A Model Based Approach to System of Systems Risk Management

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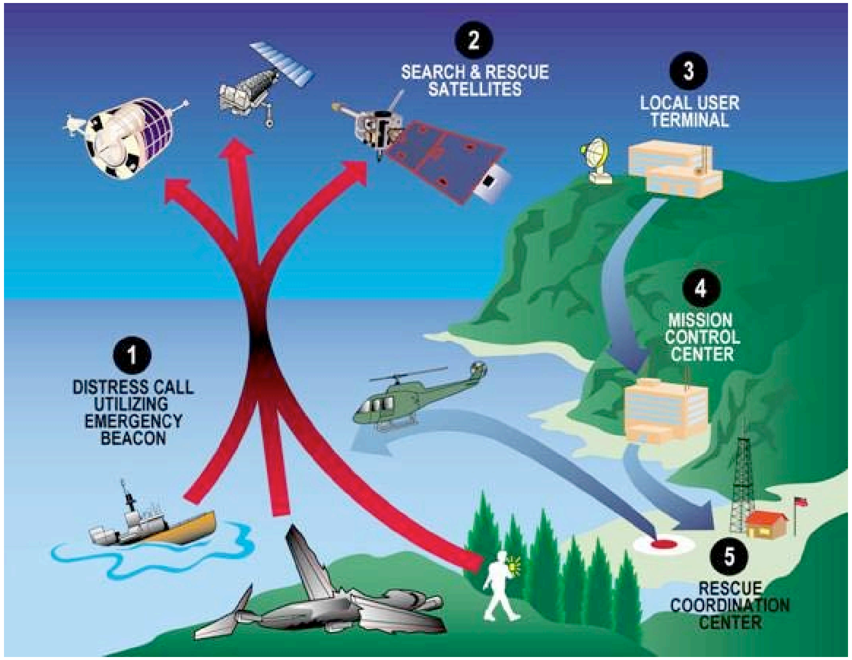
Content

- Motivation
- What is Risk?
- SoS Risk Management
- Model Based Approach
- Case Study
- Next Steps
- Conclusions



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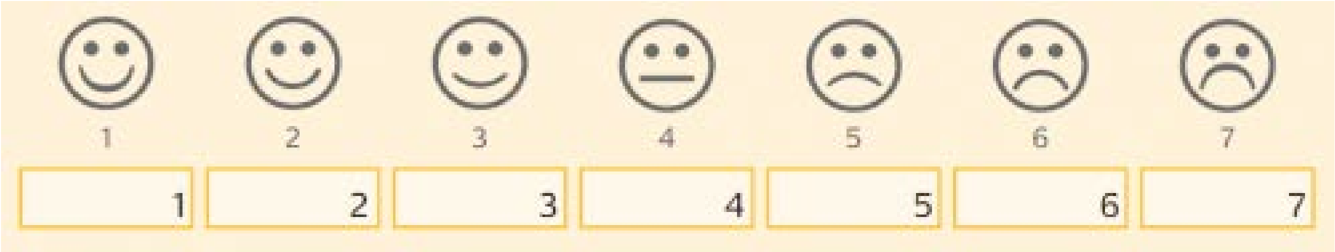
Motivation

- System of Systems (SoS) Engineering (SoSE) is an emerging sub-discipline of which Risk Management is a critical, but immature, element

- Likelihood of risk is typically determined through qualitative approaches - results are subjective



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Motivation

- Traditional Systems
  - Tools and methodologies are available to address defined problems
  - System boundaries are fixed
  - Expected behaviour is known
  - Scoping these problems and the associated risks is relatively straightforward

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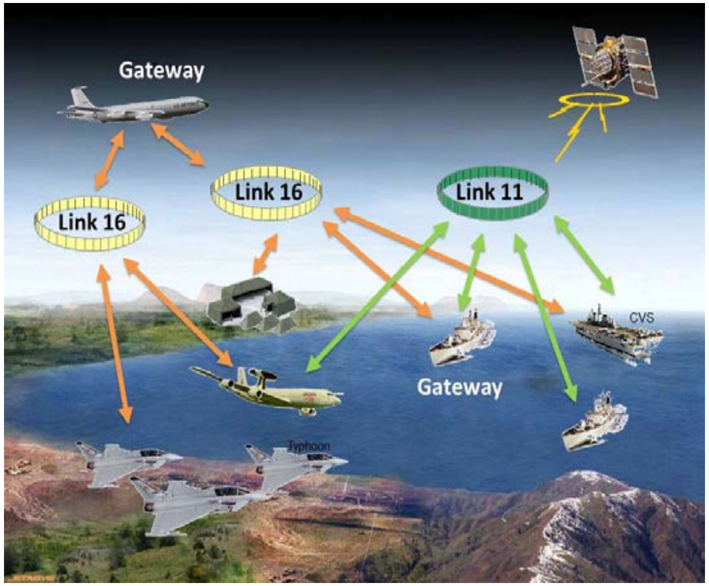
Motivation

- System of Systems
  - Boundary is not necessarily static
  - Component systems may not all be identified
  - Behaviour is emergent
  - Therefore new tools and methodologies are required



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What is Risk?

- The ISO Guide relating to risk management vocabulary defines risk as;
  - “*the effect of uncertainty on objectives*”

a deviation from the expected — positive and/or negative

deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood”.

Perception of Risk

- Risk is frequently determined as a subjective estimate of likelihood utilising experience of an individual or team
- Affect heuristic - assessment of risk is related to the perceived “goodness” or “badness” of an activity
- Conspiracy of optimism - likelihood or impact of a risk may be underestimated due to financial, managerial or political pressures

System of Systems Risk Management

- Identification of SoS objectives and the identification of the risks that threaten the achievement of those objectives
- Minor individual program risks could be major risks to the SoS
- Significant system risks may have little or no impact on the SoS functionality
- May be risk to a set of SoS objectives which are not risks to the constituent systems

DoD. Systems Engineering Guide for Systems of Systems

Why a Model Based Approach?

- A SoS is inherently complex.
- Risks typically quantified through, subjective expert opinion
- Derived from a mental model of the problem
- Human processing of problems involving five variables is at “chance level”

Halford, Graeme S., et al. "How many variables can humans process?"

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Model Based Approach – a caveat

- All models are wrong, but some are useful
- Models are abstractions and simplifications
- Over reliance on poorly tested models, based on false assumptions, providing the illusion of a sophisticated risk management method is the "worst" case
- "Best" case to be the use of proven, quantitative models

Box, G. E. P., and Draper, N. R., Empirical Model Building and Response Surfaces
Hubbard, Douglas W. The failure of risk management: why it's broken and how to fix it

The System of Systems Risk Model

- A modelling approach has been developed to reflect the holistic nature of SoS Risk
- Allows the interaction of risks to be modelled and enables the integration of heterogeneous modelling techniques
- Ensures the use of methods appropriate to individual risk characteristics, as opposed to a ‘one size fits all’ approach

Model Based Approach

Identify Risks Using SoS System
of Interest Model

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Central Bayesian Risk Model

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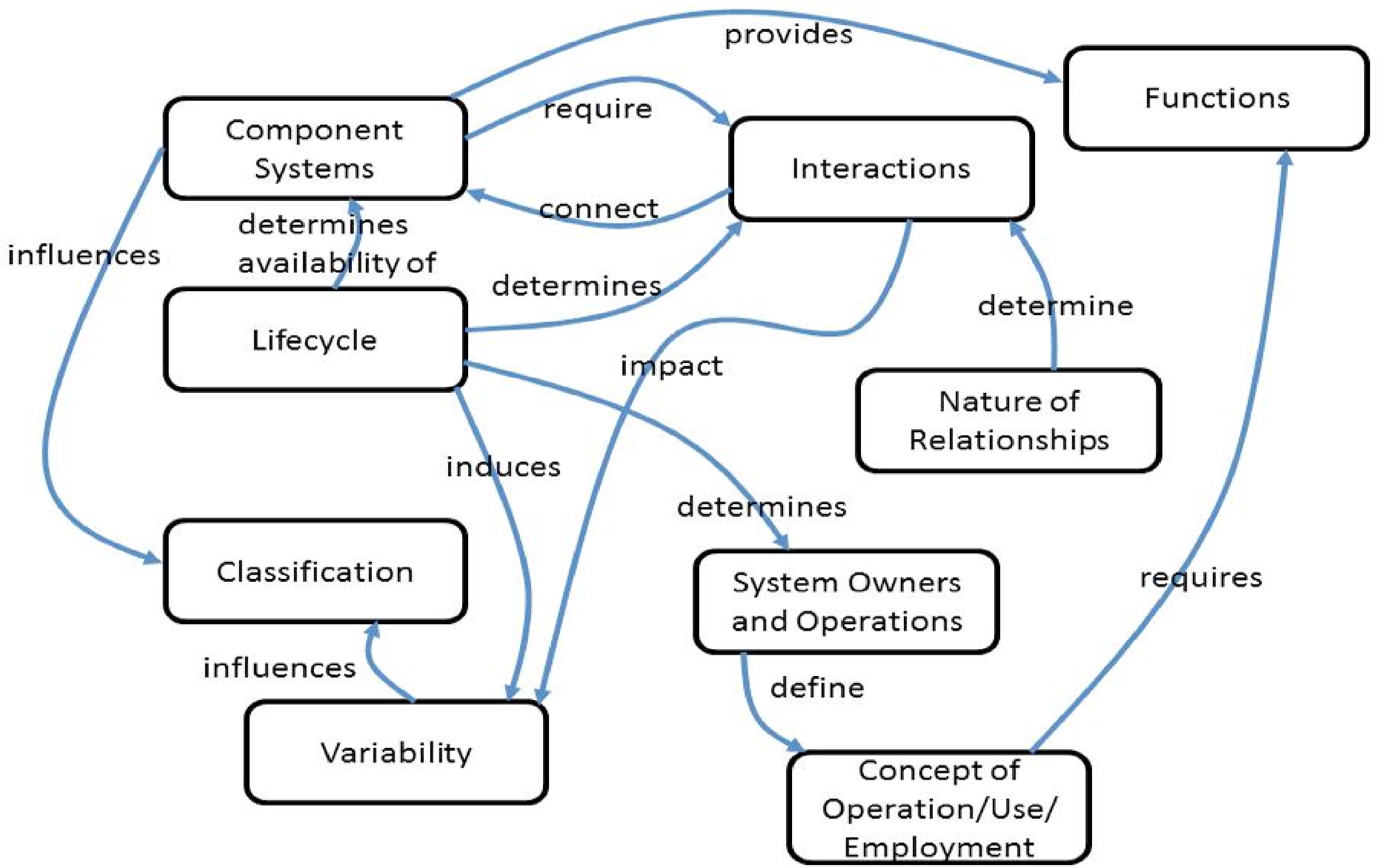
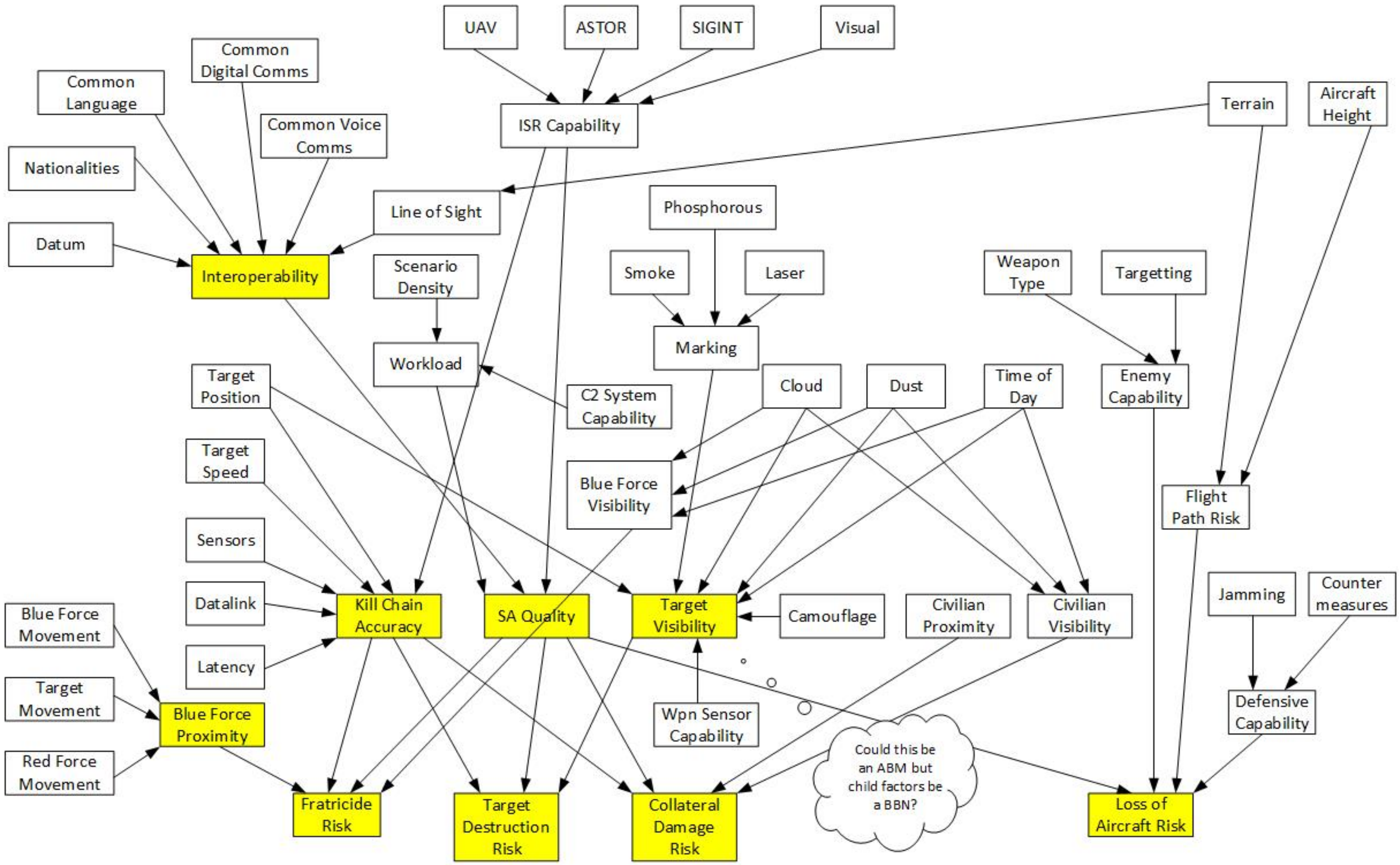
Supporting Models

SoS Risk Identification



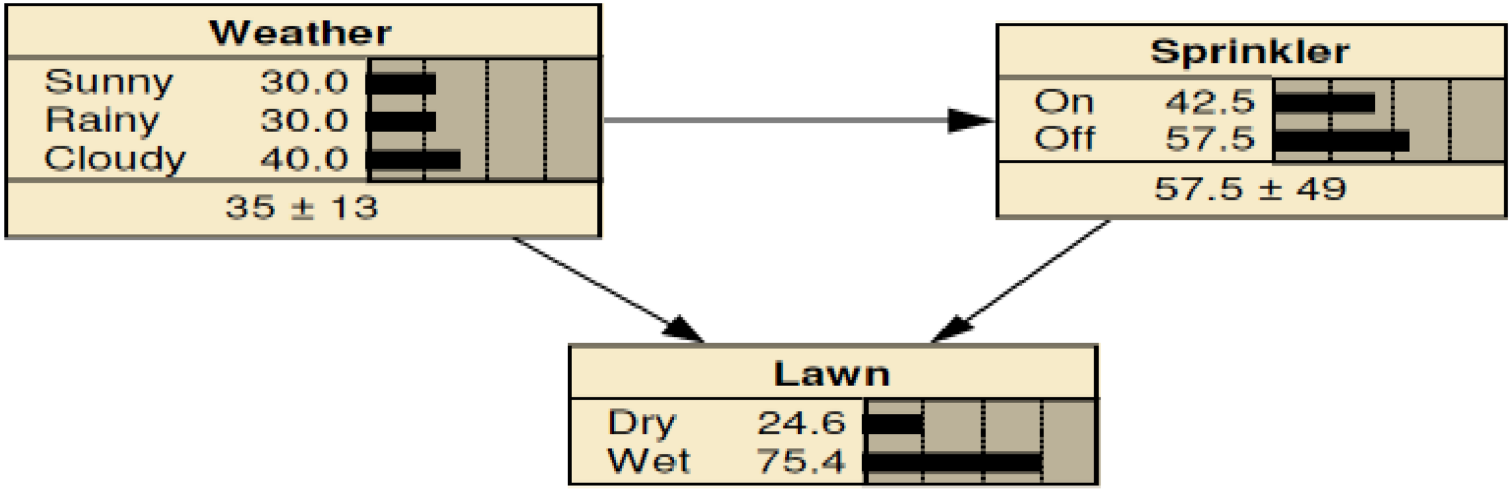
Kinder, A.; Barot, V.; Henshaw, M.; Siemieniuch, C., "System of Systems: "Defining the system of interest"

Initial Risk Model



Central Bayesian Model

- To enable the dependency between risks and contributing factors throughout a SoS to be modelled it is proposed that these are represented using a Bayesian Belief Network (BBN).



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Modelling Technique Selection Tool

Model Components	Dynamic	Stochastic	Uncertainty	Component Systems	Interactions	Lifecycle	Variability	Classification	Functions	Systems Owners and Operations	Concept of Operation / Use / Employment	Relationships	Ease of creation	Verifiable	
Common Digital Comms	No	Yes	No	No	No	Operational	Yes	Acknowledged	No	No	Yes				
Common Datum	No	Yes	No	No	No	Operational	Yes	Acknowledged	No	No	Yes				
Nationalities	No	Yes	No	No	No	Operational	Yes	Acknowledged	No	Yes	Yes				
Common Language	No	Yes	No	No	No	Operational	Yes	Acknowledged	No	Yes	Yes				
Common Voice Comms	No	No	No	No	No	Operational	Yes	Acknowledged	No	No	Yes				
	0	4	0	0	0	0	5		0	2	5	0			
DES/DEVS	HIGH	HIGH	LOW	HIGH	HIGH	LOW	LOW	LOW	HIGH	LOW	LOW	HIGH	LOW	HIGH	1
Petri Nets	HIGH	HIGH	LOW	HIGH	HIGH	LOW	LOW	LOW	LOW	LOW	LOW	HIGH	LOW	HIGH	1
ABMS	HIGH	HIGH	LOW	HIGH	HIGH	LOW	LOW	LOW	HIGH	LOW	LOW	LOW	LOW	HIGH	1
System Dynamics	HIGH	HIGH	LOW	LOW	LOW	HIGH	HIGH	HIGH	LOW	HIGH	HIGH	LOW	LOW	HIGH	4
Surrogate Models	HIGH	HIGH	LOW	HIGH	LOW	HIGH	LOW	LOW	LOW	LOW	LOW	LOW	LOW	HIGH	1
ANN	HIGH	LOW	LOW	LOW	LOW	HIGH	HIGH	HIGH	HIGH	LOW	LOW	LOW	HIGH	HIGH	1
BNN	LOW	LOW	HIGH	LOW	LOW	HIGH	HIGH	HIGH	LOW	HIGH	HIGH	LOW	HIGH	HIGH	3
Markov Models	LOW	LOW	HIGH	LOW	LOW	HIGH	HIGH	HIGH	LOW	HIGH	HIGH	LOW	HIGH	HIGH	3
Game Theory	LOW	LOW	HIGH	LOW	LOW	HIGH	HIGH	HIGH	LOW	HIGH	HIGH	LOW	LOW	LOW	3
Decision Trees	LOW	HIGH	LOW	LOW	LOW	HIGH	HIGH	HIGH	LOW	LOW	LOW	LOW	HIGH	HIGH	2
Network Models	LOW	LOW	LOW	LOW	HIGH	LOW	LOW	HIGH	LOW	LOW	LOW	HIGH	HIGH	HIGH	0
EAF	LOW	LOW	LOW	HIGH	HIGH	HIGH	LOW	HIGH	LOW	HIGH	HIGH	HIGH	HIGH	LOW	2
Modelling Languages	LOW	LOW	LOW	HIGH	HIGH	LOW	LOW	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	LOW	2
Monte Carlo	HIGH	HIGH	LOW	LOW	LOW	HIGH	HIGH	HIGH	LOW	LOW	LOW	LOW	HIGH	HIGH	2

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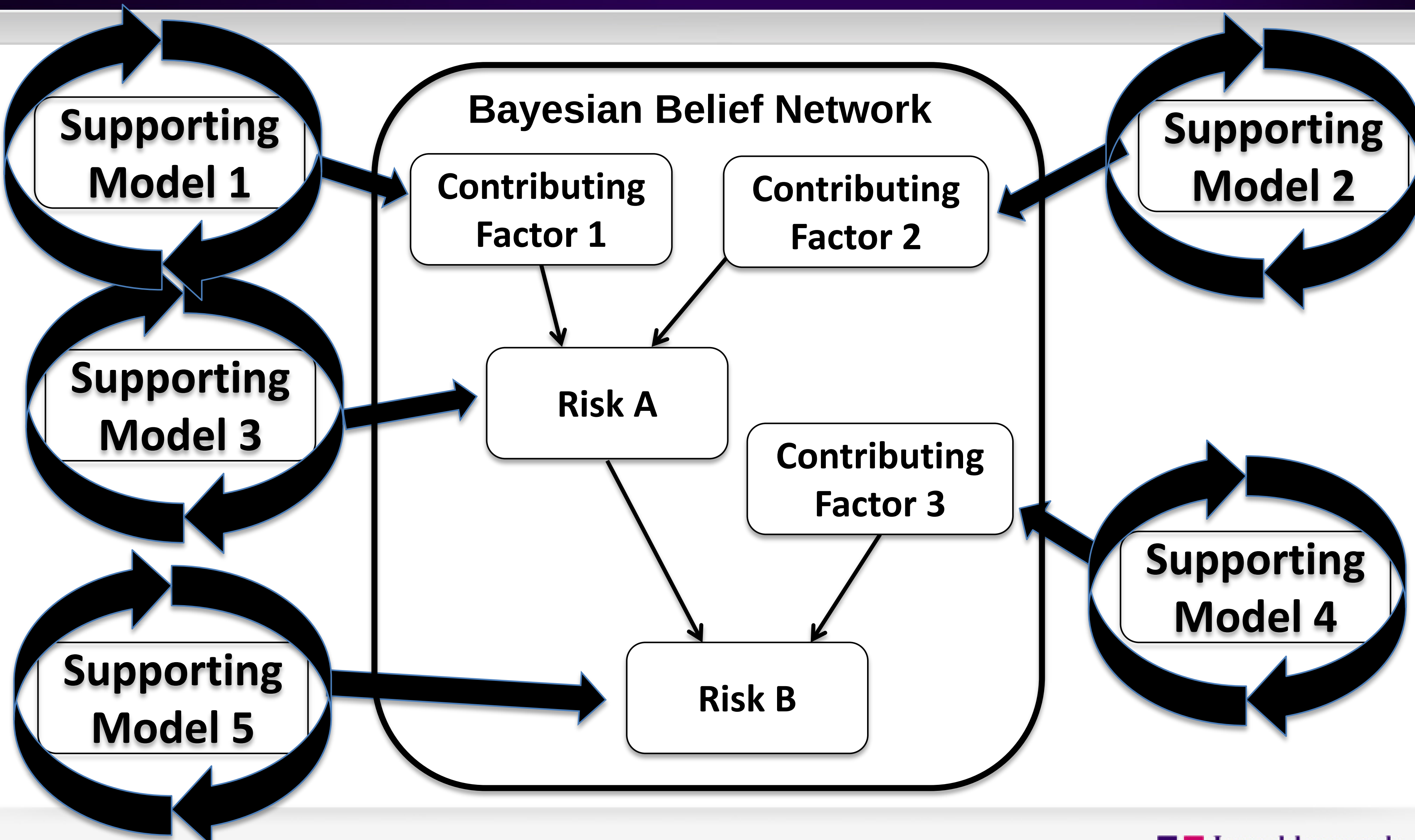
Monte Carlo

Monte Carlo

Monte Carlo Simulation



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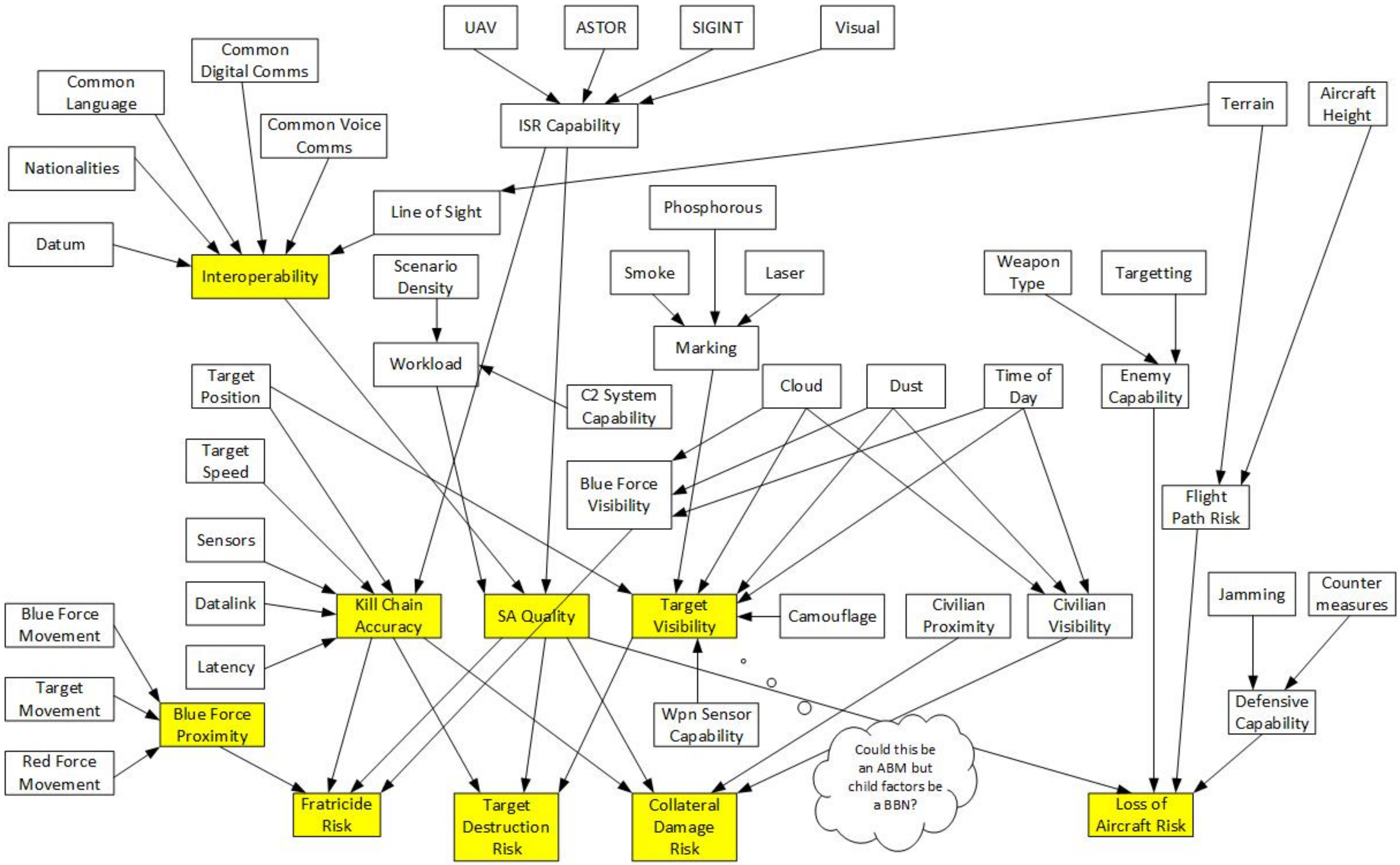
Close Air Support Risk Management Support Tool – Case Study

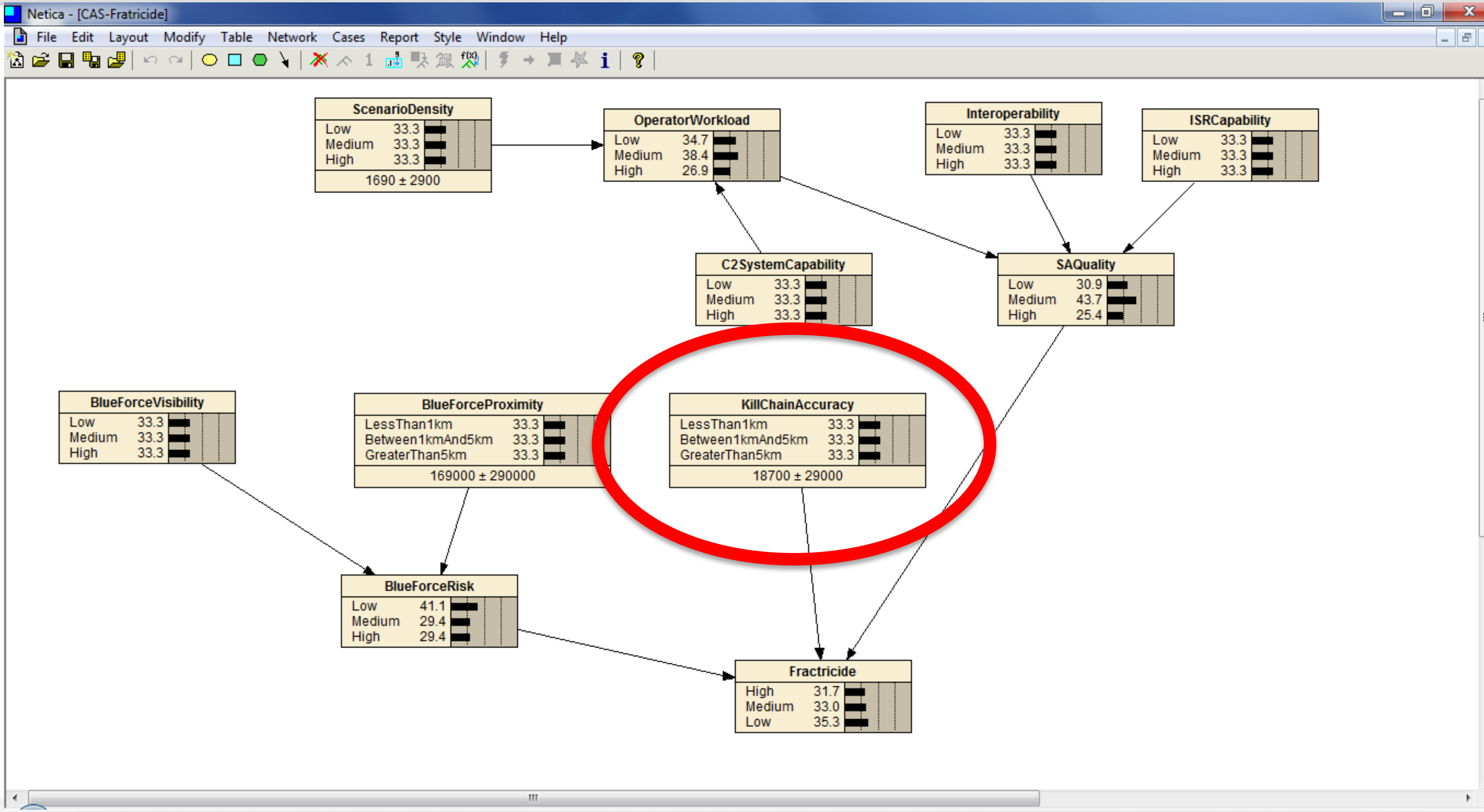
"..air action against hostile targets which are in close proximity to friendly forces and requires detailed integration of each air mission with the fire and movement of those forces."

NATO publication; Tactics, Techniques and Procedures for Close Air Support Operations

Initial Risk Model



Close Air Support Risk Management Support Tool – Case Study



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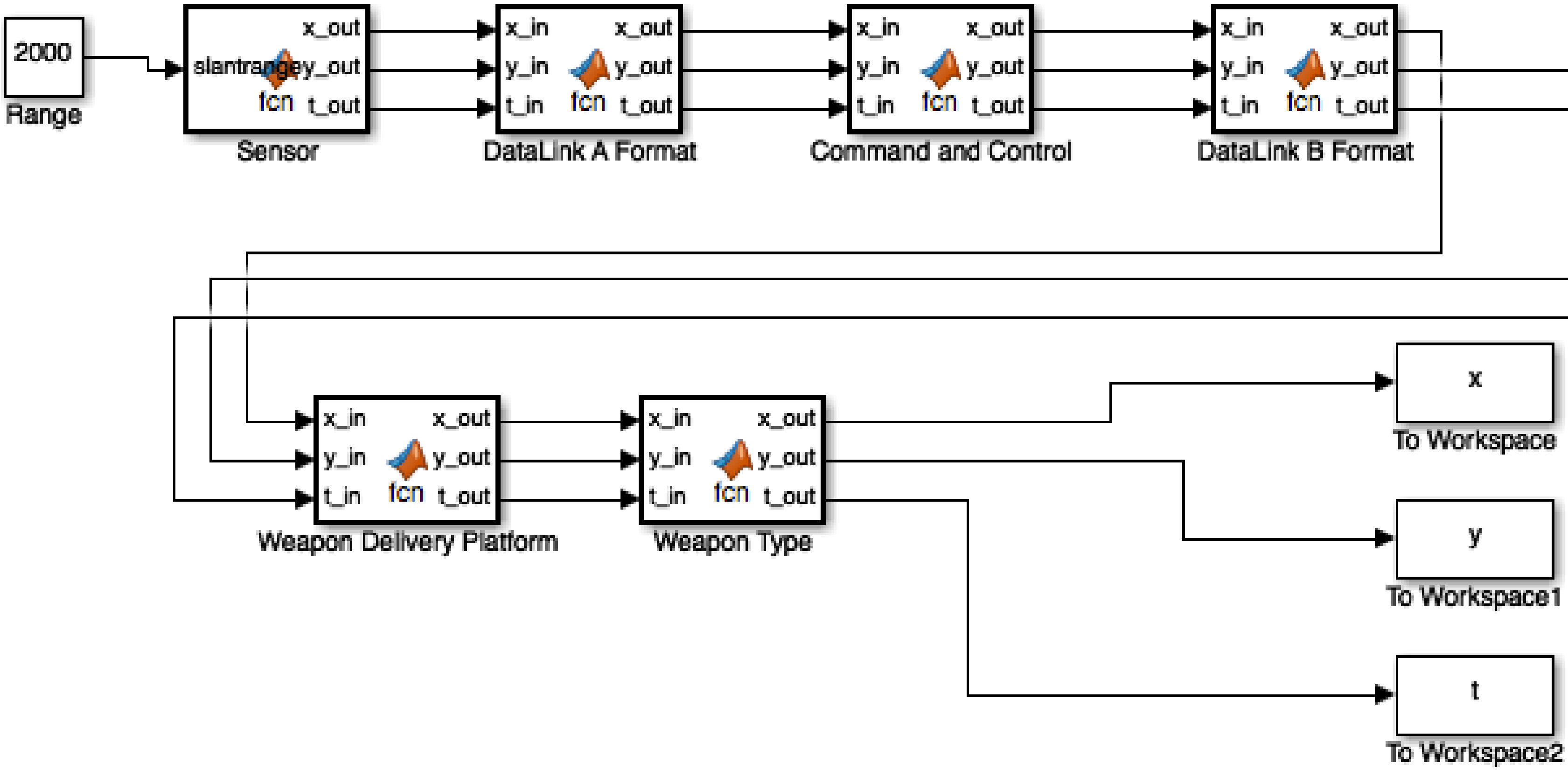
Kill Chain Model



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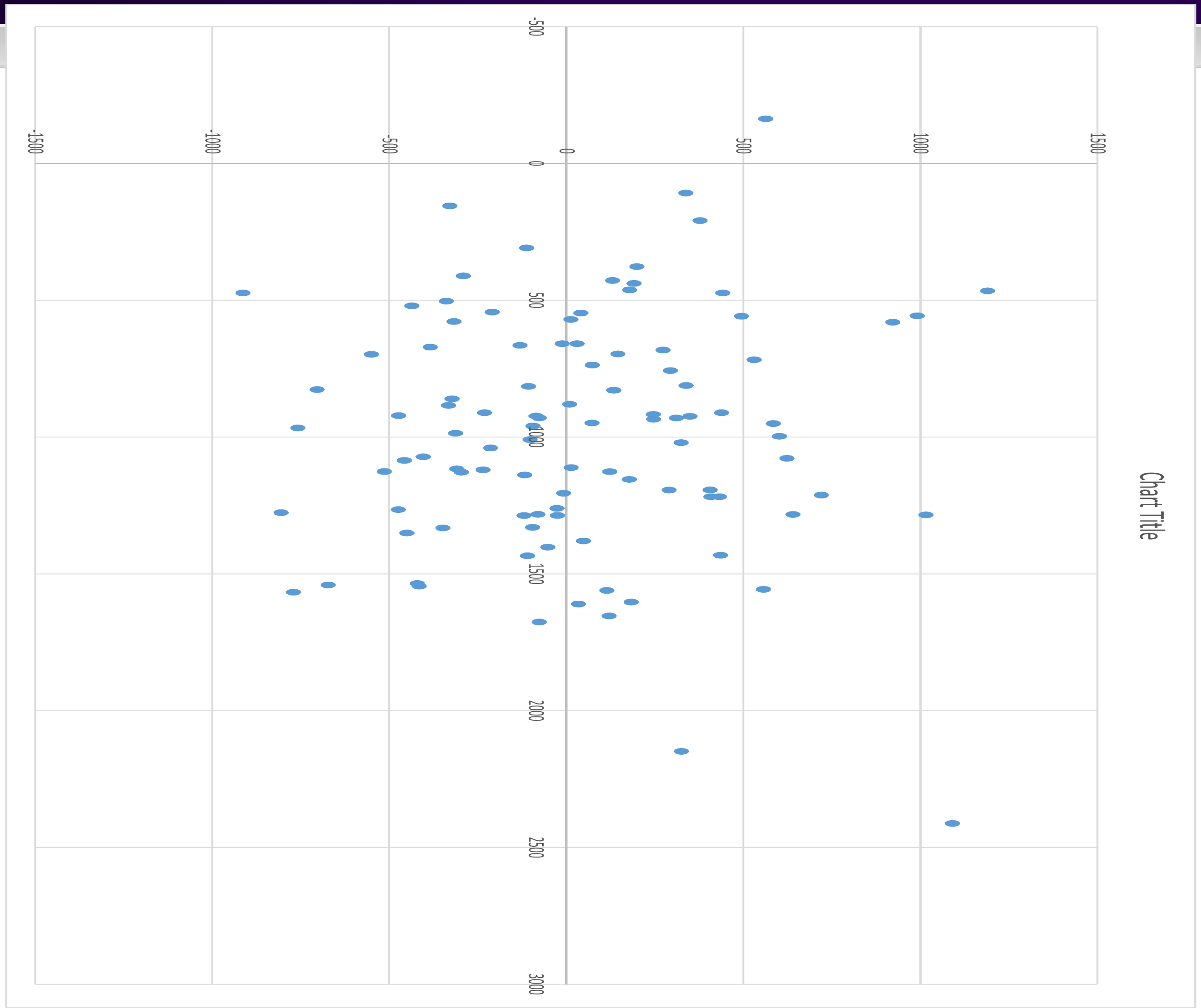
Kill Chain Model Output



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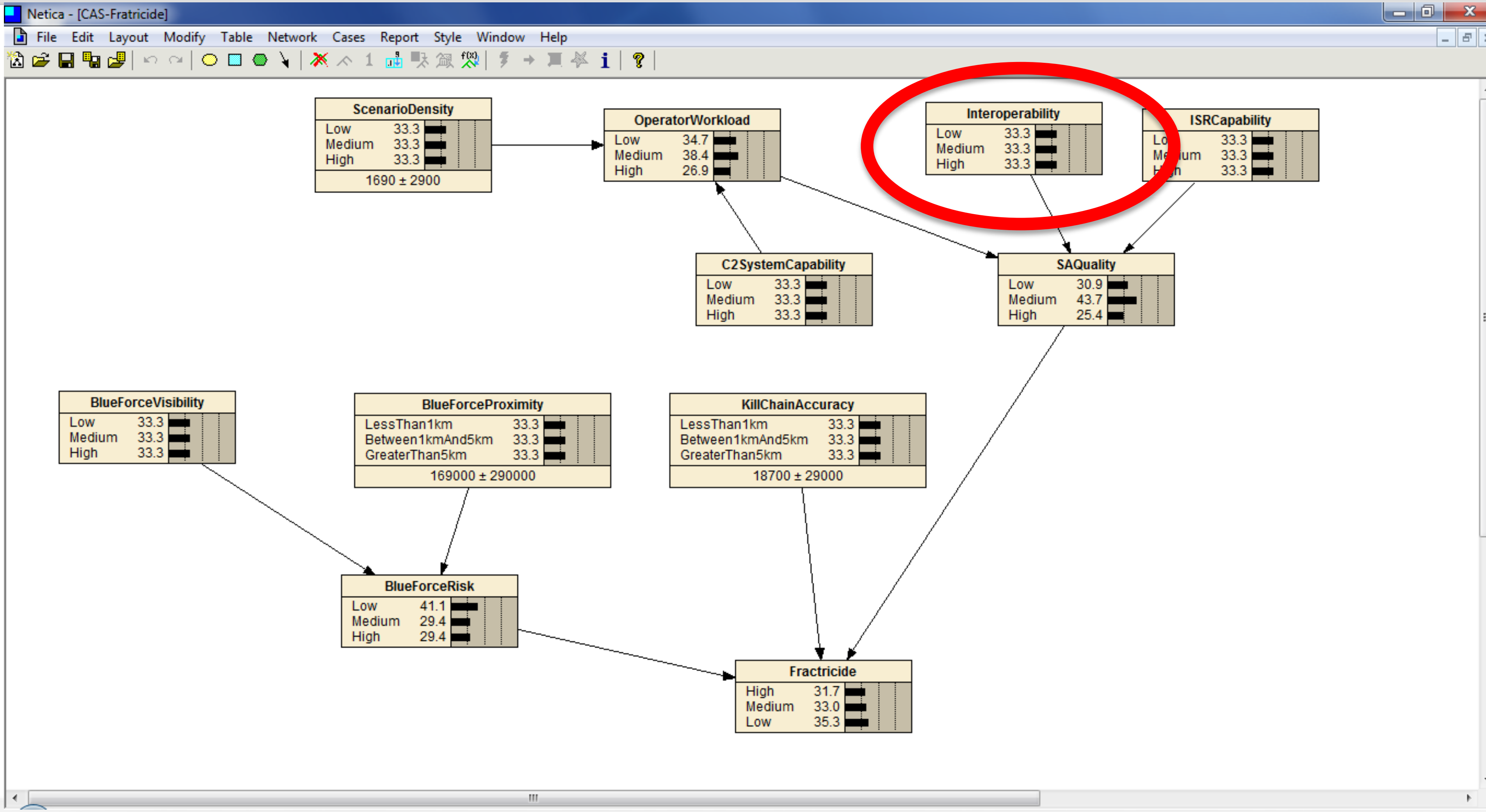
Close Air Support Risk Management Support Tool – Case Study



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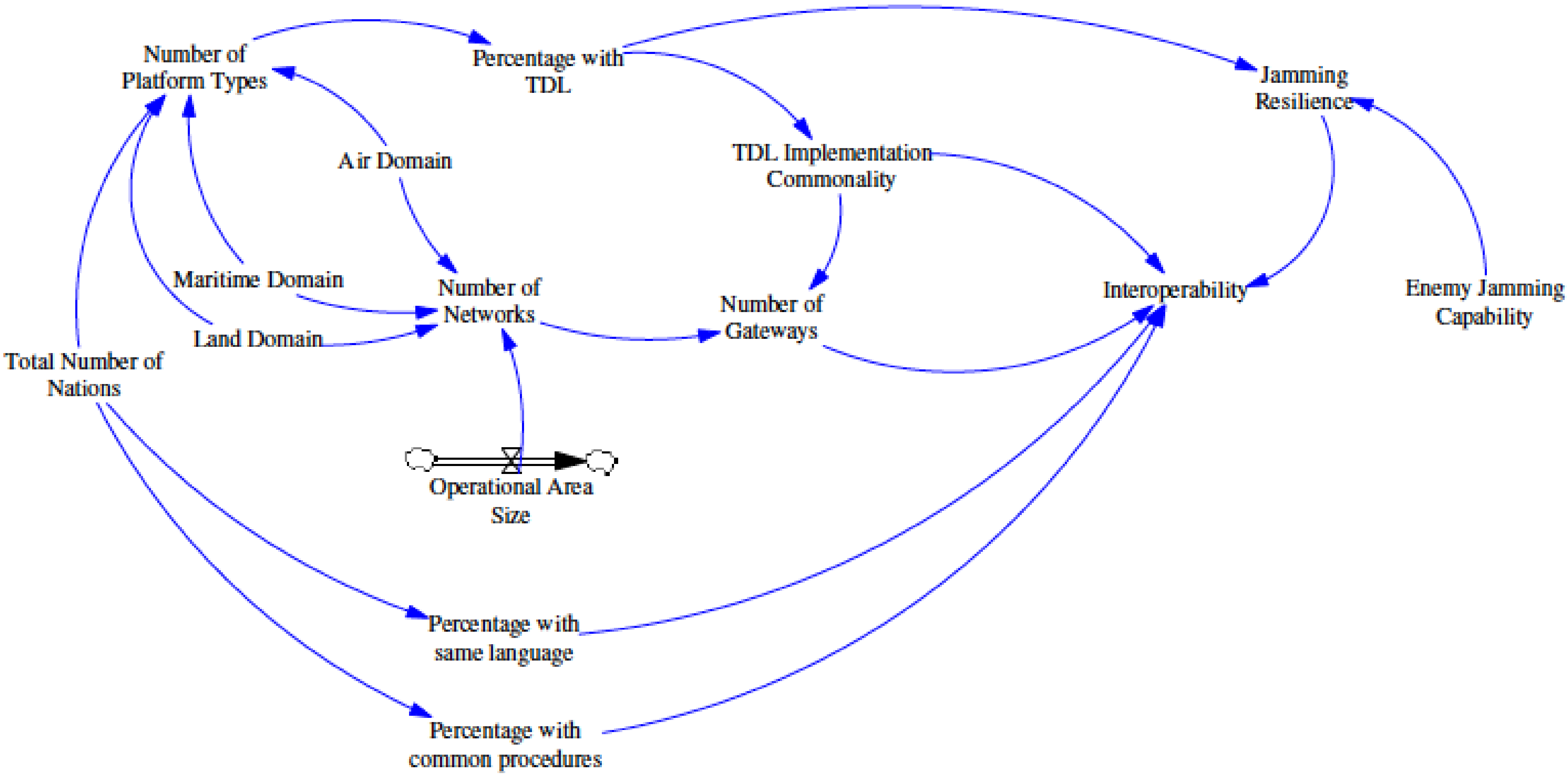
Interoperability Model



Next Steps

- Refine current supporting models
- Implement additional supporting models
- Identify a further case study
- Develop a generic modelling approach

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Conclusions

- Risk Management in the engineering of systems - currently uses qualitative techniques, subjective probabilities
- SoS inherent complexity require quantitative methods
- SoS risk management must be holistic
- Modelling will support a quantitative, holistic approach
- Proposed approach utilises a central Bayesian Network with supporting models run in Monte Carlo simulations

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Questions?

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