



# The Language of Complexity: Ontology in Systems Design and Engineering



### **Raytheon Missile Systems**

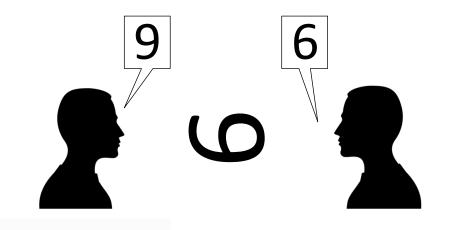
Abe Wu, Dr. George Ball, Dr. Kit Runge, Randy Ramsey, Nick Barrett, Todd Schneider, Dr. Cary Butler, Martin Kittrell

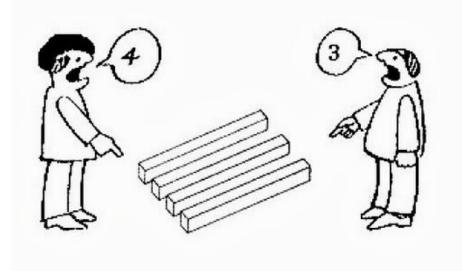
Oct 24, 2017

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## Toilet Out of Order Use Floor Below

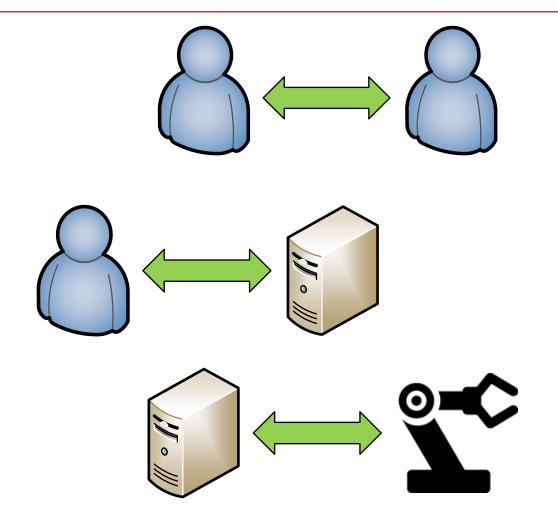




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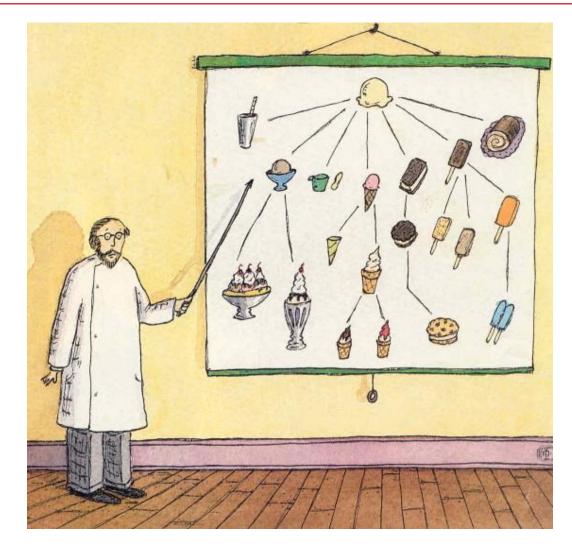
# The Problem (cont'd)

- During Systems Development, how do we ensure we **consistently communicate** the **correct meaning** in language used between:
- humans & humans
  - across domains / disciplines
- humans & machines
- machines & machines



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# What is an Ontology?

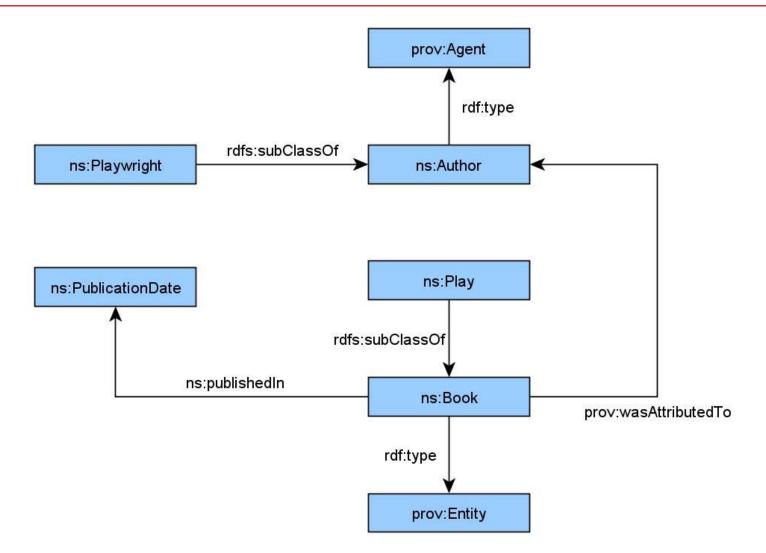


A formal specification of things, concepts, and the relationships between them, within some knowledge domain.

### **Describes:**

- classes: abstractions of things
- individuals: the actual things themselves
- properties: relationships between individuals
  - includes constraints / restrictions on relationships

## Written Works Ontology



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# Why Ontologies?

- Language disambiguation
- Well established technology
- Can model any system
- Formal relationships between objects
- Machine and human readable
- Reasoning / Inferencing engines
- Complex queries
- Information model to complement physics-based models



## **Industry Application**



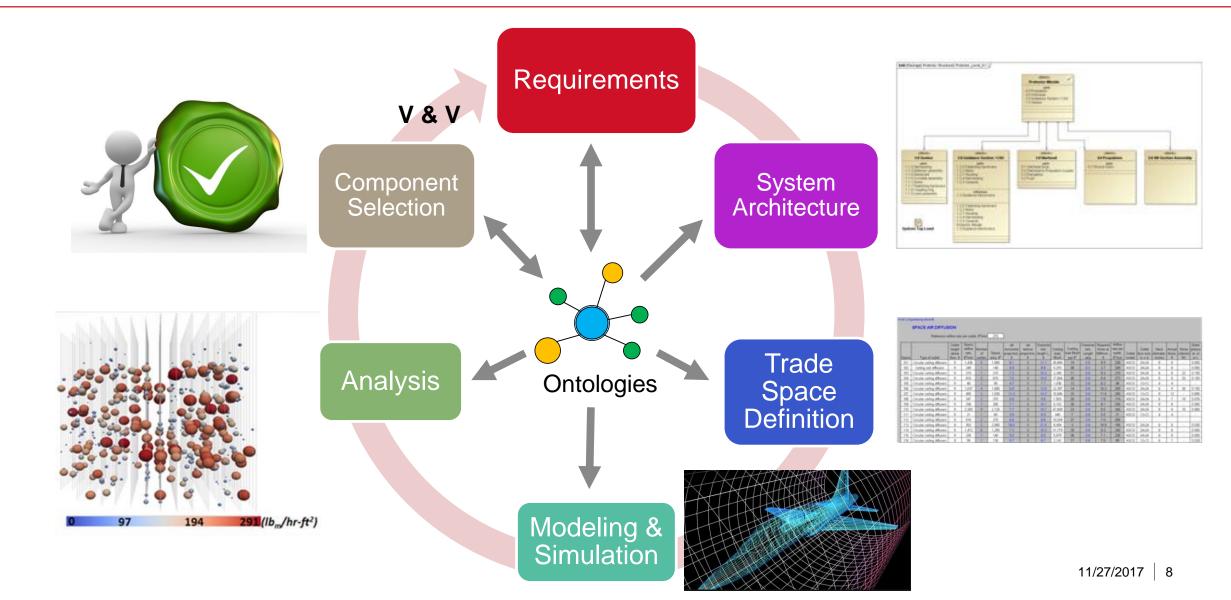


### Ford

- Started developing ontologies to capture their manufacturing process in 1989 (Rychtyckyj, 1999)<sup>3</sup>
- Digitized and standardized "process sheets": vehicle assembly work instructions
- Improved labor time estimation accuracy
- Invested effort to rewrite ontology in a newer language, even with impact to production (Rychtyckyj, 2016)<sup>4</sup>

## **Design Process with Ontologies**





# **Domain Ontology**

#### 14 64 🕺 🚿 Thing Measurement Unit Property Quality **T** Subsystem Airframe Subystem Communication Subsystem Control Subsystem Guidance\_Subsystem Launch Subsystem Navigation Subsystem Payload Subsystem Power Subsystem Propulsion Subsystem Satellite System Seeker Subsystem Vehicle Vehicle Aerial 🔻 😑 Missile

#### Air-to-Surface\_Missile

- Missile\_Air-to-Air
- Missile\_Cruise
- 🗝 Missile\_Surface-to-Air
- Missile\_Surface-to-Surface
- Vehicle\_Aerial\_Winged\_Fixed
- Wehicle\_Aerial\_Winged\_Rotary
- Wehicle\_Ground
- 🕨 😑 Vehicle\_Marine

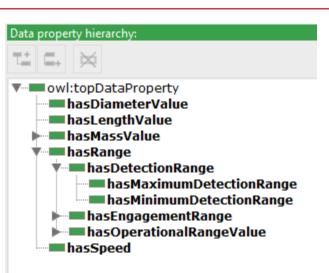
#### Object property hierarchy:

#### 답 다 🔀

#### owl:topObjectProperty

hasEngine

- hasMeasurementUnit
- hasSubsystem
  - hasAirframeSubsystem
  - hasCommunicationSubsystem
  - hasControlSubsystem
  - 💻 hasGuidanceSubsystem
  - 🗝 hasLaunchSubsystem
  - hasNavigationSubsystem
  - 💻 hasPayloadSubsystem
  - hasPowerSubsystem
  - hasPropulsionSubsystem
  - hasSatelliteSubsystem
  - hasSeekerSubsystem



# Value Proposition to the DoD

- Improve acquisition process
  - Design products faster (Better Buying Power<sup>5</sup>).
  - Improve ability to compare competitive product proposals.
  - Evaluate a broader assessment of alternatives.
- Consistency among stakeholders
  - Ensure that the DoD's interpretation of requirements equals manufacturer's interpretation.
- Traceability
  - Allow for traceability of design decisions back to the requirements



### **Questions?**

### References

- 1. Roz Chast, <u>http://rozchast.com/cartoons\_newyorker.shtml</u>.
- 2. IBM developerWorks, 2012, <u>Reification and Trust: Ontology-driven NLP</u>.
- 3. Rychtyckyj, N. 1999. DLMS: Ten Years of AI for Vehicle, Assembly Process Planning. In *Proc. of AAAI'99/IAAI'99*, 821–828.
- 4. Rychtyckyj, N. 2016. Ontology Re-Engineering: A Case Study from the Automotive Industry. In *Proc. of AAAI'16/IAAI'16*, 3974-3981.
- 5. <u>Better Buying Power</u>

## **Contact Info**

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