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ISRAEL INSTITUTE OF TECHNOLOGY

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ENTERPRISE SYSTEMS MODELING LABORATORY

INCOSE International Symposium
Philadelphia, PA
June 24-27, 2013

I^5: A Model-Based Framework for Architecting System-of-Systems Interoperability, Interconnectivity, Interfacing, Integration, and Interaction

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23rd Annual INCOSE International Symposium -
Philadelphia, PA – 24-27 June, 2013

Client:

"I just want the platoon commander to transfer his position to the approaching pilot!

I don't care how you do it!"

LNG Carrier

Who cares about LNG carriers, transformation hubs and relay stations?

Interconnectivity & Interoperability

- **Synergetic qualities** of a system (of systems).

- **Interconnectivity** is among (sub)**systems**.
- **Interoperability** is among **users**.
  - It utilizes interconnectivity.

- **Interconnectivity/Interoperability Programs** focus on the integration of disparate systems to create value from interaction

Challenges

- Core system functionality prioritization
- Expectations for “transparency”
- Complexity of integration among disparate systems with independent objectives
- Manning the SoS integrator’s role
- Traditional system-oriented modeling, analysis and design methods

Model-Based Systems Engineering

- *The formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.* (INCOSE 2007)

Applying MBSE to System Integration Programs

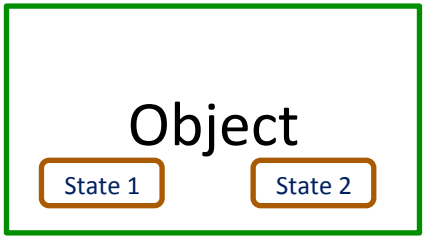
- A framework for integration program managers and designers.
- A holistic perspective for system-level stakeholders and designers.

Underlying Framework: OPM (Object-Process Methodology)

- OPM (Dori, 2002) is a comprehensive systems engineering paradigm for modeling, communicating, documenting, engineering and lifecycle support of complex, multi-disciplinary systems and processes.
- Has a minimal set of symbols.
- Provides a bimodal coherent graphical and textual representation.
- Listed as a leading MBSE methodology (Estefan, 2008)
- Emereging ISO standard 19450
- Has a free CASE tool - OPCAT

OPM Entities

- **Object**: A thing that **exists**.
  - can have states



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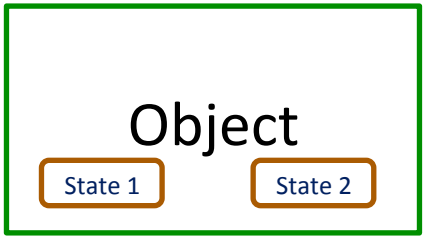

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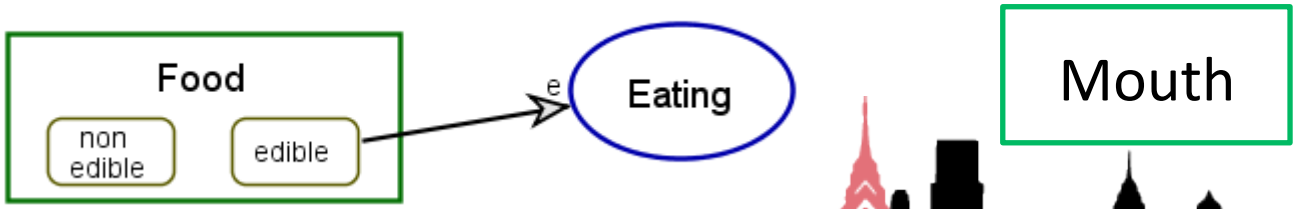
OPM Ontology

- Unified structural and behavior model.
- Single type of diagram.
- Links: Structural vs. Procedural.
- Eating consumes Food.
- Eating requires Mouth.



OPCAT

- Simultaneous generation of graphical and textual description.
- Detail decomposition (“drill-down”) engine.
- Simulative Capabilities.
- Code generation capabilities.
- Easy and fast to study and get started.

Why OPM?

- **Single model** for the structural, functional, and dynamic aspects of the system.
- Unique **complexity management** approach.
- Dual representation: **graphical + textual**.
- **Extensible** – allows extra layer modeling.
- Free CASE tool – OPCAT.
- **ISO standardization**.
- Proven capability to capture and simulate complex interactions (Dori, Reinhartz-berger, and Sturm 2003).

Some Useful References

- Sage & Lynch (1998)
- Brooks & Sage (2006)
- Haskins et al. (2007)
- Estefan (2007)
- Vernadat (2007)
- Chen, Doumeingts, and Vernadat (2008)
- Naudet et al. (2010)
- Lamparthaki et al. (2012)

Architecture Frameworks for Systems of Systems Integration

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- Levels of Information Systems Interoperability (LISI) – C4ISR Architecture Working Group (1998)
- NATO Architecture Framework (NAF) – NATO
- The Open Group Architecture Framework (TOGAF)

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I^5:
Interoperability, Interconnectivity, Interfacing, Integration, and Interaction

The Emergence of Interoperability

- **Interoperability** – organizations and users sharing information and other payloads.
- **Interconnectivity** – systems seamlessly handle and transfer the payloads.
- **Interfacing** – systems exposing interfaces, services and ports for communication and payload exchange.
- **Integration** – coordination and alignment of all interfaces to work together
- **Interaction** – realization and utilization of the capabilities, in various modes and fashions, to cooperate, collaborate, and conduct end-to-end transactions

Main Principle

- The infrastructure is a system in its own right.
- Modeling and architecting the infrastructure is the same as for any regular system.

Building Blocks

- **Infrastructure**: assembly of all the components, media, services, and functions, facilitating I^5.
- **Medium** is the means within the infrastructure that carries payload (e.g., wires, cables, fibers, pipes, conveyor belts, roads, and bridges – as well as the air, atmosphere, time-space, and cyberspace).
- **Payload** is any transferrable object (e.g., information, matter, material, energy, or currency).
- **Interface** is the component of the system with which the system interacts with other systems.

"Object Affects Object" Relation

- Concise description: Coffee Machine provides Cup of Coffee.
- Detailed description:
  - Coffee Machine exhibits Coffee Making process.
  - Coffee Making process consumes ingredients and yields Cup of Coffee.
- Procedural detail extension is modeled with OPM's process suppression mechanism: An object assumes the role of its internal process in handling or modifying another object.

Infrastructure Modelling

- Duality problem:
  - System // Link.
  - Form // Function.
- The infrastructure is modeled as a compound OPM object (containing both objects and processes).
- Can be obtained by the in-zooming of a simple link between two or more systems.

Payload Modeling

- We use OPM's shading notation to distinguish Payload from Component.
- Location duality:
  - Location as a state.
  - Location as a position in or relation to model artifacts (objects and processes).
- Location/Status State suppressed as needed.
- State can be linked to a position/phase it reflects

Interface Modeling

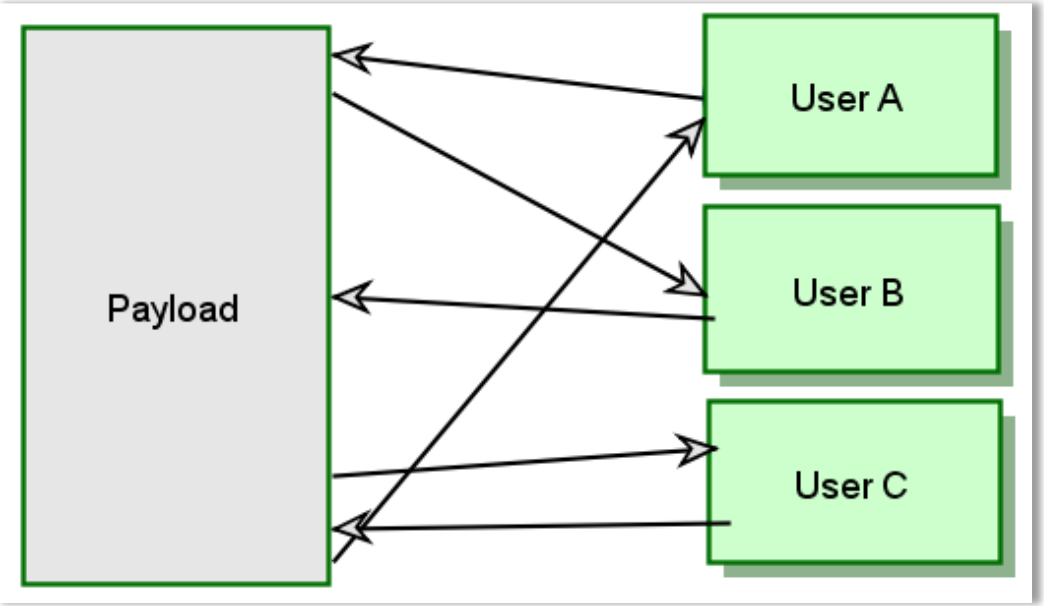
- Interface Duality:
  - Port (object) // Service (process)

- We define the interface as a form-function couple – object exhibiting process.
- Process Suppression as in Medium modeling.
- Process in-zooming – several functions under the same interfacing process.

Views

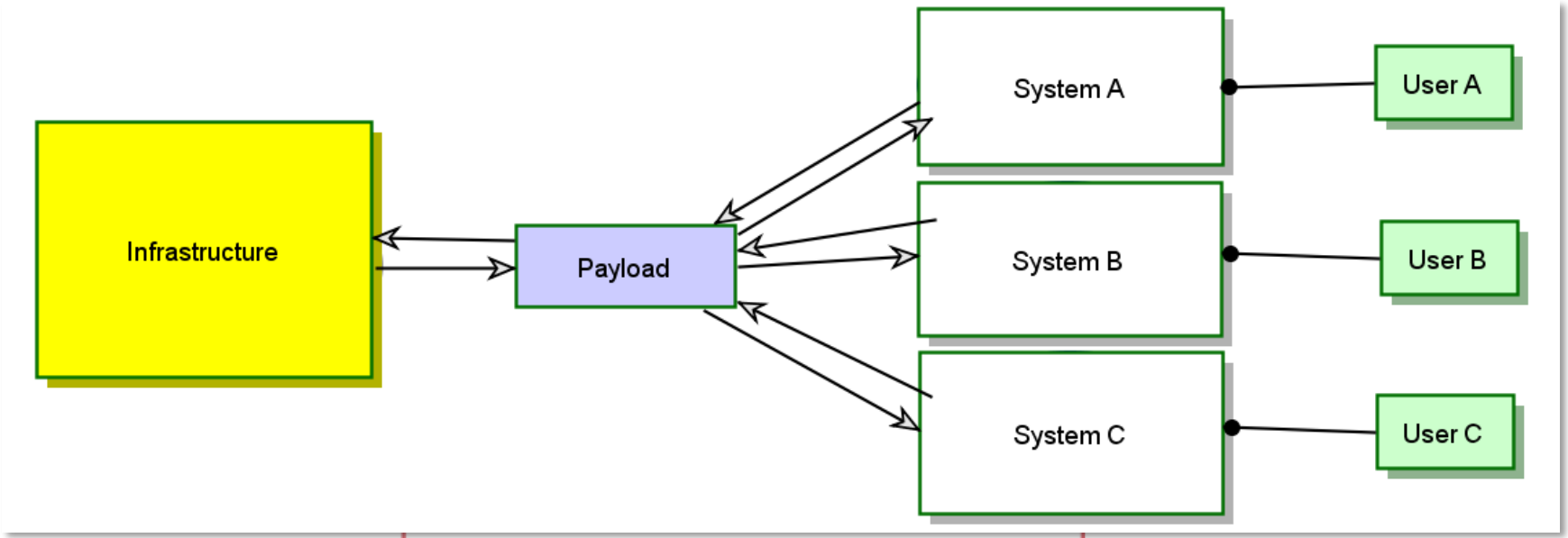
- Interoperability View:
  - Focus on end users/beneficiaries.
  - Highlighting the main payloads.
- Interconnectivity View:
  - Focus on systems and infrastructure with Process Suppression.
  - Payload under State Suppression.
- Interface View:
  - Focus on interface and payload handling functionality.
  - Explicit Payload State visualization.

Interoperability View

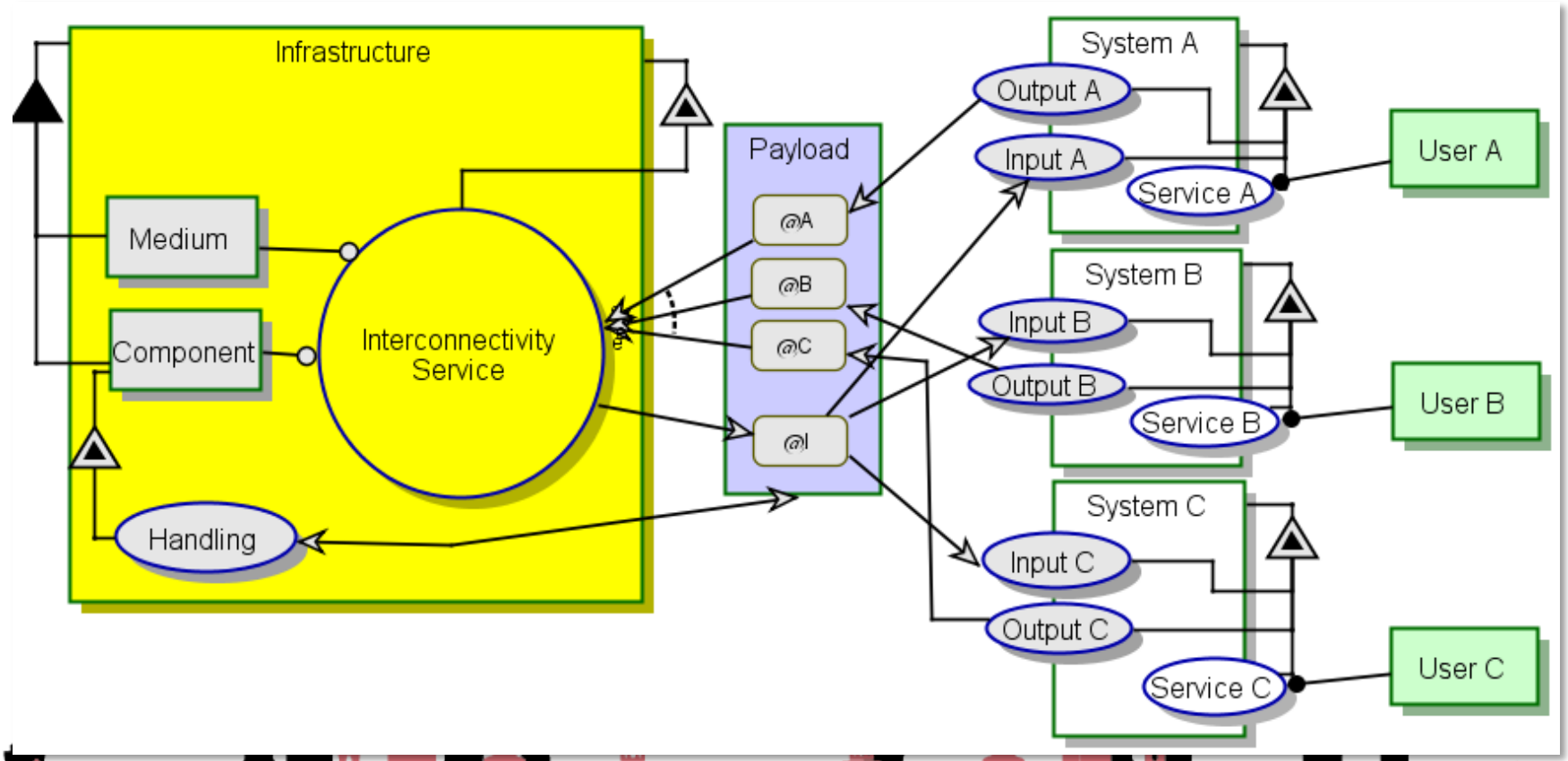


1) User A yields Payload. User B consumes Payload.
2) User B yields Payload. User C consumes Payload.
3) User C yields Payload. User A consumes Payload.

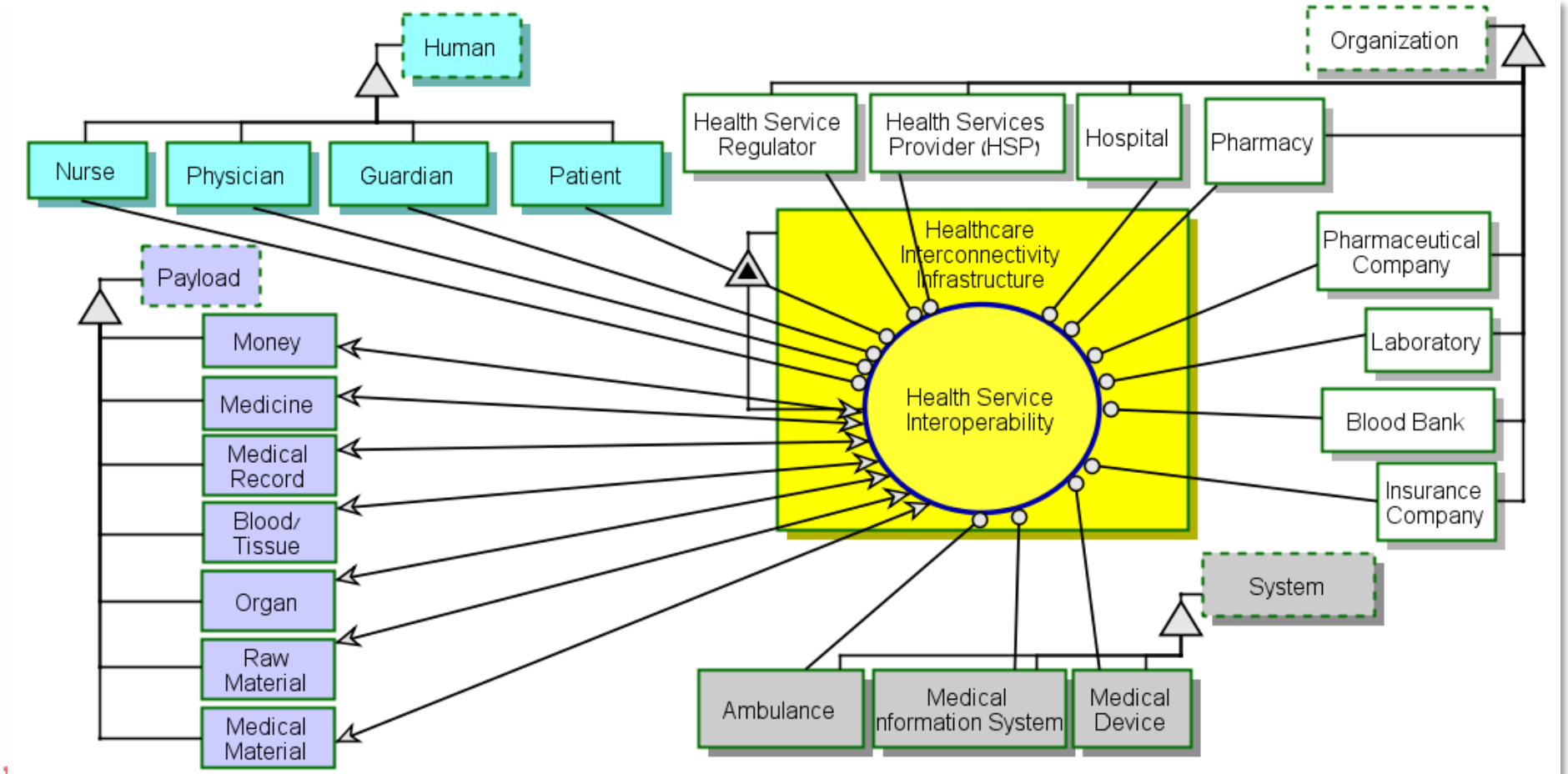
Interconnectivity View



Interface View



Example: Healthcare Services



Blood Sample Handling Concise View

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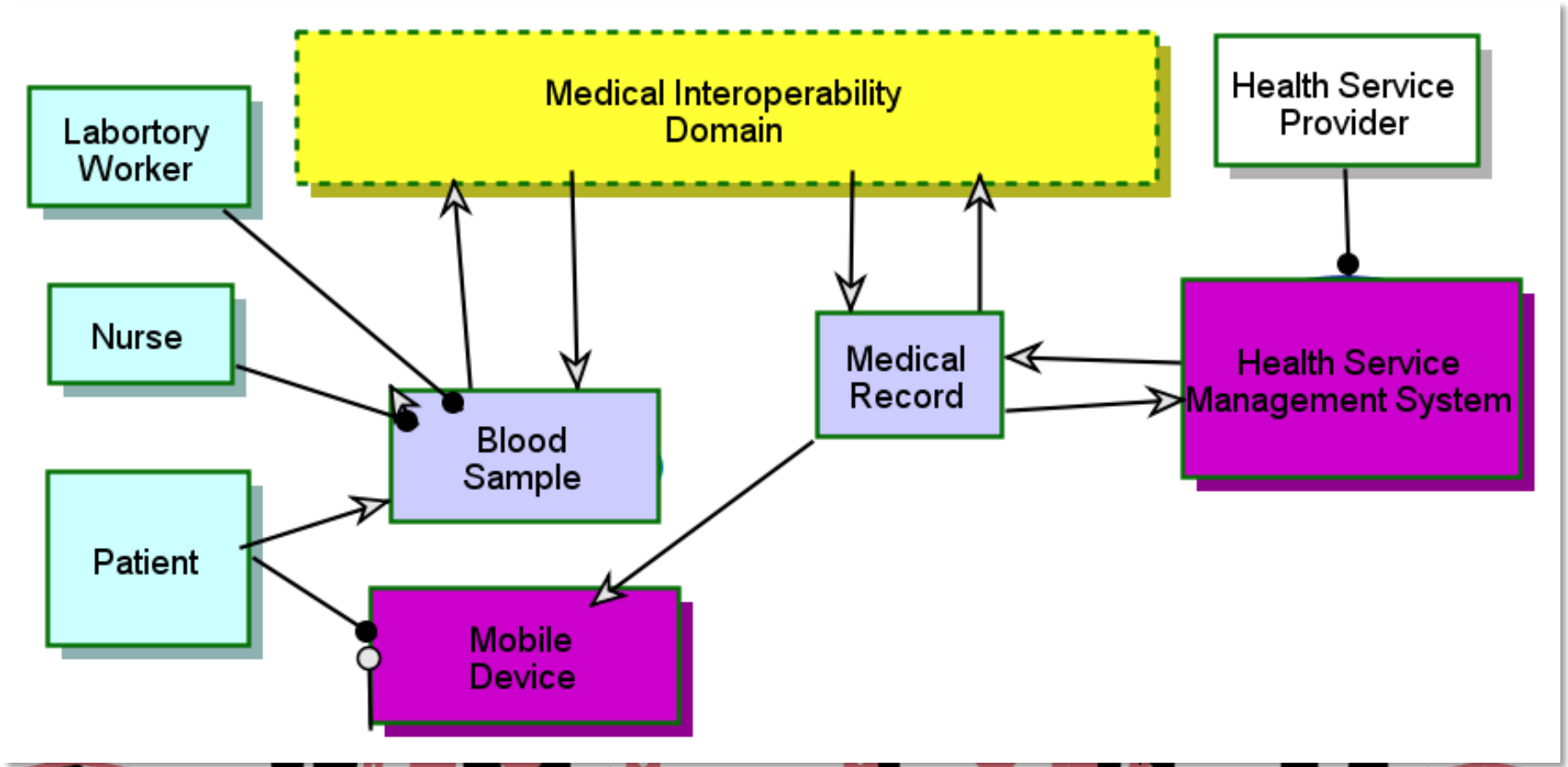

Blood Sample Handling Detailed View

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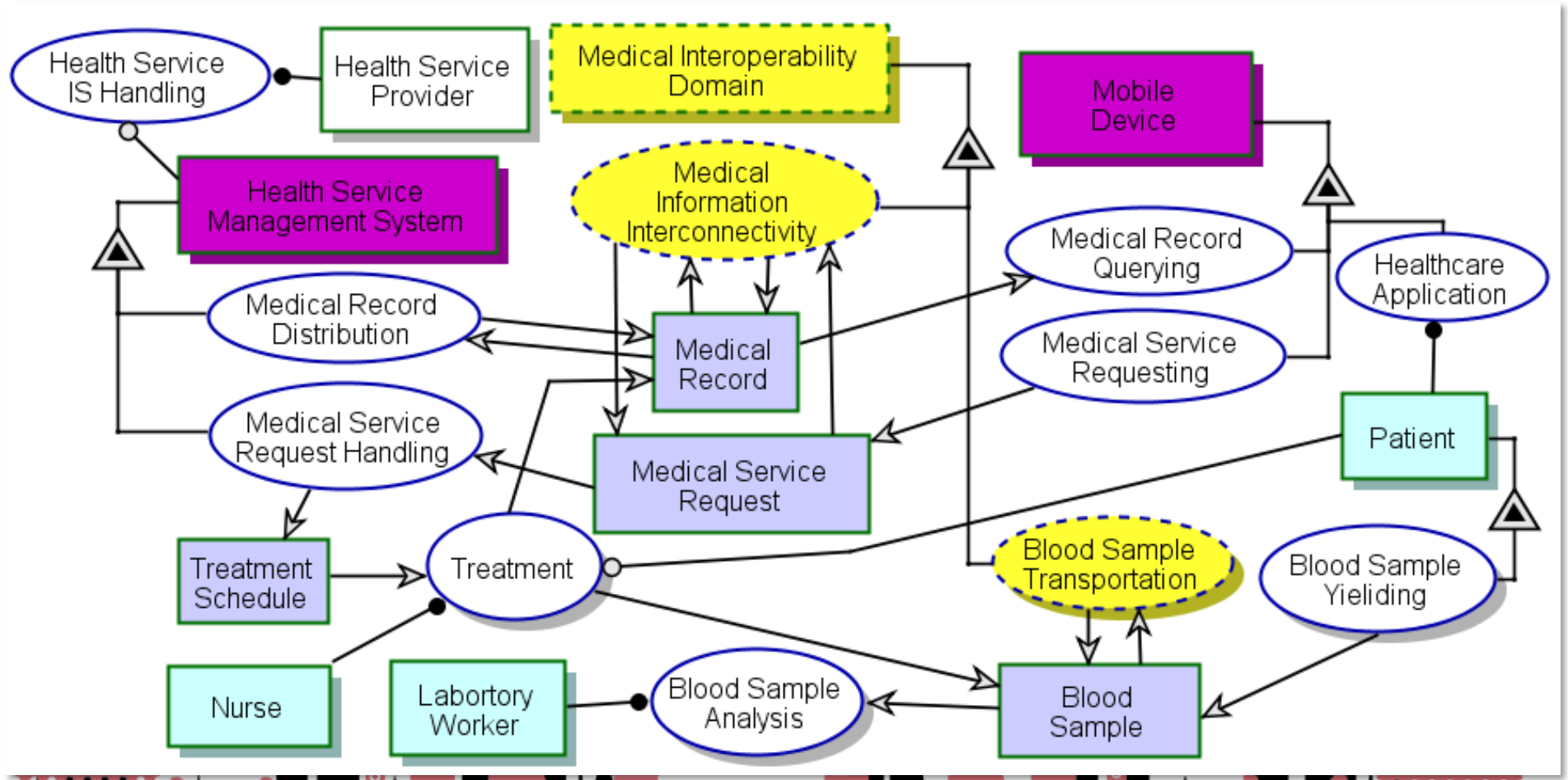

Example Summary

- Capturing a simple, everyday process, such as a patient receiving her blood test results.
- The process conceals complex integration and interaction among various disparate organizations, users, and systems.
- Exchange, processing, and analysis of information and physical payloads.
- Can be further elaborated and enhanced to include all the devices required to safely and securely transfer the payloads from one point to another, the media through which they are transferred, and the applicable conditions and constraints.

Summary

- Focus on SoS I^5 Programs
- Dedicated approach for complexity handling and gradual detail exposure in complex interaction architecting and design
- Utilizing and extending OPM for paradigm shift from system-centered to integration-centered modeling
- Focus on conceptual model – not on technical issues

I[5] Framework – Main Advantages

- Consists of a well-defined modeling methodology – OPM
- Purely semantic and generic; it does not deal with technical aspects and issues arising from the physical nature of the interaction, the media, or type of systems
- Intentionally developed to accommodate various domains and unify informatical and physical integration modeling – a gap and a challenge in current modeling languages

Thanks!
And… Don't Forget the LNG Carrier!