Physics, Physicists and Revolutionary Capabilities for the Intelligence Community

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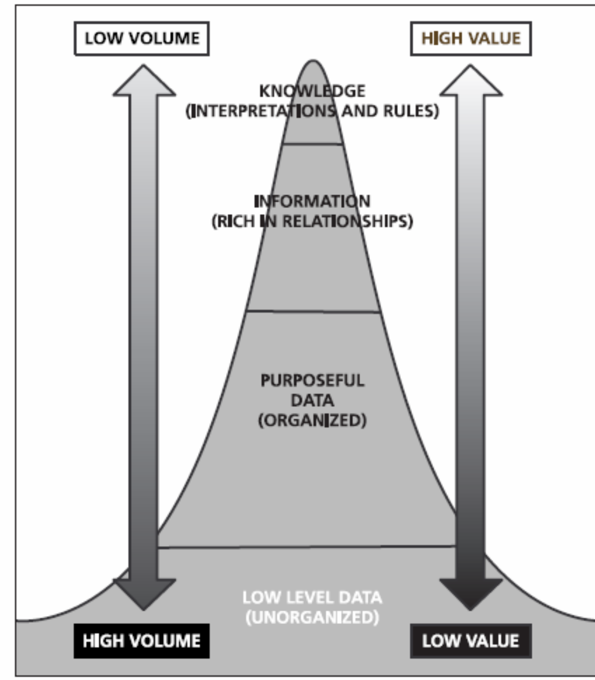
The Three Strategic Thrusts of IARPA

- **Smart Collection**: dramatically improve the value of collected data
  - Innovative modeling and analysis approaches to identify where to look and what to collect
  - Novel approaches to access
- **Incisive Analysis**: maximizing insight from the information we collect, in a timely fashion
  - Advanced tools and techniques that will enable effective use of large volumes of multiple and disparate sources of information
  - Innovative approaches (e.g., using virtual worlds, shared workspaces) that dramatically improve the productivity of analysts
  - Methods that incorporate socio-cultural and linguistic factors into the analytic process
- **Safe and Secure Operations**: countering new capabilities of our adversaries that could threaten our ability to operate effectively in a networked world
  - Cybersecurity, with a focus on future vulnerabilities
  - Quantum information science and technology



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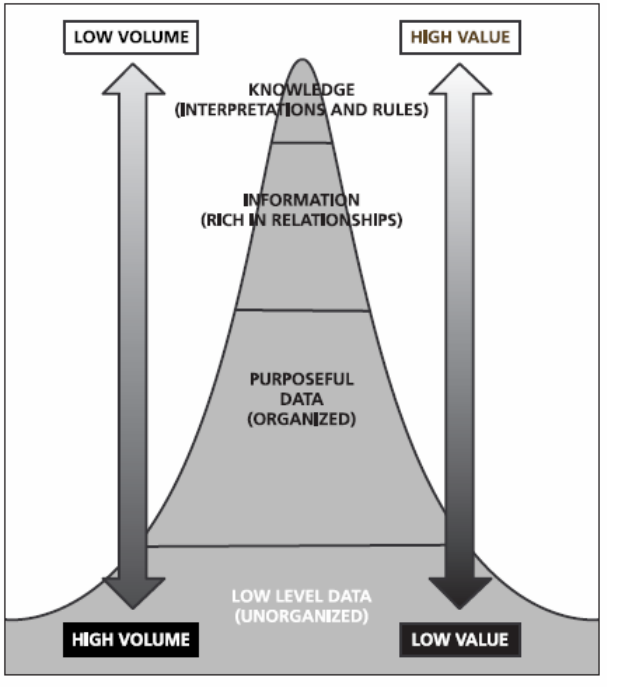

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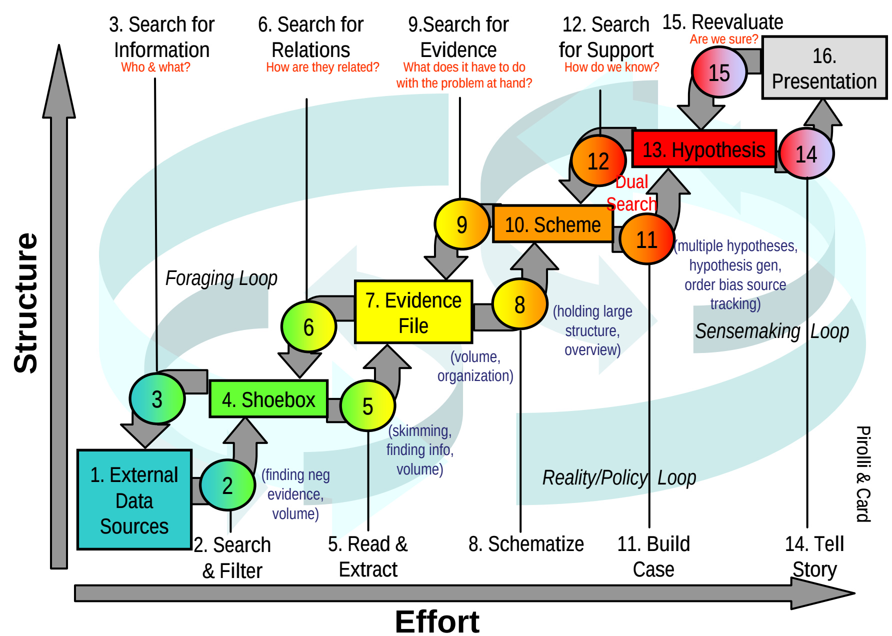
The “Obvious” Need for Physics

- Novel Sensors/Collectors
  - Modalities (e.g., acoustic, chemical, optical, RF, etc)
  - Size, weight, and power
  - Emplacement
  - Exfil of data

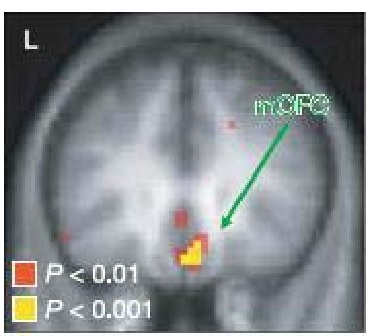
- Quantum Information Science
  - 1994: Shor’s algorithm
  - 1995-96: Shor and colleagues: QEC
  - Steady progress in basic understanding and operation of many different kinds of qubits since
  - Challenges as we move beyond 1-3 qubits include:
    - Controllable qubit interactions
    - Miniaturization and integration to increase qubit density
    - New physics arising from the assembly of many-qubit systems
    - Process and state validation for larger systems

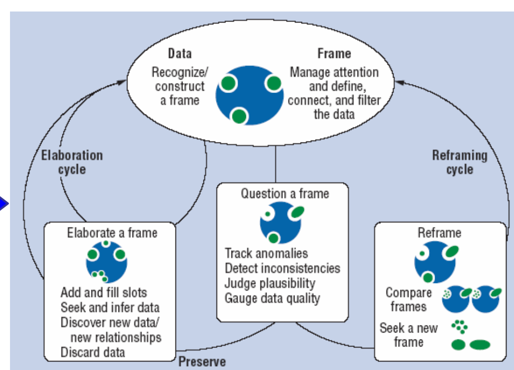
The "Not-So-Obvious" Need for Physics: Incisive Analysis

- **Understanding and Improving the Analytic Process**
  - Computational cognitive models of the analysis process that bridge the gap between neurobiological "first principles" models and psychological "macro models"
- This would enable
  - Prediction of effects of various analysis techniques
  - New strategies for mitigating human failure modes
  - Identification of the impact of individual cognitive traits on analytic style and performance
  - Development of automated sense-making tools to assist human analysts
- **What lessons can we bring to this challenge from multi-scale modeling in physics disciplines? E.g.,**
  - CFD: DNS to RANS
  - Materials: Ab initio to Continuum Mechanics



Most understood **Least understood**





Sensemaking loop

- Higher-level cognition
- Relational processing
- Model learning
- Hypothesis generation/testing
- Top-down attention

The "Not-So-Obvious" Need for Physics: Incisive Analysis

- Estimation and Communication of Uncertainty and Risk
  - Sources of Uncertainty
    - Sensors/detectors with multiple modalities
    - Fusing huge volumes of data that are in multiple formats, languages
    - Cultural models; human models
    - Intentional errors
  - What can we leverage from Uncertainty Quantification methods?
    - Aleatory (inherent variability with sufficient data) vs Epistemic (uncertainty from lack of knowledge)
- Experimental Design & Validation of Results
  - Scientific method: Experimental results should be repeatable
    - Clearly stated hypotheses with transparent experimental design
  - Challenge of good statistics when dealing with human subjects
  - Ground truth for rare event modeling and human modeling
    - Standard approach is to "validate" with a handful of SMEs

The "Not-So-Obvious" Need for Physics: Cybersecurity

- The internet will soon be connected to all manner of devices, from environmental monitoring sensors to home appliances.
  - Very soon, the number of device-to-device communications will exceed human-centric communications.
  - Ultimately, the future internet could connect over a trillion devices.
  - The most common interface will not be the traditional computer.
  - Embedding the physical world into the cyberspace will result in many benefits, including remote real-time monitoring, enhanced routing for delivery services, just-in-time maintenance, demand-based servicing, etc.
  - But is also obviously introduces new and unexplored vulnerabilities.
- It will not be long before reliable access to the internet will be possible from almost anywhere in the world: "ubiquitous connectivity"
- Couple ubiquitous access with the possibility of storing all of one's information and tools in the network (the "cloud"):
  - The need to protect government and commercial (IP) information in the "cloud" will require usable and robust data encryption and privacy protection tools.

The "Not-So-Obvious" Need for Physics: Cybersecurity

- There are no fundamental laws or limits in this domain
  - There are no conservation laws.
  - There is no Shannon's Law equivalent or Carnot cycle equivalent.
- What is a secure system?
  - What are meaningful quantitative measures of security of a system?
  - Given 2 systems, are there meaningful ways to compare their security?
  - What does "more secure" mean?
- Are there a finite number of attack classes?
- Given a System P and an attack class A, is there a way to:
  - Prove that P is not vulnerable to any attack in A?
  - Construct a system P' that behaves similarly to P except is not vulnerable to any attack in A?
- Can we reason about composed systems such that the security properties of compositions can be derived from the properties of their components?
- The push-back:
  - The predictive power of physical science is too high a standard.
  - Physicists do not have to contend with electrons as antagonists that may want to hide their true behaviors or intent.

Concluding Thoughts

- Physicists will continue to play a critical role in advancing our nation's intelligence capabilities in the "obvious" ways, in areas ranging from novel sensors to quantum information science.
- However, there are many ways that physicists can impact other challenge areas by bringing their methodologies and approaches to bear on the problems. Examples include:
  - Understanding and Improving the Analytic Process
  - Dealing with Uncertainties
  - Validation and Experimental design
  - Cybersecurity
- True multidisciplinary approaches will be key.
- How to find out more about IARPA: www.iarpa.gov