



Cybersecurity Metrics History

Jennifer Bayuk

© 2020 Decision Framework Systems, Inc.





Measures versus Metrics

Measurement is the process of *mapping* from the empirical world to the formal, relational world. The measure that results characterizes an *attribute* of some object under scrutiny. Information Security is not the object, nor a well-understood attribute.

This means you are not directly measuring security, you are measuring other things and using them to create **Metrics** in order to draw conclusions about security.



Measures versus Numbers

- Nominal – labels (exists, not exists)
- Ordinal – order (low → medium → high)
- Interval – order and quantity (temperature) 
- Ratio – interval with respect to zero (length, dollars) 

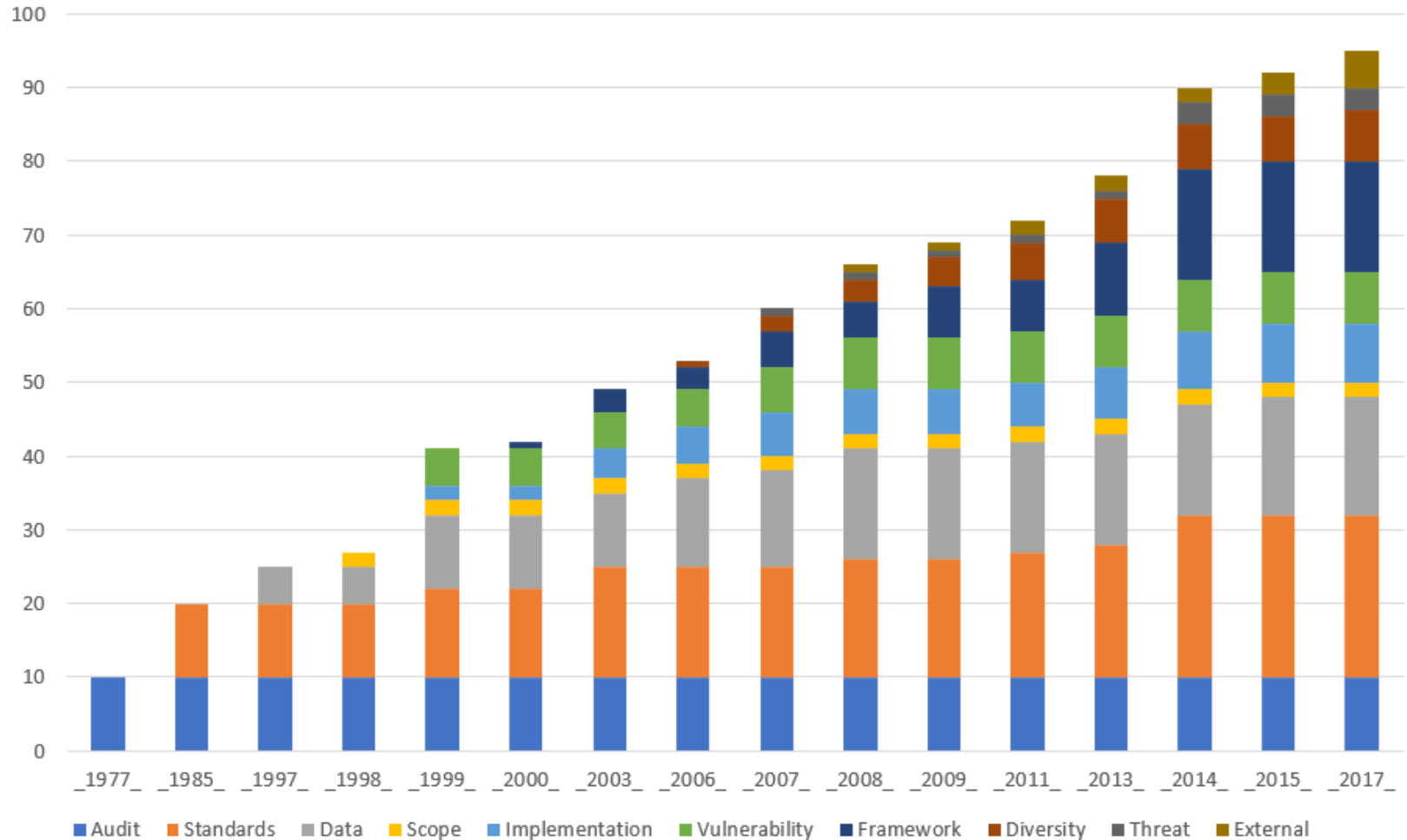


Measurement Criteria

- Accurate: data reflects the content of measurement as it was envisioned
- Numeric: data can be precisely quantified
- Correct: data is collected according to specifications
- Consistent: measure is independent of measurer
- Time-based: there is a fixed reference point of data collection
- Replicable: measurement repeated in same manner in same environment will yield same result
- Unit-based: data may be expressed in terms of a unit
- Informative: data provides information without additional context



History of the Practice in Cybersecurity Metrics



Control Objectives

Standards for management control over computer systems processing published by The Electronic Data Processing Auditors Association, now known as ISACA.

A global consortium was formed to aggregate, review, and agree on technology control:

- Standards
- Procedures
- Guidelines
- Best practices
- Standards for conducting EDP audits entitled "Control Objectives"
- Focused on whether standard input produces expected output

**BETTER
SECURITY**



Output meets expectations based on standard input

Output partially meets expectations based on standard input

Output does not meet expectations based on standard input

**NO
SECURITY**

UNITS OF MEASURE

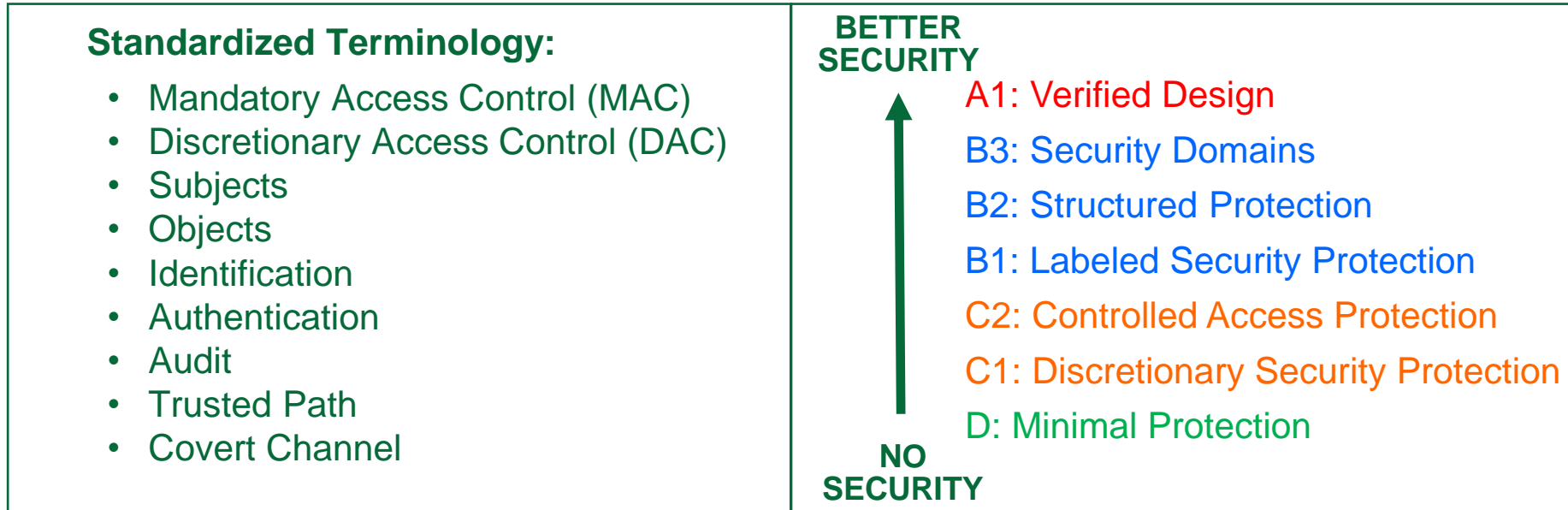


ATTRIBUTES OF A SINGLE COMPUTER



The Orange Book

aka: TCSEC: Trusted Computer System Evaluation Criteria



UNITS OF MEASURE



ATTRIBUTES OF AN OPERATING SYSTEM



The Orange Book Metric Calculation

From measurable attributes to conclusions about security:

	C1	C2	B1	B2	B3	A1(Verified Design)
Discretionary Access Control	+	+	nc	nc	+	nc
Object Reuse	0	+	nc	nc	nc	nc
Labels	0	0	+	+	nc	nc
Label Integrity	0	0	+	nc	nc	nc
Exporting Labeled Information	0	0	+	nc	nc	nc
Labeling Human-Readable Output	0	0	+	nc	nc	nc
Mandatory Access Control	0	0	+	+	nc	nc
Subject Sensitivity Labels	0	0	0	+	nc	nc
Device Labels	0	0	0	+	nc	nc

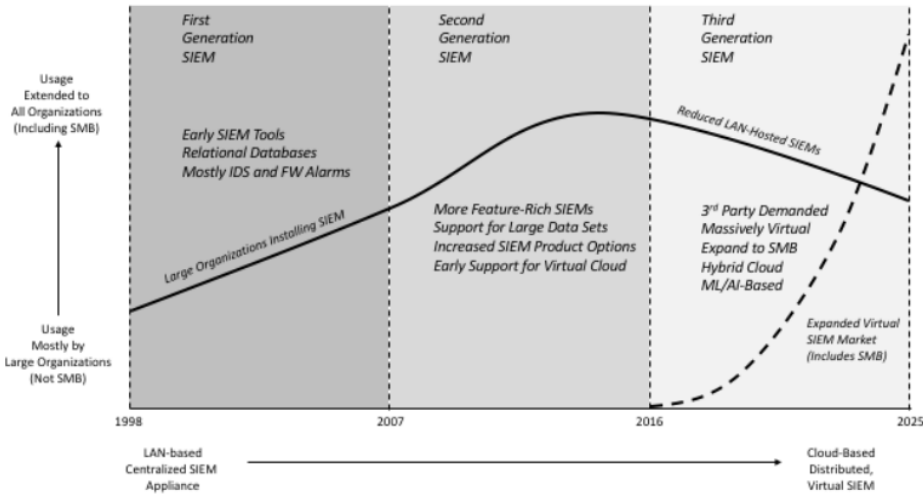
Key: 0: no requirement, +: added requirement, nc: no change



Tools for Security Metrics

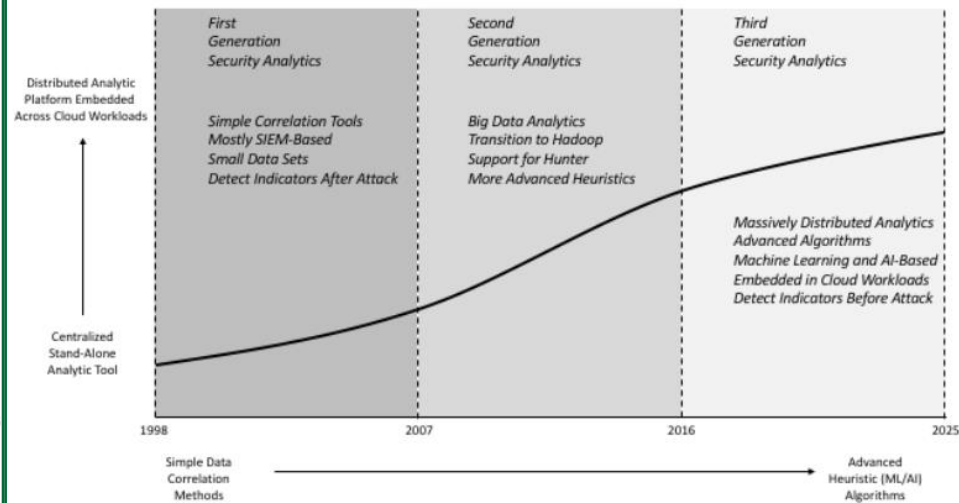
Technology vendors became aware of the appetite for data aggregation in security operations centers and started accommodating with specialized tools.

Security Incident and Event Management



UNITS OF MEASURE: *Incidents, Anomalies*

Security Analytics

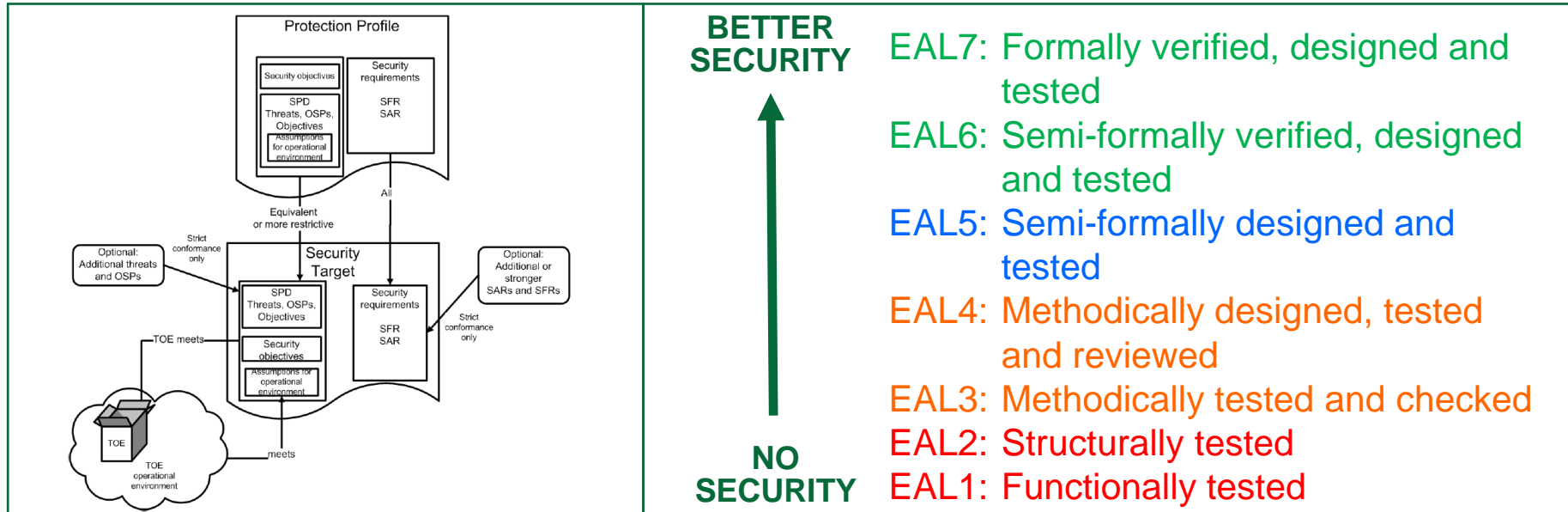


ATTRIBUTES OF *Threats and Vulnerabilities*



The Common Criteria

A Global consortium acknowledges all systems are different and security must be customized and formally verified.



UNITS OF MEASURE



ATTRIBUTES OF A TARGET OF EVALUATION



Systems Security Engineering Capability Maturity Model

An influential publication developed by Carnegie Mellon Software Engineering Institute with support from US DoD (*abbreviated as SSE-CMM*).

Specifies security activities to incorporate into the systems engineering lifecycle:

- Administer Security Controls
- Assess Impact
- Assess Security Risk
- Assess Threat
- Assess Vulnerability
- Build Assurance Argument
- Coordinate Security
- Monitor Security Posture
- Provide Security Input
- Specify Security Needs
- Verify and Validate Security

**BETTER
SECURITY**



5. Continuously Improving
4. Quantitatively Controlled
3. Well-Defined
2. Planned and Tracked
1. Performed Informally

**NO
SECURITY**

UNITS OF MEASURE



ATTRIBUTES OF ENGINEERING PROCESS



National Vulnerability Database

The NVD is a U.S. government repository of security vulnerability management data represented using the Security Content Automation Protocol (SCAP).

This data enables automation of software vulnerability identification via publication of:

- unique vulnerability identifier
- security checklist references
- security-related software flaws
- security-related misconfigurations
- baseline vulnerability impact metrics

**BETTER
SECURITY**



**NO
SECURITY**

The NVD includes a Common Vulnerability Scoring System (CVSS) Calculator to help evaluate risk of negative impact from any given vulnerability.

None	0.0
Low	0.1-3.9
Medium	4.0-6.9
High	7.0-8.9
Critical	9.0-10.0

UNITS OF MEASURE

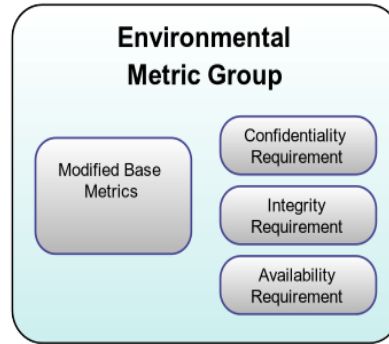
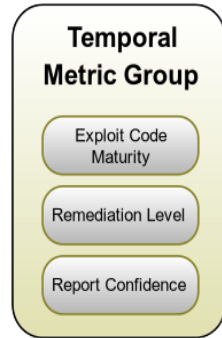
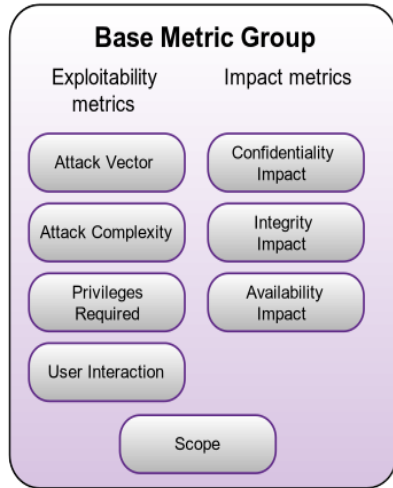


ATTRIBUTE OF SOFTWARE VULNERABILITY



Common Vulnerability Scoring System (CVSS)

Indirectly analyzes threat by assessing how easy it is to exploit a vulnerability. Initial score is set by the Forum of Incident Response and Security Teams (FIRST), and organizations may customize.



MySQL Stored SQL Injection (CVE-2013-0375)

CVSS v3.0 Base Score: 6.4

Metric	Value	Metric	Value
Attack Vector	Network	Confidentiality Impact	Low
Attack Complexity	Low		
Privileges Required	Low	Integrity Impact	Low
User Interaction	None	Availability Impact	None
Scope	Changed		

Acronym	Measure	Possible Values
MAV	Modified Attack Vector	[X,N,A,L,P]
MAC	Modified Attack Complexity	[X,L,H]
MPR	Modified Privileges Required	[X,N,L,H]
MUI	Modified User Interaction	[X,N,R]
MS	Modified Scope	[X,U,C]
MC	Modified Confidentiality	[X,N,L,H]
MI	Modified Integrity	[X,N,L,H]
MA	Modified Availability	[X,N,L,H]
E	Exploit Code Maturity	[X,H,F,P,U]
RL	Remediation Level	[X,U,W,T,O]
RC	Report Confidence	[X,C,R,U]
CR	Confidentiality Req.	[X,H,M,L]
IR	Integrity Req.	[X,H,M,L]
AR	Availability Req.	[X,H,M,L]

Example Values:

A = Adjacent
 C = Critical
 F - Functional exploit code exists
 H = High
 L = Local
 M = Medium
 N = None, No impact, Network
 O = Official Fix Available

P = Proof of concept exploit code exists
 R = Reasonable
 T = Temporary Fix Available
 U = Unknown, Unavailable, Unproven
 W = Workaround Available
 X = Not Applicable

<https://nvd.nist.gov/vuln-metrics/cvss>



National Institute of Standard and Technology

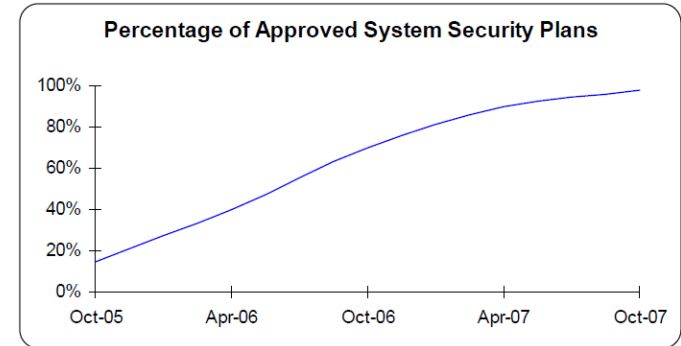
Performance Measurement Guide for Information Security (Special Publication 800-55 Rev 1, first version 2003).

Fundamentally a Goal, Question Metric Approach where the goals are *implementation, effectiveness, efficiency, and impact* for each critical element of the security program, as defined in self-assessment requirements.*



BETTER SECURITY

800-55 specifies that each security program critical element should have trending metrics and provides examples such as:



NO SECURITY

UNITS OF MEASURE



ATTRIBUTES OF A SECURITY PROGRAM



*In 2003, the goals came from SP800-26, *Security, Self-Assessment Guide for Information Technology Systems*. A 2008 Revision changed this citation to SP800-53A, *Guide for Assessing the Security Controls in Federal Information Systems*.

Example Enterprise Adoption of SP800-55

Measure W:

The number of firewall devices in operation.

Measure X:

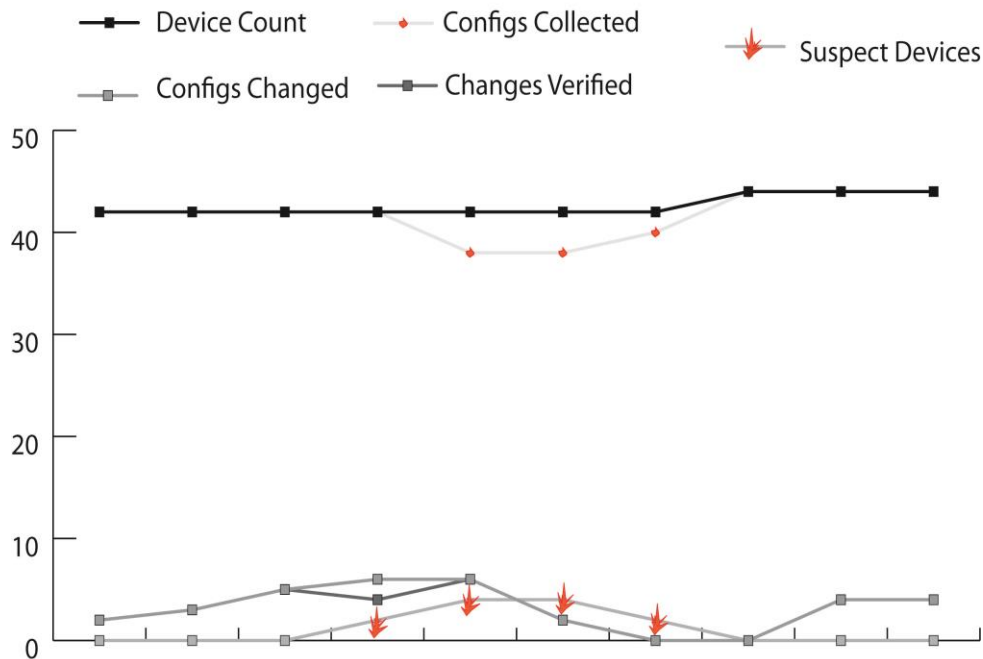
The number of firewall devices whose configuration was retrieved in past 24 hours by network management system.

Measure Y:

The number of firewall devices configurations that deviate from yesterday's configuration.

Measure Z:

The number of deviant device configurations where deviations directly compare to authorized planned changes.



UNITS OF MEASURE



ATTRIBUTES OF A SECURITY PROGRAM

Network Periphery Control Performance Metric:
 Suspect Devices as % of Total: $((W-X) + (Y-Z)) / W$

2004



Metricon

A periodic meeting of specialists in cybersecurity metrics was formed by Dan Geer and Andy Jaquith, and drew dozens of volunteer program committee participants as well as sponsors.

Presentations cover a variety of cybersecurity metrics categories, including but not limited to:

Adversary Skills:	Metrics that estimate adversary skills levels.
Adversary Goals:	Metrics gleaned from intelligence on adversary motivation and justification.
Deterministic Models:	Metrics that combine measures with inference rules (e.g. artificial intelligence) to form conclusions about cybersecurity.
External activity:	Metrics that track threats (“weather”).
Internal activity:	Metrics that chart work activity (“busyness”).
Performance:	Metrics that demonstrate capability to deliver system features.
Process Monitor:	Metrics that monitor security processes.
Remediation:	Metrics that show progress toward a security objective.
Resilience:	Metrics that demonstrate system ability to recover from harmful impact.
Stochastic Models:	Metrics that combine measures with probability estimates based on historical data.
Target:	Metrics that have a measurable 100% target.
Vulnerability:	Metrics that show susceptibility to known threats.

As consensus matured, Metricon attendees published several textbooks, including but not limited to:

Jennifer Bayuk: Stepping Through the InfoSec Program
Fred Cohen: IT Security Governance Guidebook with Security Program Metrics on CD-ROM (The CISO Toolkit 1)
Lance Hayden: IT Security Metrics: A Practical Framework for Measuring Security & Protecting Data
Jay Jacobs and Bob Rudis: Data-Driven Security: Analysis, Visualization and Dashboards
Andrew Jaquith: Security Metrics: Replacing Fear, Uncertainty, and Doubt
Richard Seiersen: The Metrics Manifesto: Confronting Security with Data
Caroline Wong: Security Metrics, A Beginner's Guide

Validation Metric: Threat Intelligence

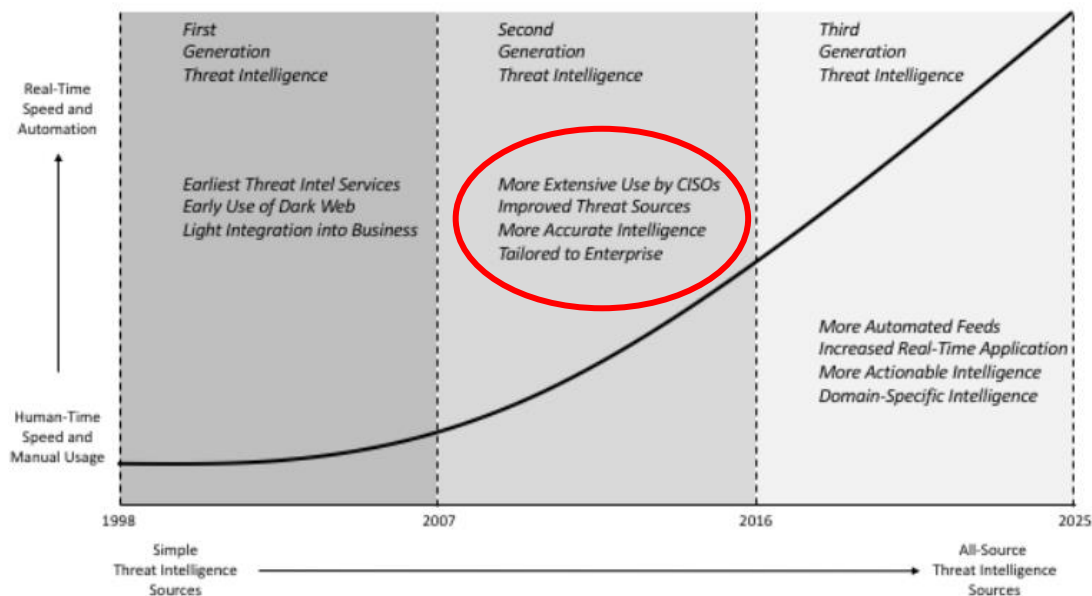
Cybersecurity vendors customize threat hunting to find evidence of a company's data breach on the dark web.

Customized metrics on:

Internal Data found on dark web
Mail sent from lookalike Domains
Lookalike Websites

Delivered in bulk via:

- TAXII™, the Trusted Automated eXchange of Indicator Information;
- STIX™, the Structured Threat Information eXpression; and
- CybOX™, the Cyber Observable eXpression.



UNITS OF MEASURE:



ATTRIBUTES OF Targeted (maybe successful) Attacks



Verizon Data Breach Incident Report

An annual analysis of data breach incidents collected by dozens of cybersecurity service providers and law enforcement agencies world-wide.



BETTER SECURITY



NO SECURITY

No overlap in your data and report

Data from your peers in report

Your data in report

UNITS OF MEASURE



ATTRIBUTES OF A CYBERATTACK

Directions in Security Metrics Research (NISTIR7564)

The report followed SP-55-Rev1 and emphasized the difference between

Correct

security performance an

Effective

security performance.

This is the same distinction made by SSE-CMM as:

Verification

versus

Validation

Security

In systems engineering terms:

Building the system right

versus

Building the right system



“

The current practice of security assessment, best illustrated by lower level evaluations under the Common Criteria, emphasizes the soundness of the evaluation evidence of the design and the process used in developing a product over the soundness of the product implementation. The rationale is that without a correct and effective design and development process, a correct and effective implementation is not possible. While this is true, the

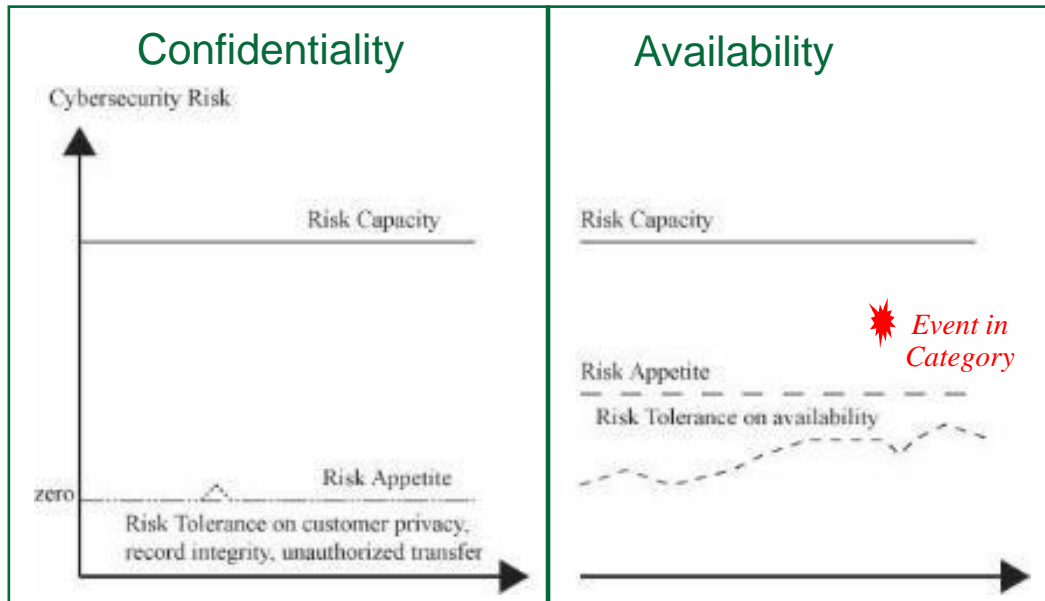
*emphasis on **design and process evidence** versus **actual product software** largely overshadows practical security concerns involving the implementation and deployment of operational systems.”*

– Note - NISTIR 7564 author (Wayne Jansen) was at this time an active Metricon program committee member



Cybersecurity Viewed as Operational Risk

- For each cybersecurity risk (e.g. confidentiality, availability), qualitatively declare Risk Appetite far lower than Risk Capacity
- Qualitative Risk Appetite is be measured with quantifiable Risk Tolerance Metrics
- Investigate negative trends in tolerance metrics to determine whether:
 - Tolerance metrics sound justified alarms; or
 - Tolerance metrics need to be revised and recomputed



Note: though trends are intended to be correlated with probability, actual negatively impacting events may result in breach of appetite and/or a reexamination of tolerance measures



NIST Cybersecurity Framework

Function Unique Identifier	Function	Category Unique Identifier	Category
ID	Identify	ID.AM	Asset Management
		ID.BE	Business Environment
		ID.GV	Governance
		ID.RA	Risk Assessment
		ID.RM	Risk Management Strategy
		ID.SC	Supply Chain Risk Management
PR	Protect	PR.AC	Identity Management and Access Control
		PR.AT	Awareness and Training
		PR.DS	Data Security
		PR.IP	Information Protection Processes and Procedures
		PR.MA	Maintenance
		PR.PT	Protective Technology
DE	Detect	DE.AE	Anomalies and Events
		DE.CM	Security Continuous Monitoring
		DE.DP	Detection Processes
RS	Respond	RS.RP	Response Planning
		RS.CO	Communications
		RS.AN	Analysis
		RS.MI	Mitigation
		RS.IM	Improvements
RC	Recover	RC.RP	Recovery Planning
		RC.IM	Improvements
		RC.CO	Communications



Metric NIST-CSF: Coverage of NIST-CSF

Category: Performance

Description: Report of gaps in coverage of NIST CSF functions with existing security controls and tools.

Scope: Cybersecurity Program

Measure: NIST-Controls - Controls Map to NIST, (Subcategory,Control)

Measure: NIST-Target - NIST CSF, Subcategory

Measure: NIST-Tools - Tools Map to NIST, (Subcategory,Tool)

Algorithm: For each SUBCATEGORY in NIST-TARGET:
If SUBCATEGORY not in NIST-Controls or NIST-Tools
Potential_Gap.append(SUBCATEGORY)
For SUBCATEGORY in Potential_Gap:
List SUBCATEGORY

Unit: Subcategory

Interval: Monthly

Basis for KRI: Cybersecurity Standards

Explanation: Coverage of NIST-CSF with Security Policies, Controls, and Tools

Comparison: Equals Threshold

Threshold: Target Profile

Use Case: Leading

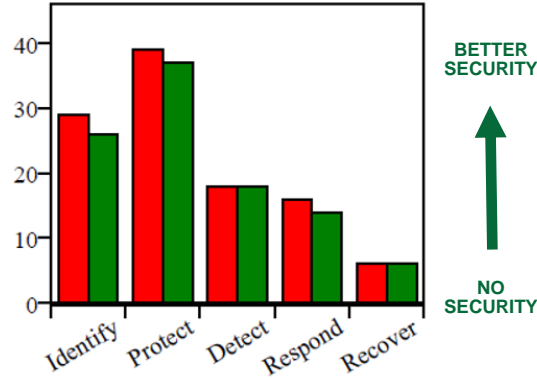
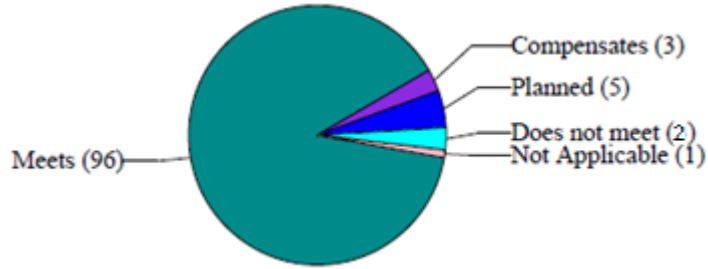
UNITS OF MEASURE: Subcategories



ADEQUACY OF A SECURITY PROGRAM



Enterprise Example: SP800-55 NIST-CSF Coverage for SP800-53



Enterprises are encouraged to set their own targets at a subcategory level.

GAPS

- ID.AM-3:** Organizational communication and data flows are mapped, Response: Compensating Control
- ID.RM-2:** Organizational risk tolerance is determined and clearly expressed, Response: Plans to Meet
- ID.SC-2:** Suppliers and third-party partners of information systems, components, and services are identified, prioritized, and assessed using a cyber supply chain risk assessment process, Response: Compensating Control
- ID.SC-4:** Suppliers and third-party partners are routinely assessed using audits, test results, or other forms of evaluations to confirm they are meeting their contractual obligations., Response: Does not Meet
- ID.SC-5:** Response and recovery planning and testing are conducted with suppliers and third-party providers, Response: Does not Meet

Section Status:

IDENTIFY: 100% complete, 2 compensated, 1 planned, 2 not met, section has 78 control links and 1 evidence attachments section has 2 flagged issues

PROTECT: 100% complete, 2 compensated, 3 planned, 1 not applicable, section has 233 control links and 0 evidence attachments section has 3 flagged issues

DETECT: 100% complete, 1 planned, section has 125 control links and 7 evidence attachments section has 1 flagged issues

RESPOND: 100% complete, section has 72 control links and 2 evidence attachments section has 0 flagged issues

RECOVER: 100% complete, section has 18 control links and 0 evidence attachments section has 0 flagged issues

Total number of Requirements: 108

Count Completed: 108

Total so far fully met: 96, 88.9%

Total number of Requirements with linked controls: 102

Total number of Requirements with linked evidence: 10



Security Scorecard Standards

Transparency: Rating companies shall provide sufficient transparency into the methodologies and types of data used to determine their ratings, including information on data origination as requested and when feasible, for customers and rated organizations to understand how ratings are derived. Any rated organization shall be allowed access to their individual rating and the data that impacts a change in their rating.

Dispute, Correction and Appeal: Rated organizations shall have the right to challenge their rating and provide corrected or clarifying data. Rating companies should have an appeal and dispute resolution process. Disputed ratings should be notated as such until resolved.

Accuracy and Validation: Ratings should be empirical, data-driven, or notated as expert opinion. Rating companies should provide validation of their rating methodologies and historical performance of their models. Ratings shall promptly reflect the inclusion of corrected information upon validation.

Model Governance: Prior to making changes to their methodologies and/or data sets, rating companies shall provide reasonable notice to their customers and clearly communicate how announced changes may impact existing ratings.

Independence: Commercial agreements, or the lack thereof, with rating companies shall not have direct impact on an organization's rating; any rated organization will be able to see and challenge their rating irrespective of whether they are a customer of the rating company.

Confidentiality: Information disclosed by a rated organization during the course of a challenged rating or dispute shall be appropriately protected. Rating companies should not publicize an individual organization's rating. Rating companies shall not provide third parties with sensitive or confidential information on rated organizations that could lead directly to system compromise.

UNITS OF MEASURE: ??????

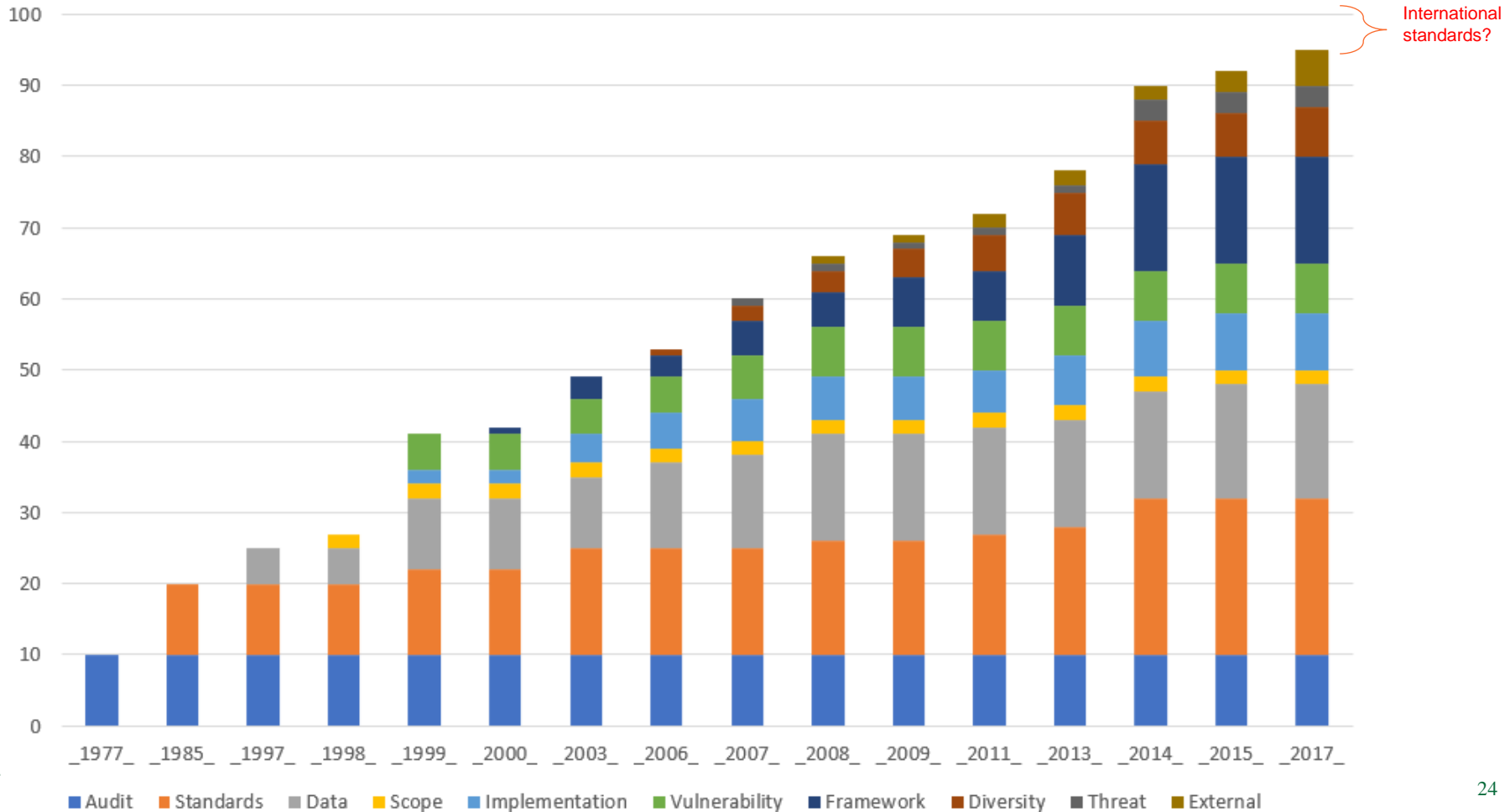


SPECTATOR OPINION OF FIRM SECURITY

2017



State of the Practice in Security Metrics





Thank you!

<https://www.framecyber.com>

Publications available at: <https://www.bayuk.com>

jen@framecyber.com

jennifer@bayuk.com

