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Cyber Early Warning & the Commonality of Cyber Warfare and Electronic Warfare

SESSION ID: TRM-T08

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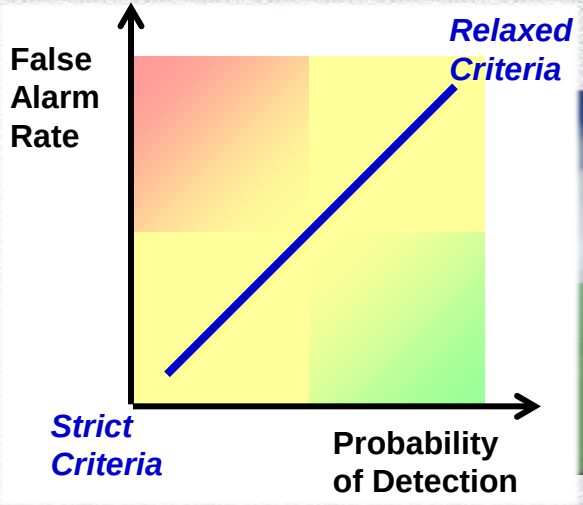
Cyber Early Warning Key Difficulty

The Goal:	Early warning of cyber attacks
Currently:	Many tools & techniques to detect “non-legitimate” activity or “abnormal” behavior
Suggested:	A new layer to handle complex & sophisticated attacks
The Challenge:	Too many False Alarms that cannot be handled; OR: Reduce false alerts by stricter criteria, while unfortunately masking out subtle events, typical to APT attacks



Towards Cyber Warfare

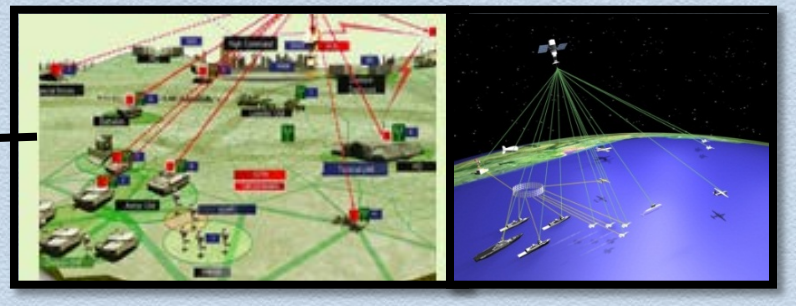
Electronic Warfare (EW)

Integrated SIGINT
(ELINT&COMINT) Solutions

Electronic Protection (EP)
& Electronic Attack (EA)

Cyber Warfare
Intelligence & Situation Awareness

Communication & C^{4}I



Cyber Warfare vs. Electronic Warfare

	Electronic Warfare	Cyber Warfare
Mission	• Air-situation picture (surveillance) • Guiding missiles • Navigation • C&C/data networks	• IT • SCADA • Business • Government services
Intelligence	• SIGINT (ELINT, COMINT) • IMINT (Opt., Radar)	• Hacking • Accessibility tools

Attack	• Electronic Attack (EA)
	  ◦ ECM (Victim: radars)
	  ◦ ComJam (Victim: comm. links)
		• Cyber attacks
		  ◦ (Victim: network services & resources)

Attack type	• Jamming
	  ◦ Spoofing, noise
	• Deception
	  ◦ False targets, missile stealing
		• Jamming
		  ◦ DoS, DDoS
		• Deception
		  ◦ Identity theft, MITM, phishing, Trojan horses

Counter-measures	• ECCM:
	  ◦ Filters, guards, SLB&SLC,…
	  ◦ Decoys,…
	• Immunity
	  ◦ LPI: waveform, agility,…
		• Counter-measures
		  ◦ FW, IPS,…
		  ◦ Honeypots,…
		• Immunity
		  ◦ Encryption, virtualization

Cyber & EW Integration in Battlefield

- An example:
  The US Army has published(*) the ICE (Integrated Cyber & Electronic Warfare) program
  - Define common data contexts & mechanisms to allow Cyber & EW frameworks to communicate and combat the threats in an integrated fashion

(*) http://www.army.mil/article/113678

Multi-Entity Multi-Sensor Scenario & Multi-Hypothesis Tracking

Cyber Early Warning Challenges

- **Huge amount of activity**
  - Data availability, especially in real time
    - Technical & regulatory difficulty to maintain effective coverage of everything
  - Derive insight from the mass of data
  - Data diversity
  - Data dynamics
- **Attacker/defender asymmetry**
  - Proliferation of attack types
  - Difficulty of "attribution" to actual actors
- **Attacks that involve subtle activities**
  - Eliminating false alarms: Discrimination between legitimate activity and cyber incidents
- **Attacks that involve multiple assets**
  - Identification based on the aggregated picture

Persistent Surveillance Challenges

- **A multitude of entities, of various types**
- **Dynamic scenario**
- **Integration of different sensors**
  - Each interprets the situation picture in its manner
  - Some get only a partial situation picture; Some overlap
- **Discrimination between "innocent" entities (false) and "malicious" targets (real threats)**
  - Threats attempt to avoid interception by hiding or behaving like legitimate entities

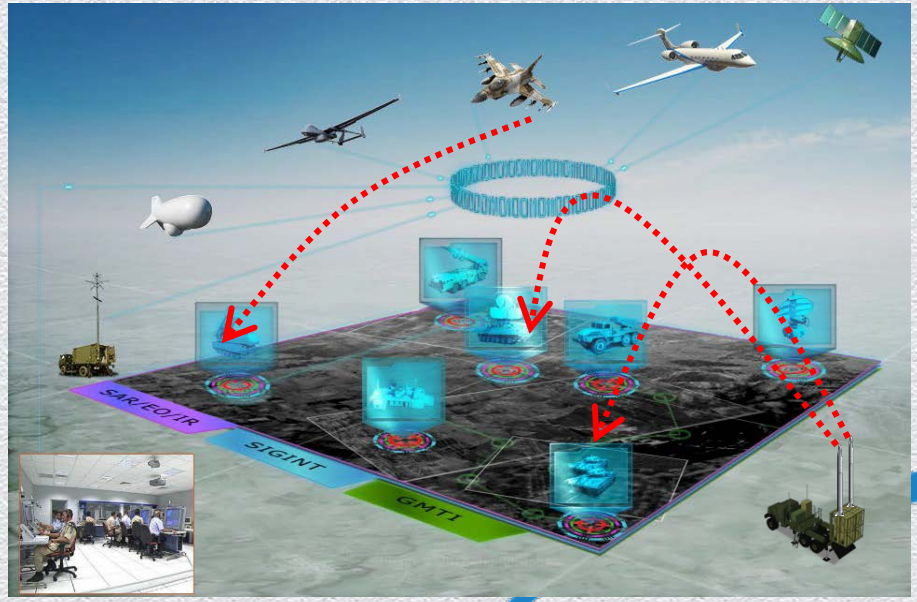
quantity, variability, dynamics

integration

discrimination

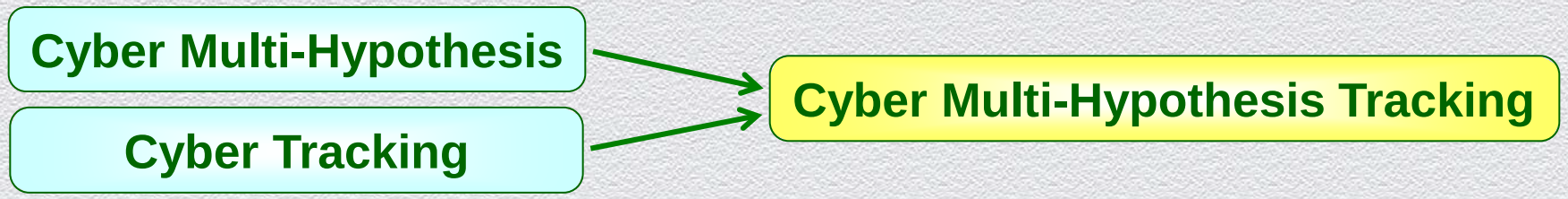
Challenges are similar to Cyber situation awareness;

Solutions can be similar, too…



Multi-hypothesis Tracking for Cyber Situation Awareness

- **Multi-Hypothesis Tracking (MHT)**
  is a powerful means towards achieving
  Cyber Situation Awareness
- **Situation Awareness is a broader & better concept than Alert**
  - more information & comprehension
  - more threat assessment
  - more reliable & informative alerts



Cyber Multi-Hypothesis

- **Multi-Hypothesis Analysis is a method to handle the uncertainty**

- **An algorithmic methodology to handle complex & dynamic data**
  - Collected with various sources/sensors,
  - Involving many entities,
  - Information is partial and/or ambiguous,
  - Information is streaming & dynamically changing

- **For example:**
  - Physical situation awareness (e.g., air situation picture)
  - SIGINT-based order of battle (EOB)
- **Applicable to Cyber Situation Awareness**
  - Integrating the various security tools & techniques
  - Handling the uncertainty and supporting decision making

Multi-Sensor Multi-Entity Tracking

Tracking is the logical process of associating data of activity (including past data) of various entities into disjoint sets - tracks

- Examples:
  - Geographical data of platform entities into physical movement tracks
  - EW & SIGINT data of electromagnetic entities into threat interception tracks
- **Logical tracks of data enable**
  - **Verification of data consistency**
  - **Identifying the past origin of the track**
  - **Predicting the future evolution of the track**

Cyber Tracking

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Cyber events data

Cyber entities

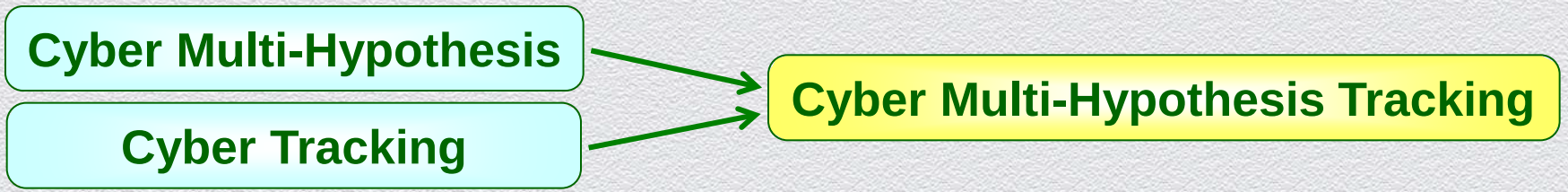
Cyber Incident tracks!

Eliminate False!

Attribution!

Threat Alert!

Cyber Multi-Hypothesis Tracking (MHT)



- **MHT associates distinct cyber events to a single cyber incident**
  - When a new message from any sensor or information source is received, to which incident track does that message correspond?
- **Events may initially be distinct**
  - by "time": evolution in time
  - by "location": events detected at different items/hosts/etc.
  - by "sensor": events detected by various sensor & security tools
  - by "type": events of different type (a malicious file, illegitimate login, etc.)

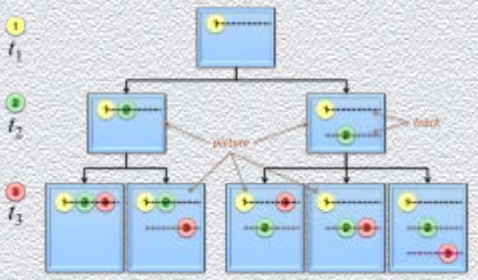
Highlights of the MHT Algorithm

MHT Algorithm Main Modules

- **Hypothesis Management engine**
  - **A generic module**
    - Applicable to physical entities, electronic warfare signals or cyber events
  - Maintaining ambiguities, tracks, pictures, and history
- **Correlation & Scoring**
  - **Specific modules**
    - Depend on the application sensor characteristics
  - Correlating observations to system states and to previous data based on specific models

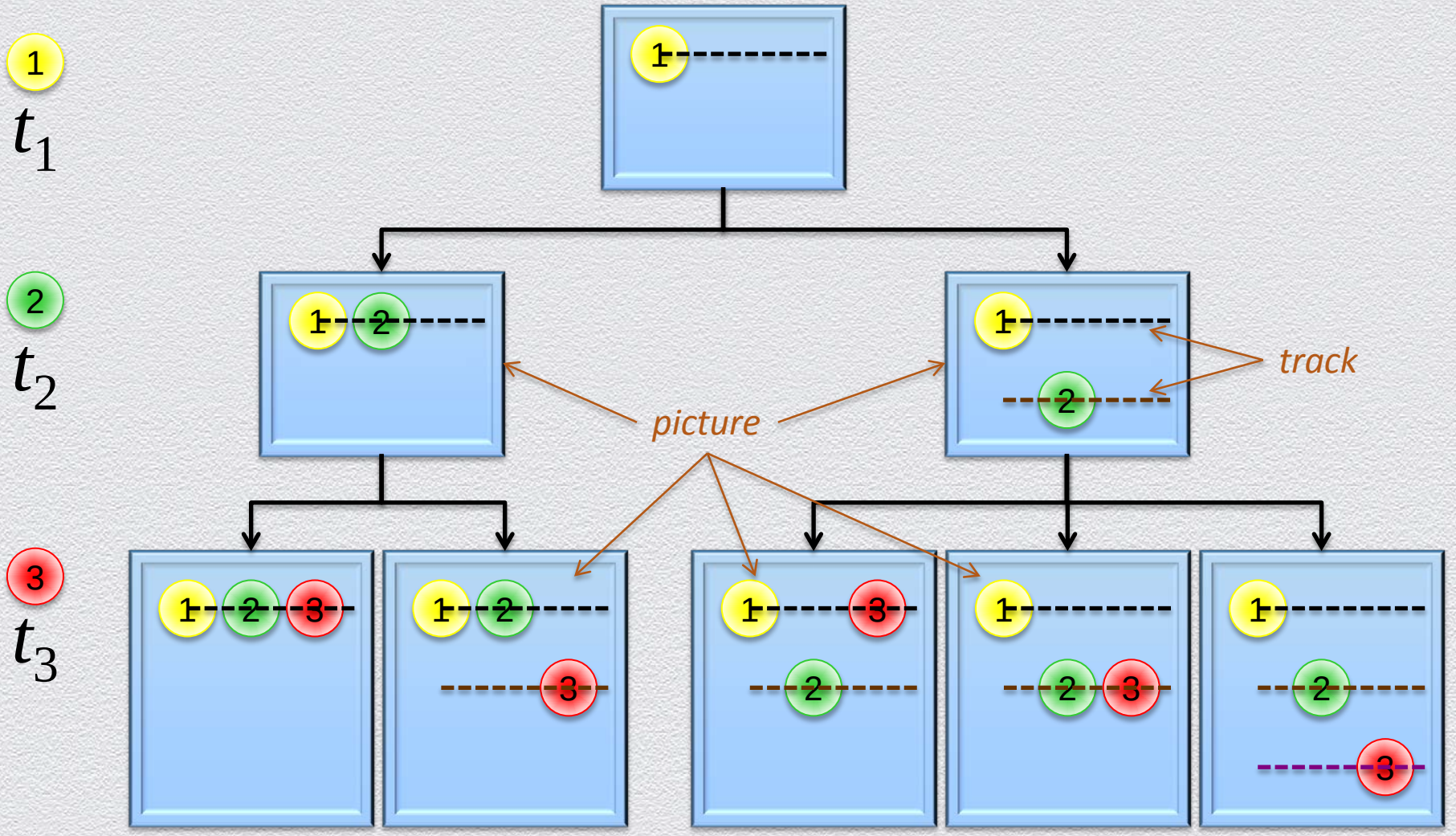
Tracks & Pictures

- **A Track consists of set of data that may be associated with a single platform/system/incident**
  - There can be alternative tracks to the same data
- **A Picture includes a set of alternative tracks that are consistent with each other**
  - There can be alternative pictures to the same data



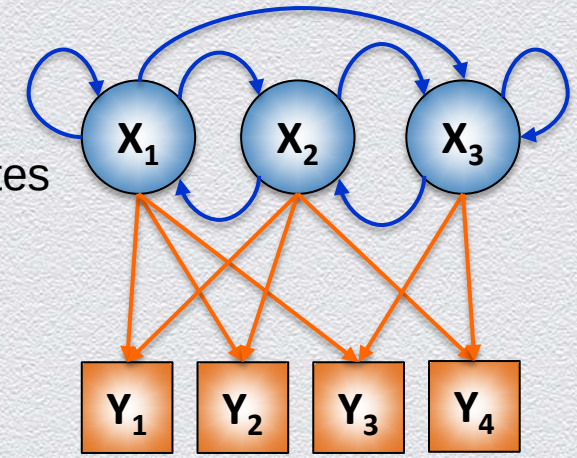
- **The "best" picture in any moment is the one which is selected for report, but many are maintained**

Tracks & Pictures Schematic Example



Observations & Hidden States

- **States describe the status, behavior or properties of a system**
  - There are transition probabilities between system states
- **Observations include the data streaming from the sensors**
- **Observations relate to the system states, but the relationship may be ambiguous**
  - There may be several possible different observations (with some probabilities) to each state;
    an observation may point to several possible alternative hidden states
- **Example in Electronic Warfare**
  - Looking at the electronic order of battle (EOB) picture:
    The hidden states are the emitter/system type and the platform carrying it, while the observations are the intercepted electronic parameters
  - Looking at the geographic situation picture: The hidden states are the position & velocity of the platforms that should be estimated from observed bearings

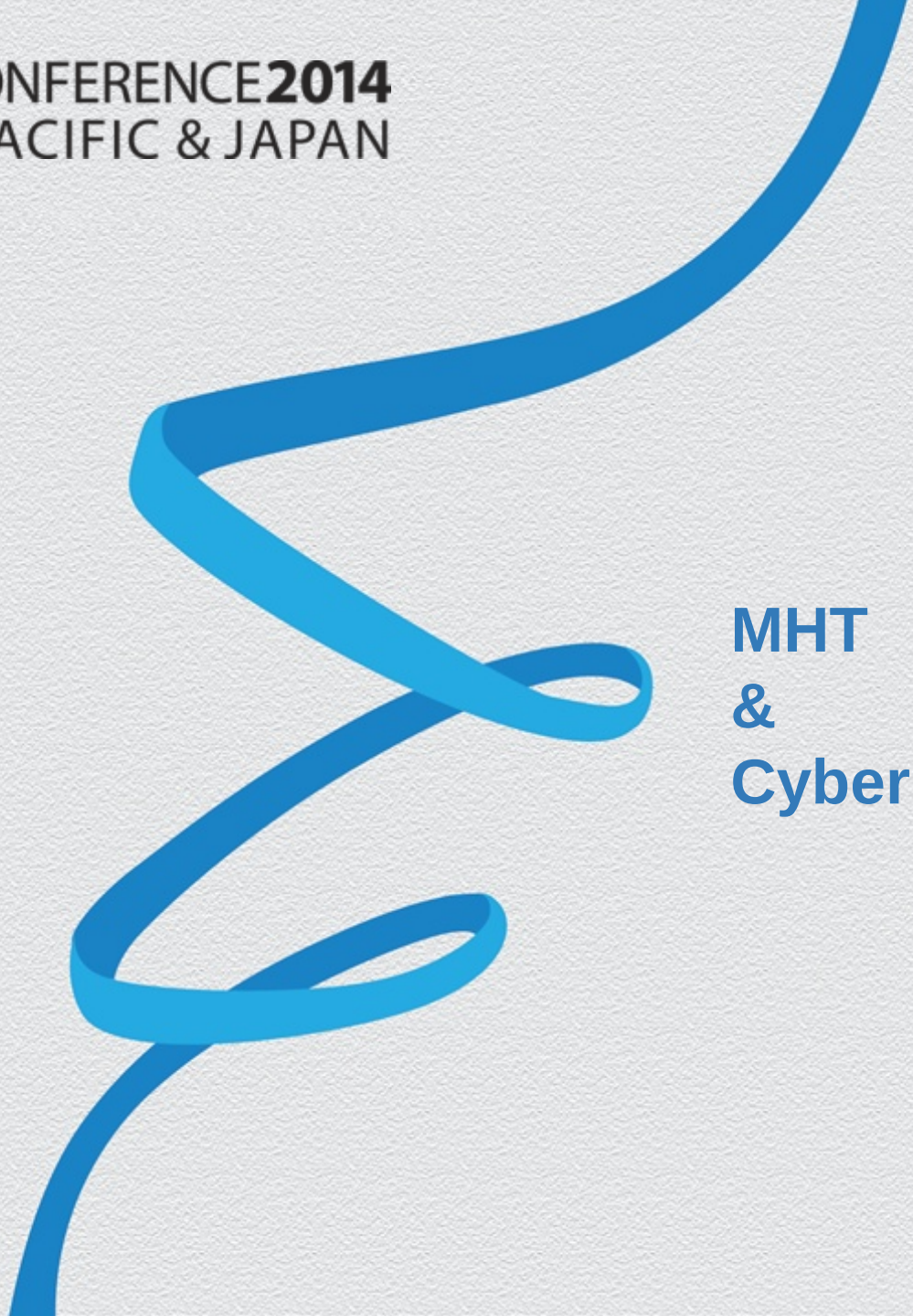


Correlation & Tracking Models

- **Models are used to correlate between the observations and the hidden-states of the system, based on the knowledge of expected processes & behavior**
- **Model types**
  - **Kinematic** for continuous dynamics
    - e.g., platform trajectory based on direction observations
  - **Rule-based** for simple logic correlation
    - e.g., emitter type based on electronic parameters
  - Discrete **Markov chain** for discrete states
  - **Hidden Markov model (HMM)** when the states are not directly observable
  - **Ontology-based** analytics of related entities using patterns
- **In Cyber**
  - The hidden states can be individual host states (trusted, compromised, etc.)
  - The observations derive from firewalls, IDS sensors, server/network logs, etc. as well as context & intelligence
  - Relevant models are HMM and ontology-based with adaptation to attack types (worm, virus, DDOS, etc., and combinations)

More Aspects of MHT Algorithms

- **Observability**
  - A state cannot always be estimated from a sequence of observations; necessary and sufficient conditions for observability should be evaluated
  - In Cyber: The state of a host or network may not be identifiable from the reported events; the conditions can be estimated using attack models
- **Hypotheses management**
  - The number of hypotheses may increase exponentially as observations arrive; consequently the computational complexity of maintaining the hypotheses and finding the optimal solution may grow too much
  - Algorithms of clustering & pruning are employed to overcome the complexity of growing number of hypotheses
    - Deleting tracks, which have not been updated during a "purge time", which depends on estimated progress rate
    - Pruning the unlikely (low-score) hypotheses, with the risk of eliminating the future optimal hypothesis
  - Clustering the tracks into independent sets and using scalability in the algorithms enable distributing the computational load



MHT
&
Cyber Early Warning

Cyber MHT Process (1)

- The **hidden states** can be individual states (trusted, compromised, etc.) of a host, a network, or a service
- The **observations** derive from firewalls, IDS sensors, server/network logs, etc., as well as context & intelligence

- Relevant **models** are HMM and ontology-based; Models are adapted to attack types (worm, virus, DDOS, etc., and their combinations)
- Each **picture** hypothesis represents a set of events associated to an independent cyber incident

Context & Intelligence

- **Context refers to internal (organization) information**
  - Structure, procedures, etc.
- **Intelligence refers to relevant external data collected using WEBInt & accessibility tools**
  - Hints to expected attackers, their behavior and their targets

Context & Intelligence are key factors for decision making

They add an important dimension to MHT scoring by allowing to judge events using adapted criteria

Cyber MHT Process (2)

- **Hypothesis score (track & picture) depends on**
  - Information quality & consistency
  - Likelihood as estimated by the tracking model
  - Intelligence & relevant context
  - Impact assessment
- **The hypothesis with the highest score is reported**
- **Many of the other hypotheses & tracks are maintained**
- **Each new event is checked against many hypotheses (not just the previously best)**
  - An updated set of hypotheses is formed with updated scoring
- **MHT keeps some history, in a special way of tracks & pictures, which is more efficient to utilize, when data is streaming and early response is required**
  - (All data is logged for later forensic research)

Multi-Hypothesis Tracking on Time

- **MHT associates events on a time scale to follow cyber incident evolution backward & forward**

Backward ⟵ *t* ⟶ **Forward**

- Confirm information consistency
- Investigate overlooked or dropped events
- Look for actor trend & behavior

- Predict "expected" information
- Guide efforts of monitoring events to suspicious paths
- Project situation evolution to assess impact

ALERT

Track Triggering

- **In Electronic Warfare MHT**
  - Usually, any new intercept data is a possible trigger for tracking
    - For example: each plot of Radar, every signal in EW
  - All entities (including legitimate) are tracked, to distinguish the hostile ones
- **At a Cyber Warfare scenario**
  - The amount of data is enormous
  - Tracking all legitimate activity is impossible
  - However, analysis of known APT attacks, demonstrate that (eventually) suspect activity has been overlooked, resulting in miss of detection

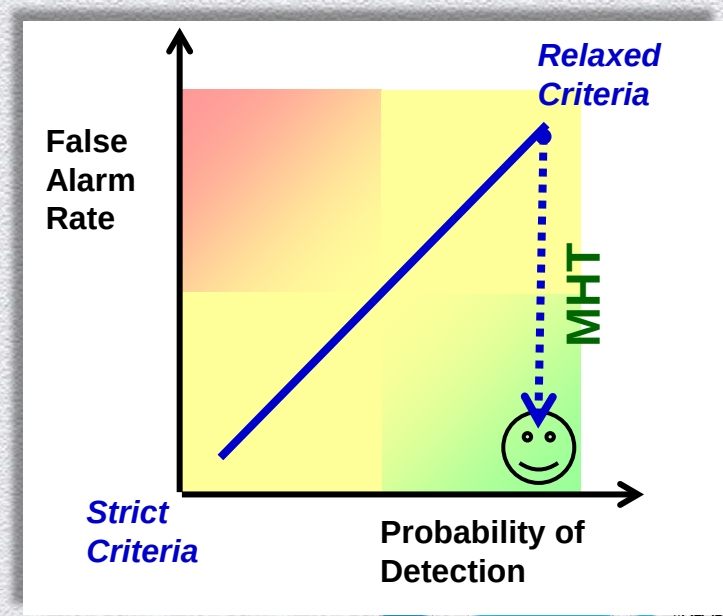
Track before Detect

- **The approach is to track the events even before making the decision**

IF an hypothesis track is consistent and has a high scoring, if its backward evolution suggests a threat actor and/or its forward projection indicates possible impact

THEN Report “Detection”

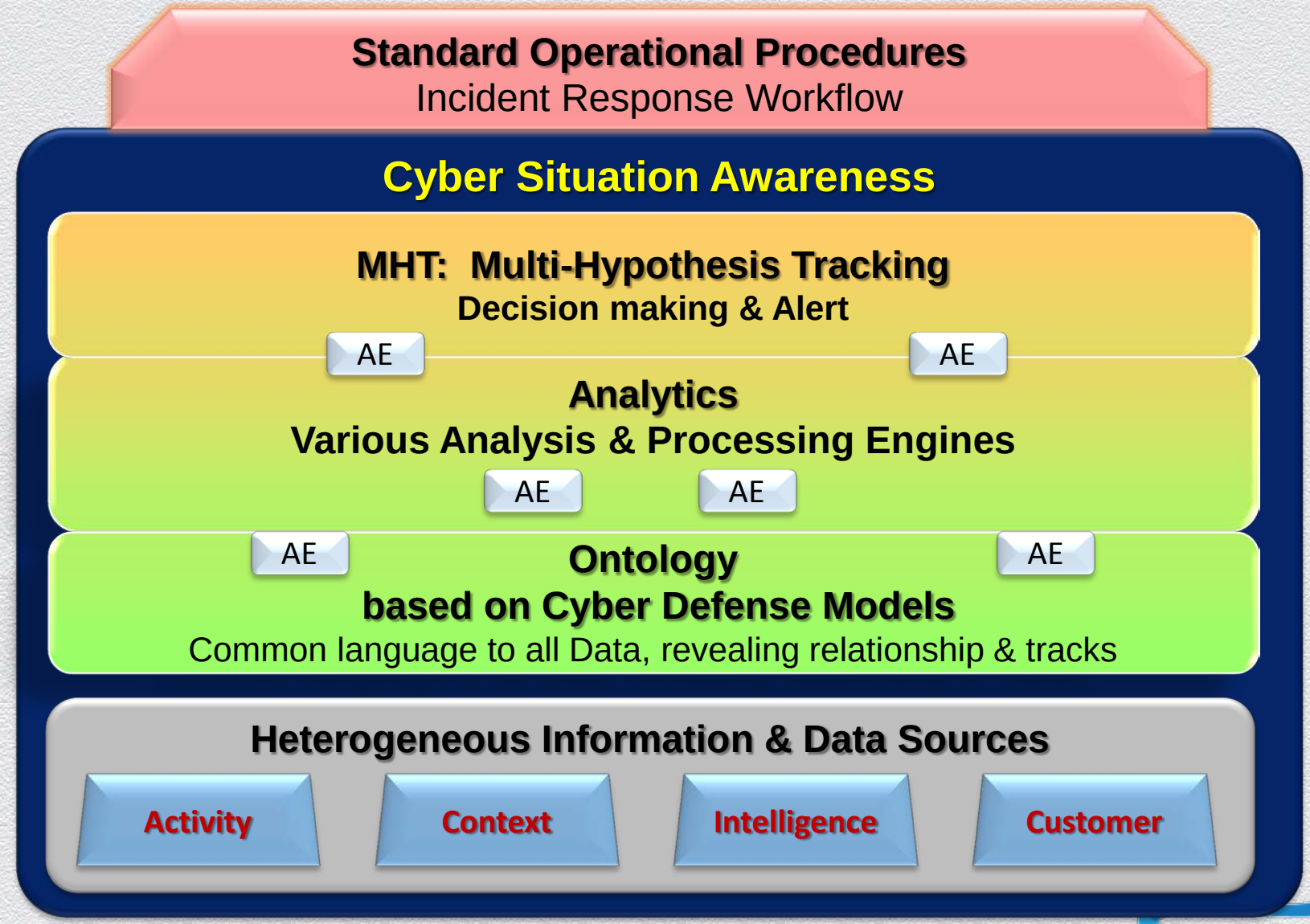
- **And immediately get**
  Incident track details
  - **All associated events**
  - **Possible actor attribution**
  - **Estimated future impact**



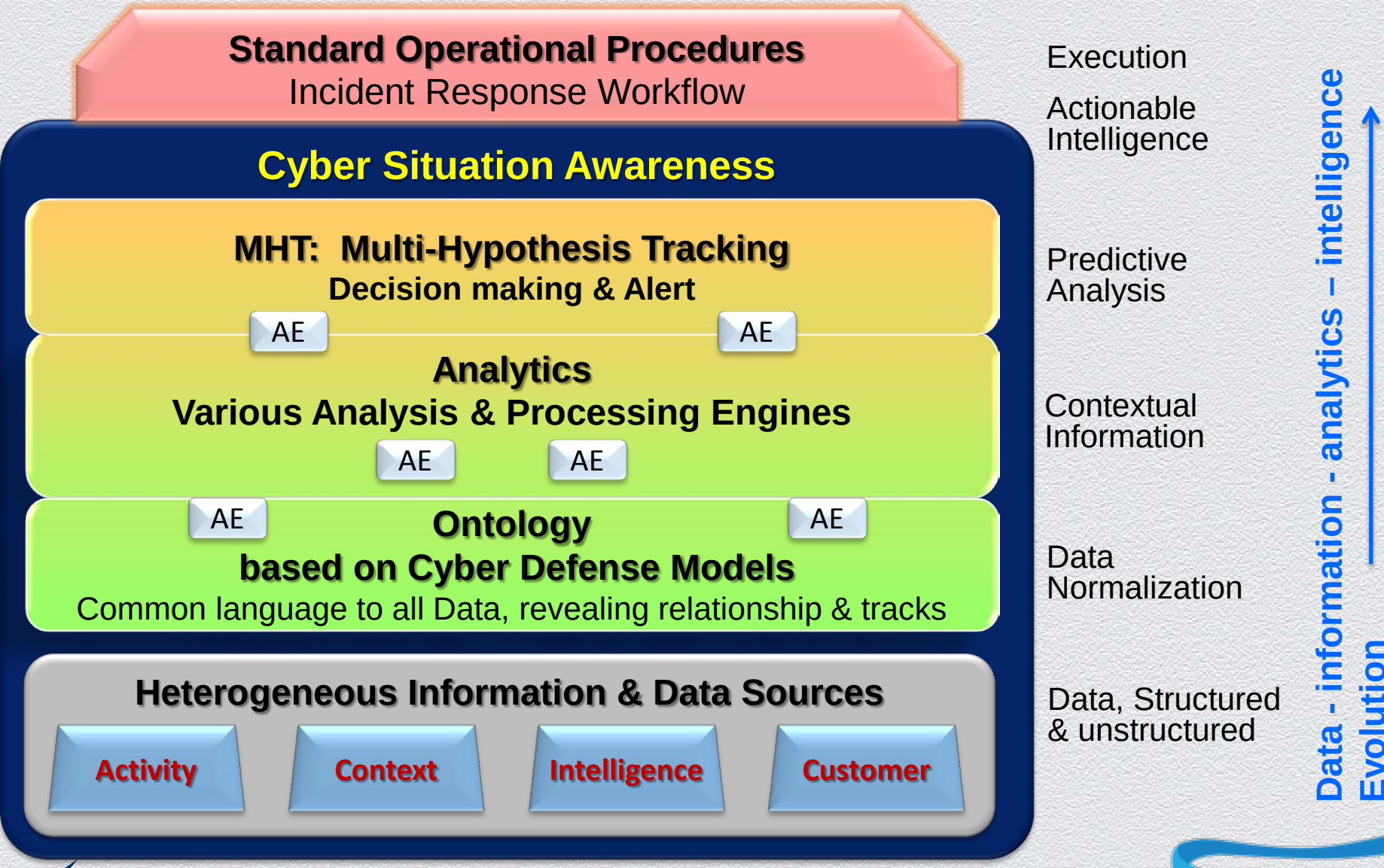
Research Challenges

- **Ongoing research to improve performance**
  - Flexible data modeling to handle all types of information, structured & unformatted, activity & intelligence
  - Best tracking models of events and attacks
  - Analytic engines & optimal hypothesis scoring
  - Efficient pruning & clustering
  - etc.

New Generation Cyber Situation Awareness



New Generation Cyber Situation Awareness



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