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# Developing A Requisite Analytic Trade-Space For Assessing Agile Mission Grouping

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## Approach Adopted For The Construction And Implementation Of The DARNSTORMS Model

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# Abbreviations Used In This Presentation

- C2 – Command and Control
- C3I - Command, Control, Communications and Intelligence
- Dstl – UK Defence Science and Technology Laboratory
- DSTO – Australian Defence Science and Technology Organisation
- NCW – Network Centric Warfare
- UML – Unified Modelling Language

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# Developing A Requisite Analytic Trade-Space For Assessing Agile Mission Grouping

- A series of three papers:
  - Problem Definition For The Development Of The DARNSTORMS Model
  - Theoretical Foundations of the DARNSTORMS Model
  - Approach Adopted For The Construction And Implementation Of The DARNSTORMS Model

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# STORM-DARNOS

- **Background**
  - The UK have developed the STORM algorithm, capable of representing a wide range of social and cultural variables inherent in the adaptive teamworking typically required here.
  - AUS have developed DARNOS, a model capable of representing agile teamforming as part of a wider network centric approach to operations.
- **Goals**
  - **UK goal** to demonstrate STORM algorithm is practical & effective, opening the way for wider exploitation in emerging UK simulations. Also will obtain valuable insights from DARNOS into how to represent agility in C3I assessment studies.
  - **AUS goal** to gain a key improvement in modelling capability, allowing a wider range of social & cultural issues to be addressed by DARNOS.

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# The DARNSTORMS Project

- The DARNSTORMS project arose out of the above -
- It is a joint Australia-UK Collaborative Effort, to combine:
  - DARNOS – Dynamic Agent Representation of Networks of Systems, with
  - STORM – Socio-cultural Teamworking for OR Models
  - To produce the DARNSTORMS model
- Recognition of mutual benefit from the development of a sufficient representation of agile, networked, multi-national forces, which DARNSTORMS aims to provide.
- Provision of a requisite analytic tradespace to provide OR modeling support to key planning processes.
- Joint funding by DSTO (Australia) and Dstl (UK), with model implementation by KESEM International.

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# Part 1. The DARNSTORMS Model – Key Components

- UML-Based Development Approach
- DARNSTORMS Architectural Components
- DARNSTORMS' NCW Player Perspective
- Decision Maker Infrastructure
- Functional Architecture of the Analyst Utilities
- Interaction Of STORM With DARNOS C2 Task Working Activities
- The Current Set Of 15 STORM Settables
- Generic Sine Wave Function Relationship between STORM Variables

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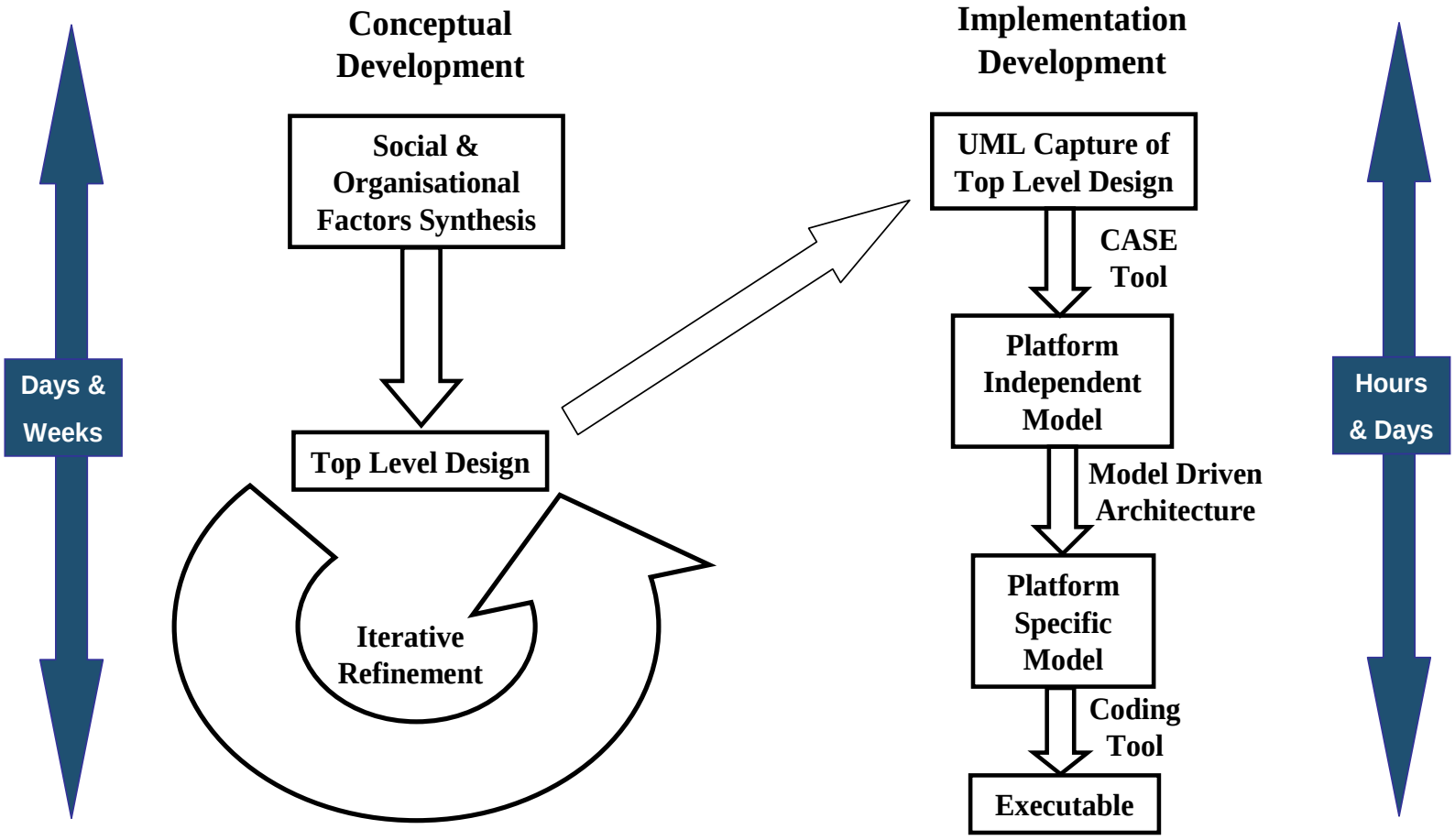
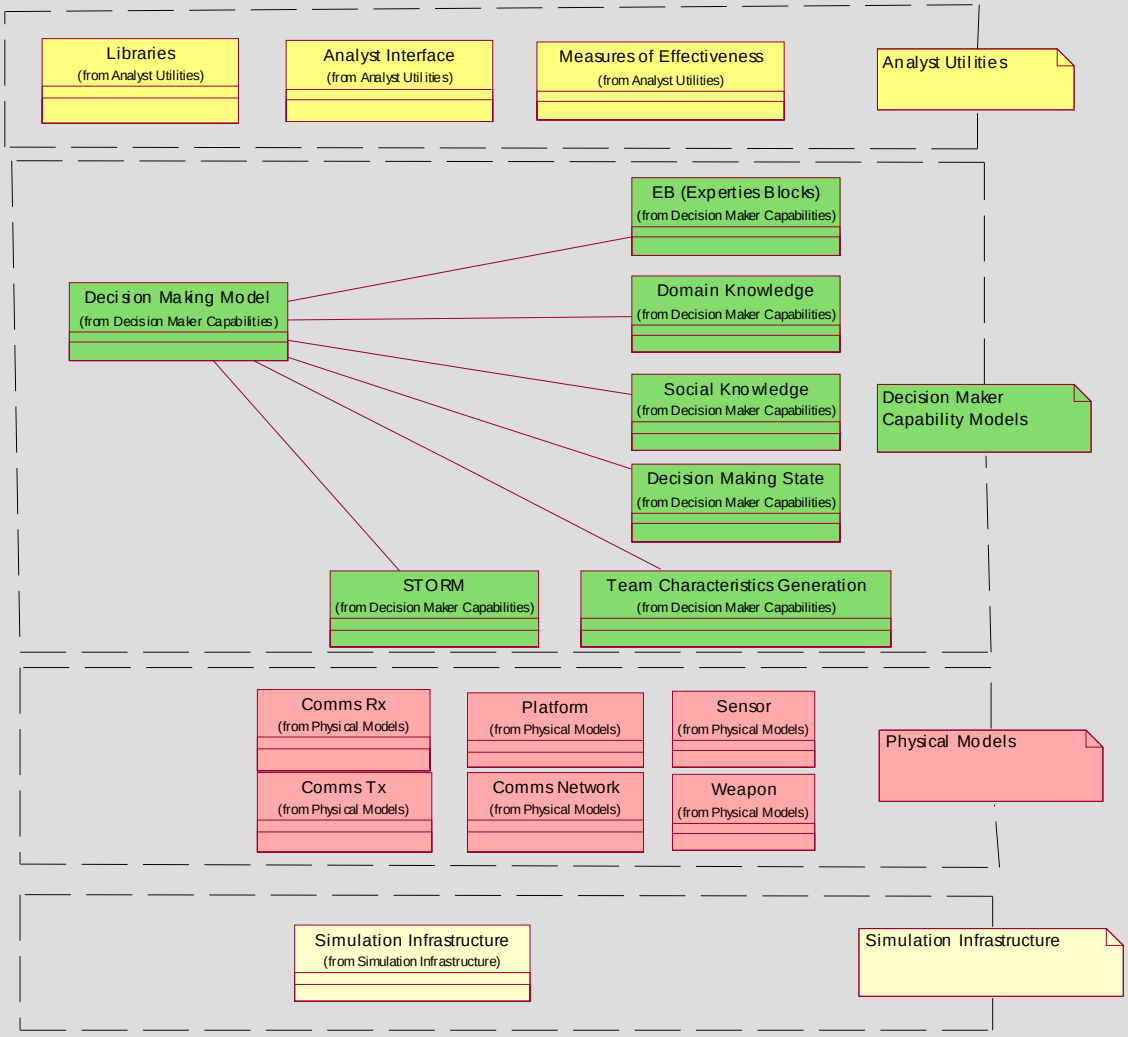
# A UML-Based Development Approach Is Used For DARNSTORMS (Shown Is That For STORM)



# DARNSTORMS Architectural Components

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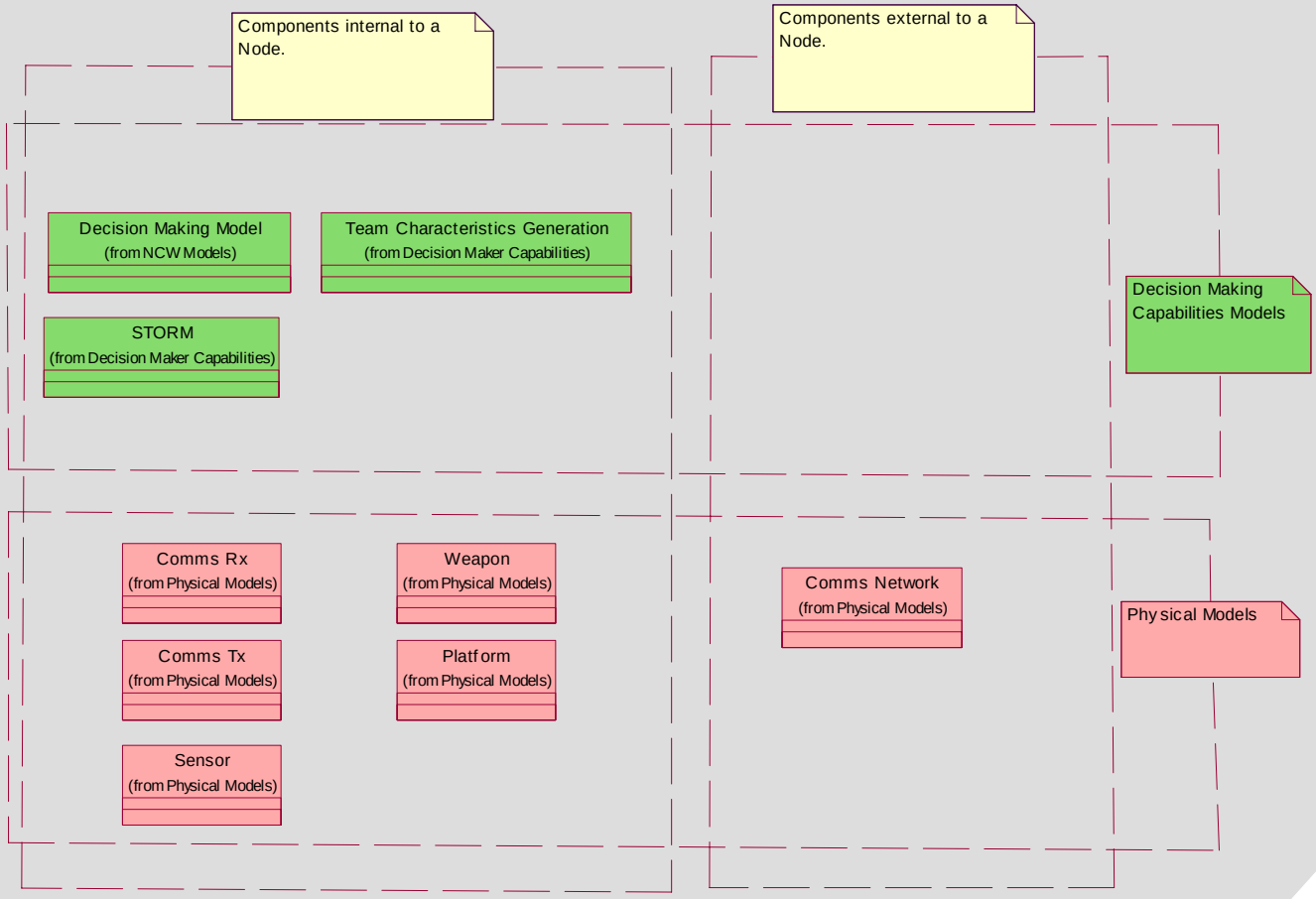
# DARNSTORMS' NCW Player Perspective

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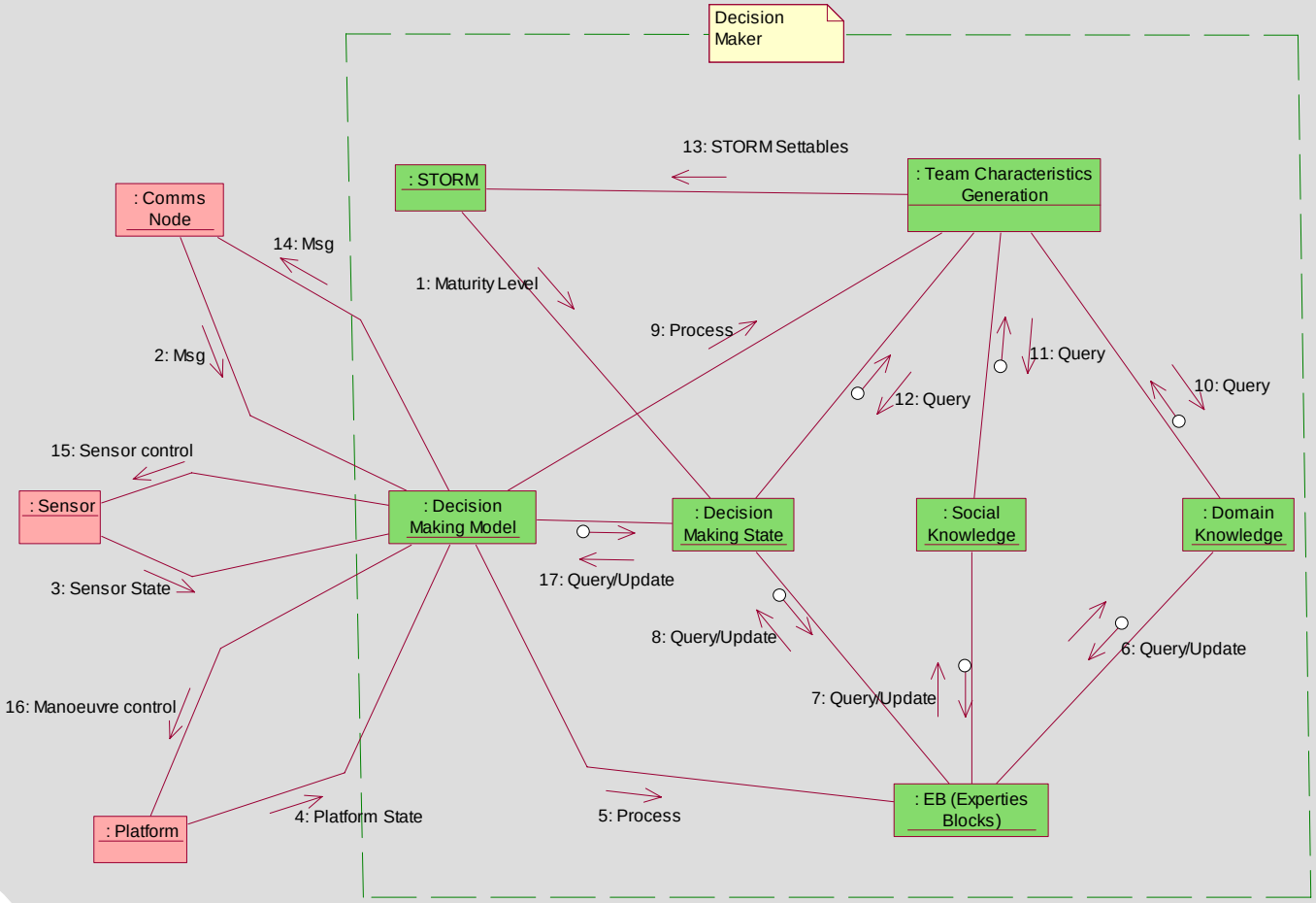
# Decision Maker Infrastructure

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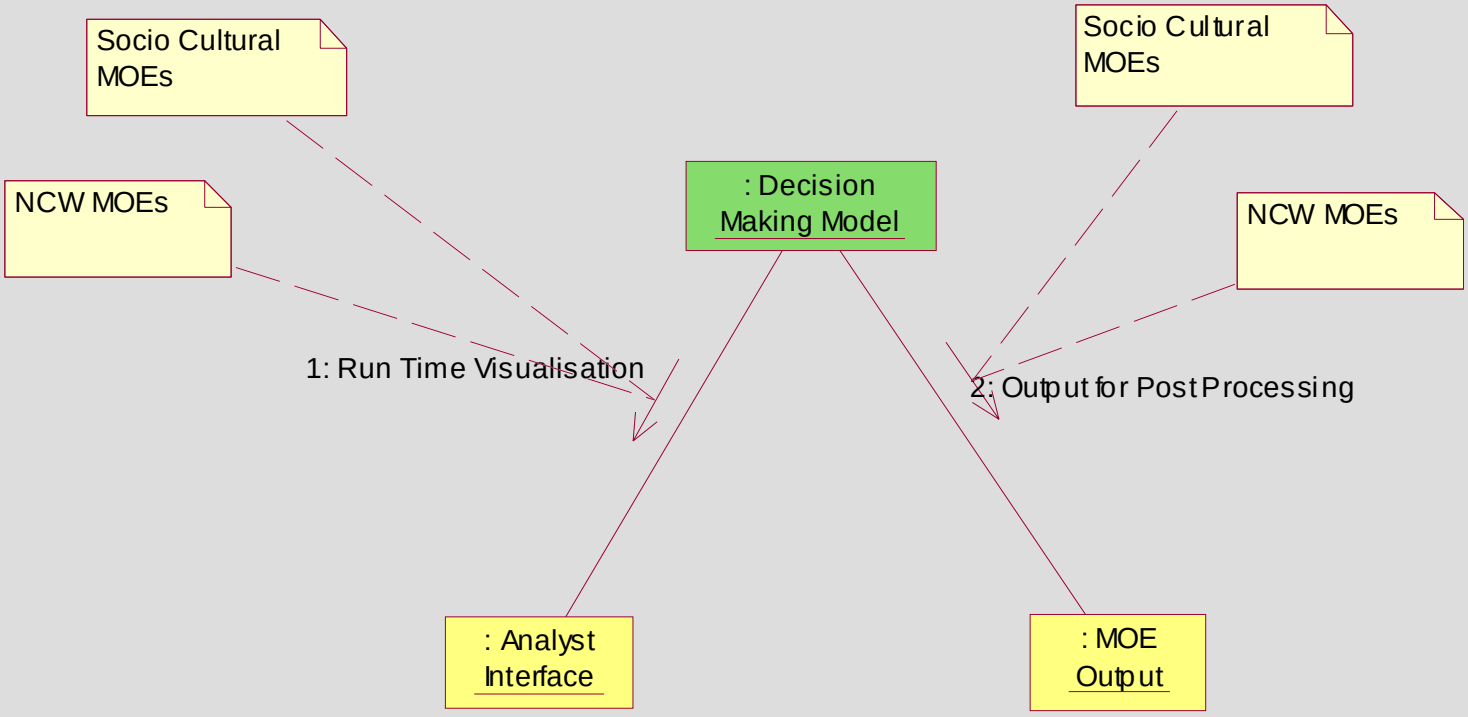
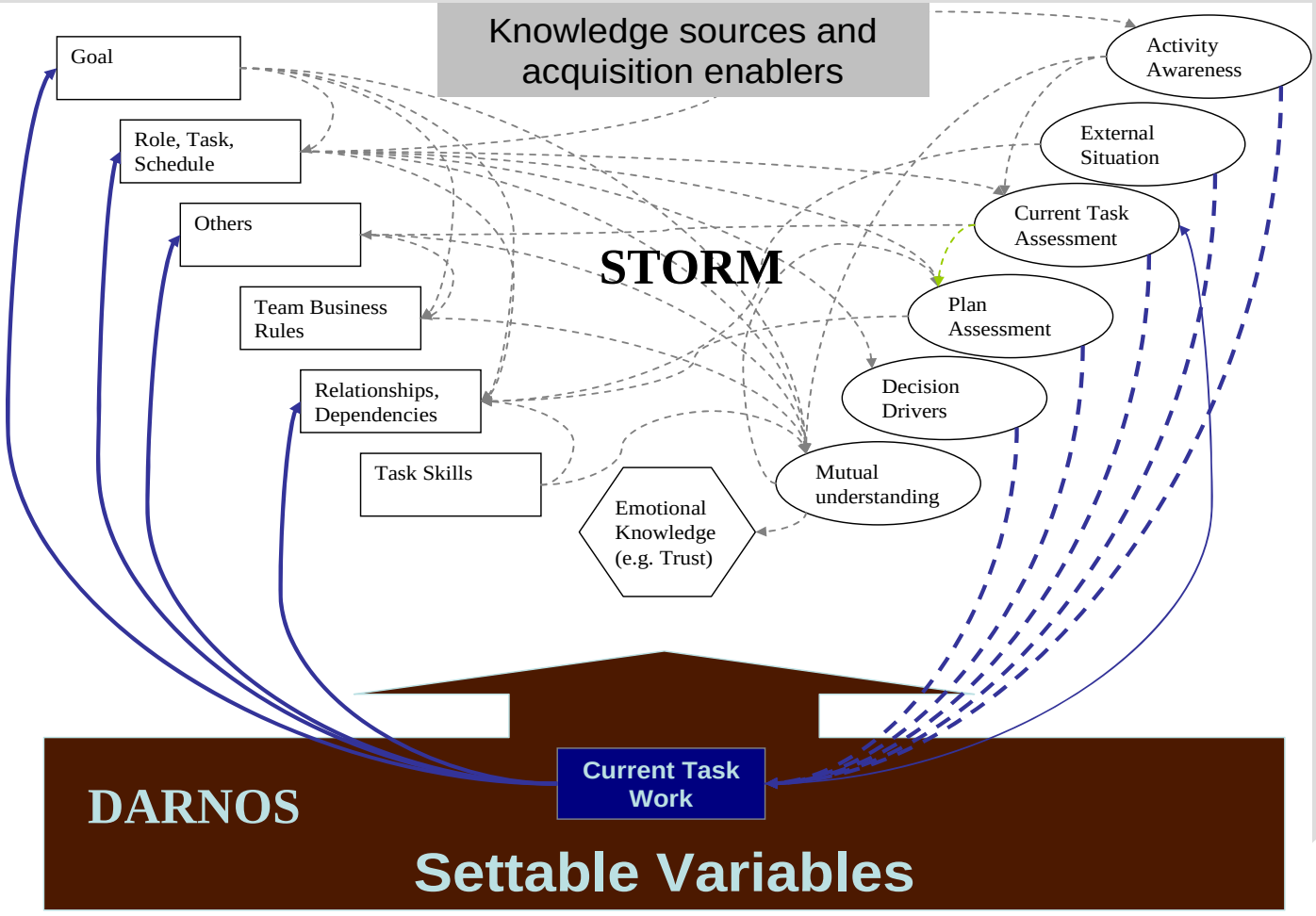
# Functional Architecture of the Analyst Utilities



# Interaction Of STORM With DARNOS C2 Task Working Activities

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# The Current Set Of 15 STORM Settables

- Socio-cultural coherence
- Organisational coherence
- Personal experience/coherence
- Leader-ship style
- Coordination style
- Team- work skills
- Task skills
- Situation brief
- Goal brief
- On-task location
- Off-task location
- Adversary environment
- Task difficulty
- Task richness
- Task novelty

## Settable Variables

Coalition C2

Agile Mission Grouping

Training & Experience

Rapid Deployment

Net-enabled C2

Comprehensive Approach

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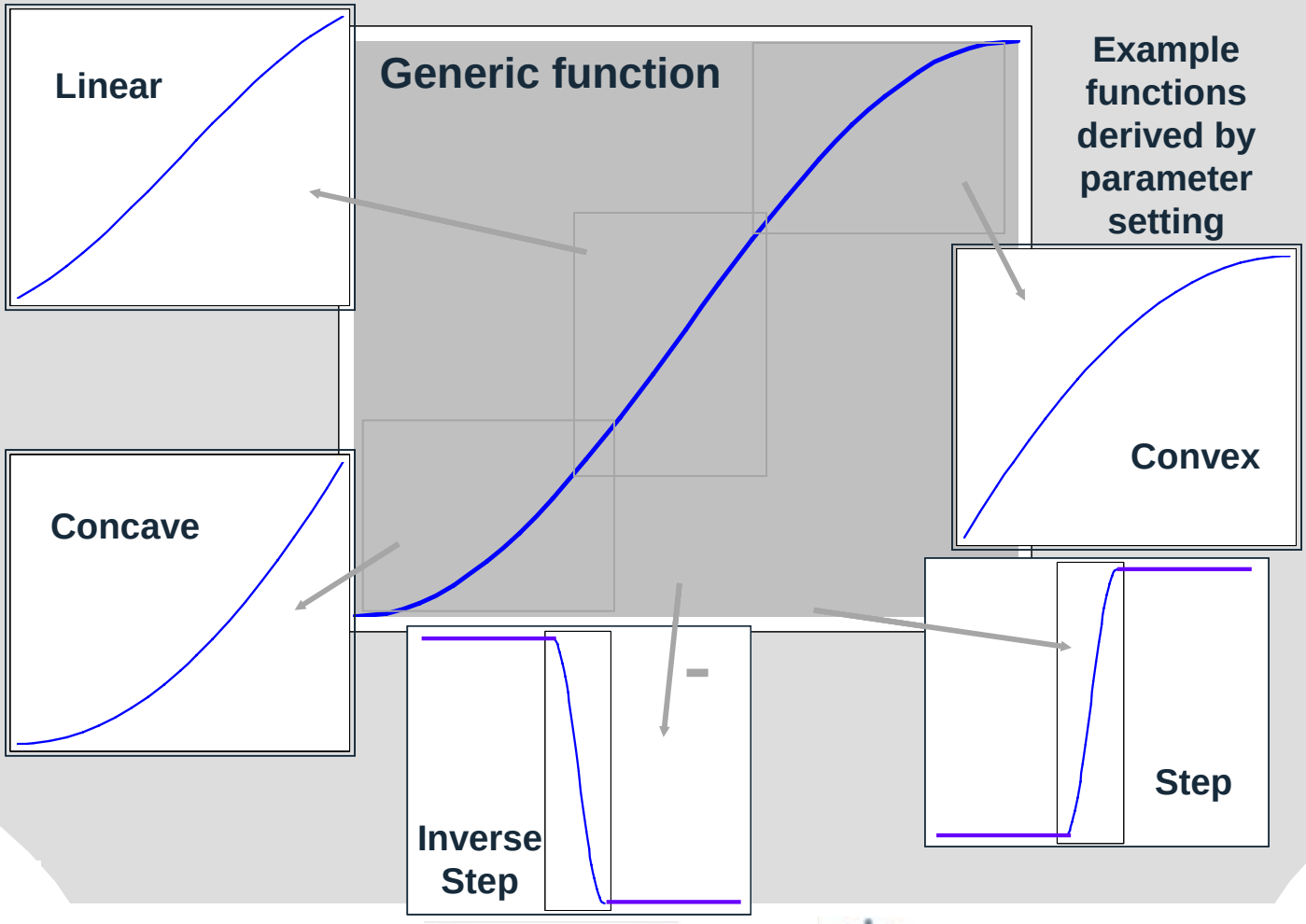
# Generic Sine Wave Function Relationship between STORM Variables



# Part 2. Open-Loop Sensitivity Analysis On STORM

- The Need For This To Be Done
- The Sensitivity Analysis/Calibration Process
- The Approach Adopted
- Summary Of The Findings
- Confirmatory Analysis
- Further Work In The DARNSTORMS Project

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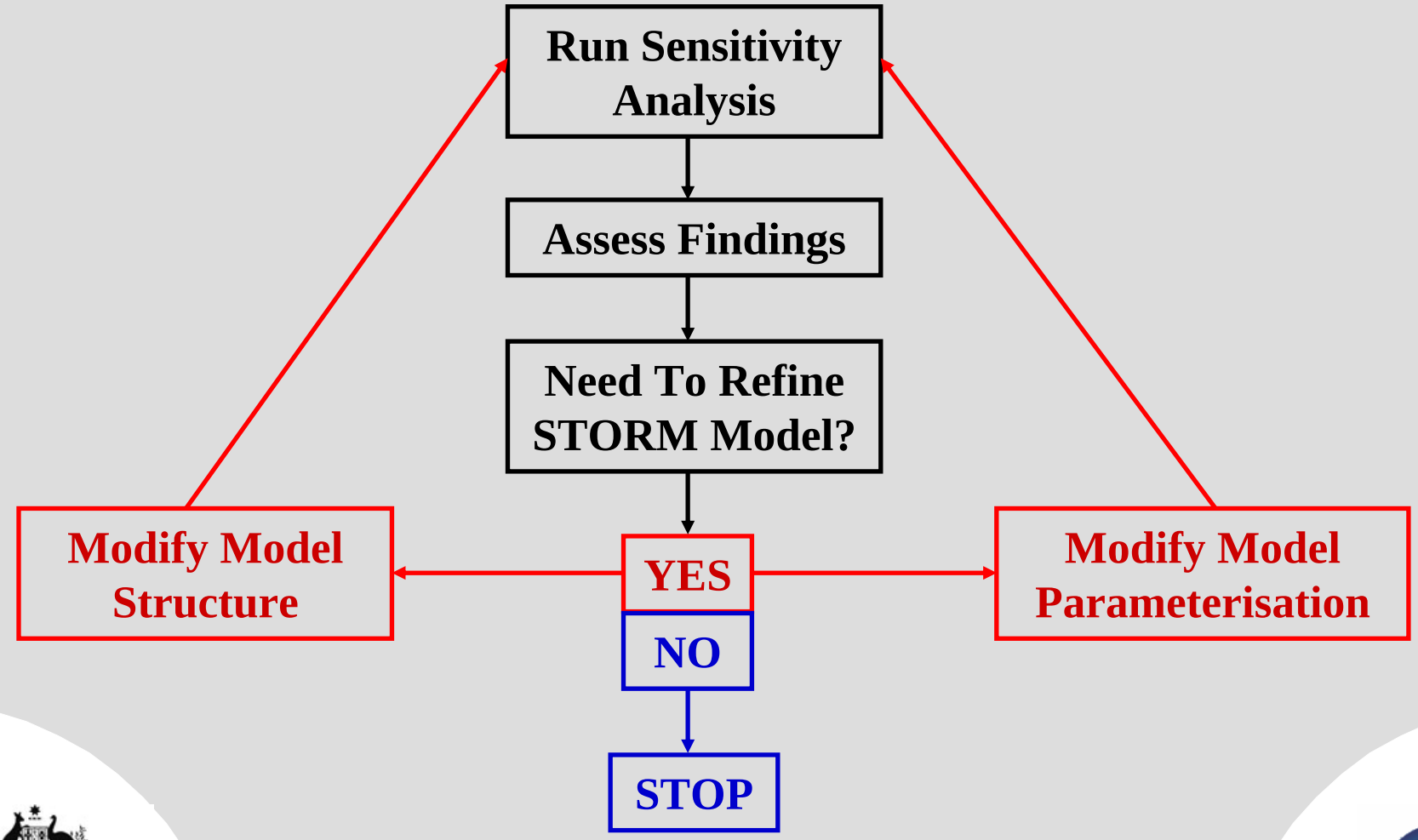
# Open-Loop Sensitivity Analysis On STORM – The Need For This To Be Done

- As far as possible, STORM includes a requisite set of variables
- Variable data quality and availability for the STORM variables
- So, need to assess the impact of this on STORM outputs
  - Team maturity levels and Team performance on tasks
  - Variation of these with changing values for the Settables
- STORM model calibration & sensitivity analysis to achieve this
  - Ensure the model behaves appropriately with variation of the Settables
  - Minimise the impact of the uncertainties on model performance
  - Quantify the impact that remains, identifying any pivotal variables
- A 'well behaved' STORM model is a pre-requisite for DARNSTORMS
- To be followed by further, closed loop sensitivity analyses on the DARNSTORMS combined model

# The Sensitivity Analysis/Calibration Process



# Open-Loop Sensitivity Analysis On STORM – The Approach Adopted #1

- We adopted a ‘sensible range’ approach for variables
  - 0-10 scale for all variables, with sensible minimum(2), maximum(8) and average(5) values characterised.
  - Scale up or down as appropriate to obtain the desired variable effect.
- SIMLAB sensitivity/uncertainty analysis package used to:
  - Specify, generate datasets to a sampling scheme
  - Run STORM executable and harvest output data
  - Analyse input-output relationships for pivotal variables
  - Modify STORM if required to obtain appropriate behaviour
- Result – a calibrated and uncertainty-bounded set of variables and parameters for STORM to employ within DARNSTORMS

# Open-Loop Sensitivity Analysis On STORM – The Approach Adopted #2, The Details

- Assess the impact of varying the Settables on the behaviour of STORM
  - 2 level factorial design – using sensible minima (2) and maxima (8)
  - Full factorial is $2^{15}$ runs , so use 1/16$^{th}$ fraction (2048 runs)
  - Outputs are the 10 knowledge variables that drive the maturity state
  - Obtain sensitivity measures for the impact of the Settables on each of these (the size of the effect and the statistical significance)
- Assess the findings from the above with the relevant SMEs
  - Scientific/conceptual validity of the significant effects found
  - Identify any 'false positives' **and** 'false negatives' in the analysis
- Calibrate STORM to attune its behaviour with the science
  - Re-parameterise any relationships as necessary
  - Further, focussed and more detailed sensitivity analyses as required

# Open-Loop Sensitivity Analysis On STORM – The Approach Adopted #3, Inputs And Outputs

**INPUTS**

- Socio-cultural coherence
- Personal experience/coherence
- Leader-ship style
- Organisational coherence
- Coordination style
- Team- work skills
- Situation brief
- On-task location
- Off-task location
- Adversary environment
- Task difficulty
- Task skills
- Goal brief
- Task novelty
- Task richness

**INPUT LEVELS**

2

8

**OUTPUTS**

- Customer Goal
- Team Goal
- Personal Goals
- Role
- Task
- Schedule
- Willingness to Interoperate
- Interpersonal Communications
- Member Capabilities
- Teamwork Rules
- *Plan Assessment*
- *Task Status*
- *Task Relevance*
- *Team Membership*

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# Open-Loop Sensitivity Analysis On STORM – Summary Of The Findings

- Three iterations of the sensitivity analysis were required to obtain the desired STORM response to the changes in the Settables.
- The first pass sensitivity analysis showed that, with a few exceptions, the overall behaviour of STORM was already sensible
  - Only one additional inter-variable link was added to the model
  - Some tweaking of the model parameterisation was needed
- The second and third pass analyses focussed on the model parameterisation and maturity threshold values
- The calibrated STORM model is now suitably well behaved and stable for incorporation into DARNSTORMS.

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# Open-Loop Sensitivity Analysis On STORM – Confirmatory Analysis

- The sensitivity analysis findings have also been used in a confirmatory analysis role
- Important Settables can feed into STORM variables in 2 ways
  - Directly, as inputs to them
  - Indirectly, via the other variables that input directly to them
- An example of this is the Team Goal knowledge variable
  - Organisational Coherence, Task Difficulty & Task Richness are direct inputs to Team Goal
  - Socio-Cultural Coherence, Personal Experience/Coherence & Goal Brief feed it indirectly, via Customer Goal and Personal Goals
  - The sensitivity analysis confirms that all of the 'indirect' Settables influence the behaviour of Team Goal in the calibrated model, in the manner and to the extent required.

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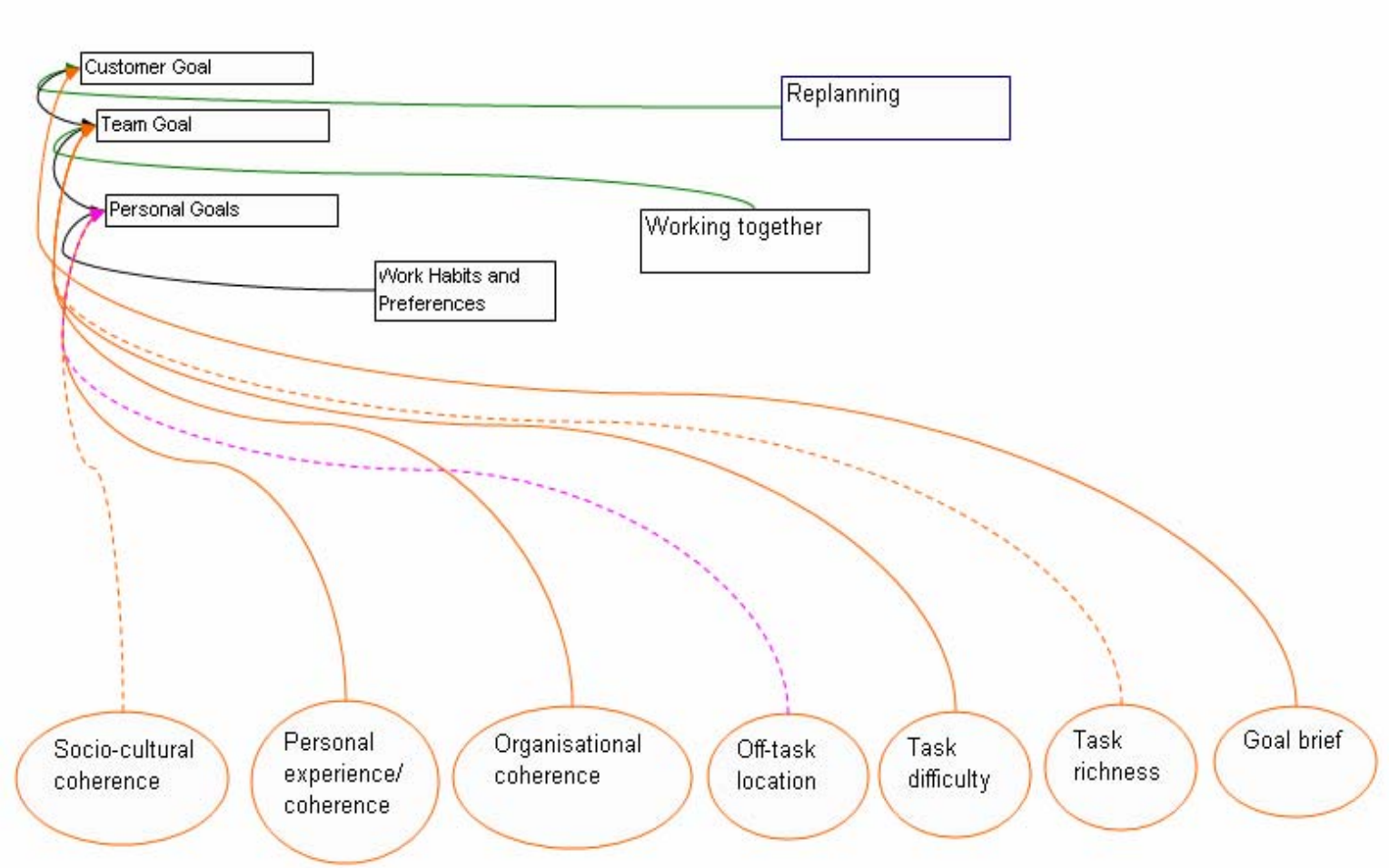
# STORM Sensitivity Analysis – An Example

**Inputs to Team Goal, plus inputs to those inputs**

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# Further Work In The DARNSTORMS Project

- Case study to explore the full range of each of the main STORM Settables
- Closed-loop calibration of DARNSTORMS
  - Scenario provides the required context for this
  - Sensitivity analysis provides uncertainty bounding
  - Informs the STORM model refinement process
- Iterate over the calibration, sensitivity analysis and refinement process
- Final product will be a usable DARNSTORMS executable model

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# To Summarise

- DARNSTORMS is a joint Australia-UK Collaborative Effort, to combine two models:
  - DARNOS – Dynamic Agent Representation of Networks of Systems, with
  - STORM – Socio-cultural Teamworking for OR Models
  - To produce the DARNSTORMS model.
- As a pre-requisite to the integration of STORM into DARNSTORMS, it needed to be shown that it
  - Is stable in operation.
  - Exhibits appropriate behaviour in response to varying input values of the Settables.
- This objective was achieved through the open-loop sensitivity analysis and calibration exercise that was undertaken on it.
- Further scenario-based closed loop analyses form a central part of the DARNSTORMS model development and testing programme.

# Approach Adopted For The Construction And Implementation Of The DARNSTORMS Model

**Questions?**

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