Information Assurance Science and Engineering Tools

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Considering Metrics for Information Assurance

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Discussion outline

- **Presentation**
  - **IASET interest in metrics**
  - **Who and what uses them?**
  - **Types of metrics**
  - **Methodology for metrics**

Before we begin…

- Information presented here is intended to motivate thought in the area of metrics for IA
  - we have a long way to go to make this a useful discipline and even further before it is mature
- Concepts are my opinion, based upon experience in this area, my thoughts on the subject, and ideas gathered from others in this area
  - so...please provide input and constructive criticism

IASET
the problem to be addressed

- **What:** Our military and civilian information systems are at risk
  - increased use, reliance, complexity, visibility
- **One reason why:** IA is vital for reliable, secure functioning of information systems - yet IA design, assessment, and operational understanding are:
  - currently unreliable, not understood, not scientific, not systematic, often non-existent
- **Why is IA in this condition?**
  - even though some people know there is a problem, we have yet to experience the wreckage of a true information system disaster

...but we cannot wait for one!

IASET
focus on the IA problem

- **We don't understand the science of IA in systems**
  - An understanding of the basic laws governing IA does not exist
  - there are none to few useful ways to measure IA or its components to compare, define requirements, measure changes
  - we don't know how to compute, make decisions or otherwise utilize IA measures
- **We don't know how to design and assess IA in systems**
  - A system-level, methodical process is rarely taken, which leads to numerous uncovered vulnerabilities
  - Sufficient types and quantities of tools do not exist to allow for effective design, assessment, operation
  - Designers, assessors, and operators cannot access common information about a system: no common language, tools do not work together, no common environment to express, define, communicate the attributes of a system
  - Knowledge is rarely passed forward therefore we've often been doomed to repeat history

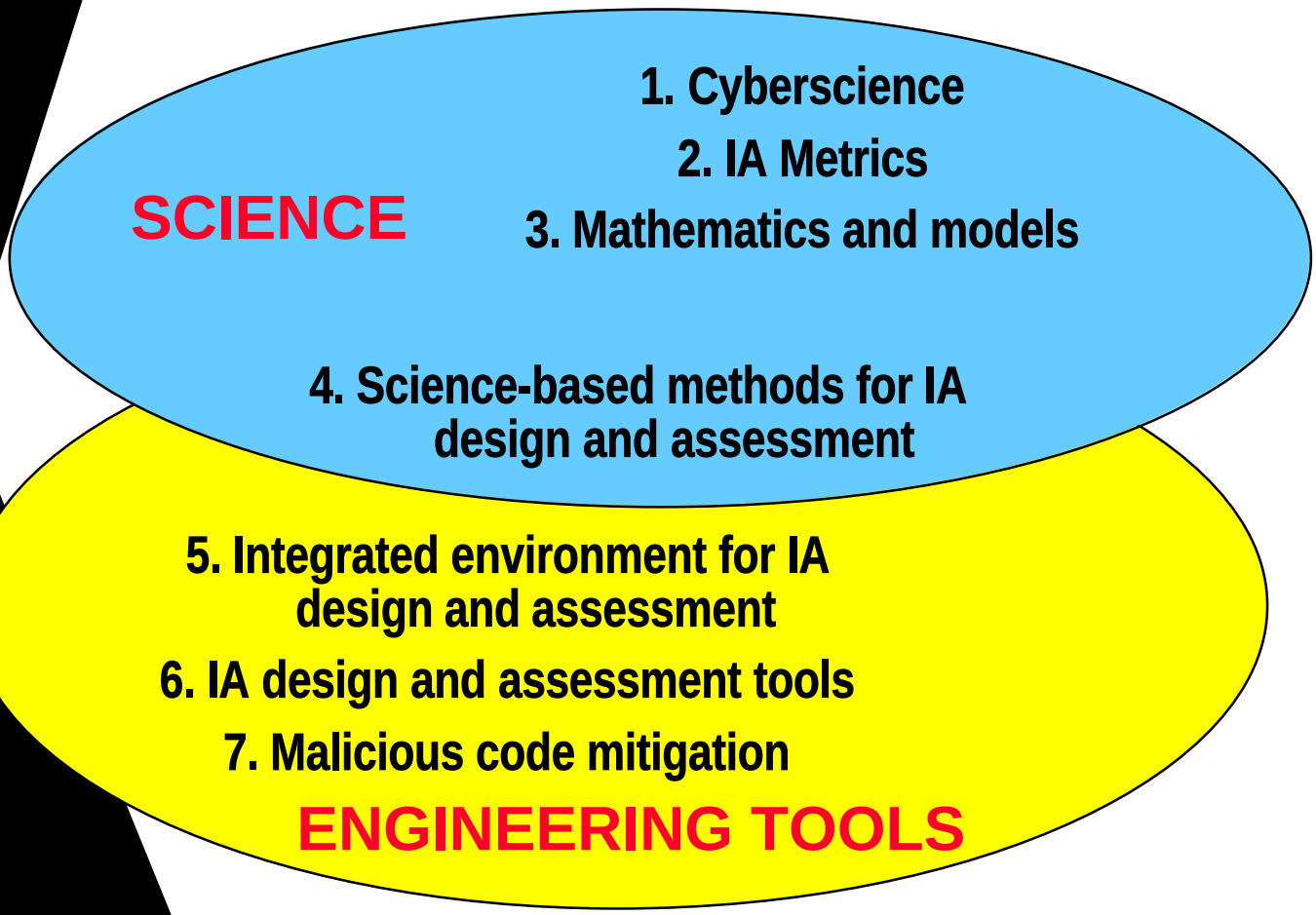
IASET will endeavor to look at the IA problem in new ways

"..so many centuries after the Creation it is unlikely that anyone could find hitherto unknown lands of any value." - committee advising Ferdinand and Isabella regarding Columbus' proposal, 1486

IASET
where we want to go

- **Provide a science-based environment for design and assessment that will:**
  - yield improved system IA
  - allow for faster design and assessment at less cost
  - assist the designer and assessor at developing the system
  - allow the user to understand the system IA, and risks
- **This environment will consist of:**
  - methodologies, metrics, common languages
  - IA models with objects that carry along all information about their being
  - suite of automated tools that can operate together seamlessly within the environment

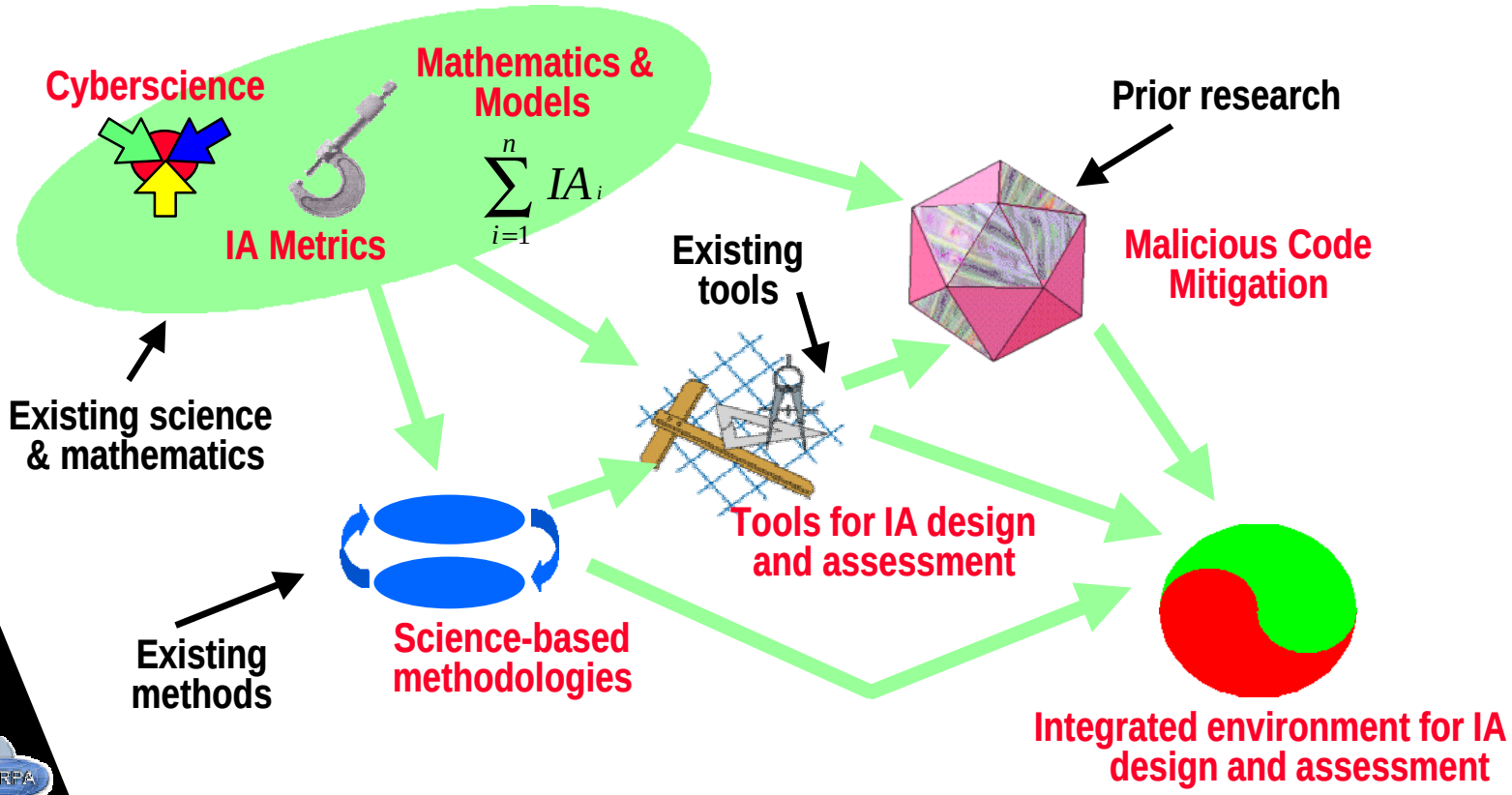
IASET
a view of the seven areas



- IASET addresses systems level problems, not discrete technology problems
- IASET is primarily focused on design-time; however, fundamentals will apply to operation-time work including that in the IA, AIA, and CC2 programs

IA Science & Engineering tools
internal program flow

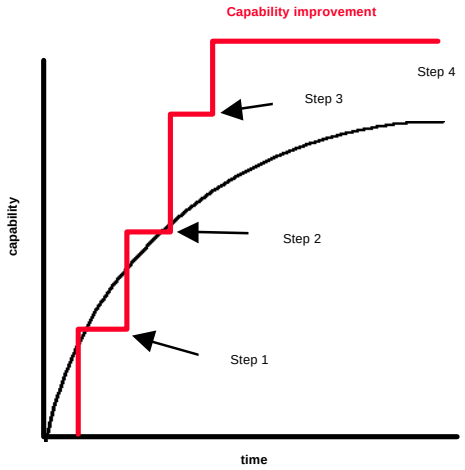
- Research will be started independently in each area, but results will be brought together throughout the program
- All results will be provided to other IA&S programs and the IA community
- All areas should produce transitionable technologies for DoD & industry



Metric ('me-trik, noun)

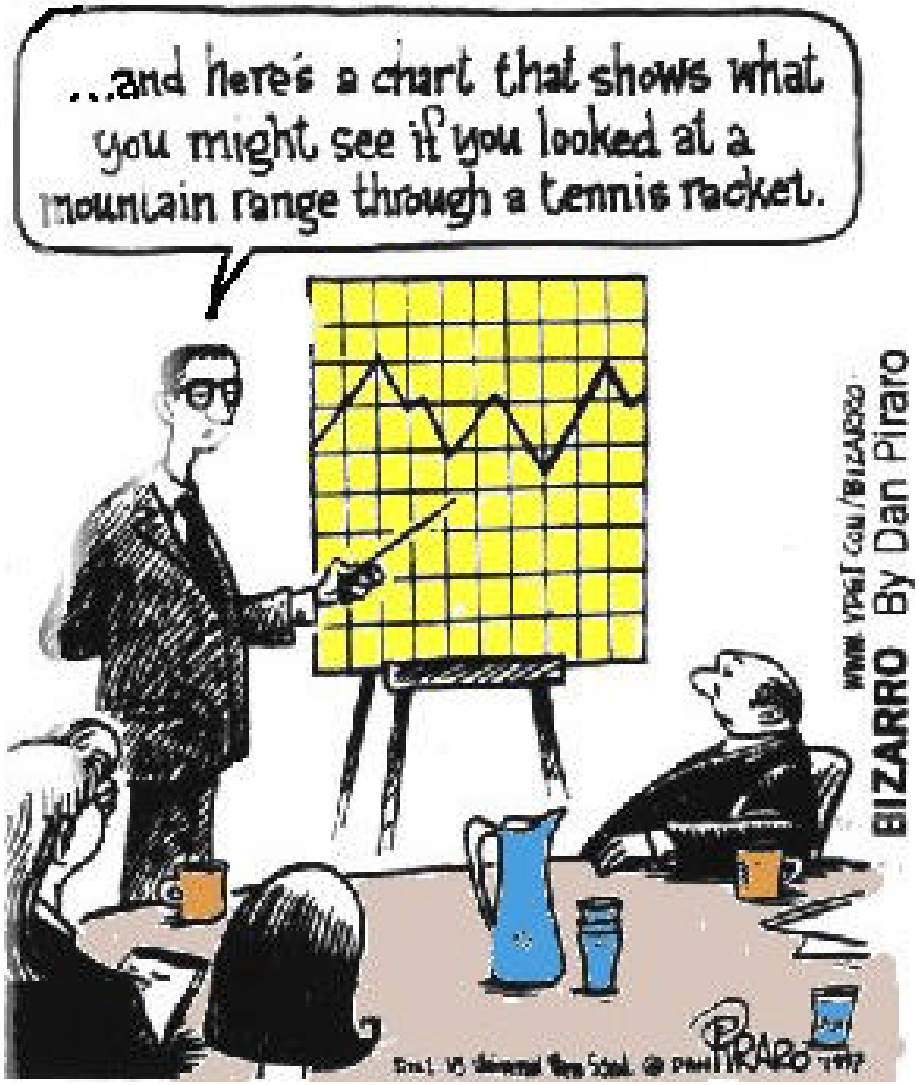
What do I mean by metric?

- simply, a standard of measurement
  - easy definition, hard to produce
- we wish to focus on metrics which have relevance to information assurance

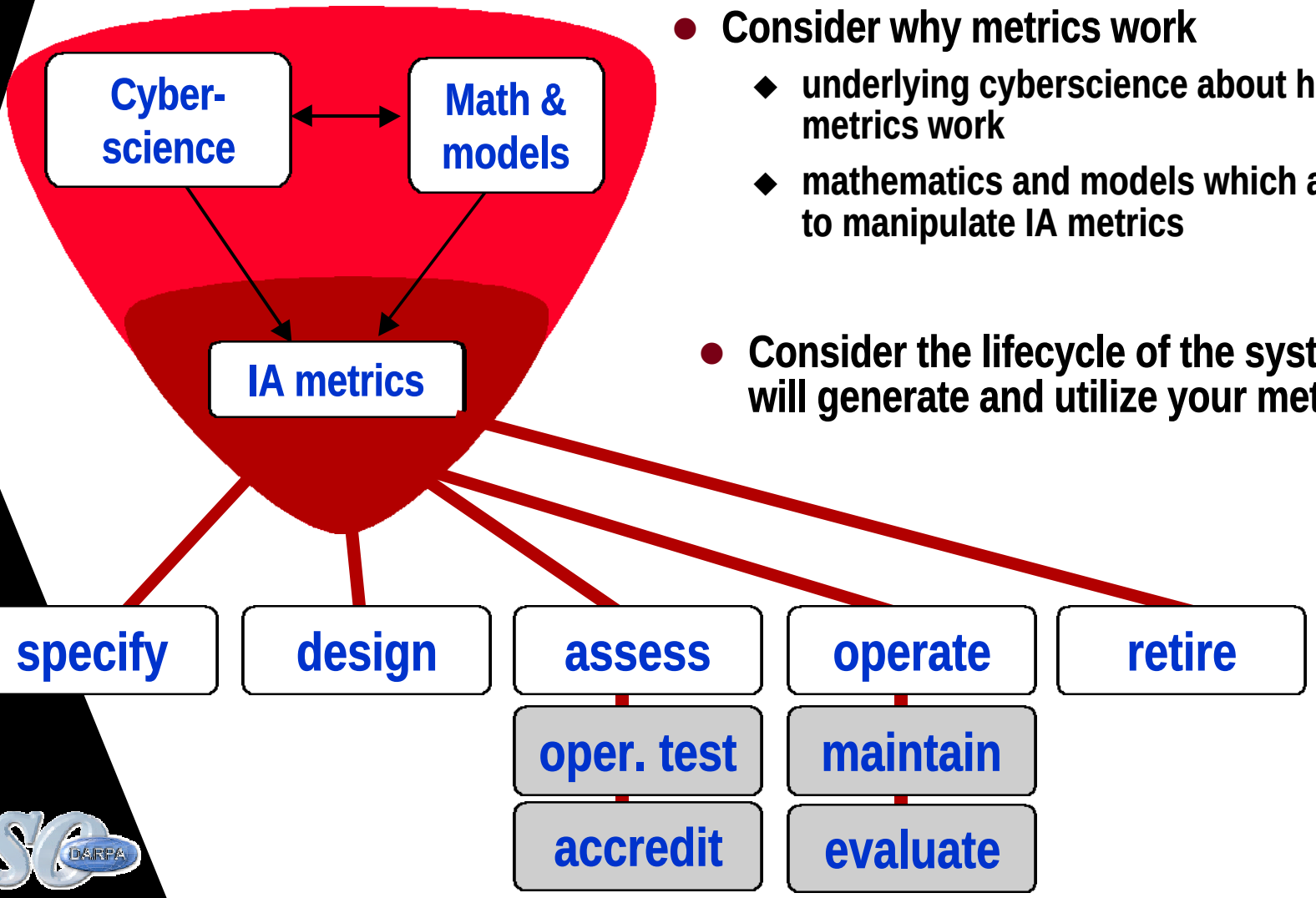


We don't understand the science of IA in systems
IA metrics

- **Utility of metrics**
  - identify those that are important for IA
  - must be useful to the end user or some intermediate process in understanding IA
  - understand how they relate to each other, are used in calculations, can be used to make decisions



Consider the needs for metrics before deciding which to use



- Consider why metrics work
  - underlying cyberscience about how IA metrics work
  - mathematics and models which are used to manipulate IA metrics
- Consider the lifecycle of the system that will generate and utilize your metrics

Who needs metrics?

- **R&D community** needs concrete goals
  - to compare competing approaches
  - to mark progress as a function of time
- **Vendors** want products certified and way to specify performance
- **Planners** need a way to specify requirements for design or procurement
- **Designers** need them to create better systems, and systems that meet requirements (in a systems and in-between systems)
- **Assessors** need ways to measure red team evaluations, compare to requirements, measure improvement
- **Testers / Accreditors** need specifications, benchmarks and reliable data from assessors
- **Commanders / Operators / Users** need to know how well they are protected
  - in the unique environment in which they are using a system
- **Regulators**
- **Intel Community**

What needs metrics?

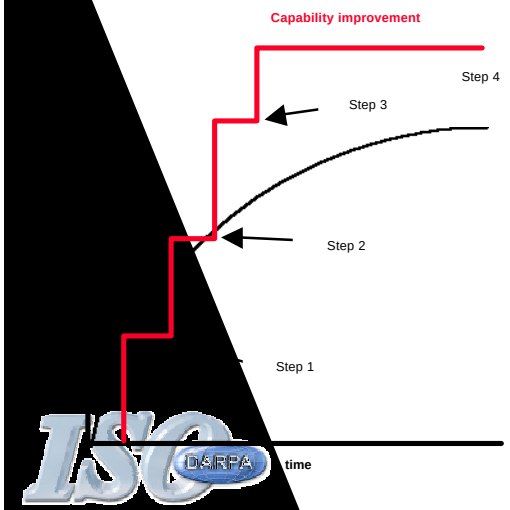
- **Design / production processes, tools**
  - design and assessment (IASET common environment)
- **Operational processes**
  - lifecycle: deployment, setup, operation, hardness surveillance and maintenance (HMHS), improvement
- **Decision processes, systems, tools**
  - Autonomic Information Assurance (AIA) program - reflexive defense against attacks
  - Cyber Command and Control (CC2) program - information for human-based decision
- **Analysis processes, tools**
  - strategic planning, future research, forensic, Intel

Select metrics for their utility

- Useful to meet goals of your system
  - design, assess, operation, improvement, ...
- Ease of measurement
- Ease of use (calculation, understanding, extensibility)
- Cost to obtain
- Quality:
  - precision (significant digits), uncertainty (in source)
  - consistency (between people), repeatability (over time)
- Are they relevant? (measure something we care about)
- Are they comprehensive? (measure all we care about)

We don't understand the science of IA in systems
IA metrics

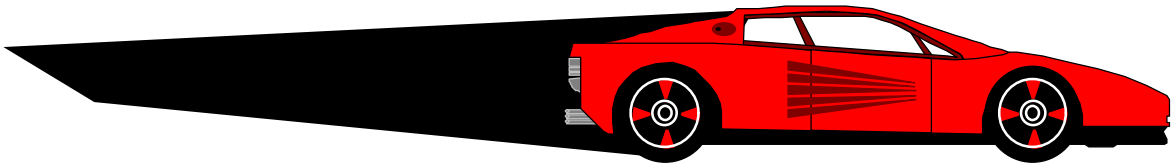
- **Qualitative**
  - not all measures can be reduced to numbers
  - need common frame of reference and language
  - need methods for correlation and extraction of information from qualitative metrics
  - benchmarks systems are needed



- **Quantitative**
  - measures should be science-based
  - need mathematical relationships to other metrics and the physical world

Metrics: direct vs. indirect measurement

- **We will often need to measure more detail than the user will requires to make a decision**



Speed?

- **Direct: speedometer**
  - **metric: v = 80 mph**

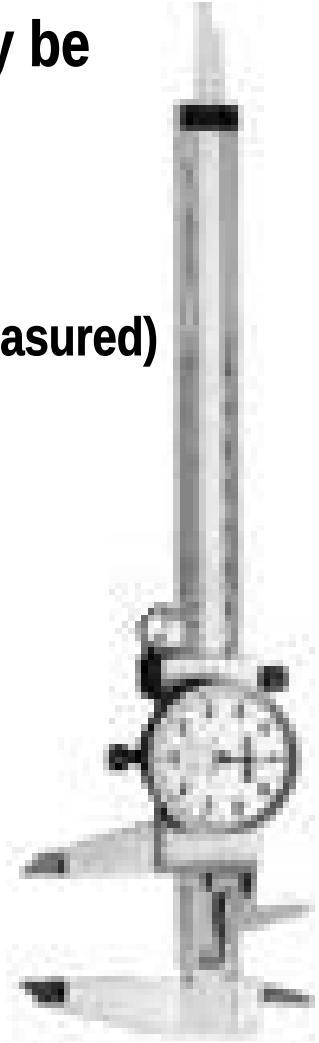
Hidden metrics:
- **rotation rate**
- **wheel size**

- **Indirect: calculation**
  - **metric: distance (d)**
  - **metric: time (t)**
  - **calculate:**

metric: v = d/t = 80 mph

Metrics: what are we measuring?

- **Consider that with a single measurement you may be obtaining more than a single quantity or value...**
  - **Value of metric (scalar, vector, concept)**
  - **Units of metric (meaning)**
  - **Related measures for metric (time, place, way it was measured)**
  - **Uncertainty related to measurement**



Assets Required

- To develop new metrics:
  - Good imagination, patience
  - Good understanding of information systems, IA requirements
  - Awareness of previous efforts in the field of metrics, and of the things people *want* to measure
    - Survey of metrics from other industries also relevant
- To estimate / measure metrics for a system:
  - Be able to do the analyses that produce a particular metric
    - May require a number of different skill sets
  - System design and functional requirements must be captured in an accessible format
  - Sometimes: need facility to actually simulate system or run a test.
    - Required to compute some metrics (e.g., Red Team)
    - Required to validate other metrics

Methodology for metrics

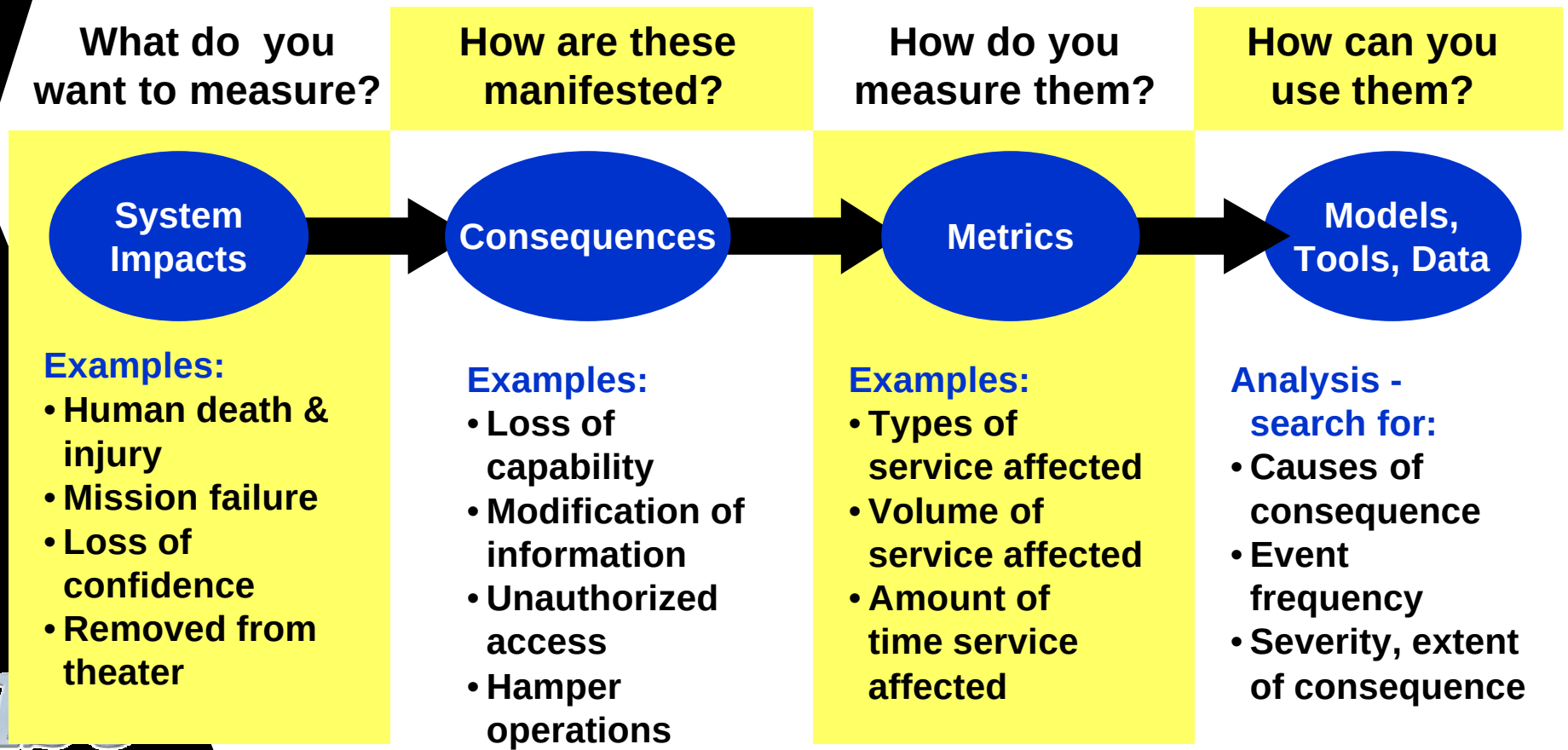
- e should have a ethodology or rocess to help us consistently understand how we might best generate metrics

awman methodology r steps to consider

1. Understand metric basics
   - How used, how relates to other things
2. Understand application, user, system
   - Expertise, players, users
3. What are objectives and goals that must be met?
4. What are observables of above?
5. How to quantify observables?
   - Quantitative/quantitative
   - Units, bounds, relationships
   - Nature - binary, analog, range, choices…
6. How to measure metrics?
   - Methods, certainty, error bounds
   - Repeatability

Methodology for metrics

- ere's an example framework for how you could generate metrics, and o further by considering how they will be used



Methodology for metrics

- Other frameworks that may be of use
  - Physical access analogy
    - protect, detect, delay, react, impact
  - System objectives
    - access control, integrity, availability, utility, safety, non-repudiation
  - System state
    - architecture, transactions, state changes, information flow, interfaces
  - Views of the “universe”
    - spatial, logical, temporal, lifecycle, system

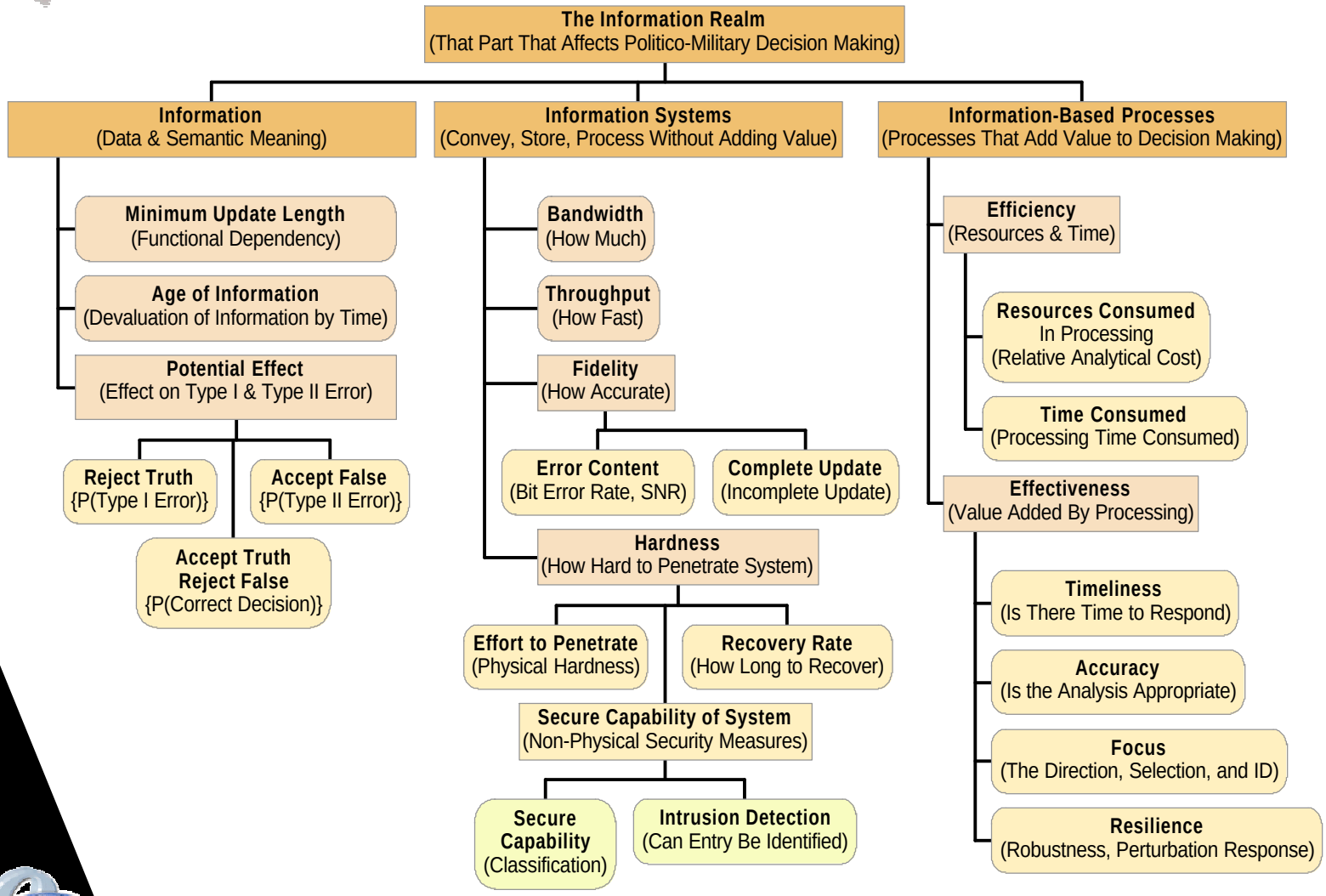
Metrics: example from AFIT*

- **Value Driven Measures of Merit for Offensive Information Operations, *Dr. Richard F. Deckro, et al.***

Constructed Definitions for Each Element of the Information Realm	
Information	Data and semantic meaning
Information System	Conveyance, storage, or processing that does not add value with respect to decision making
Information-based Process	Any process that adds value with respect to decision making

***AFIT CENTER FOR MODELING SIMULATION & ANALYSIS**

Metrics: example from AFIT

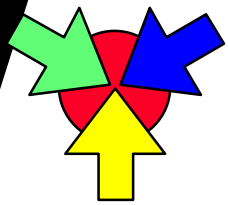


Metrics: example from AFIT

DEFINED OBJECTIVE	MEASURE UNIT	MEASURE TYPE	LOWER BOUND	UPPER BOUND
Increase Minimum Update	Level of support required to maintain awareness level	Category	User-level	Maintenance-level
Likely Accept False	Level of expected effect on adversary decision making	Probability	No Change	High probability
Increase Error Content	Percentage Error Content on System	Percentage	0	100
Penetrate System	Level of defeat effected	Category	No Capability	Completely Defeat
Increase Recovery Time	Change Cycles Over Which System is Unable to Perform Mission	Quantity	0	5
Defeat Security	Likelihood of Gaining Access to System	Category	No Change	High Probability
Defeat Detection	Our Expected Ability to Defeat the Adversary's Intrusion Detection	Category	Certain Detection	Low Likelihood of Detection
Consume Essential Resources	Percentage of Essential Resources Consumed	Percentage	0	100
Reduce Timeliness	Number of Change Cycles that the Processed Product is Late	Quantity	0	3
uce Resilience	Expected Ability to Reduce Resilience	Category	No Change	Catastrophic Failure
nize ral Damage	Expected level of Collateral Damage	Percentage	0	1

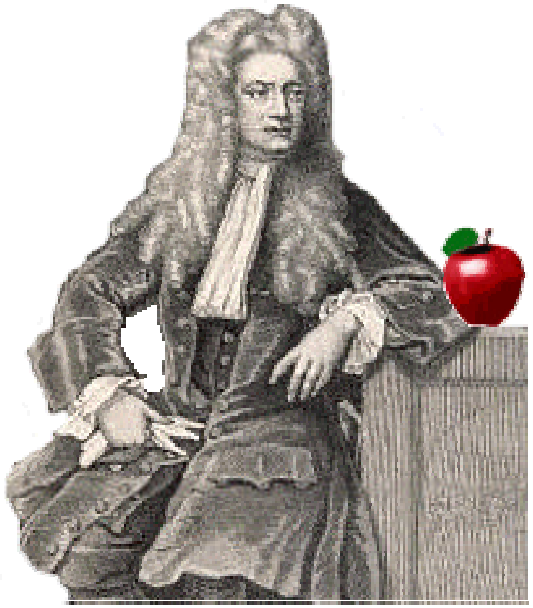
Success Criteria (When are we "done" creating metrics?)

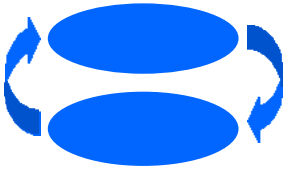
- **Evident utility (each metric "means something")**
- **Wide adoption**
- **A good *set* of metrics should be complete enough to cover all important IA aspects of a system**

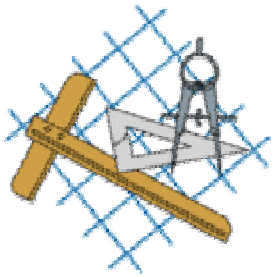


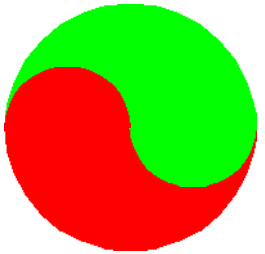
$$\sum_{i=0}^{n} IA_i$$

Questions?









Back-ups

IA Science & Engineering tools description - overview

- **Program components**
  - ***Cyberscience***
    - We don't understand the science of IA in systems
  - ***IA Engineering***
    - We don't know how to design and assess IA in systems
  - ***Malicious Code Mitigation***
    - We are increasingly vulnerable to effects of malicious code
- **Hypotheses:**
  - Science and scientific methods applied in an environment for design and assessment will yield stronger system Information Assurance, faster design for less cost
  - Successful research approaches for Malicious Code Mitigation are now feasible due to foundational DARPA IS/IA research; we must continue IA science-based research to crack the problem

IA Science & Engineering tools rational for program

- **Primary concerns**
  - Information system users, designers, and assessors have no:
    - meaningful measure of system vulnerability, risk, assurance level
    - formal, repeatable methods for design, assessment, and specification of IA
    - ability to understand, identify, and mitigate effects of malicious code
- **Weak areas**
  - no understanding of the cyberscience which underlies the systems that are currently being created
  - few and inconsistent measures of IA
  - same mistakes made decades ago continue to show up in current systems
  - malicious code problem is increasing due to threat and rapid adoption of insecure technologies

National security impact

- **Information systems present an asymmetric risk**
- **Complexity and connectivity (Internet, mobile code, etc.) is increasing**
- **Military and civilian information systems rely on COTS**
- **COTS currently have little incentive to include IA**
- **Design, assessment and user understanding of IA is not keeping pace with information technologies**

Metrics: qualitative

- **Qualitative metrics need frame of reference / definitions**
  - **promotes consistency between generators of metrics**
  - **promotes repeatability of metrics over time**
  - **provides understanding to others about what metrics mean**

Example:

Percent attack complete (red team attack scenario)

value	*meaning*
10	**conceptual** attack, no analysis performed
20	**preliminary** attack, minimal analysis performed
30	**initial** attack, moderate analysis, possibly some data not reviewed
40	**developed** attack, moderate analysis, most to all available data reviewed
50	**well developed** attack, moderate analysis, consider high-level contingencies
60	**detailed** attack, relatively complete analysis, many details considered
70	**finely detailed** attack, relatively complete analysis, fine details considered
80	**validated** attack, well developed, peer reviewed, gaming or role playing used
90	**simulated** attack, well developed, simulated through computer code or mockup
100	**tested** attack, physically tried the attack through field test or real thing

Level of Abstraction -- Bounds

- **Includes:**
  - **Confidentiality, integrity, availability, authentication, non-repudiation, etc.**
  - **Aggregation of "small" measures**
    - **Component metrics ==> system metrics**
    - **Dissimilar metrics ==> overall "utility" score**
  - **Support of trending (consistency over time)**
- **Different metrics for different parts of a product lifecycle (design, operations, analysis, etc.)**
- **Excludes:**
  - **Considerations that are not IA-related (e.g., environmental conditions, cost, "functional" metrics) as they are the responsibility of others.**

Methodological Hierarchy

- **What's "Above" Metrics -- Who Uses Metrics**
  - **Risk analysis, Decision Theory**
  - **Design process; composition**
  - **Specifications/Requirements (to the extent that they do not specifically call out metrics)**
- **What's "Below" Metrics -- Who "Measures" or "Estimates" Metrics**
  - **Red teaming ("measures" the metrics)**
  - **Test & Evaluation; Simulation; Vulnerability analysis**

Preconditions & Assumptions to Identification & Use of Metrics

- **For developing new metrics: ???**
- **For the use of metrics: *Given* a "toolbox" of relevant metrics, I need to know:**
  - **What do I care about in the system? (so I know which metrics to select)**
  - **Where are the "bounds" on the system? (so I know where to compute those metrics)**

Metrics to be Considered / Used (What Makes a Good Metric?)

- **Quality of Metrics includes:**
  - **Metrics are computable within a time frame that is useful to decision makers**
  - **Makes intuitive sense (don't fail the giggle test)**
  - **Repeatability / Consistency**
  - **Really measures what you think it measures**

Metrics

- **Aggregation**
  - **Composite metrics aggregate simple (basic) metrics.**
  - **Values for weights in aggregation vary by customer -- elicitation of these is a social science task that needs research**
  - **Mathematics of aggregation may need some research**