SOFIT: Sociotechnical and Organizational Factors for Insider Threat

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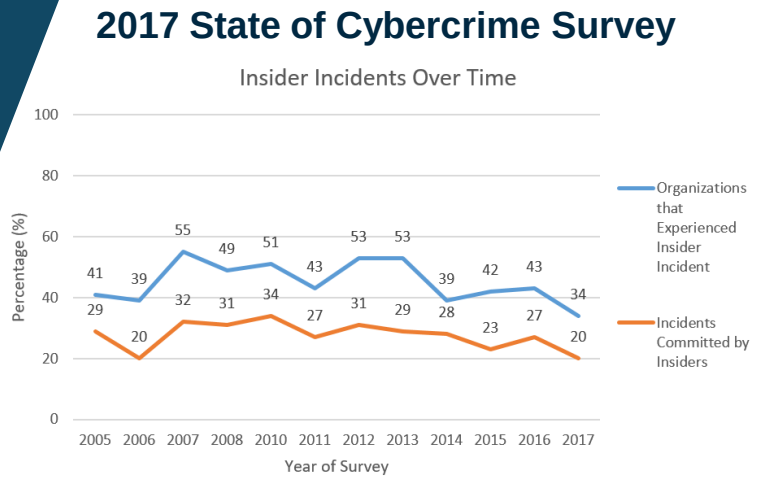
Motivation

CERT/CSO Magazine annually conducts Cybercrime survey of >500 organizations that self-report on information security issues:

- 34% of reporting organizations experienced cybercrime incident
- 20% of these incidents were caused by insiders
- ~ 30% of insider attacks were more costly or damaging than outsider attacks.

ODNI and NITTF recognize need for tools to assess maturity levels of Insider Threat Program capabilities

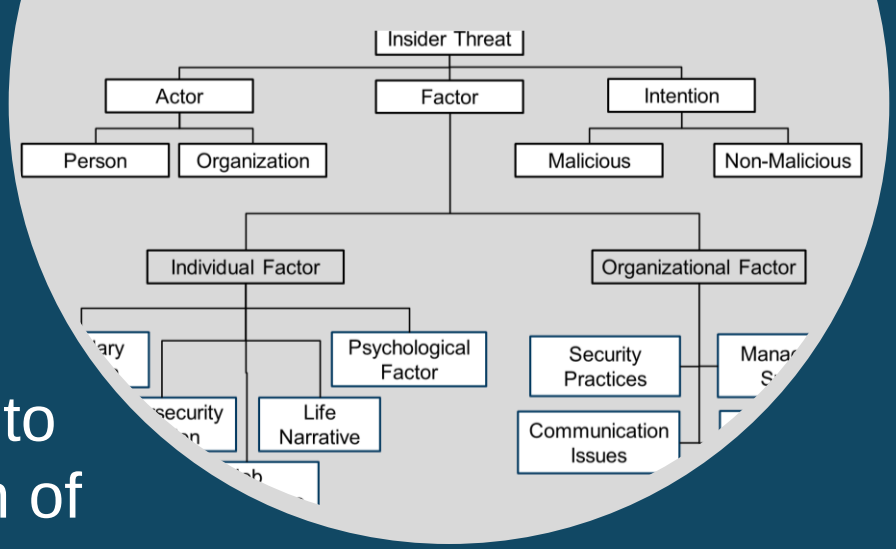
- NITTF to conduct ‘’independent assessments of the adequacy of agency programs to implement established policies and minimum standards.’’
- All executive branch depts./agencies with national security information or classified networks are subject to NITTF independent assessments.



https://insights.sei.cmu.edu/insider-threat/2018/01/2017-us-state-of-cybercrime-highlights.html

National INSIDER THREAT Task Force

Objectives

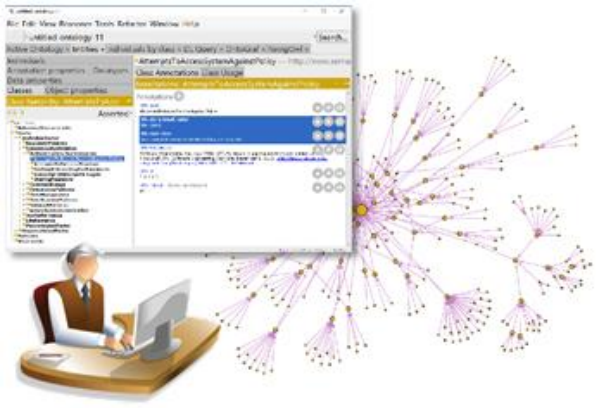


A major goal of this research is to develop a formal representation of factors underlying insider threats

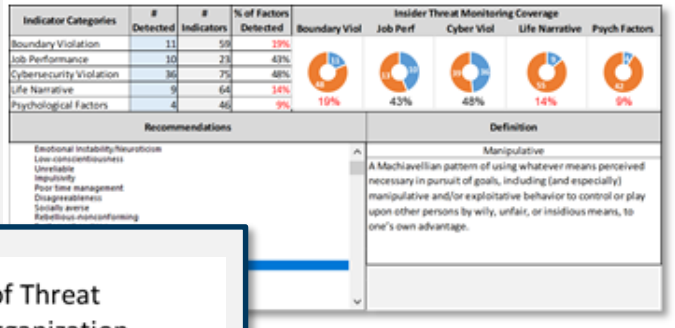
- Extend current insider threat ontology frameworks by incorporating sociotechnical constructs reflecting individual/behavioral and organizational as well as cyber/technical factors
- Support modeling and reasoning approaches for insider threat assessment

Envisioned Applications

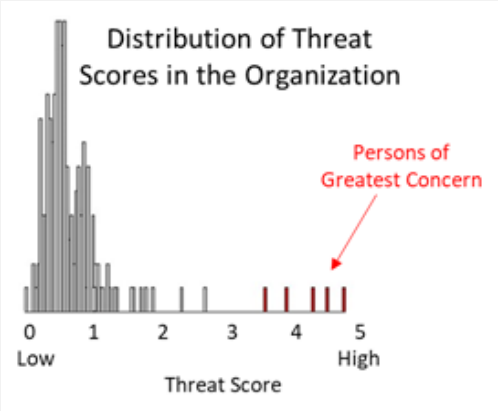
Expert Knowledge Repository for Research/Operational Communities



Aid for Evaluating Maturity Level of an Organization's Insider Threat Program

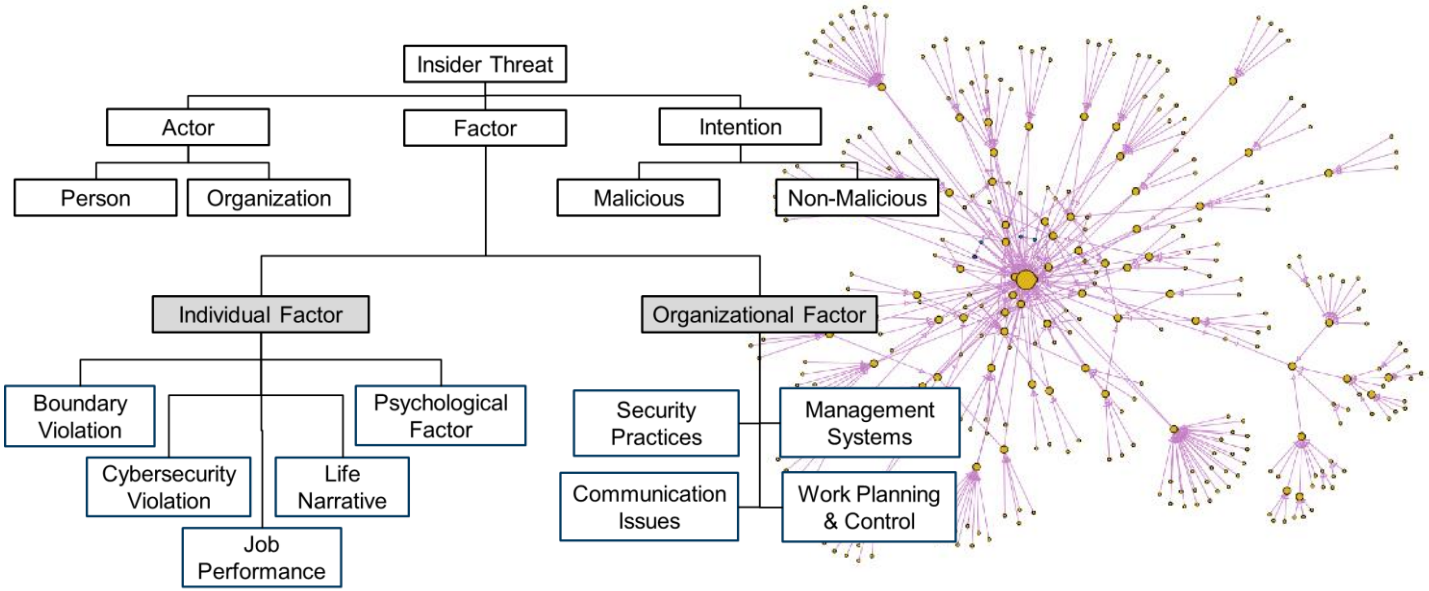


Tool for Assessing Individual Insider Threat



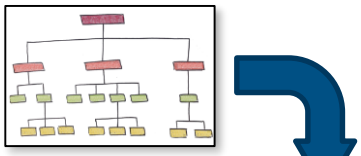
Developing SOFIT:

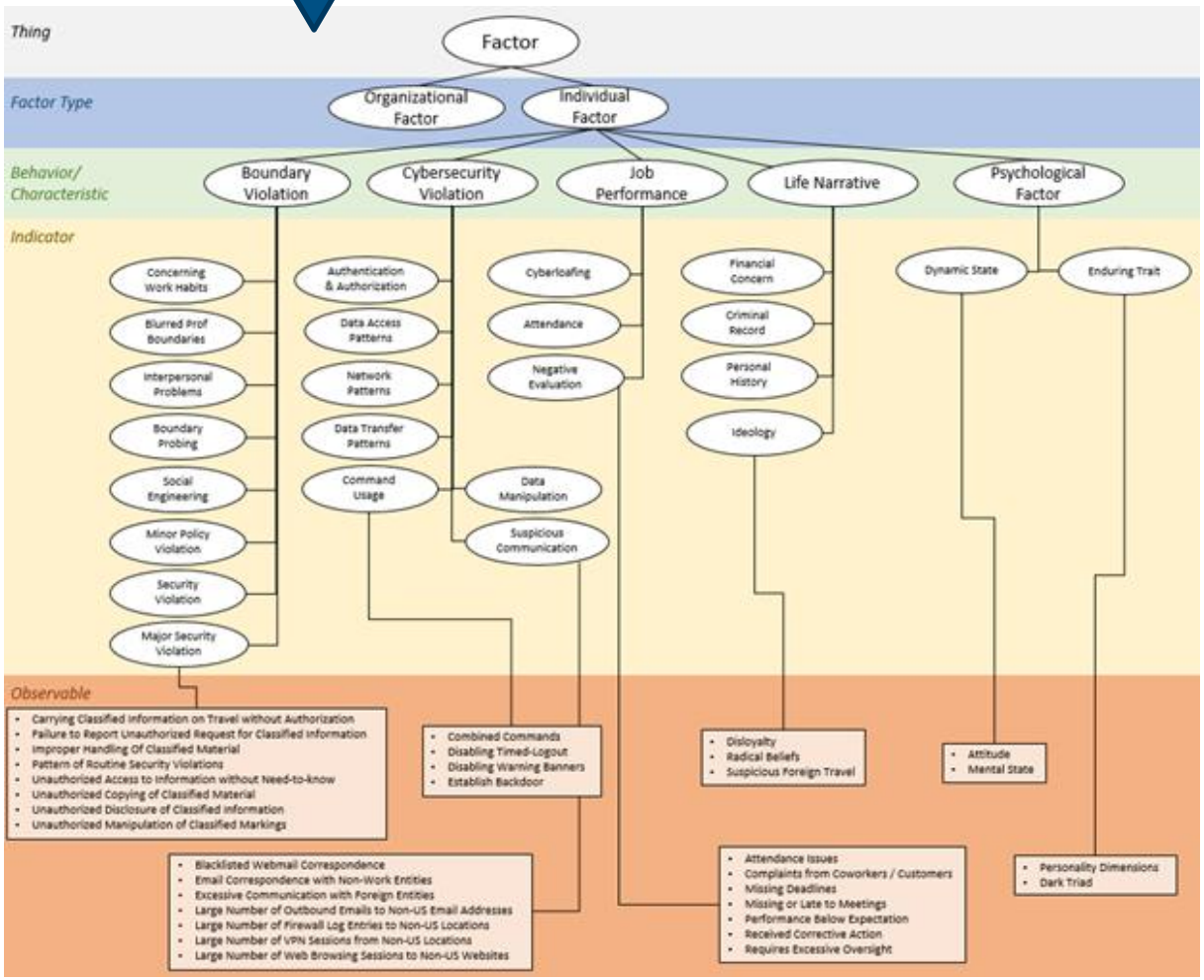
Sociotechnical and Organizational Factors for Insider Threat



Approach

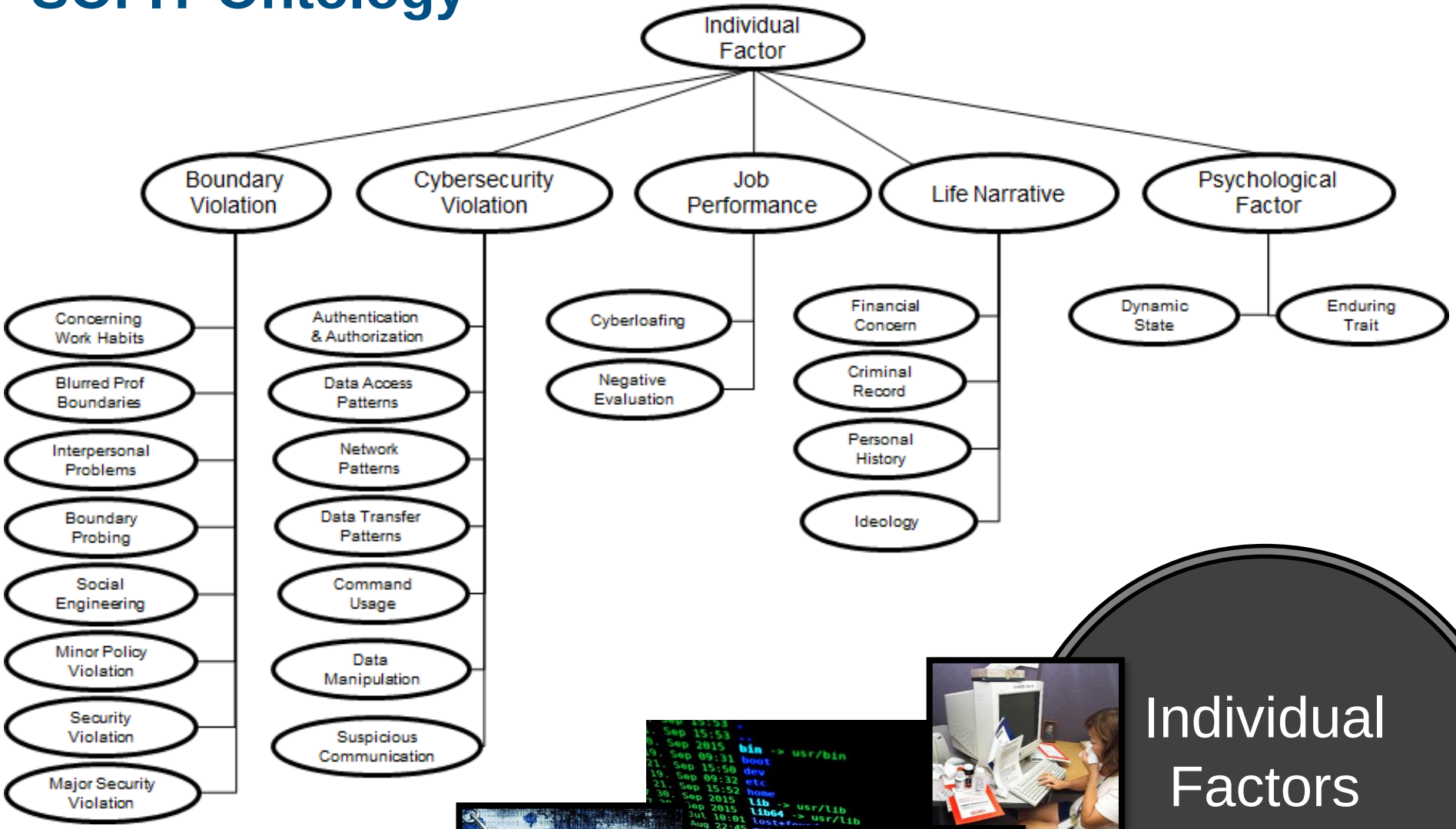
- Develop taxonomy of relevant factors based on the available knowledge contained in the research literature, case studies, and expert judgment
- Implement ontology using Protégé and the OWL-DL ontology language





SOFIT Ontology includes > 300 Individual and Organizational Contributing Factors

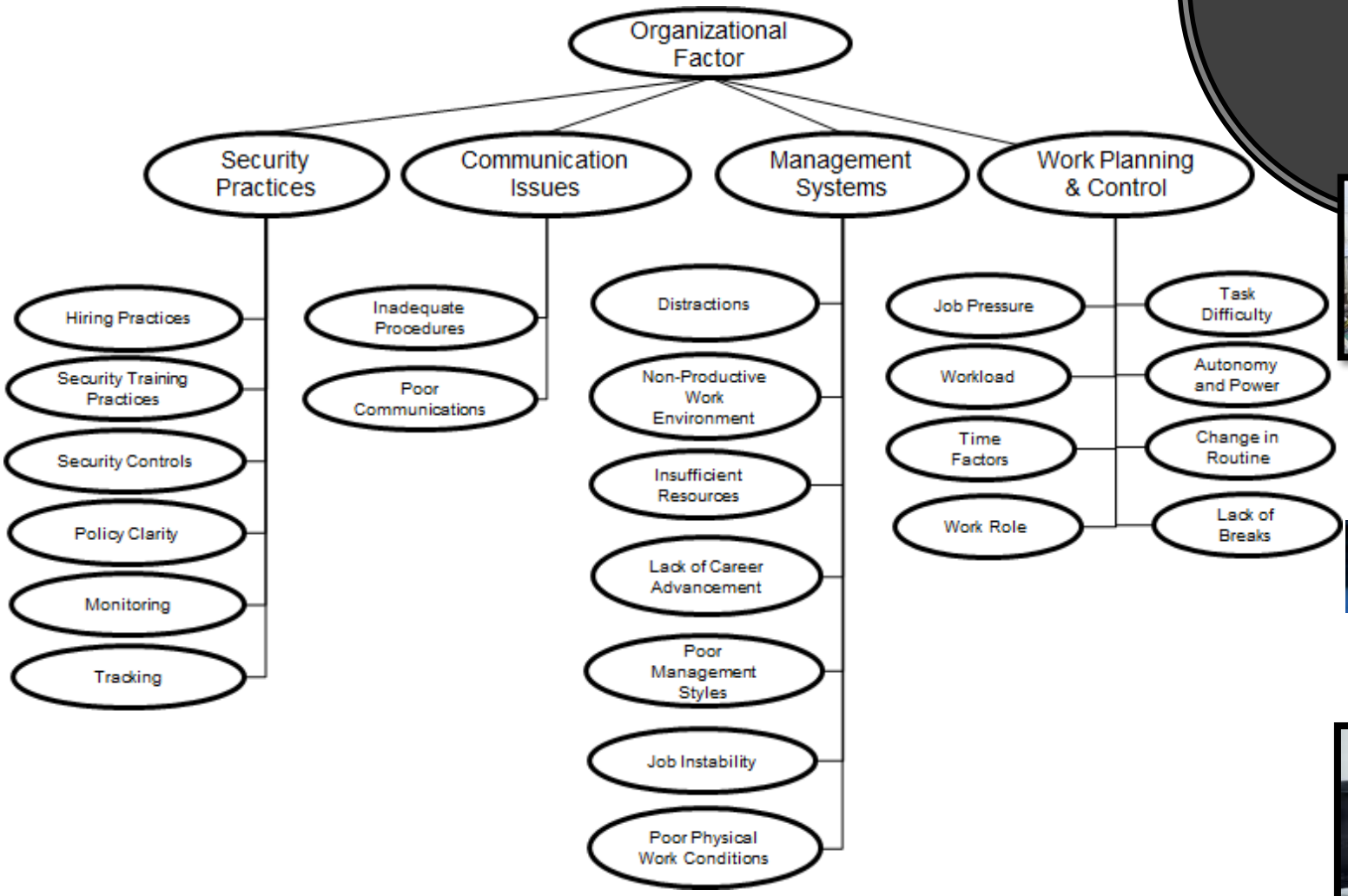
SOFIT Ontology



Individual Factors

SOFIT Ontology

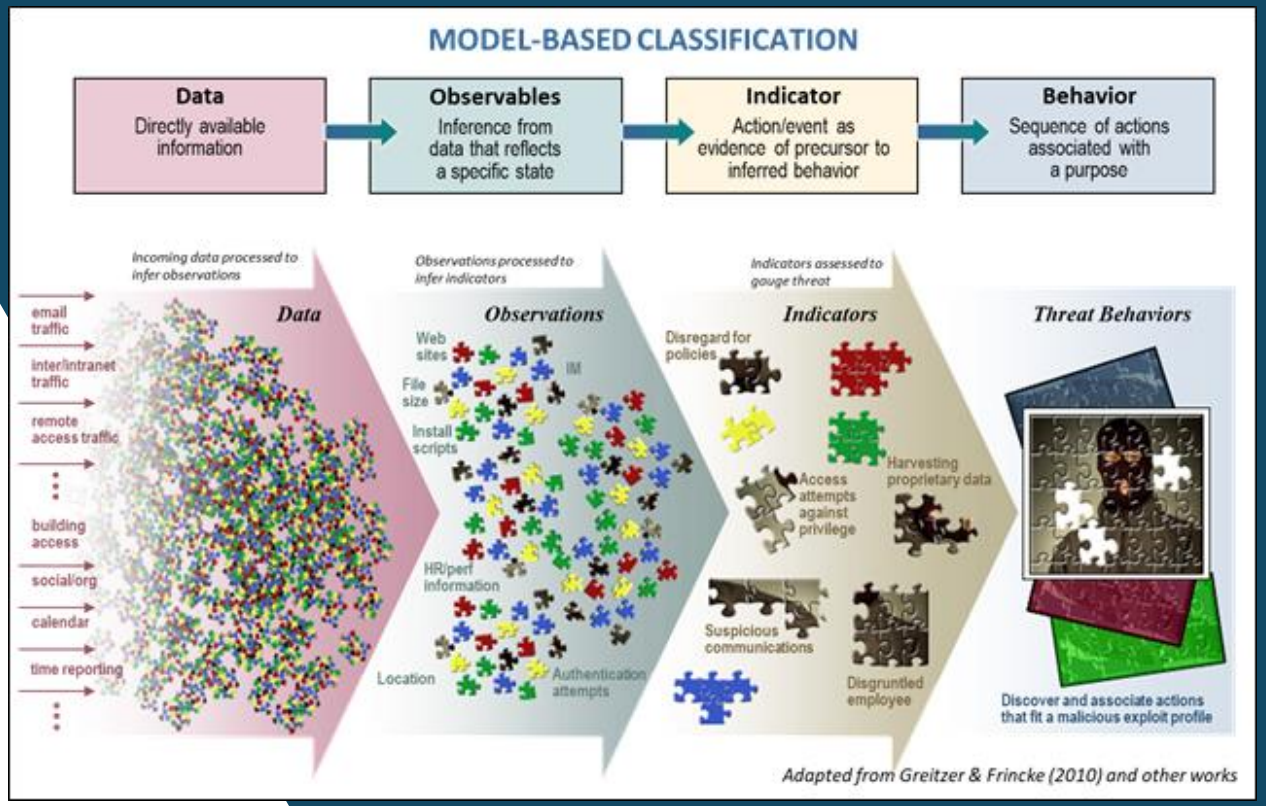
Organizational Factors



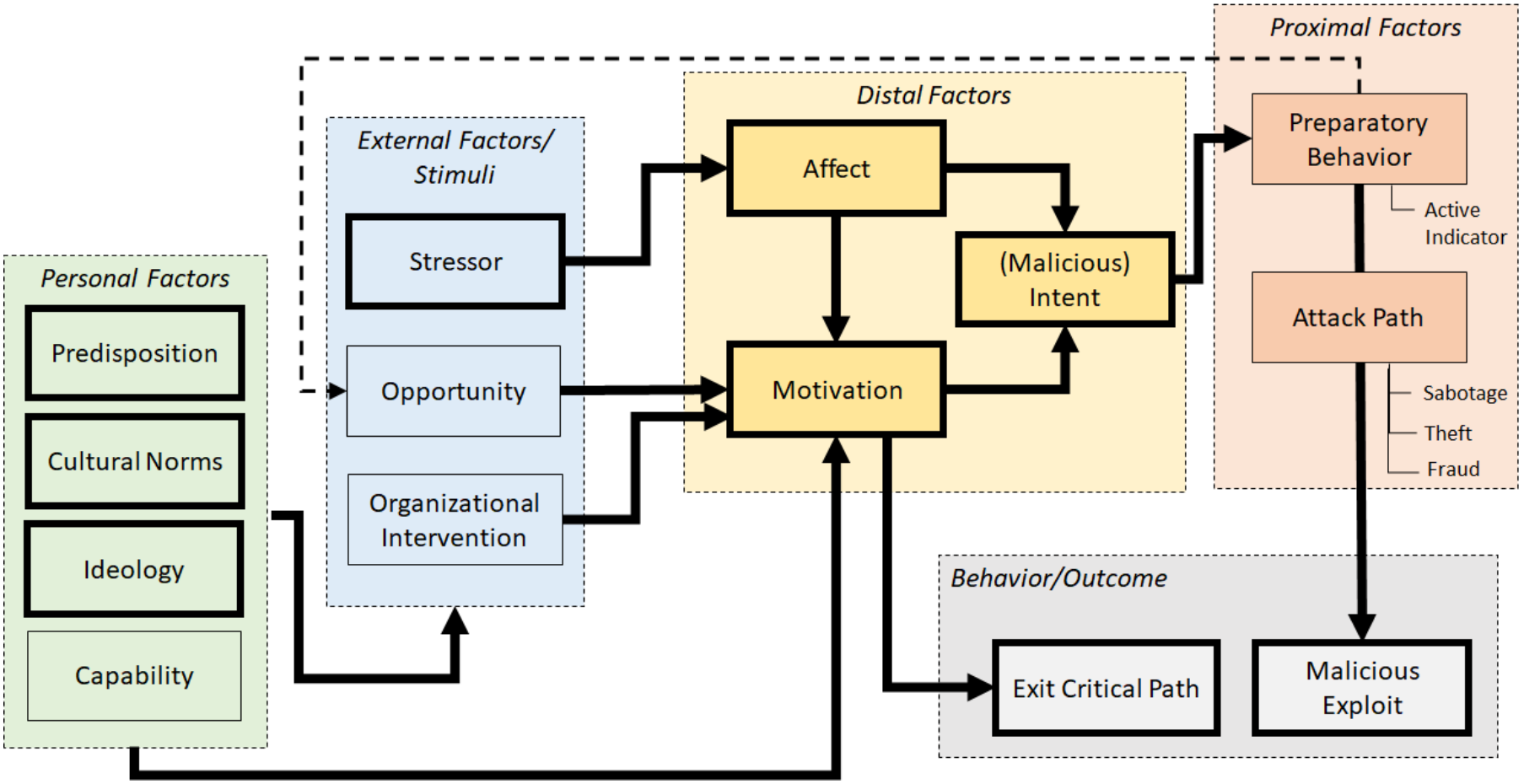
Related Ontology Frameworks

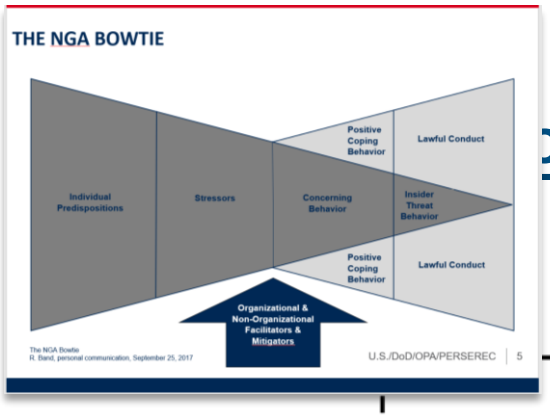
Summary of Current Ontology Representations in Cybersecurity/Insider Threat				
Ontology/Reference	Domain/Scope	Types of Constructs Represented		
		Technical/ Cyber	Human/ Behavioral	Organizational
CERT ITIO	Insider Threat	✔	-	-
MITRE (STIX)	Cyber Security	✔	-	-
MITRE (CAPEC)	Cyber Security - Attack Patterns	✔	-	-
MITRE (CWE)	Cyber Security - Weaknesses	✔	-	-
MAEC	Cyber Security - Malware	✔	-	-
CRATELO	Cyber Security	✔	-	-
HUFO	Cyber Security - Trust	✔	✔	-
SOFIT	Insider Threat	✔	✔	✔

Model Development



General Framework for Malicious Insider Threat Constructs





ork for Malicious Insider Threat Constructs

Proximal Factors

Distal Factors

External Factors/ Stimuli

Personal Factors

Predisposition

Cultural Norms

Ideology

Capability

Stressor

Opportunity

Organizational Intervention

Affect

Motivation

(Malicious) Intent

Preparatory Behavior

Active Indicator

Attack Path

Sabotage

Theft

Fraud

Behavior/Outcome

Exit Critical Path

Malicious Exploit

Complex Relationships among Constructs

We are considering possible relationships between the insider threat indicators and additional constructs: *threat types* and an indicator's *role* in the insider threat exploit:

Threat Types

- **Insider Sabotage.** An act by an insider to direct specific harm toward an organization or its assets.
- **Insider Data Theft/Exfiltration.** Theft of an organization's intellectual property by an insider.
- **Insider Fraud.** Modification, addition, deletion, or theft, of an organization's data for personal gain, leading to an identity crime (e.g., identity theft, credit card fraud).
- **Unintentional Insider Threat (UIT)**. An act or failure to act by an insider, without malicious intent, that causes harm or substantially increases the probability of future harm to an organization or its assets.
- **Workplace Violence.** Any act or threat of physical violence, harassment, intimidation, or other threatening disruptive behavior that occurs at the work site.

Indicator Roles

- **Precipitating Event.** An event that triggers or motivates the insider to carry out an insider crime
- **Personal Predisposition.** A characteristic historically linked to a propensity to exhibit malicious insider behavior.
- **Behavioral Precursor.** An individual action, event, or condition that involves personal or interpersonal behaviors and that precedes and is associated with insider activity.
- **Technical Precursor.** An individual action, event, or condition that involves computer or electronic media and that precedes and is associated with malicious insider activity.
- **Access Path.** Sequence of one or more access points that occur within an attack or exploit—also known as "attack vector" or "kill chain."
- **Contextual Variable.** Factor that adds context; not necessarily predictive.

Qualitative Threat Assessment

Case #1:

- Depression
- Misses or late for meetings
- Recent change in marital status
- Receiving large email attachments
- Requires excessive oversight

Case #2:

- Terminated
- Extreme discontent
- Establish backdoor
- Transfer large amount of data
- Strong reaction to organizational sanctions

Characterization of Case #1	**Characterization of Case #2**
Precipitating Event ● Recent change in marital status Behavioral Precursor ● Misses or late for meetings Contextual Variable ● Depression ● Receiving large email attachments ● Requires excessive oversight Indication of Insider Threat: None While there are contextual factors of concern about this employee that may indicate a need for follow-up, there is no indication that this person represents an insider threat risk.	Precipitating Event ● Terminated Behavioral Precursor ● Extreme discontent ● Strong reaction to organizational sanctions Technical Precursor ● Establish backdoor ● Transfer large amount of data Indication of Insider Threat: Strong The presence of both behavioral and technical precursors, as well as a precipitating event associated with insider threat risk, yields a high level of concern that justifies further analysis by insider threat team.

Quantitative Models

Counting Model

A simple approach is to count the number of indicators observed (*n*), irrespective of the level of concern associated with any indicator. Formally, the counting model risk score is $R = n$, where n is the number of indicators.

Sum of Risk Model

A simple elaboration of the counting model is obtained by adding the ratings to form a risk score. This model takes account of the variability revealed in the rating task in the most basic way possible. Formally, the risk score is simply the sum of the individual risk values for the reported indicators (x_i) within a given combination:

$$R = \sum_{i=1}^{n} x_i$$

Linear Regression Weight Model

One such method would be to have analysts make judgments about a sample of (or the full set of) indicator combinations, and regress (using linear regression) the presence of an indicator on the judgments of risk.

$$R = \sum_{i=1}^{n} b_i.$$

Sequential Weighted Model

An aggregated risk score is obtained by adding increments for each indicator (r_i), based on the indicator's unique risk value (i.e., the individual indicator risk judgment [x_i]), with the constraint that an upper limit is imposed on the aggregated total risk for the set of reported indicators (*X).* For a case with *n* indicators that represent *k* classes, the risk computation is given by:

$$R = \sum_{i=1}^{n}(r_i),$$

$$r_i = x_1, for\, i = 1$$

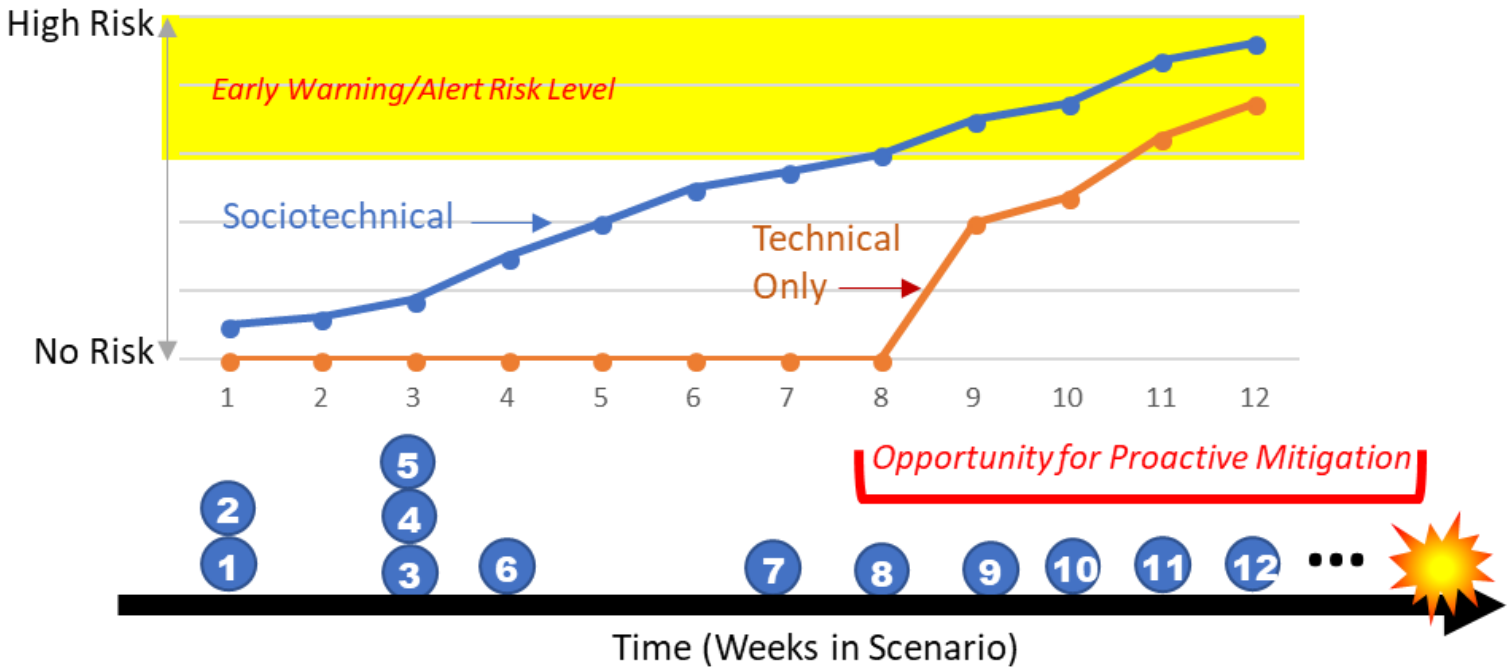
$$r_i = \left(X - \sum_{i=1}^{i-1} r_i\right) * \left(\frac{x_i}{X}\right) * w, \; for\; i = 2, \ldots, n$$

where the increments are weighted by $w = (k/n^2)$

$$= \left(X - \sum_{i=1}^{i-1} r_i\right) * \left(\frac{x_i k}{X n^2}\right), \; for\; i = 2, \ldots, n$$

substituting (k/n^2) *for* w

Illustrative Timeline Highlighting Potential Proactive Impact of Monitoring Sociotechnical Indicators



Indicators in Scenario Use Case

- Sociotechnical
- Technical

1. [PSYCHOLOGICAL FACTOR: ENDURING TRAIT: NARCISSISM]
2. [PSYCHOLOGICAL FACTOR: ENDURING TRAIT: MANIPULATIVE]
3. [PSYCHOLOGICAL FACTOR: ENDURING TRAIT: CALLOUSNESS]
4. [BOUNDARY VIOLATIONS: INTERPERSONAL PROBLEMS: VERBAL ABUSE]
5. [BOUNDARY VIOLATIONS: INTERPERSONAL PROBLEMS: INTIMIDATING]
6. [BOUNDARY VIOLATIONS: INTERPERSONAL PROBLEMS: INTIMIDATING]
7. [JOB PERFORMANCE: NEGATIVE EVALUATION: ATTENDANCE]
8. [PSYCHOLOGICAL FACTOR: DYNAMIC STATE: ATTITUDE: OVERLY CRITICAL]
9. [CYBERSECURITY VIOLATION: ATTEMPTED ACCESS AGAINST POLICY]
10. [JOB PERFORMANCE: WORKING AT UNUSUAL HOURS]
11. [CYBERSECURITY VIOLATION: PROHIBITED FILESHARING WEB SITE]
12. [BOUNDARY VIOLATION: POLICY VIOLATION: UNREPORTED CONTACT WITH FOREIGN NATIONALS]

Expert Knowledge Elicitation Study

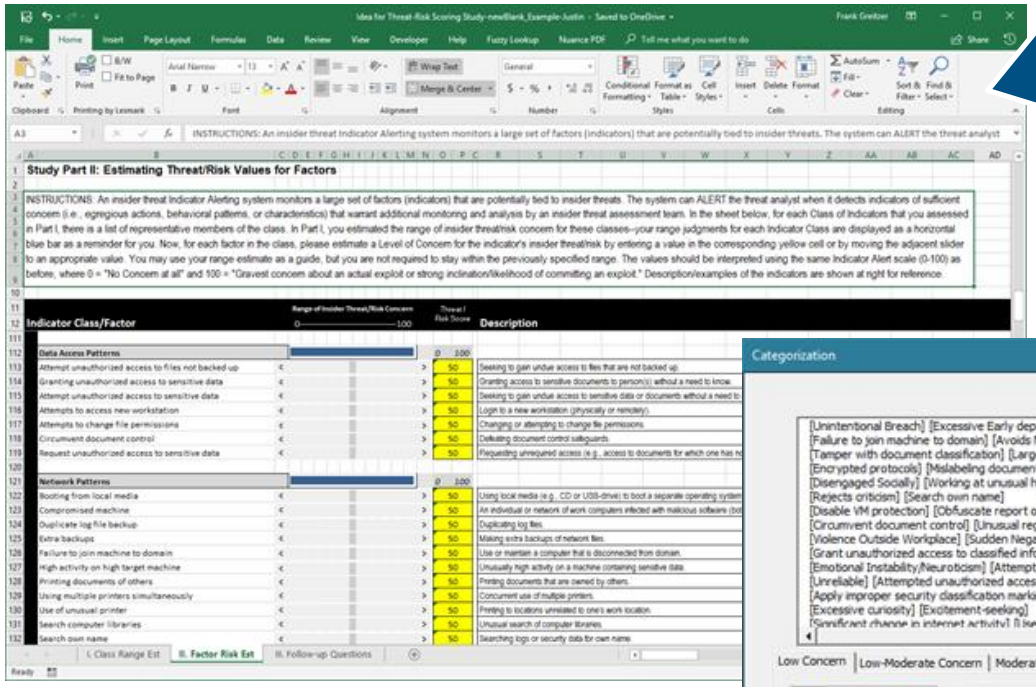
We conducted two distinct studies:

- An initial proof of concept study, narrowly focused on obtaining expert judgments for a small number of indicators (nine experts rated 24 indicators selected from the ontology)
- A broader study seeking expert judgments on all individual indicators (14 experts rated 203 indicators).

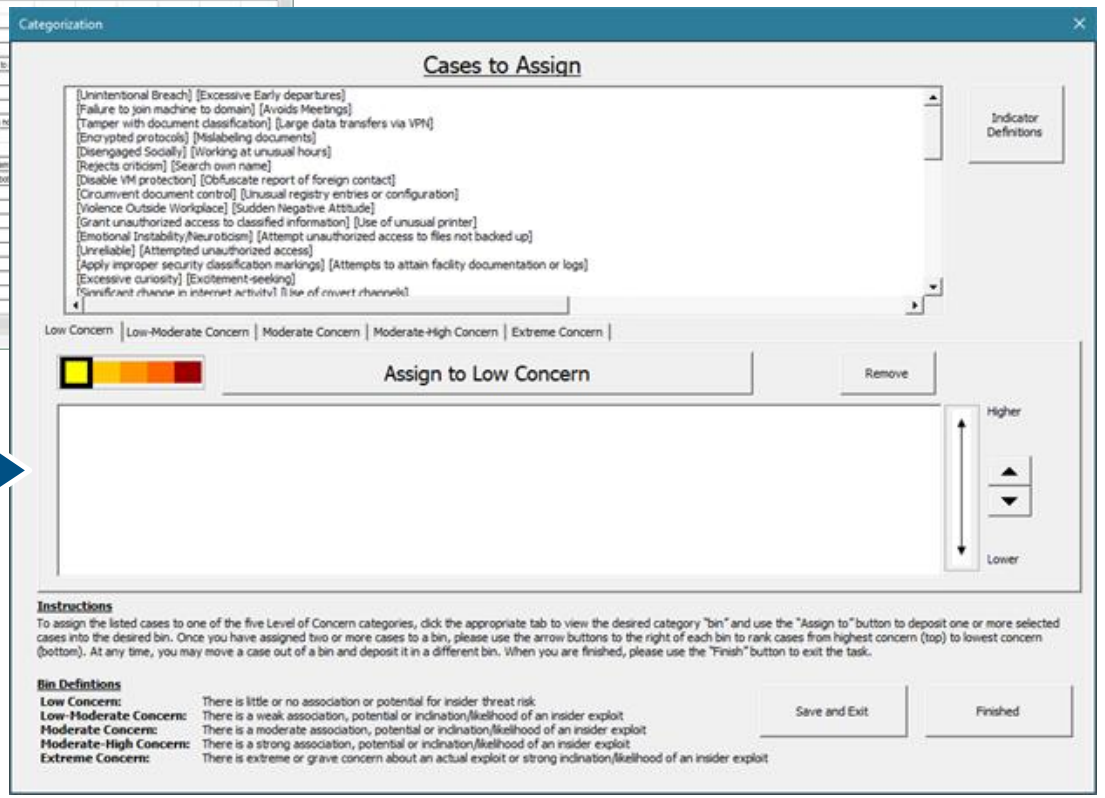
Method:

1. Obtain judgments of individual indicator risk to estimate risk scores x_i (level of concern, 0-100)
2. Obtain expert judgment rankings of cases comprising multiple indicators
3. Test ability of alternative models to predict expert judgments of rankings of cases, based on estimates of x_i

Materials Used for Expert Knowledge Elicitation



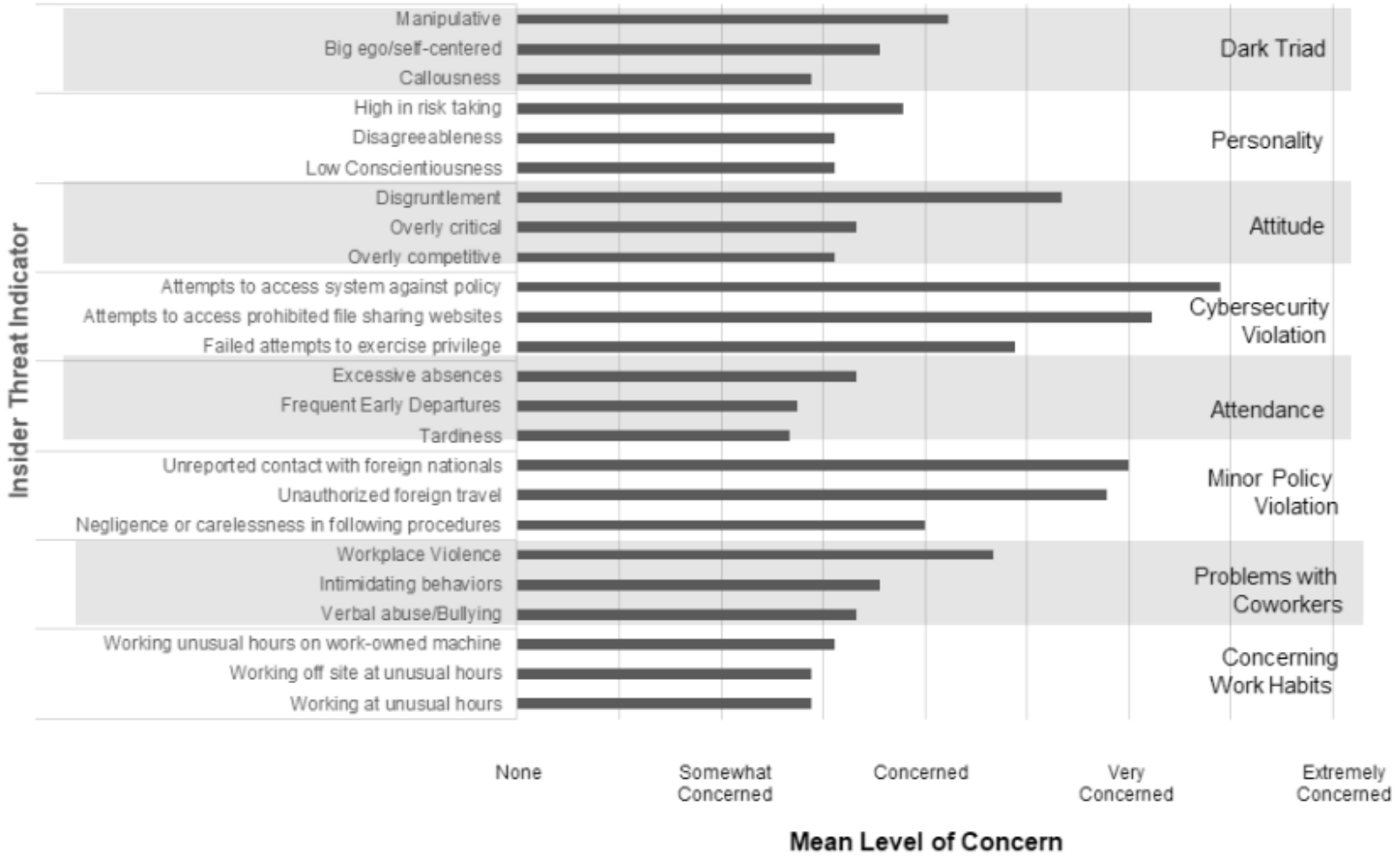
Estimating Individual Indicator Level of Concern



Ranking of cases comprising multiple indicators

Initial Results – Study 1

Individual Indicator Mean Concern/Risk Scores



Preliminary Results from Study 1

Amount of variance accounted for by alternative models in predicting ranking of cases used in Study 1

Model	R^2	*Study2*
(1) Counting Model	0.12	0.26
(2) Sum of Risks Model	0.55	0.48
(3) Linear Regression Weight Model	0.85	0.62
(4) Sequential Weighted Model	0.68	0.45

- The simple counting model is clearly inadequate
- The Linear regression model empirically derives indicator weights from the ranking data and therefore represents an optimal (though data-intensive) prediction of the data
- The Sequential weighted model performed reasonably well in Study 1, but not as well in Study 2. Given these results, and the comparative simplicity of the Sum of Risks model, the latest results tend to provide the greatest support for the Sum of Risks model. (We are currently exploring other variations of models).

[Study 2 data are still being analyzed]

Summary & Contributions

- The SOFIT knowledge representation substantially advances the specification of human/social/behavioral and organizational indicators of insider threat.
- The knowledge base is shareable to facilitate reuse and collaboration with the research community.
- The SOFIT ontology can serve as a foundation for assessments of an organization's insider threat mitigation program, and thus can help to inform the technology maturation assessment of existing programs and approaches, identifying gaps in coverage that would be the most productive areas for improvement.

This paper received the Best Paper Award!

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39th IEEE Symposium on Security and Privacy Workshops

Best Paper Award

Presented to

Frank Greitzer, Justin Purl, Yung Mei Leong, and D.E. Sunny Becker

Co-Authors of
"SOFIT: Sociotechnical and Organizational Factors for Insider Threat"
at the Workshop on Research for Insider Threat

May 24, 2018

Thank You for your Attention

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