Building An Ontology For Command & Control

10th International Command and Control Research and Technology Symposium

The Future of C2

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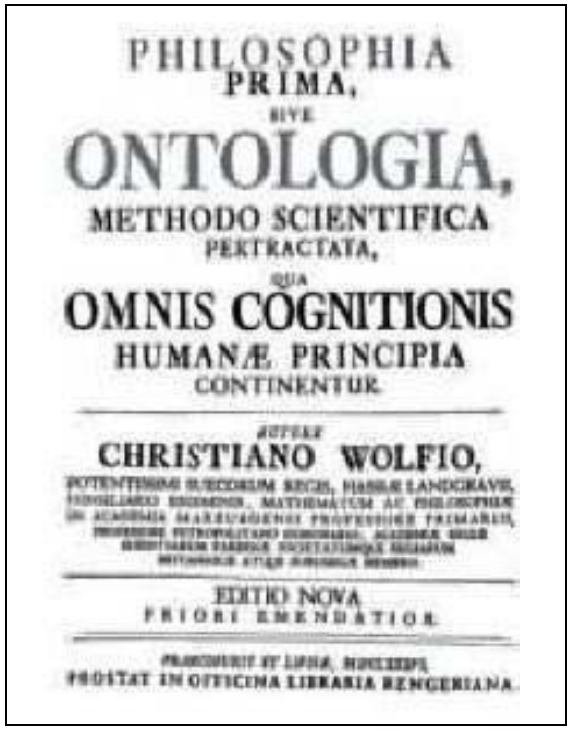
Agenda

- Background
  - What is an Ontology?
  - Modeling a Domain
  - What is Command & Control (C2)?
  - C2 Processes
- Ontologies & C2
- Ontological Constructs
  - Building Blocks
  - Establishing an Ontology Baseline
  - A 7-Step Process
- Where Do We Go From Here?

Background

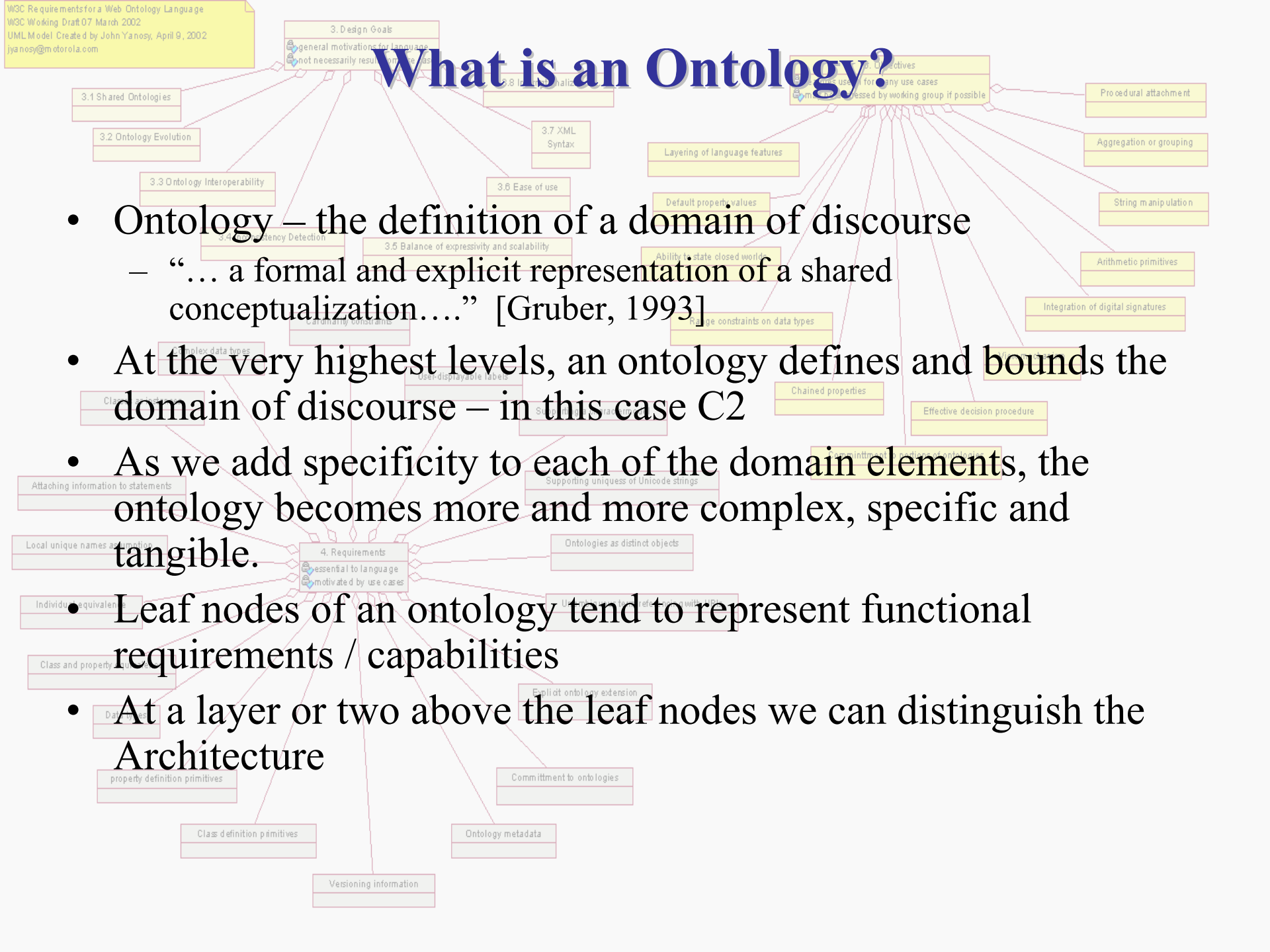
- C2 Processes have been the subject of investigation since the inception of military forces
- For the last 20+ years we have been developing *Architectures* to help formulate a better understanding of C2 and to gain efficiency and interoperability from C2 systems
- Recently our attention has turned to C2 ***Ontologies*** in an attempt to better define C2 Architectures and enhance our understanding of C2 itself


PHILOSOPHIA
PRIMA,
SIVE
ONTOLOGIA,
METHODO SCIENTIFICA
PERTRACTATA,
QUA
OMNIS COGNITIONIS
HUMANÆ PRINCIPIA
CONTINENTUR.
AUTORE
CHRISTIANO WOLFIO,
EDITIO NOVA
PRIORI EMENDATIOR.

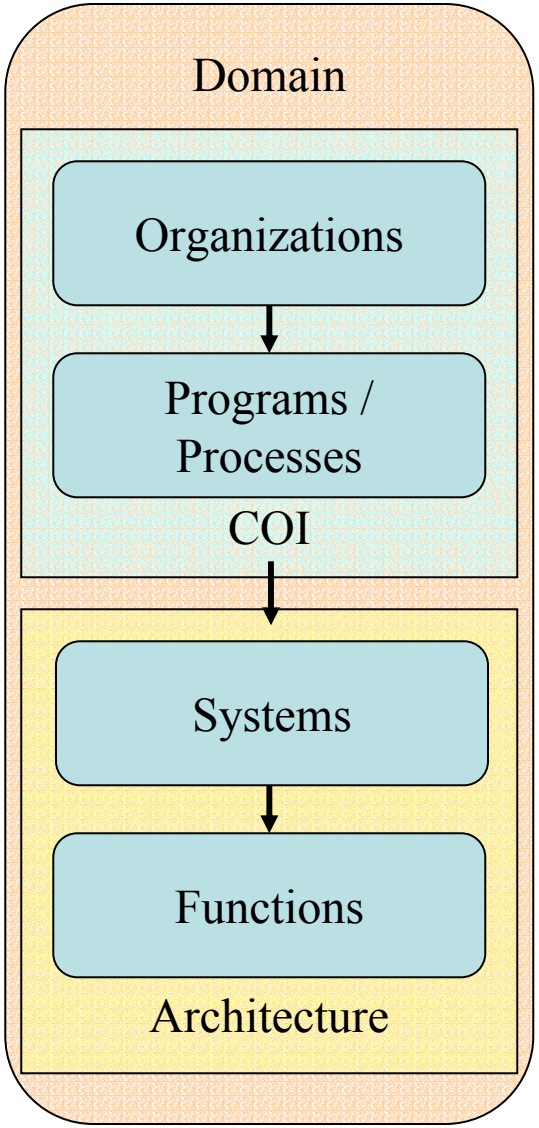
Christian Wolff's Philosophia prima sive Ontologia (1729) - First book with the word "ontology" in the title

What is an Ontology?

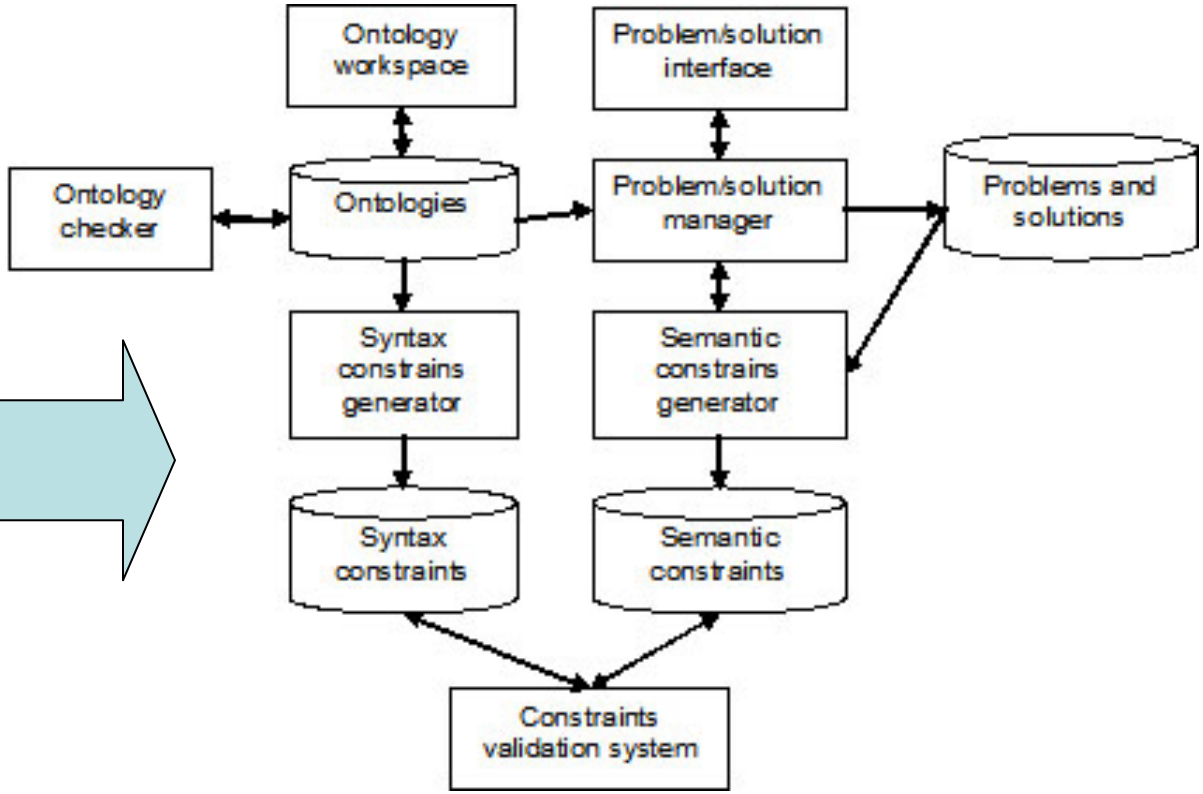
- Ontology – the definition of a domain of discourse
  - "… a formal and explicit representation of a shared conceptualization…." [Gruber, 1993]
- At the very highest levels, an ontology defines and bounds the domain of discourse – in this case C2
- As we add specificity to each of the domain elements, the ontology becomes more and more complex, specific and tangible.
- Leaf nodes of an ontology tend to represent functional requirements / capabilities
- At a layer or two above the leaf nodes we can distinguish the Architecture



Ontology / Architecture Domain Model



Systems Architecture of an Ontology



Modeling a Domain

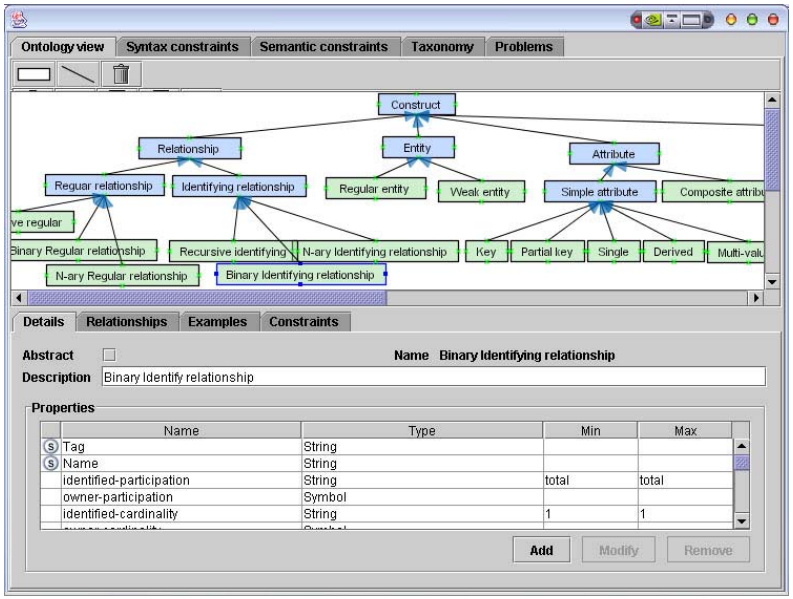
- There is no one correct way to model a domain - there are always viable alternatives.
  - The best solution almost always depends upon the application and anticipated extensions.
- Ontology development is necessarily an iterative process and, in some sense,
  - an art

    as much as
  - a science.

Air Force: Draw up a contract
Navy: Lock the doors
Army: Post guards
Marine Corps: Enter and take over

Ontology Development

- Concepts in the ontology are primarily objects (physical or logical) and relationships within the domain of interest.
- In general,
  - ***nouns*** become *objects*,
  - ***verbs*** generally indicate *relationships* and
  - ***adjectives*** *and* ***adverbs*** become descriptive *attributes* of those objects and relationships.



There are more than 50 automated ontology toolsets available to assist in such development, including Protégé, Construct, DUET, Haystack, IODE, Knowledge Builder, SMORE, etc

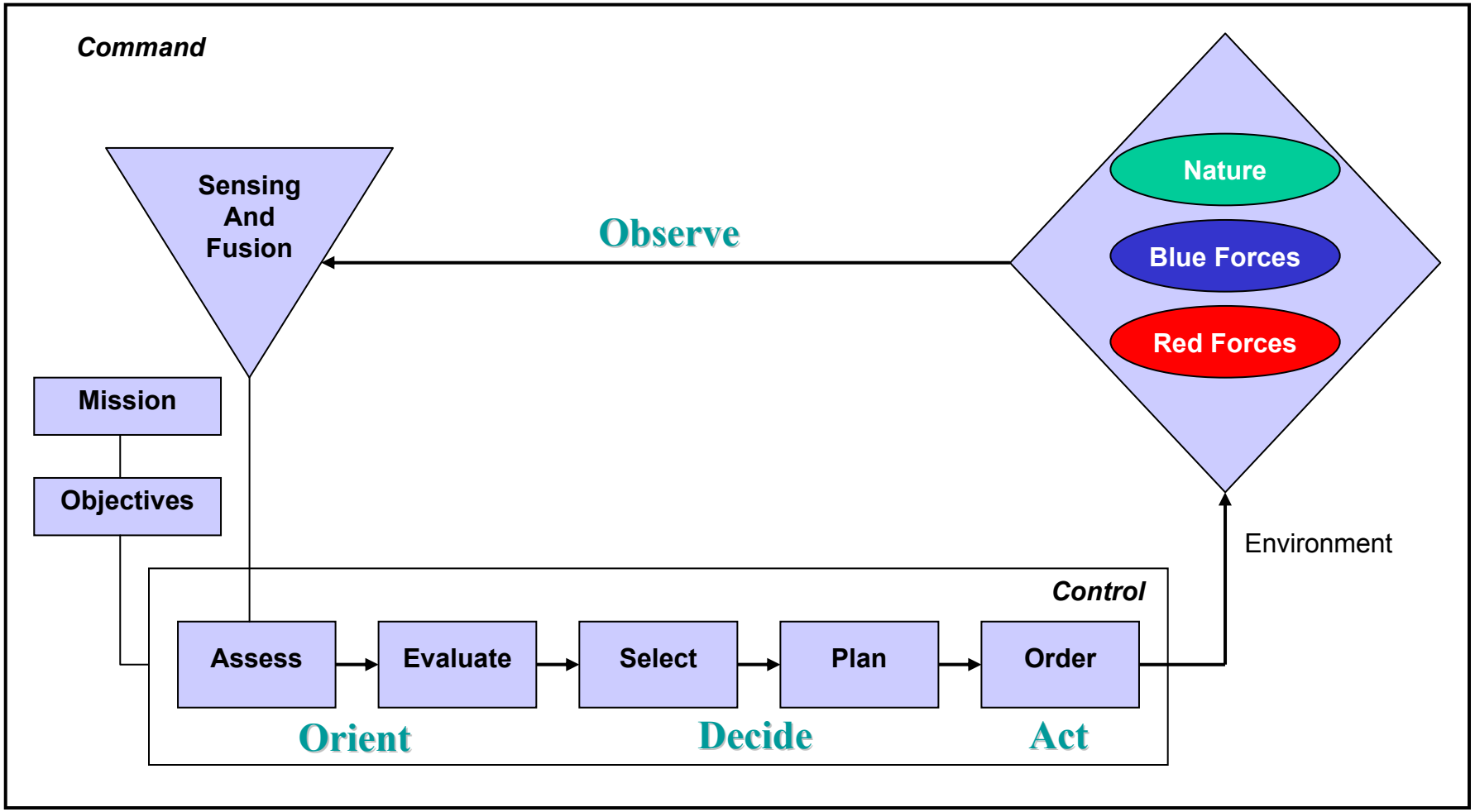
What is Command & Control?

- As simply as possible, Command & Control can be defined as the actual process of directing and controlling forces.
- It is the authority that a commander exercises over his subordinates by virtue of his rank or assignment. Specifically:

"Command & Control is the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the mission. Command & Control is performed through an arrangement of personnel, equipment, communications, facilities and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission."

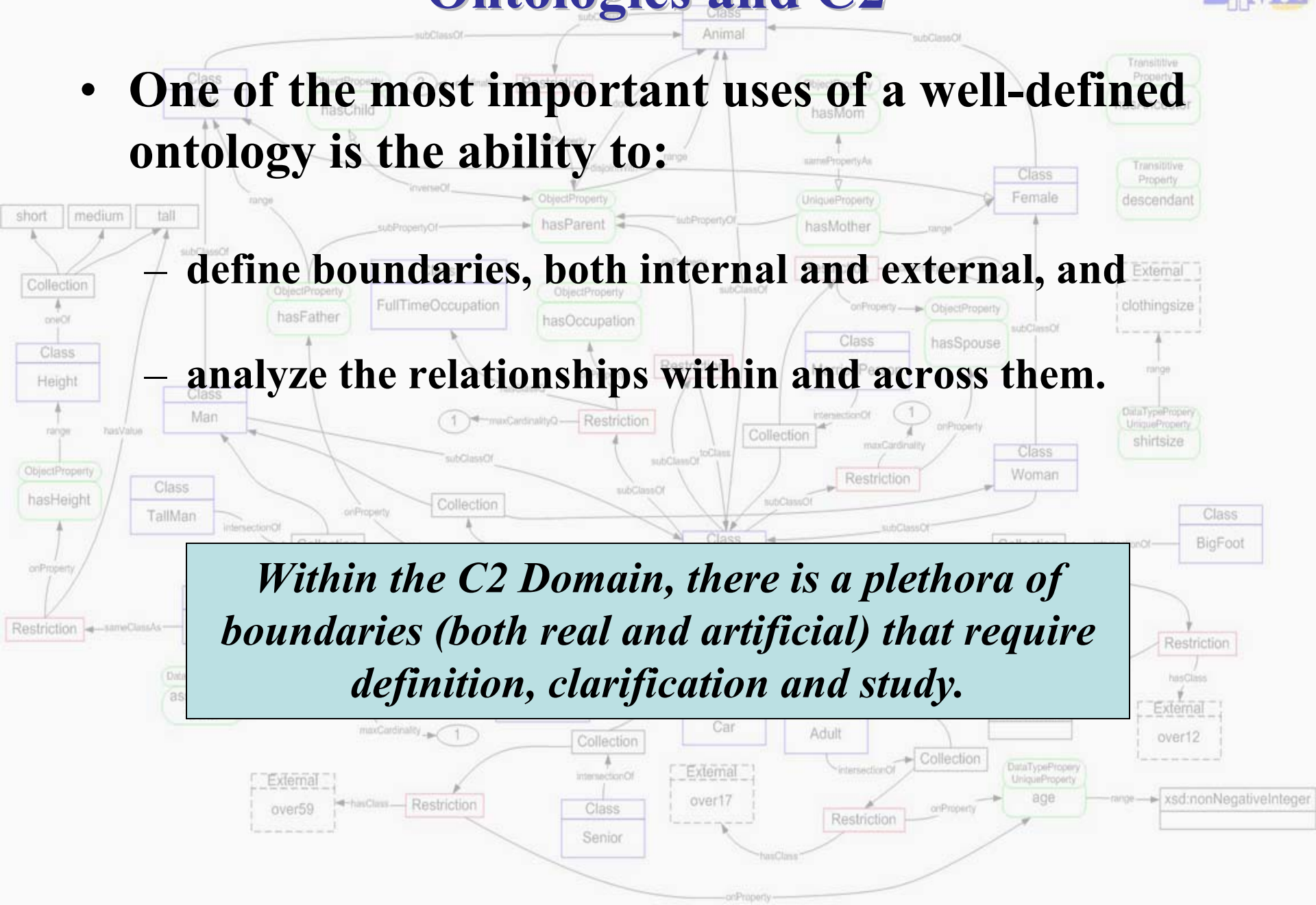
JCS Pub 1-02

Command & Control Process



Ontologies and C2

- **One of the most important uses of a well-defined ontology is the ability to:**
  - **define boundaries, both internal and external, and**
  - **analyze the relationships within and across them.**

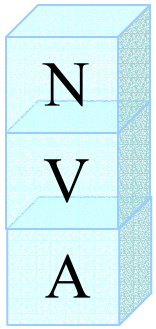


Within the C2 Domain, there is a plethora of boundaries (both real and artificial) that require definition, clarification and study.

Ontological Constructs as BUILDING BLOCKS

Basic Building Blocks

Ontological Constructs



Nouns / Objects

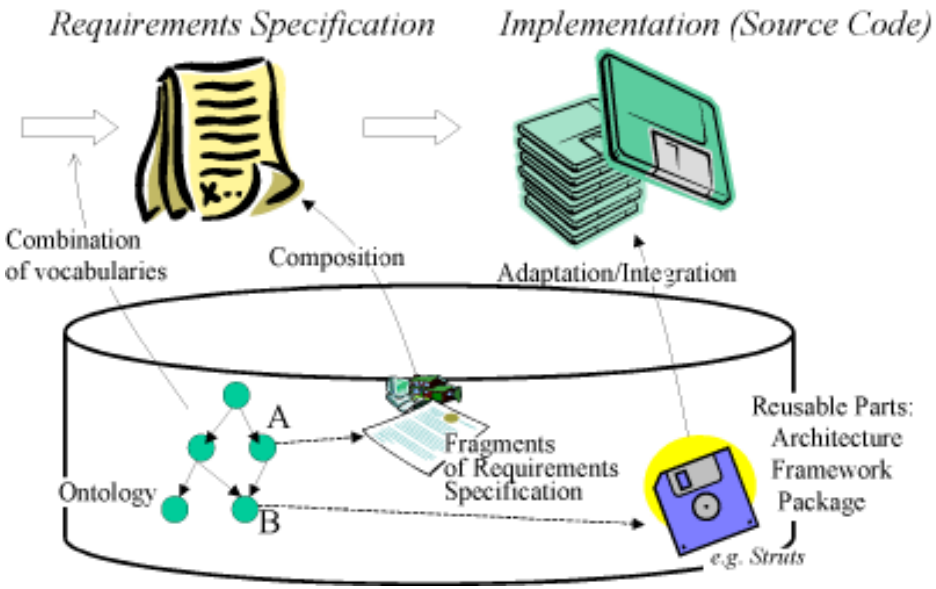
Verbs / Relationships

Adjectives / Adverbs / Attributes

Basic building blocks of Ontological concepts.

Establishing an Ontology Baseline

- Like any ontology, we start by listing the relevant *nouns, verbs* and *adjectives / adverbs* and begin to build the ontological relationships.
- In order to prevent the evolution of "stove-piped" ontologies similar to the "stove-piped" systems and architectures of the past, it is generally a good idea to attempt to define the breadth of the domain first then fill in details as time and resources permit.



- ❖ Helps keep the "Big Picture" in focus while concentrating on the pieces and
- ❖ Forces us to consider all of the inter-connections between / among them

A 7-Step Process

Step 1. Determine the domain and scope of the ontology (breadth first)

Step 2. Consider reusing existing ontologies or ontology segments

Step 3. Enumerate important terms in the ontology

Step 4. Define the classes and the class hierarchy

Step 5. Define the properties of classes – attributes

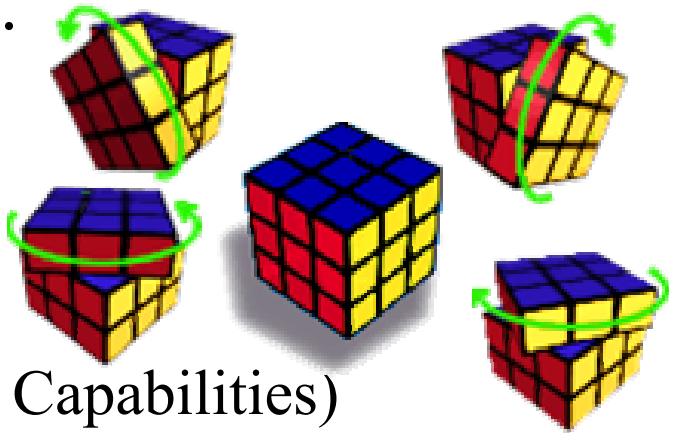
Step 6. Define the facets of the attributes

Step 7. Create instances of the objects comprising the ontology

[Noy, 2001]

Ontological Views

- Much like Architectures there can be many ***views*** of an Ontology but there is ***one and only one Ontology*** for any given domain.
  - Operational View
  - Organizational View
  - System (Physical) View
  - Technical View (Standards)
  - Functional View (Requirements / Capabilities)
  - Mission Capabilities Package View



- Ontologies are made up of a variety of constructs
  - *Policies* define *operations* which are carried out by *organizations* and resourced by *systems* which combine *functional capabilities* into *Mission Capability Packages*.

Where Do We Go From Here?

- Ontologies are fast becoming the *de jour* method of describing domains and their internal and external relationships
- The C2 domain needs to be bounded, defined, clarified and studied.
- Ontologies provide a construct for modeling the domain including internal and external relationships
  - e.g., COIs, Architectures, Responsibilities, etc.

Efforts are needed to position "C2 Ontology" as an acceptable method of helping us understand the C2 domain.

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