

An Ontological Approach to Consolidate Standards-Based Concepts in Production Engineering

Tish Chungoora and Bob Young

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IMKS

Interoperable Manufacturing Knowledge Systems

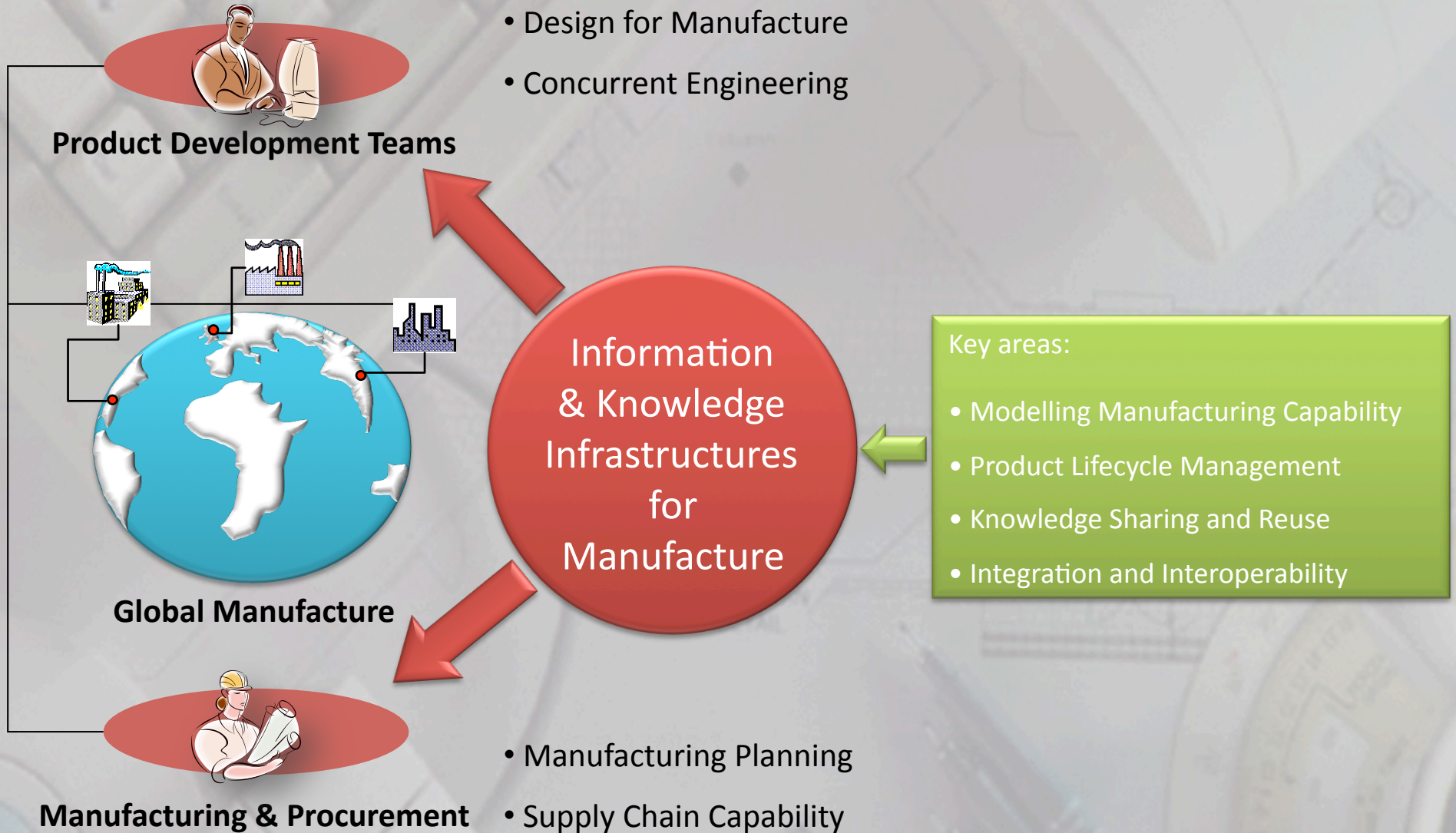
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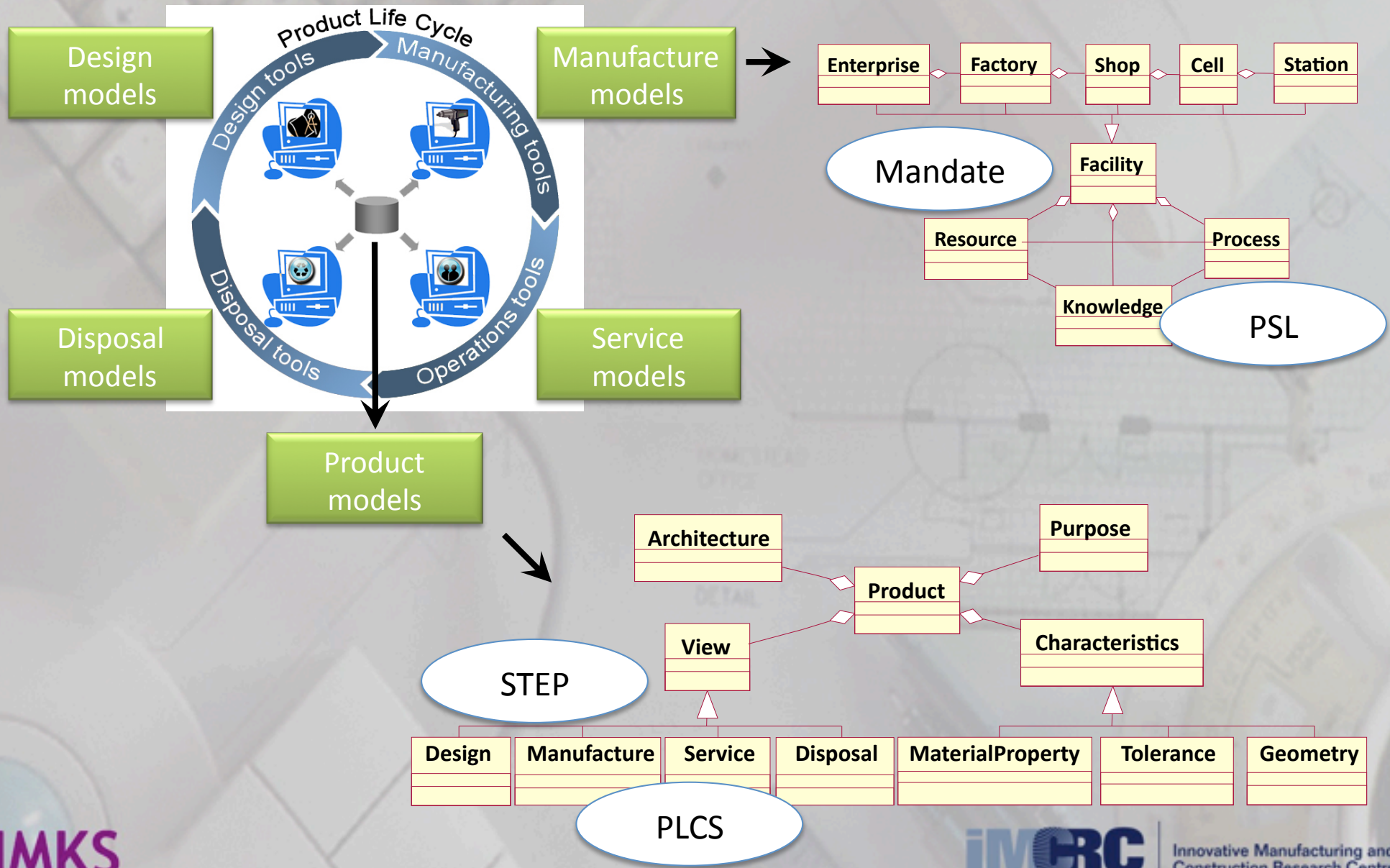
Presentation Outline

- Background
- Multiple standards, textual definitions and loose semantics
- A Common Logic-based approach for the consolidation of semantics
- Initial implementation
- Issues and Conclusions

Background

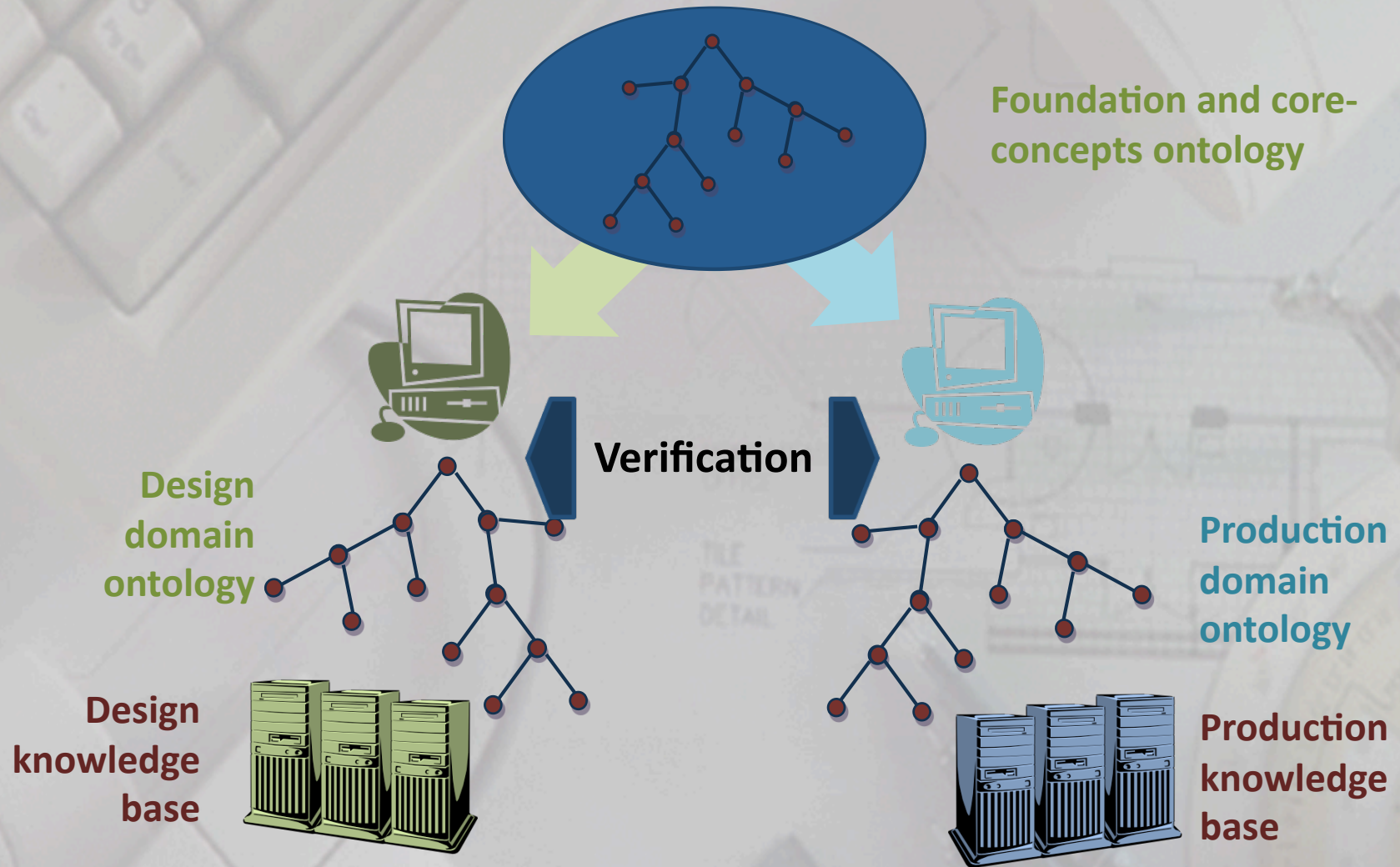


Background



The IMKS Project

IMKS: Interoperable Manufacturing Knowledge System



IMKS

Interoperable Manufacturing Knowledge Systems

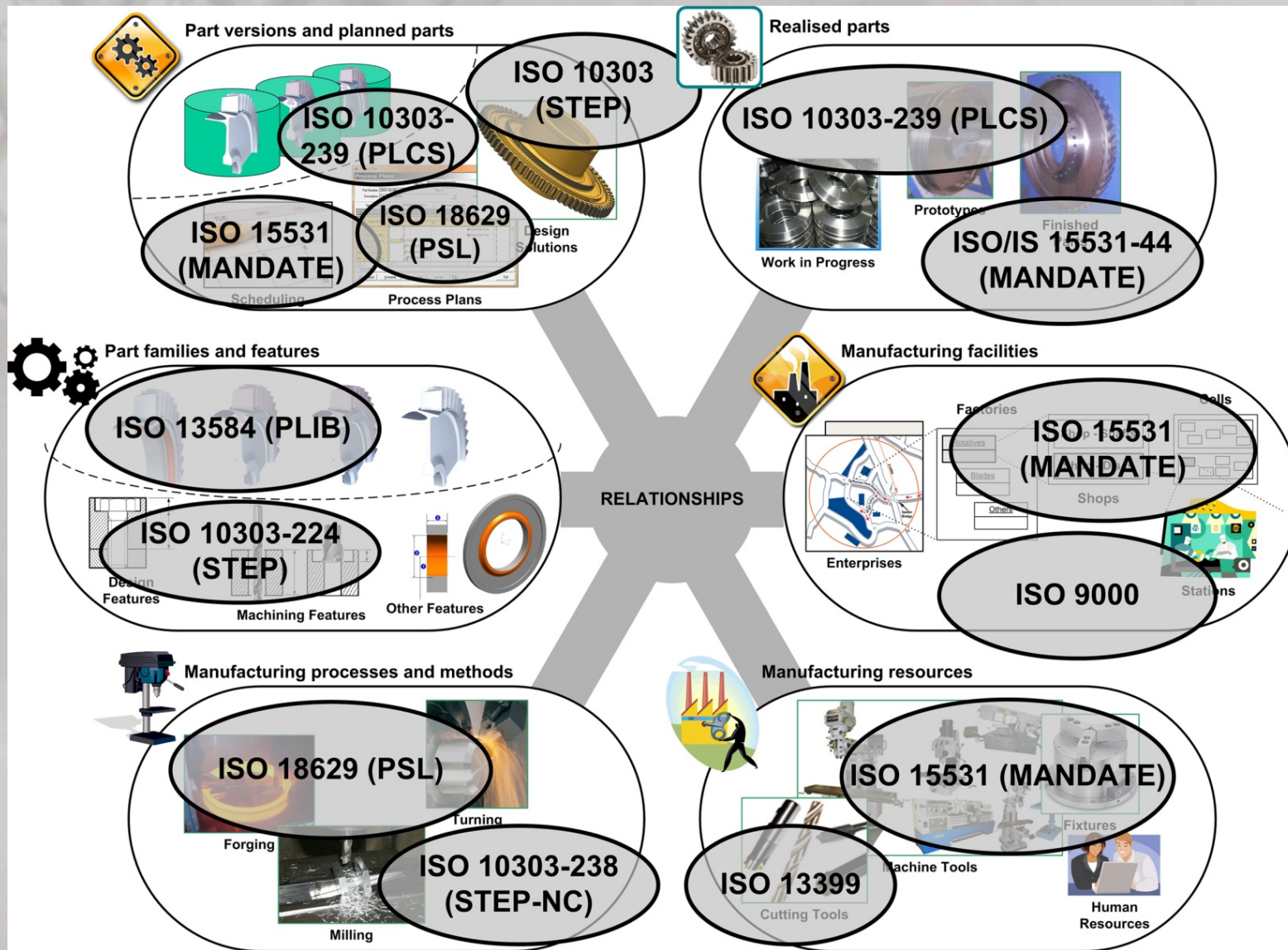
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Background

- ISO TC184 SC4 “Future SC4 Architectures”
 - *“Explore the range of options for exploiting new technologies to support interoperability between SC 4 standards*”
 - Potential of exploiting ontology-based approaches such as the Web Ontology Language (OWL) and Common Logic (CL)
 - Now “Industrial Data Integrated Ontologies and Models” (IDIOM)

Manufacturing Information - Multiple Standards

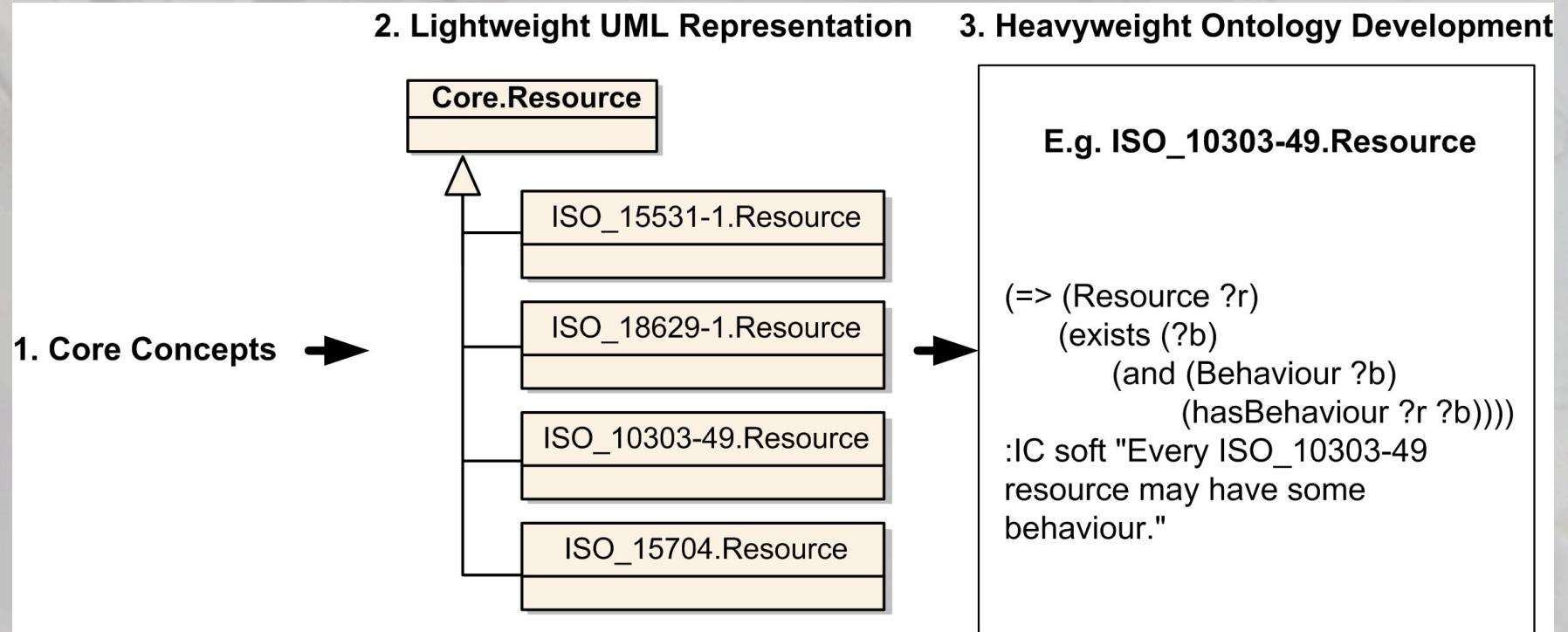


Informal Definitions: e.g. 'Resource' term

- **Resource (ISO 15531-1; ISO 18629-1):** Any device, tool and means, except raw material and final product components, at the disposal of the enterprise to produce goods or services. This definition includes ISO 10303-49 definition.
- **Resource (ISO 10303-49):** Something that may be described in terms of a behavior, a capability, or a performance measure that is pertinent to the process.
- **Resource (ISO 15704):** An enterprise entity that provides some or all of the capabilities required by the execution of an enterprise activity and/or business process.

Michel, J.J., 2005. Terminology extracted from some manufacturing and modelling related standards. CEN/TC 310 N1119R2.

Ontology-Based Methodology

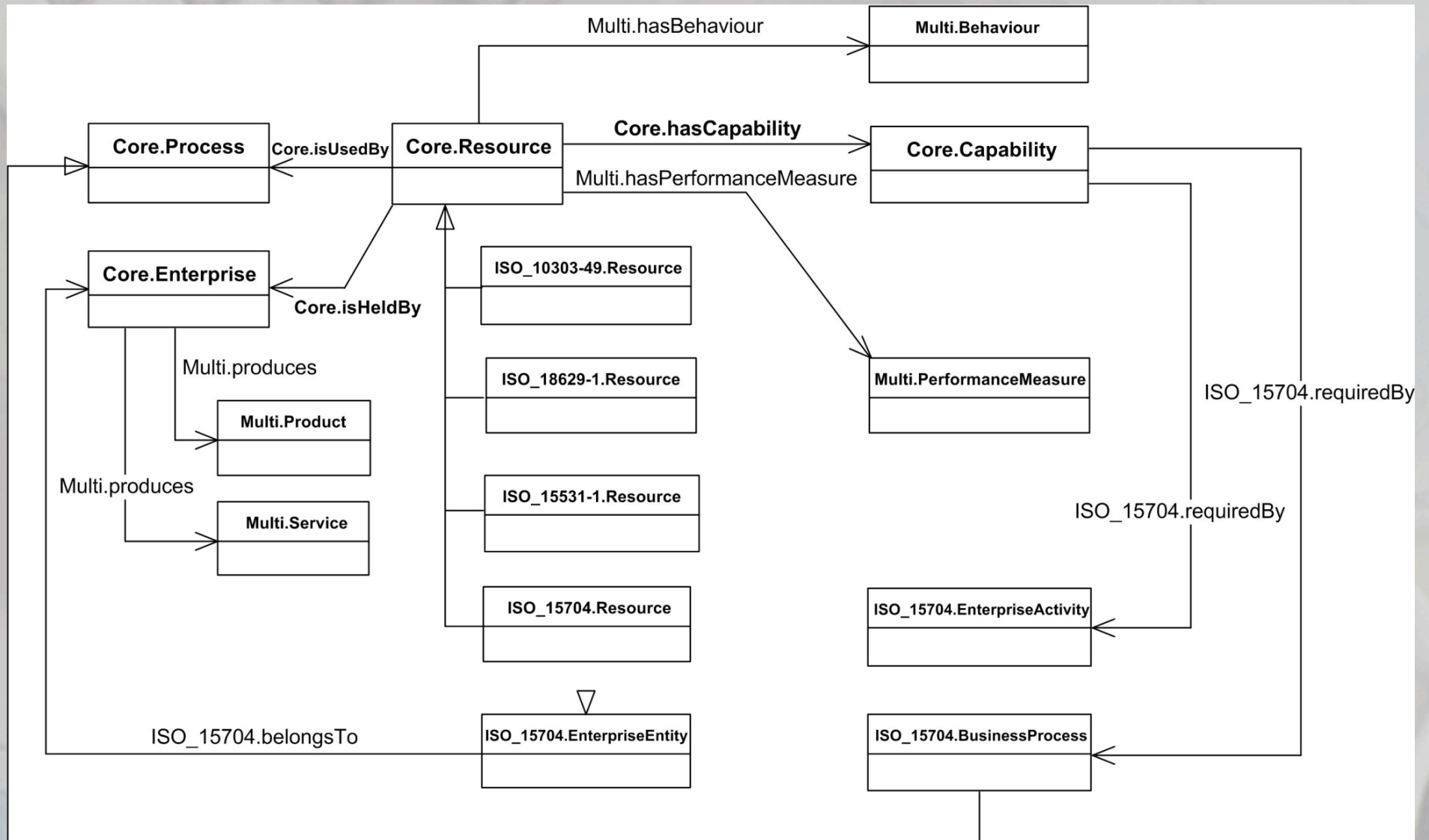


- Knowledge Frame Language: an extended implementation of Common Logic Interchange Format (CLIF)

Establish Core Concepts

- Requires input from domain experts and knowledge architects
- Consensus-driven
 - E.g. The term 'Resource' as a core concept
- Other core concepts can also be identified at this stage
 - E.g. 'Capability' and 'Process' (recurrent across standards)

Develop Lightweight Representation



Develop Heavyweight Representation

- Basic structures such as contexts, classes and relations
- E.g. Declare class ISO_15704.Resource:

(Type ISO_15704.Resource)

(sup ISO_15704.Resource Core.Resource)

(sup ISO_15704.Resource ISO_15704.EnterpriseEntity)

- Logic-based axioms (integrity constraints)

Core Concept Semantics

(=> (Core.Resource ?r)
(exists (?c)
 (and (Core.Capability ?c)
 (Core.hasCapability ?r ?c))))
:IC soft **“Every resource may have some capability.”**

(=> (Core.Resource ?r)
(exists (?e)
 (and (Core.Enterprise ?e)
 (Core.isHeldBy ?r ?e))))
:IC soft **“Every resource may be held by some enterprise.”**

(=> (Core.Resource ?r)
(exists (?p)
 (and (Core.Process ?p)
 (Core.isUsedBy ?r ?p))))
:IC soft **“Every resource may be used by some process.”**

- Generic allowable but not compulsory conditions

Specific Concept Semantics: E.g. ISO_15704.Resource

```
(=> (ISO_15704.Resource ?r)
(or (exists (?c ?a)
      (and (Core.Capability ?c)
            (ISO_15704.EnterpriseActivity ?a)
            (Core.hasCapability ?r ?c)
            (ISO_15704.requiredBy ?c ?a))))
(exists (?c ?a)
      (and (Core.Capability ?c)
            (ISO_15704.BusinessProcess ?a)
            (Core.hasCapability ?r ?c)
            (ISO_15704.requiredBy ?c ?a))))))
```

:IC hard **“Every ISO 15704 resource has some capability required by some enterprise activity and/or business process.”**

- Specific and compulsory conditions

- Textual definition: An enterprise entity that provides some or all of the capabilities required by the execution of an enterprise activity and/or business process.

Implementation in Highfleet IODE

• Taxonomy of classes

- MLO.Object
 - Core.Resource
 - ISO_15531-1.Resource
 - ISO_18629-1.Resource
 - ISO_10303-49.Resource
 - ISO_15704.Resource
 - Core.Process
 - ISO_15704.BusinessProcess
 - Core.Capability
 - Core.Enterprise
 - Multi.Behaviour
 - Multi.PerformanceMeasure
 - Multi.Product
 - Multi.Service
- ISO_15704.EnterpriseEntity
 - ISO_15704.Resource
 - ISO_15704.EnterpriseActivity

• Relations

Relations

```
Core.Resource
- Core.hasCapability: Core.Resource X Core.Capability
- Core.isHeldBy: Core.Resource X Core.Enterprise
- Core.isUsedBy: Core.Resource X Core.Process
- Multi.hasBehaviour: Core.Resource X Multi.Behaviour
- Multi.hasPerformanceMeasure: Core.Resource X Multi.PerformanceMeasure
```

• Integrity Constraints

Assertions

```
(integrityRule
  (fidEx "Resource_Consolidation" 1)
  (=>
    (Resource ?r)
    (exists
      (?c)
      (and
        (Capability ?c)
        (hasCapability ?r ?c))))))

(integrityRule
  (fidEx "Resource_Consolidation" 2)
  (=>
    (Resource ?r)
    (exists
      (?e)
      (and (Enterprise ?e) (isHeldBy ?r ?e))))))

(integrityRule
  (fidEx "Resource_Consolidation" 3)
  (=>
    (Resource ?r)
    (exists
      (?p)
      (and (Process ?p) (isUsedBy ?r ?p))))))
```

Implementation: Consistency Checking

1. (ISO_15704.Resource ISO_15704.LboroCuttingTool) ← Loading an instance of 'ISO_15704.Resource' with inconsistent semantics

Check ICs?

```
(ISO_15704.Resource ISO_15704.LboroCuttingTool) to (ISO_15704.Resource ISO_15704.LboroCuttingTool)
Asserting 1 fact(s) ...
  (ISO_15704.Resource ISO_15704.LboroCuttingTool) aid: #5-6-182
Committing 1 ...
Soft IC Violation: Every resource may be used by some process.
Soft IC Violation: Every resource may be held by some enterprise.
Soft IC Violation: Every resource may have some capability.
Hard IC Violation: Every ISO 15704 resource has some capability required by some enterprise activity and/or business process.
Hard IC Violation: Every enterprise entity belongs to some enterprise.
Assertions cancelled.
```

ICs inherited from 'Core' context

ICs specific to 'ISO_15704' context
2. (ISO_15704.Resource ISO_15704.LboroCuttingTool) ← Loading an instance of 'ISO_15704.Resource' with consistent semantics

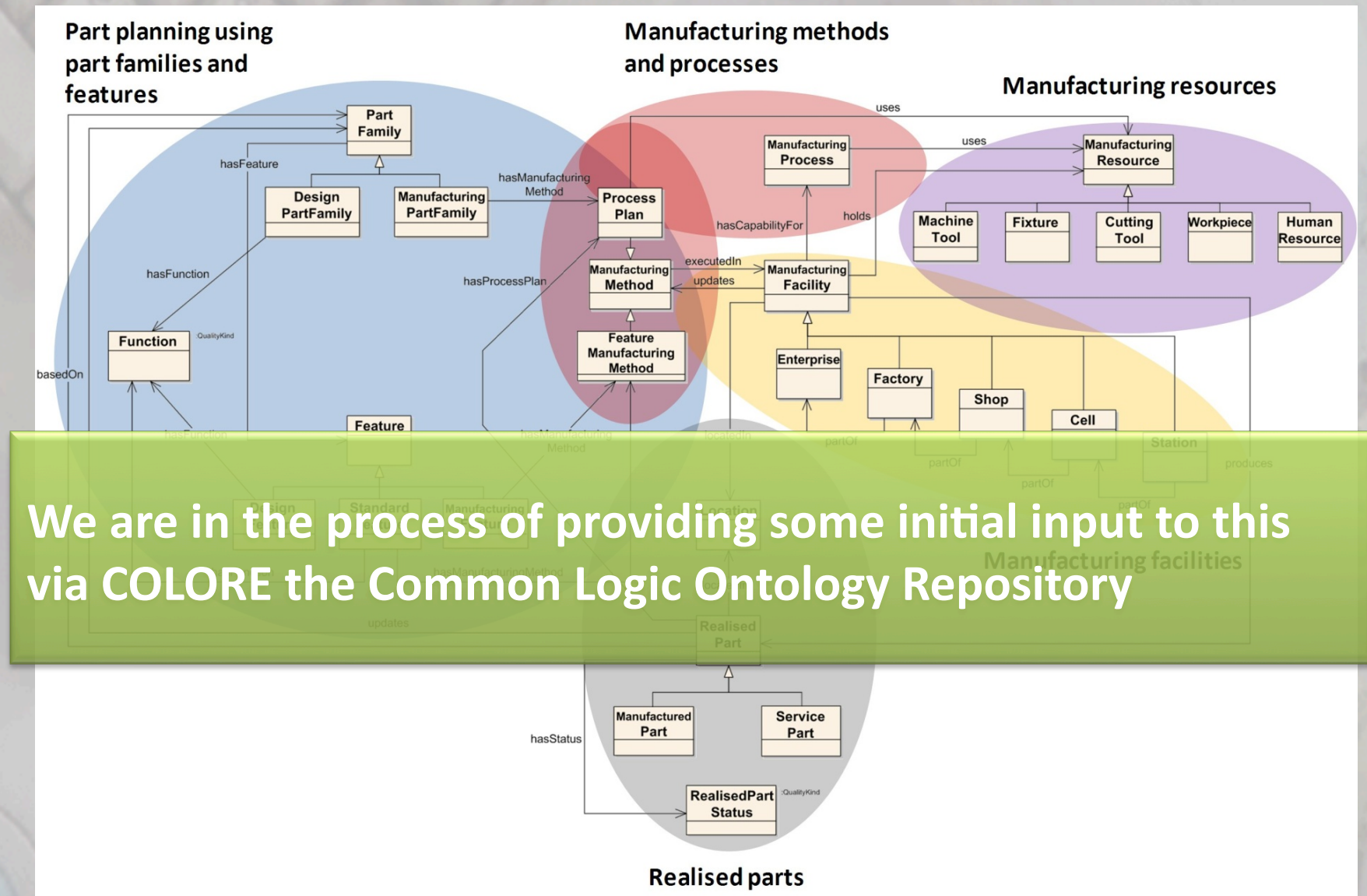
```
(Core.Capability ISO_15704.ToleranceRange_10microns)
(Core.hasCapability ISO_15704.LboroCuttingTool ISO_15704.ToleranceRange_10microns)
(ISO_15704.EnterpriseActivity ISO_15704.MachiningDemonstration)
(ISO_15704.requiredBy ISO_15704.ToleranceRange_10microns ISO_15704.MachiningDemonstration)
(Core.Enterprise ISO_15704.LoughboroughUniversity)
(ISO_15704.belongsTo ISO_15704.LboroCuttingTool ISO_15704.LoughboroughUniversity)
```

Check ICs?

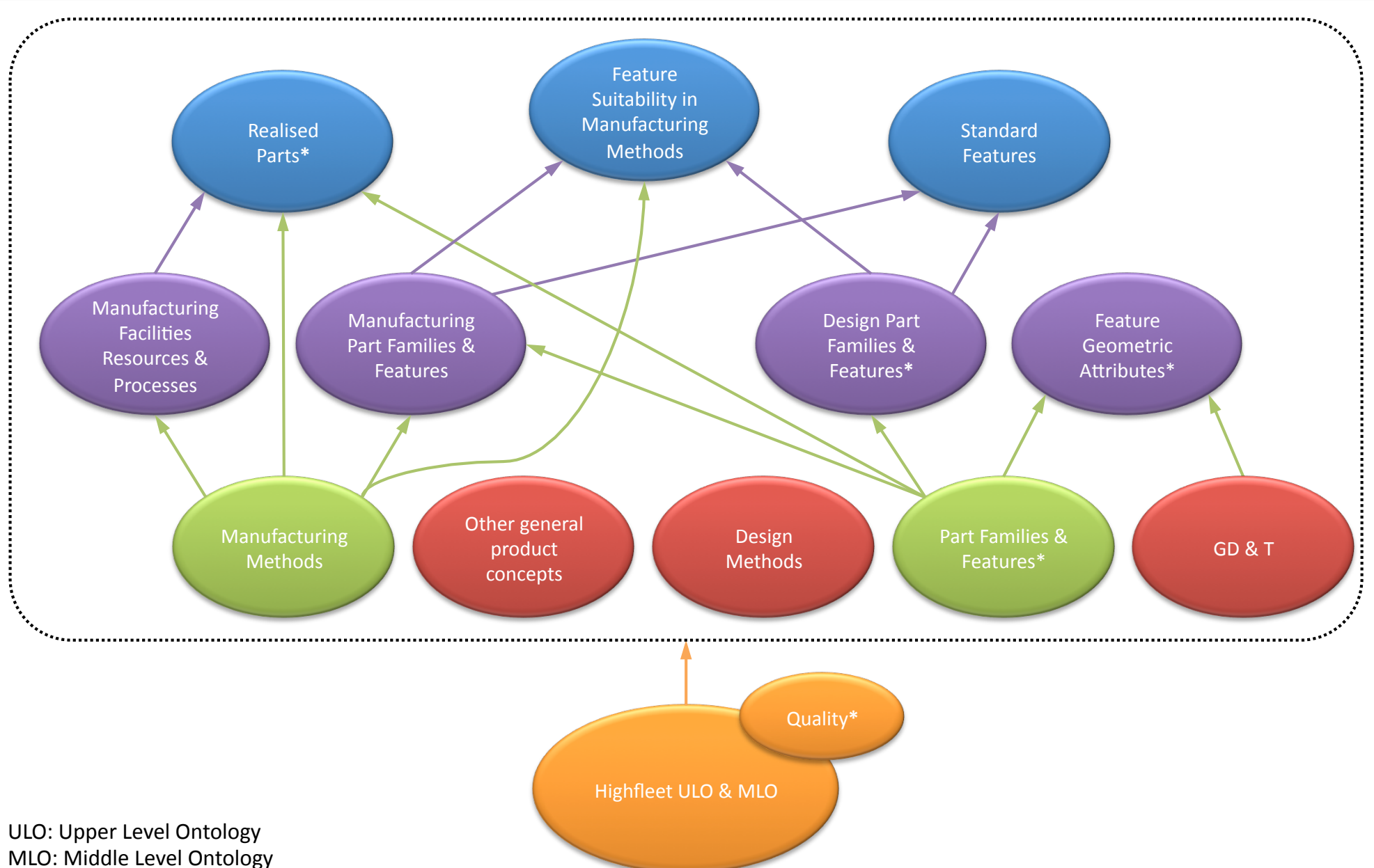
```
Committing 7 ...
Soft IC Violation: Every resource may be used by some process.
Soft IC Violation: Every resource may be held by some enterprise
Committed 7 ... 7 in 0:00:00.329 @ 21/sec
Finished Loading: 7 in 0:00:00.329 @ 21/sec
```

Soft ICs

Further Work: Manufacturing Reference Ontology



We are in the process of providing some initial input to this via COLORE the Common Logic Ontology Repository



ULO: Upper Level Ontology
 MLO: Middle Level Ontology
 GD & T: Geometric Dimensioning and Tolerancing (started but not complete)

 Areas for further development

Key issues

- Clarify the requirements for the effective consolidation of production-based standards.
 - e.g. Language OWL v CL?
 - mapping/verification methods?
 - others?
- Relate core concepts to foundational ontologies e.g. DOLCE, SUO, GFO ?

Conclusions

- There is a need for improved concept semantics where multiple standards need to be used in conjunction
- A well-defined and extensible set of formal core concepts could support a wide range of production-centric standards
- A Manufacturing Reference Ontology, defined in Common Logic, could provide radical improvements in managing the interoperation of multiple production-centric standards