# Enabling Systems Engineering with an Integrated Approach to Knowledge Discovery and Architecture Framework

**Michael R. Collins**

**Advantage Development, Inc.**

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Phone: 216-570-8775
mcollins@advan-devel.com

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- **Engineering employs <u>analysis of function</u> to iteratively decompose and separate a primarily functional representation of a whole into representations of economically producible components that can be assembled to construct the functional whole.**

  - ♦ **Big implication here!  Engineering requires an "initial point" - a representation of the whole — to be successful!**
    **<u>Engineering does not work without an initial point!!</u>**

- **We refer to this "initial point" as:**

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### *<u>Engineerible Requirements</u>*
The set of *engineering requirements* necessary and sufficient to <u>initiate</u>
the successful engineering and production of a system

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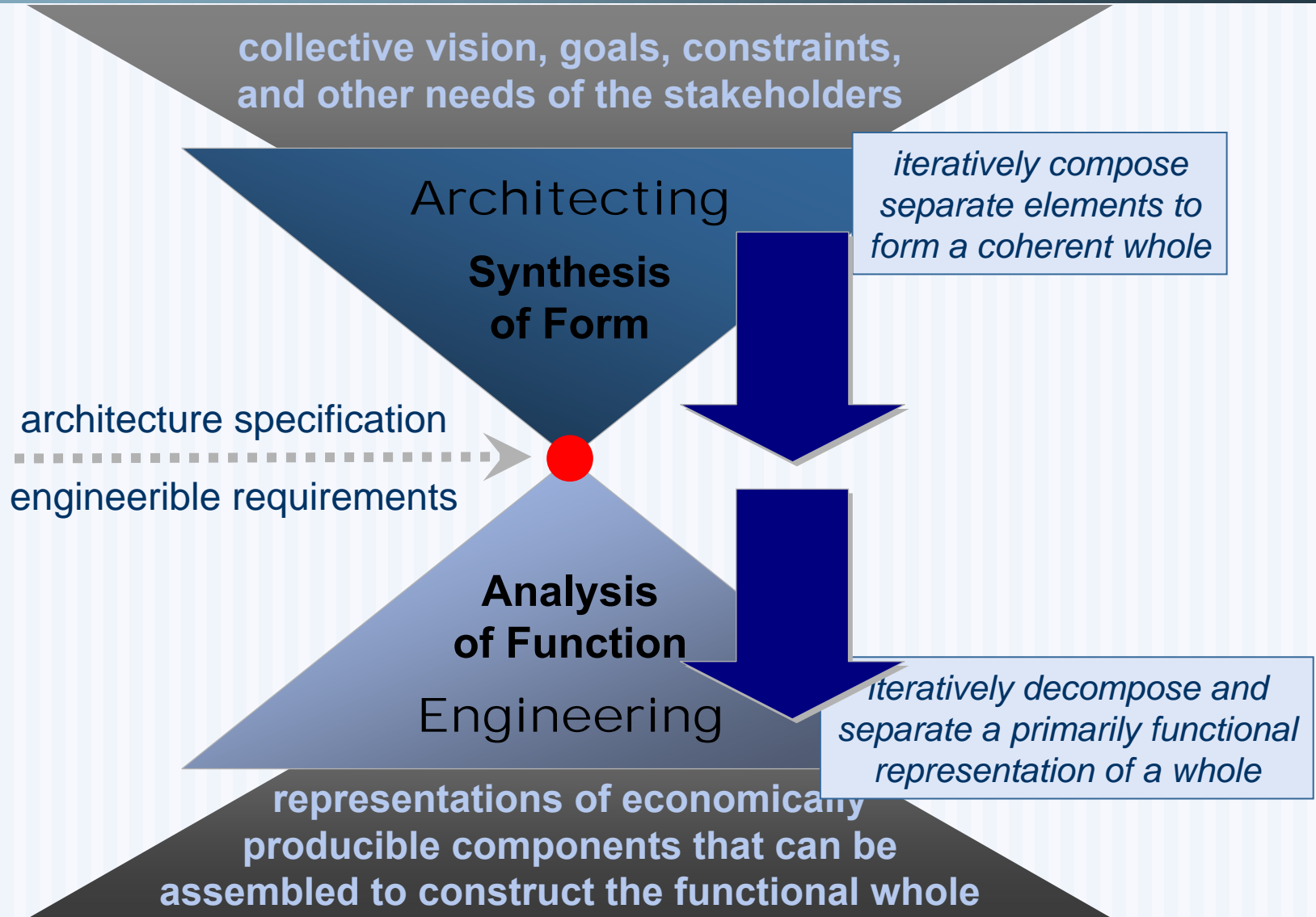*Brad Mercer, MITRE, Chief Architect Maritime IT and Engineering*

- **Architecting employs <u>synthesis of form</u> to iteratively compose separate elements to form a coherent whole, or a representation of a coherent whole, that can serve as an "initial point" for system development.**

- **Architecting synthesizes this "initial point" from the collective vision, goals, constraints, and other needs of the stakeholders in the to-be-developed system — converting conflicting stakeholder demands into a conceptualized whole that maximizes the satisfaction of each stakeholder.**

- **From the point of view of architecting, we refer to this "engineering initial point" as an:**

> ### *<u>Architecture Specification</u>*
> **An architecture description to which all system implementations must adhere; and a set of principles, practices, and constraints guiding implementation, operation, and evolution of the developed system**

*Brad Mercer, MITRE, Chief Architect Maritime IT and Engineering*

# Architecting and Engineering
# Different Sides of the Same Coin

collective vision, goals, constraints,
and other needs of the stakeholders

## Architecting

### Synthesis of Form

*iteratively compose separate elements to form a coherent whole*

architecture specification

engineerible requirements

### Analysis of Function

## Engineering

*iteratively decompose and separate a primarily functional representation of a whole*

representations of economically producible components that can be assembled to construct the functional whole

*Brad Mercer, MITRE, Chief Architect Maritime IT and Engineering*

ADVANTAGE DEVELOPMENT
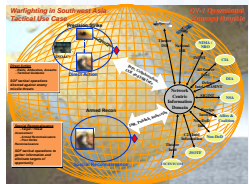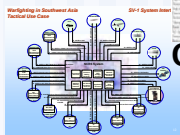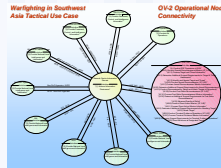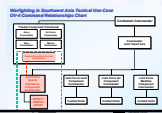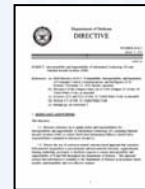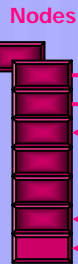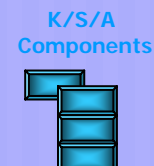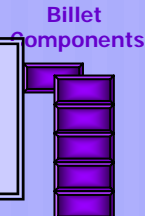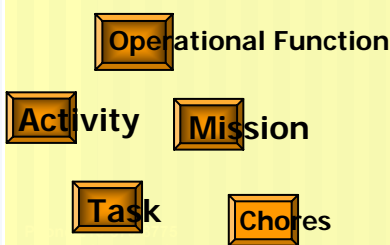
- **Complexity of data elements is overwhelming**
- **Difficult to support the book-keeping management of all of the data elements and their relationships across all the echelons of the Enterprise**
  - ♦ **'Structuring' complexity**
  - ♦ **'Echelon integration and enterprise description'– everything is a part of a larger system**
  - ♦ **Persistent, iterative, and evolutionary incorporation in a knowledge and reuse environment**

- *Every object, relationship and aggregation of objects in the knowledge metamodel* is in documents, the universe of textual models

- *Discovery* is about finding the objects, relationships, aggregations and descriptions of each of these in the authoritative and original data sources

- *Integration* is about using Discovery to build and describe the Architecture using an architecture meta-model

- **A concept, or theme, is the encapsulation of a pattern that is identified as a gestalt: a persistent and unique 'signature'**

- **Documents are textual patterns**

- **Models are labeled, structured patterns**

- **Labels are knowledge anchors to concepts and themes**

- **Knowledge is pattern recognition, association and application in integrated textual and model gestalts**

- **'Information' can be treated as quantifiable symbols in communications**
- **Natural language has a high degree of unessential content, the less frequently a unit of communication occurs, the more information it conveys**
- **Information objects extracted from Natural Language text form a *index unique to that concept***
- **The architecture metamodel is the syntactic of the knowledge pattern and is semantically rigorous**
- **Information objects cluster based upon an inference relationship measuring semantic completeness**

**Cluster the indexes of the information objects using Statistical Inference!**

**Example Cluster Picture from the Cartia: ThemeScape Web Site**

**Define the information objects and index them**

*Program Reporting Object #1*

*Program Reporting Object #N*

*Program Reporting Object #2*

*Program Reporting Object #R*

email

phone company

McKinsey Consulting

misnomers and myths

Info-Tech Research

VoIP (Voice-over-IP)

*Program Implementation Baseline*

"standard" phone lines

VoIP (Voice-over-IP)

Long distance call

legacy and low-end VoIP systems

de facto standard

**THE UNIVERSE OF DOCUMENTS CONTAINS THE INFORMATION OBJECTS THAT DESCRIBE THE IMPLEMENTATION BASELINE**
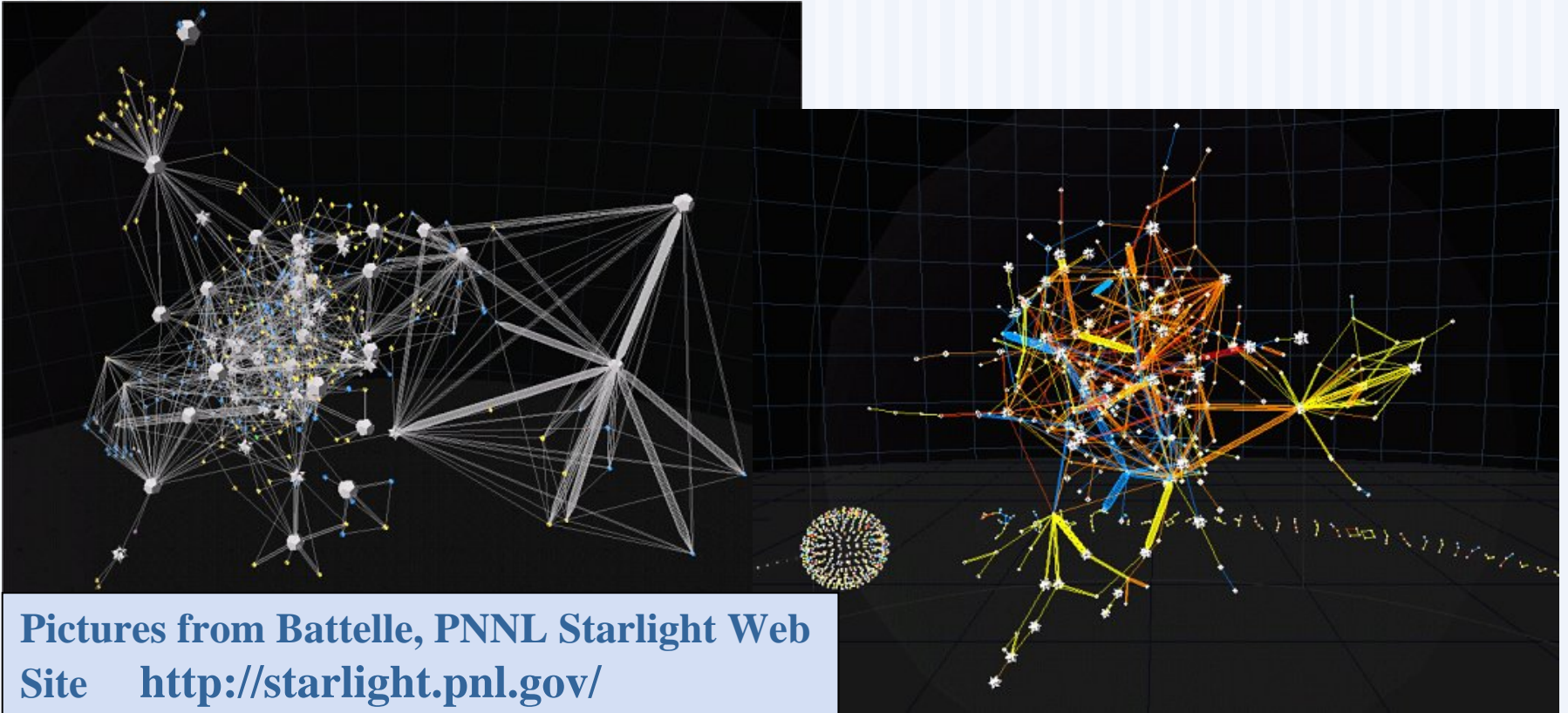
Pictures from Battelle, PNNL Starlight Web Site    http://starlight.pnl.gov/

Cluster and integrate using the architecture meta model

Visualization can take many forms presenting many perspectives.

Tracing of the models back to the authoritative and original data sources.

# DISCOVERY PROCESS
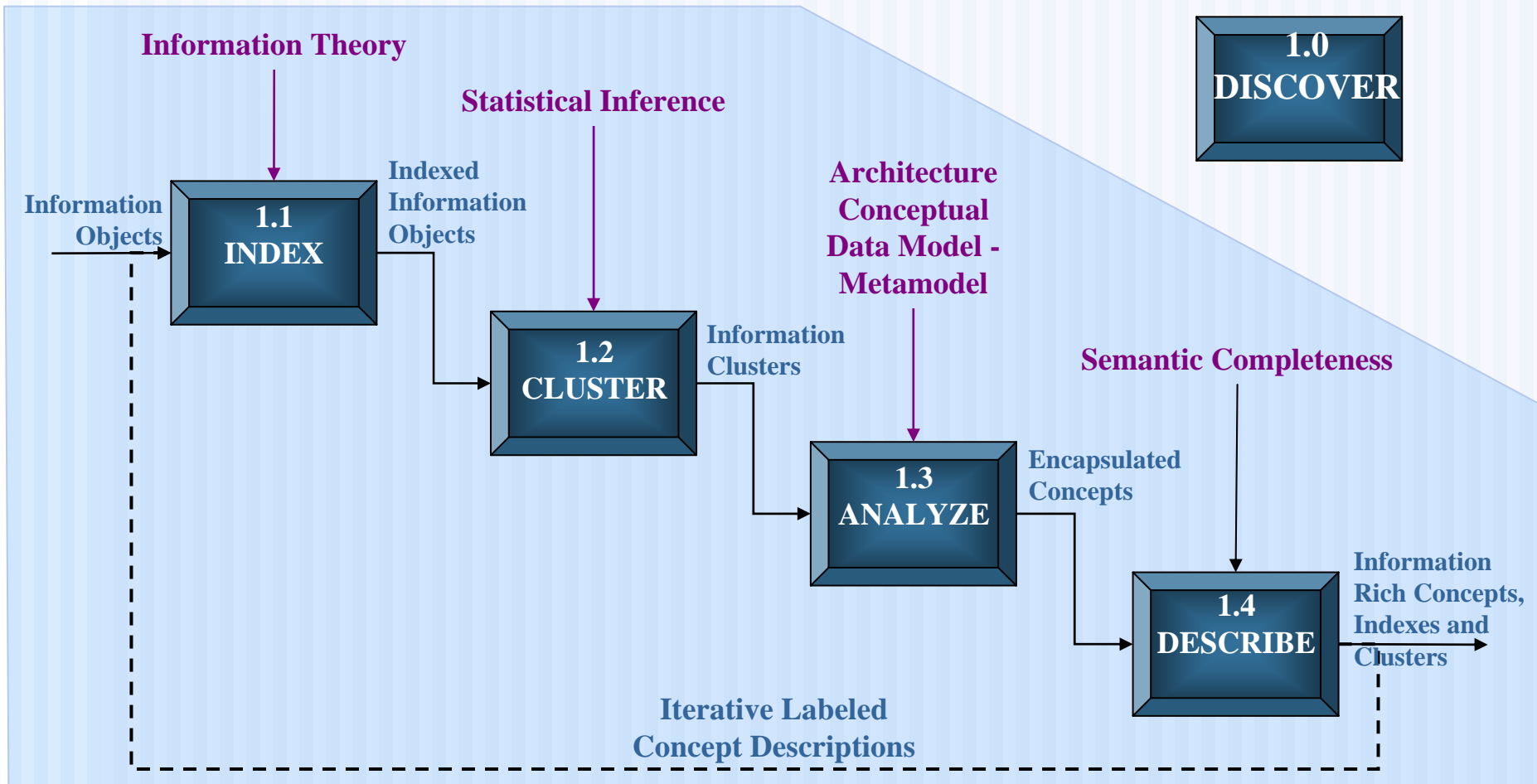
**Discovery works best when it has a pre-existent form upon which it can operate.**

- **Architecture is the *description* of the *intrinsic* relationships, characteristics and behaviors of the system under study**

    ♦ **All systems have an architecture ─ intentionally architected or not ─ and that architecture is a primary determinant of the system's behavior. Brad Mercer, MITRE Principal Architect**

    ♦ **Architecture *is* the model in Modeling and Simulation and a rigorous and well-constructed model can be executed**

- **Discovery: the process for identifying the conceptual syntactic of architecture and the rich semantics**

- **Present architecture efforts are neither semantically complete nor rich: they contain a series of model artifacts (products) built and limited to "*labeled*" components and relationships; it has no processes, only product templates**

- **Indexing and clustering builds initial identification and organization of labeled themes and concepts**
- **Clusters are labeled taxonomical elements**
- **Rich taxonomies can be developed from clusters**
  - ♦ **Structured and organized categorization of information**
  - ♦ **Syntactic and semantic descriptions**
  - ♦ **Parent – child relationships**
- **Labeled themes and concepts are the architecture primitives**

- **Topology in architectures relates to the connectedness of child – child with order of precedence and importance**

- **Information object references contain topological reference information useful in describing and identifying the syntactic and semantic elements**

- **The taxonomical and topological elements provide the structure and precedence of concepts and their references provide the content for specification**

**To be Persistent, the model must decompose to its fundamental components, its primitives.**

Diagram: A*1: Major Combat Operations  (Joint Operations Concept)  (FEO)

Force Protection
Force Application

Amphibious Assault

Conduct Planning (Orient)

OPORD Force Application Annex
OPORD Logistics Annex
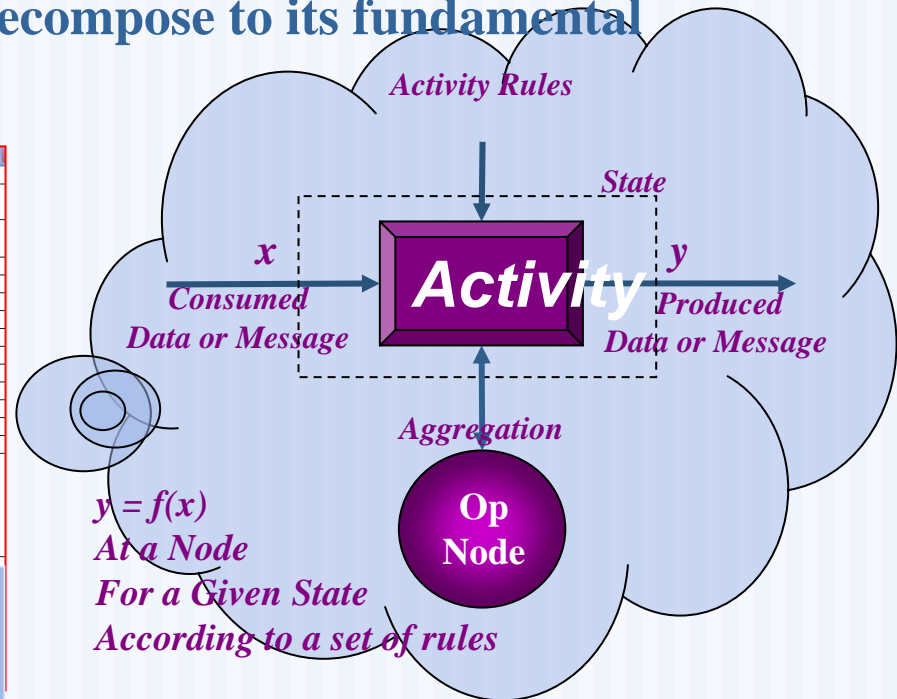OPORD Force Protection Annex
Fire Support Plan
Countermeasures Plan
EMCON Plan
Assault Support Plan
Air Support Plan
Air Defense Plan
COMSEC and OPSEC Plan
CONOPs
OPORD
Intelligence Preparation of the Battlespace and Updates
Intel Products Request
Intel Requirements Priorities
OPORD Intel Annex

A*11

SITREP Imagery
SITREP Message

**IDEF0 MODELS mix component information and concerns and are _a visualization standard, not a data standard_.**

*Activity Rules*

*State*

$x$
*Consumed Data or Message*

**Activity**

$y$
*Produced Data or Message*

*Aggregation*

**Op Node**

*y = f(x)*
*At a Node*
*For a Given State*
*According to a set of rules*

**To be Re-useable, the model must encapsulate its fundamental components, or primitives into re-useable Objects.**
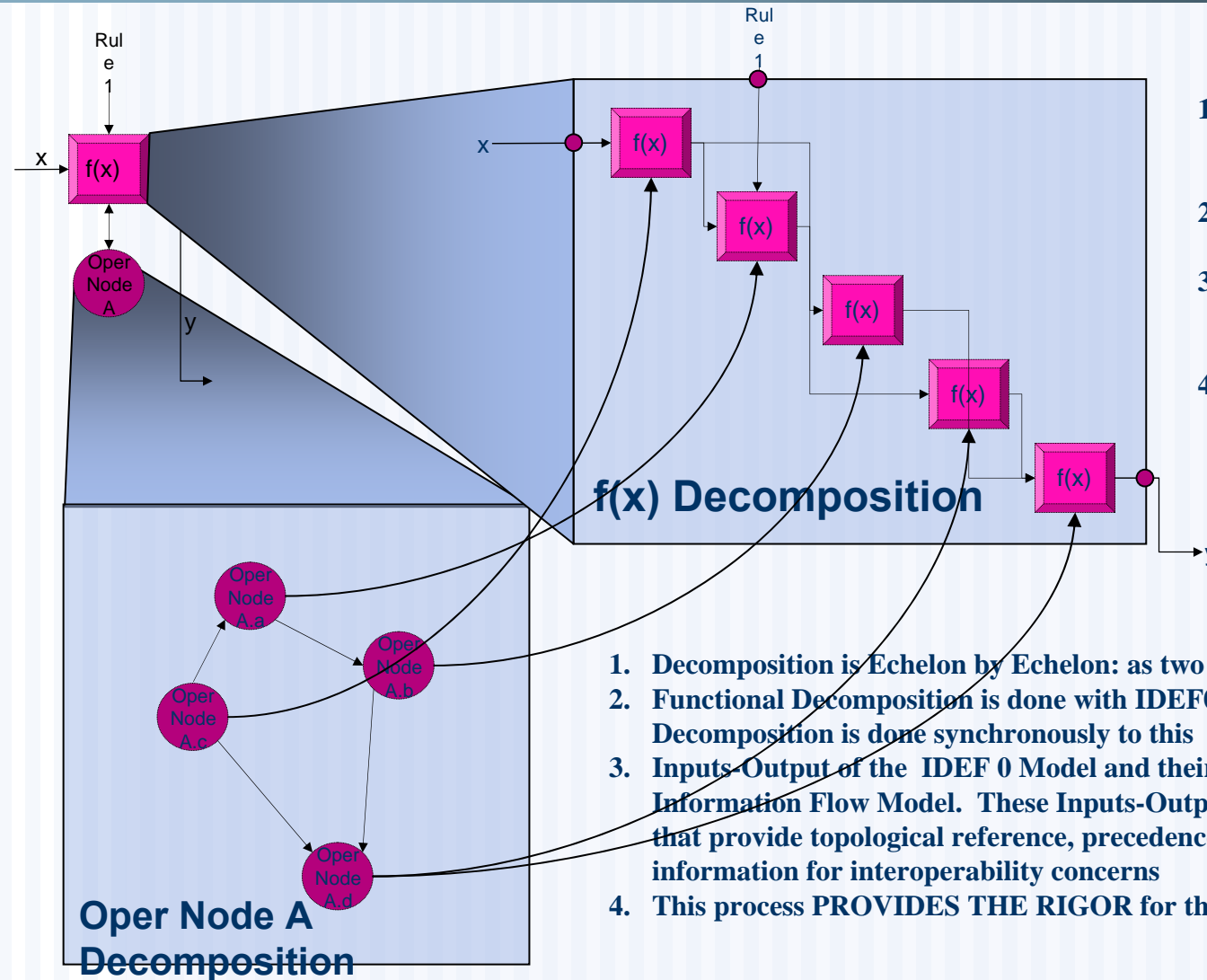
1. De-confliction of meta-model components to remove mixing of concerns
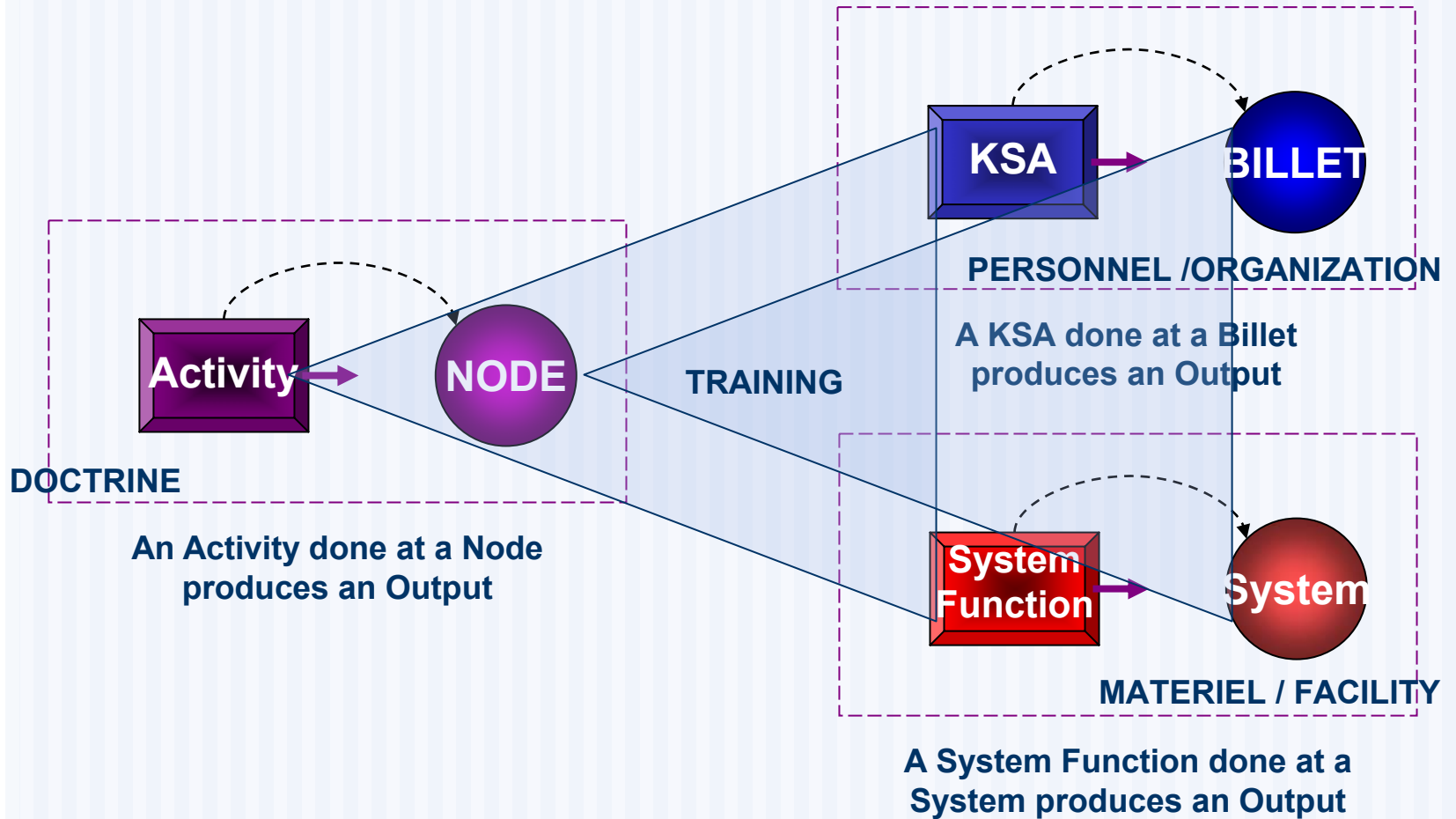2. Encapsulation represents the statement of a gestalt.
3. Incremental instances of encapsulation represent Rules and States.
4. Decomposition is a basic principle of Architecting and Engineering

**f(x) Decomposition**

**Oper Node A Decomposition**

1. Decomposition is Echelon by Echelon: as two separate 'synchronous' taxonomies
2. Functional Decomposition is done with IDEF0, and the Operational Node Decomposition is done synchronously to this
3. Inputs-Output of the IDEF 0 Model and their mapping to the Node Model are the Information Flow Model. These Inputs-Outputs are the Information Elements that provide topological reference, precedence of function and critical exchange information for interoperability concerns
4. This process PROVIDES THE RIGOR for the architecture primitives.

**KSA**

**BILLET**

**PERSONNEL /ORGANIZATION**

**A KSA done at a Billet produces an Output**

**Activity**

**NODE**

**TRAINING**

**DOCTRINE**

**An Activity done at a Node produces an Output**

**System Function**

**System**

**MATERIEL / FACILITY**

**A System Function done at a System produces an Output**

# DISCOVERY ENABLED ARCHITECTURE SPECIFICATION

- **Document information objects describe the taxonomy and topology of architecture primitives and relationships**

- **Integration is accomplished using the principles and practices of a tightly coupled discovery-based architecting process**

  - ♦ **Indexing and Clustering provide navigation to the authoritative and original sources for descriptions of the information objects**

  - ♦ **Clustering, using these descriptions, iteratively refines and extracts more relevant information objects**

    *This enables the Synthesis of Form*

- **Discovery described Architectures enables the development of Rigorous, Semantically complete Architecture Specifications, i.e., engineerible requirements**

    *This enables the Analysis of Function*

# QUESTIONS

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**Michael R. Collins**

**440-808-1250 Office**

**216-570-8775  Cellular**

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