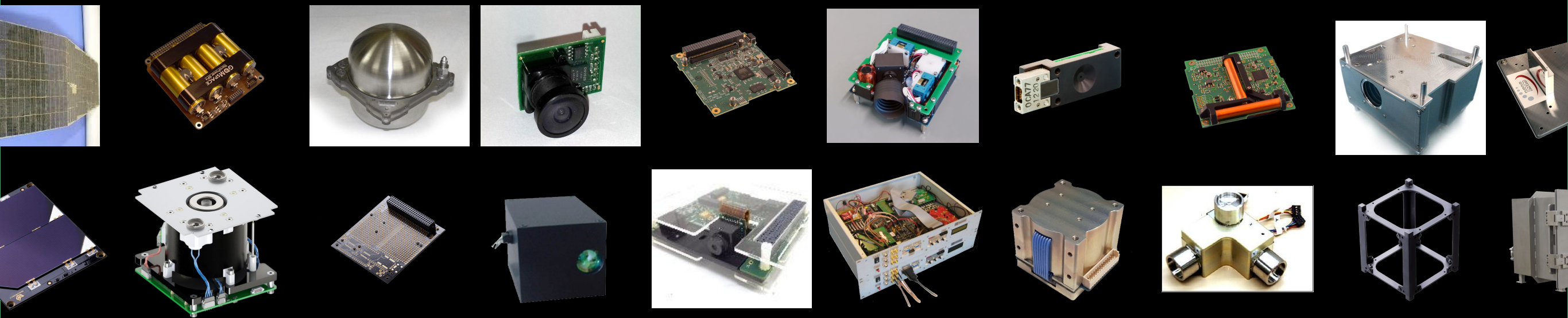


Development of a universal ontology for the global space supply chain



24th June, 2019

Space System Ontology - Brainstorming Workshop
ESA/ESTEC, Noordwijk

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Space engineers face hard questions ...

What is the standby power of Aerojet's MR-103G thruster?

How do the RW-0.03 and RWA-05 reaction wheels compare?

How many satellites have been delivered to orbit in the last quarter?

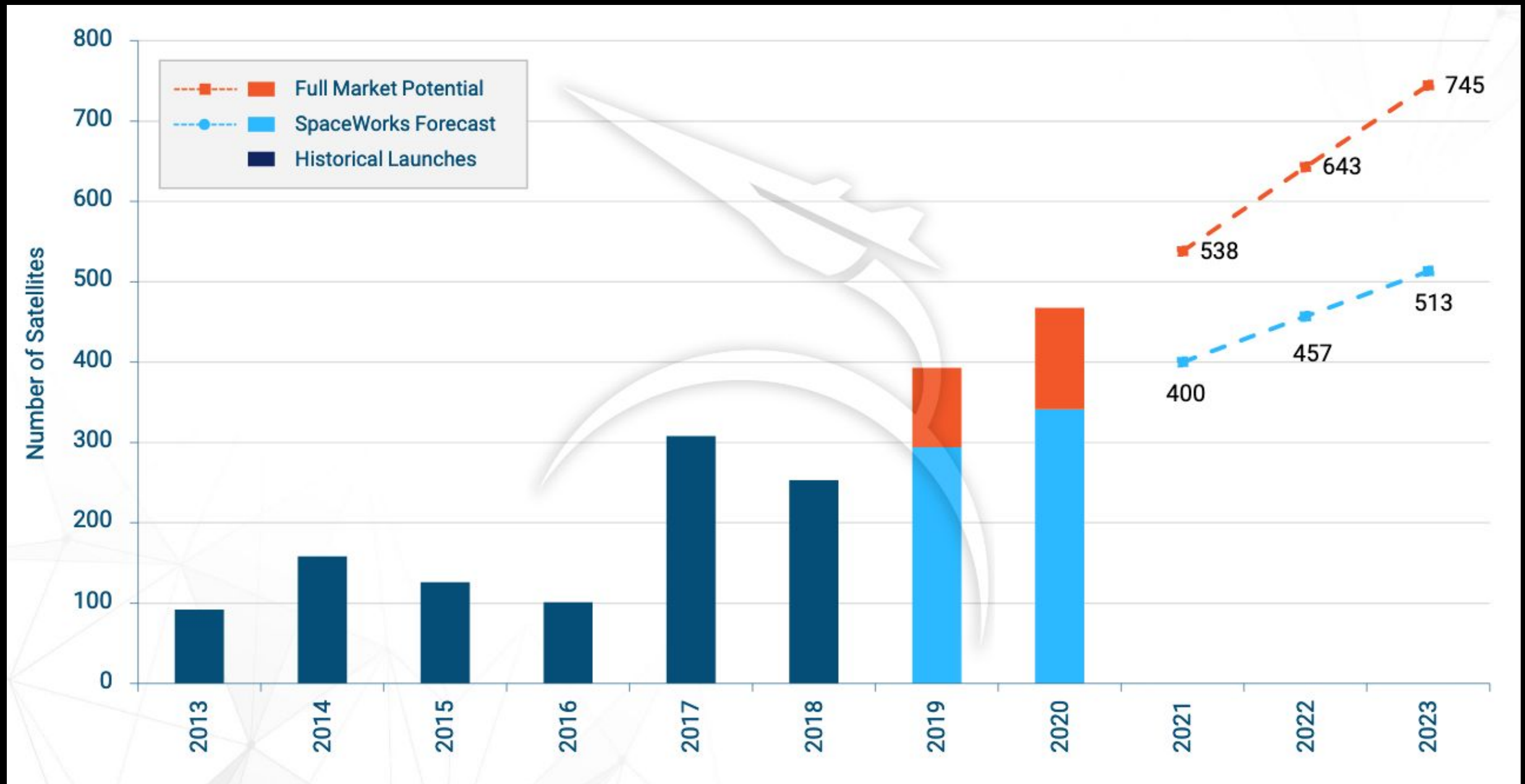
Which on-board computer is recommended for my payload suite?

Are satellites getting bigger or smaller?

How reliable is my supply chain and where are the key risks?

Who produces Cubesat batteries with flight heritage?

Industry growth is making this much harder

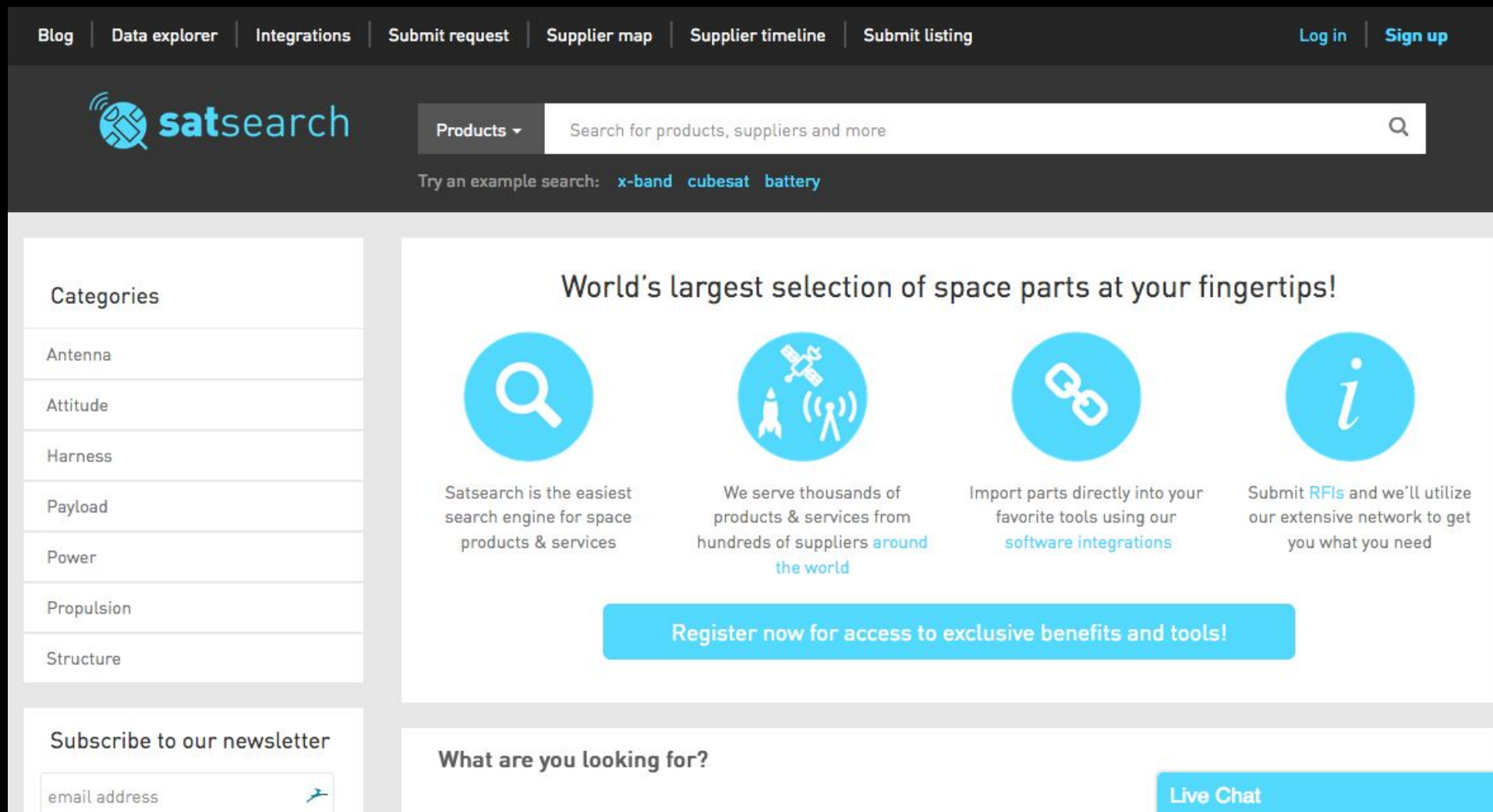


(SpaceWorks, 2018)

Open supply chain is necessary for commercialization



A B2B marketplace that indexes the global space supply chain



satsearch.co

Our platform is growing



> 1,100 suppliers



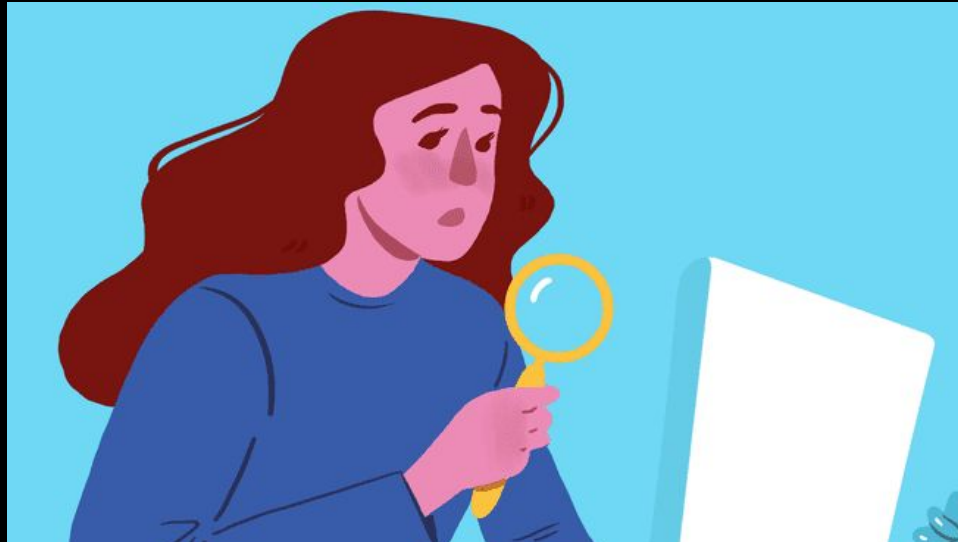
> 5,200
products & services



>1,500 users/month

€10M+ qualified lead volume in 2019

Our users want to ...



Search



Sort



Filter

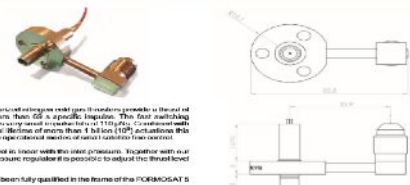


Compare

Information is locked in “messy” documents

AST Advanced Space Technologies GmbH

Cold Gas Thruster (CGT)



AST's modular cold gas thruster range provides a thrust of 42 mN to more than 500 N specific impulse. The fast switching thruster allows very small impulses of 100 µN. Constant with its exceptional lifetime of more than 8 million (8M) operations, the thruster is a proven operational service of over 1 million hours.

The CGT is used in linear mode or pulse pressure. Together with our electronic pressure regulator it operates to produce the desired thrust.

The CGT has been fully qualified in the frame of the FORMOSAT-5 mission.

Performance Characteristics	
Operating Media	GN
Inlet Pressure (MEOP)	1 - 6 bar
Final Pressure	2 x MEOP
Start Pressure	4 x MEOP
Internal Leakage	< 10 ⁻⁸ sec/sec
External Leakage	< 10 ⁻⁸ sec/sec
Thrust	42 mN to 500 N
Minimum Impulse Bit	100 µN
Specific Impulse	> 65 s
Weight	0.040 kg
Operating Voltage	27 - 50 V
Cold Resistance	140 Ohm
Operating Temperature Range	-20° - +60° C
Life	> 8M operations
Other	1 million activation qualified

AST Advanced Space Technologies GmbH
Zapfenstrasse 10
82008, Germany

satsearch PHASEFOUR

RFT Radio Frequency Thruster

Overview
RFT uses RF waves to efficiently ionize and then heat xenon plasma, causing it to expand. Thermally, as the heated propellant expands outward, the thruster uses magnetic fields to direct the xenon plasma out of the thruster orifice, producing thrust.

Thruster Performance
The RFT Thruster can be paired with any xenon propellant management system and can be tested in nearly any configuration. 1x (2-3%), 1x2 (3%), 2x2 (12%) and 3x3.

Characteristic	Unit	Specification
Thrust	mN	1 - 15
Thrust to Power Ratio	mN/W	10 - 150
Specific Impulse	s	500 - 1,000

Plug and Play Solution for CubeSats
The following specifications represent our plug and play solution, which includes a thruster, propellant management unit, power processing unit and drive electronics, all in a compact and scalable CubeSat form factor.

Characteristic	Unit	Specification
Total Impulse	Ns	5,000
Dwell/V	ms	1,000+
Dry Mass**	kg	1.0 - 1.5
Propellant Mass (Xenon)	grams	500
System Volume**	L	0.5 - 1.0 + "bus can"

* Data/V delivered to a 3.3 Ohm load (4 kg dry mass)
** Dry mass and system volume depend on required propellant storage

Typical Applications
Rapid Constellation Deployment
Mission Lifetime Extension
Collision Avoidance
Space Debris Mitigation
Formation Flying
Cislunar Operations
Interplanetary Trajectories

Taking orders now
Ready for flight 2018

info@phasefour.io | www.phasefour.io
Tel: 415-255-7777

AMR

Properties and Performance

While the required power to operate the IFM starts at around 6 W, at higher thrust levels one can choose between high thrust and high specific impulse operation. The IFM 350 can operate at an Isp range of 2000 to 5000 s. At any given thrust point, higher Isp operation will increase the total impulse while it will also increase the power demand. The thruster can be operated along the full dynamic range throughout the mission. That means, that high Isp and low Isp maneuvers can be included in a mission planning, as well as high thrust climb maneuver and low thrust precision control maneuvers.

Parameter	Value
Dynamic thrust range	10 µN to 2.5 mN
Normal thrust	350 µN
Specific impulse	2,000 to 5,000 s
Propellant mass	250 g
Total impulse	more than 6,000 Ns
Power at nominal thrust	35 W incl. neutralizer
Outside dimensions	94 x 90 x 78 mm
Mass (dry / wet)	640 / 670 g
Total system power	8 - 40 W
Hot standby power	3.5 W
Command interface	RS422/RS485
Temperature envelope (non-operational)	-60 to 120° C
Temperature envelope (operational)	-20 to 60° C
Supply voltage	12V, 28 V, other voltages upon request

Modularity
The IFM Nano thruster can be clustered in order to meet any specific mission need. As we are using a number of pre-qualified modules (building blocks), this customization can be done without increasing the cost or lead times of the thruster.

Number of Modules: 1, 2, 3, 4, 5, 6, 7
Total Impulse: > 5000 Ns, > 10000 Ns, > 15000 Ns, > 20000 Ns, > 25000 Ns, > 30000 Ns, > 35000 Ns

HYDROS™ -M

'Green' High-Performance Propulsion for MicroSats


HYDROS-M provides: high impulse, high thrust, flexible propulsion, and delivers 'bolt-on' orbit agility for MicroSats. HYDROS-M is powered by a safe, storable, and non-toxic 'green' propellant - water - which is electrolyzed on orbit to deliver high performance bipropellant propulsion.

Capabilities
HYDROS is a novel high-TL propulsion architecture that uses a hybrid electrical/chemical scheme to provide small spacecraft with both high thrust (> 1.5 N) and high Isp (> 310 s) propulsion. HYDROS propulsion systems enable secondary payloads to perform missions requiring orbit agility and large ΔVs while launching with the ultimate 'green' propellant: water. Once on orbit the HYDROS system splits the water propellant using electrical power to produce hydrogen and oxygen gas which is then combusted in a bipropellant thruster.

- Sized to fit within the keep-in zones of 15" diameter launch vehicle separation ring.
- Flexible system CONOPS allows HYDROS to scale performance to meet mission imposed power limits.

Performance
HYDROS-M delivers high performance bipropellant pro...

Specifications
• > 3 year LEO mission design life



Monopropellant Thruster Valves





Characteristic	Performance Characteristics			
	0.17 MPa (25 MPa) Thrust Single Seal	0.2 MPa (30 MPa) Thrust Redundant Seal	0.3 MPa (45 MPa) Thrust Single Seal	0.5 MPa (75 MPa) Thrust Single Seal
Max Operating Pressure (MEOP) (bar)	300 (30.0)	400 (40.0)	500 (50.0)	700 (70.0)
Final Pressure (bar)	845 (84.5)	1000 (100.0)	1500 (150.0)	2100 (210.0)
Start Pressure (bar)	1400 (140.0)	2000 (200.0)	2900 (290.0)	4000 (400.0)
Flow Coefficient (Cv) (m³/sec/√Pa)	0.00033	0.00044	0.00055	0.00077
Operating Voltage Range (Vdc)	24V-32	24V-32	24V-32	24V-32
Material: Open/Response Time (sec)	1	10	15	30
Maximum Close/Response Time (sec)	1	10	15	30
Power Consumption (Watt)	10.4 at 27Vdc, 40W	14.0 at 27Vdc, 40W	20.5 at 27Vdc, 70W	27.2 at 27Vdc, 70W
Leakage (cc/sec, internal leakage)	0.4	0.4	0.2	0.2
Leakage, External (cc/sec)	1E-4	1E-4	1E-4	1E-4
Life (cycles)	1,000,000	1,000,000	100,000	100,000
Weight (gms) including hardware	0.015 (1.5)	0.040 (4.0)	0.050 (5.0)	0.070 (7.0)
Max Efficiency (bar/sec absolute)	15	20	25	25
Operating Temperature Range (°C)	-40 to 370 (-40 to 149)	-40 to 370 (-40 to 149)	-40 to 370 (-40 to 149)	-40 to 370 (-40 to 149)
Nondestructive Model Number	-251-271	-251-340	51-250	52-251B




Monopropellant Thrusters

Parameter	Performance Characteristics					
	MONARC-1	MONARC-2	MONARC-3	MONARC-4	MONARC-5	MONARC-6
Thrust	1.0 mN	1.0 mN	1.0 mN	1.0 mN	1.0 mN	1.0 mN
Specific Impulse	2000 s	2000 s	2000 s	2000 s	2000 s	2000 s
Mass	0.010 kg	0.010 kg	0.010 kg	0.010 kg	0.010 kg	0.010 kg
Power	10 W	10 W	10 W	10 W	10 W	10 W
Life	1,000,000 cycles	1,000,000 cycles	1,000,000 cycles	1,000,000 cycles	1,000,000 cycles	1,000,000 cycles
Weight	0.010 kg	0.010 kg	0.010 kg	0.010 kg	0.010 kg	0.010 kg
Volume	0.010 L	0.010 L	0.010 L	0.010 L	0.010 L	0.010 L
Operating Temperature	-40 to 125 °C	-40 to 125 °C	-40 to 125 °C	-40 to 125 °C	-40 to 125 °C	-40 to 125 °C
Storage Temperature	-40 to 125 °C	-40 to 125 °C	-40 to 125 °C	-40 to 125 °C	-40 to 125 °C	-40 to 125 °C
Shock Resistance	1000 g	1000 g	1000 g	1000 g	1000 g	1000 g
Vibration	10 g	10 g	10 g	10 g	10 g	10 g
EMI/RFI	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m
EMC	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m
EMF	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m
EMR	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m
EMT	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m
EMF	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m
EMR	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m
EMT	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m
EMF	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m
EMR	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m
EMT	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m	1000 V/m

Unlocking this knowledge is essential to deep searching, filtering, sorting, comparing of products & services

Solution: Structured docs from source data

				
	RWP015	RWP050	RWP100	RWP500
Momentum	0.015 Nms	0.050 Nms	0.10 Nms	0.50 Nms
Max Torque *	0.004 Nm	0.007 Nm	0.007 Nm	0.025 Nm
Mass	0.130 kg	0.24 kg	0.35 kg	0.75 kg
Volume	42 x 42 x 19 mm	58 x 58 x 25 mm	70 x 70 x 25 mm	11 x 11 x 3.8 cm
Voltage	12 VDC	12 VDC	12 VDC	28 VDC
Power @ 1/2 Momentum	< 0.6 W	< 0.5 W	< 0.5 W	< 3.0 W
Power @ Full Momentum	< 1.0 W	< 1.0 W	< 1.0 W	< 6.0 W
Design Life	> 5 years	> 5 years	> 5 years	> 10 years
Static Unbalance * (Fine)	< 1.2 g-mm (0.25 g-mm)	< 1.2 g-mm (0.35 g-mm)	< 1.5 g-mm (0.5 g-mm)	< 3 g-mm (1 g-mm)
Dynamic Unbalance * (Fine)	< 20 g-mm ² (2.5 g-mm ²)	< 20 g-mm ² (2.5 g-mm ²)	< 20 g-mm ² (5 g-mm ²)	< 25 g-mm ² (10 g-mm ²)

			
	RW1	RW4	RW8
Momentum	1.0 Nm	4.0 Nms	8.0 Nms
Max Torque *	0.1 Nm	0.3 Nm	0.3 Nm
Mass	0.75 kg	3.0 kg	4.1 kg
Volume	11 x 11 x 3.8 cm	17 x 17 x 7 cm	19 x 19 x 9 cm
Voltage	28 VDC	28 VDC	28 VDC
Power @ 1/2 Momentum	< 4.5 W	< 5 W	< 5 W
Power @ Full Momentum	< 9 W	< 10 W	< 10 W
Design Life	> 10 years	> 10 years	> 10 years
Static Unbalance * (Fine)	< 3 g-mm (1 g-mm)	< 6 g-mm (2 g-mm)	< 8 g-mm (2.8 g-mm)
Dynamic Unbalance * (Fine)	< 25 g-mm ² (10 g-mm ²)	< 150 g-mm ² (75 g-mm ²)	< 200 g-mm ² (100 g-mm ²)

* Custom options are available

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A common, universal language describing space systems is necessary

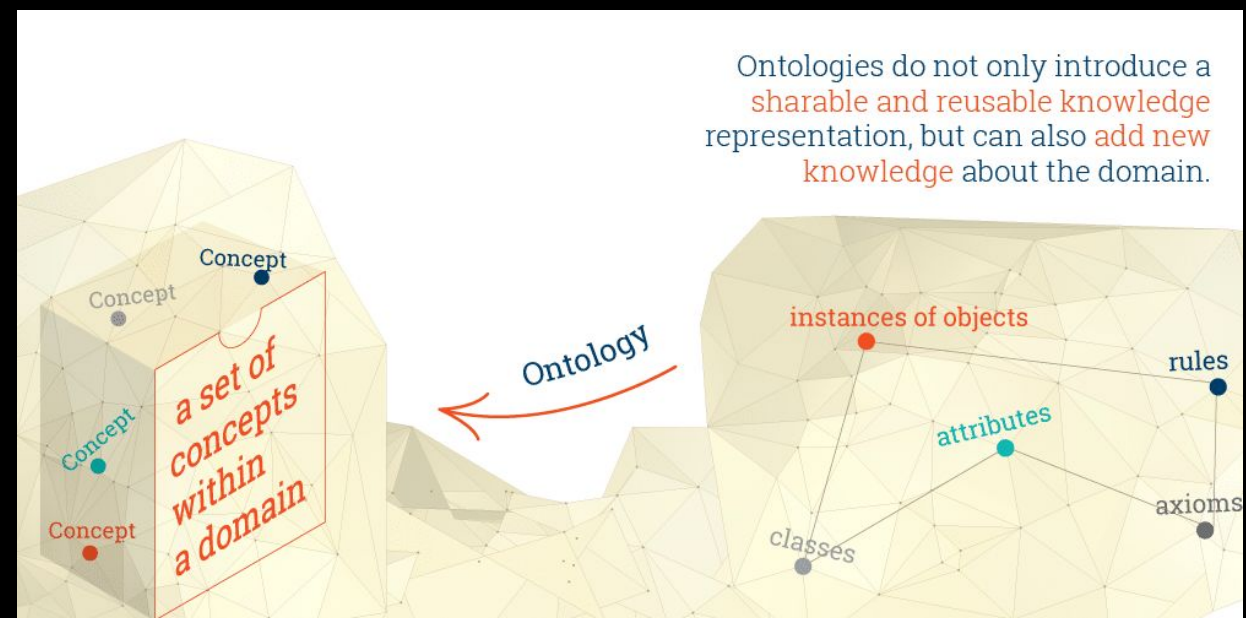
What do we understand as an ontology?

“a set of representational primitives with which to model a domain of knowledge or discourse”

(Gruber, 2009)

Fundamental ingredients

- Classes (or sets)
- Attributes (or properties)
- Relationships (or relations among class members)



(ontotext, 2019)

A universal ontology for the space industry can help reduce cost, lead time, and failures

What problems do we observe?

- Inconsistent nomenclature
- Inconsistent use of units
- Varied use of precise values and (open/closed) ranges
- “Random” symbols: \sim , \pm
- Complex values, e.g., interdependencies
- Inconsistent notation for uncertainty
- Graphical data
- Data incompleteness
- ...

Result

We’re all talking different “dialects”

Developing a universal space systems ontology

1. Top-down

- a. “Design by committee”
- b. Requires stakeholders to be active in discussions

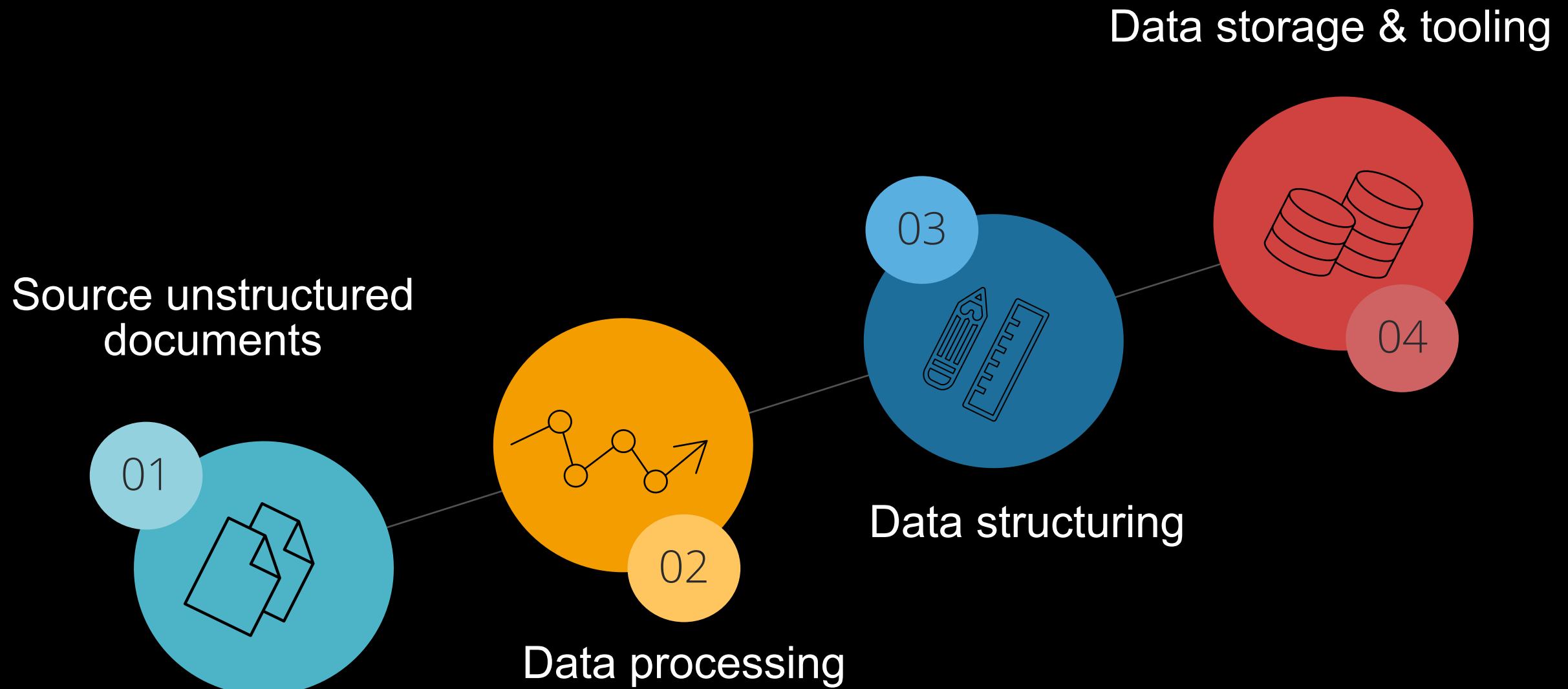
2. Bottom-up

- a. “Design by data”
- b. Requires stakeholders to actively provide source data

Ideal solution

Hybrid top-down and bottom-up approach

A software pipeline to generate an ontology



A learning system would enable rapid development of a flexible, comprehensive, and reliable ontology

We serve structured data through our API

x

Product
Get full product details
List product attribute classes
List product categories
List products

Supplier
Get full supplier details
List suppliers

Satsearch API

Satsearch API app

1.0.0 ▾

Product

Product - Get full product details

1.0.0 ▾

GET

```
https://api.satsearch.co/v1/products/:uuid
```

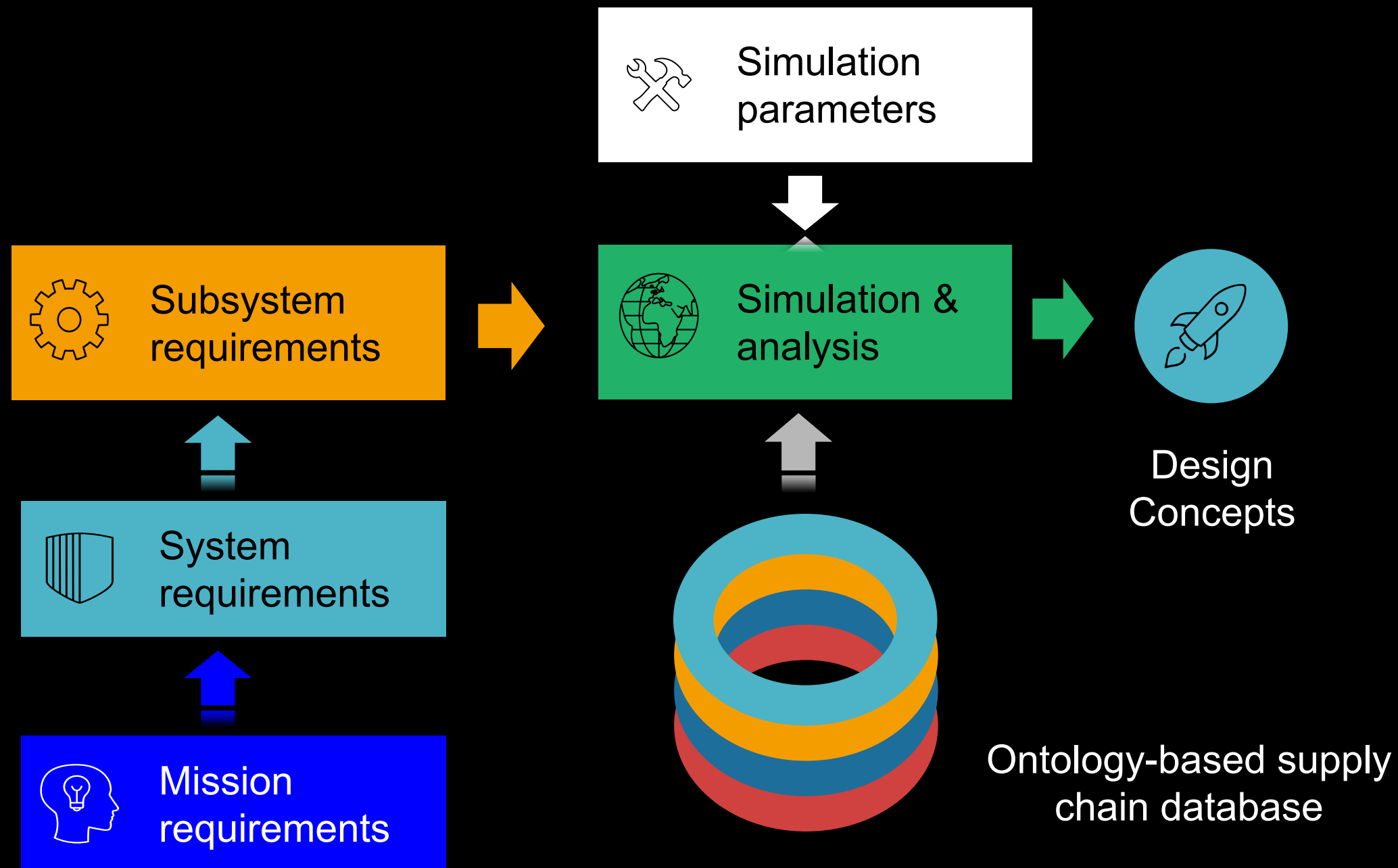
Header

Field	Type	Description
Authorization	String	Replace <code>:token</code> with supplied Auth Token Allowed values: <code>"Bearer :token"</code>
X-APP-ID	String	Replace <code>:app-id</code> with supplied secret app id Allowed values: <code>":app-id"</code>

Parameter

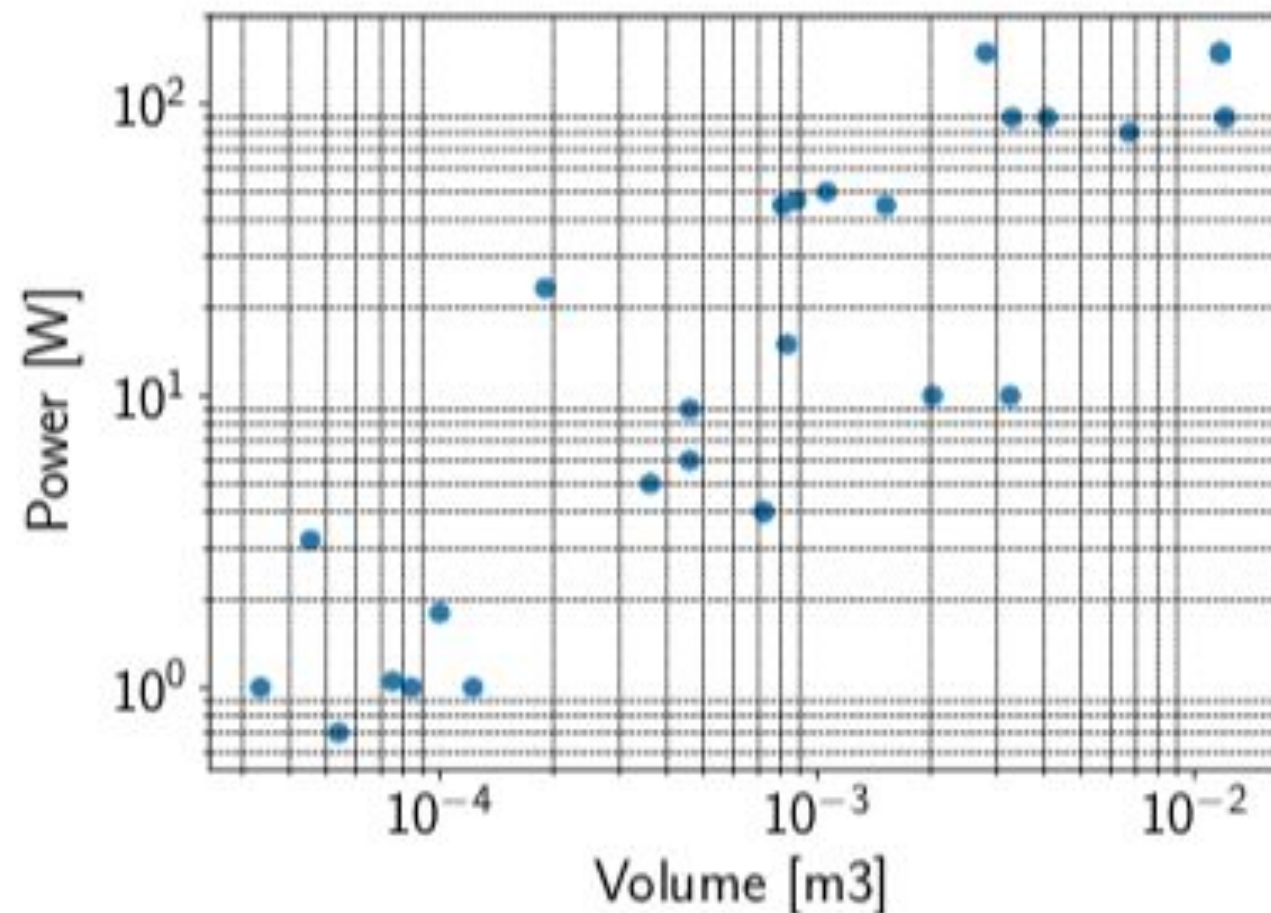
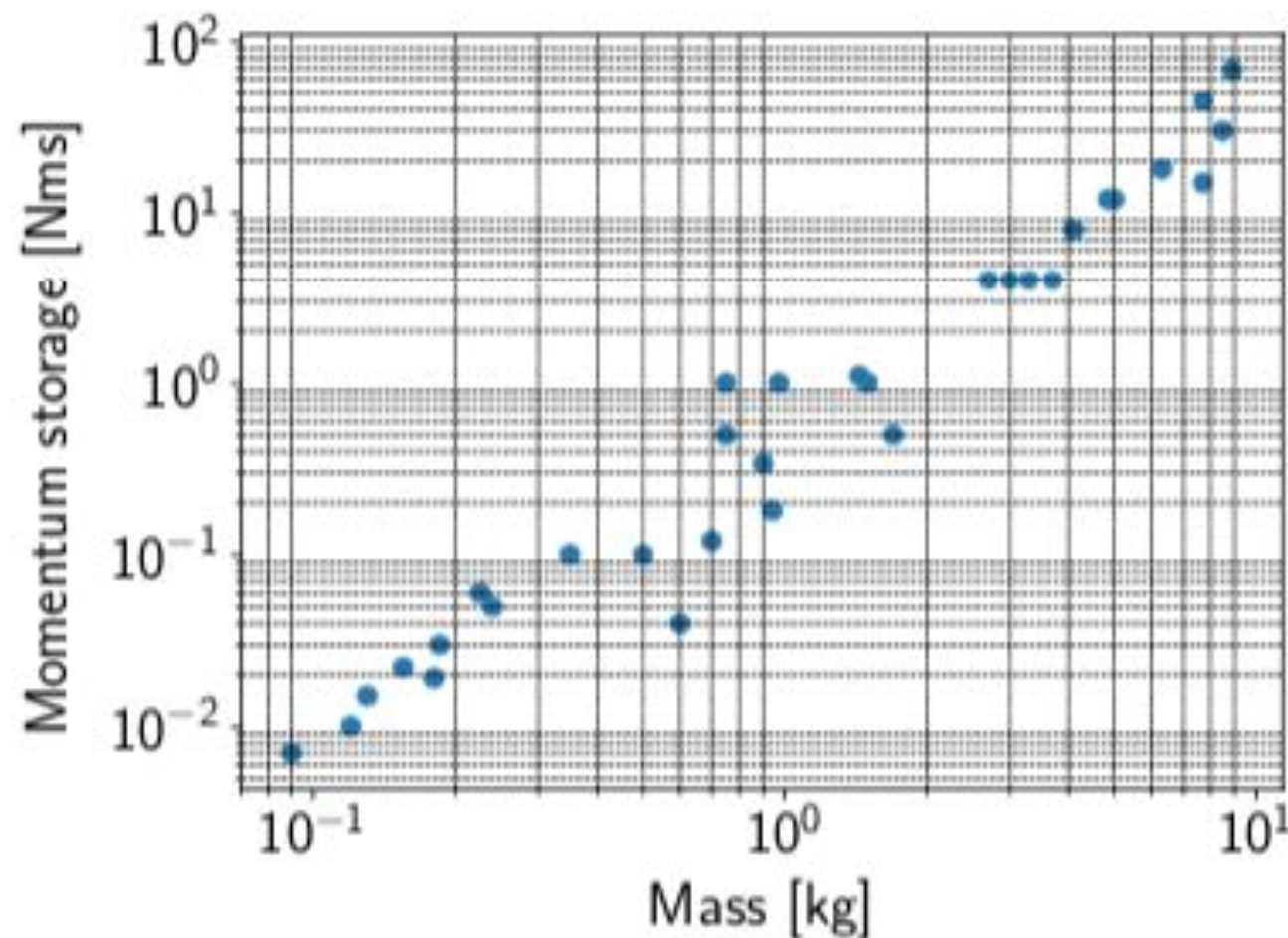
api.satsearch.co

Application: Integrated Mission Design



Connecting an ontology-based supply chain database to mission design process enables intelligent automation

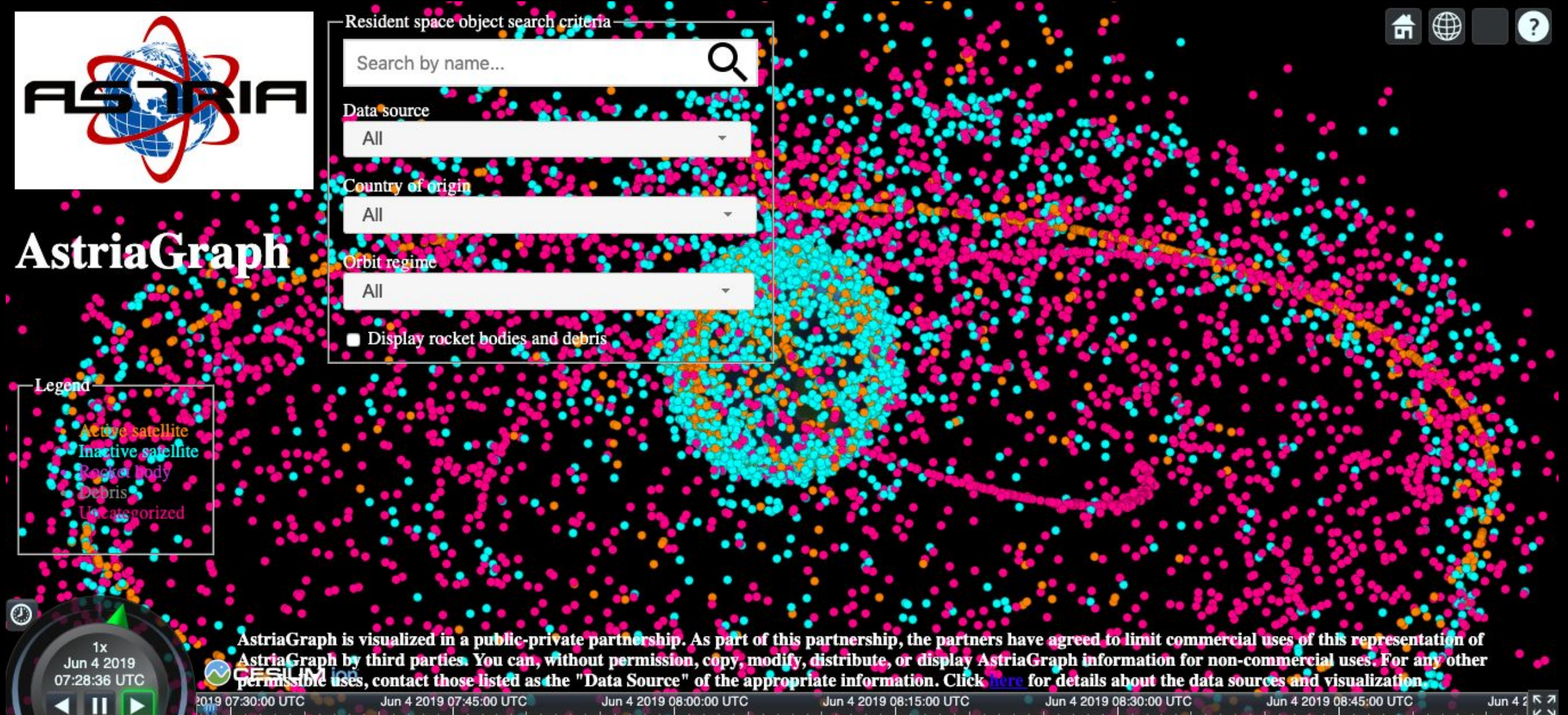
Application: Business Intelligence



(Cherukuri, 2019)

Connecting an ontology-based supply chain database to BI tooling enables deep insights into the state of the market

Application: Space debris risk analysis



Connecting an ontology-based supply chain database to space debris knowledge base enables deep risk insights

The biggest challenges for the future

- Gathering comprehensive, reliable, up-to-date source data
- Building robust tooling to enable increasibly automatic generation of electronic datasheets
- Developing strong (economic) incentives to accelerate rate of stakeholder adoption globally
- Enabling interoperability through open interfaces to avoid fragmentation & duplication

[illegible]

Space System Ontology - Brainstorming Workshop

ESA/ESTEC, Noordwijk

