



712CD

75TH MORSS CD Cover Page

If you would like your presentation included in the 75th MORSS Final Report CD it must :

1. Be unclassified, approved for public release, distribution unlimited, and is exempt from U.S. export licensing and other export approvals including the International Traffic in Arms Regulations (22CFR120 et seq.);
2. Include MORS Form 712CD as the first page of the presentation;
3. Have an approved MORS form 712 A/B and
4. Be turned into the MORS office no later than: **DEADLINE: 14 June 2007 (Late submissions will not be included.)**

Author Request (To be completed by applicant) - The following author(s) request authority to disclose the following presentation in the MORSS Final Report, for inclusion on the MORSS CD and/or posting on the MORS web site.

Name of Principal Author and all other author(s): John F. Lemmer; Edward Verenich

Principal Author's Organization and address:
 US Air Force Research Laboratory/IFSA
 525 Brooks Road
 Rome, NY 13441

Phone: 315 330 3657

Fax: 315 330 7723

Email: john.lemmer@rl.af.mil

Please use the same title listed on the 75TH MORSS Disclosure Form 712 A/B. If the title of the presentation has changed please list both.) "Bayesian Causal Modeling Extended and Applied to Resource Requirements"

Original title on 712 A/B:

If the title was revised please list the original title above and the revised title here:

PRESENTED IN:

| | | | |
|--------------------|-------|----------------|-----|
| WORKING GROUP: | 4, 26 | DEMONSTRATION: | Yes |
| COMPOSITE GROUP: | | POSTER: | |
| SPECIAL SESSION 1: | | TUTORIAL: | |
| SPECIAL SESSION 2: | | OTHER: | |
| SPECIAL SESSION 3: | | | |

This presentation is believed to be: **Unclassified, approved for public release, distribution unlimited, and is exempt from U.S. export licensing and other export approvals including the International Traffic in Arms Regulations (22CFR120 et seq.)**

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

| | | | |
|---|------------------------------------|--|----------------------------------|
| 1. REPORT DATE 01 JUN 2007 | 2. REPORT TYPE N/A | 3. DATES COVERED - | |
| 4. TITLE AND SUBTITLE Bayesian Causal Modeling Extended and Applied to Resource Requirements | | 5a. CONTRACT NUMBER | |
| | | 5b. GRANT NUMBER | |
| | | 5c. PROGRAM ELEMENT NUMBER | |
| 6. AUTHOR(S) | | 5d. PROJECT NUMBER | |
| | | 5e. TASK NUMBER | |
| | | 5f. WORK UNIT NUMBER | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) US Air Force Research Laboratory/IFSA 525 Brooks Road Rome, NY | | 8. PERFORMING ORGANIZATION REPORT NUMBER | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | 10. SPONSOR/MONITOR'S ACRONYM(S) | |
| | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) | |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited | | | |
| 13. SUPPLEMENTARY NOTES See also ADM202526. Military Operations Research Society Symposium (75th) Held in Annapolis, Maryland on June 12-14, 2007, The original document contains color images. | | | |
| 14. ABSTRACT | | | |
| 15. SUBJECT TERMS | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT |
| a. REPORT unclassified | b. ABSTRACT unclassified | c. THIS PAGE unclassified | UU |
| | | | 18. NUMBER OF PAGES 17 |
| | | | 19a. NAME OF RESPONSIBLE PERSON |

Bayesian Causal Modeling Extended and Applied to Resource Requirements

John F. Lemmer

john.lemmer@rl.af.mil

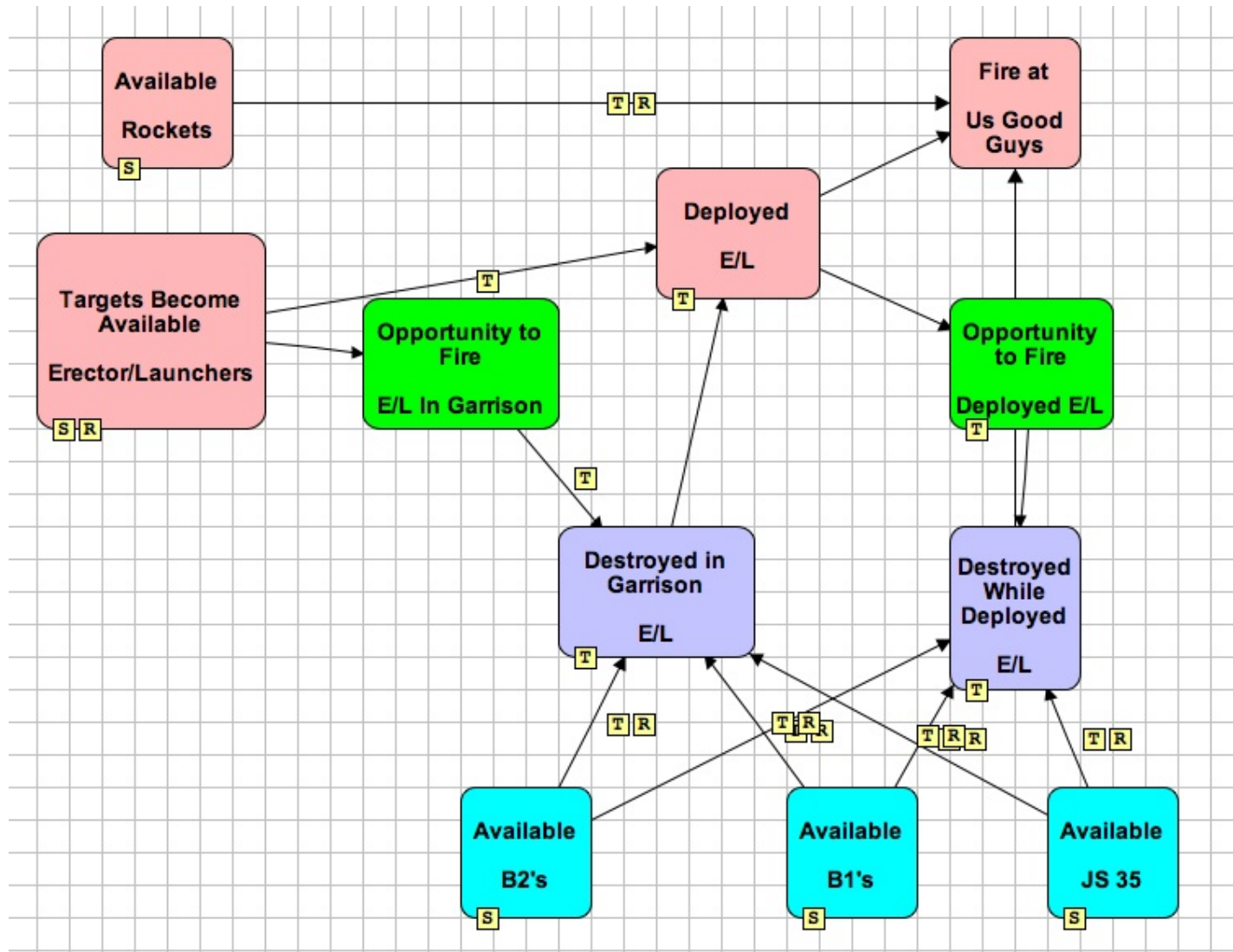
Edward Verenich

edward.verenich@rl.af.mil

Resourced Bayesian Networks

- Missile Defense Example
- How it has been done
 - Extension to Bayes Technology
 - Resource Constrained Persistence
- Relationship to other common approaches

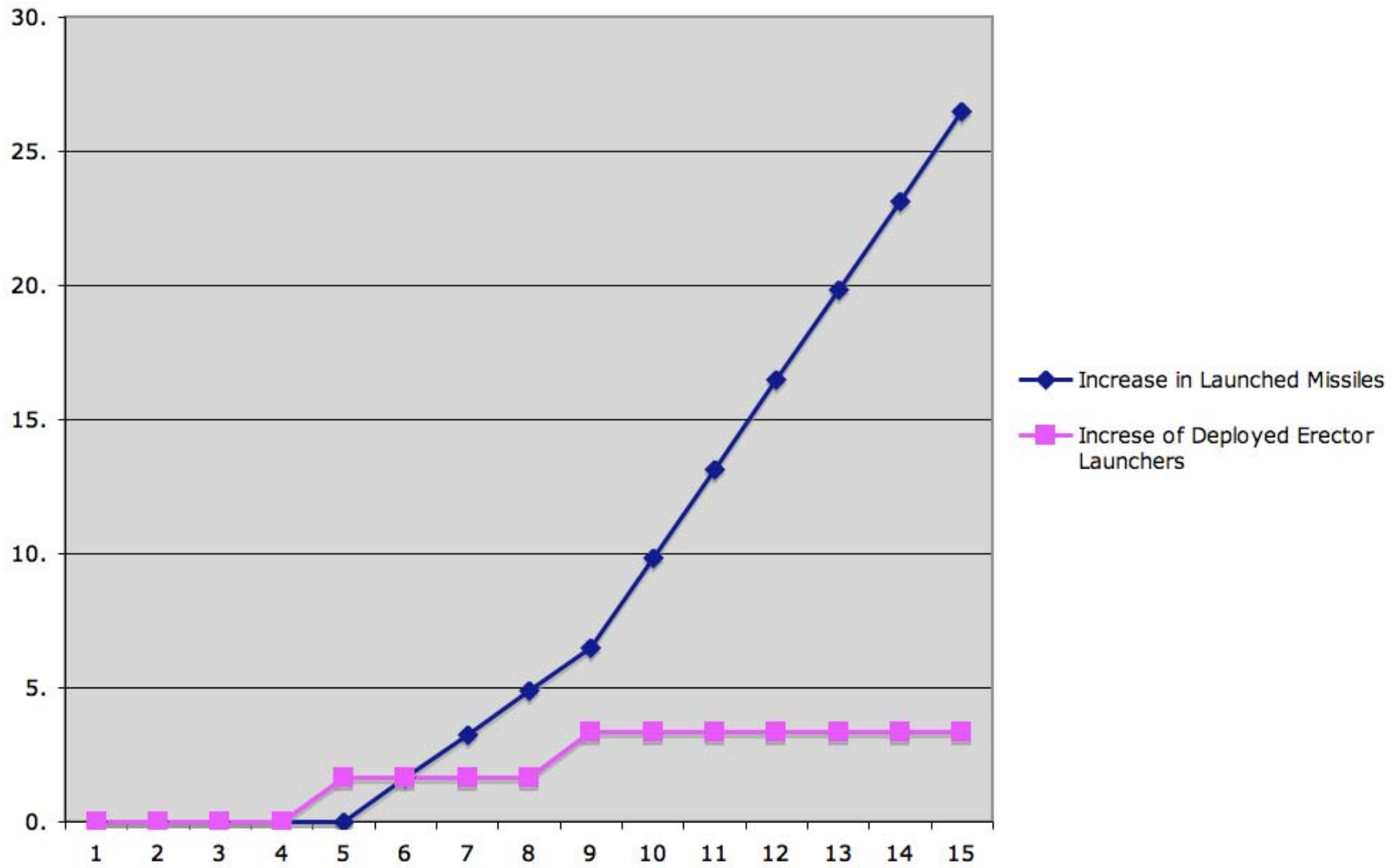
Mini Kill Chain



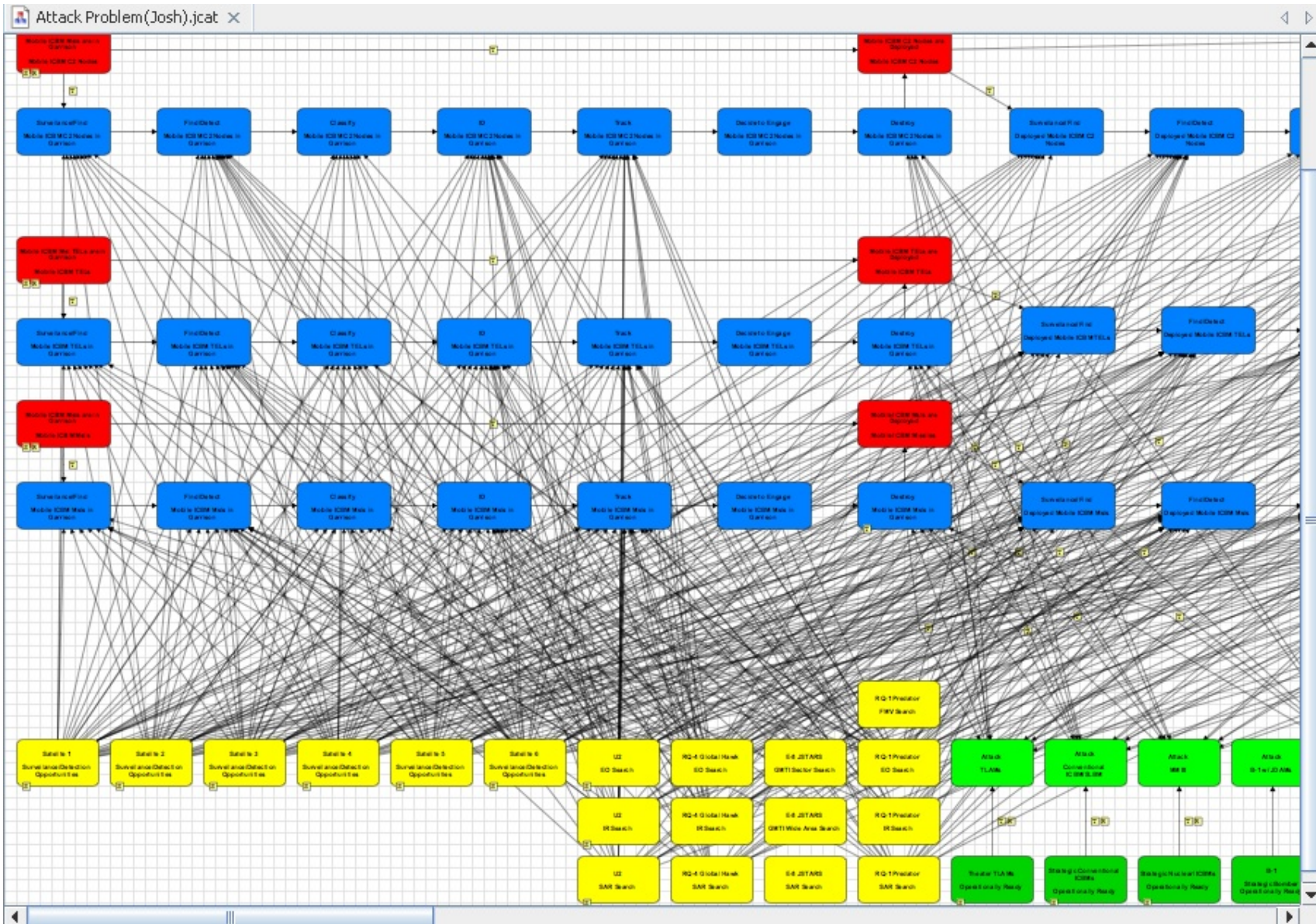
Two Ticks

| Node | 0 | 1 | 2 | 3 | 4 | 5 |
|---|------|-------|-------|-------|-------|---------|
| Available (B1's) [Process] | 20. | 0. | 0. | 0. | 0. | 0. |
| Available (B2's) [Process] | 20. | 0. | 0. | 0. | 0. | 0. |
| Available (JS 35) [Process] | 20. | 0. | 0. | 0. | 0. | 0. |
| Available (Rockets) [Process] | 20. | 0. | 0. | 0. | 0. | 0. |
| B1 Strike (null) [Consolidator] | 7. | 7. | 0. | 0. | 0. | 0. |
| B2 Strike (null) [Consolidator] | 11. | 11. | 11. | 11. | 11. | 10.284 |
| Deployed (E/L) [Process] | 0. | 0. | 0. | 0. | 0.716 | 0.716 |
| Destroyed While Deployed (E/L) [Process] | 0. | 0. | 0. | 0. | 0.703 | 0.716 |
| Destroyed in Garrison (E/L) [Process] | 0. | 7.788 | 9.284 | 9.284 | 9.284 | 16.036 |
| E/L Not Operational (null) [Signal] | 0. | 0. | 0. | 0. | 0.703 | 0.716 |
| Fire at (Us Good Guys) [Process] | 0. | 0. | 0. | 0. | 0.716 | 0.716 |
| In Deployed Position (null) [Signal] | 0. | 0. | 0. | 0. | 0.716 | 0.716 |
| In the crosshairs (null) [Signal] | 0. | 0. | 0. | 0. | 0.716 | 0.716 |
| JS 35 (null) [Consolidator] | 13. | 13. | 10. | 7.788 | 7.788 | 7.072 |
| Killed (null) [Signal] | 0. | 7.788 | 9.284 | 9.284 | 9.284 | 16.036 |
| Loaded (null) [Signal] | 250. | 250. | 250. | 250. | 250. | 249.284 |
| Move Out (null) [Signal] | 0. | 0. | 0. | 0. | 10. | 0. |
| Opportunity to Fire (E/L In Garrison) [Process] | 0. | 10. | 0. | 0. | 0. | 10. |
| Opportunity to Fires (Deployed E/L) [Process] | 0. | 0. | 0. | 0. | 0.716 | 0.716 |
| Ready (null) [Signal] | 0. | 0. | 0. | 0. | 0.716 | 0.716 |
| Something to See (null) [Signal] | 0. | 10. | 0. | 0. | 0. | 10. |
| Targets Become Available (Erector/Launcher) [Process] | 0. | 10. | 0. | 0. | 0. | 10. |

2 tic vs. 1 tic



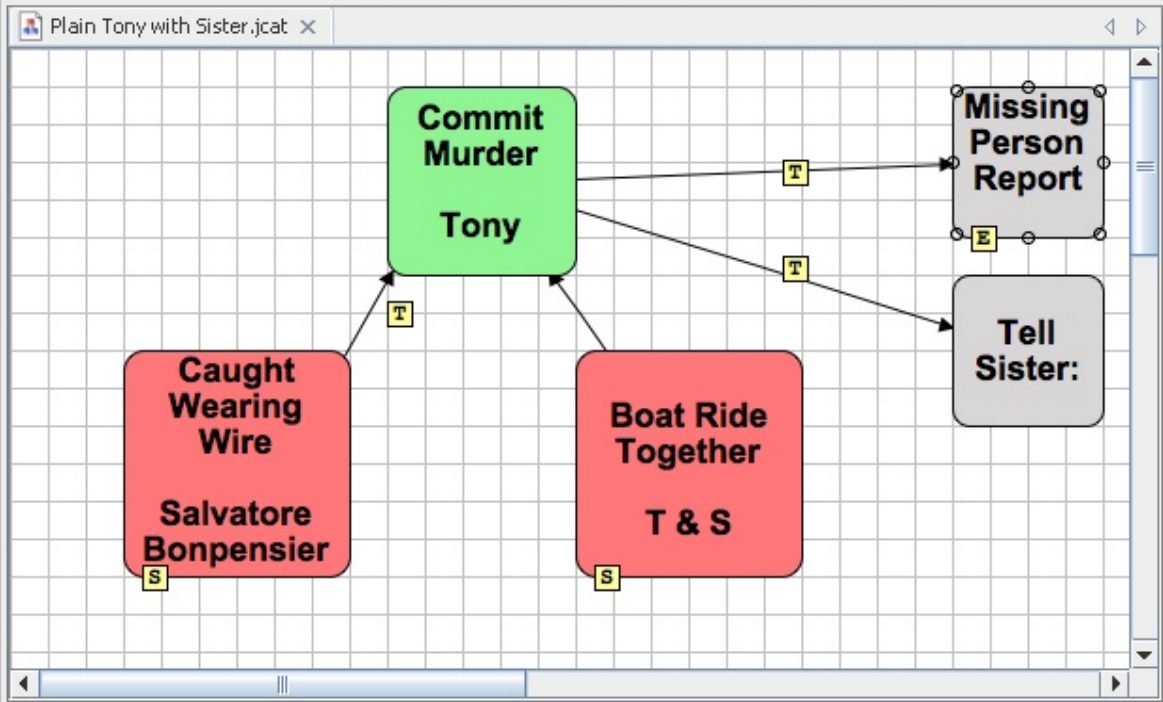
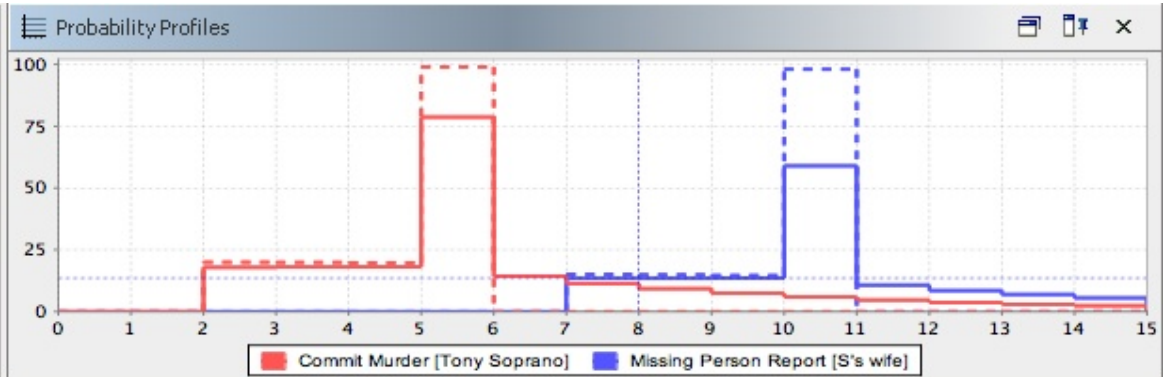
Kill Chain for Missile Defense

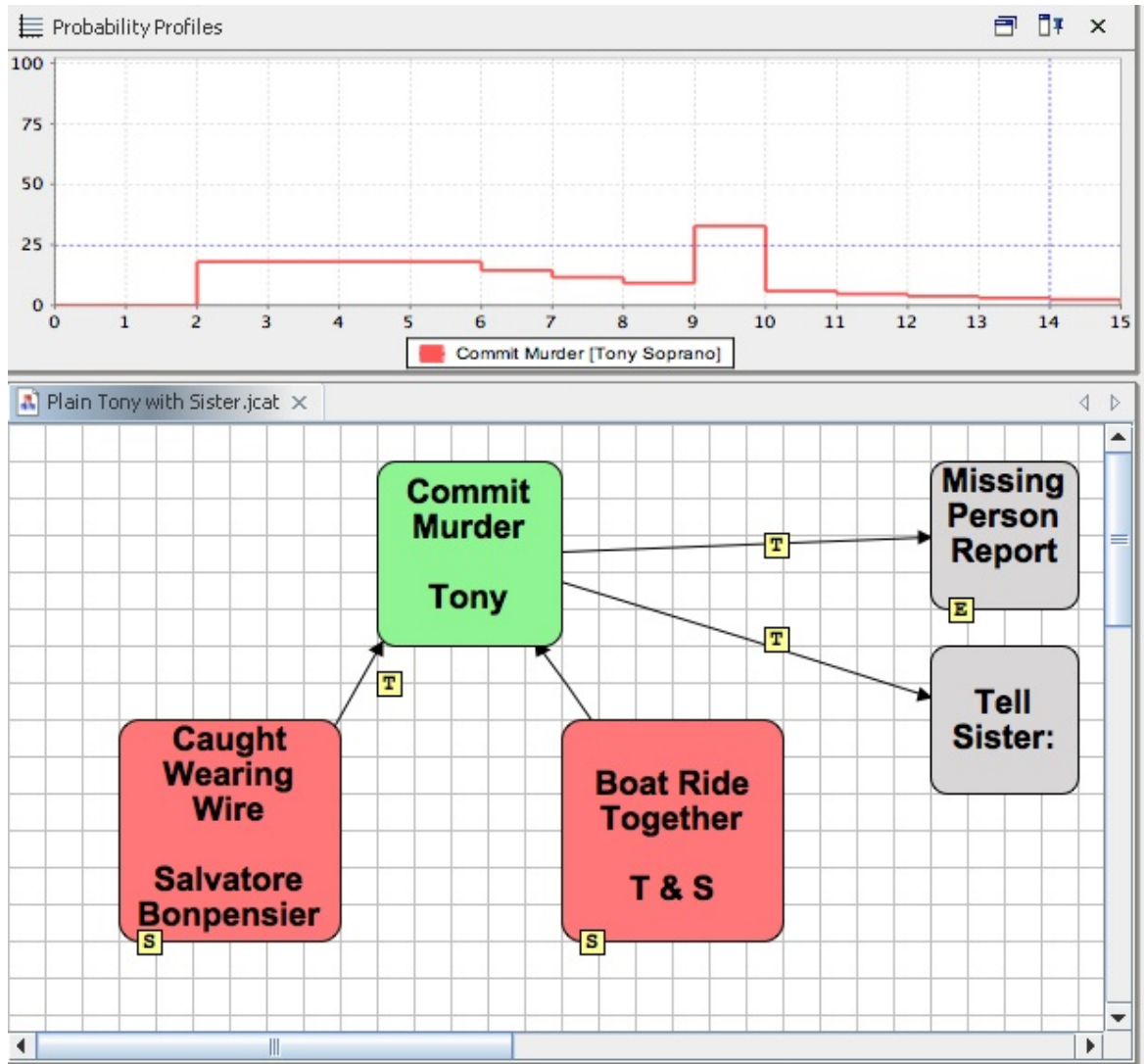


Bayes Network Types

- Static Bayes Net
- Temporal (Dynamic) Bayes Net
 - Delay
 - Persistence
 - Fixed
 - Decaying
 - Resource Constrained
- Parallel Events Bayes Net
 - Ensemble

COA
Early Ride
Late Ride

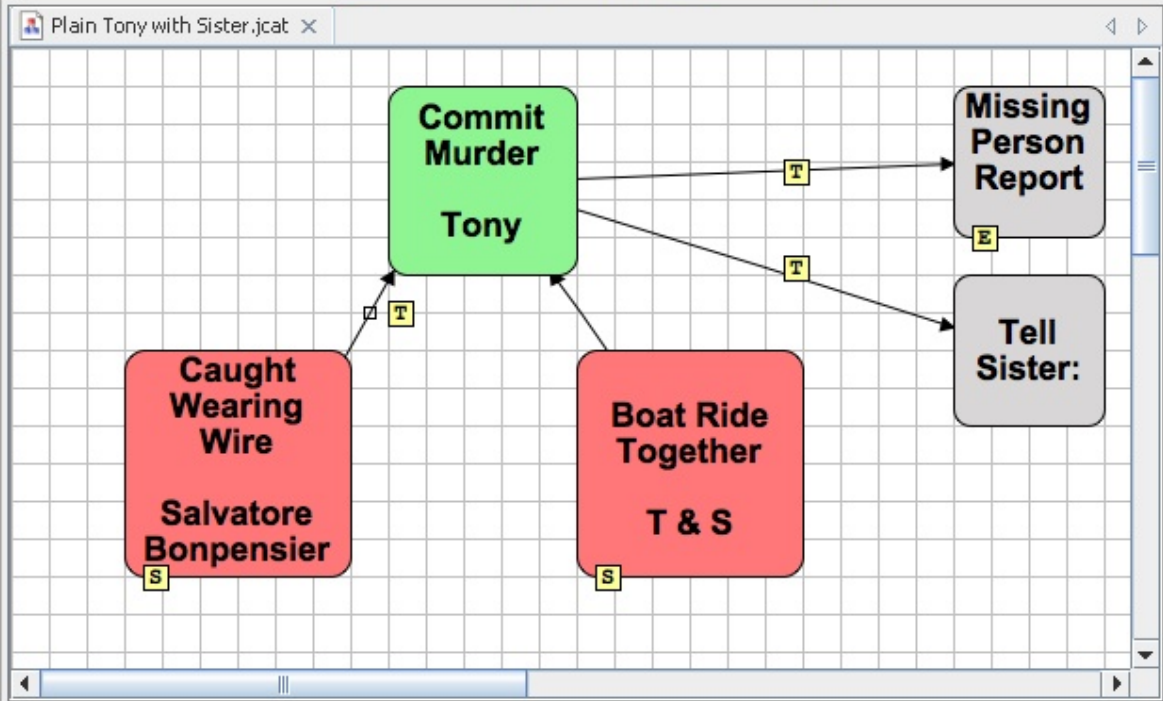
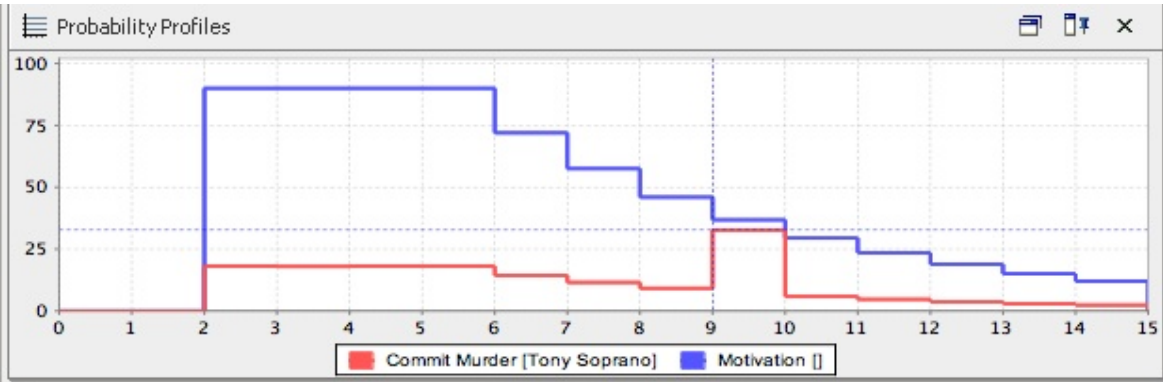




COA

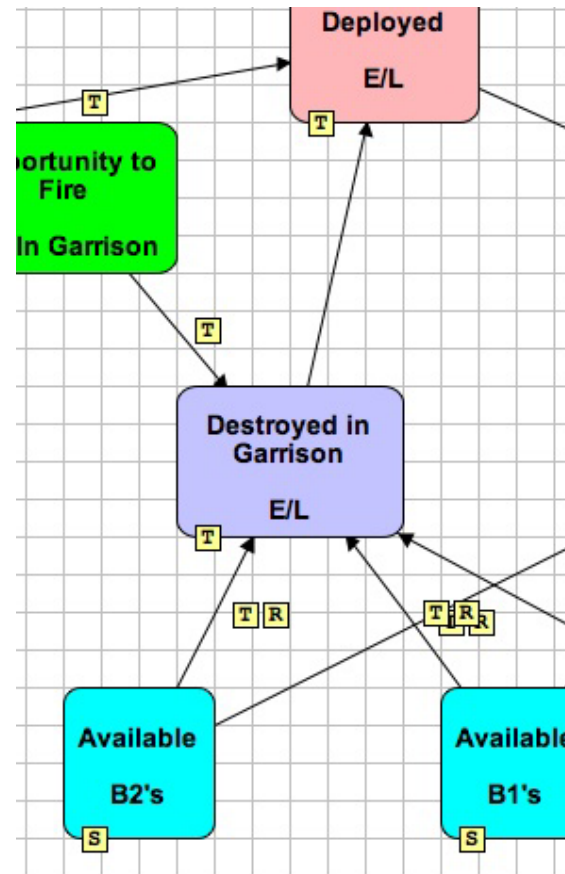
- Early Ride
- Late Ride

Apply COA Delete COA



Resource Constrained Persistence

- How long does B2 availability persist?
 - At best until there are too many targets
- Number of targets?



Parallel Event Bayes Net

- Solve by sampling
 - Vice: Junction Tree Algorithm
- Ensemble Sampling
 - While still sampling
 - For each time step
 - For each threat
 - » Take a sample
 - Reset resources

Open Issues

- Target Weapon Pairing
 - Multiple Resource Usage Possible
 - Related to OR Gates
- Expending a resource
 - E.g. Attack vs. Destroy
- Re-firing
 - Technical Details
 - Policy

Comparison to Petri Nets, etc

- Petri Nets
 - At simulation level there are
 - Places
 - Transitions
- System Dynamics(Wikipedia)
 - Feedback
 - Accumulation of flows into stocks
 - Time delays

Advantages

- Clear Semantics
- Quick Build
 - Supports iterative refinement
 - Comparison of Alternatives
- Automated Support
 - Explanation
 - Sensitivity Analysis

Available

- To obtain JCAT
 - Contact either of the authors.