Network Mission Assessment Toolkit

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Network Mission Assessment Toolkit
Problem Statement, Proposed Solution

CNW, 2009: SAB finds that the "Range of cyber attack effects is not well understood by warfighters" and recommends the development of "technology programs that enhance Mission Assurance"

The Problem:

- **Mission commanders need to understand how a threat to their infrastructure translates to a threat to their mission**
- **Existing risk / vulnerability assessment capabilities can account for mission context, but rely on resource-intensive manual processes**
- **There exists no reliable, automated system for mapping the mission onto the infrastructure**

Our Insight:

- **A mission can be represented by the group of network resources used by mission participants in support of the mission and all the associated network resources on which this group depends**

Our Hypothesis:

- **These mission groups can be inferred automatically from network-derived data using machine learning techniques and limited human contributions**

Our Solution:

- **NMAT: a decision-support tool used to identify mission groups by analyzing network data sources. These groups will be augmented with information such as host criticality, workflow models, and topic information**

Summary of Mission Assessment Approaches

- NIST: Risk Management Framework (RMF) is a formal specification of the risk assessment process
  - Promotes disciplined, structured and flexible implementation
  - However, is manual process requiring iterative customization of existing baseline models
- MORDA: Formal rigorous red-team methodology for risk assessment
  - Creates complex attack graphs and system models; includes many attack types
  - Allows users to tradeoff security, cost, performance
  - However, time consuming and requires many domain experts
- CNSS-NRAT: Automatic risk analysis for a fixed collection of threats, controls, and network types
  - Provides a high-level risk score and details about threats
  - However, uses high level network and adversary models
- RISKMap: Applies business objectives model to risk via bottom-up approach
  - Identifies infrastructure "crown jewels" that are essential to mission functions
  - Allows exploration of "what-if" scenarios off-line
  - However, requires domain expert inputs
- NMAT: Automated mission-mapping using machine learning techniques
  - Minimal human intervention required; yields repeatable and verifiable results
  - Useful on existing undocumented infrastructure
  - Can be run on an ongoing, periodic basis
  - However, relies upon representation of mission in network traffic

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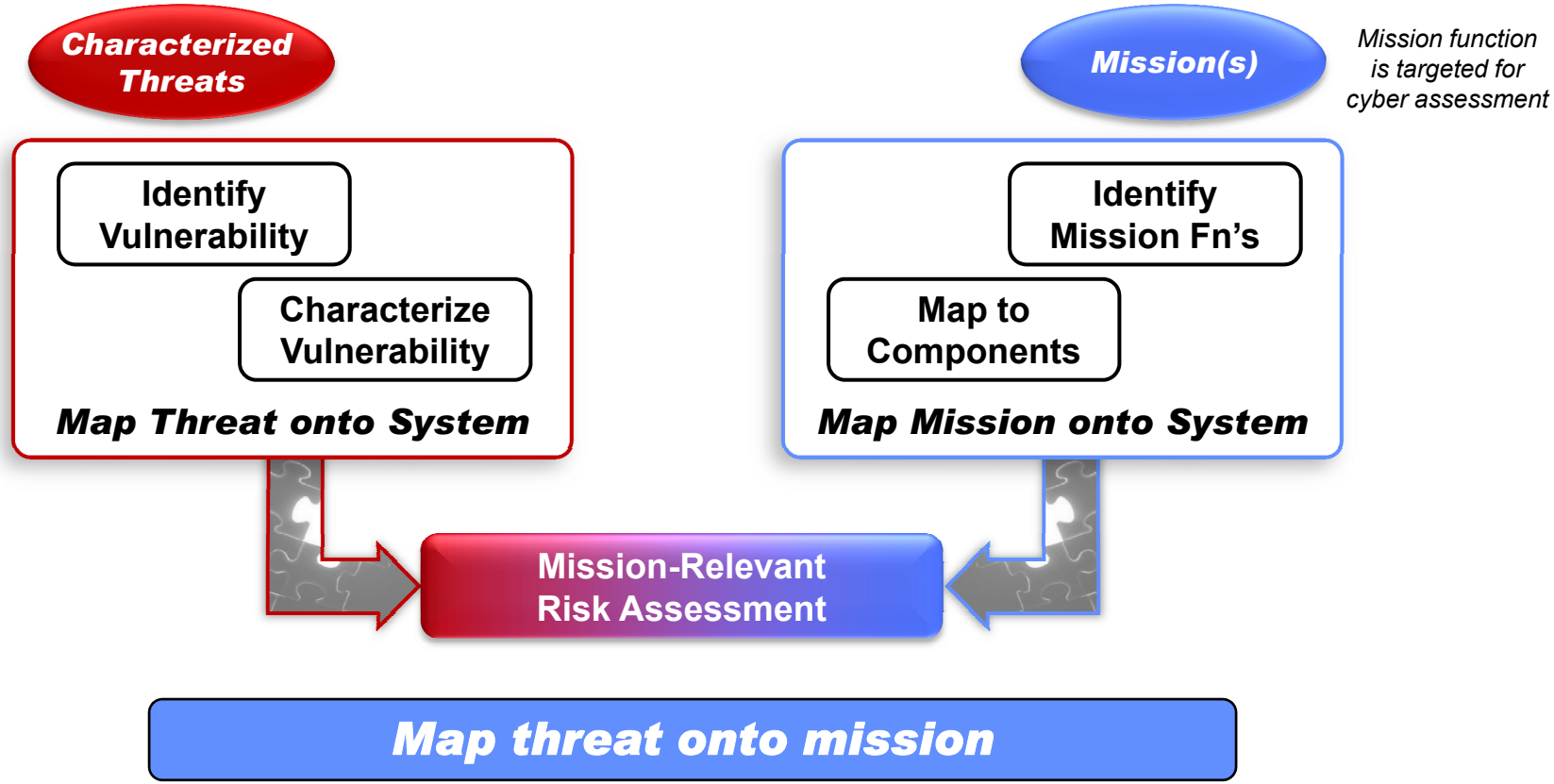
Vision and Approach

Couple with proven threat assessment capability to provide comprehensive risk assessment



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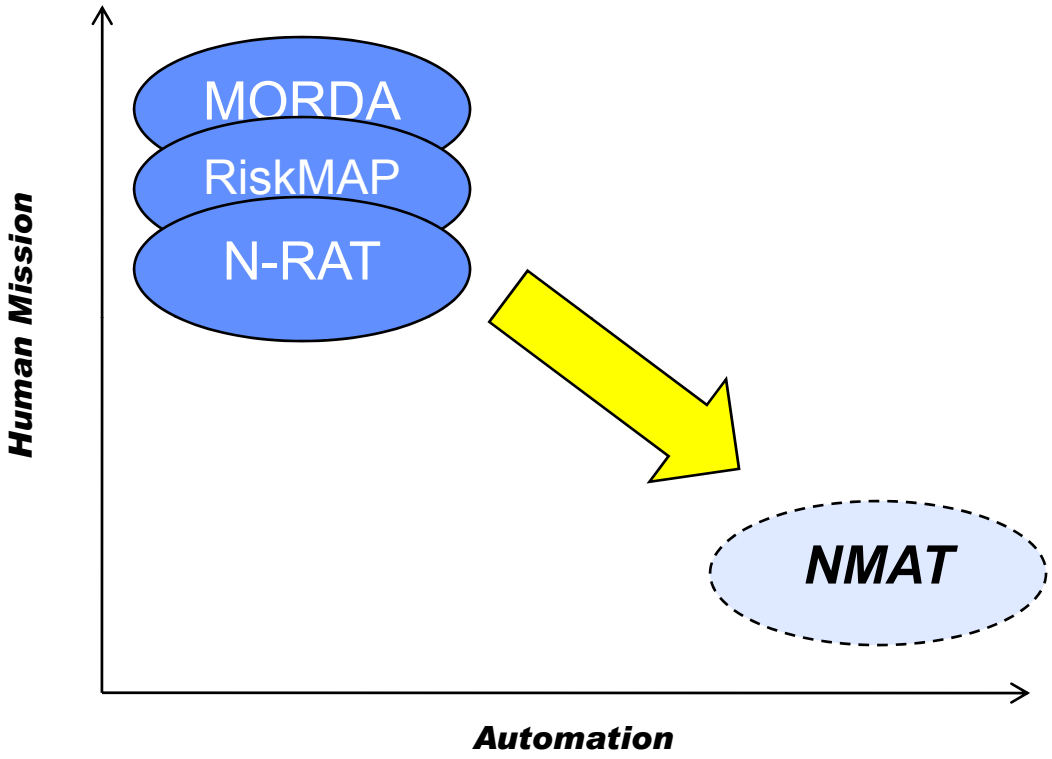
Mission Assessment Approaches



NMAT goal is to be resource-light and automated so that it could be run in "real-time" as mission operations proceed

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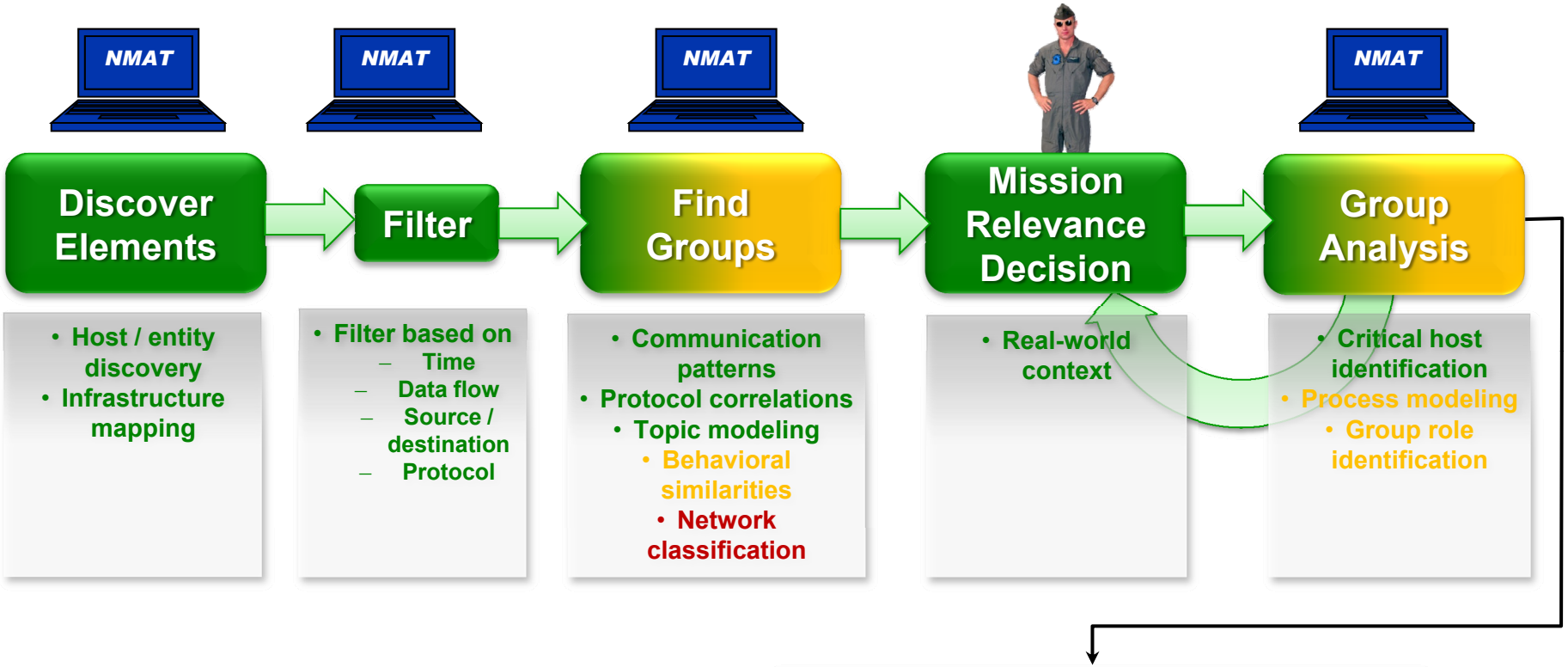
NMAT Processing Pipeline



NMAT Final Output

Mission Model

- Network elements grouped by mission they support
- Associated natural language
- Model of workflow (process)
- Roles of group elements
- Group elements ranked by criticality/importance

Complete

Continuing Research

Not started

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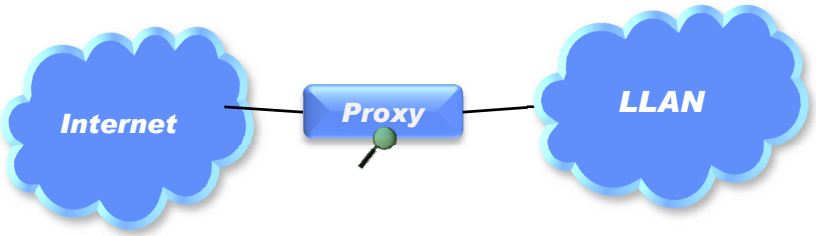
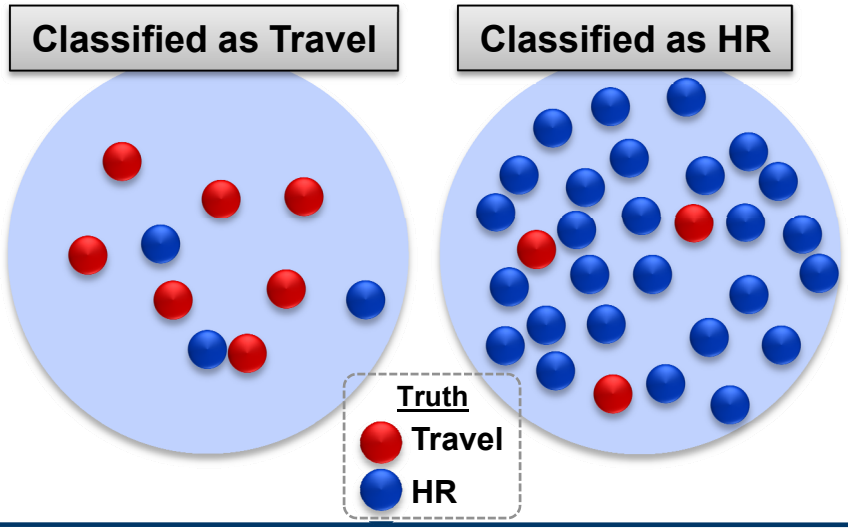
LRNOC Data (Identify Groups)



- Proxy logs captured through Splunk
  - All web traffic from the Lab network
  - Limited to 10k records, or about 30 minutes
- Ground truth available through known subnet roles
- Only examine HR and Travel traffic as these mission groups rely heavily on web traffic (HTTP)

- Using J48 decision tree, we can classify known mission participants using behavioral similarity (feature space of length-one labeled walks)
- Classify HR and Travel together with >80% accuracy
- More sophisticated methods should perform much better, but require more data
- Good preliminary results on larger datasets using probabilistic approaches



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Identify Groups
Probabilistic Approach

- Algorithms from physics, social science
  - Cluster nodes based on node-node communication
  - Nodes that communicate with each other frequently are in the same group
- Mixed Membership Stochastic Blockmodels
  - Airoldi, Blei, Feinberg, Xing 2008
  - Nodes represent IP addresses
    - Each node draws a group membership vector from a Dirichlet distribution
    - Every pair of nodes draws membership from a multinomial parameterized by their membership vectors
    - Edges are drawn from a Bernoulli distribution parameterized by the group memberships of the nodes
  - Exact solution is intractable but good approximation schemes exist (e.g., variational inference, Gibbs sampling, MCMC).

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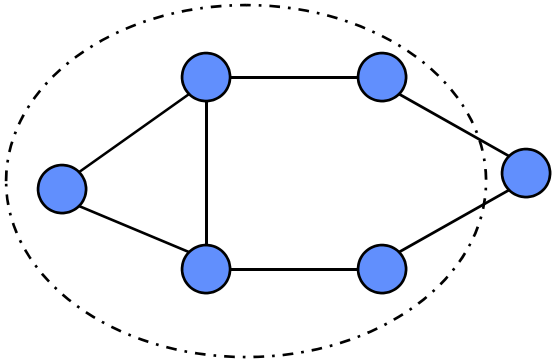
Identify Groups
Graph Theoretic Approach

- **Clique relaxations**
  - Flexible sub-structure that can indicate community
  - Excellent performance on public social-network data
- **K-clique**
  - Subset of vertices such that the shortest path between every pair of vertices is of length at most K
- **P-connected K-clique**
  - Subset of vertices such that there are K edge-distinct length P paths between every pair of vertices



2-clique

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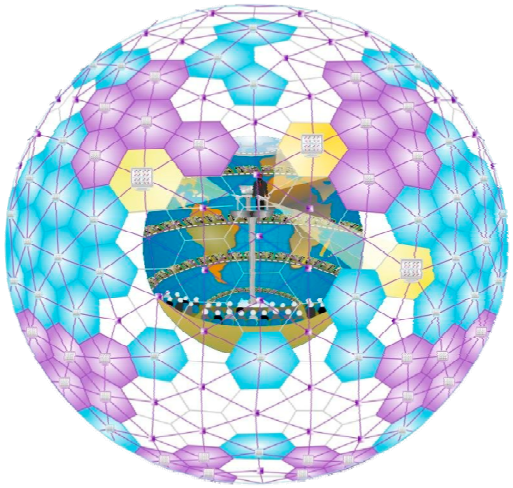
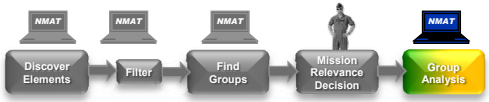
Internal Mission Data (Topic Discovery, Process Mining)

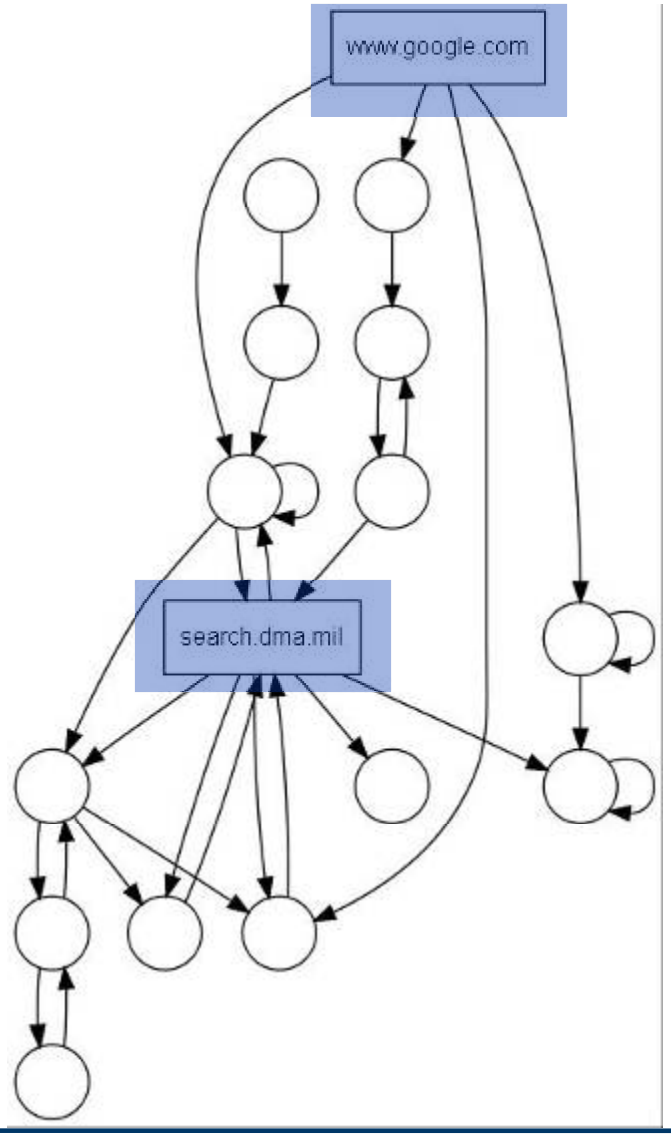
- Mission: Five people gather information about air force bases
  - Find 5 air force bases each
  - Find their commanders, location, number of resident personnel
  - Send information via e-mail to one person who combines all results
  - Information posted to internal web page over interactive SSH session
  - All participants notified of web page update
- All mission activity interspersed with non-mission activity
  - Check e-mail, chat with friends
- Each participant captured network traffic from their machine



Internal Mission Analysis: Process Mining Output



- First concentrate only on HTTP traffic from one user
- Manually identify Google as a starting point
  - This makes sense in search, explore, search template
- Eliminate obvious noise
- Process analysis using PROM reveals model of how a repeated task is executed
- Further graph mining (e.g., PageRank, min cut) can rank nodes, identify failure points



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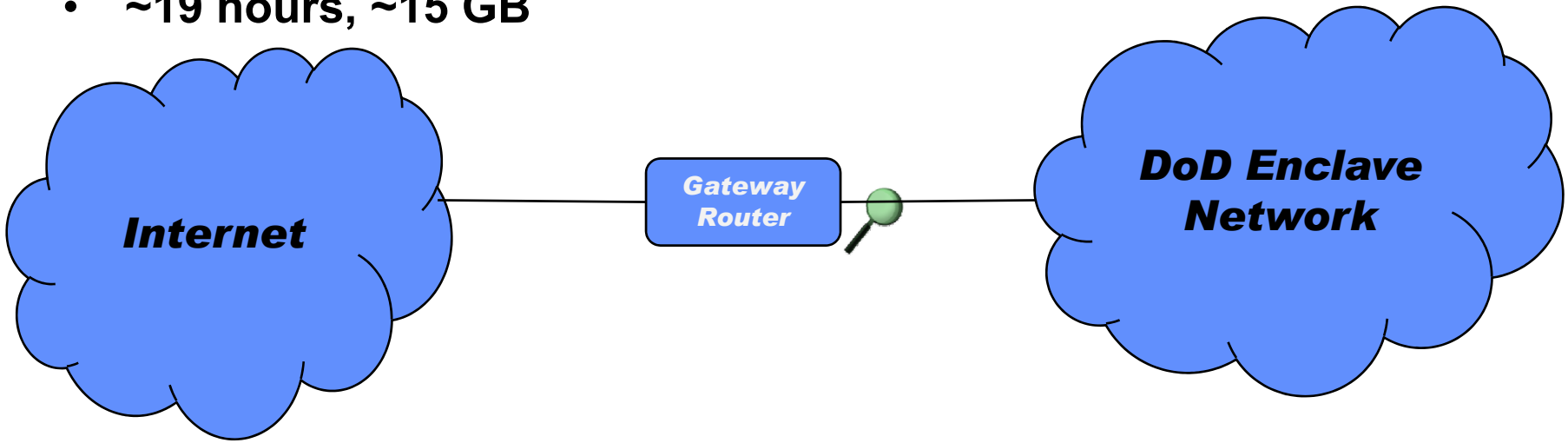
DoD Enclave Data (Critical Host Identification)

- High volume, multiple mission network
- Network tap at border gateway
  - Regular business hours, no known special events
- Limited amount of network information available
  - Requires constant communication with administrators
- ~19 hours, ~15 GB



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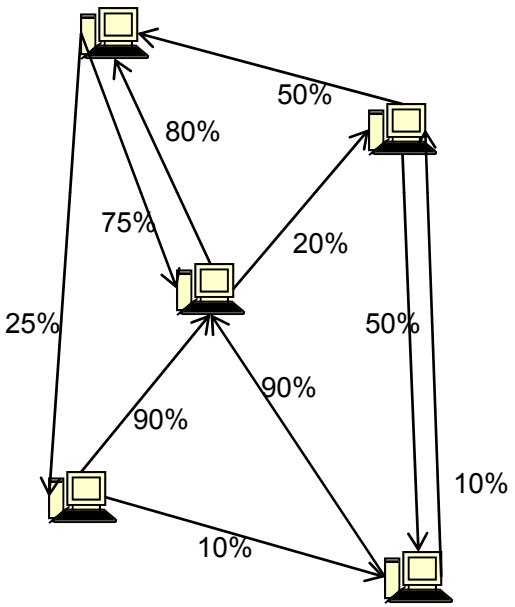
Critical Host Identification

- Model network as a Markov Chain
- States are IP addresses
- Transition probability
  - log(number_of_bytes)
- Critical hosts have higher probability in stationary distribution
- Identifies
  - Critical hosts
  - Non-mission traffic (noise)



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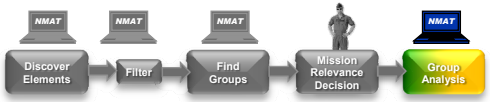
DoD Enclave Data Analysis: Critical Host Identification



Critical hosts identified

- X.X.X.A (leave reservation, end of November)
- X.X.X.B (information portal)
- X.X.X.C (information portal)
- disa.mil
- microsoft.com
- msftncsi.com

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Deployable Features

- Several modules could be deployed soon in a decision support role
  - Critical Host Identification
    - Help operator prioritize issues and attention
  - Group Identification
    - Can be used on almost any data source (PCAP, proxy logs, server logs, e-mail logs, etc.)
    - Flexible "target group" design
    - "False positive" rate can be reduced over time as ground truth is given
  - Topic Modeling
    - Works almost off the shelf
    - Requires natural language
    - Best used as a way to enrich other modules

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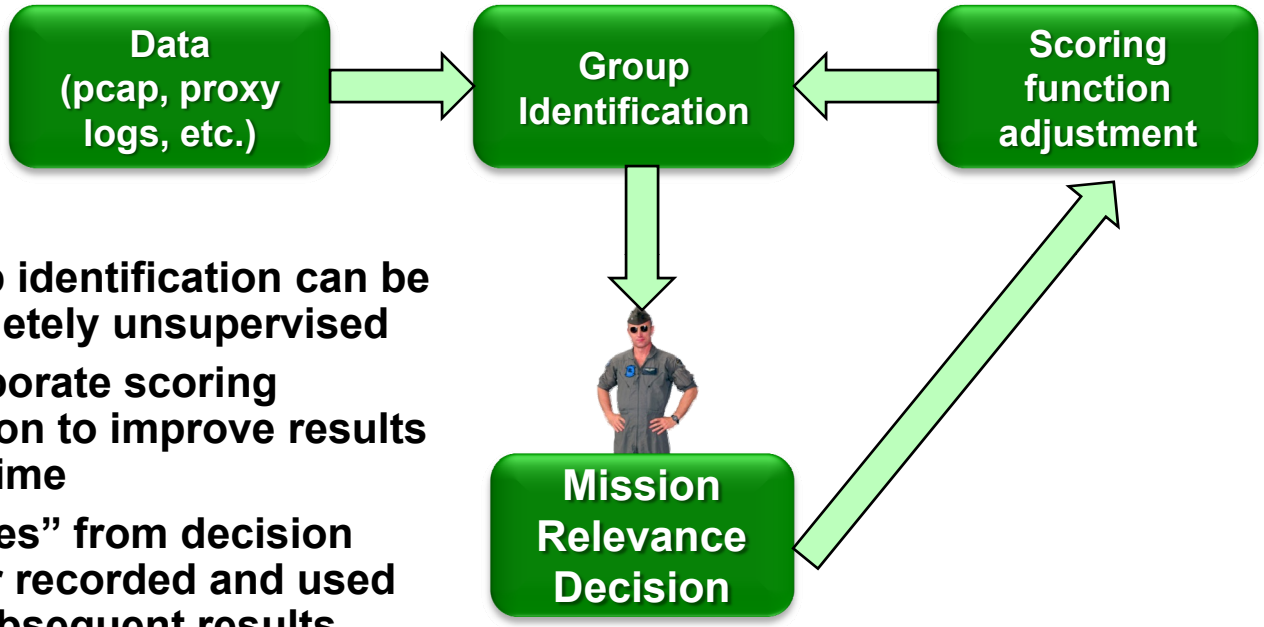
Training the Modules



- Group identification can be completely unsupervised
- Incorporate scoring function to improve results over time
- "Scores" from decision maker recorded and used for subsequent results

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Conclusion

- NMAT applies various techniques in a new setting
  - Probabilistic approaches to graph analysis
  - Structural approaches to graph analysis
  - Stationary distribution of a Markov Chain
  - Process modeling
- Several steps in the pipeline deployable individually
  - Critical host id
  - Group id
- Offers key analysis in a decision support role
  - Shows operator how mission is supported by the infrastructure
  - Enables operator to focus on most important issues