data using GPS locations



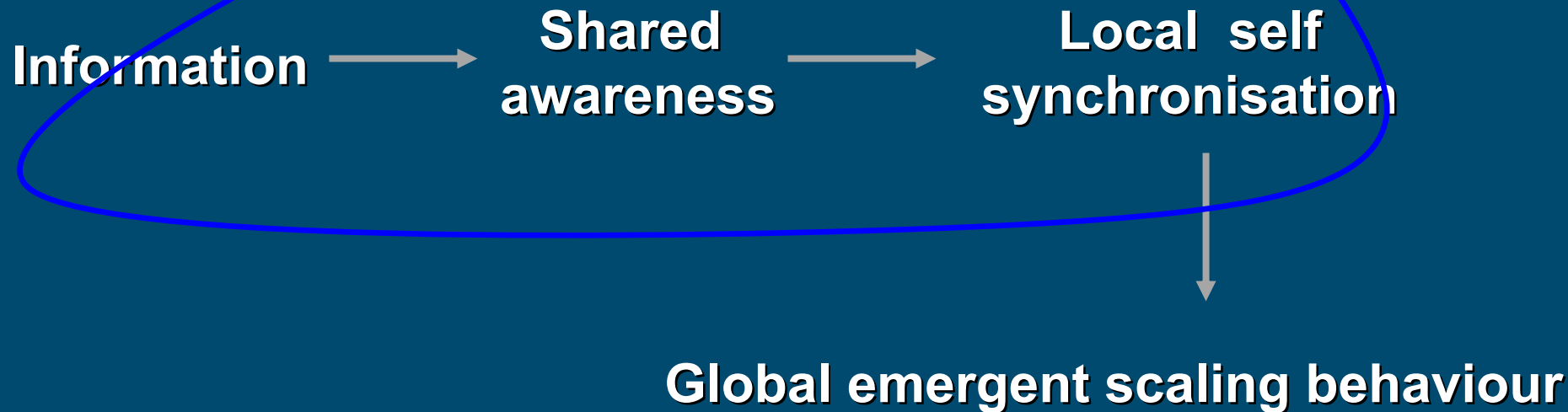
# Power spectrum of casualties from agent simulation



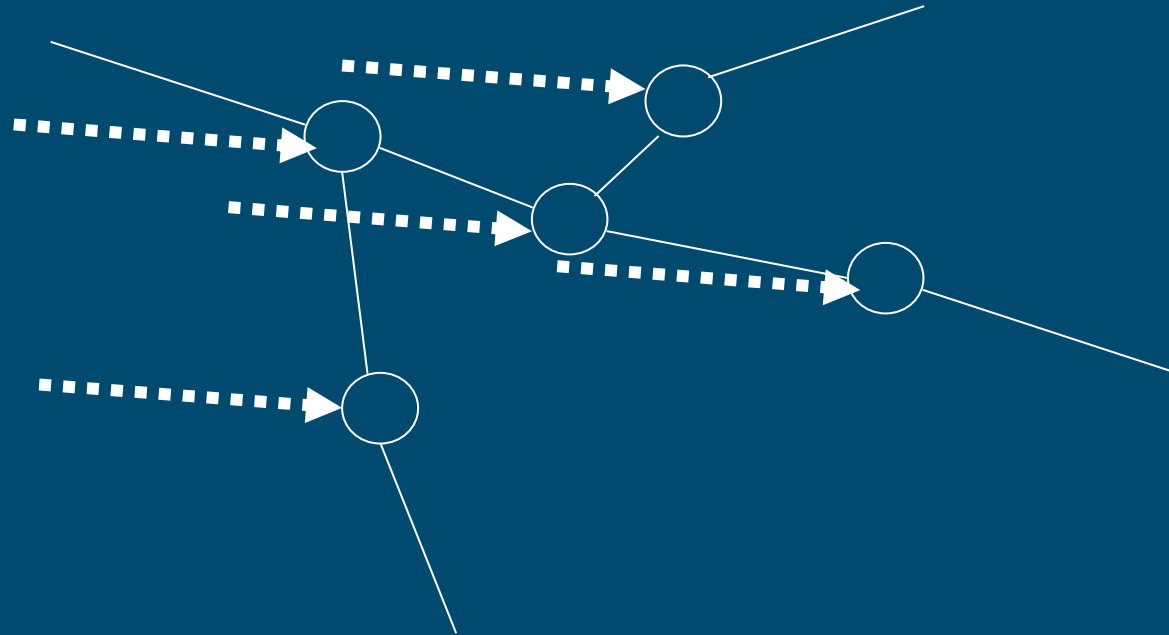
**[dst1]**

***Challenge 3 - modelling  
clustering across an  
information network***

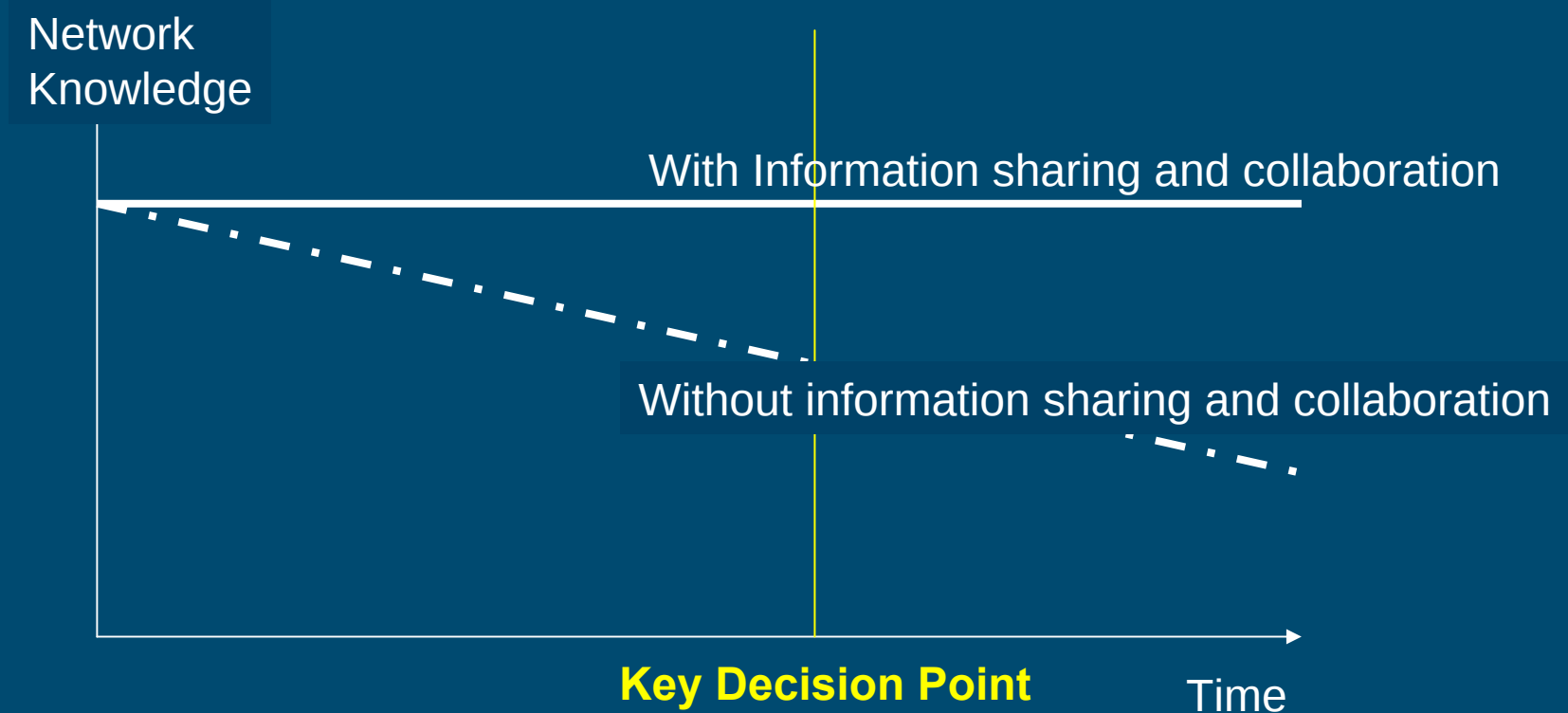
# network enabled warfare/Information age warfare



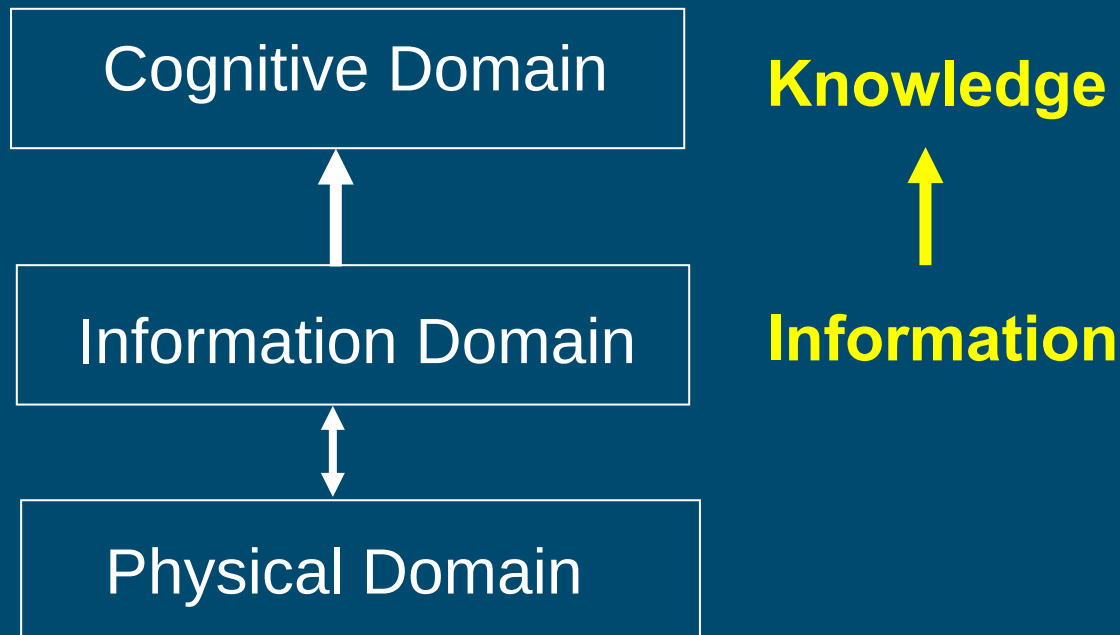
# A Network of Decision Making Nodes



# Increased Network Knowledge improves rapid planning



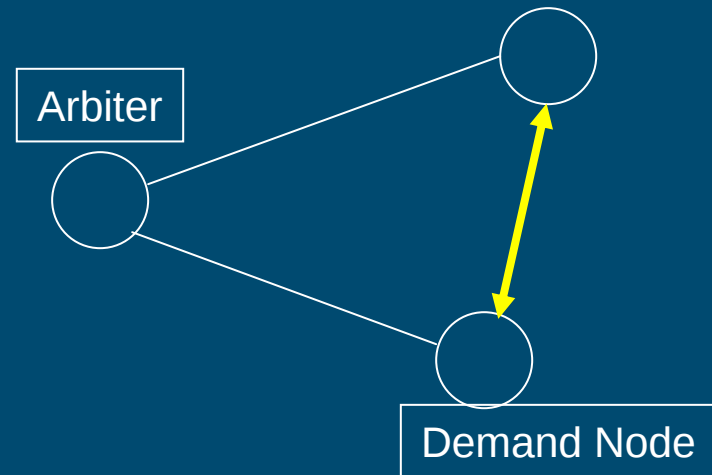
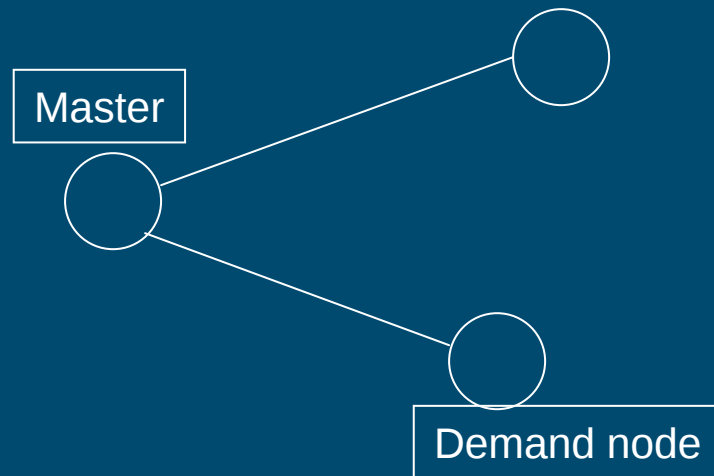
# Information Superiority Reference Model



# Collaboration Across the Network



# Simple Example of Collaboration - Fuel Demand at Two Nodes

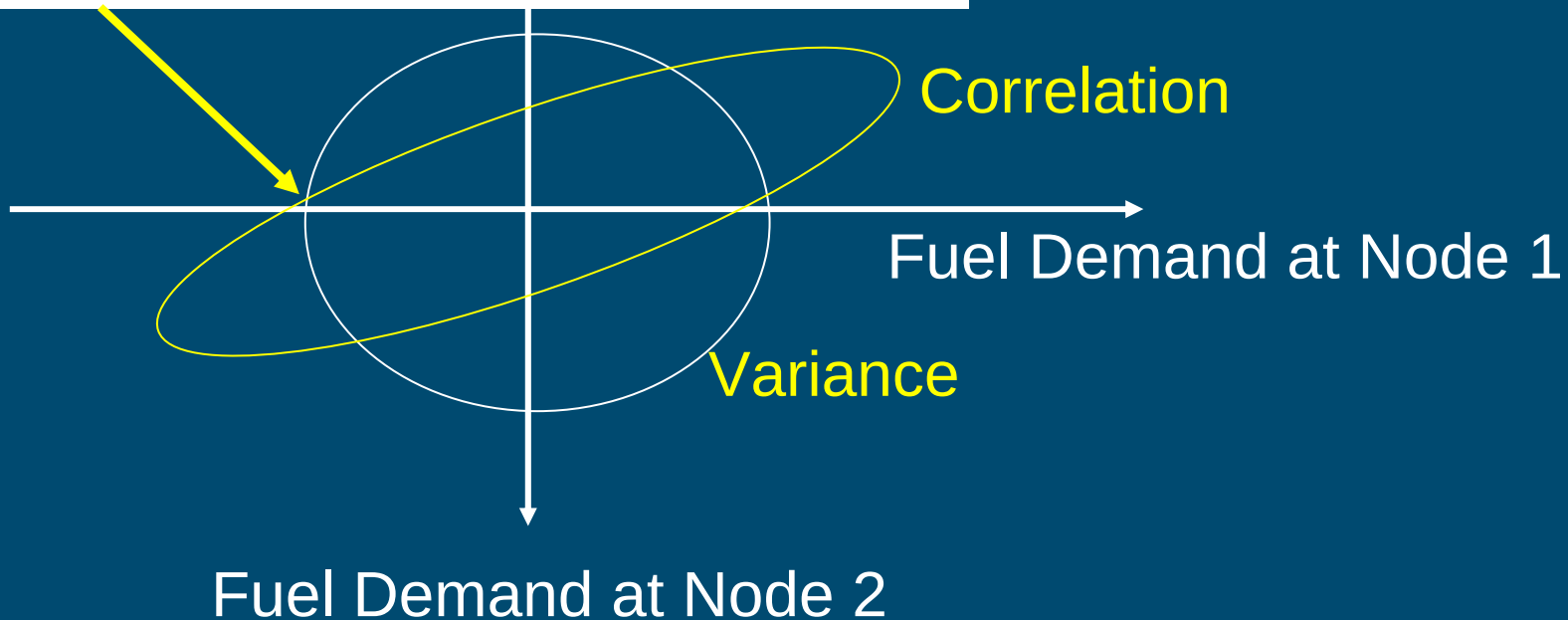


# The Benefit of Collaboration

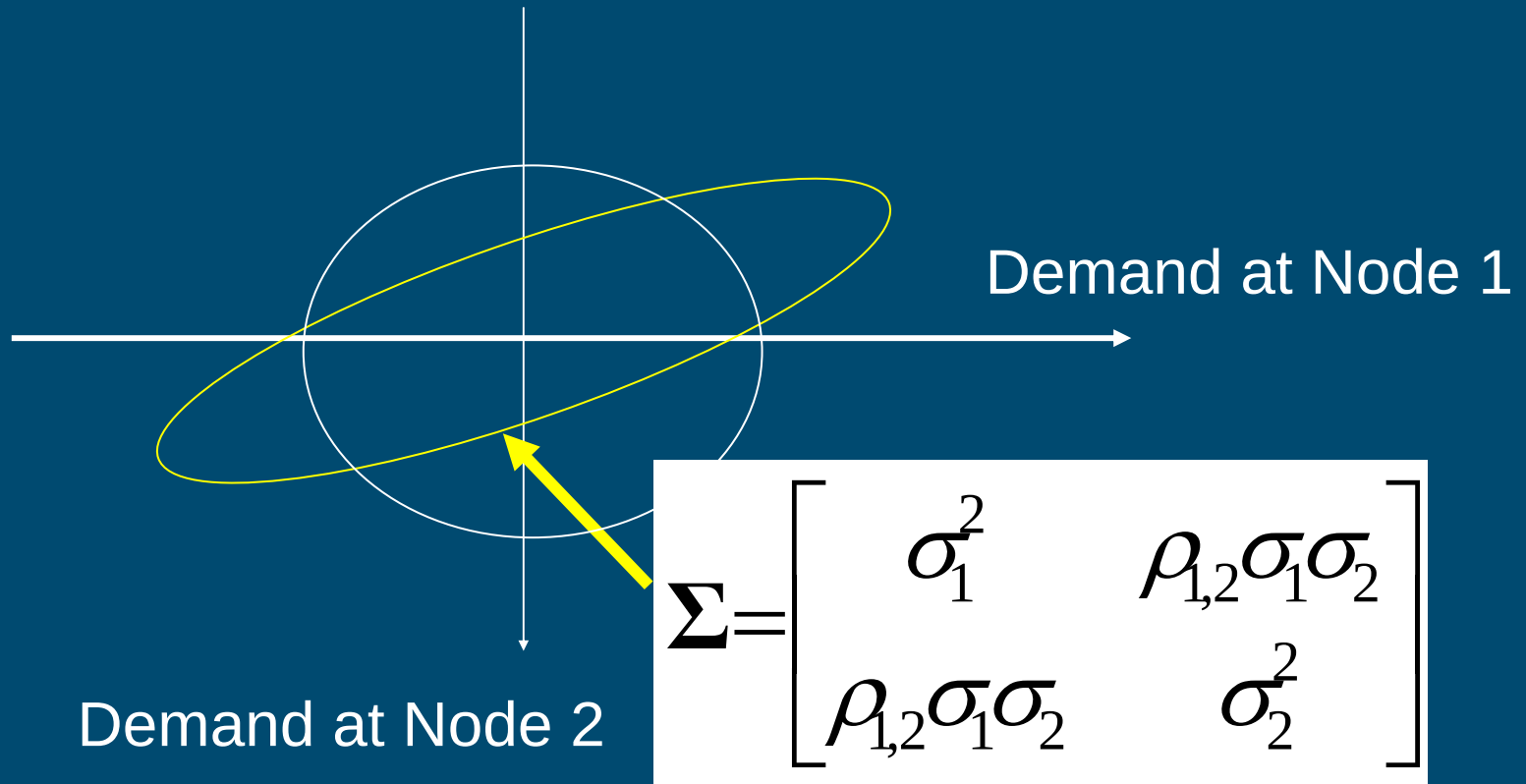
- Precision
  - The ability of a collaborating team to provide estimates that are very close together
  - It affects the estimate's distribution **variance**
- Accuracy
  - The ability of the collaborating team to provide estimates close to ground truth
  - It affects the estimate's distribution **mean**
- Correlation
  - The ability of the collaborating team to understand the way variables relate to each other
  - It affects the estimate's **joint probability distribution**
- All Contribute to Knowledge

# The Covariance Matrix $\Sigma$

$$f(\mathbf{X}) = \frac{1}{\sqrt{(2\pi)^N |\Sigma|}} e^{\left(-0.5[\mathbf{X}-\mu]^T \Sigma^{-1} [\mathbf{X}-\mu]\right)}$$



# The Covariance Matrix $\Sigma$



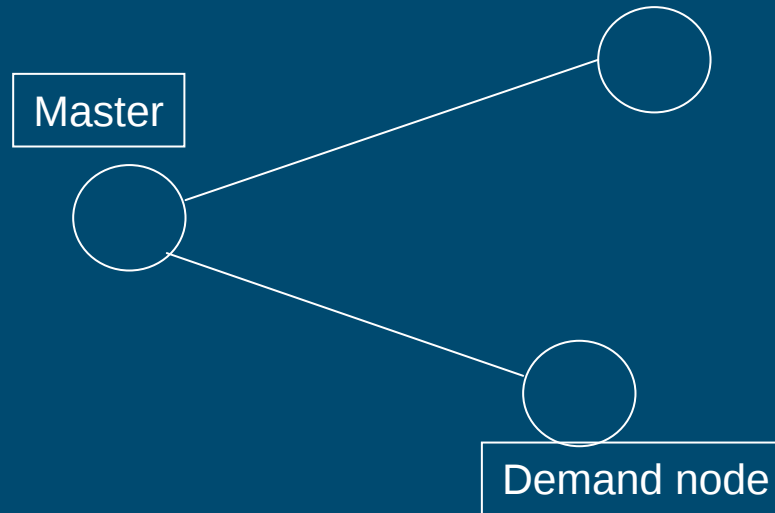
# Information Entropy - Normal Distribution

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

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

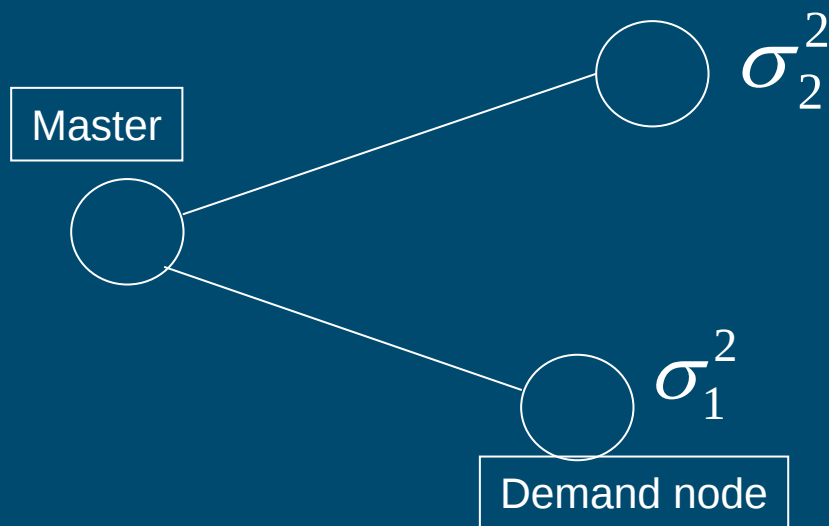
# Simple Logistics Example

## No Collaboration - No Covariance



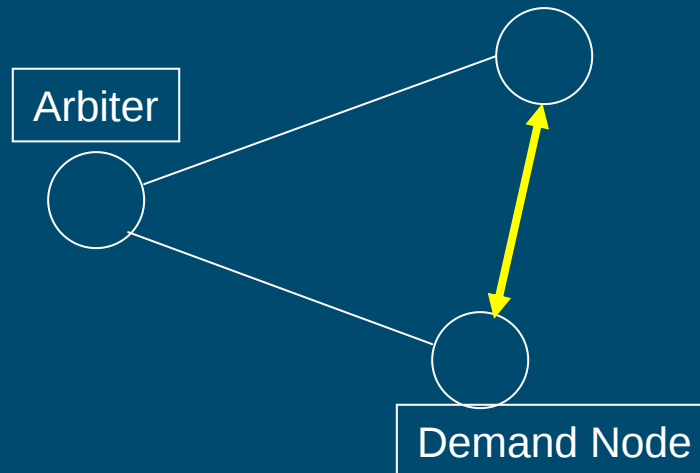
Total Entropy = Entropy at Node 1  
+ Entropy at Node 2

# Total Information Entropy - No Collaboration



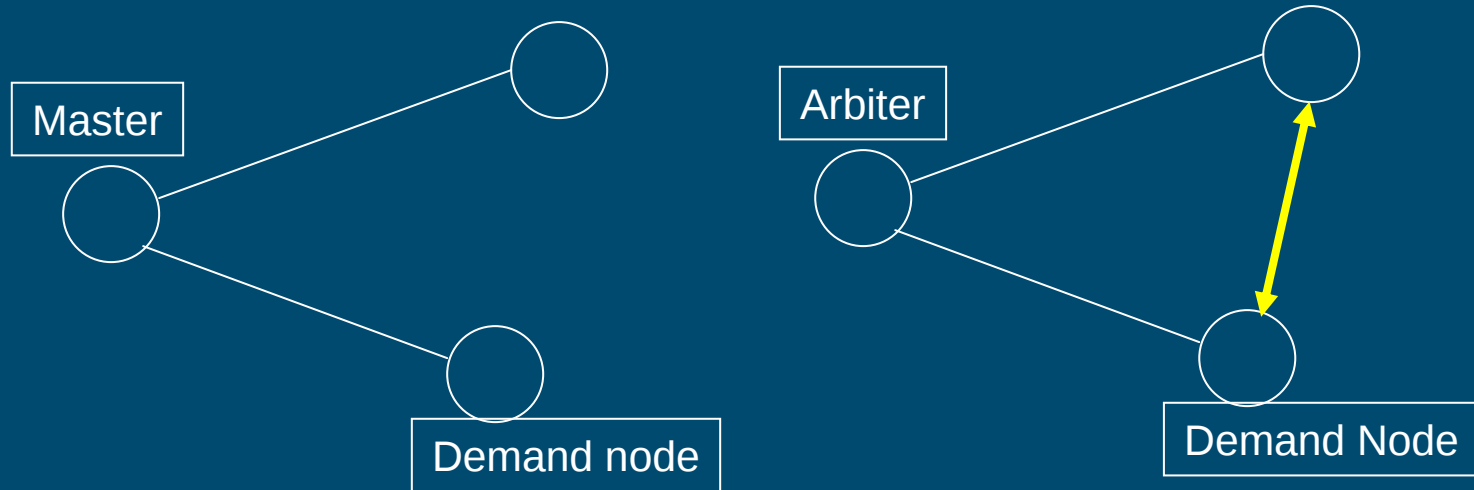
$$\text{Total Entropy} = \text{Log} \begin{vmatrix} \sigma_1^2 & 0 \\ 0 & \sigma_2^2 \end{vmatrix} = \text{Log} \sigma_1^2 \sigma_2^2 = \text{Log} \sigma_1^2 + \text{Log} \sigma_2^2$$

# Total Information Entropy - With Collaboration



$$\text{Total Entropy} = \text{Log} \begin{vmatrix} \sigma_1^2 & \rho_{1,2}\sigma_1\sigma_2 \\ \rho_{1,2}\sigma_1\sigma_2 & \sigma_2^2 \end{vmatrix} = \text{Log} \sigma_1^2 \sigma_2^2 (1 - \rho_{1,2}^2)$$

# Entropy Reduction due to Collaboration



$$\text{Entropy Reduction} = \text{Log}(1 - \rho_{1,2}^2)$$

# Source References

- J Moffat 'Command and Control in the Information Age - Representing its Impact' The Stationery Office, London, UK, 2002.
- J Moffat 'Complexity Theory and Network Centric Warfare' in press, CCRP, OSD,DoD, USA, 2003.
- W Perry, J Moffat 'Information Sharing among Military Headquarters; The Impact on Decision Making' in press, RAND Corporation DRR-2965-UK, 2003.

# *Challenges for the information age*

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  - command effectiveness/force effectiveness
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  - local collaboration/force level effects
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