



# Development of Electronic Data Sheets for Model-Based Systems Engineering

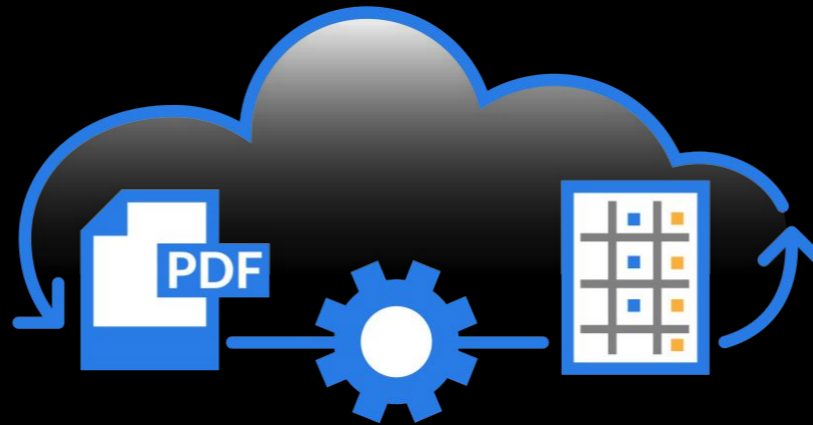
ADCSS2018  
ESA/ESTEC  
Noordwijk, the Netherlands

Kartik Kumar, Co-founder & CEO  
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# Engineers lose time finding the right parts



**SEARCH**



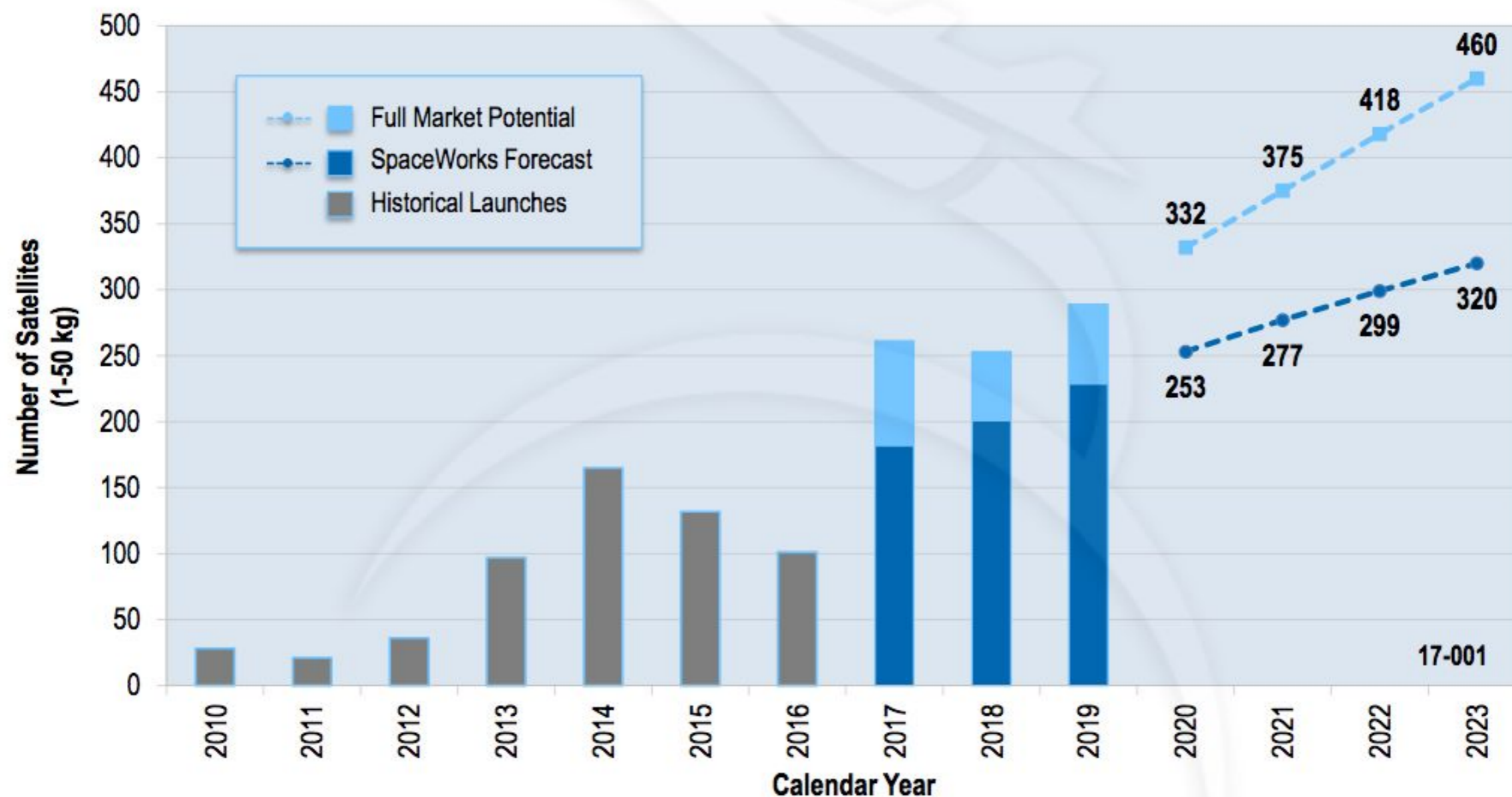
**EXPORT**



**COMPARE**

**Search in the space industry is broken**

# Industry growth makes search harder



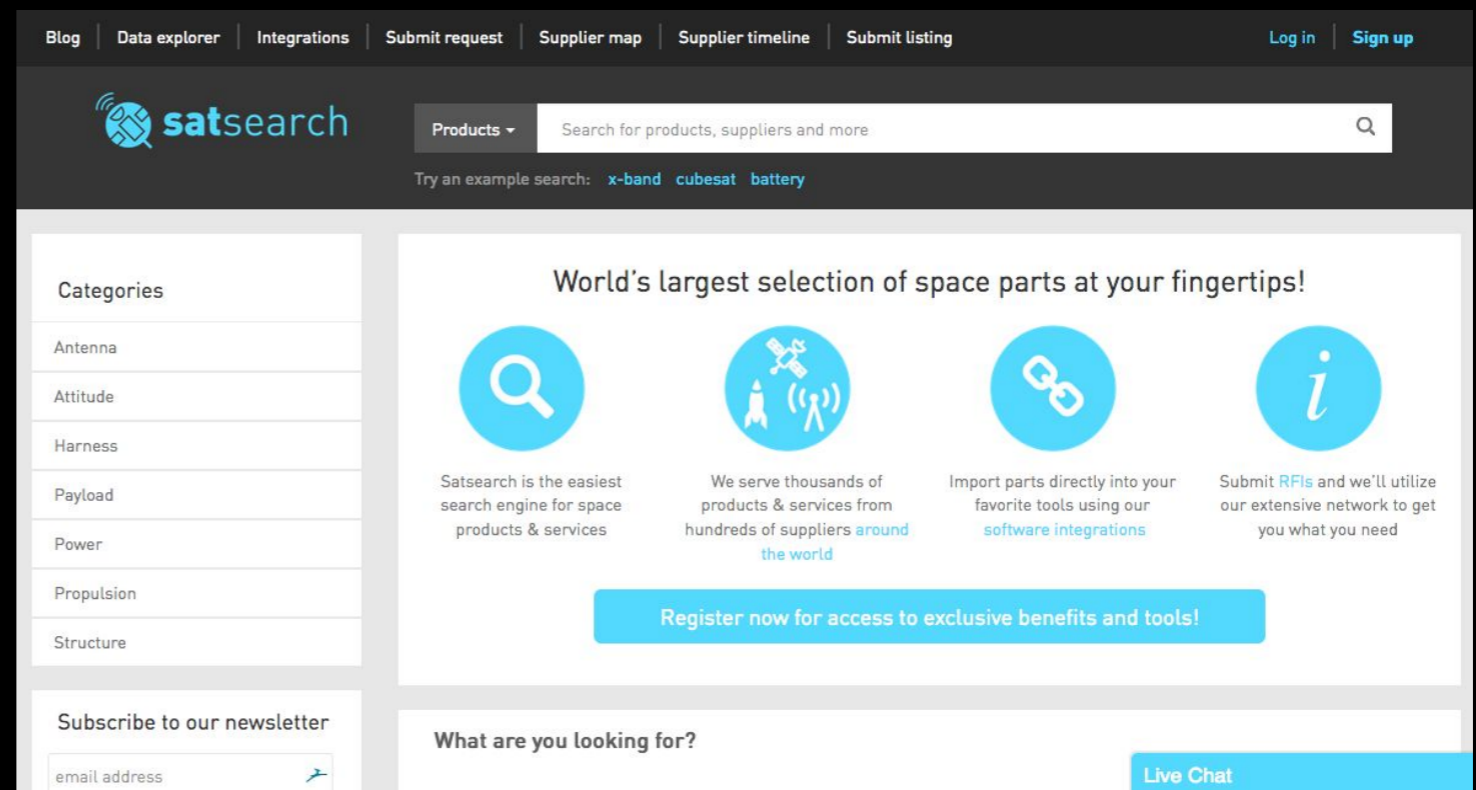
SpaceWorks 2017

# *A marketplace* that indexes the global space supply chain

Find  
the right suppliers

Understand  
your customers

Design  
better space missions



**satsearch.co**



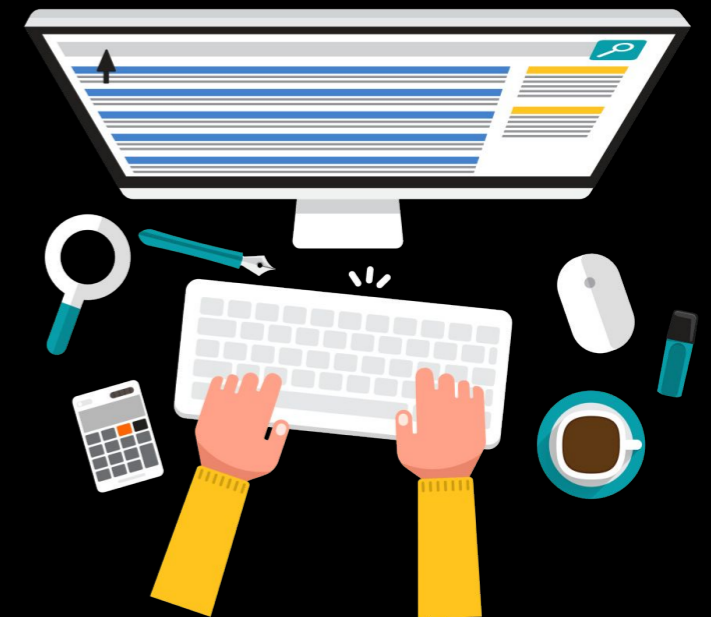
# Our platform is growing



731 suppliers



5224 products



>1000 MAU

**10,000+ suppliers worldwide**

# The team behind satsearch



Kartik Kumar  
CEO



Alberto Vaccarella  
CTO



Narayan Prasad  
COO



POLITECNICO  
MILANO 1863



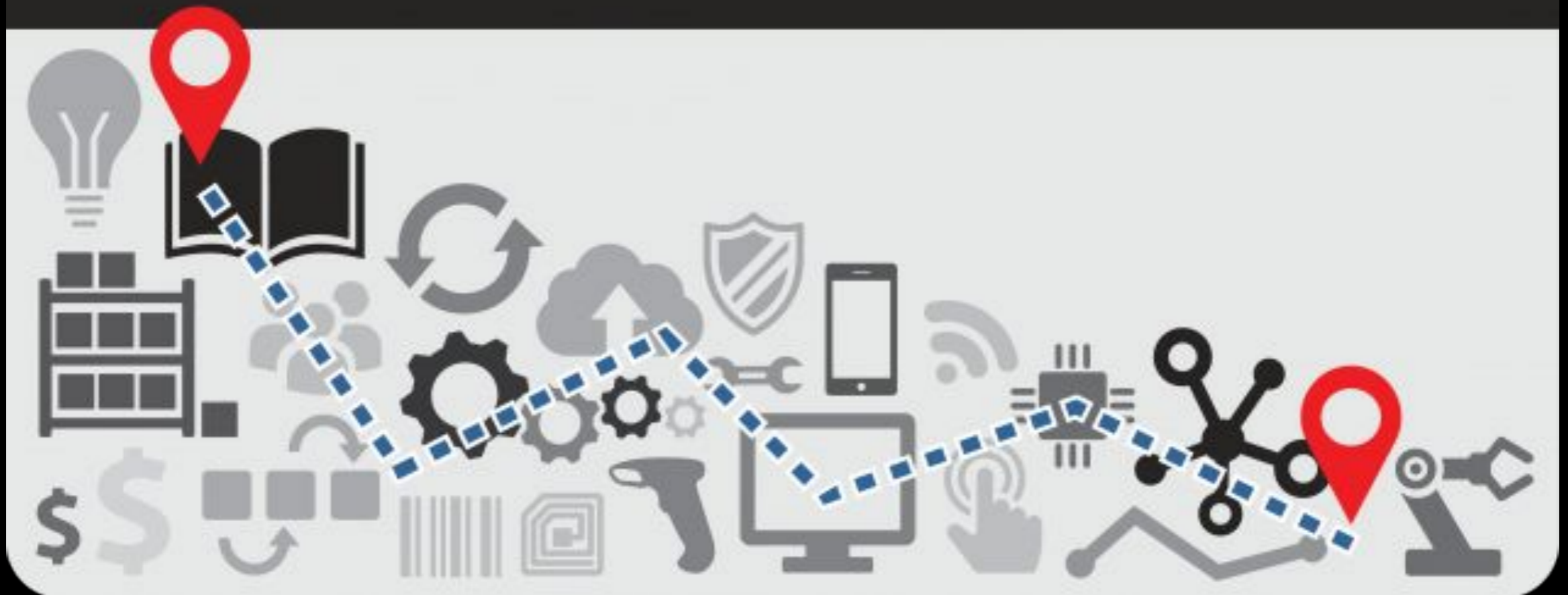
# An open supply chain is essential for growth



## We deliver global supply chain intelligence

# Supply chain digitalization is the future

## The Digital Supply Chain Transformation

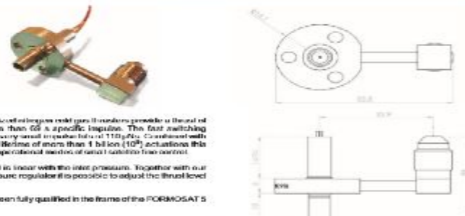


Source: [AudreyCox, 2018](#)

# Knowledge is locked in “messy” documents

## AST Advanced Space Technologies GmbH

### Cold Gas Thruster (CGT)



AST's miniaturized cold gas thrusters provide a thrust of 42 mN at more than 65 s specific impulse. The fast switching between on and off enables a pulse width of 100 µs. Combined with its exceptional lifetime of more than 1 billion (10<sup>9</sup>) actuations this system is now the preferred choice of many satellite designers.

The thrust level is linear with the inlet pressure. Together with our electronic pressure regulator it is possible to adjust the thrust level in flight.

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

Performance Characteristics	
Operating Media	GN <sub>2</sub>
Inlet Pressure (MEOP)	1 - 6 bar
Proof Pressure	2 x MEOP
Burst Pressure	4 x MEOP
Internal Leakage	< 10 <sup>-8</sup> sec <sup>2</sup> /bar
External Leakage	< 10 <sup>-8</sup> sec <sup>2</sup> /bar
Thrust	20 mN / 42 mN @ 1.5 bar GN <sub>2</sub> nominal
Minimum Impulse Bit	170 µN s @ 1 bar
Specific Impulse	> 65 s
Weight	0.042 kg
Operating Voltage	27 - 56 V <sub>DC</sub> max
Coil Resistance	500 mΩ
Operational Temperature Range	-30° - +50° C
Vibration	> 10g RMS
Life-time	1 million actuations qualified
Other media	2 billion actuations demonstrated

AST Advanced Space Technologies GmbH  
Zoopternstrasse 5b  
32285 Bielefeld

## 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 RF Thruster can be paired with any xenon propellant management system and can be arranged in nearly any configuration, 1x1 (2-3L), 1x2 (6L), 2x2 (12L) and so on.

Characteristic	Unit	Specification
Thrust	mN	1 - 15
Thrust to Power Ratio	mN/kW	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	N-s	5,000+
Delta V*	m/s	1,000+
Dry Mass**	kg	1.0 - 1.5
Propellant Mass (Xenon)	grams	500
System Volume**	L	0.5-1.0 + "tuna can"

\* Delta V delivered in a 30 s coast (4 kg dry mass)  
\*\* Dry mass and system volume depend on required propellant storage

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

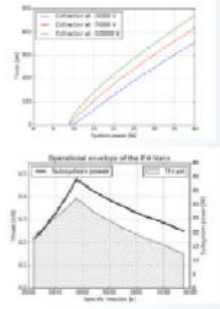
Taking orders now  
Ready for flight 2018

info@phasefour.io | www.phasefour.io  
t40000-12-15-17

## 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 380 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 orbit maneuver and low thrust precision control maneuvers.



Parameter	Value
Dynamic thrust range	10 µN to 0.5 mN
Nominal thrust	350 µN
Specific impulse	2,000 to 5,000 s
Propellant mass	250 g
Total impulse	more than 5,000 Ns
Power at nominal thrust	35 W incl. neutralizer
Outside dimensions	94 x 90 x 78 mm
Mass (dry / wet)	640 / 870 g
Total system power	8 - 40 W
Hot standby power	3.5 W
Command interface	RS422/RS485
Temperature envelope (non-operational)	-60 to 120°
Temperature envelope (operational)	-20 to 60 °C
Supply voltage	12V, 20 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  
Total Impulse  
1 = 5000 Ns  
2 = 10000 Ns  
3 = 15000 Ns  
4 = 20000 Ns  
5 = 25000 Ns  
6 = 30000 Ns  
7 = 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-TRL propulsion architecture that uses a hybrid electrical/chemical scheme to provide small spacecraft with both high thrust (> 1.5 N) and high I<sub>sp</sub> (> 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

Performance Characteristics				
Characteristic	0.47 lbf (0.76 N) Thrust Single Seat	3.2 lbf (5.7 N) Thrust Redundant Seat	9 lbf (40 N) Thrust Single Seat	150 lbf (711 N) Thrust Single Seat
Max Operating Pressure, MEOP (psia/MPa)	300 (20.7)	400 (27.6)	500 (34.5)	270 (18.7)
Proof Pressure (psia/MPa)	880 (61.0)	1500 (103.4)	1500 (103.4)	450 (31.0)
Burst Pressure (psia/MPa)	1485 (102.9)	2850 (199.8)	2900 (200.0)	710 (49.3)
Flow Coefficient (Cv) (m³/sec @ 100 psi)	0.00033	0.00101	0.0013	0.019
Operating Voltage Range (Vdc)	24 to 32	24 to 32	22 to 32	18 to 136
Maximum Open Response Time (msec)	1	10	15	30
Maximum Close Response Time (msec)	1	10	15	20
Power Consumption (watts)	10.4 at 32Vdc, 10F	8.0 at 25Vdc, 45F	26.5 at 28Vdc, 70F	129 at 136Vdc, 70F
Leakage per Seat, Internal (cc/hr)	0.4	0.4	0.2	3.6
Leakage, External (cc/hr)	1E-6	1E-6	1E-6	1E-3
Life (cycles)	1,000,000	1,000,000	100,000	100,000
Weight (lbf) (grams) including hardware	0.067 (1.5)	0.48 (108)	0.6 (136)	2.5 (1134)
Mini Filtration (microns absolute rating)	15	20	25	25
Operating Temperature Range (°F/°C)	40 to 370 (4.4 to 149)	40 to 300 (4.4 to 149)	40 to 300 (4.4 to 149)	40 to 300 (4.4 to 149)
Booster/Drive Model Numbers	-051-271	-051-0490	51-258	53-2810




## Monopropellant Thrusters

Performance Characteristics							
Engine	MONARC-1	MONARC-2	MONARC-22-8	MONARC-22-12	MONARC-DELTA	MONARC-DELTA	MONARC-440
Steady State Thrust	0.25 lbf (0.41 N) (0.276 psi)	1.0 lbf (4.45 N) (0.075 psi)	5.0 lbf (22.0 N) (0.075 psi)	5.0 lbf (22.0 N) (0.075 psi)	30 lbf (133.4 N) (0.236 psi)	25 lbf (111.2 N) (0.236 psi)	100 lbf (444.8 N) (0.236 psi)
Grid Pressure	20 - 400 psia (1.3 - 27.3 bar)	10 - 400 psia (0.7 - 27.3 bar)	30 - 400 psia (2.1 - 27.3 bar)	30 - 400 psia (2.1 - 27.3 bar)	10 - 400 psia (0.7 - 27.3 bar)	10 - 400 psia (0.7 - 27.3 bar)	10 - 400 psia (0.7 - 27.3 bar)
Nozzle Expansion	50:1	15:1	10:1	10:1	40:1	40:1	10:1
Water Power	15 watts	15 watts	30 watts	30 watts	72 watts	72 watts	65 watts
Mass	0.30 lbf (0.30 kg)	1.00 lbf (0.45 kg)	1.00 lbf (0.45 kg)	1.00 lbf (0.45 kg)	2.47 lbf (1.12 kg)	2.47 lbf (1.12 kg)	35 lbf (15.9 kg)
Engine Length/Total Mass	5.2 in (13.1 cm) 2.8 x 0.8 in (7.1 x 2.0 cm)	5.4 in (13.8 cm) 4.1 x 0.8 in (10.4 x 2.0 cm)	8.0 in (20.3 cm) 1.8 x 0.8 in (4.6 x 2.0 cm)	1.6 in (4.1 cm) 1.2 x 0.8 in (3.0 x 2.0 cm)	15.0 in (38.1 cm) 3.3 x 0.8 in (8.4 x 2.0 cm)	15.0 in (38.1 cm) 3.3 x 0.8 in (8.4 x 2.0 cm)	18.0 in (45.7 cm) 6.8 x 0.8 in (17.3 x 2.0 cm)
Specific Impulse	237.5 sec	255.0 sec	255.0 sec	238.1 sec	222.1 sec	222.1 sec	220.0 sec
Water to Impulse Ratio	0.00010 lbf-sec (0.00010 sec)	0.00010 lbf-sec (0.00010 sec)	0.00010 lbf-sec (0.00010 sec)	0.00010 lbf-sec (0.00010 sec)	0.00010 lbf-sec (0.00010 sec)	0.00010 lbf-sec (0.00010 sec)	0.00010 lbf-sec (0.00010 sec)
Life (cycles)	25,000 (10,000 to 100,000)	100,000 (50,000 to 200,000)	100,000 (50,000 to 200,000)	200,000 (100,000 to 400,000)	100,000 (50,000 to 200,000)	100,000 (50,000 to 200,000)	100,000 (50,000 to 200,000)
Price	20,000	20,000	20,000	100,000	90,000	70,000	120,000

# Solution: conversion to Electronic Data Sheets

				
	<b>RWP015</b>	<b>RWP050</b>	<b>RWP100</b>	<b>RWP500</b>
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	< 5.0 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 <sup>2</sup> (2.5 g-mm <sup>2</sup> )	< 20 g-mm <sup>2</sup> (2.5 g-mm <sup>2</sup> )	< 20 g-mm <sup>2</sup> (5 g-mm <sup>2</sup> )	< 25 g-mm <sup>2</sup> (10 g-mm <sup>2</sup> )

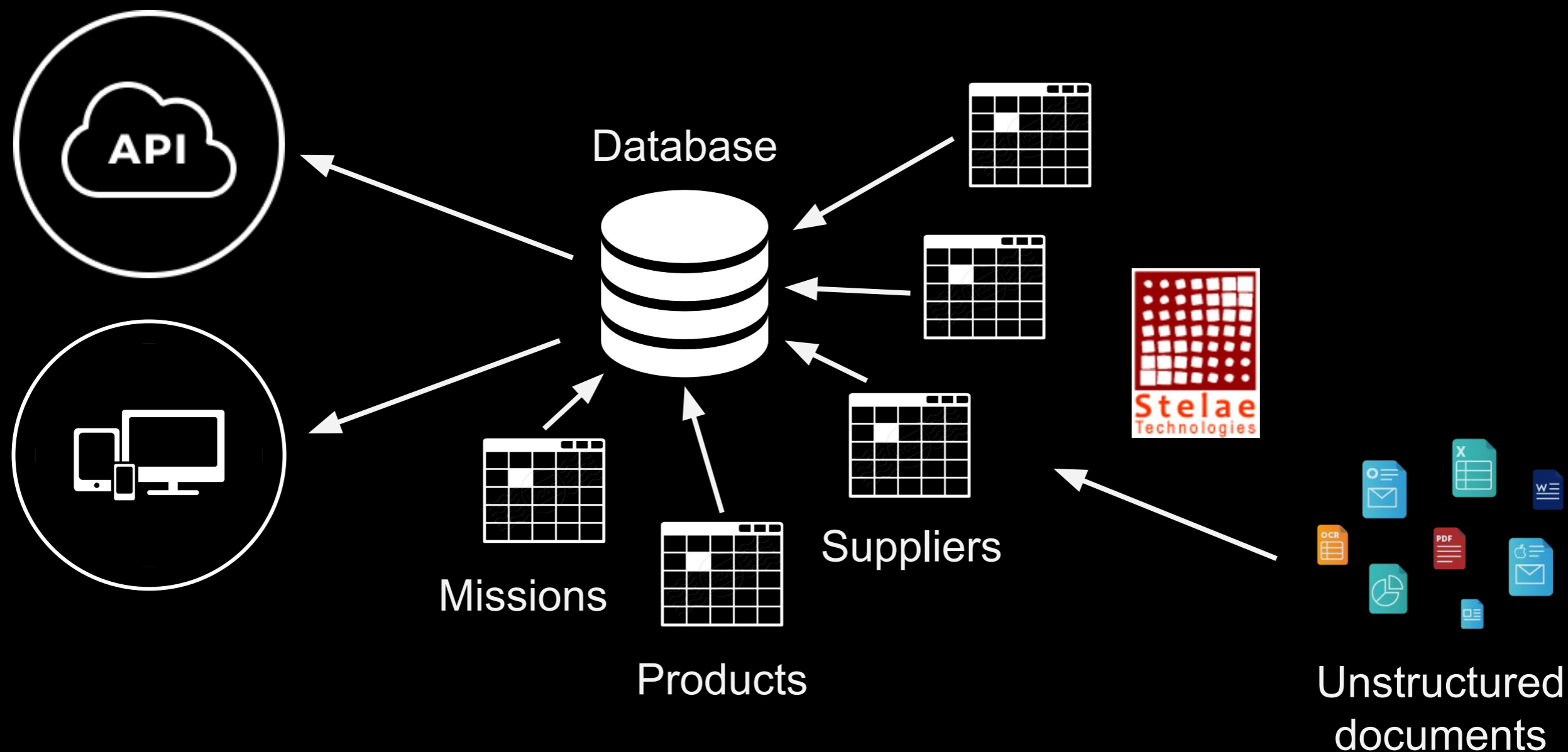
  

			
	<b>RW1</b>	<b>RW4</b>	<b>RW8</b>
Momentum	1.0 Nm	4.0 Nms	8.0 Nms
Max Torque *	0.1 Nm	0.3 Nm	0.3 Nm
Mass	0.75 kg	3.0 kg	4.1 kg
Volume	11 x 11 x 3.8 cm	17 x 17 x 7 cm	19 x 19 x 9 cm
Voltage	28 VDC	28 VDC	28 VDC
Power @ 1/2 Momentum	< 4.5 W	< 5 W	< 5 W
Power @ Full Momentum	< 9 W	< 10 W	< 10 W
Design Life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

\* Custom options are available

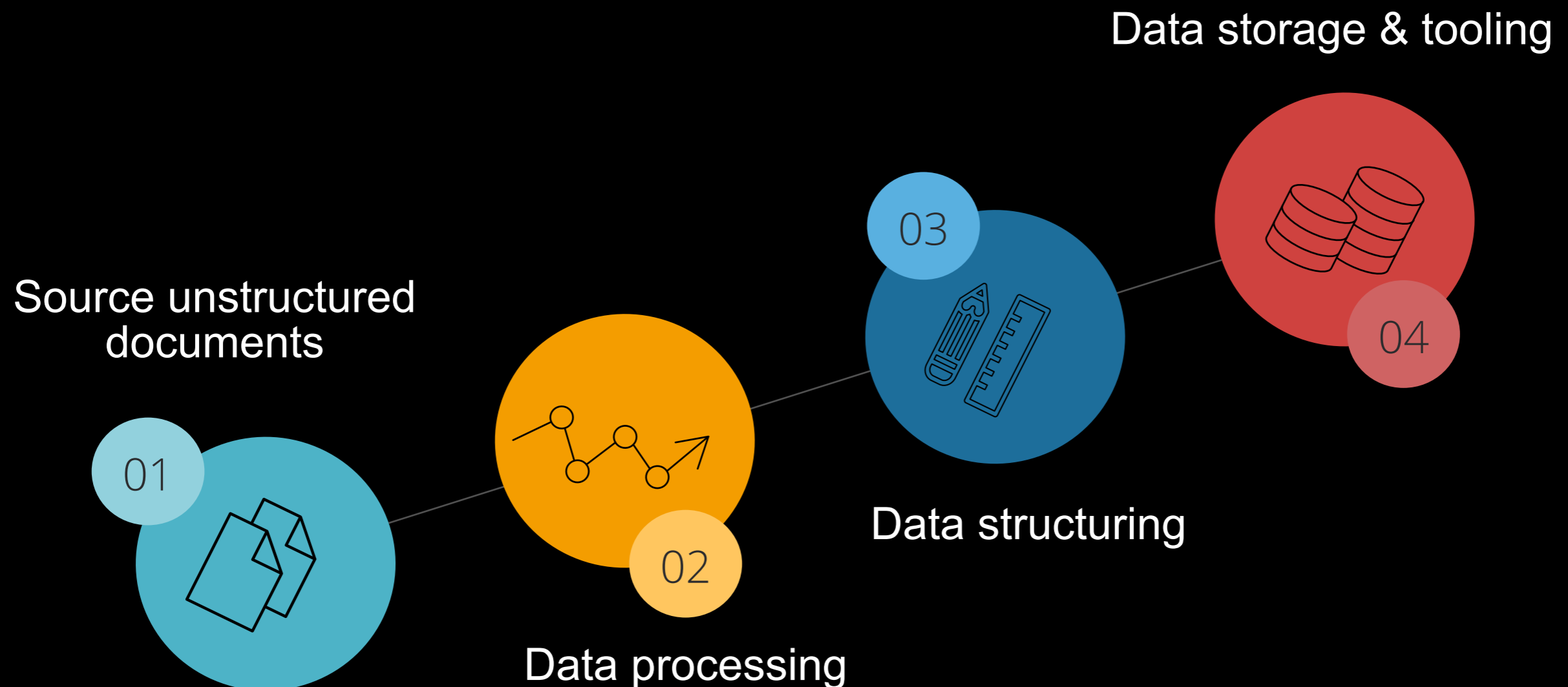
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# The technology stack behind satsearch



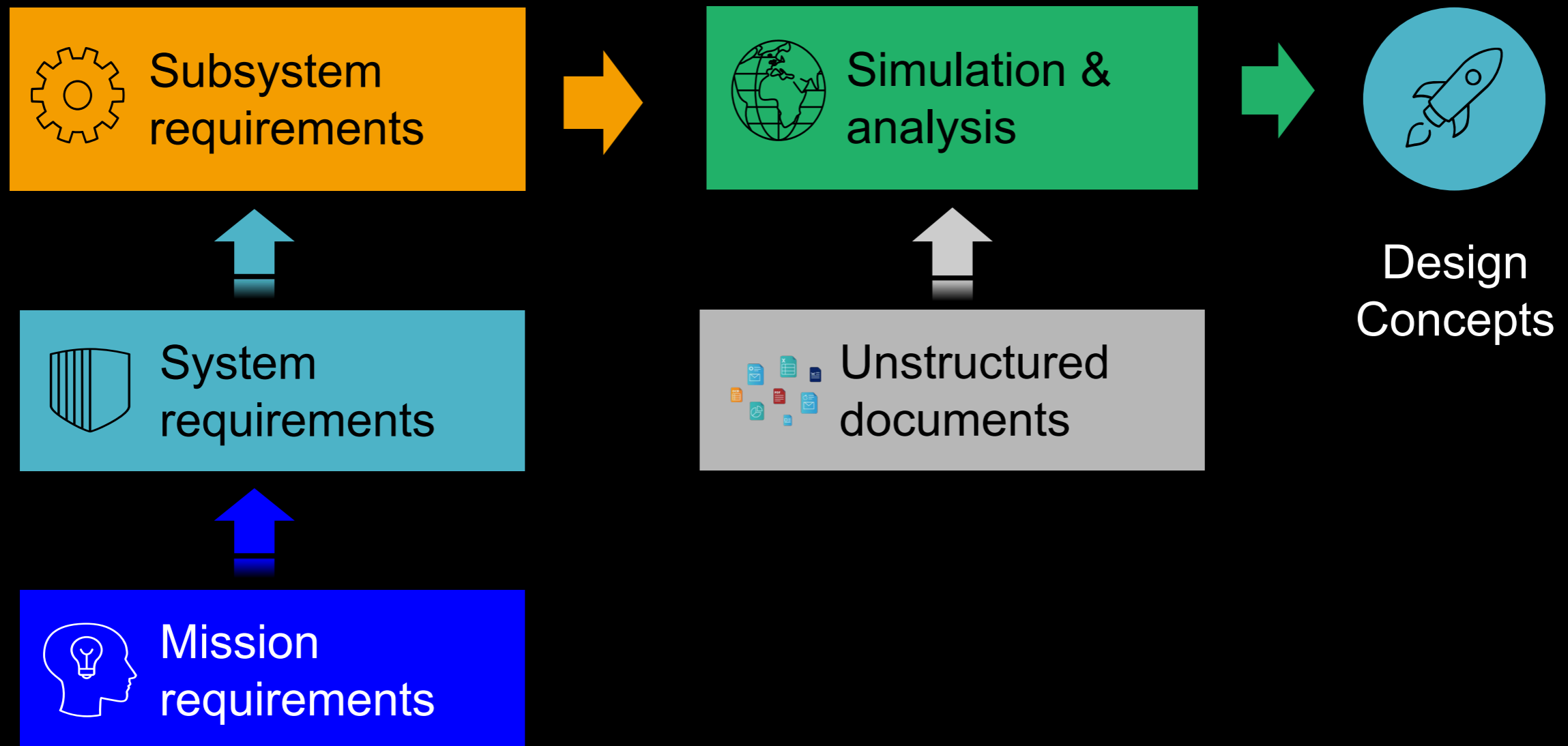
**Toolchain for creation & use of Electronic Data Sheets**

# The conversion pipeline to EDS

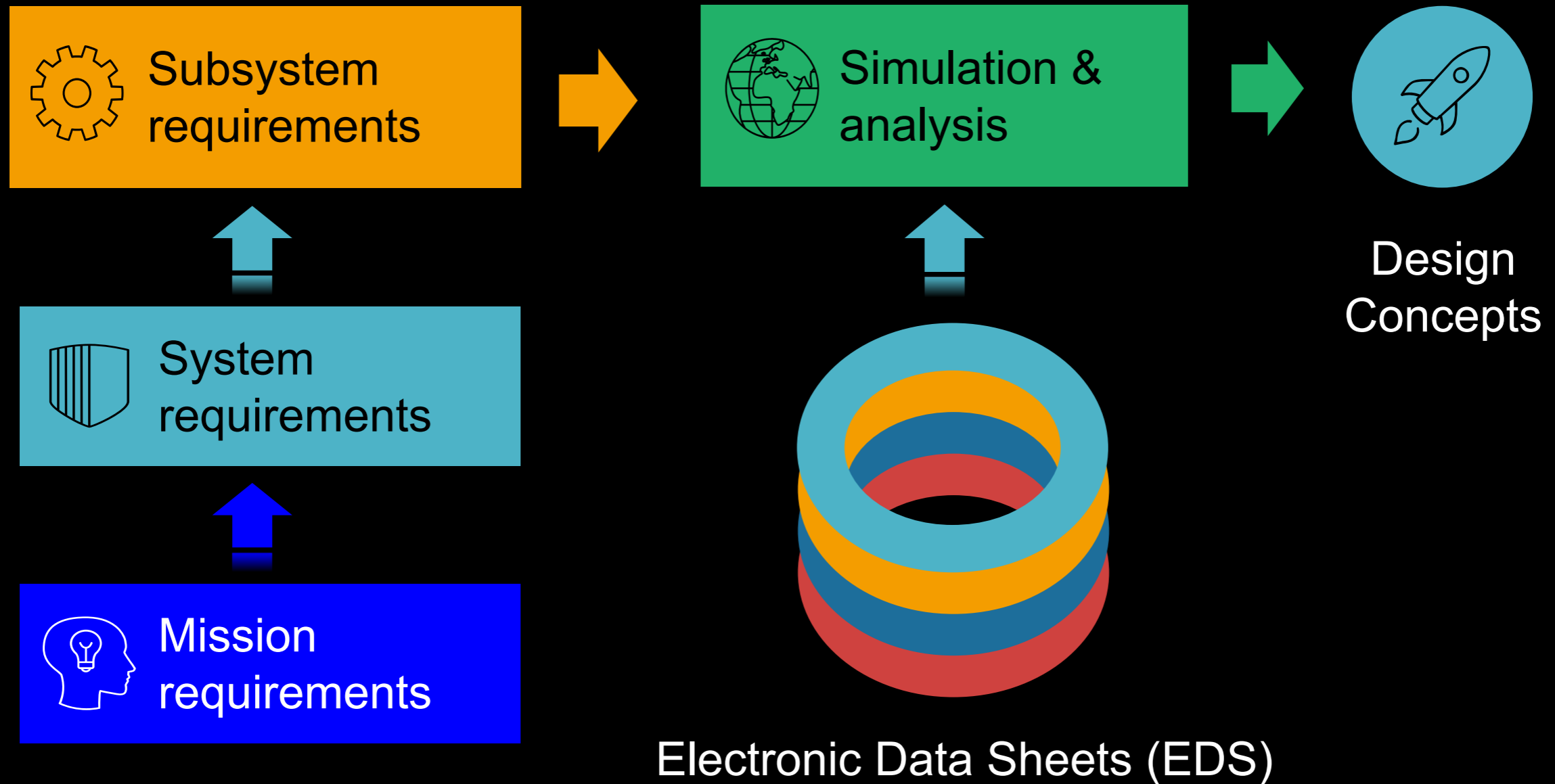


**Growing need to develop “best of class” standards for EDS**

# Integrating supply chain data into design




# Integrating supply chain data into design



**Integrated Mission Design is essential to adoption of MBSE**

# Example: Concept generation for ACS



Specs	
lifetime	> 10 yr
Maximum torque	0.055 N m
angular momentum storage	min: 4 N m s, max: 12 N m s
mechanical vibration	19.8 Grms
radiation tolerance	300 krad
mass	min: 3.6 kg, max: 5.0 kg
diameter	267 mm
height	120 mm
dynamic unbalance	< 3.1 g cm <sup>2</sup>
static unbalance	< 0.2 g cm
maximum power	< 80 W
voltage	min: 14 V, max: 23 V
operating temperature	min: -19 C, max: 60 C

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Got it!

<https://youtu.be/doXnAeJXh-o>

# Example: CDP4™ integration

CDP4 VME SE - 1.0.0.0

Home Reference Data View Model Directory Requirements Diagram editor Built-in Rules

Show deprecated things Clear highlighting Show the Property Grid Show the Log Panel

Scripting Engine - satsearch

Element definitions

Name	Manual	Reference
Reaction Wheel 150		
diameter	150	
height	68	
radius	7	
mass	1.5	
power in standby		
torque	0.03	
voltage		
satellite		

Product tree: Option 1

Name	Value	Owner	Switch
satellite		SYS	

satsearch

Name:


Supplier:

Category:

Search Next Clear


Drag a column header here to group by that column

NR-1075

Image: 

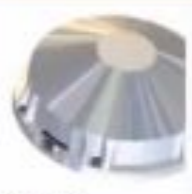
Name: NR-1075  
Supplier: Aerojet Rocketdyne Holdings Inc.  
Supplier URL: /suppliers/aerojet-rocketdyne-holdings  
Product URL: /products/aerojet-rocketdyne-holdings-nr-1075  
Last Modified: 3/23/2018

Pocketcube IP Structure

Image: 

Name: Pocketcube IP Structure  
Supplier: Alfa Orbital Ltd.  
Supplier URL: /suppliers/alfa-orbital-ltd  
Product URL: /products/alfa-orbital-ltd-pocketcube-ip-structure  
Last Modified: 3/23/2018

Reaction Wheel 150

Image: 

Name: Reaction Wheel 150  
Supplier: Astro- und Feinwerktechnik Adienthof GmbH  
Supplier URL: /suppliers/astro-und-feinwerktechnik-adienthof-gmbh  
Product URL: /products/astro-und-feinwerktechnik-adienthof-gmbh-rw-150  
Last Modified: 3/23/2018

Name: Reaction Wheel 150  
Supplier: Astro- und Feinwerktechnik Adienthof GmbH  
Supplier URL: https://satsearch.co/suppliers/astro-und-feinwerktechnik-adienthof-gmbh  
Product URL: https://satsearch.co/products/astro-und-feinwerktechnik-adienthof-gmbh-rw-150

Summary:  
The RW 150 is a smart reaction wheel for small and micro satellites with integrated wheel drive electronics, different operation modes for speed and acceleration using model based controllers, high torque and speed stability (low noise), internal compensation of friction and time delays, provides extensive housekeeping (e.g.: measured and estimated speed, voltage, current, acceleration reserves etc.), various protective and monitoring mechanisms for voltage and current, temperature and data processing and low level emitted vibrations, due to the mechanical design and the high level of alignment and balancing.

# Example: Valispace integration

Valispace

Components

Analysis

Export

Simulation

search tree...

Satsearch\_imports

- 30L\_Propellant\_Tank\_satsearch\_2018\_06\_12\_12
- 30L\_Propellant\_Tank\_satsearch\_2018\_06\_12\_18
- 30L\_Propellant\_Tank\_satsearch\_2018\_06\_15\_12
- HR\_0610\_satsearch\_2018\_06\_12\_12
- HR\_0610\_satsearch\_2018\_06\_12\_18
- HR\_0610\_satsearch\_2018\_06\_15\_12
- HR\_0610\_satsearch\_2018\_07\_23\_16
- HR\_0610\_satsearch\_2018\_07\_24\_17
- RW1\_satsearch\_2018\_04\_26\_15\_00
- RW\_0\_03\_satsearch\_2018\_04\_26\_16
- Reaction\_Wheel\_35\_satsearch\_2018\_04\_26\_16
- Reaction\_Wheel\_35\_satsearch\_2018\_04\_26\_16
- Reaction\_Wheel\_35\_satsearch\_2018\_04\_26\_16

HR\_0610\_satsearch\_2018\_07\_24\_17\_38\_47

create alternative

delete HR\_0610\_satsearch\_2018\_07\_24\_17\_38\_47

add tag

The HR 0610 Reaction Wheel provides a high-speed, low-weight solution for small spacecraft. Standard microelectronics provide flexibility for wheel performance over a wide range of spacecraft interfaces.

add vali

name

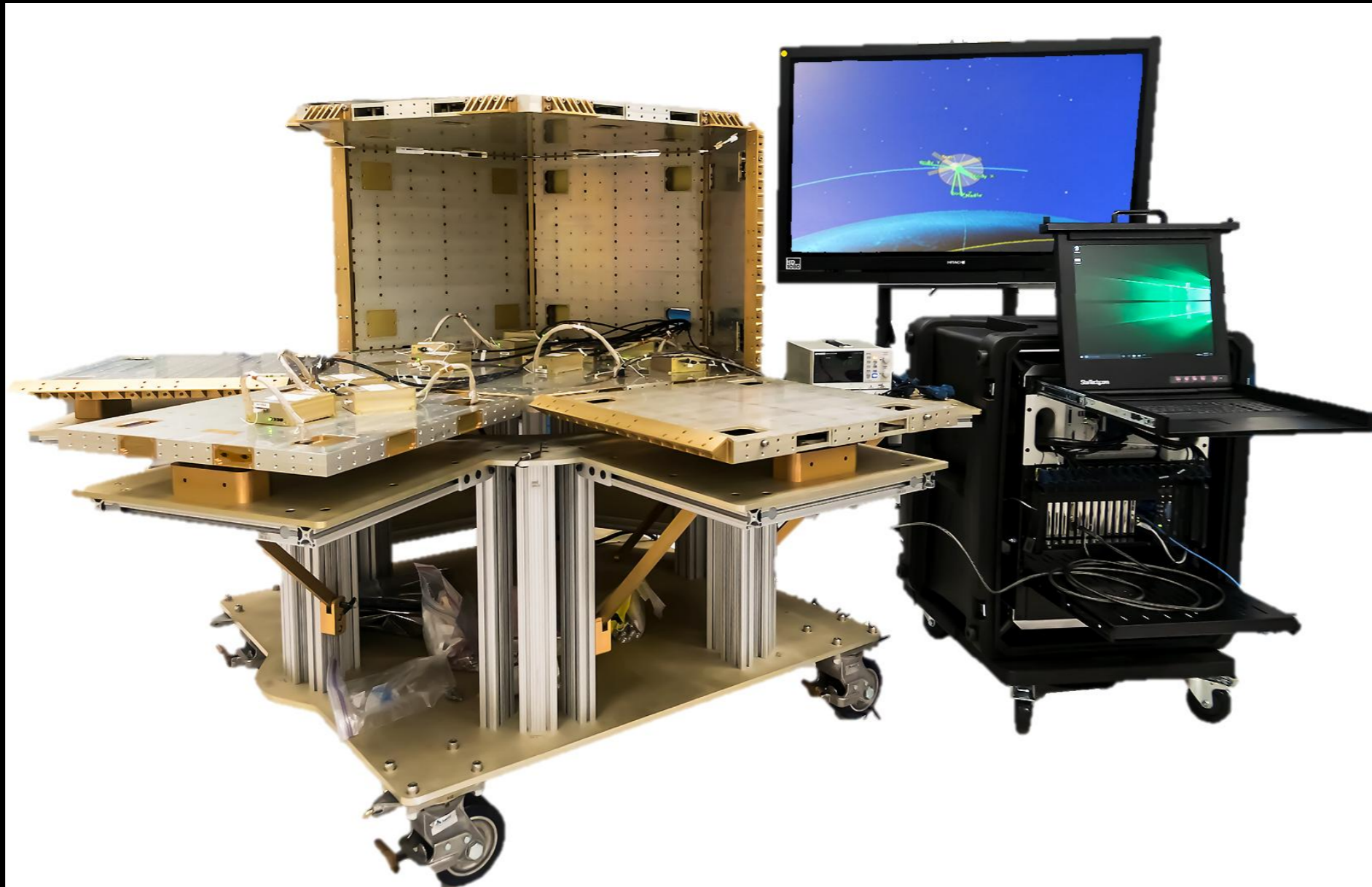
value / formula

unit

save

Name	Value	Margin	Total margin	Worst case	Tags
angular_momentum_storage	0 N m s	+   -	+0.0%   -0.0%	0.000 N m s	<div>Value not imp</div> <div>subscribe</div>
angular_speed	6000 rpm	+   -	+0.0%   -0.0%	6000 rpm	<div>add tag</div> <div>subscribe</div>
category	Reaction wheel				<div>add tag</div> <div></div>
category_uuid	fdc836a2-7a0e-5bce-ac48-8225ddb73a83				<div>add tag</div> <div></div>
configurations_1	base				<div>add tag</div> <div></div>
diameter	267 mm	+   -	+0.0%   -0.0%	267 mm	<div>add tag</div> <div>subscribe</div>
dynamic_unbalance	0 g cm^2	+   -	+0.0%   -0.0%	0.000 g cm^2	<div>Value not imp</div> <div>subscribe</div>
height	120 mm	+   -	+0.0%   -0.0%	120 mm	<div>add tag</div> <div>subscribe</div>

# Example: ACORN integration



# Data-driven design methods are the future



We are supporting a ESA NPI led by University of Strathclyde to develop a Design Engineering Assistant (DEA)



The global marketplace for space

ADCSS2018  
ESA/ESTEC  
Noordwijk, the Netherlands

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+31 6 14634697