Australian Government
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Science and Technology

Simulation of Future Operating Concepts to Support Whole-of-Force Analysis

Drs Edward H. S. Lo, T. Andrew Au, Peter J. Hoek and Andrew Gill
Defence Science & Technology Group
Australian Department of Defence

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Improving Force Design Force Structure Review

Force Structure Review (FSR) process:

- Senior leadership applying **military judgement** over force options through seminar wargaming

Complexity of modern ops → difficult to **rely on intuition** for Force Design

- Many factors affect modern ops
- Difficulty in assessing impact of new capability (yet to be developed)
- Future wars fought differently to past

SR2 will deliver a sim capability for exploring & developing complex **whole-of-force** operating concepts

Operating Concepts for Exploration

- Force Level Electronic Warfare
- Maritime Force Defence
- Space Concepts
- Cooperative Engagement
- Information Age Combat Model
- Cyber Warfare
- New Operating Concepts

Involved Methods & Fields of Study

Future Operating Concepts

1. FLEW: Force Level EW
2. CEC: Cooperative Engagement Capability
3. Space Concepts
4. Maritime Force Defence
5. Cyber Warfare

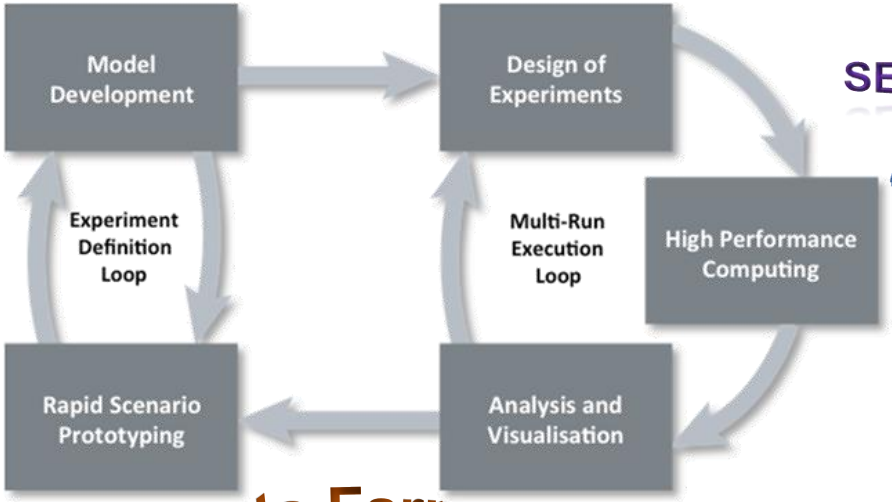
M&S

- Develop novel modelling strategies to represent abstract concepts in HPC-sim
- Resolving computational intractability in large scale simulation (many factors)

HPC DoE

Analysis & Visualisation

- Develop new analysis strategies for high dim problem spaces (big data)
  - Many response vars.
  - Many design points
  - Many iterations @ a design point



JFOrCE: Joint Future OpeRating Concept Explorer

Whole-of-force **agent-based** sim supporting analysis of future operating concepts

JFOrCE:

- **NetLogo**
- Blue & Red forces

Platform Capabilities:

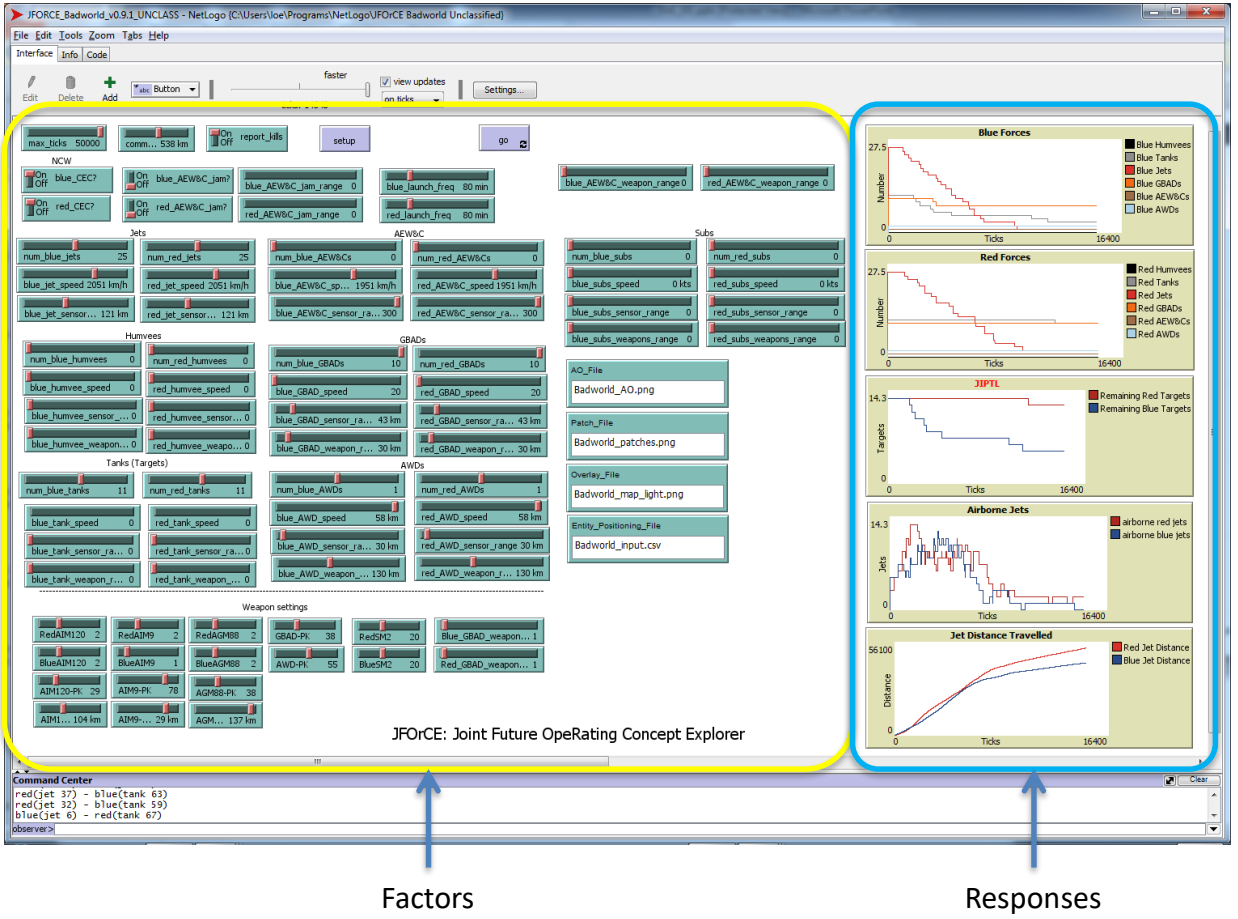
- Fast jets, AEW&Cs
- Light & heavy armoured vehicles, GBADs
- Submarines, destroyers

System Capabilities:

- Electronic Warfare jamming
- Cooperative engagement
- Network connectivity

Platforms characterised by:

- Numbers of assets
- Sensor range
- Weapons range

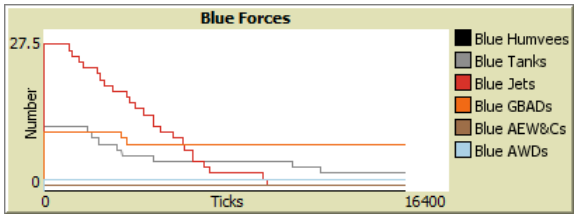


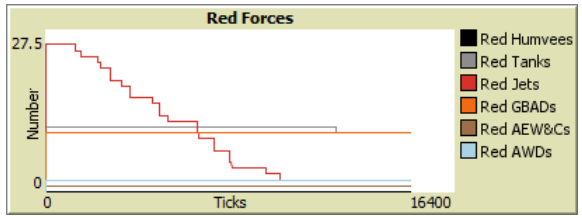
Run sim-experiments to observe impact of **factors** on system **responses**

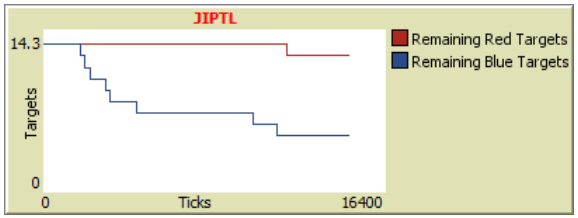
JFOrCE: Joint Future OpeRating Concept Explorer

- Agents undertake missions
- **Sense** environment & **react**

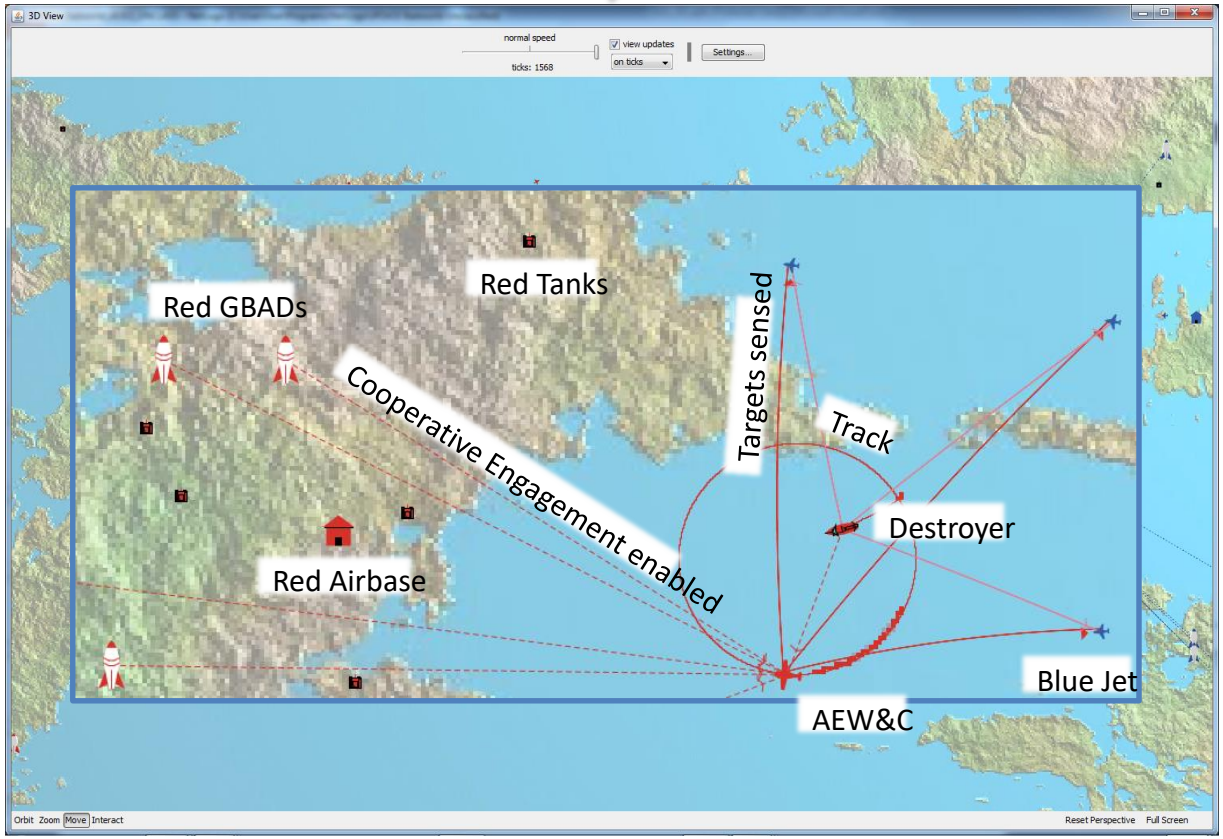
Assess impacts on MoEs







Sim Visualisation



Simulation results contribute experiment data at a **design point** (a specific force structure)

Behaviour Space: Experiment Designs

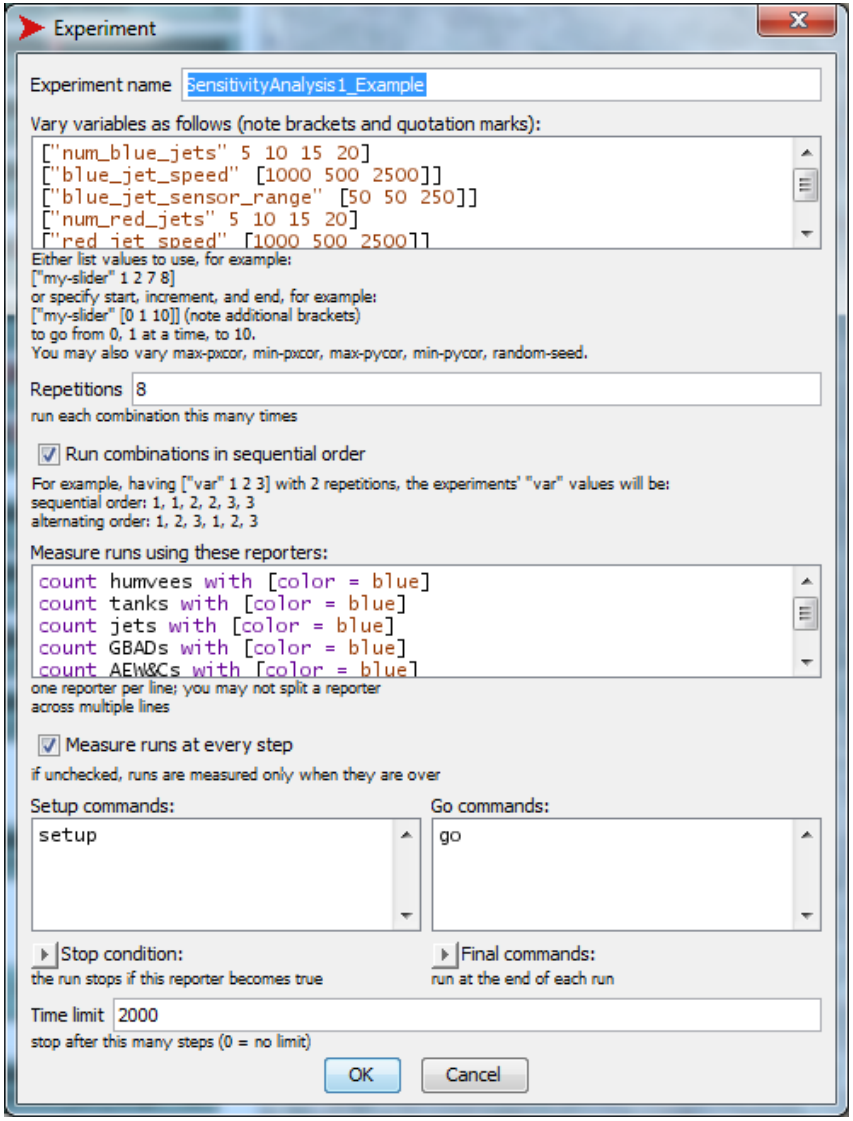
Configuring design points for simulation experiments:

- Specific or range of IVs:
  - [“slider1” v_k]
  - [“slider2” v_1 v_2 … v_n]
  - [“slider3” [v_{min} δ v_{max}]]
- # **reps** at a design point
- Identify DVs to report on

NetLogo headless-mode

- Running without GUI
- Support: Data farming

Only Full-Factorial designs



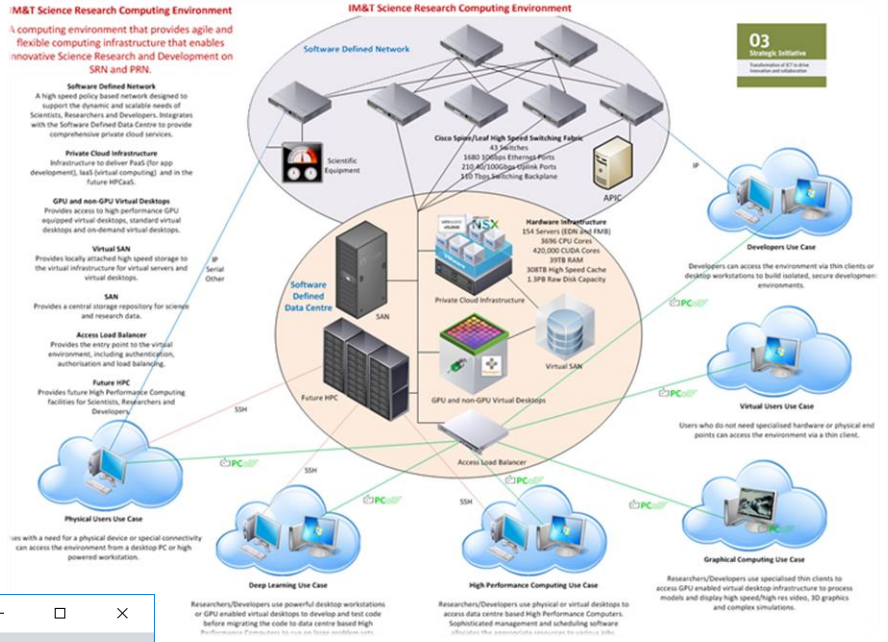
Web Services supporting NetLogo DF as a Service

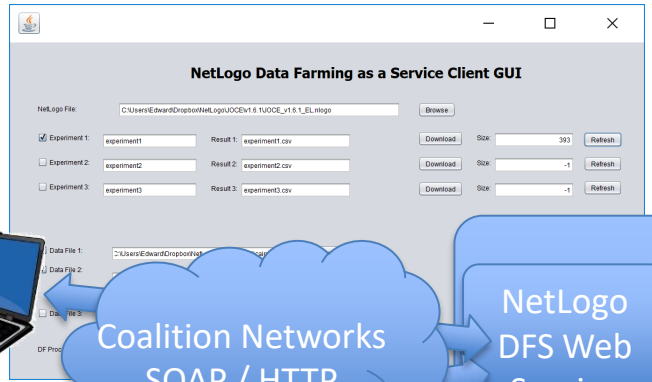
NATO MSG-155: investigating Data Farming **as a Service**

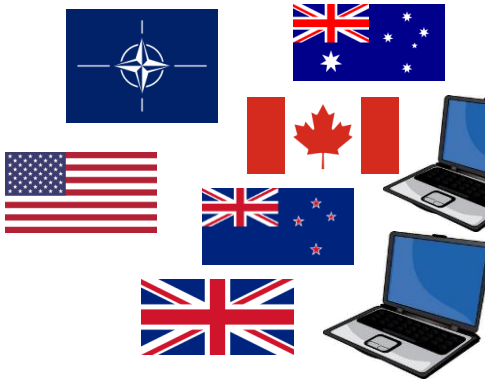
DST is acquiring PC Clusters & **High Performance Computing**

Proof of concept: **demo NetLogo data farming as a Web Service**

Open up HPC functionality for **data farming**

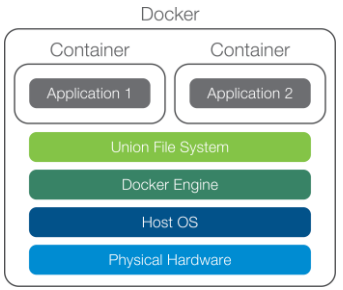






Coalition Networks SOAP / HTTP

NetLogo DFS Web Service



Client

Under the Bonnet

Server Execution: NetLogo-Headless

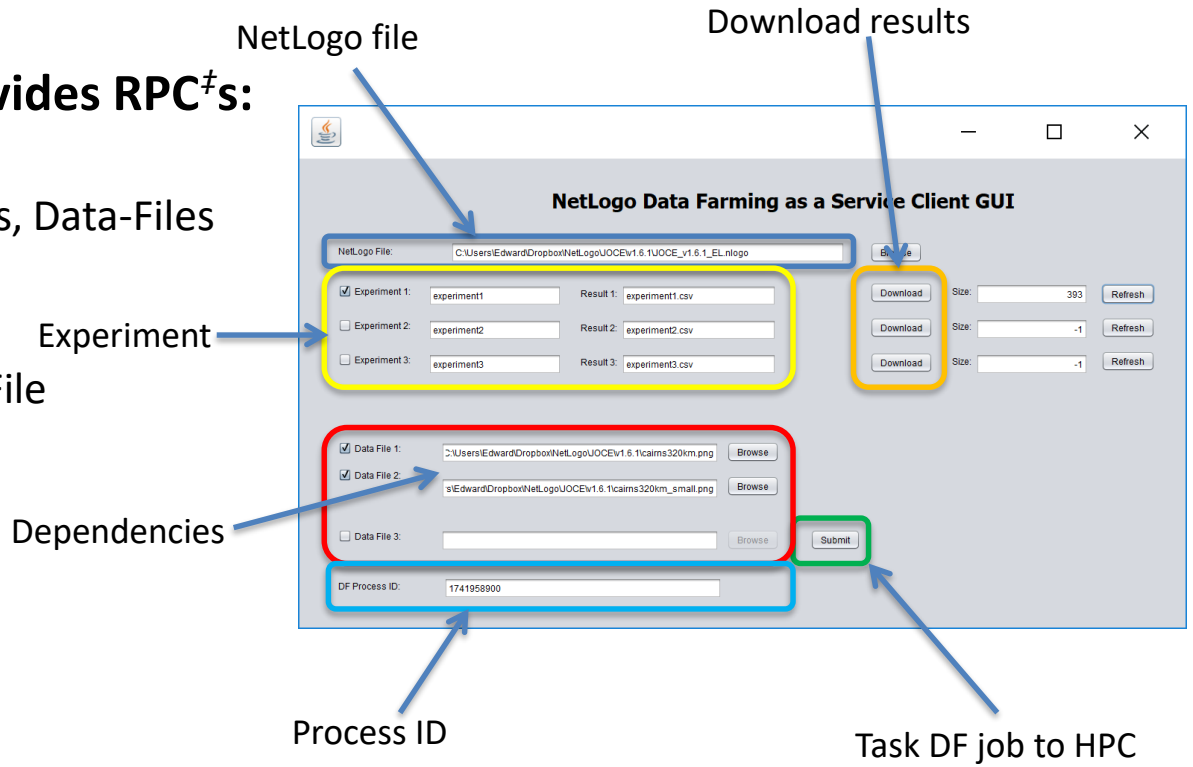
- No GUI, command-line invocation
- Run DF simulation experiments & output results to a CSV file
- Results file remains undeleted

Net Logo Web Service Client

- GUI: connect to HPC backend
- WS client stubs automatically generated from WSDL† file

NetLogo Web Service provides RPC‡s:

- Run-Model
  - In: Model, Experiments, Data-Files
  - Out: Process-ID
- Get-Result-Size
  - In: Process-ID, Result-File
  - Out: File-Size
- Download-Result
  - In: Process-ID
  - Out: Result-File



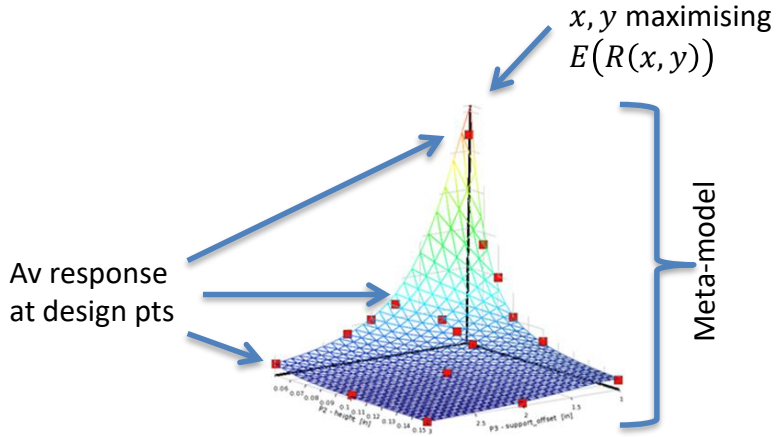
‡RPC: Remote Procedure Call

†WSDL: Web Service Description Language

DASE: Design & Analysis of Sim Experiments

How to run massive numbers of sim runs on HPC by brute-force?

- Not always necessary!
- DASE to the rescue:
  - Decides on choosing combos of IVs
  - Strategies for analysis of results



$$E[R(x,y)] = \beta_0 + \beta_x x + \beta_y y + \beta_{xy} xy + \beta_{xx} x^2 + \beta_{yy} y^2$$

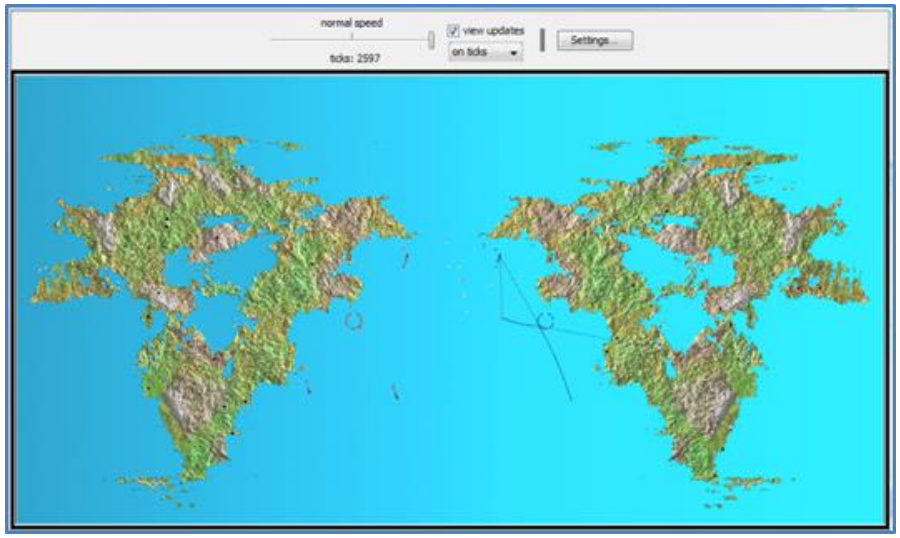
Screened IVs — Intercept — Main effect terms — Interaction term — Quadratic terms

Experiment Objective:

- **Screening**: cull IVs with negligible influence on sim response
- **Sensitivity Analysis**: fit meta models to characterise influential IVs
- **Optimisation**: IV settings for max response
- **Analysis of Alternatives**:
  - Ranking (best to worse)
  - SSCB: Select Subset Containing Best
  - SotB: Selection of the Best

Example: Evaluate Information or Force Advantage

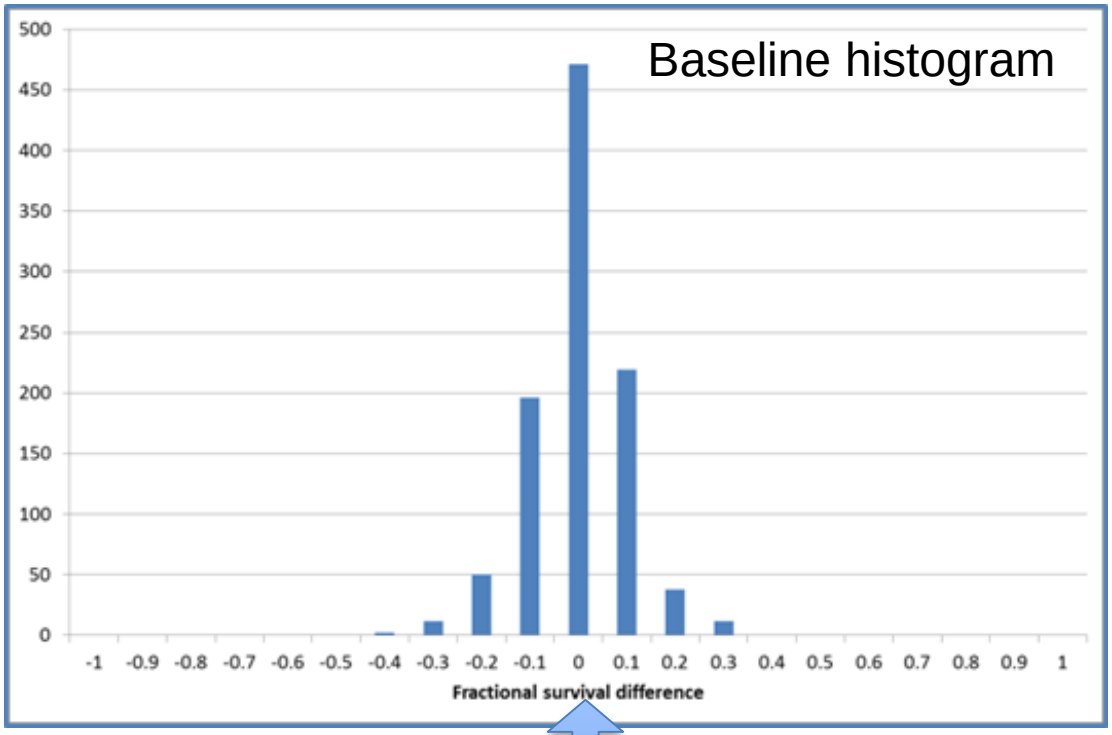
- Aim: measure how advantages in force or info influence chance of winning
- Fictitious geographically symmetrical scenario
- Baseline: 72 jets, 8 GBADs, 1 AWD, 1 AEW&C, 12 vehicles



- Force advantage: having more firepower than opponent, 4 more jets, 2 more GBADs, or 2 more AWDs
- Info advantage: AEW&C capable of sharing sensor info with GBADs & AWDs for target execution (afforded by CEC)

Measure of Effectiveness (MOE)

- Offensive MOE: fraction of red killed after run
- Defensive MOE: fraction of blue surviving after run
- Winning side is one having higher fraction of force surviving after run



More red remaining

More blue remaining

Outcome = blue survival ratio – red survival ratio

Influence of Force and/or Info Advantage

Blue Information Advantage	*Blue Force Advantage*			
	Like force	More jets	More GBADs	More AWDs
No	0.36	0.42	0.47	0.66
Yes	0.57	0.58	0.58	0.73

Blue's force advantage:

- Tendency to win
- Order of improvement: more jets, more GBADs, more AWDs
- Remarkable strength with more AWDs

Blue's info + force advantage:

- Info adv dominating as force multiplier
- More jets/GBADs made not much difference to info only
- Info + more AWDs sufficient to magnify tendency to win

Offensive Power vs Defensive Power

Best outcome for Blue, further enhanced with info adv

Any increased with info adv

Force adv of more AWDs has great significance to either side

- X-axis: Defensive power = fraction of Blue surviving [0, 1]
- Y-axis: Offensive power = fraction of Red killed [0, 1]
- Blue dominate conflict if positioned in upper right corner
- Increasing info or force adv enhances combat effectiveness
- All arrows pointing towards top right corner
- Sharing sensor info with air warfare assets amplified both defensive & offensive power

Red's force adv suppress Blue's combat power

Worst outcome for Blue, alleviated by info adv

Arrows indicating effects of info advantage

Summary

- Agent based simulation can **compare relative worth** of combat units in terms of **operational effectiveness**
- Analysis using JFOrCE can gain **quantitative insight** on info or force advantage
- Info advantage has marked payoff, tend to multiply any additional combat capability in terms of defensive & offensive power
- **Force design supported by combat simulation** can provide refined statements of requirement, preliminary trade-off analyses, & improved cost benefit analyses
- Future Work:
  - Develop **broad types of capability** for force advantage with wide range of parameters
  - Explore implications of **future operating concepts** – FLEW, IAMD, CEC, & cyber
  - Employ methods for **design of experiments** to support data farming