9TH International Command and Control Research & Technology Symposium

MODEL-DRIVEN DEVELOPMENT OF COMMAND AND CONTROL CAPABILITIES

FOR JOINT AND COALITION WARFARE

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What's The Subject?

- **Model Driven Development**
  - **using executable UML modeling**
  - **building the core of collaborative FoS for NCW**
  - **applies to end item and the building process**
- **of Command and Control Capabilities**
  - **applications for information and cognitive functions**
  - **Single Integrated Air Picture (SIAP) is not just about an air picture, but is a prototype for all BM/C2**
  - **peers build and use distributed, replicated data for BM/C2 ops**
- **for Joint and Coalition Warfare**
  - **ad hoc dynamic groupings of networked peers**
  - **heterogeneous systems**
  - **varied peer data-access privileges**

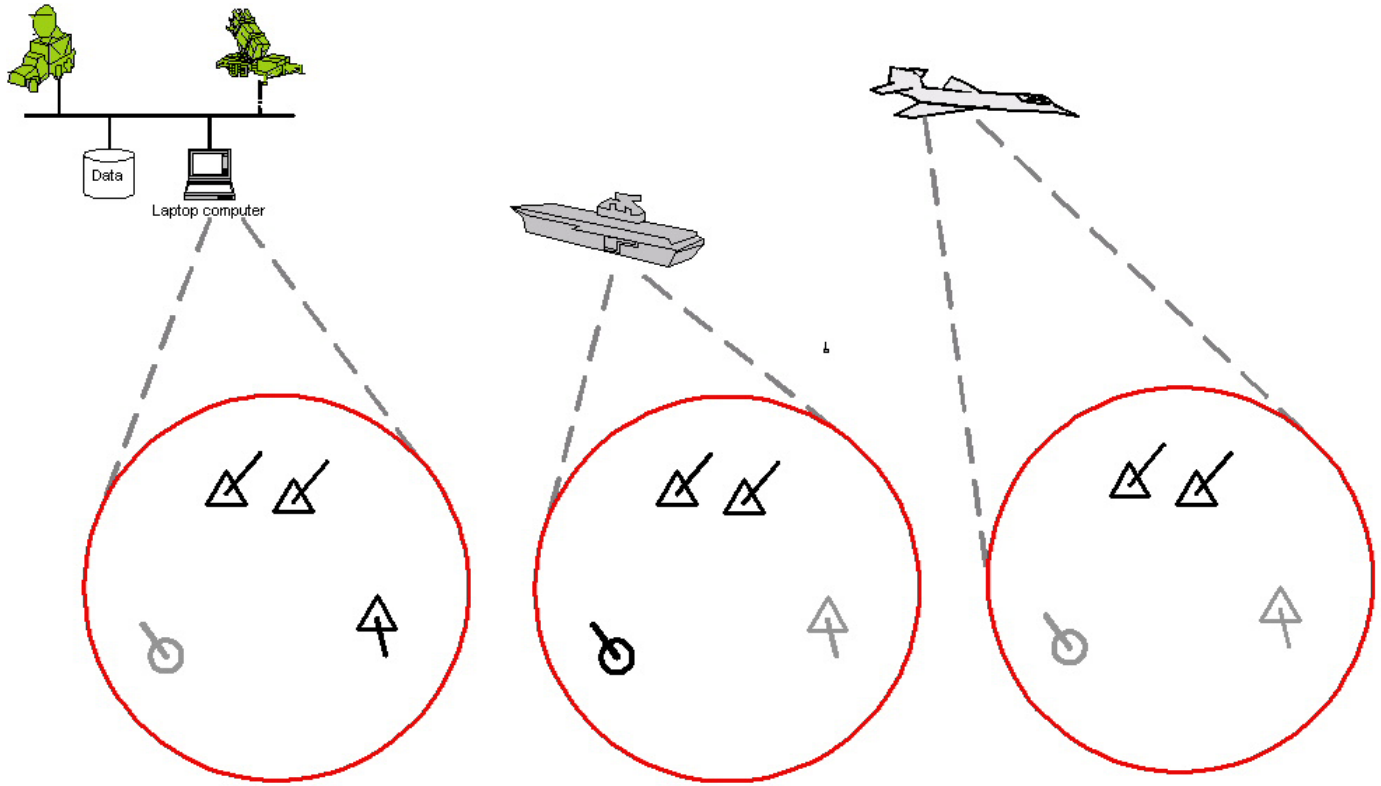
Bottom Line

- ***Tactical Real-Time*** **Net Centric Operations and Warfare (e.g., shared awareness) call for collaborative Federations of Systems (FoS)**
  - **Therefore, DoD acquisition system processes must lead to collaborative FoS**
- **Assertions**
  - **Existing DoD NCW transformation initiatives for interoperability are not strong enough for FoS solutions**
  - **OMG™ Model Driven Architecture (MDA™) approach meets the need**
  - **Complexity of the interoperability problem requires executable architecture**
- **Joint SIAP System Engineering Organization (JSSEO) is prototyping the technical and management path for collaborative FoS**

OUTLINE

- JSSEO Background
- MDA™
- JSSEO Technical and Management Approach
- Implications and Recommendations

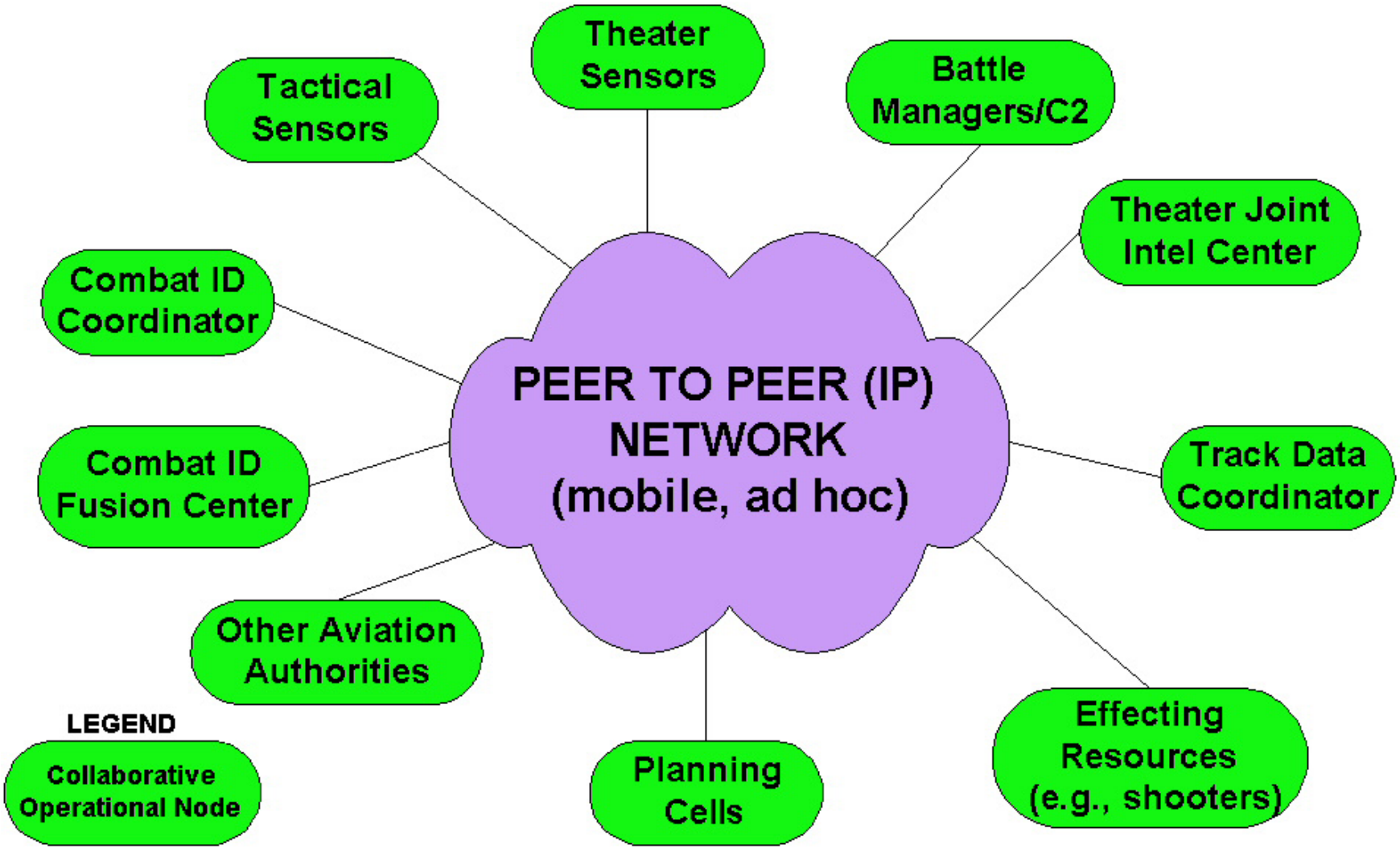
SINGLE INTEGRATED AIR PICTURE



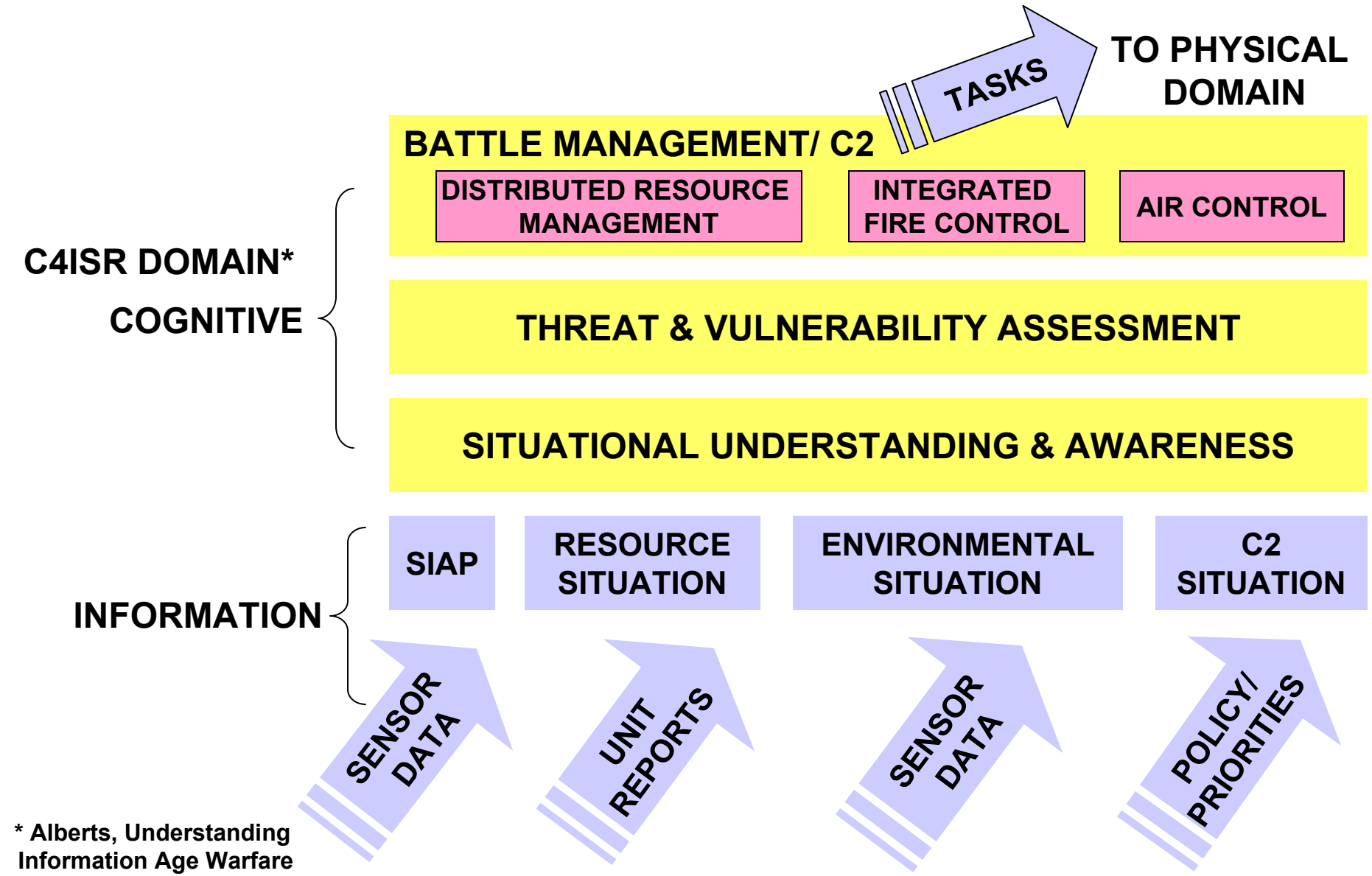
User viewpoint: common, correct, complete, continuous, timely

System: state of data consistency among distributed replicated data stores, for objects of peer interest

GENERALIZED SIAP CONTEXT

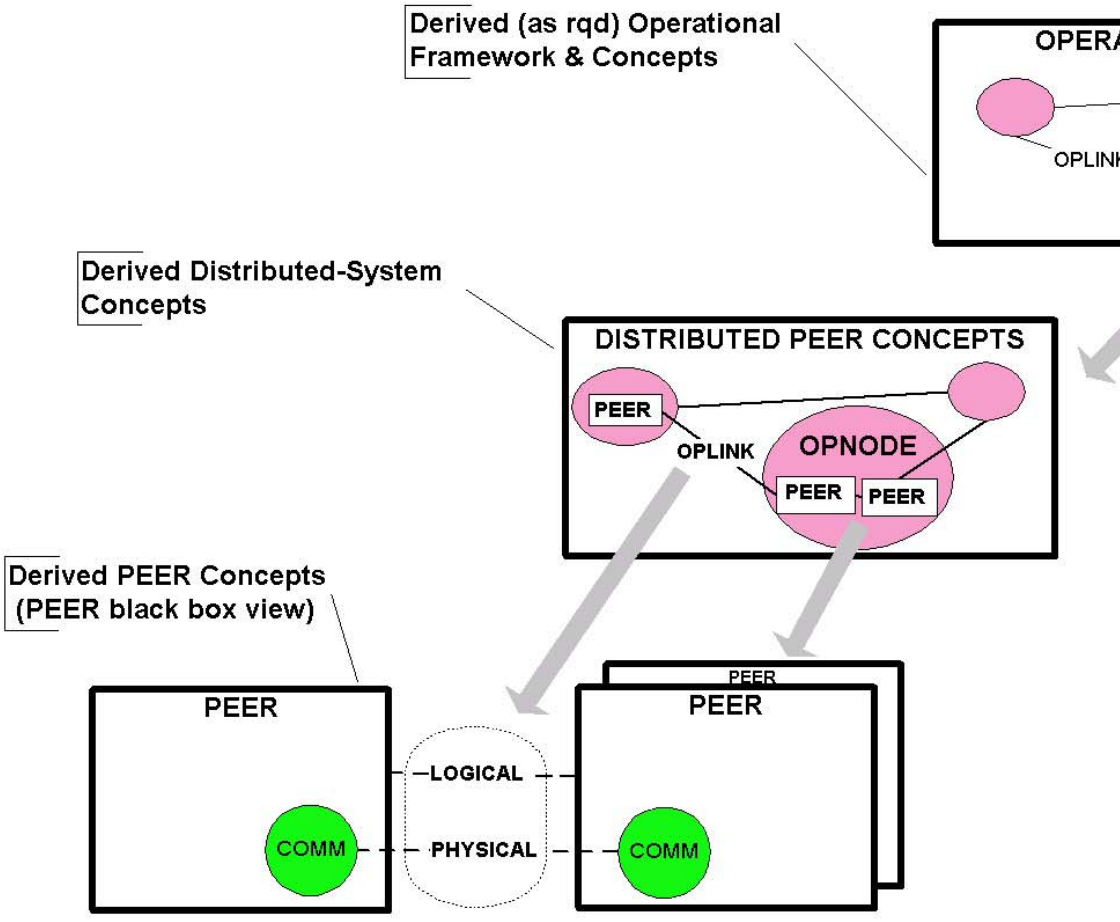


JSSEO JOINT/COALITION BM/C2 SCOPE



* Alberts, Understanding Information Age Warfare

FEDERATION OF SYSTEMS



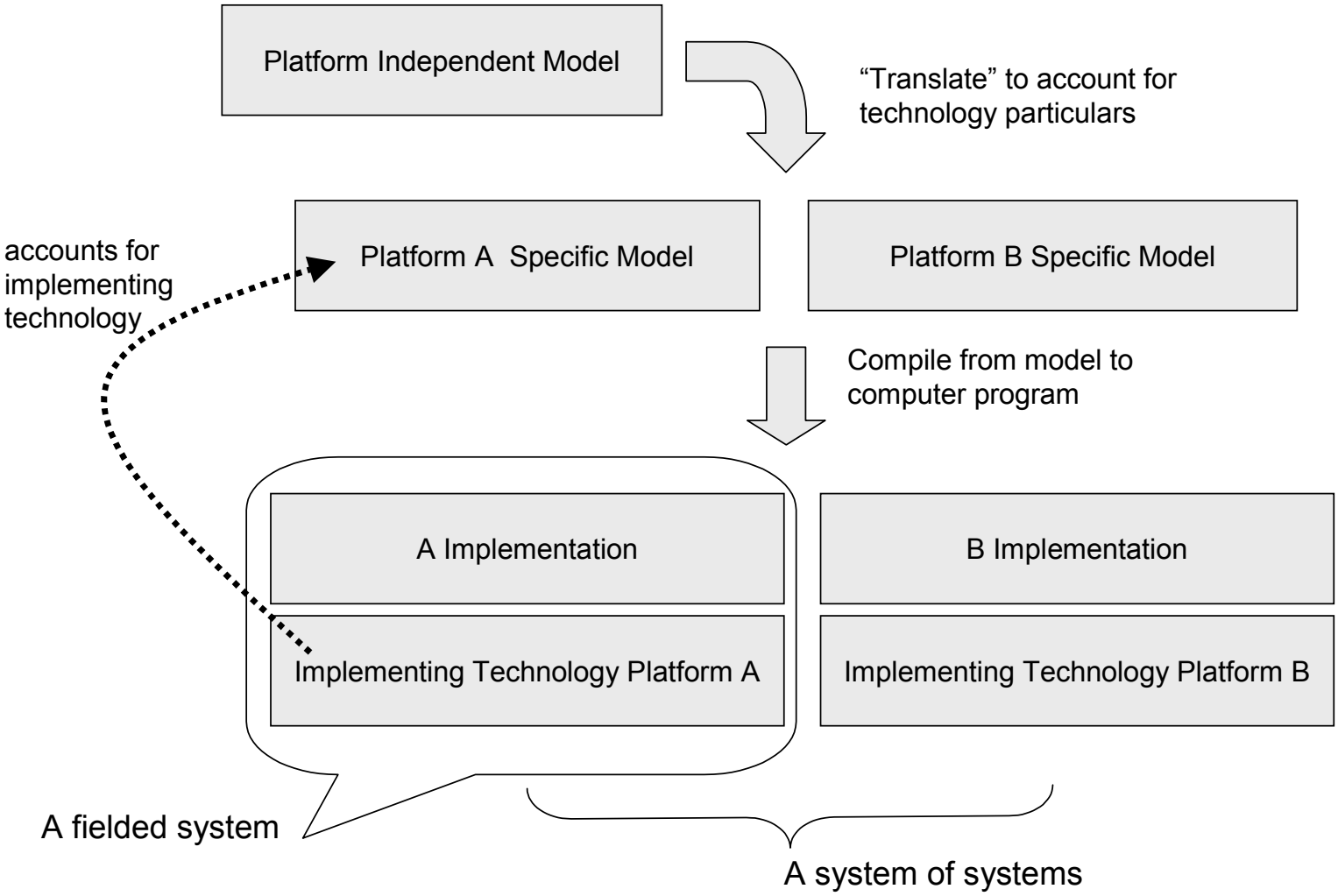
NCW BEHAVIOR REQUIREMENTS

- **Post before process**
- **Smart pull**
- **Collaborate for sense-making**
- **Only handle info once**
- **Communicate with reliability & assurance**

OMG™ Model Driven Architecture™

- OMG™ learned with CORBA™ that middleware was not enough
- MDA™ is a standards framework, mainly
  - Unified Modeling Language (UML)
  - Meta-Object Facility (MOF)
- Precept: separate the implementation technology from business concerns
- Depends on modeling
  - Platform-Independent Model (PIM)
  - Platform-Specific Model (PSM)
  - Platform = host computing machine (could be distributed)

MDA™ CONCEPTS



MOF META-LEVELS

(Adapted from Frankel)

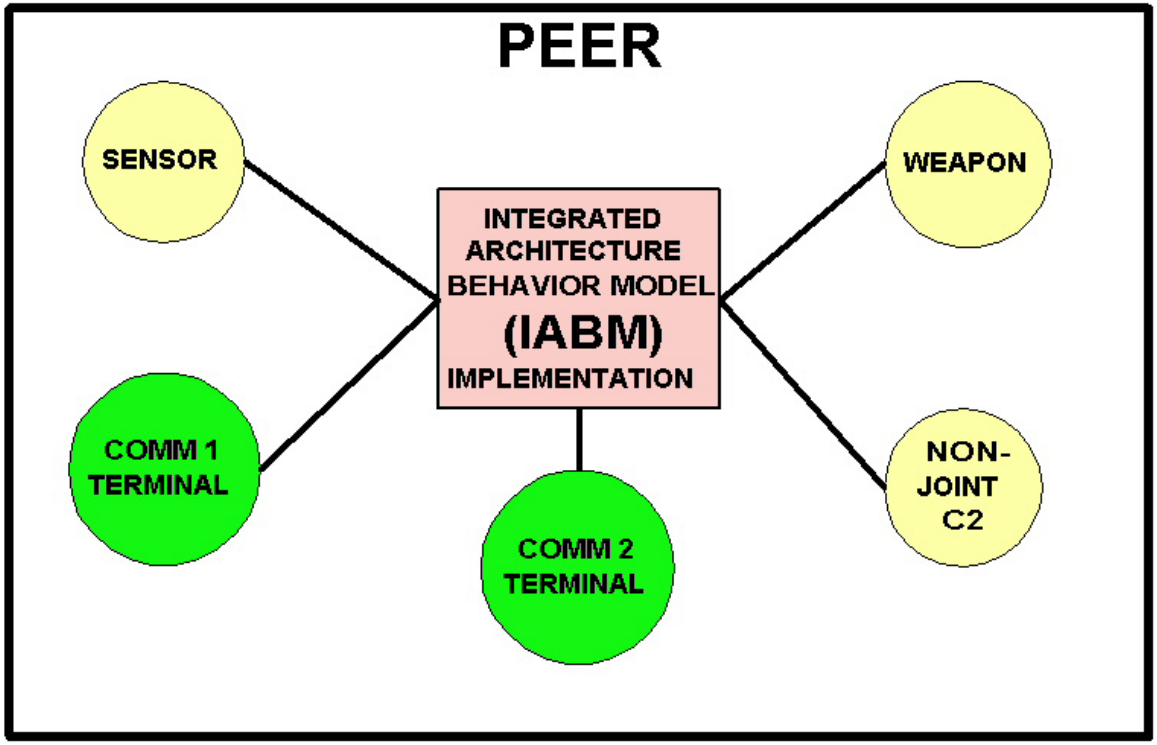
Meta-Level	Description	Example Elements
M3	MOF, i.e. the set of constructs used to define metamodels	MOF Class, MOF Attribute, MOF Association, etc.
M2	Metamodels, consisting of instances of MOF constructs	UML Class, UML Association, UML Attribute, UML State, UML Activity, (& other-modeling-language elements)
M1	Models, consisting of instances of M2 metamodel constructs	Class "Customer," Attribute "Account#" (& types modeled in other languages)
M0	Objects and data, i.e., instances of M1 model constructs	Customer "Joe Doaks", Account# "6543" (& other instances of types)

EXECUTABLE UML AND MDA

- **Executable UML is a profile of UML**
  - **Classes**
  - **State machines**
  - **Action Specification**
- **Executable models run in simulation**
- **Tools to support MDA are available***
- **Assertions: Tactical BM/C2 interoperability is so complex, that**
  - **understanding requires an executable model of the business (*DoD static approaches won't do it!*)**
    - for understanding requirements, &
    - understanding the distributed system under development
  - **technical detail of the platform should be in the model compiler so translation is automated**

***JSSEO is using Kennedy-Carter iUML**

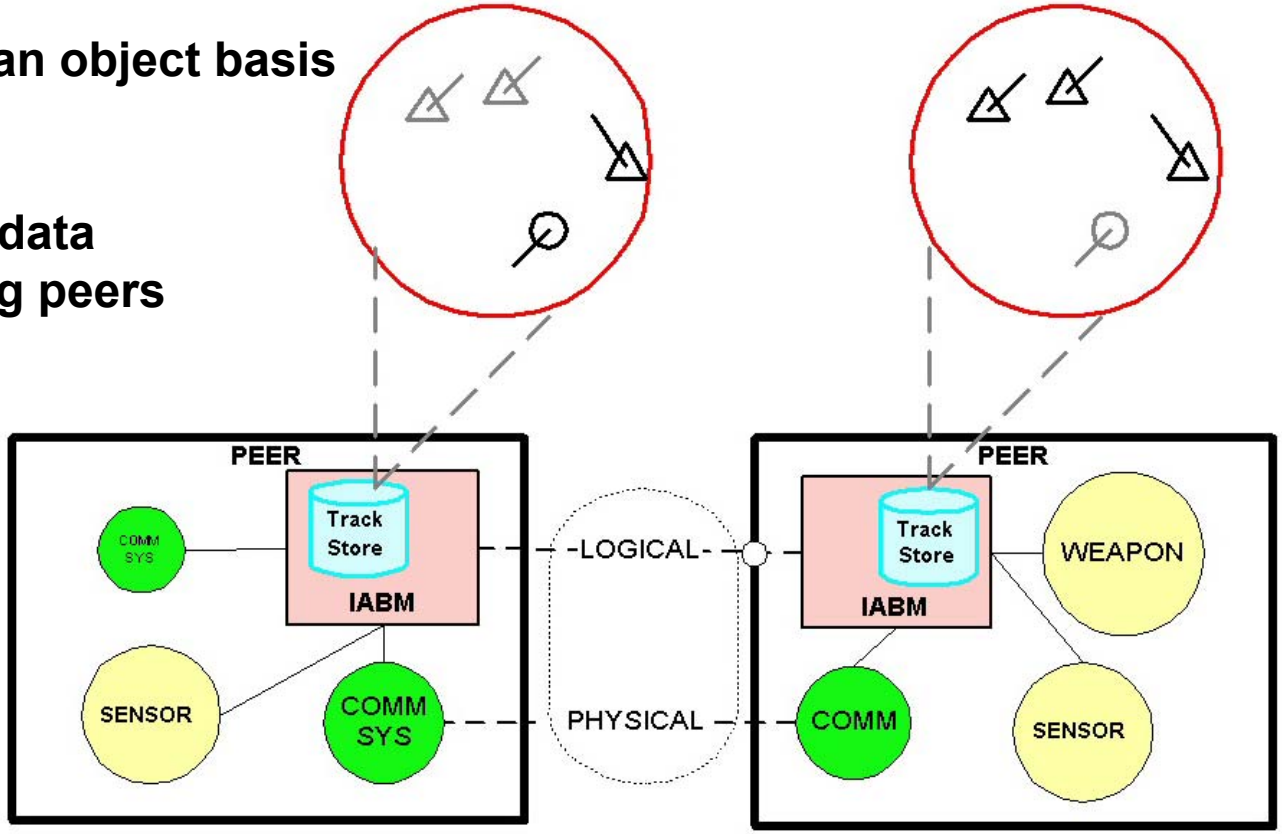
COMPONENTS OF A PEER



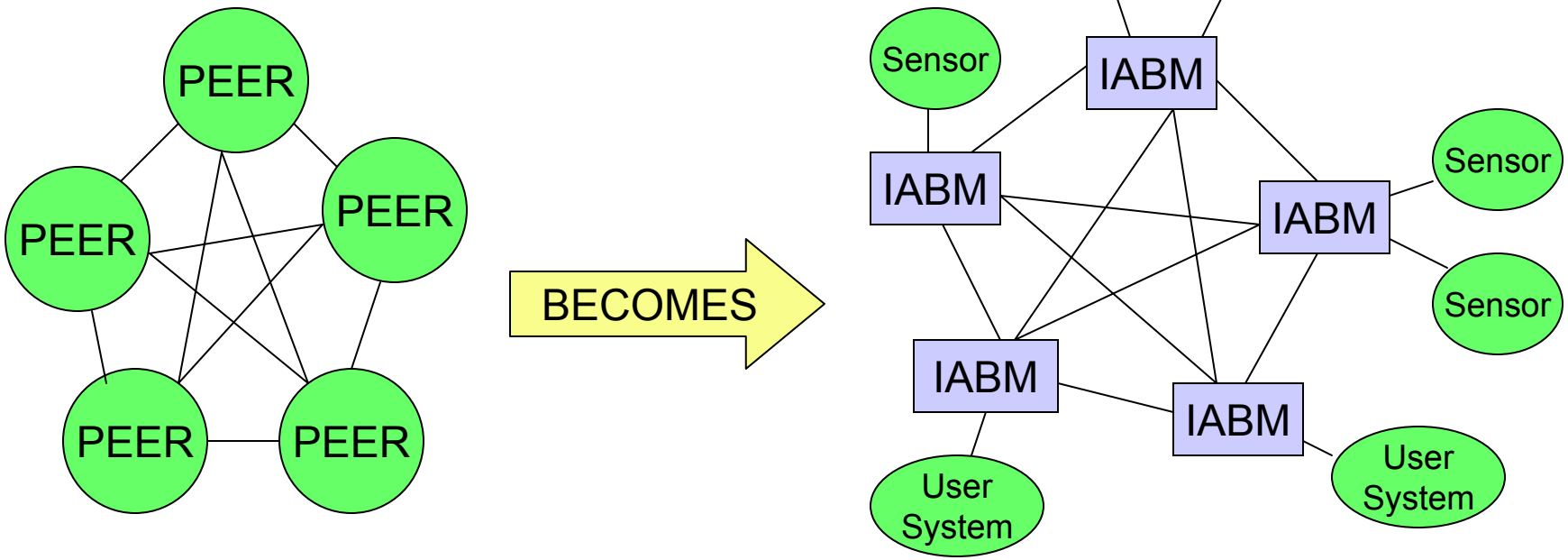
- The IABM is a Platform Independent Model
- The IABM Implementation is a computer program hosted on one or more processors of the peer systems
- IABM initial configuration is due to complete in Sep 2005

IABM Distributed Replicated Data

- Replicated data stores at peers are built by sharing source data (e.g., sensor measurements)
- Replication is on an object basis per peer need
- SIAP = a state of data consistency among peers



COMMON PROCESSING ARCHITECTURE



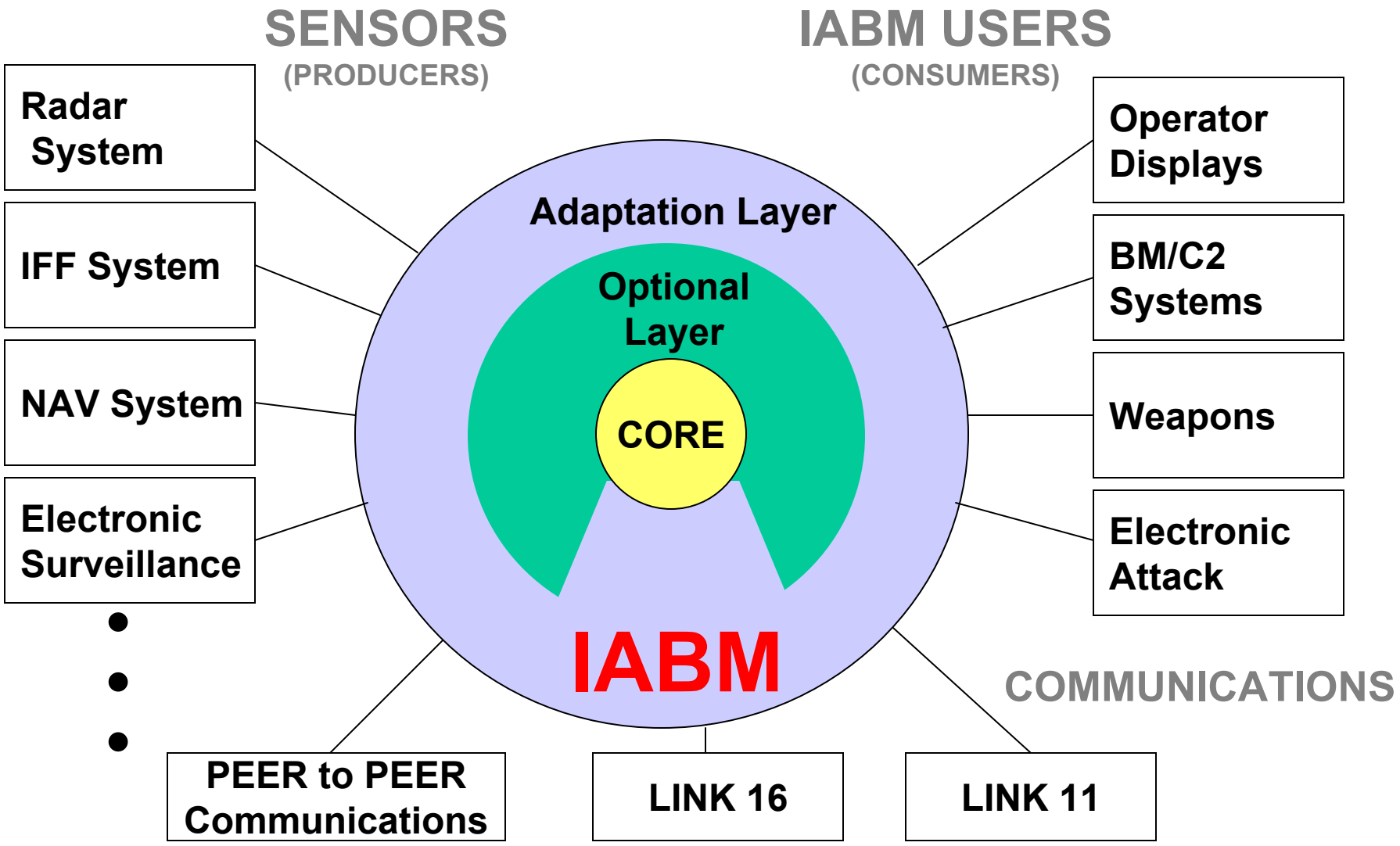
Unpredictable Heterogeneous Set of Systems

Predictable, Logically Homogeneous FoS

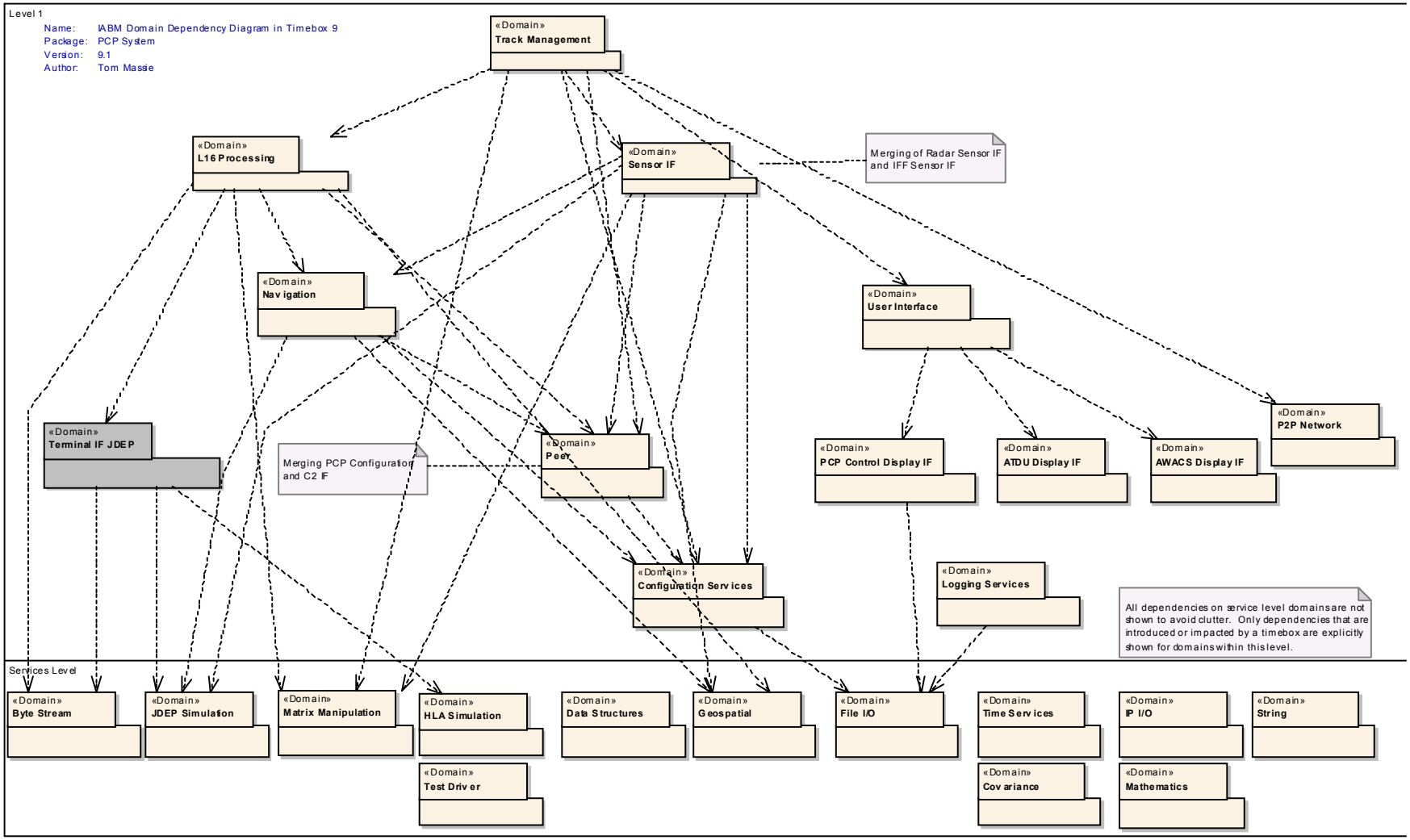
The JSSEO ARCHITECTURE SOLUTION FOR FoS COMPLEXITY

IABM: INTEGRATED ARCHITECTURE BEHAVIOR MODEL

IABM NOTIONAL CONFIGURATION



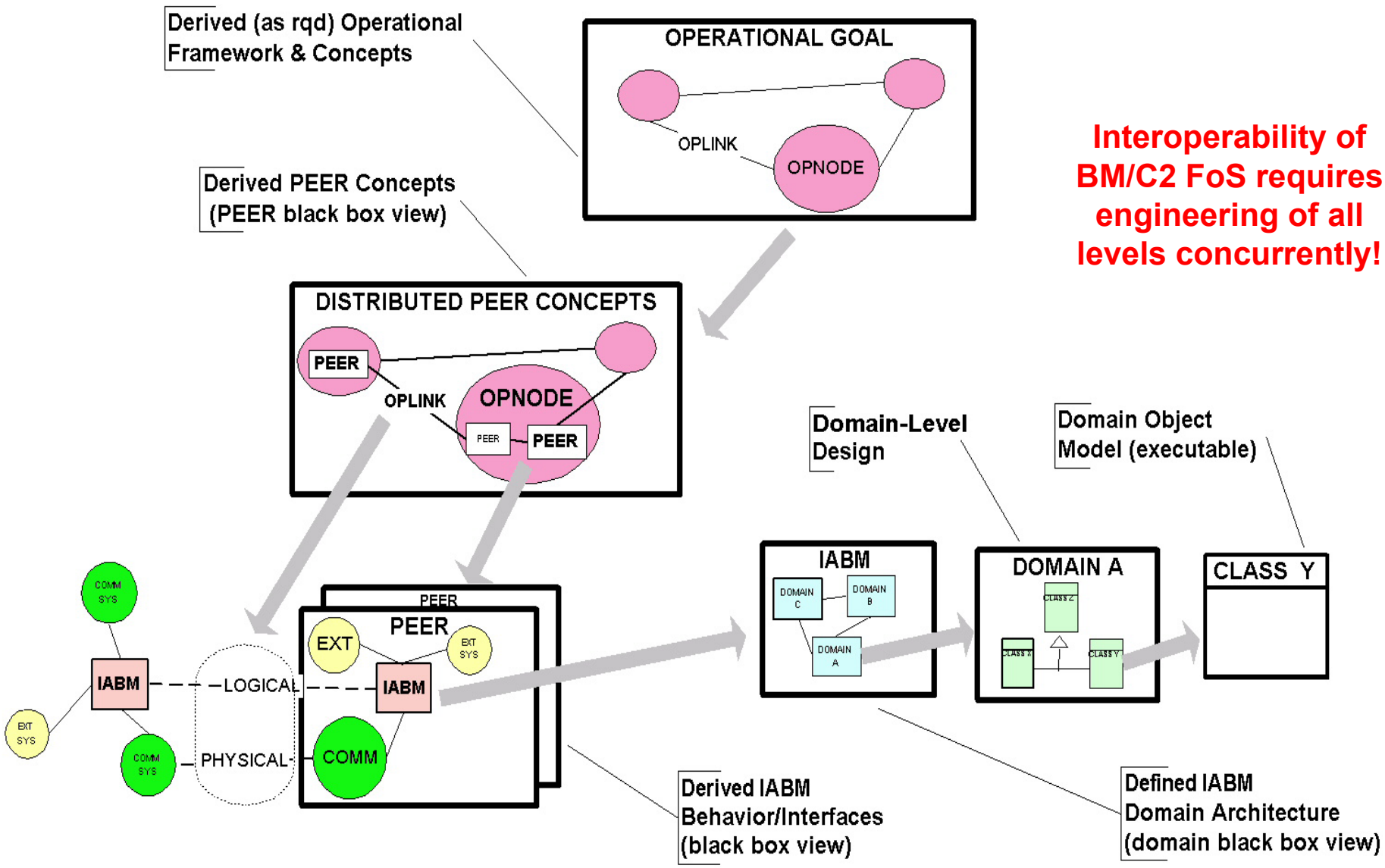
IABM: SET OF INTERACTING DOMAINS



DOMAINS, A KEY CONCEPT

- **Domains are:**
  - **"Autonomous world inhabited by conceptual entities" [Mellor]**
  - **Subject matter encapsulations**
    - Used "as is" in every implementation, if applicable to mission
    - Domains are coupled via bridges
      - loose coupling: cross-domain "pollution" is in the bridges
  - **The System Engineering primitive component**
    - Elemental configuration item; test item
    - Foundation of modeling teams
    - Reusable, maintainable

JSSEO ENGINEERING DIMENSIONS



JSSEO DEVELOPMENT PROCESS (1)

- **JSSEO is using *AGILE* development**
  - **Delivering a running end item every 4 weeks (final PIM due Sep 05)**
  - **Model testing is in-phase (lagging) with deliveries**
    - local testbeds for domain and project integration testing
    - HLA interface for distributed simulation test bed (JDEP)
  - **Regular reflection and feedback**
  - **Working code is the primary progress metric**
  - **Changing/new requirements are expected**
    - each build cycle timebox has a dedicated requirements/architecture phase; refactoring is constant
    - higher level requirements/architecture cycle more slowly
  - **SMEs (operational, technical) and developers work closely on domain teams**

JSSEO DEVELOPMENT PROCESS (2)

- **JSSEO leads a joint/allied distributed SE task force**
  - **Central development site for PIM**
  - **Partner involvement/ownership in PIM development (esp. adaptation domains)**
  - **Partner/Service integration sites for PSMs, model compilers**
- **The IABM is the collaboration mechanism integrating the team**
  - **Unambiguous specification**
    - functions
    - interfaces
  - **Measurable performance and progress**
  - **Generic domains for tailoring to adaptation domains**

JSSEO is not just experimenting and prototyping, but is directly engineering FoS interoperability

MODEL-DRIVEN DEVELOPMENT
RECOMMENDATION #1

- **Design FoS interoperability using federated object models**
  - **NCW battlefield requires *ad hoc* federations of systems (FoS)**
  - **JSSEO building aerospace object model, but...**
    - Resources (e.g., sensors, networks) and Cognitive Domain activities cross mission areas
    - Multiple "pictures" in development without peer-to-peer interoperability
  - **Federated executable business models using JSSEO MDA™ approach permits design of FoS capabilities**

DoD should scale up JSSEO MDA™ processes to federate executable architecture models covering mission-area partitions

MODEL-DRIVEN DEVELOPMENT
RECOMMENDATION #2

- **Leverage MDA™ by preparing hosts for PIM/PSM**
  - **PIM handling (e.g., code manipulation) during implementation increases risk to interoperability**
    - PIM interoperability testing voided if PIM altered
    - Model translation and compiling safest if by machine
    - Risk extends to life cycle maintenance and upgrade
    - Technology aspects become embedded in PIM
  - **Open up system architectures, build platform-specific tools and system object models**
    - Let tools embed the platform technology
    - Enables closely coordinated release of PIM upgrades
    - Readies partner participation on SE task forces

DoD acquisition leaders plan for and incentivize programs' transition to MDA as part of NCW transformation

MODEL-DRIVEN DEVELOPMENT
RECOMMENDATION #3

- **Pursue executable Operational Architectures**
  - **NCW Operational Concepts for Joint/Coalition BM/C2 are scarce, imprecise, and poorly articulated**
  - **NCW developers need definition of the "business" of Joint/Coalition BM/C2, i.e. the *operational*...**
    - structures
    - behaviors
    - data
  - **Executable Operational Architectures permit Warfighter specification of NCW**
    - Technology independent
    - Mission Capability Package (MCP) alignment

Empower warfighters with tools and cadre of systems engineers to generate executable operational architectures

MODEL-DRIVEN DEVELOPMENT
RECOMMENDATION #4

- **Common-processing in GIG edge devices has special DoD enterprise-level implications**
  - **Streamlining of system operational testing and certifications is needed to avoid redundancies**
    - model-based testing has a different meaning with MDA; the model is a component, not an abstraction
  - **Can push smart enterprise-common design solutions into GIG edge devices using PIMs or reference implementations**
    - information assurance and security processes
    - Net-Centric Enterprise Service interfaces
    - network C2, transport QoS, COI management
    - data characterization

DoD policy-makers must appreciate and leverage the implications of large-scope common processing architectures

MODEL-DRIVEN DEVELOPMENT
RECOMMENDATION #5

- **DoD enterprise-level interoperability should be achieved using a model-driven development environment**
  - **Current/planned environment is tech-dependent and unsuited for real-time, weakly connected, battlefield ops**
  - **Needed: a development-phase system for designing FoS and federating object models**
  - **Analogous to OMG, environment should support model-based specification, model interoperability, tool interoperability, model-driven testing**
  - **Build a general-purpose GIG testbed for edge-device federation testing**

DoD acquisition leaders should establish a model-driven engineering environment analogous to OMG MDA environment

CONCLUSIONS

- JSSEO is successfully performing NCW transformation of Joint/Coalition tactical aerospace BM/C2
- MDA™ methods using executable architectures have the technical power to engineer complex FoS
  - Current DoD NCW transformation initiatives do not go far enough for real-time tactical BM/C2 FoS
  - JSSEO should be considered an acquisition process pathfinder or prototype for mission areas outside aerospace BM/C2
- NCW transformation can be accelerated by leveraging MDA™ in DoD enterprise policies and processes