Application of Probabilistic Graphical Models to Warfighting Capability and Capacity Assessments

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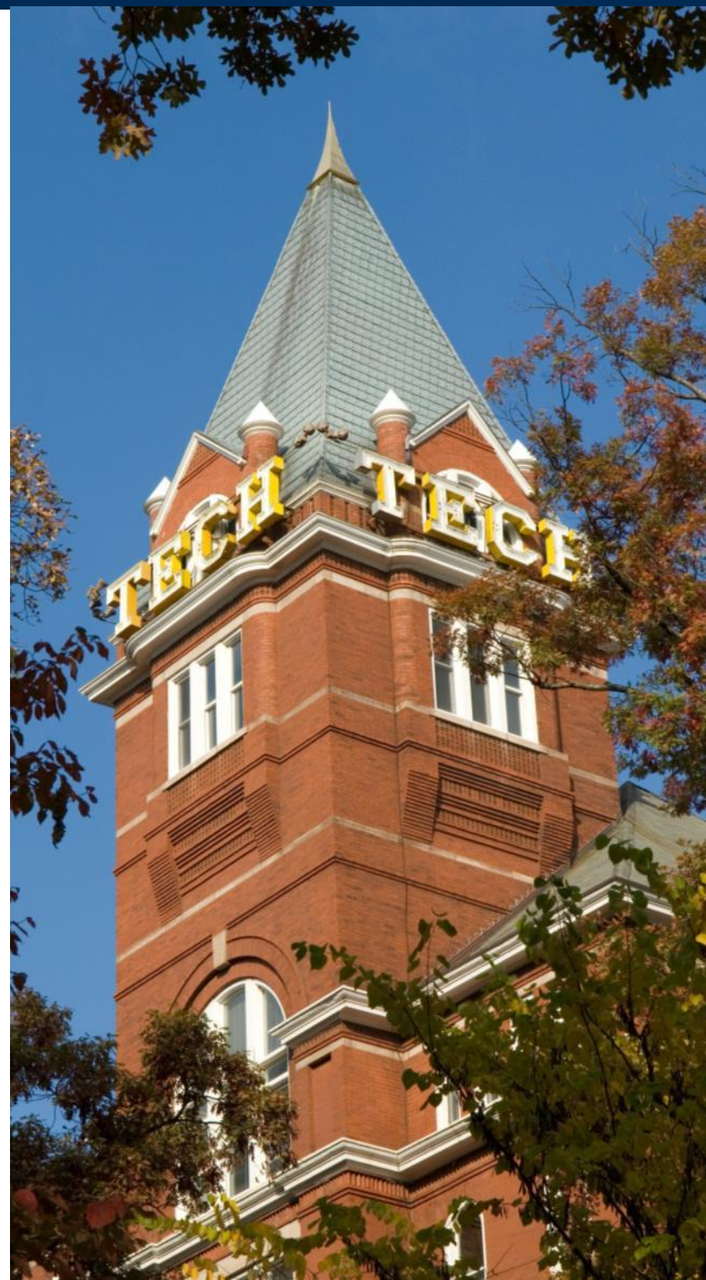
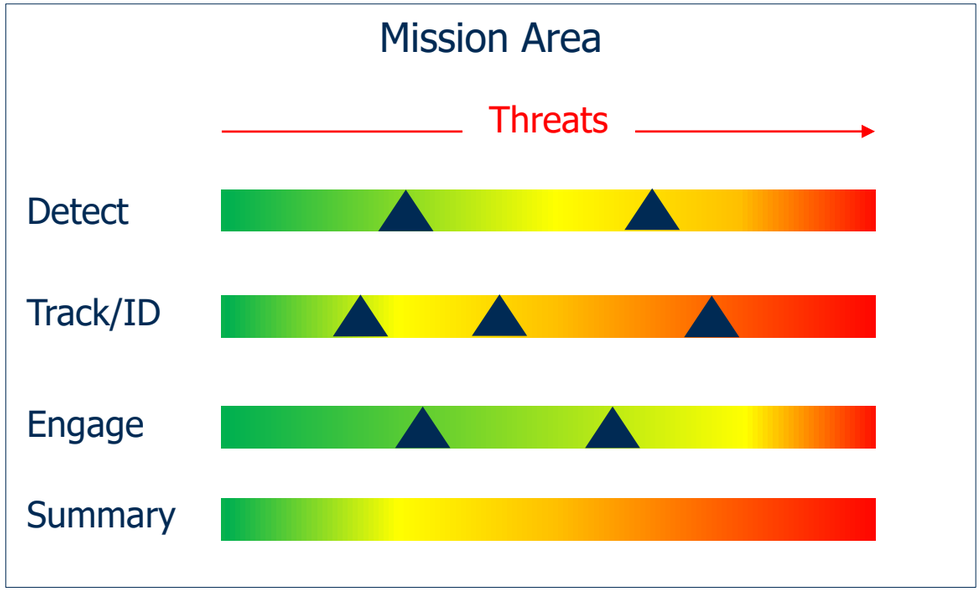


Background: Warfighting Capability and Capacity Assessments (WCCAs)

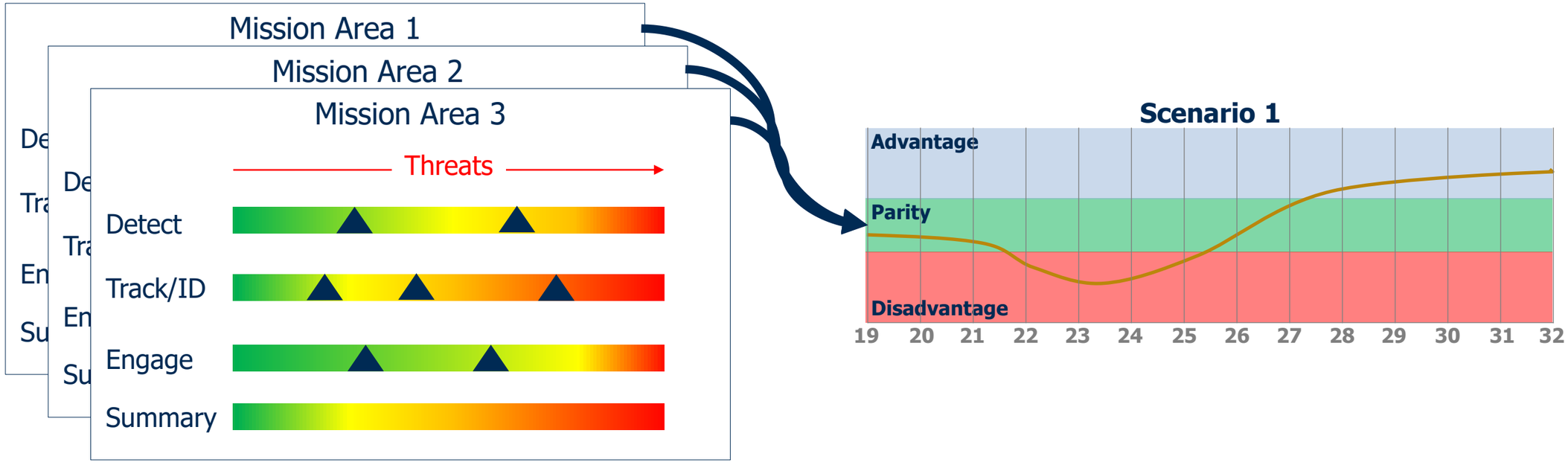
- OPNAV Warfighting Assessment Division (N81) product
- ~30 Mission Areas
- Relative capability/capacity vs. most stressing threat
- SME assessment, aggregated from experience, studies, campaign analyses, etc.
- Developed for the POM to provide insight to potential relative capability, given certain budget decisions



Background: Warfighting Capability and Capacity Assessments (WCCAs)

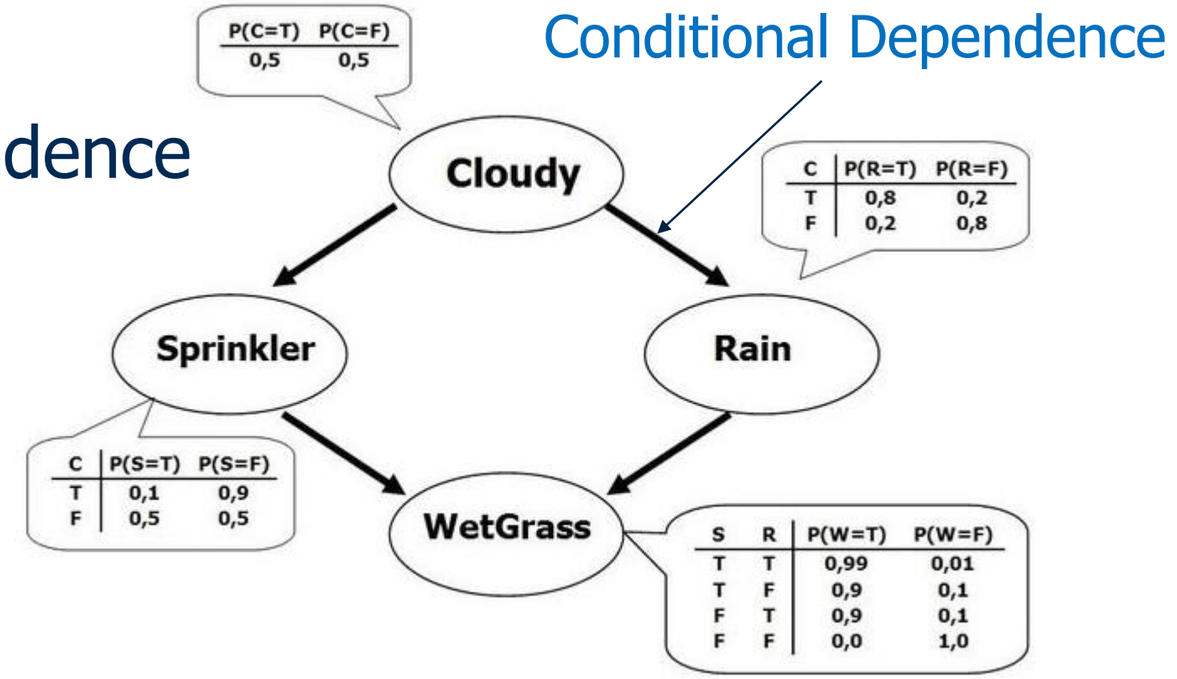
- Desire to understand overall capability against an adversary for a given O-Plan/strategy

- All Mission Areas that apply to a threat aggregate to an overall relative capability



Background: Probabilistic Graphical Models

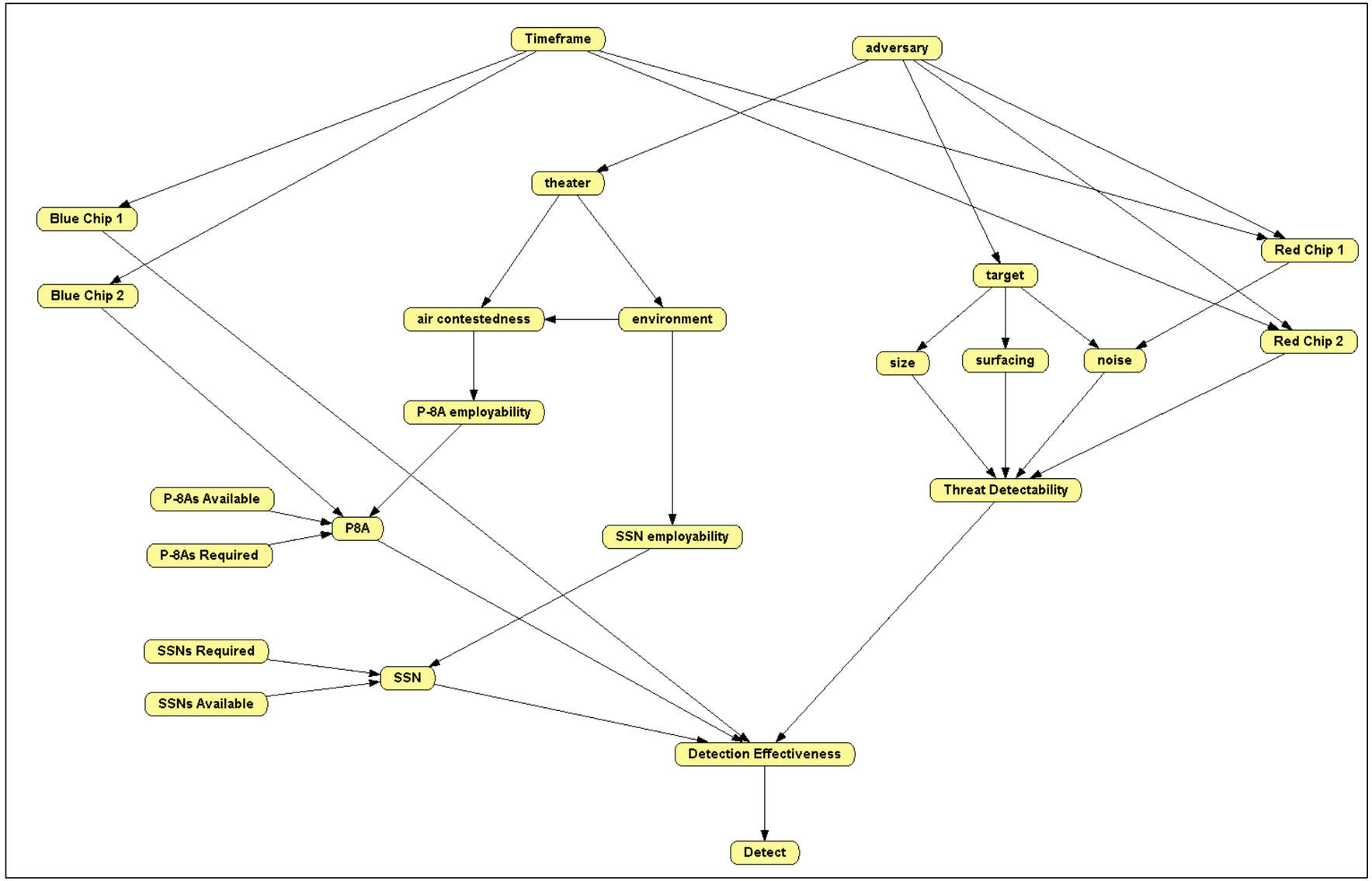
- Acyclic Probabilistic Graphical Model
- Statistical Principles
  - Conditional dependence/independence
  - Probability distributions
  - Bayesian inference



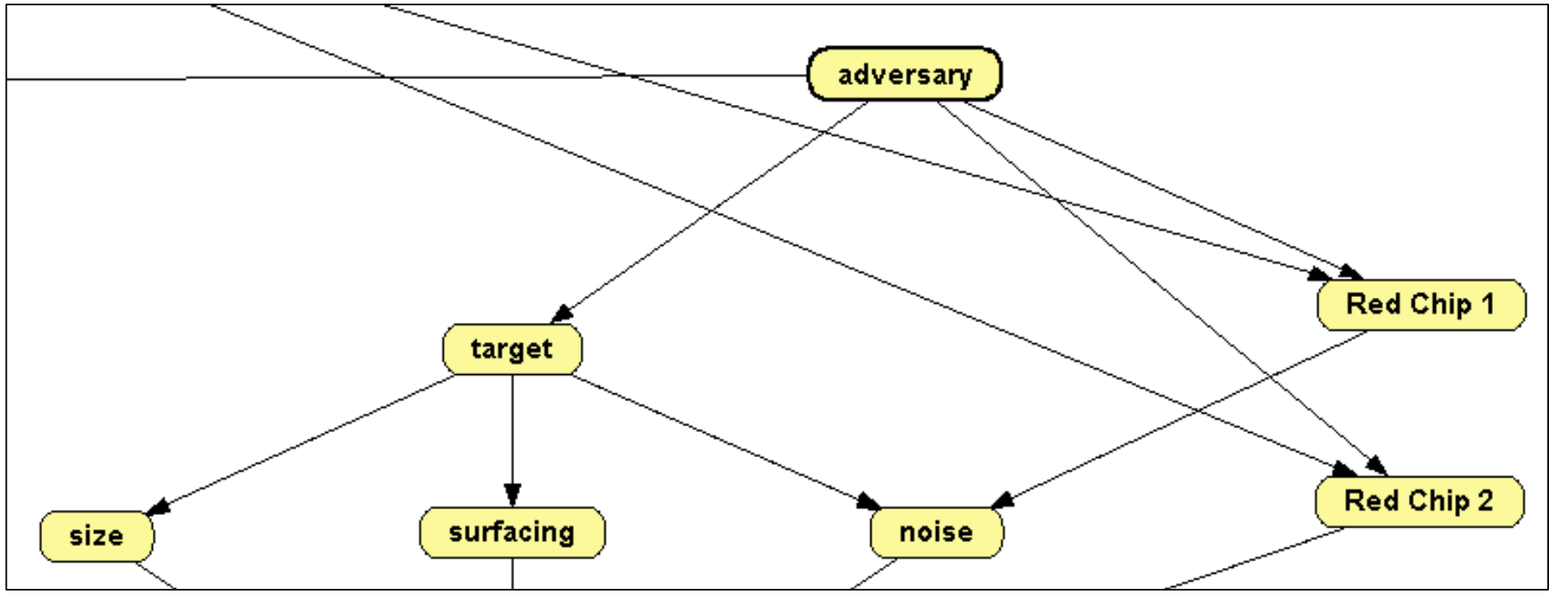
Tiered Approach to WCCA Model Development

Tier	Name	Description
Tier 1	Nodes	The individual components (e.g. chips, whether red or blue) are captured as Nodes in a Graph associated with the WCCA being digitized.
Tier 2	Nodes, Edges, and Conditions	Relationships between the individual components identified in Tier 1 are created, including the relationships to the functions necessary to successfully carry out the warfighting area (these are new nodes that would be added to the graph in this tier). Often, the functions are related to the kill chain. For each cascading relationship, the conditions necessary for an SME to integrate knowledge to answer proficiency questions are also captured.
Tier 3	SME Probability Tables	SMEs populate the probability tables that are created based on the Nodes, Edges, and Conditions captured in Tier 2. In this Tier, it is assumed that SMEs may be referencing authoritative data sources, but they are still manually entering values and the referenced data sources are not integrated directly.
Tier 4	Integrated External Data Sources	In this Tier, specific authoritative data sources, specifically models or simulation results, are directly integrated to populate the Bayesian network. The values provided by SME knowledge integrated in Tier 3 are replaced with these values provided by external data sources.

Notional WCCA in PGM Form



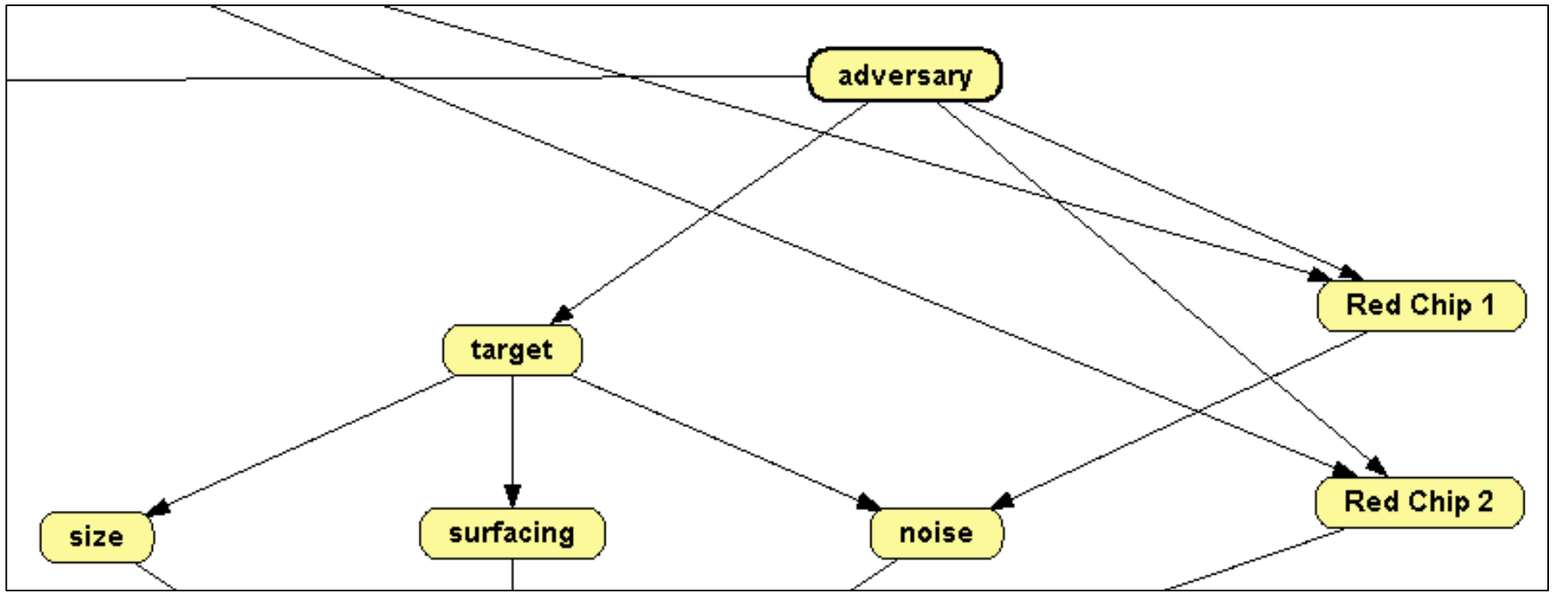
Notional WCCA in PGM Form



Target				
Adversary	Rhode Island	California	North Dakota	Iowa
Raft	25%	25%	25%	25%
Rowboat	25%	25%	25%	25%
Diesel	25%	25%	25%	25%
Nuclear	25%	25%	25%	25%

Noise												
Red Chip 1	None				MWC				FOC			
Target	Raft	Rowboat	Diesel	Nuc	Raft	Rowboat	Diesel	Nuc	Raft	Rowboat	Diesel	Nuc
Loud	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%
Medium	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%
Quiet	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%

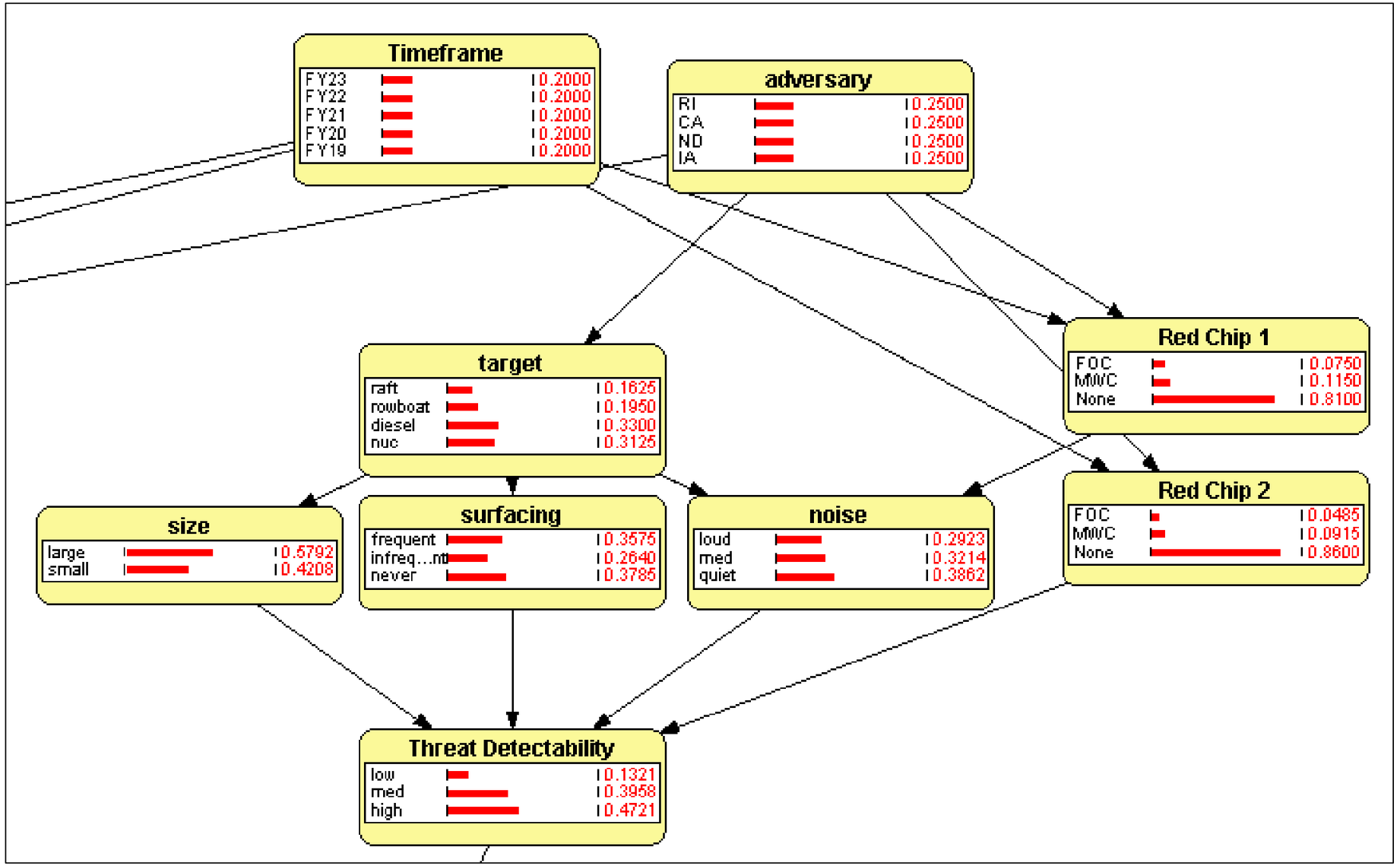
Notional WCCA in PGM Form



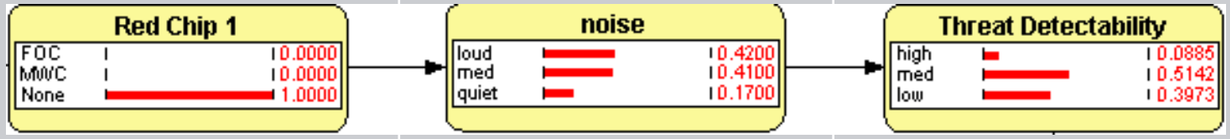
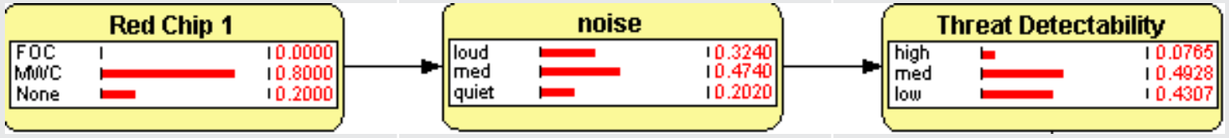
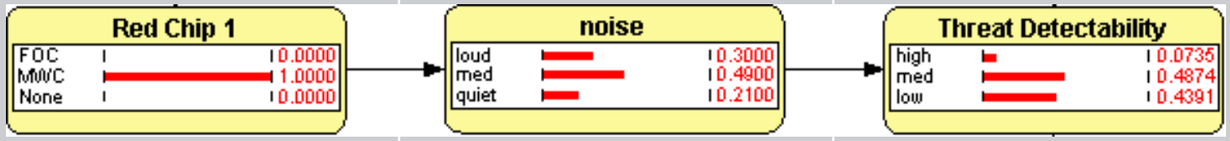
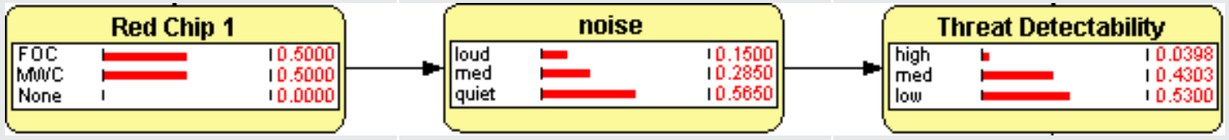
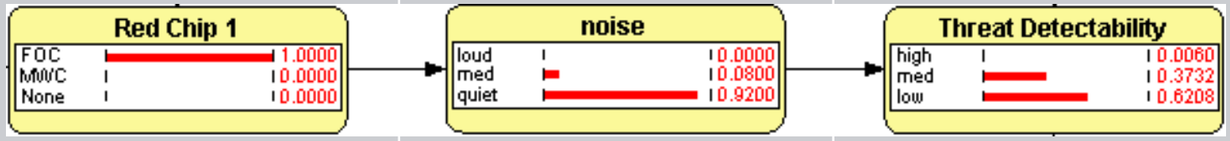
Target				
Adversary	Rhode Island	California	North Dakota	Iowa
Raft	10%	40%	0%	15%
Rowboat	10%	43%	0%	25%
Diesel	40%	12%	40%	40%
Nuclear	40%	5%	60%	20%

Noise												
Red Chip 1	None				MWC				FOC			
Target	Raft	Rowboat	Diesel	Nuc	Raft	Rowboat	Diesel	Nuc	Raft	Rowboat	Diesel	Nuc
Loud	5%	10%	75%	20%	5%	10%	45%	20%	5%	10%	15%	10%
Medium	25%	30%	20%	55%	25%	30%	40%	50%	25%	30%	50%	50%
Quiet	70%	60%	5%	25%	70%	60%	15%	30%	70%	60%	35%	40%

Populated Probability Tables Inference with No Evidence

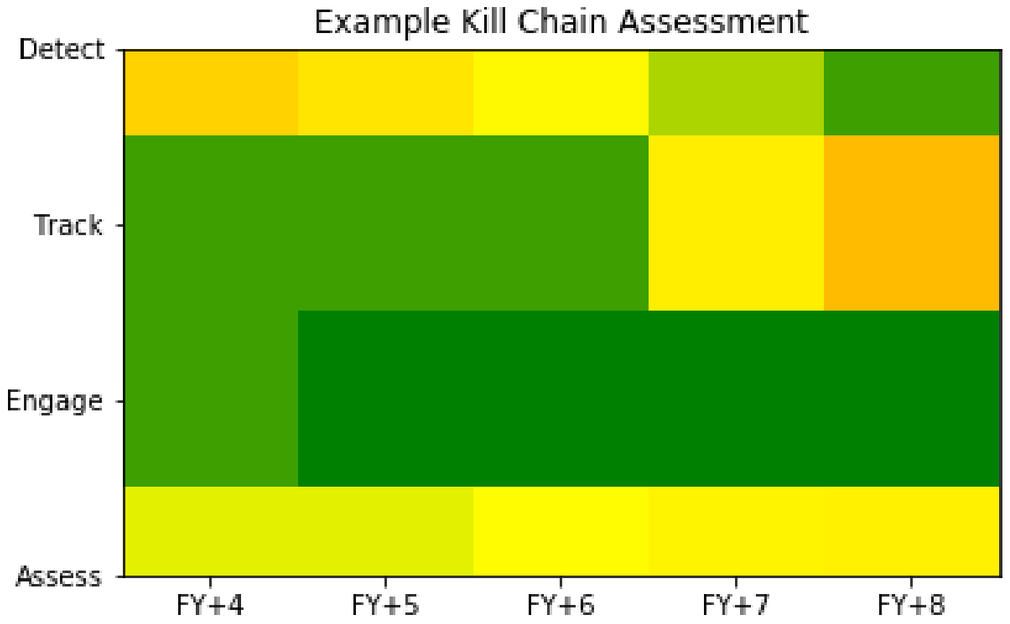


Sequential Inference Across Years of Concern

Timeframe	Red Chip 1	Noise	Threat Detectability
FY19			
FY20			
FY21			
FY22			
FY23			

Advantages of PGM Based Assessments

- Components/nodes common to multiple WCCAs can be integrated
- Visualization is automatically generated from model
- Enables “What-If” analysis through simple model table updates and unique inference cases
- Provides traceable, rigorous assessment
- Enables future capability of having tables be populated by other models or simulation results



Challenges to PGM Based Assessment

- Data elicitation for probability distribution tables can be burdensome
  - Size of tables are factorial of the states of all parent nodes
- Attempts to lighten the burden with a simpler model can lead to hidden assumptions in probability tables, or force SME to aggregate data internally
- Future work to investigate techniques for pre-populating tables with minimal burden to SME, resulting in table review vs. table population