

Automatic Enrichment of Ontology for Engineering Design Process

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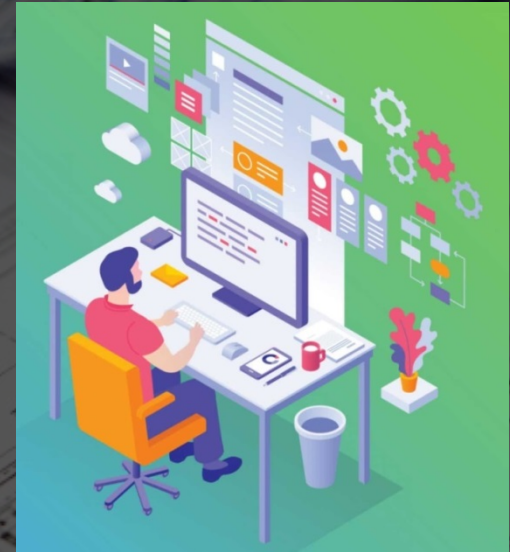
SEMANTiCS 2019, September 9-12
Karlsruhe

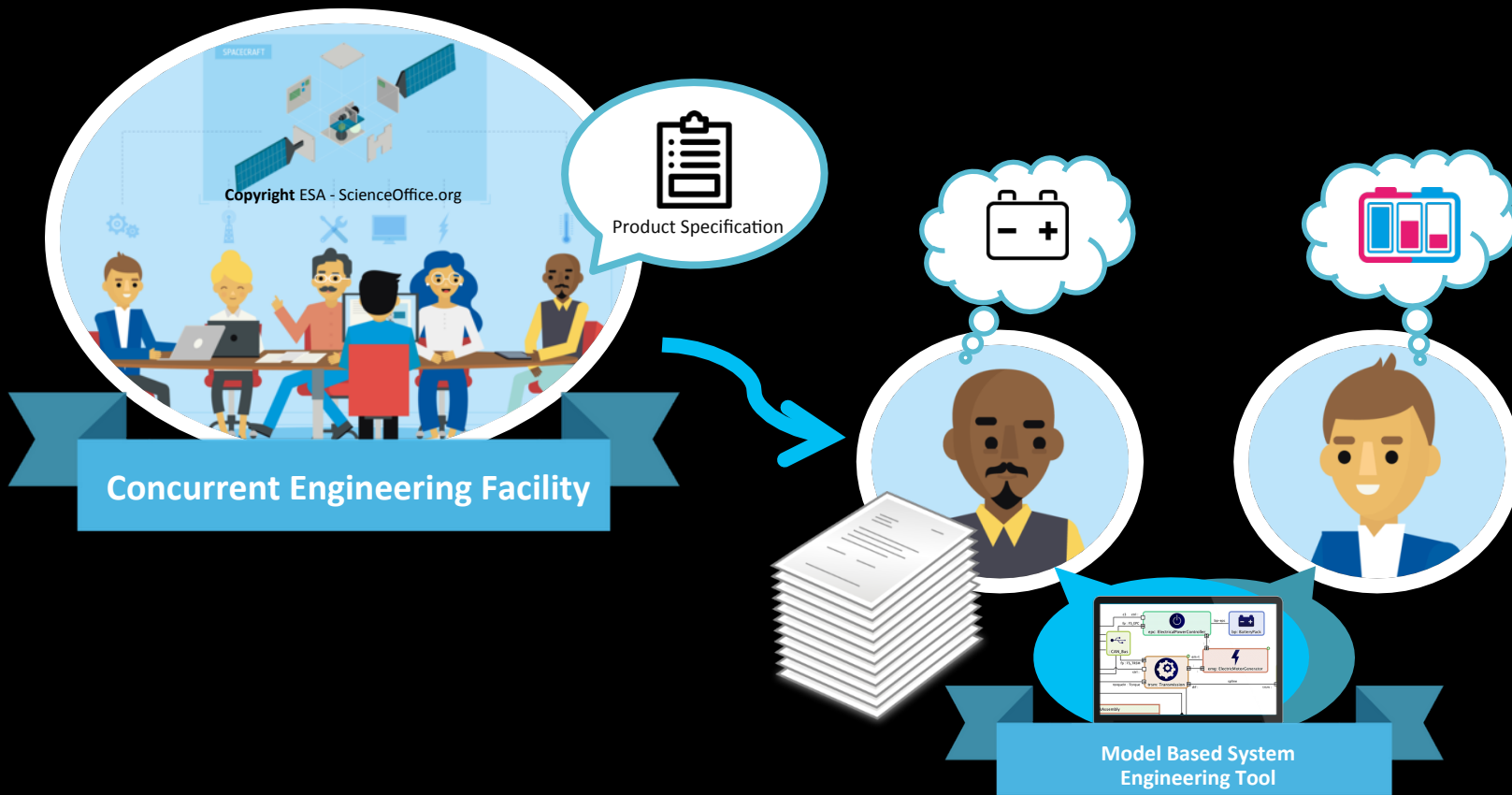


Knowledge for Tomorrow

Agenda

- Scenario
- Ontology for Satellite Design Process
 - Structure & Current Development
- Automatic Improvement of Ontology
 - ConTrOn – Continuously Trained Ontology
- Summary & Outlook





Challenge #1 Heterogeneous Formats

OVERVIEW

Under a grant from the Defense Production Act Title III, Ball is developing a new line of affordable, fully-domestic star trackers: CT-2020.

Domestically-sourced, secure solution

Utilizing all U.S. trusted suppliers, secure systems and flight software, the CT-2020 is an assured, fully U.S.-sourced solution for the nation's most important missions.

Low cost, high performance

Blending medium and high accuracy star tracker heritage in a compact, fully-integrated package, CT-2020 offers high performance and operational flexibility at a competitive price point.

CT-2020 integrates the latest high-efficiency Complementary Metal Oxide Semiconductor (CMOS) detector technology developed in the U.S. specifically for star trackers, enabling the CT-2020's cost-effective, small mass and volume design.

Operational flexibility, on-orbit upgrades

Featuring operational flexibility, CT-2020 provides customers two modes of operation: fully autonomous attitude and directed search, in which the user can select certain regions of interest. In autonomous attitude mode, the tracker can achieve single head accuracies in the realm of 1 arcsec, with even higher accuracies in directed search mode.

CT-2020's robust software features an on-orbit environment simulator, allowing the tracker to emulate mission-specific integration and operations for risk reduction. In addition, the tracker's software can be upgraded while on-orbit, allowing updates to the star catalog, spatial/intensity calibration and software algorithms.

HERITAGE

For more than 40 years, Ball has delivered the highest-reliability, highest-performance star trackers available to support civil, commercial and defense missions. We are leveraging this heritage to optimize the CT-2020 for cost and performance to bring an affordable, domestic star tracker solution to the U.S. market.

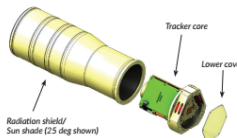
Expected availability of the CT-2020 is fourth quarter of 2019.

Ball Aerospace
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SPECIFICATIONS

- 1 arcsec performance stand-alone unit
- Provides full three-axis ± 1.0 arcsec performance with typical two-axes on a spacecraft
- Full performance with a 15 deg sun angle
- Tracks with moon in field of view
- High rate capable (up to 8 deg/sec) with reduced performance to enable track-through-slew
- 1553, RS-422 command and data interfaces, SpaceWire option
- Simultaneous attitude output and full frame image output at 10 Hz over high speed LVDS
- On-orbit upgradeable software, star catalog, algorithms and spatial re-calibration
- TEC provides efficient, stable detector temp control, on-orbit adjustable
- Hardware-in-the-loop testing with built-in focal plane simulator enables end-to-end mission simulations
- Integrated LED polarity tester
- Two modes of operation: fully autonomous or directed search
- Mass: 3 kg
- Power: 8 W
- Modular options:
 - Nominal +28 V power, +120 V, +5 V options
 - Three sun shade options (15, 20, 30 deg)
 - Q or V-Level parts with full EEE parts traceability
- Radiation-hardened-by-design CMOS and ASIC
- Meets all relevant MIL-STD and SMC requirements
- Complete set of documentation and analysis available with production

SYSTEM COMPONENTS



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μSTAR Tracker

APPLICATIONS

- Satellite Attitude and Rate Determination
- GEO and LEO Satellite Orbits
- Long Duration/High Reliability Missions

SOFTWARE FEATURES

- Star Identification Based on Pyramid Code
- Integrated Systematic Error Correction Allows for High Accuracy
- Real-Time On-orbit Calibration Accounts for Degradation
- Extended Kalman Filter Produces Attitude and Rate Estimates
- Less Sensitive to Spurious Signals and Upsets

CONFIGURATION OPTIONS

Feature	MIST	uStar-100M	uStar-200M	uStar-200H	uStar-400M
FPA	Ruby	HAS2	HAS2	HAS2	HAS2
Accuracy [1σ]	30 arcsec	5-20 arcsec	1-20 arcsec	< 1 arcsec	1-5 arcsec
Average Power	<3W	< 5 W	8-10 W	< 10 W	< 18 W
Update Rate	10 Hz	1 Hz	10 Hz	10 Hz	100 Hz
DPE Mass (kg)	0.5	0.9	1.2	1.2	1.2
CHU Mass (kg)	[Integrated Unit]	0.9	0.9	1.5	2.1
Total (kg)	0.5	1.8	2.1	2.7	3.3

*Contact Warehouse for availability

RADIATION TOLERANCE

Total Ionizing Dose (TID)	> 100 and 300 krad (option)
Single Event Latchup (SEL)	> 80 MeV/mg/cm ²
Single Event Upset (SEU)	< 10 ³ errors/system-day
Neutrons	> 2x10 ¹² n/cm ²

SUPPORTING ELECTRONICS

The μSTAR™ features proven, high performance, radiation hardened supporting electronics to ensure accurate, reliable functionality in the harsh space environment.

PROTON 200K™ RADIATION HARDENED SPACE COMPUTER

The Proton200K™ space computer is flight-proven, high speed, and radiation hardened to provide extraordinary performance benefits by removing the barriers associated with commercial processor offerings. It is a qualified space computer for onboard data processing with 1.8 GFLOPS @ 200 MHz Floating Point, 900 MFLOPS @ 200 MHz with SEU mitigated to 1E-4 errors/day



Specifications Subject to Change Without Notice

4/9/2015




Size & Mass	154 mm x 154 mm x 237 mm approx. 2 kg	including baffles including baffles, GEO-shielding, OCDC-converter, MIL1553
Imaging System Design	Optics: refractive, focal length 43 mm, f/1.2 Detector Resolution: 1024 x 1024 pixels Field of View: 20 deg Detector Options: HAS2 S/NR: 1200	spherical lens technology, rad-hard glass material circular APS CMOS radiation tolerant APS CMOS radiation tolerant
Temperature Range	Operational: -30 °C ... +60 °C Non-operational: -40 °C ... +70 °C	typical cooler controller set point at TAPS+30°C
Attitude Performance	Random Error: < 1 arcsec [1-σ] across boresight Bias Error: < 5 arcsec, all axes Acquisition Time: < 10 sec, after switch-on Slew Rate & Acceleration: < 5 sec, no-acquisition "Test in space" Sensitivity: 0.3 deg/sec, 0.3 deg/sec ² Sampling Rate: 10 Hz Stary Light: Sun: 20 deg exclusion angle Earth: < 20 deg Moon: accepted in field of view	includes LSFE, HSFE, TE over full operational temperature range direct entry to attitude tracking with spiori information full performance STAR1000 single head capability HAS2 single head capability end of life performance full core depending on orbit height and Earth illumination conditions
Interfaces	Data: MIL-STD-1553B RS422 Power: 28V nominal 50V nominal 100V nominal	optional, selectable, others on demand optional selectable, either on demand primary power SA; bus architectures other voltages on demand
Power Consumption	MIL-STD-1553B: < 6 W, Pelletier Cooler DFF data interface: < 1.2 W, Pelletier Cooler CH4XX RS422: < 5 W, Pelletier Cooler DFF data interface: < 1.1 W, Pelletier Cooler CH4XX	end of life end of life
Operations	Reliability: 460 FIT, Tu=20°C Operational Modes: Boot Standby-Mode Autonomous Attitude Determination (AAD) Nominal Attitude Tracking (NAT) Photo, Upload/Download, Self-Test	with Class E EEP parts fully autonomous mode switching from Power-On to NAT by software parameter set-up possible



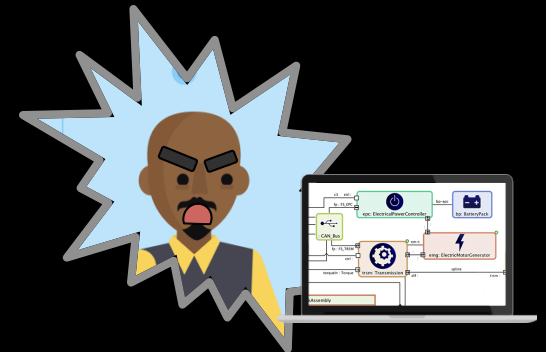
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Challenge #2 Standard description

ECSS-E-ST-60-20C –
Star sensor terminology and performance specification

3.2.7.2	correct attitude threshold	
		maximum quaternion absolute measurement error (AMEq) for which an attitude is a correct attitude
3.2.7.3	false attitude	
		attitude which is a non correct attitude
		
3.2.7.4	false star	
		signal on the detector not arising from a stellar source but otherwise indistinguishable from a star image
	NOTE	This definition explicitly excludes effects from the Moon, low incidence angle proton effects etc., which can generally be distinguished as non-stellar in origin by geometry.
3.2.7.5	image output time	
		time required to output the detector image

- Not machine-interpretable
- Require manual efforts transferring data into tools

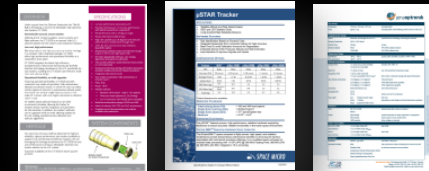
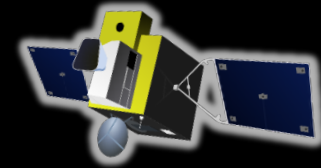




#1 ONTOLOGY FOR SATELLITE PARTS

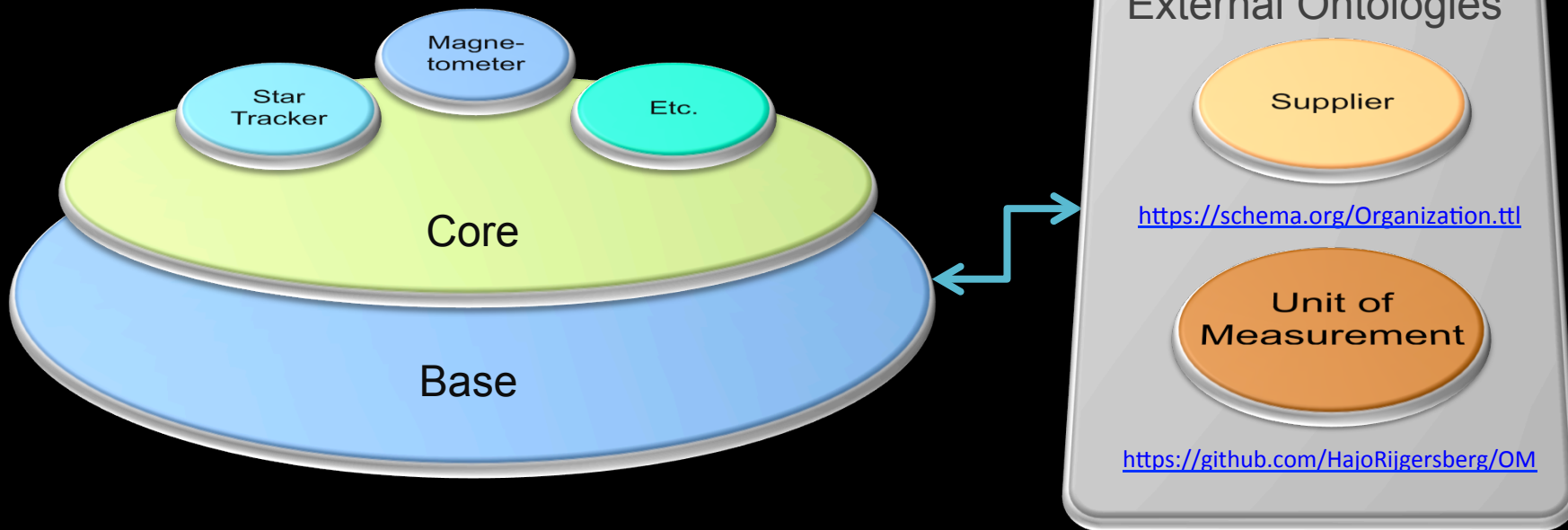
Ontology: Sources

- Data models developed by DLR's in-house MBSE tool
 - <https://github.com/virtualsatellite>
- Existing product description standards
- Actual product data sheets
- Interview with system engineers and manufacturers
- Current version: <https://zenodo.org/record/2616374>



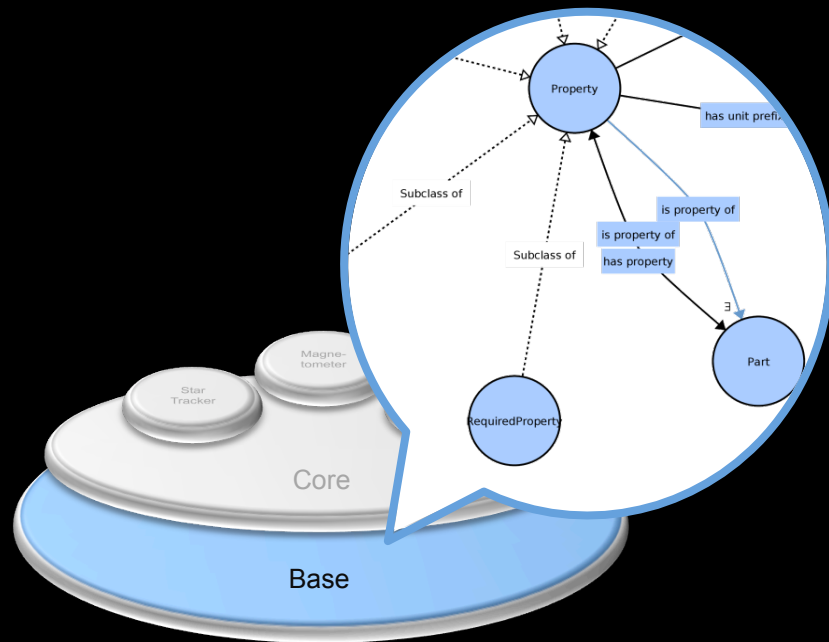
Ontology: Hierarchical Structure

Spacecraft parts ontologies



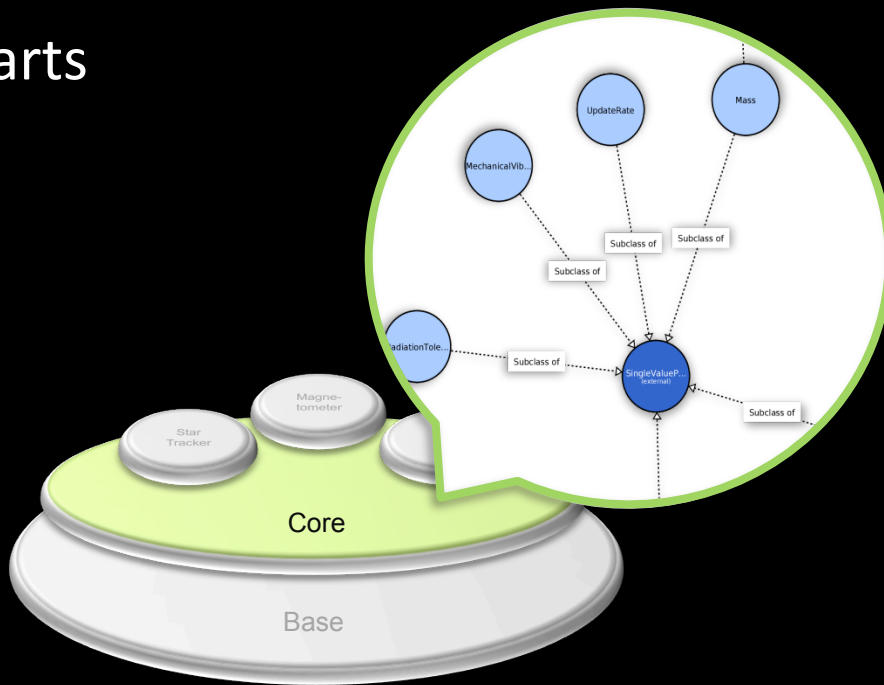
Spacecraft Parts Ontology: Base

- Primary classes
 - Part (Product)
 - Part's attribute
 - Type of attribute
- Primary properties
 - “is property of”
 - “has property”
 - “has unit”



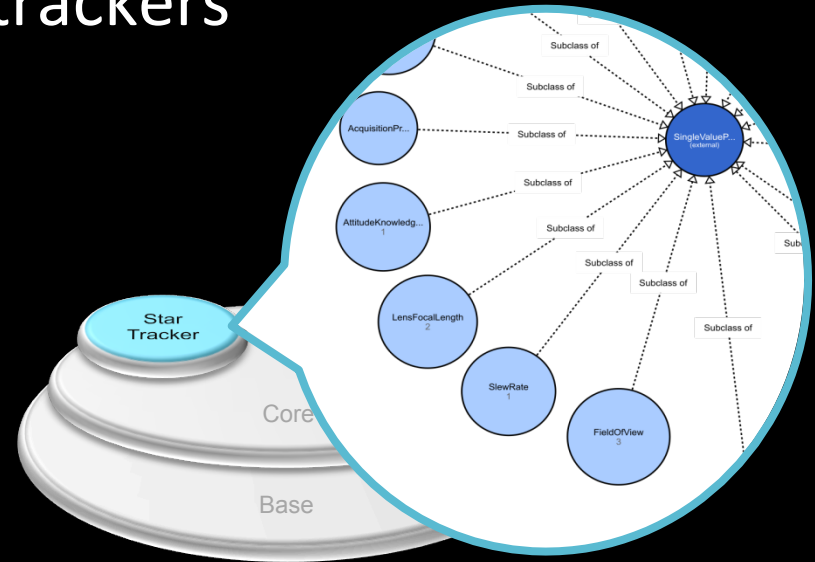
Spacecraft Parts Ontology: Core

- Common attributes for all parts
 - Mass
 - Lifetime
 - Operating Temperature
 - Width, Height, Length
- 26 attributes



Spacecraft Parts Ontology: Star Tracker

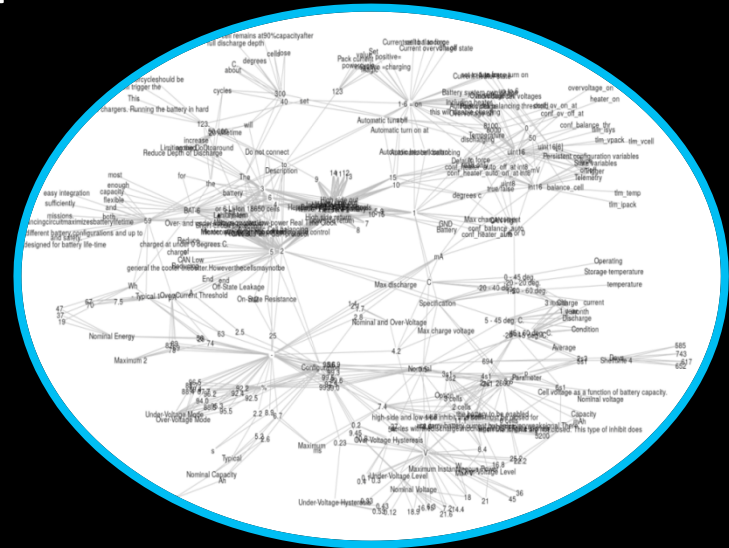
- Specific attributes to star trackers
 - Attitude accuracy
 - Field of view
 - SNR
 - Etc.



- 36 Attributes

Product Ontology: Further Usages

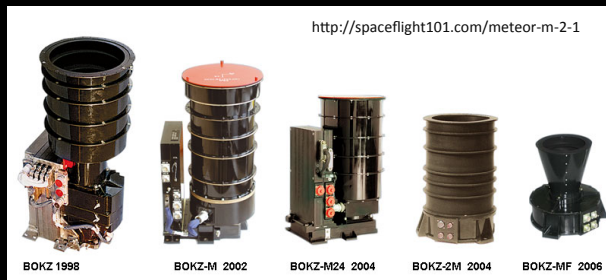
- Conversion to database schema
<https://gitlab.com/dlr-dw/ontocode>
- Part data exchange interface
 - Web API
- Knowledge graph
 - Information retrieval



However, as time flies



People change, products change



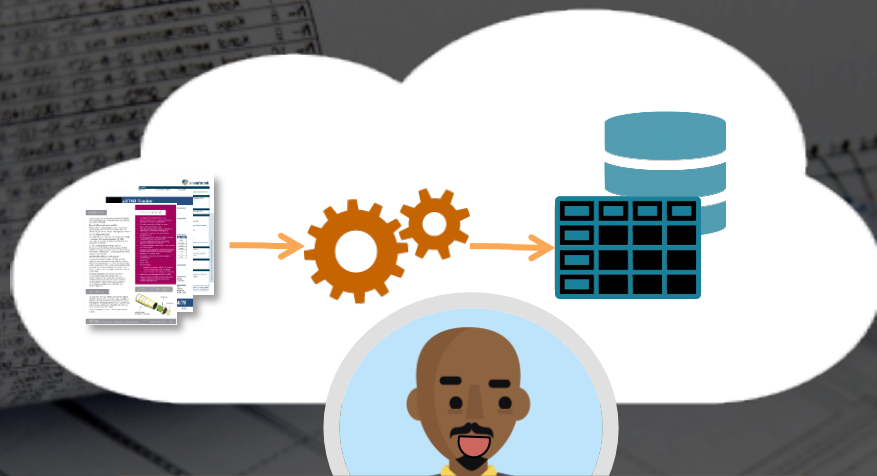
And ontology should evolve

But, how ...





#2 AUTO-IMPROVEMENT OF ONTOLOGY



Information Extraction

- Natural Language Processing
- Semantic Knowledge

Existing Tools: Entities Extraction

DBpedia Spotlight

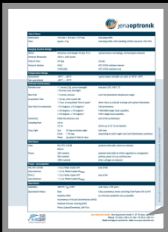


The ASTRO APS has been designed with compact dimensions, low mass, and low power consumption. Since July 2013, the ASTRO APS has been accumulating space heritage operating flawlessly on board of Alphasat.

The Jena-Optronik [ASTRO APS](#) is an Autonomous Star Sensor with the most advanced [radiation hard CMOS](#) Active Pixel Sensor detector technology for long-term missions on Telecom, Science and [Earth](#) Observation satellites. space for success

The [ASTRO APS](#) has been designed with [compact](#) dimensions, low mass, and low power consumption.

Since http://dbpedia.org/resource/American_Society_for_Radiation_Oncology [space heritage](#) operating [flawlessly](#) on board of [Alphasat](#).



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Picture Alphasat © ESA

Jena-Optronik GmbH

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Size & Mass

Dimensions 154 mm

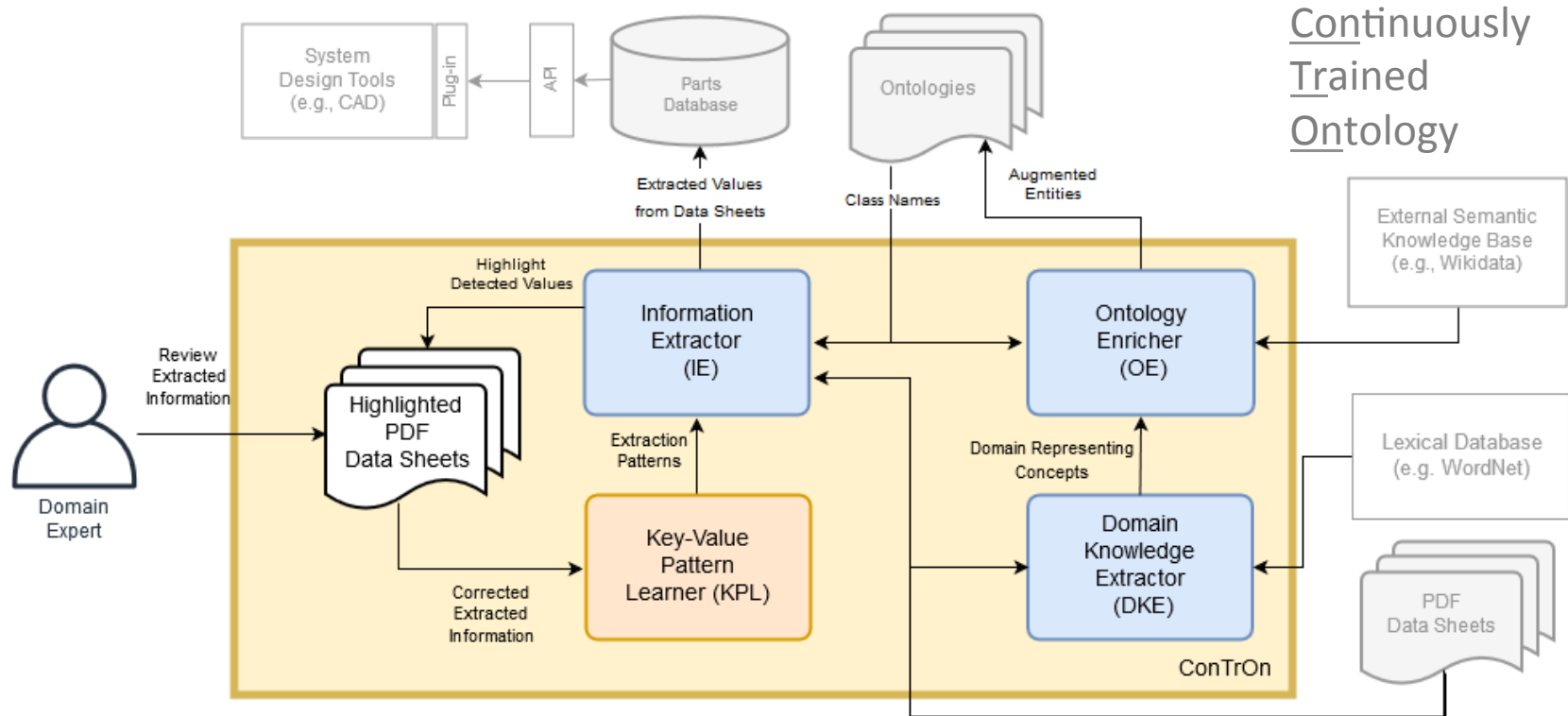
Mass approx. 2 kg

OPEN CALAIS

ESA Contact Details Company Technology

RELATION CONTACT DETAILS

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Domain Knowledge Extractor



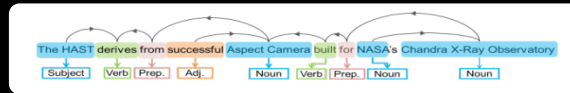
data, power, mm, space, receiver, temperature, mass, thruster, radiation, noise, battery, weight, **magnetic_field**, reliability, **data_rate**, payload, telemetry, resolution, thermal, baffle, lifetime, gauss, **data_rates**, **propulsion_system**, tracker, solar



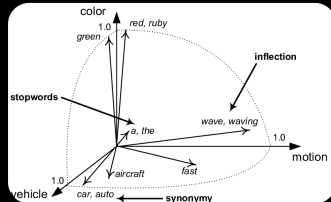
- Extract keywords
 - Bag-of-words
 - Tf-idf



Definition, Synonyms, Hypernyms, ...



- Word Disambiguation
 - <https://wordnet.princeton.edu/>
 - Part-of-Speech Tagging
 - Vector Space Model




Ontology Enricher



- If ambiguous (multiple entities matched), compare to domain knowledge keywords
- At this step, only enriching the existing classes

Information Extractor



Standard NST

Attitude Solution	5 Hz
Sky Coverage	> 99 %
Mass	0.35 kg w/ baffle
Volume	10 x 5.5 x 5 cm
Peak Power	< 1.5W
Field of View	10 x 12 degrees
Sun Keep Out	45 degrees (half cone)
Design Life	> 5 Years (LEO)

- Search text based on ontology classes
 - Name, label, superclass, same as
- Extract values that come after keywords

Extraction approach	Extracted property-value pairs			Recall	Precision	F-measure
	Ideal	Extracted	Correctly extracted			
ConTrOn		427	256	0.94	0.6	0.73
Text-based search	271	542	263	0.97	0.49	0.65

- Need human-in-the-loop: Next

Key-Value Pattern Learner

- Users provide feedback via a UI (human-in-the-loop)

Jena-Optronic Astro 15

ASTRO 15 Star Sensor Performance

Key: Lens
Value: focal length 55 mm
Remarks:

Comments:

Key Value Remarks

Key	Value	Remarks
Dimensions	192 mm D x 496 mm	Sensor with 30° baffle
Mass	4350 g f	Sensor without baffle
Lens	focal length 55 mm	

- Key → Add to the ontology
 - Enrich by adding new classes

- Value → Improve the information extraction

179 x 75 x 112 mm 154 mm x 154 mm x 237 mm 25 x 10 x 10 cm

Pattern Example

179 x 75 x 112 mm

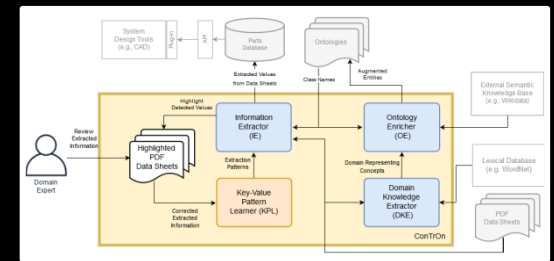
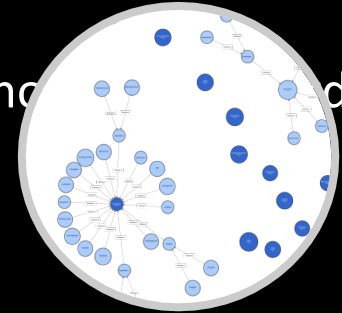
154 mm x 154 mm x 237 mm

25 x 10 x 10 cm

- Learned patterns
 - `<number>+" x "+<number>+" x "+<number> + <unit>`
 - `<number> <unit>+" x "+<number> <unit>+" x "+<number> <unit>`
- Verify the pattern
 - Apply to the information extractor
 - Choose the pattern that yield the minimum error

Summary

- Current satellite parts ontology is available at: <https://zenodo.org/record/2616374>
- ConTrOn: automatically improve ontology from data sheets
 - ✓ Ontology Enrichment
 - ✓ Domain Knowledge Extraction
 - ✓ Ontology-based Information Extraction
 - ☐ Key-Value Pattern Learner (human-in-the-loop)



Outlook

- Collecting feedbacks from users
 - Baseline for evaluation of information extraction
- Extension of ontology
- Knowledge graph from data sheets



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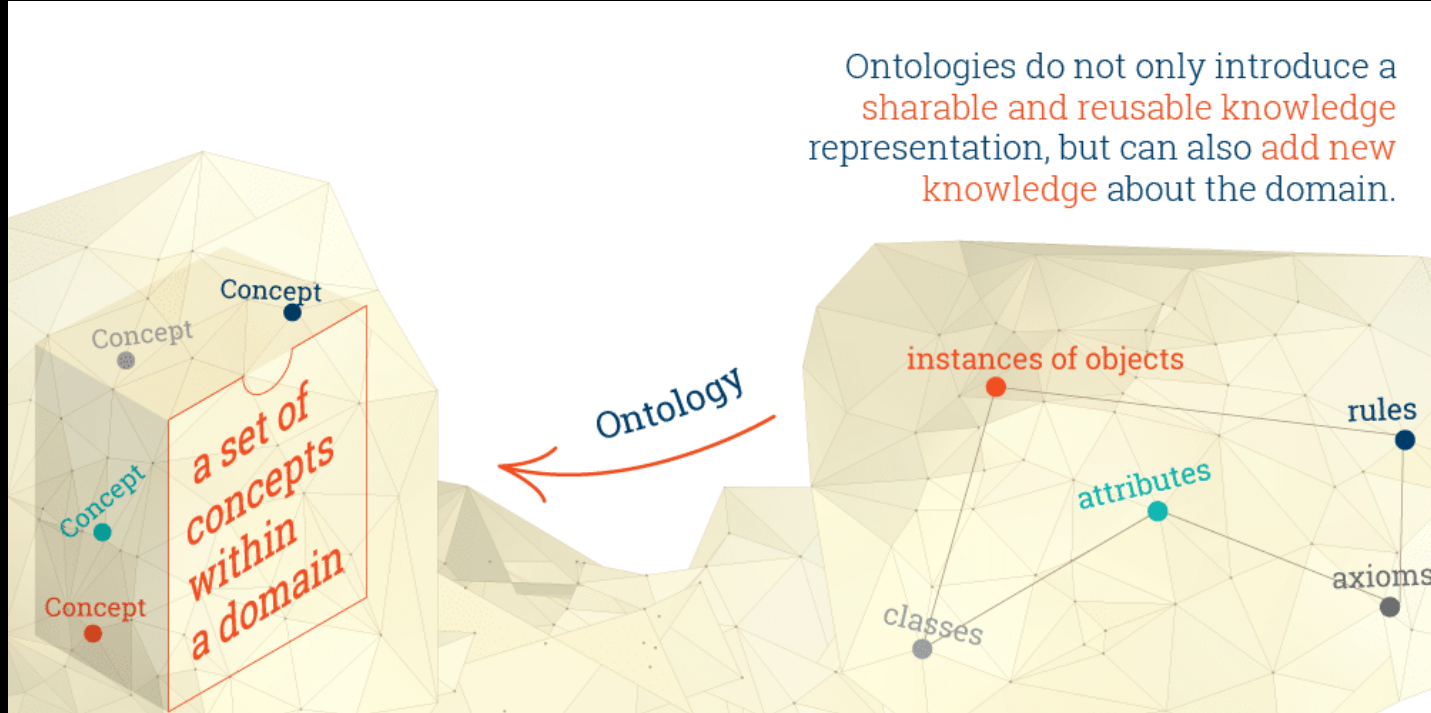


kobkaewo

Thank you for your attention!

Ontology: Concept

Ontologies do not only introduce a sharable and reusable knowledge representation, but can also add new knowledge about the domain.



Semantic Knowledge



<https://www.ontotext.com/knowledgehub/fundamentals/>