Network-centric Biomedicine:
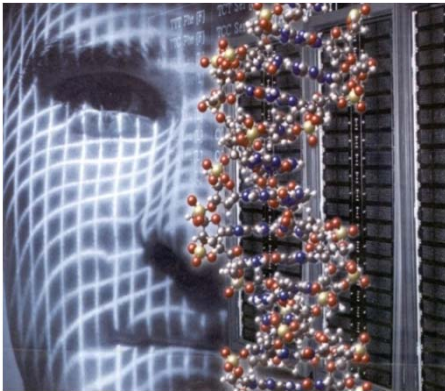## re-engineering the Knowledge Enterprise

Ken Buetow, Ph.D.

**Director Computational Science and Informatics Core Program,
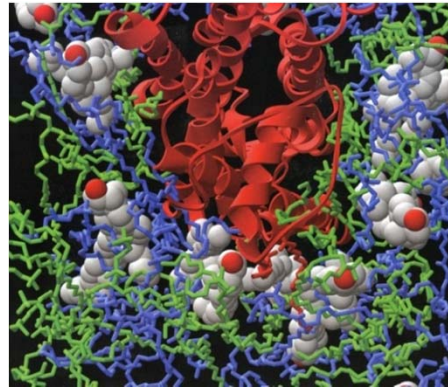Complex Adaptive Systems Initiative
Arizona State University**

**Bio IT World
2012**

Determinng The Molecular Basis of Disease:
The Intellectual Foundation of Rational Diagnosis and Treatment Selection
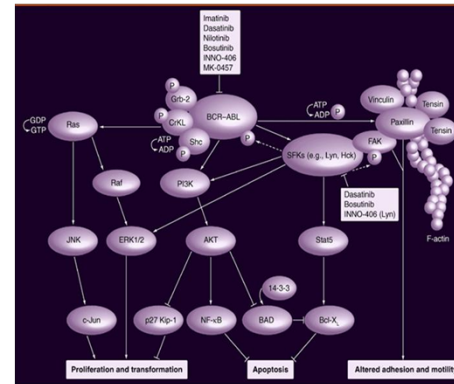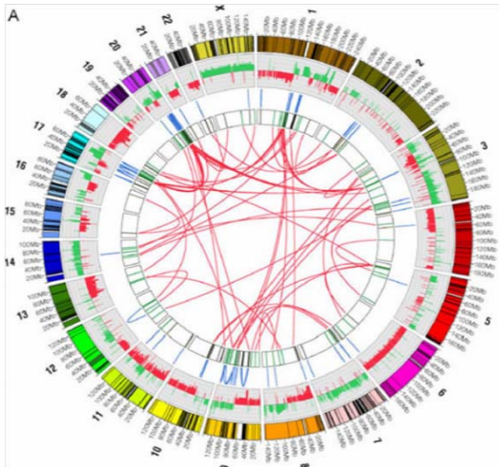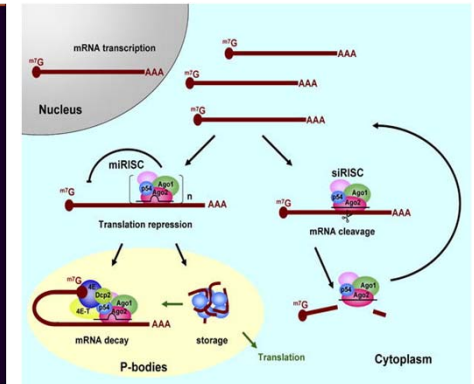

Genomics

Proteomics

Molecular Pathways and Networks

Network Regulatory Mechanisms

ID of Causal Relationships Between Network Perturbations and Disease

Patient-Specific Signals and Signatures of Disease or Predisposition to Disease

Courtesy G. Poste

Data are the life blood of biomedicine

- **Diverse types**
  - Clinical Observation
  - Clinical Laboratory
  - Imaging
  - Registry
  - Molecular Characterization
  - Biospecimens
  - Reference

- **Distributed sources**
  - Research Center
  - Care Delivery Setting
    - Hospital
    - Practice
    - Laboratory
  - Registry
  - Consumer
  - Industry

Generating "evidence"

Increasing "connectedness"

Knowledge ("evidence")

Understanding patterns

Information

Understanding relationships

Data

Increasing Understanding

From Bellinger et al, http://www.systems-thinking.org
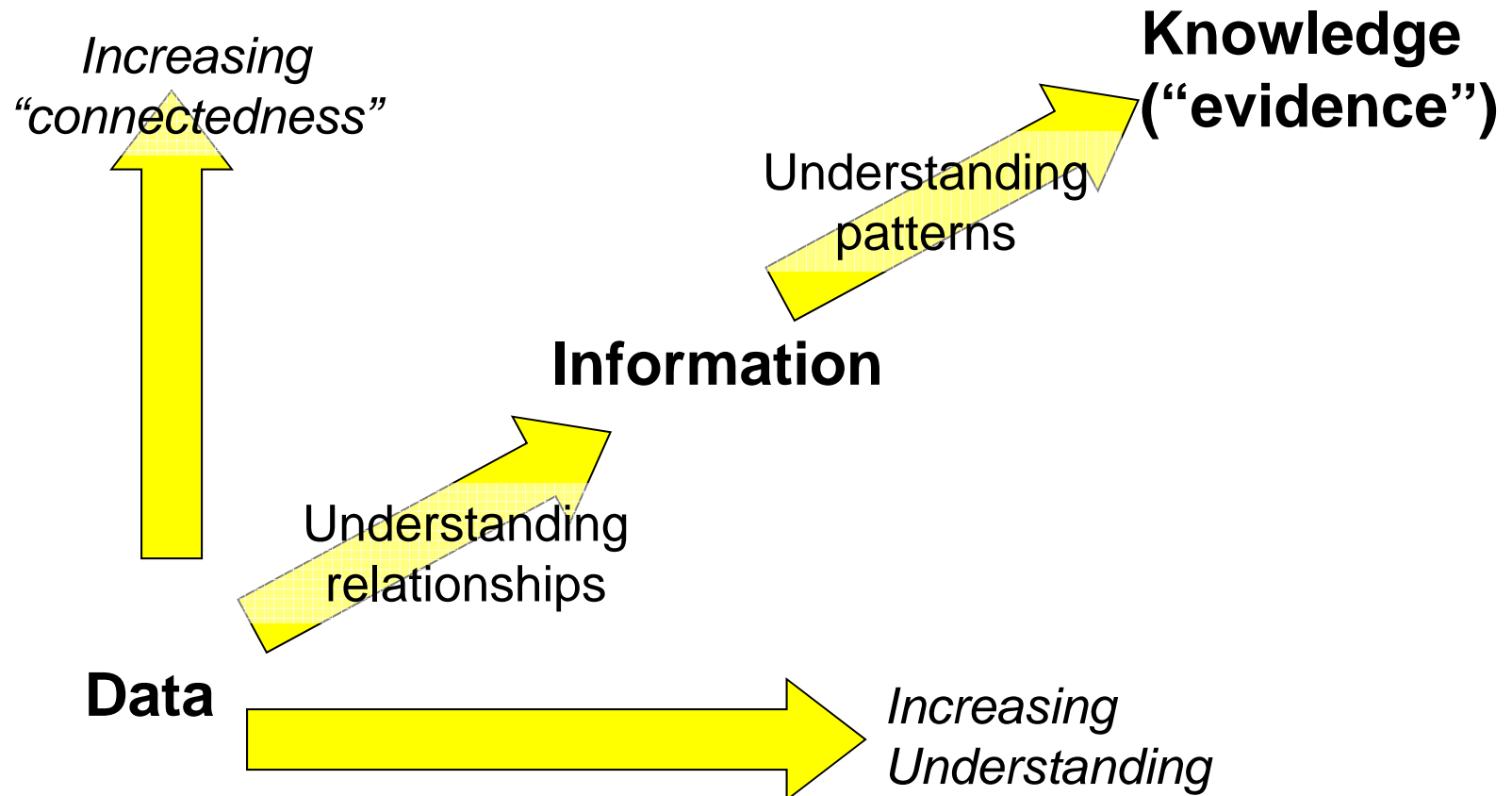
The Multiple Users and Complex Connectivities for Seamless Information Transfer in the HIT Ecosystem

ASU COMPLEX ADAPTIVE SYSTEMS INITIATIVE
ARIZONA STATE UNIVERSITY
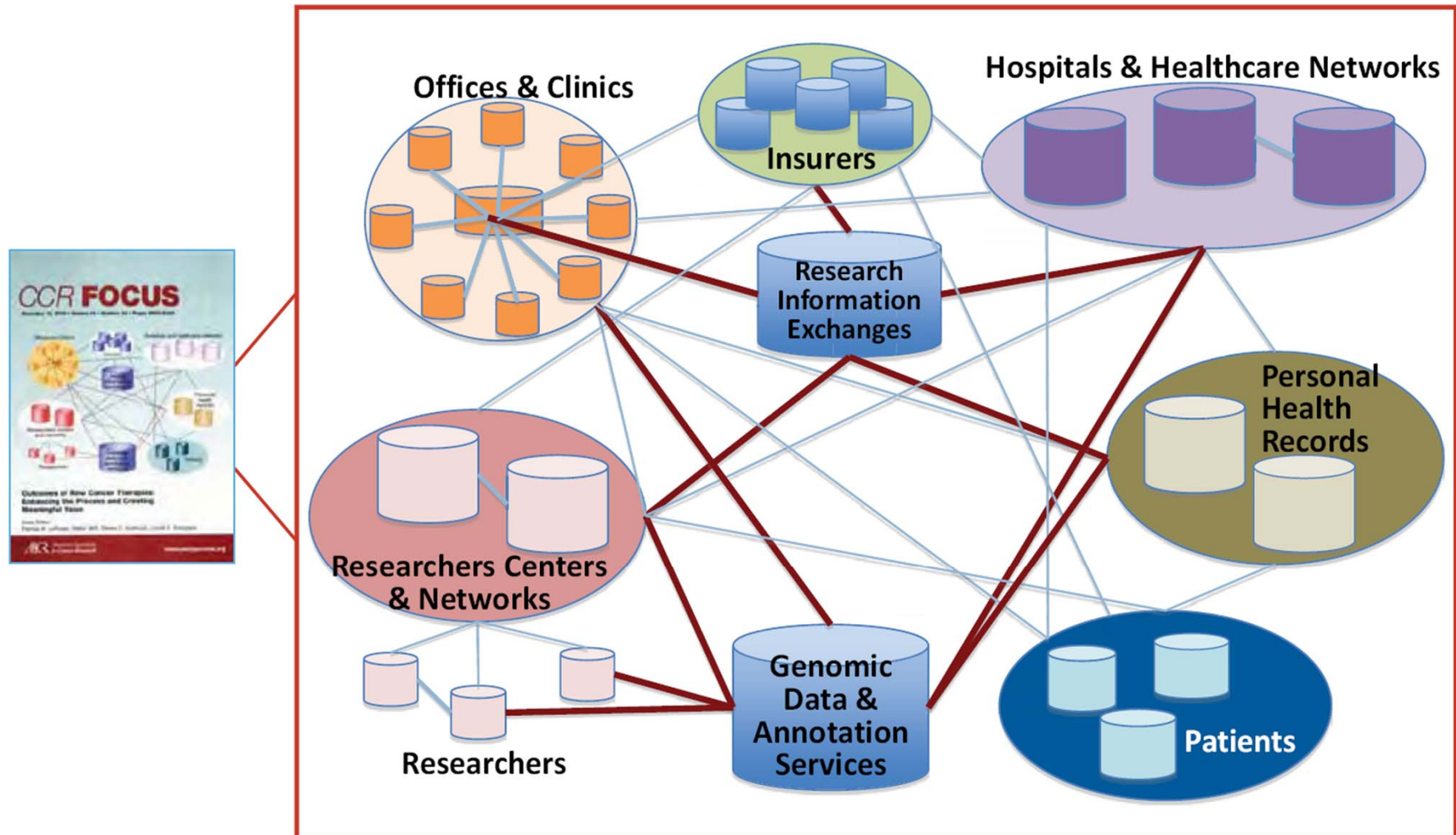
Biomedicine: "fallen and can't get up"

- Healthcare ecosystem is broken

- Poor understanding of the underlying biological complexity – current dominance of reductionist paradigm

- Vertically integrated development model (FIPCo) vs networked model (FIPNet) that dominates other sectors

- Exponential fragmentation of health information

- Impending "*Pharmageddon*"*: Declining R&D Productivity with Rising Costs

need to embrace biomedicine as *SYSTEM*

* from M. King Jolly, Pharm.D. Quintiles, Inc. **DIA 2011**

ASU COMPLEX ADAPTIVE SYSTEMS INITIATIVE
ARIZONA STATE UNIVERSITY

Biomedicine: a Complex Adaptive System
"the whole is more than the sum of the parts"

- Diverse stakeholders: multidimensional, interacting *"ecosystem"*
  - Industry, Academe, Government, **NGOs**
  - Physicians, Regulators, Researchers, **Payors, Consumers, Public Health Officials**
  - Biology, Chemistry, Medicine, Business, **Sociology, Anthropology**
- Adaptive behaviors (dynamic as opposed to static)
- Emergent properties (or unintended consequences)
- Interdependencies
  - Resourses
  - **Information**

Strategies for "Managing" Complexity

- **Networking**
  - **Differentiated functions** connected though well-defined **interfaces** – e.g.
    - Biologic processes
    - Manufacturing
- **Layering**
  - **Abstracted combinations of functions** into hierarchical/multidimensional strata which connect through well defined **interfaces** –e.g.
    - Quantum physics – Newtonian physics
    - Biologic complexity : cell, organism, society
   - Organizational hierarchies

Network-centric "warfare"

A **military doctrine or theory of war pioneered by the United States Department of Defense**. It seeks to translate an information advantage, enabled in part by information technology, into a competitive warfighting advantage through the **robust networking** of **well informed geographically dispersed forces**. This networking, combined with changes in technology, organization, processes, and people - may allow new forms of organizational behavior.

Specifically, the theory contains the following four tenets in its hypotheses:
- A robustly networked force **improves information sharing;**
- Information sharing **enhances the quality of information** and shared situational awareness;
- Shared situational awareness **enables collaboration** and **self-synchronization,** and **enhances sustainability** and speed of command; and
- These, in turn, dramatically **increase mission effectiveness.**

(Wikipedia)

BROADCAST
INTEL

SATCOM

JSWS
AOC/FOL
THEATER INTEL
FIGHTER BASES

VOICE

LINK 16

SCDL

CGS
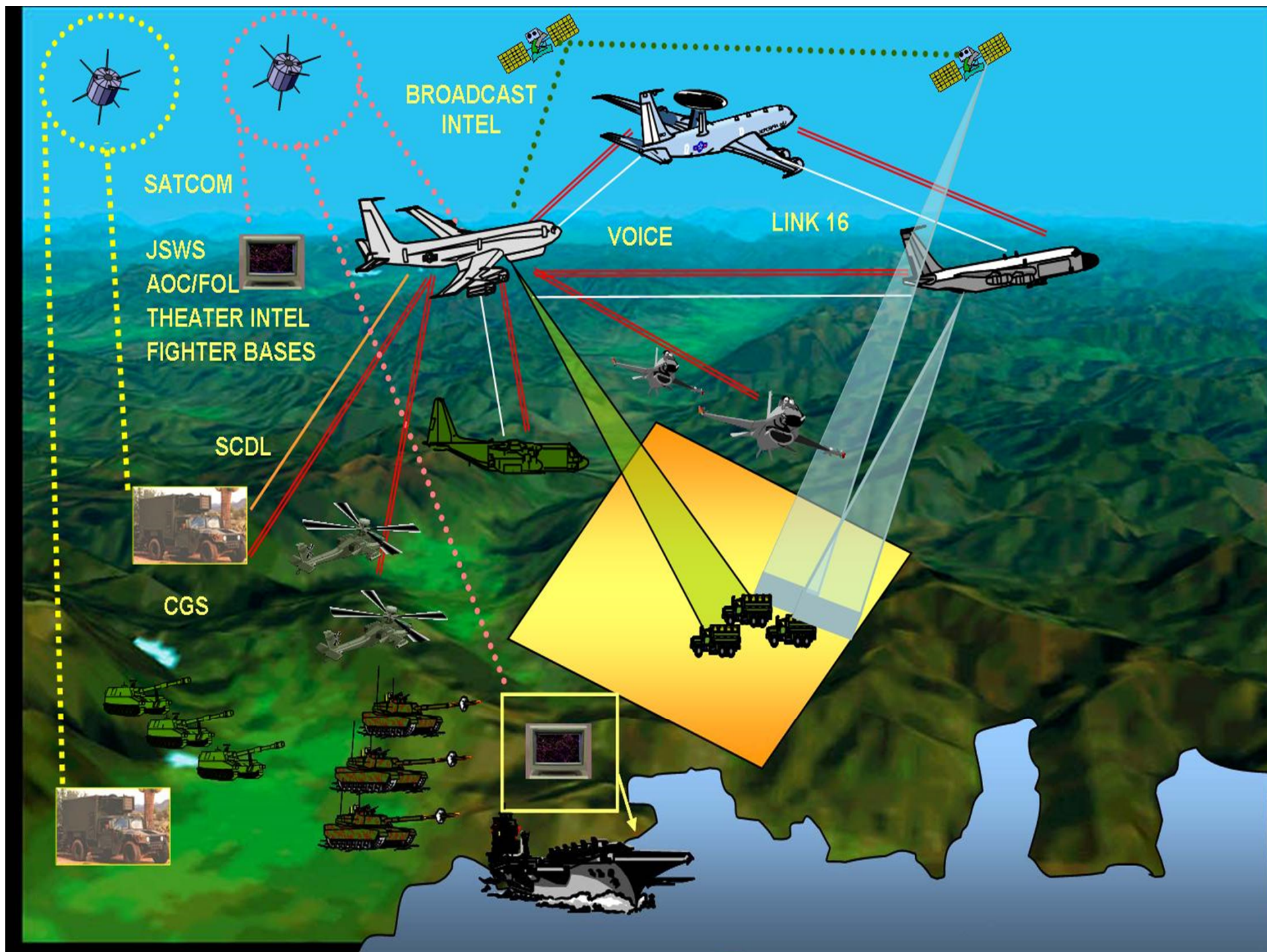
Applying CAS Principles to Facilitate Information Flow

- Define *modules* that address specific needs

- Connect *through "well-defined electronic interfaces"*

- *Semantic Interoperability*
  - Defined *syntax*
  - Defined *semantics*
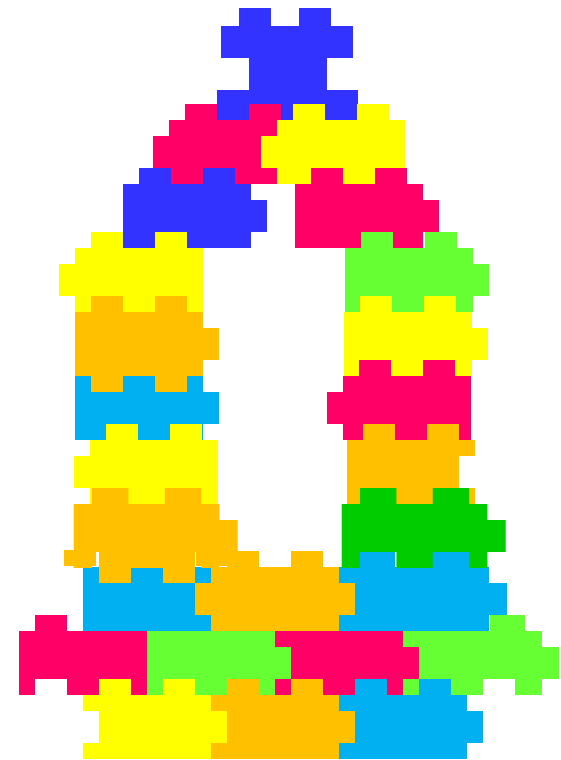
Complicating Considerations

- **Nature of Data**
  - "Data Validity": Garbage In- Garbage Out
  - Human Subjects Protections
  - Intellectual Property
- **Technical**
  - Secure access
  - Volume/Magnitude
  - Need for integration
    - Diverse Data
    - Multiple Source
  - Need for choreography
- **One size does not fit all**
  - Nature of the data to be accessed
  - The question one wants to answer

Continuum of need mediates the need for adding layers of complexity

Strategies for Addressing Complexity

- Diversity of APIs that support paradigms within given communities (expose multiple "flavors" where possible)
- Adding modules to address issues ONLY when necessary
- Federating Access: Data control remains local
- Escalating introduction of standards-based metadata
- Analytics go to the data/co-reside with the data
- Virtual Communities where access to individual level data is needed

A Biomedical Informatics Ecosystem

Analytical Tools

Biospecimens

Array Data

Clinical Trials

Research Unit

Research Center

Medical Center

Research Center

Medical Unit

Research Center

Research Center

Medical Center

Research Center

Medical Center

Common Data Elements

Security Service

Index Service

Vocabularies & Ontologies

Workflow Management Service

Federated Query Service

Information Models

Security

Advertisement / Discovery

Workflow

Federated Query

Metadata Management

Biomedical Knowledge Cloud
(Services Infrastructure)

Research Center

Research Unit

Medical Unit

Research Center

Medical Center

Research Center

Research Center

Medical Center

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Research Center

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Dorian GTS

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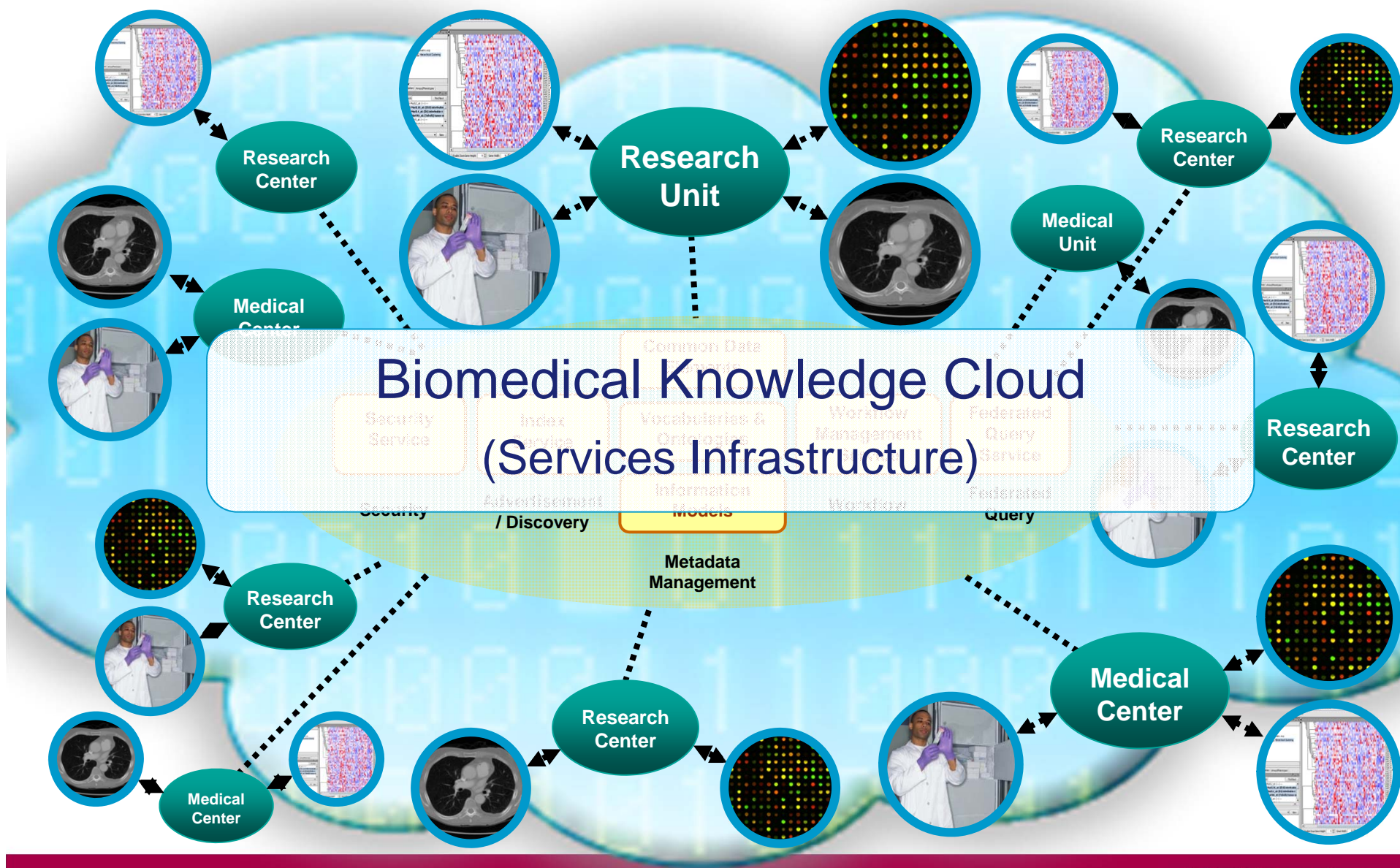
Models

Workflow

Federated Query

Metadata Management

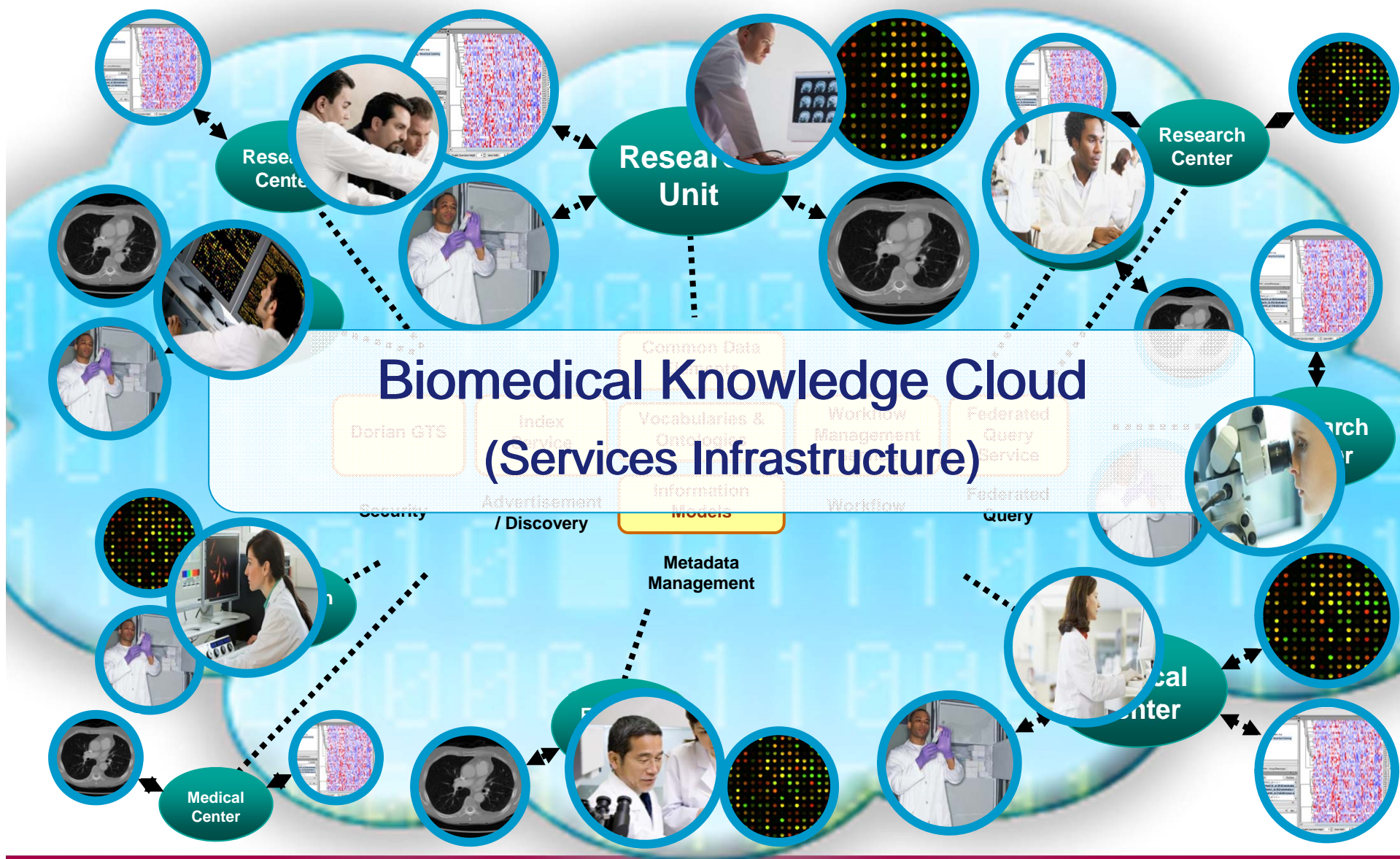Medical Center

Medical Center

How do we get there from here?

- Approach as **Ultra Large Scale Systems** problem
  - "**City planning**" as opposed to "**building architecture**"
    - "**Building codes**"
    - Over-arching **framework**
  - **Incremental**, problem-directed, implementation
  - Bias toward "**working code**"
- **Coalition of the Willing**
- **Policy** to address **regulated environment** and **cultural barriers**

Summary

- Approaching **Biomedicine as a Complex Adaptive System** may help address some of the challenges it currently faces

- **Information**, and as such Information Technology can serve as the glue to **connect the Ecosystem**

- It is **technically feasible** to create and deploy technology to exchange information within and between members of the ecosystem

- A **multi-stakeholder, multidimensional community** will be necessary to create a sustainable ecosystem