Analyzing and Attributing Cyber-Attacks

446H - Applied Network Security

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Agenda

1. Examples of Digital Investigation Process Models
2. Attacks' Modus Operandi and Motivations
3. A Reasoner for Attributing Cyber-Attacks
   - The Attribution Problem
   - Argumentation-Based Reasoner

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Main Steps in Digital Investigation Process Models

- **Preparation**: Create a plan of actions
- **Identification**: Finding potential sources of evidence
- **Preservation**: Collecting and storing the evidence
- **Examination and Analysis**: Extracting and viewing information from the evidence, and analyzing it, by answering different questions (who, what, where, when, how and why)
- **Presentation**: Reporting the findings in a satisfiable way (legal, corporate, military, etc.)

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Different Types of Evidence

The evidence can be distinguished in different categories:

- *Digital Evidence* e.g., email, logs, invoices, /var/log/messages;
- *Network-Based Digital Evidence* e.g., chat log, emails, browser activities, logs;
- Real Evidence, e.g., physical hard drive or USB device, the computer itself;
- Best Evidence, e.g., a file recovered from the hard drive, a snapshot of a network transaction;
- Direct Evidence e.g., somebody is stating "I saw him with that USB";
- Circumstantial Evidence, e.g., email signature, a file containing password hashes;
- Hearsay Evidence e.g., a personal letter, a memo, bookkeeping records;
- Business Evidence e.g., access logs, /var/log/messages.

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OSCAR (1 of 4)

OSCAR is a Network Forensics Investigative Process Model.
Its main steps are:

- Obtain
- Strategise
- Collect
- Analyse
- Report

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OSCAR (2 of 4)

- **Obtain** information about the incident and about the environment.
  - Description of the incident, date, time, method of discovery, persons involved, systems and data involved, actions taken since discovery, time frame for the investigation/recovery/ resolution, legal issues;
  - Information about the environment (that is constantly changing, complex social and political dynamics): business model, legal issues, network topology, available sources of network evidence, organizational structure, incident response management process/procedures, communication system, resources available.

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Oscar (3 of 4)

- **Strategise**: it is crucial to have a strategy where you assess your resources and plan your investigation.
  - Investigation strategy: Understand the goals and time frame of the investigation; understand your resources and identify sources of evidence, for each source of evidence estimate the cost and value of obtaining it, prioritise the evidence acquisition, plan the initial acquisition/analysis; decide upon methods and time of communications/updates, if needed, iterate.
- **Collect** evidence: acquire ASAP, analyze only copies, use tools that are reputable and reliable, document everything.
  - Document all the actions taken during evidence collection e.g., systems accessed log, date, time, sources, method of acquisition.
  - Capture the evidence e.g., capture the packets, copy logs, image hard drivers of web proxies or logging servers.
  - Store and transport the collected evidence.

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OSCAR (4 of 4)

- **Analyze**: this process is usually non-linear but certain elements should be considered essential.
  - Correlation: how data are related to each other, e.g., sources of evidence with the data;
  - Timeline: create a timeline of activities by using the collected and correlated evidence;
  - Events of interest: some events will stand out more than others, especially the one related to the hypotheses;
  - Corroboration: try to eliminate the "fake evidence" by using multiple sources and by identifying inconsistencies;
  - Recovery of additional evidence: the above processes might need further evidence, so we might need to re-iterate them in order to recover new evidence;
  - Interpretation: the interpretation of events is a hypothesis, that can be proved or disproved.
- **Report**: document and report the investigation in order to be understandable by technical and non technical people and factual.

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Staircase Model

Taken from "Digital Evidence and Computer Crime", Eoghan Casey, Third Edition, 2011.

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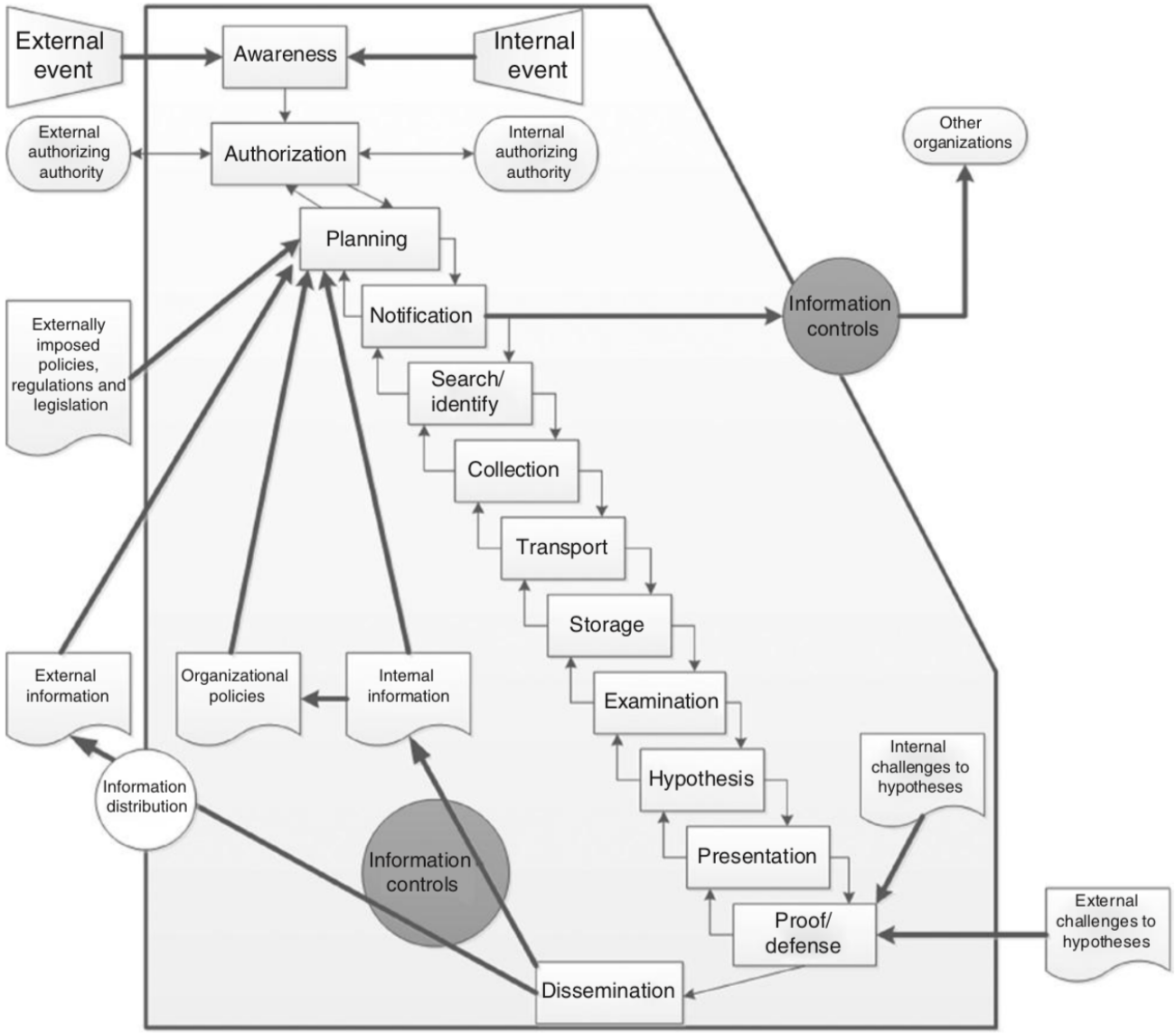
Evidence Flow Model



Taken from "Digital Evidence and Computer Crime", Eoghan Casey, Third Edition, 2011.

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Modus Operandi

Modus operandi (MO) means "a method of operating", it answers the *how* question

An example of MO behaviour is the following:

- Amount of planning before a crime;
- Materials used by the offender, e.g., system type, connection type, software;
- Presurveillance of the victim/target;
- Offender precautionary actions e.g., IP spoofing, aliases, anti-forensics countermeasures.

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Usefulness of the Modus Operandi

Understanding the modus operandi of the attacker helps to:

1. Put in act mitigation action for the current attack;
2. Put in place preventive measures;
3. Attribute the attack to a possible culprit.

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Example:Ukraine Power Grid Cyber-Attack

In 23 Dec 2015 a power grid cyber-attack took place in Ukraine[1]. The hackers compromised successfully the information systems of three energy distribution companies, and disrupted the electricity supply to around 230 thousand end-users, and left them without electricity for 1-6 hours.

- The corporate networks were compromised using spear-phishing email with BlackEnergy malware;
- The attackers took control of SCADA networks and switched off the substations;
- Disabled/destroyed IT infrastructure components, e.g., modems, converters;
- They used KillDisk malware to destroy the files (that could be used as evidence) stored on servers and workstation;
- Denial-of-service attack on the call-center.

[1] https://ics.sans.org/media/E-ISAC_SANS_Ukraine_DUC_5.pdf

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Example of MO: Ukraine Power Grid Attack Dec 2015

- **Planning**: Spear-phishing campaign to corporate networks, Manipulation of Microsoft Office documents that contained BlackEnergy malware;
- **Tool used**: BlackEnergy malware with phishing emails, KillDisk malware;
- Results of the **actions** were: Get control of the SCADA network, Destroyed IT infrastructures of 3 Energy Distribution Companies, Denial of Service Attack on Call-Center, Destruction of files on servers using KillDisk.

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Example of MO: Actions

- Spear-phishing to gain access to the companies business networks;
- Theft of credentials from the business networks;
- Used virtual private networks (VPNs) to enter the ICS network;
- Used existing remote access tools within the environment;
- Reconfigured the Uninterruptable Power Supplies (UPS) that provide backup power to two of the control centres;
- Replaced the firmware on serial-to-ethernet converts with a malicious one written by the attackers;
- At 3.30pm 23 December the attackers entered the SCADA network using the hijacked VPNs, and disabled the UPS system they had already reconfigured;
- Launched a telephone denial-of-service attack on the call-center;
- Open the breakers for the shut down;
- Used a modified KillDisk to erase the master boot records of impacted organization systems and the targeted deletion of logs;
- The KillDisk was launched using a logic bomb.

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Example of MO: Ukraine Power Grid Attack (Cont.)

- **Pre-surveillance**: the spear-phishing campaign took place months before the attack, and the attacker were observing the victim.
- **Precaution actions**: KillDisk destroyed all the files on the servers, including all the left evidence. When the systems were rebooted they had an error "*Operating system not found*".

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Motives of the Attack

- Answer the question "Why";
- Understanding the motives of an attack helps to attribute the attack to a possible culprit;
- Some of the motives that can push the offenders to commit a cyber-crime are:
  - Power Reassurance, Power Assertive, Anger Retaliatory, Sadistic, where usually the attacker knows the victims, e.g., cyberstalking;
  - Opportunistic and Profit Oriented e.g., monetary profits (ransomware), service disruption that will cause the victim economic lost, political motives.

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Ukraine Power Grid Attack Dec 2015: Motives (I)

Given the high level of organization of the attack, we expect the possible culprit to be an organized, well-trained, and well-funded group of attackers, or a collaboration between different group of attackers.

- The attack maybe had economical motives, because there were economical losses due to the service disruption and the costs of restore the service (in some cases it took months).
  - The attack did not had economical motives because:
    - The economical losses were not as high as the impact it had on the people affected.
    - The attacker could have done more damages.
- The attack maybe had political motives due to the geopolitical conflict between Ukraine and Russia, with Russian annexation of Crimea in 2014.
  - In particular, the attack had as motive to feed the anger of Ukrainian customers and weaken their trust in the Ukrainian power companies and government. (Just a theory.)

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Ukraine Power Grid Attack Dec 2015: Motives (II)

- The attack maybe had political motives as a response to the physical attack pro-Ukrainian activists made to the substations feeding power to Crimea, leaving 2 million Crimean residents without power, as well as a Russian naval base, right before Dec 2015. The physical attack was a reaction to Crimean authorities nationalising Ukrainian-owned energy companies.
  - The preparation of the attack started in Spring 2015, thus it cannot be considered as a retaliation for the attack on the Crimean substations. It could have been a catalyst but not the original motivation.
- The attack had political and somehow also economical and power assertion motives because:
  - The Ukrainian parliament was preparing a bill for nationalize privately owned power companies in Ukraine (most of them were owned by a Russian oligarch). Thus, the attack can be seen as a message sent to the Ukrainian authorities.
  - The attackers limited the damaged.

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The Attribution Problem

Attribution is the process of assigning a cyber-attack to an entity

- The growing of connectivity increases the security challenges and the need for efficient countermeasures

Attribution permits efficient attacker-oriented countermeasures

- The attribution process is a difficult one
- Attribution is mainly human based

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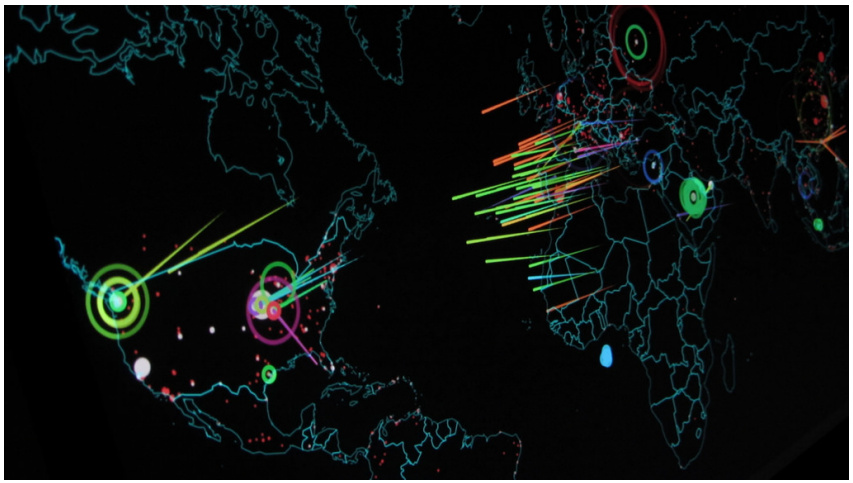
Digital Forensics Techniques

- Digital Forensics techniques help during the attribution process by collecting, storing and analyzing the evidence
- Digital Forensics techniques suffer from the quantity and quality problem;
- These techniques are not able to deal with:
  - incomplete information,
  - conflicting information,
  - and social evidence.



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An Argumentation-Based Solution

Solution

An automatic reasoner (ABR) based on argumentation and abductive reasoning.

- Given evidence of the attack, ABR helps the forensics analyst during the analysis and attribution process;
- It works with incomplete and conflicting pieces of data;
- ABR works with technical and social evidence;
- It categorises the evidence using a social model;
- ABR provides an explainable attribution.

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Preference-Based Argumentation Framework

ABR uses a preference-based argumentation framework

Definition

An *argumentation theory* is a pair $(\mathcal{T}, \mathcal{P})$ of argument rules $\mathcal{T}$ and preference rules $\mathcal{P}$.

The argument rules $\mathcal{T}$ are a set of labelled formulas of the form:

$$rule_i : L \leftarrow L_1, \ldots, L_n.$$

The preference rules are a set of labelled formulas of the form:

$$p : rule_1 > rule_2$$

where $rule_1$, $rule_2$ are labels of rules in $\mathcal{T}$, and $>$ is higher priority relation between the rules.

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Social Model used by ABR

- ABR is based on the Q-Model
- The Q-Model represents how the analysts perform the attribution process of cyber-attacks
- The pieces of evidence and the reasoning rules are divided in three layers

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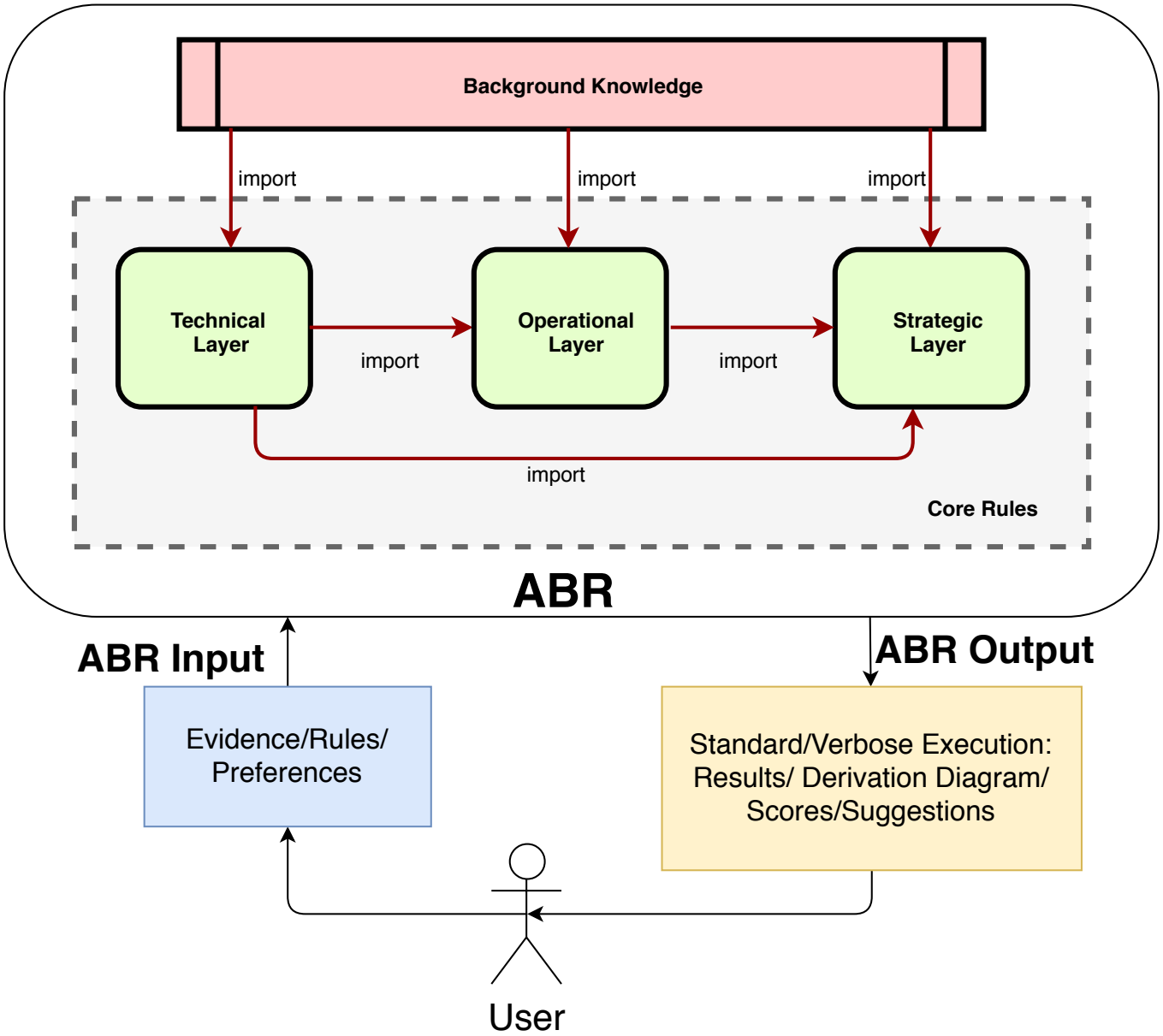
Argumentation-Based Reasoner for Attribution



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ABR Example: Ukraine Power Grid Attack Dec 2015 (1/4)

- The attack had as target Power Supplies companies in Ukraine.
- The attack (*dec*) was a high level skill attack.
- The attack was constructed to have a specific target.

$$
\begin{aligned}
&target(ukraine\_power, dec).\\
&industry(electricity, ukraine\_power).\\
&highLevelSkill(dec).\\
&targetCountry(ukraine, dec).\\
&malwareUsedInAttack(killdisk, dec).\\
&malwareUsedInAttack(blackenergy, dec).\\
&attackPeriod(dec, [2015, 12]).\\
&specificTarget(dec).
\end{aligned}
$$

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ABR Example: Ukraine Power Grid Attack Dec 2015 (2/4)

- Russia had economical motives to perform the attack.

$target(ukraine\_power, dec).$
$industry(electricity, ukraine\_power).$
$highLevelSkill(dec).$
$targetCountry(ukraine, dec).$
$malwareUsedInAttack(killdisk, dec).$
$malwareUsedInAttack(blackenergy, dec).$
$attackPeriod(dec, [2015, 12]).$
$specificTarget(dec).$
$hasEconomicMotive(russian\_federation, ukraine\_power).$

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ABR Example: Ukraine Power Grid Attack Dec 2015 (2/4)

- Russia had economical motives to perform the attack.

$target(ukraine\_power, dec).$
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$highLevelSkill(dec).$
$targetCountry(ukraine, dec).$
$malwareUsedInAttack(killdisk, dec).$
$malwareUsedInAttack(blackenergy, dec).$
$attackPeriod(dec, [2015, 12]).$
$specificTarget(dec).$
$hasEconomicMotive(russian\_federation, ukraine\_power).$
$industry(ukraine\_power).$

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ABR Example: Ukraine Power Grid Attack Dec 2015 (3/4)

- Russia had political motives (a response to the earlier physical attack occurred in Crimea) to perform the attack.

$target(ukraine\_power, dec).$
$industry(electricity, ukraine\_power).$
$highLevelSkill(dec).$
$targetCountry(ukraine, dec).$
$malwareUsedInAttack(killdisk, dec).$
$malwareUsedInAttack(blackenergy, dec).$
$attackPeriod(dec, [2015, 12]).$
$specificTarget(dec).$
$hasPoliticalMotive(russian\_federation, ukraine, [2015, 11]).$

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ABR Example: Ukraine Power Grid Attack Dec 2015 (4/4)

- Russia had motives to perform the Ukraine Power Grid Attack.

$$
\begin{aligned}
&\mathit{target}(\mathit{ukraine\_power}, \mathit{dec}).\\
&\mathit{industry}(\mathit{electricity}, \mathit{ukraine\_power}).\\
&\mathit{highLevelSkill}(\mathit{dec}).\\
&\mathit{targetCountry}(\mathit{ukraine}, \mathit{dec}).\\
&\mathit{malwareUsedInAttack}(\mathit{killdisk}, \mathit{dec}).\\
&\mathit{malwareUsedInAttack}(\mathit{blackenergy}, \mathit{dec}).\\
&\mathit{attackPeriod}(\mathit{dec}, [2015, 12]).\\
&\mathit{specificTarget}(\mathit{dec}).\\
&\mathit{hasMotive}(\mathit{russian\_federation}, \mathit{dec}).
\end{aligned}
$$

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ABR Execution US Bank Hack Example (1 of 4)

US bank hack occurred in 2012, where US banks faced denial of service (Dos) attacks.

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ABR Execution US Bank Hack Example (1 of 4)

US bank hack occurred in 2012, where US banks faced denial of service (Dos) attacks.

$$target(us\_banks, usbankhack).$$
$$targetCountry(usa, usbankhack).$$
$$attackPeriod(usbankhack, [2012, 9]).$$

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ABR Execution US Bank Hack Example (1 of 4)

US bank hack occurred in 2012, where US banks faced denial of service (Dos) attacks.

- The banks' web hosting services were infected by a malware called *Itsoknoproblembro*

$$target(us\_banks, usbankhack).$$
$$targetCountry(usa, usbankhack).$$
$$attackPeriod(usbankhack, [2012, 9]).$$
$$malwareUsed(itsoknoproblembro, usbankhack).$$

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- The banks' web hosting services were infected by a malware called *Itsoknoproblembro*
- *Itsoknoproblembro* hijacked the corporate clouds

$$target(us\_banks, usbankhack).$$
$$targetCountry(usa, usbankhack).$$
$$attackPeriod(usbankhack, [2012, 9]).$$
$$malwareUsed(itsoknoproblembro, usbankhack).$$
$$hijackCorporateClouds(usbankhack).$$

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- The banks' web hosting services were infected by a malware called *Itsoknoproblembro*
- *Itsoknoproblembro* hijacked the corporate clouds
- US placed economic sanctions against Iran in February 2012

$$
\begin{aligned}
&\mathit{target}(\mathit{us\_banks}, \mathit{usbankhack}).\\
&\mathit{targetCountry}(\mathit{usa}, \mathit{usbankhack}).\\
&\mathit{attackPeriod}(\mathit{usbankhack}, [2012, 9]).\\
&\mathit{malwareUsed}(\mathit{itsoknoproblembro}, \mathit{usbankhack}).\\
&\mathit{hijackCorporateClouds}(\mathit{usbankhack}).\\
&\mathit{imposedSanctions}(\mathit{usa}, \mathit{iran}, [2012, 2]).
\end{aligned}
$$

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ABR Execution US Bank Hack Example (2 of 4)

$target(us\_banks, usbankhack).$
$targetCountry(usa, usbankhack).$
$attackPeriod(usbankhack, [2012, 9]).$
$malwareUsed(itsoknoproblembro, usbankhack).$
$hijackCorporateClouds(usbankhack).$
$imposedSanctions(usa, iran, [2012, 2]).$

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ABR Execution US Bank Hack Example (2 of 4)

$t\_1 : highLevelSkill(Att) \leftarrow hijackCorporateClouds(Att).$

$target(us\_banks, usbankhack).$
$targetCountry(usa, usbankhack).$
$attackPeriod(usbankhack, [2012, 9]).$
$malwareUsed(itsoknoproblembro, usbankhack).$
$hijackCorporateClouds(usbankhack).$
$imposedSanctions(usa, iran, [2012, 2]).$

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ABR Execution US Bank Hack Example (2 of 4)

$t\_1 : highLevelSkill(usbankhack) \leftarrow hijackCorporateClouds(usbankhack).$

$target(us\_banks, usbankhack).$
$targetCountry(usa, usbankhack).$
$attackPeriod(usbankhack, [2012, 9]).$
$malwareUsed(itsoknoproblembro, usbankhack).$
$hijackCorporateClouds(usbankhack).$
$imposedSanctions(usa, iran, [2012, 2]).$
$highLevelSkill(usbankhack).$

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ABR Execution US Bank Hack Example (2 of 4)

$$t\_2 : reqHighRes(Att) \leftarrow highLevelSkill(Att).$$

$target(us\_banks, usbankhack).$
$targetCountry(usa, usbankhack).$
$attackPeriod(usbankhack, [2012, 9]).$
$malwareUsed(itsoknoproblembro, usbankhack).$
$hijackCorporateClouds(usbankhack).$
$imposedSanctions(usa, iran, [2012, 2]).$
$highLevelSkill(usbankhack).$

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ABR Execution US Bank Hack Example (2 of 4)

$t\_2 : reqHighRes(usbankhack) \leftarrow highLevelSkill(usbankhack).$

$target(us\_banks, usbankhack).$
$targetCountry(usa, usbankhack).$
$attackPeriod(usbankhack, [2012, 9]).$
$malwareUsed(itsoknoproblembro, usbankhack).$
$hijackCorporateClouds(usbankhack).$
$imposedSanctions(usa, iran, [2012, 2]).$
$highLevelSkill(usbankhack).$
$reqHighRes(usbankhack).$

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ABR Execution US Bank Hack Example (2 of 4)

$op\_1 : hasPolMotive(C, T, Date) \leftarrow imposedSanctions(T, C, Date).$

$target(us\_banks, usbankhack).$
$targetCountry(usa, usbankhack).$
$attackPeriod(usbankhack, [2012, 9]).$
$malwareUsed(itsoknoproblembro, usbankhack).$
$hijackCorporateClouds(usbankhack).$
$imposedSanctions(usa, iran, [2012, 2]).$
$highLevelSkill(usbankhack).$
$reqHighRes(usbankhack).$

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ABR Execution US Bank Hack Example (2 of 4)

$op\_1 : hasPolMotive(iran, usa, [2012, 2]) \leftarrow imposedSanctions(usa, iran, [2012, 2]).$

$target(us\_banks, usbankhack).$
$targetCountry(usa, usbankhack).$
$attackPeriod(usbankhack, [2012, 9]).$
$malwareUsed(itsoknoproblembro, usbankhack).$
$hijackCorporateClouds(usbankhack).$
$imposedSanctions(usa, iran, [2012, 2]).$
$highLevelSkill(usbankhack).$
$reqHighRes(usbankhack).$
$hasPolMotive(iran, usa, [2012, 2]).$

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ABR Execution US Bank Hack Example (3 of 4)

From the background knowledge, we have that:

$$cybersuperpower(iran).$$

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ABR Execution US Bank Hack Example (3 of 4)

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$$cybersuperpower(iran).$$

$$t\_3 : hasResources(X) \leftarrow cybersuperpower(X).$$

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ABR Execution US Bank Hack Example (3 of 4)

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$$cybersuperpower(iran).$$

$$t\_3 : hasResources(iran) \leftarrow cybersuperpower(iran).$$

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ABR Execution US Bank Hack Example (3 of 4)

$target(us\_banks, usbankhack).$
$targetCountry(usa, usbankhack).$
$attackPeriod(usbankhack, [2012, 9]).$
$malwareUsed(itsoknoproblembro, usbankhack).$
$hijackCorporateClouds(usbankhack).$
$imposedSanctions(usa, iran, [2012, 2]).$
$highLevelSkill(usbankhack).$
$reqHighRes(usbankhack).$
$hasPolMotive(iran, usa, [2012, 2]).$
$hasResources(iran).$

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ABR Execution US Bank Hack Example (3 of 4)

$$op\_2 : hasCapability(X, Att) \leftarrow reqHighRes(Att), \\ hasResources(X).$$

$target(us\_banks, usbankhack).$
$targetCountry(usa, usbankhack).$
$attackPeriod(usbankhack, [2012, 9]).$
$malwareUsed(itsoknoproblembro, usbankhack).$
$hijackCorporateClouds(usbankhack).$
$imposedSanctions(usa, iran, [2012, 2]).$
$highLevelSkill(usbankhack).$
$reqHighRes(usbankhack).$
$hasPolMotive(iran, usa, [2012, 2]).$
$hasResources(iran).$

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ABR Execution US Bank Hack Example (3 of 4)

$$op\_2 : hasCapability(iran, usbankhack) \leftarrow reqHighRes(usbankhack), hasResources(iran).$$

$target(us\_banks, usbankhack).$
$targetCountry(usa, usbankhack).$
$attackPeriod(usbankhack, [2012, 9]).$
$malwareUsed(itsoknoproblembro, usbankhack).$
$hijackCorporateClouds(usbankhack).$
$imposedSanctions(usa, iran, [2012, 2]).$
$highLevelSkill(usbankhack).$
$hasPolMotive(iran, usa, [2012, 2]).$
$hasResources(iran).$
$hasCapability(iran, usbankhack).$

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ABR Execution US Bank Hack Example (4 of 4)

$$op\_3 : hasMotive(C, Att) \leftarrow targetCountry(T, Att), attackPeriod(Att, Date1), hasPolMotive(C, T, Date2), dateApplicable(Date1, Date2), specificTarget(Att).$$

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ABR Execution US Bank Hack Example (4 of 4)

$$op\_3 : hasMotive(iran, usbankhack) \leftarrow targetCountry(usa, usbankhack),$$
$$attackPeriod(usbankhack, [2012, 9]),$$
$$hasPolMotive(iran, usa, [2012, 2]),$$
$$dateApplicable([2012, 9], [2012, 2]),$$
$$specificTarget(usa).$$

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ABR Execution US Bank Hack Example (4 of 4)

$target(us\_banks, usbankhack).$

$\ldots$

$highLevelSkill(usbankhack).$

$reqHighRes(usbankhack).$

$hasPolMotive(iran, usa, [2012, 2]).$

$hasResources(iran).$

$hasCapability(iran, usbankhack).$

$hasMotive(iran, usbankhack).$

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ABR Execution US Bank Hack Example (4 of 4)

$str\_1: \ isCulprit(X, Att) \leftarrow hasMotive(X, Att), hasCapability(X, Att).$

$target(us\_banks, usbankhack).$
$\ldots$
$highLevelSkill(usbankhack).$
$reqHighRes(usbankhack).$
$hasPolMotive(iran, usa, [2012, 2]).$
$hasResources(iran).$
$hasCapability(iran, usbankhack).$
$hasMotive(iran, usbankhack).$

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ABR Execution US Bank Hack Example (4 of 4)

$$str\_1 : isCulprit(iran, usbankhack) \leftarrow hasMotive(iran, usbankhack), hasCapability(iran, usbankhack).$$

$target(us\_banks, usbankhack).$
$\ldots$
$highLevelSkill(usbankhack).$
$reqHighRes(usbankhack).$
$hasPolMotive(iran, usa, [2012, 2]).$
$hasResources(iran).$
$hasCapability(iran, usbankhack).$
$hasMotive(iran, usbankhack).$
$isCulprit(iran, usbankhack).$

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