Towards Semantic Interoperability between C2 Systems Following the Principles of Distributed Simulation

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Problem of Semantic Heterogeneity

- *Coordinated efforts, collaborations and interdependencies* have increased the need for information exchange between heterogeneous systems that are owned and designed by different organizations.

- *Semantic heterogeneity* is a particularly challenging form of heterogeneity which occurs when information is described in different ways in two different systems, or when there is disagreement regarding the meaning and interpretation of the information.

Problem of Semantic Heterogeneity

- *The ongoing globalization poses new challenges for military operations* - it has become much more common to carry out activities together with other nations' civil and military organizations.
- *In order to cooperate efficiently*, it is necessary for different organizations to exchange information between their command and control (C2), management and Information Systems (IS), i.e., to be interoperable.
- *Within NATO*, semantic interoperability has been consequently identified as a core capability for future command and control systems to increase the efficiency of international operations. *An effort to address this need in the military world is currently ongoing, with the proposal of a Semantic Interoperability Framework (SIF).*

Overview of Our Effort

- Interoperability problems have been a major concern within the Modeling and Simulation community for years, especially in for distributed simulations. As in the C2 domain, *there is a need to create configurations of systems where elements of information exchanged are interpreted similarly among all participating parties, preserving the intended meaning.*
- In this study, *theories and best practices that have been accumulated by the distributed simulation community* are adapted and applied to SIF in order to develop a robust framework for semantic interoperability of C2 systems.
- In particular, *we aim at conceptualizing a common process for governing the development, execution and analysis of heterogeneous systems in a C2 context*.

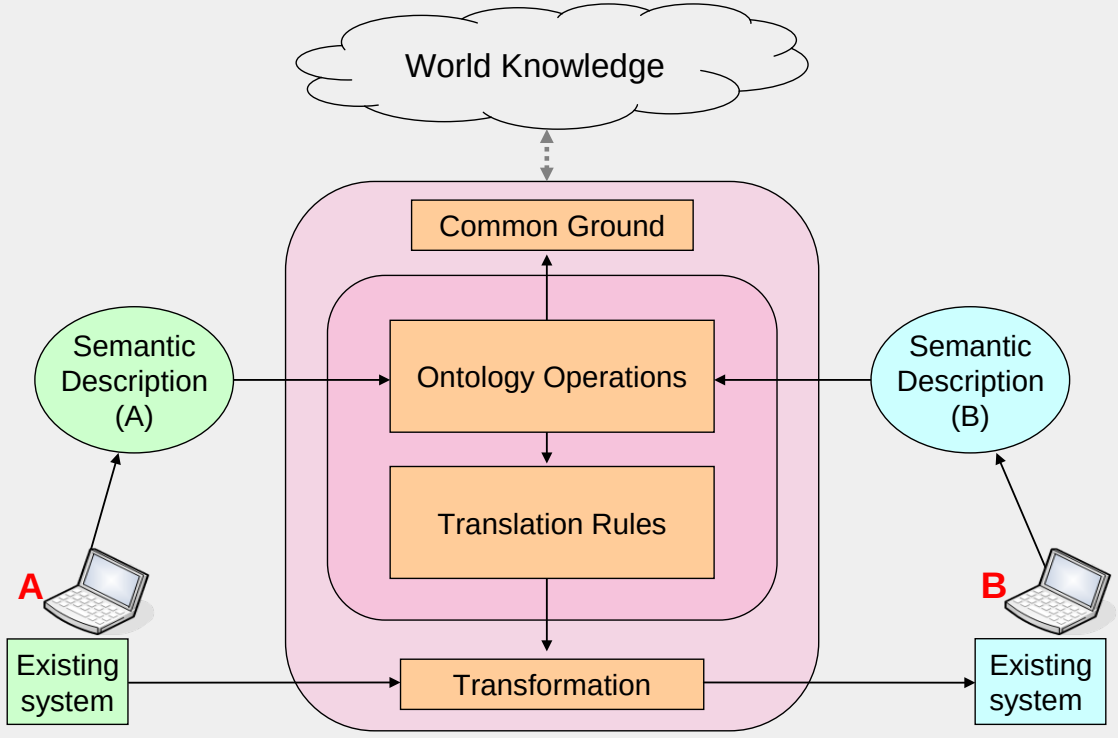
Related Work

Knowledge-based Solutions to Semantic Interoperability often exploit *the ontology notion*.

- Within the knowledge engineering community, ontology is defined as an explicit, formal specification of a shared conceptualization / knowledge.
- More recently, ontologies have become recognized as an emerging mechanism for dealing with semantic interoperability of IS.
- A way to achieve interoperability between two systems is to *align their ontologies*. Ontology alignment is the result of an ontology matching process which is the task of determining correspondences between the concepts of different ontologies.

Related Work

NATO's Semantic Interoperability Framework (SIF), a high-level interoperability architecture proposal:



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Related Work

The **Modeling & Simulation** community has tackled interoperability-related problems for many decades.

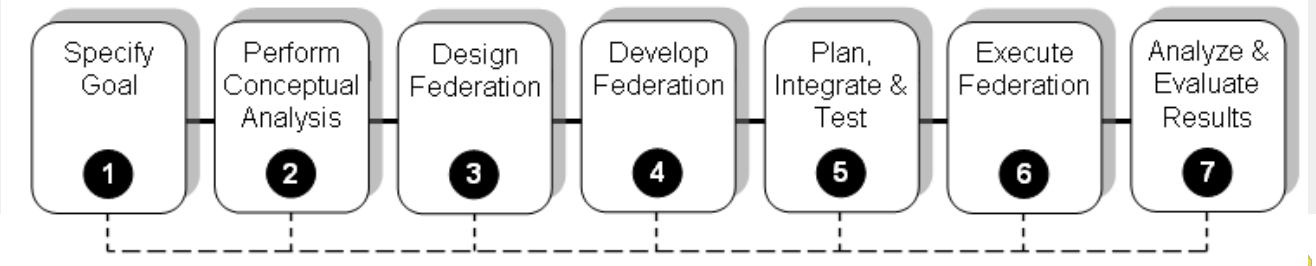
- The discipline is concerned with the execution of simulations on geographically distributed computer systems interconnected via a local area and/or wide area network, each generating its own representation of the battlefield from its own perspective.
- Since the late 1980's, there have been serious efforts to address the related problems of interoperability and reuse by encouraging the development of simulations according to well-defined standards.
- The Simulation Interoperability Standards Organization (SISO) has succeeded in establishing standards for distributed simulations, such as:
  - HLA (High-Level Architecture)
  - FEDEP (Federation Development and Execution Process)

Related Work – Modeling & Simulation

HLA

- An HLA-based distributed simulation is referred to as *federation*. Individual simulation models, that together form a federation, are called *federates*.
- Federates interact in a federation execution (simulation) through services provided by a run-time infrastructure using following:
- *Framework and Rules* – it specifies HLA components and describes the responsibilities and rules of federates and federations.
- *Federate Interface Specification* – The HLA relies on a standardized inter-federate interaction interface, in terms of a number of RTI services, such as federation management, message synchronization, etc.
- *Object Model Template (OMT) Specification* – it is a template for documenting information in HLA federations.

FEDEP -



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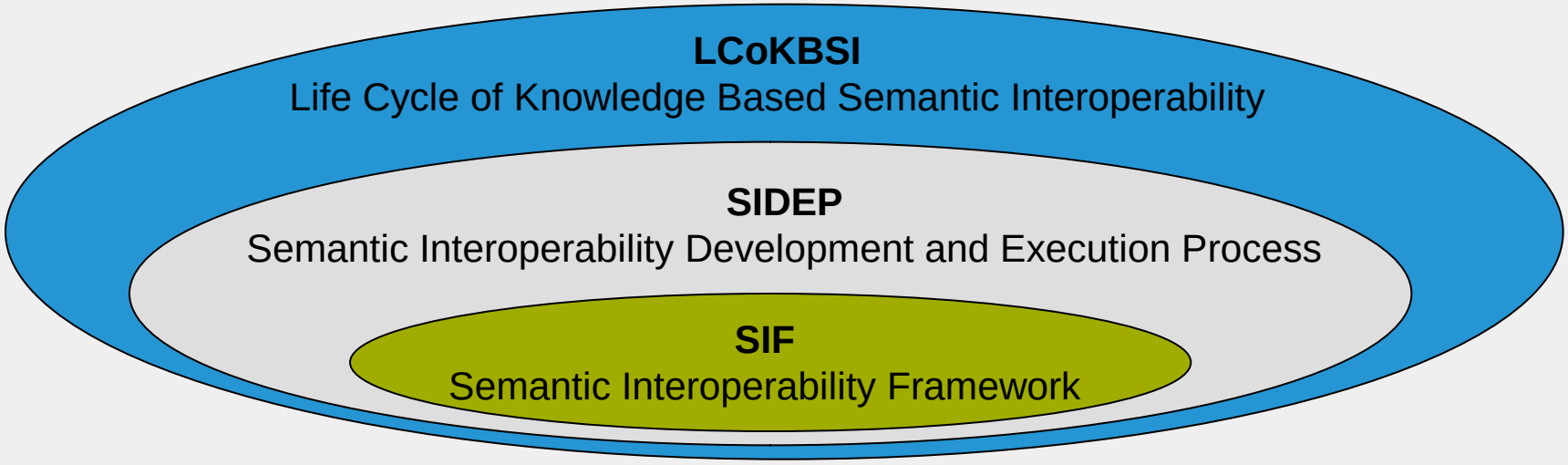
SIDEP - Overview

A Semantic Interoperability Development and Execution Process

SIDEP is based on best practice and experiences from:

- Modeling & Simulation
  - Similarly to FEDEP-HLA, SIDEP is a development and execution process for SIF
  - In both HLA and SIF an integrated context must meet several interoperability requirements, ranging from common network connectivity to semantic agreement..
  - Similarly to HLA Framework & Rules, SIDEP governs integration/development and use/execution of a C2 system configuration
- Other interoperability and semantic interoperability frameworks
  - ebXML (an XML-based framework for e-business collaboration)
  - OpenEDI (ISO standard for message protocol exchange)
  - CLC (a Collaboration Life-Cycle framework)
  - IDEP (interoperability Redevelopment and Execution. Process)
  - COA (Collaboration Oriented Architecture)

SIDEP – Scope



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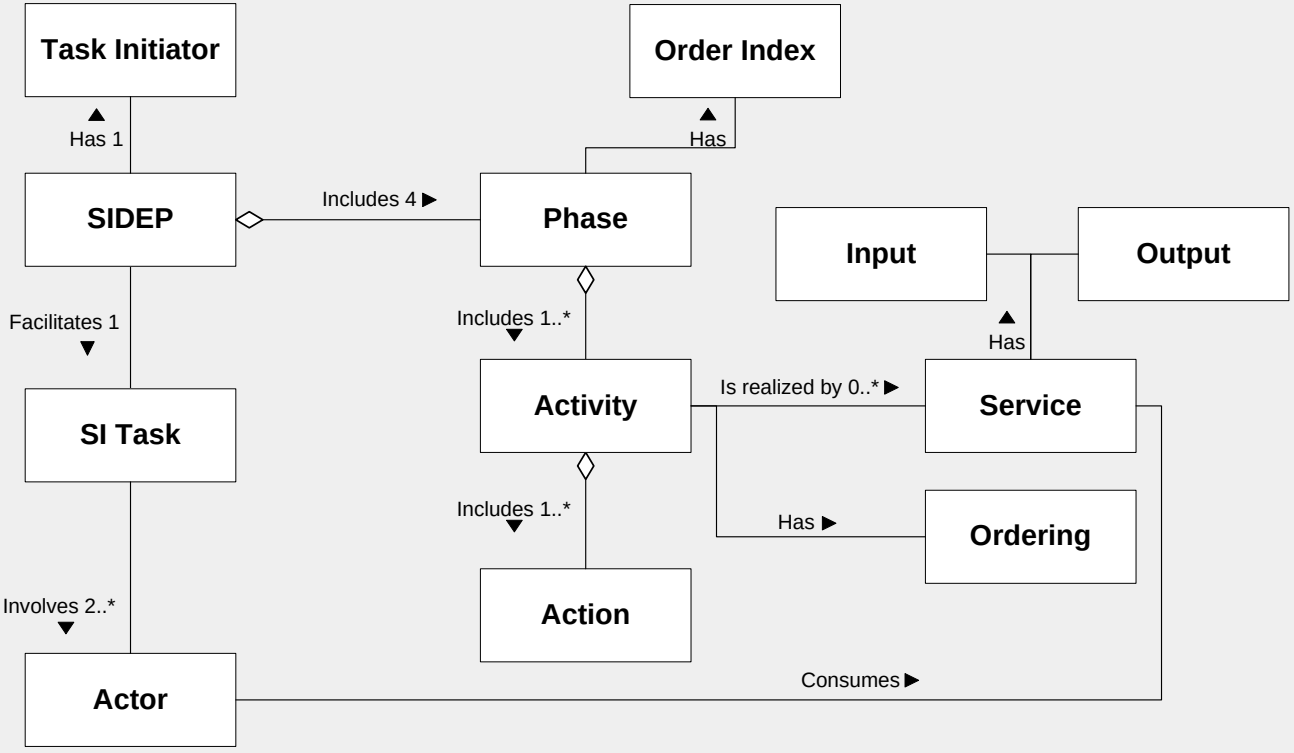
SIDEP – Conceptual Model

The major elements of the SIDEP meta-model



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SIDEP – Phases

- Preparation

  It is an “off-line” time segment in SIF. During this phase, individual actors such as military organizations or units use SIF (independently of each other) to perform a number of grounding activities.

- Configuration

  It encompasses all the essential activities related to the constitution of a common semantic base for a given interoperability task.

- Operation

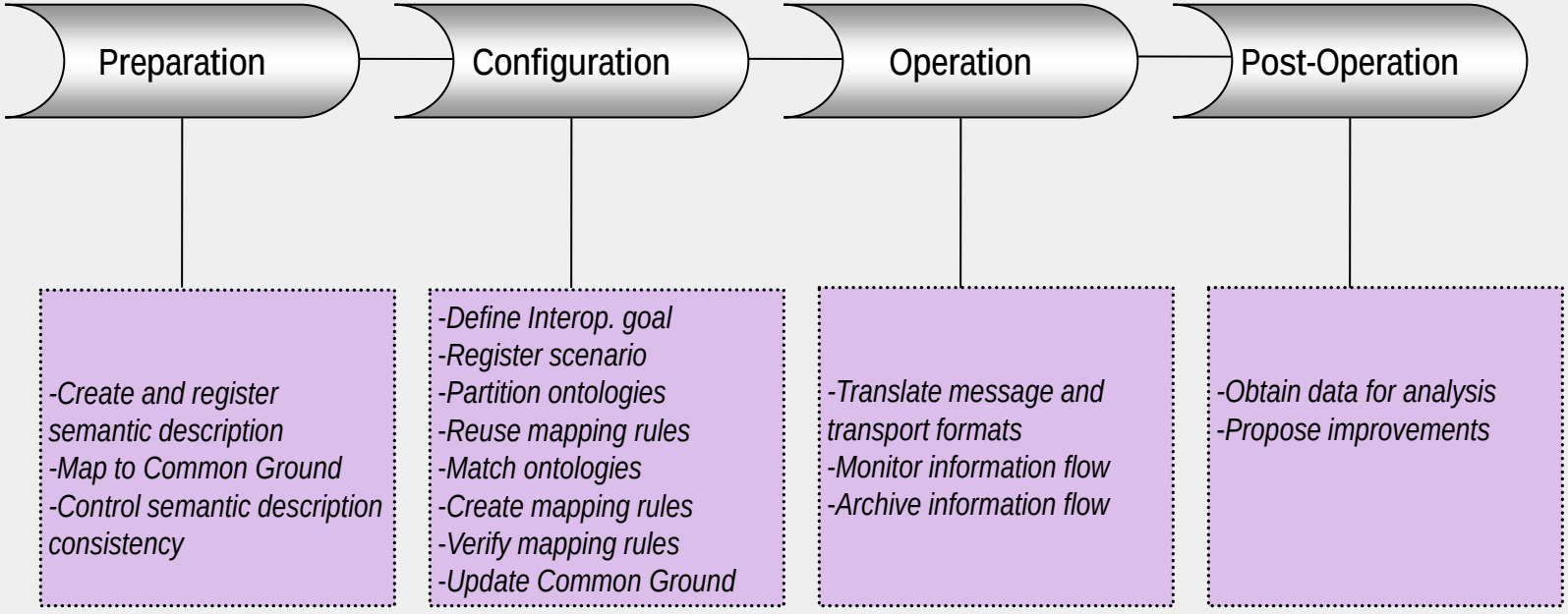
  Where the configuration is completed and the SI task is executed with the support of SIF realizing the message exchanges between the involved systems.

- Post-Operation

  In this phase the execution of the SI task is completed and the results are analyzed and evaluated.

SIDEP – Detailed Activities

All the activities are considered for realizations in the form of services.



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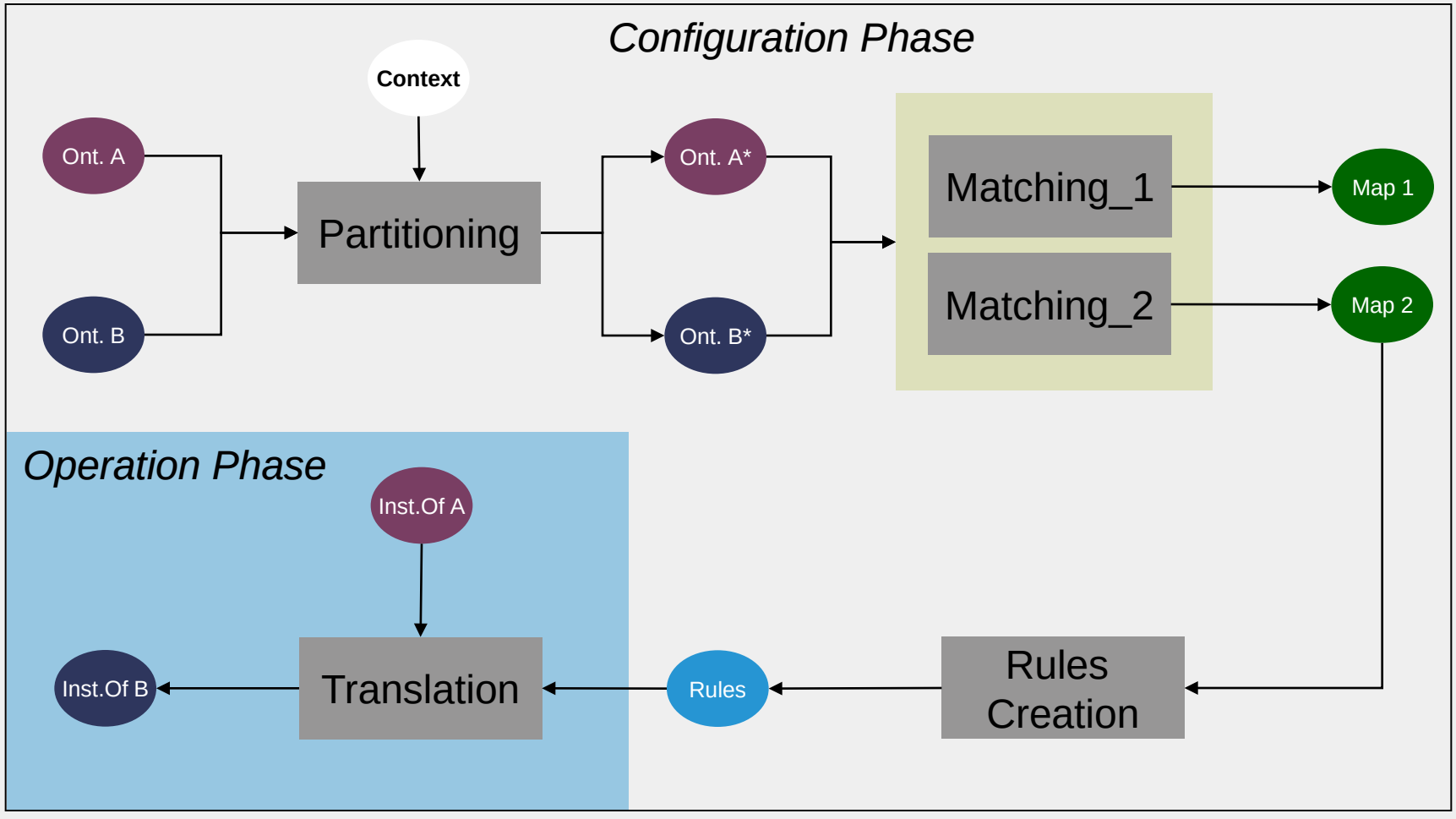
A View on Configuration and Operation Phases



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Conclusions and Future Work

- In this paper we have investigated how concepts and methods from the Modeling & Simulation discipline could facilitate in fulfilment of the requirements for SIF, a NATO semantic interoperability framework.
- Following HLA/FEDEP and other related frameworks, we have proposed a management process for semantic interoperability, SIDEP.
- SIDEP is aimed at governing the development and execution of system information exchange to meet expressed business requirements on interoperability tasks.
- Looking ahead, we intend to further refine SIDEP activities, especially in respect to flexibility of use and service orientation.
- We are working on implementing SIF and SIDEP in a service-centric semantic broker and use a prototype to validate and evaluate the usability and efficiency of SIF and SIDEP.