Uniform Trajectory Locators (UTLs) – an open API for trajectory discovery and utilisation

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6th International Conference on Astrodynamics Tools and Techniques (ICATT)

Darmstadt, Germany
16th March 2016

Graphics courtesy: Alan Taylor kokogiak.com

pocket spacecraft

a spacecraft that an individual can afford to buy, launch and operate with little or no technical expertise

personal space age

the era of exploration of space by private individuals for science, general interest and profit

Graphics courtesy: JA / PocketSpacecraft.com

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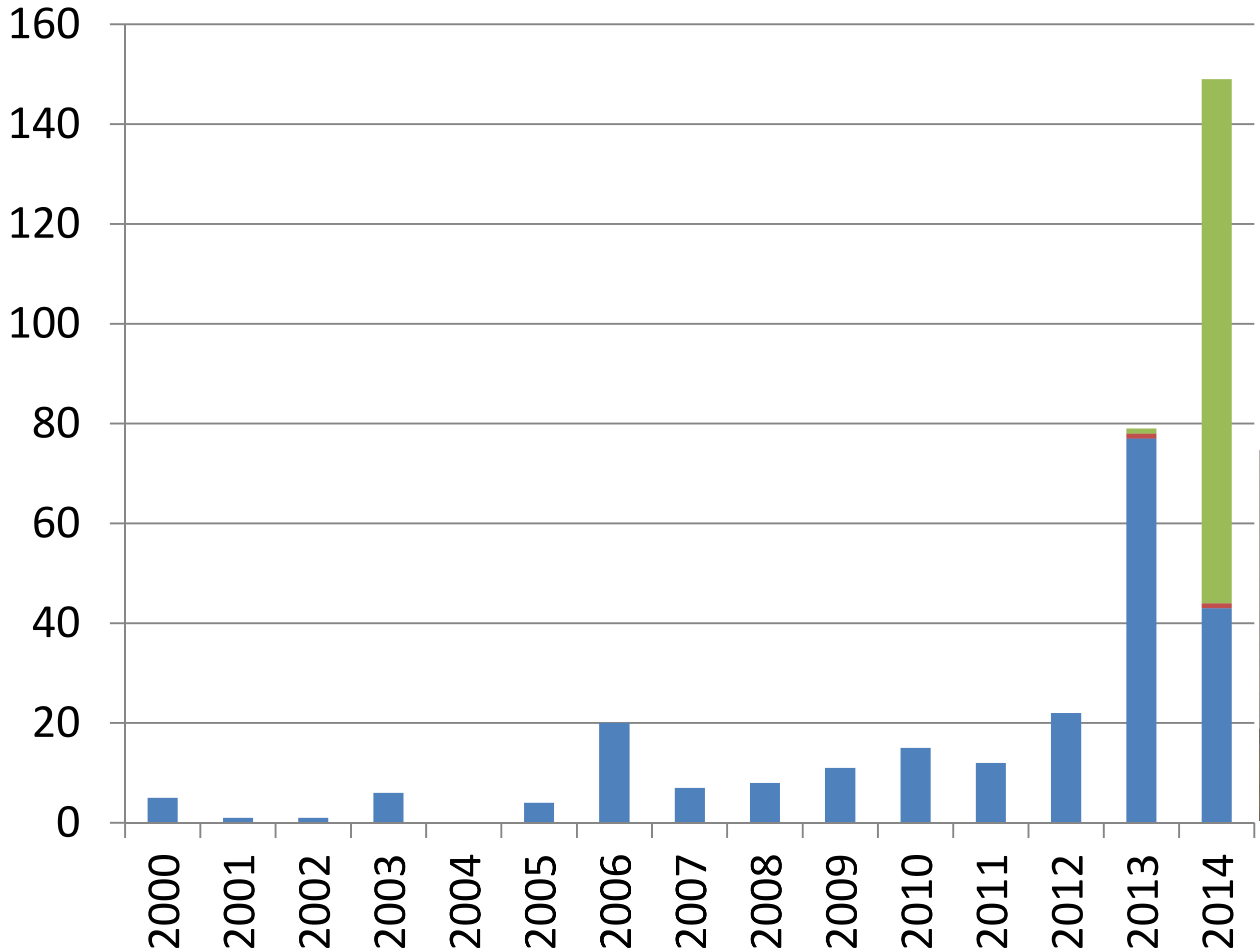
Demand for launches

PocketSpacecraft.com



Green bar – SpaceX CRS-3: most spacecraft ever launched on a single launch (>100), all privately backed

Data courtesy: CubeSat.org, Swartwout, JA Video: Matthew Travis

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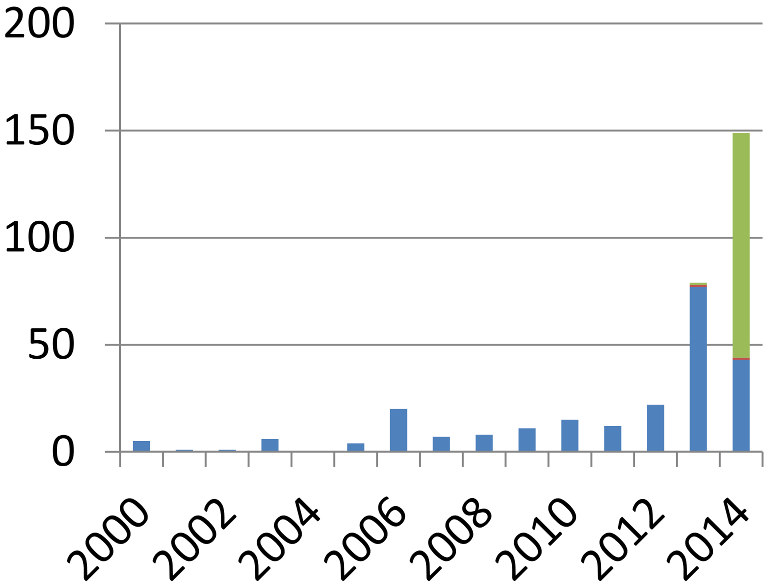
Resistance to CubeSats

PocketSpacecraft.com

- ‘You can’t do anything useful’
- ‘They are just for students’
- ‘You can’t do real science’
- ’You can’t fit real instruments’
- ‘You can’t do useful imaging with such small apertures’
- ‘They don’t have enough power’
- ‘They’re unreliable’
- ‘They will never work’ … ~~in LEO~~

~~for science missions~~
~~for NASA missions~~
~~for NSF missions~~
~~for ESA missions~~
~~for commercial applications~~
~~for GEO missions~~
~~for interplanetary missions~~
~~for lunar missions~~
~~for Mars missions~~
~~for outer planet missions…~~



Graphics courtesy: Aerospace Corporation, Josh Spradling

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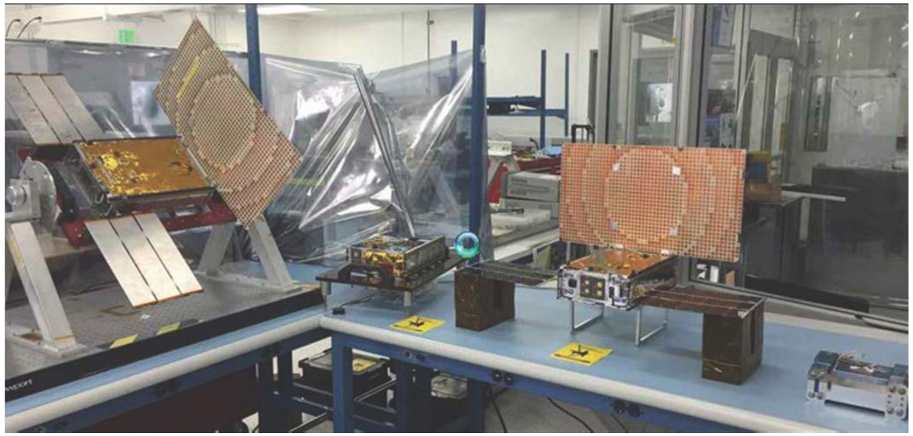
Interplanetary CubeSats

PocketSpacecraft.com

- Sizes from 0.5U → 6U
  - iCM (PocketSpacecraft.com)
  - INSPIRE (NASA/JPL)
  - MarCO (NASA/JPL)
- Lots more on the way from ESA, NASA and private companies (>$100 million)
- Complete spacecraft: **TRL8**, path to TRL9 ranging from 2016-2018
- Large toolbox of individual compatible subsystems including avionics, power, solar arrays, propulsion, etc., at **TRL9**
- **They're real, they're here <u>now</u>**



MarCO 6U CubeSats for InSight EDL comms

http://www.kiss.caltech.edu/study/smallsat/KISS-SmallSat-FinalReport.pdf

Image Credit: NASA-JPL/Caltech, Keck Institute for Space Studies

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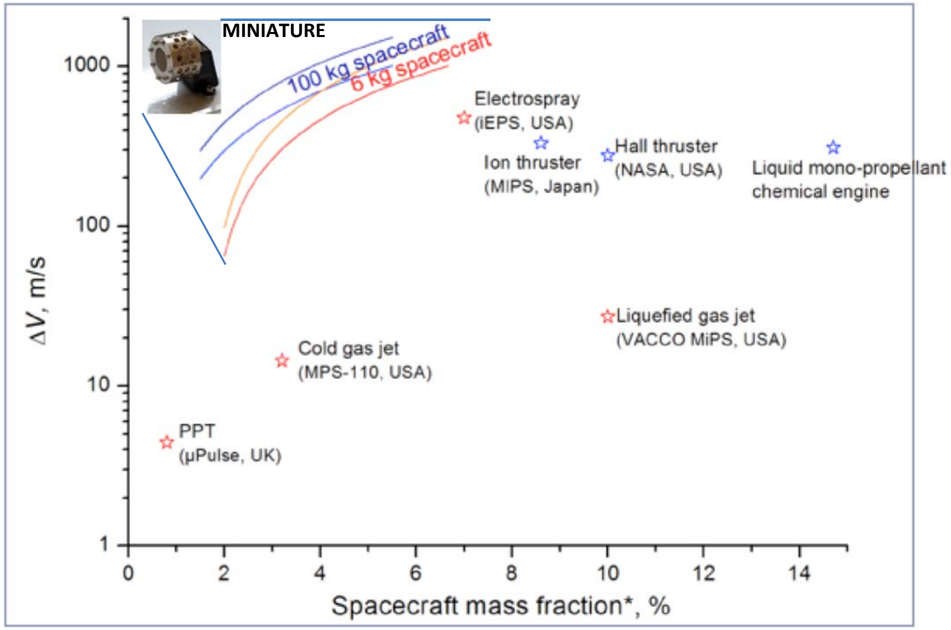
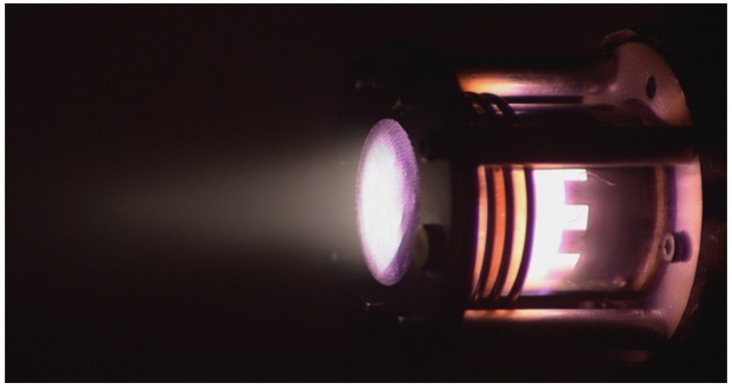
- MINIATURE
  Electric Propulsion System
  - Suitable for 3kg-500kg bus
  - Radio-frequency biased solid fuel ion thruster



- Up to 1800 m/s delta-V for 6U



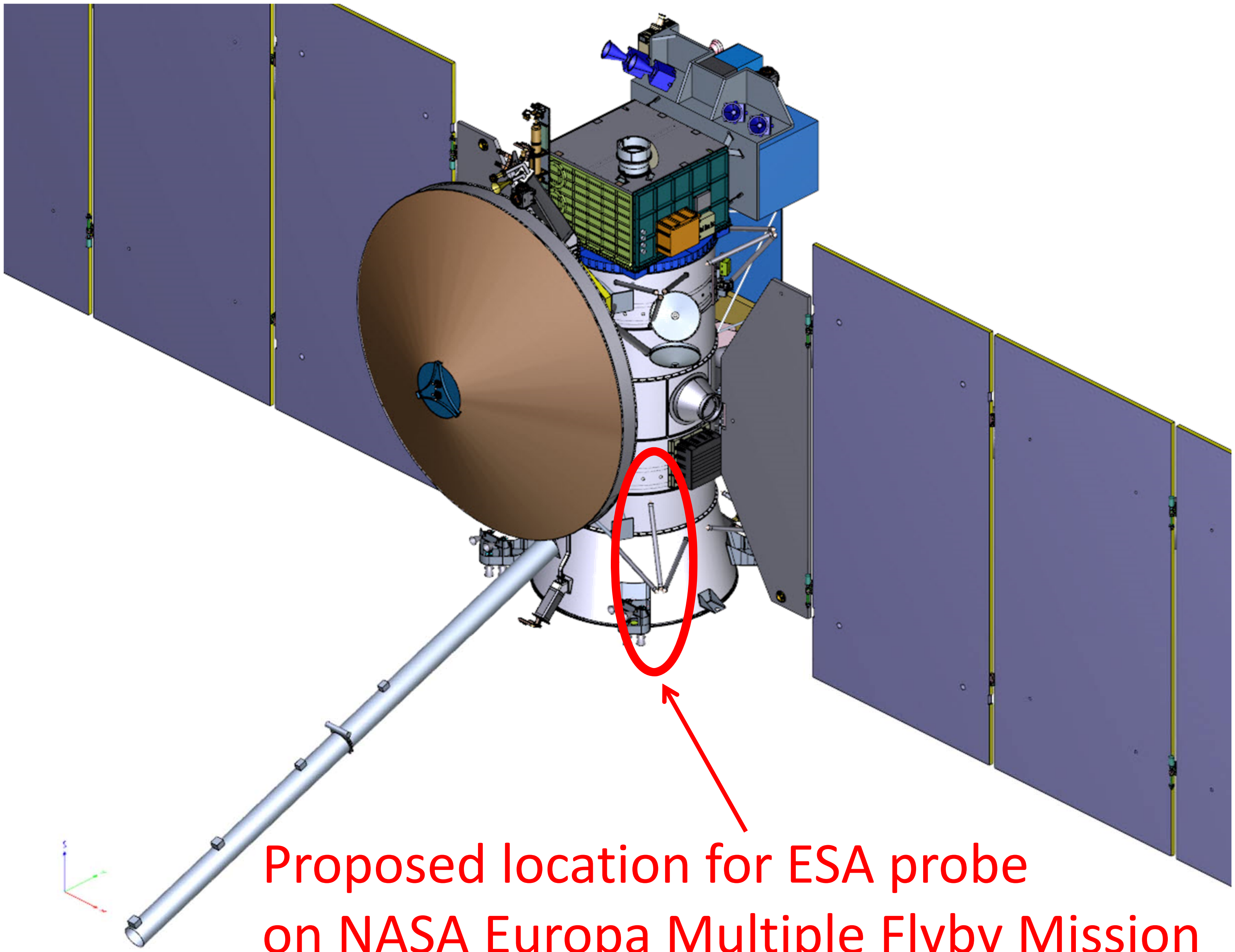
MINIATURE in action at 20W

Footprint	**<1U**
Total power	10-60 W
Thruster efficiency*	20-30%
Specific impulse (Isp)	2000-3000 s
Thrust	0.1-1.0 mN
Dry mass**	<100 g
Propellant#	~20-300 g
DeltaV (6kg wet mass)	80-1800 m/s
Operational lifetime##	300 h – 1000h
Thruster lifetime	>10 000 h
TRL (subsystem dependent)	~3-6

* Efficiencies includes power transfer, propellant utilization and neutralization. It does not include the PPU
** Does not include the PPU
# Integrated solid iodine propellant is possible but can be replaced by Xenon or Krypton on the cost of system size
Operational lifetime is limited by propellant mass, it can be increased on the cost of footprint

Graphics: CNRS, Ecole Polytechnique, ThrustMe

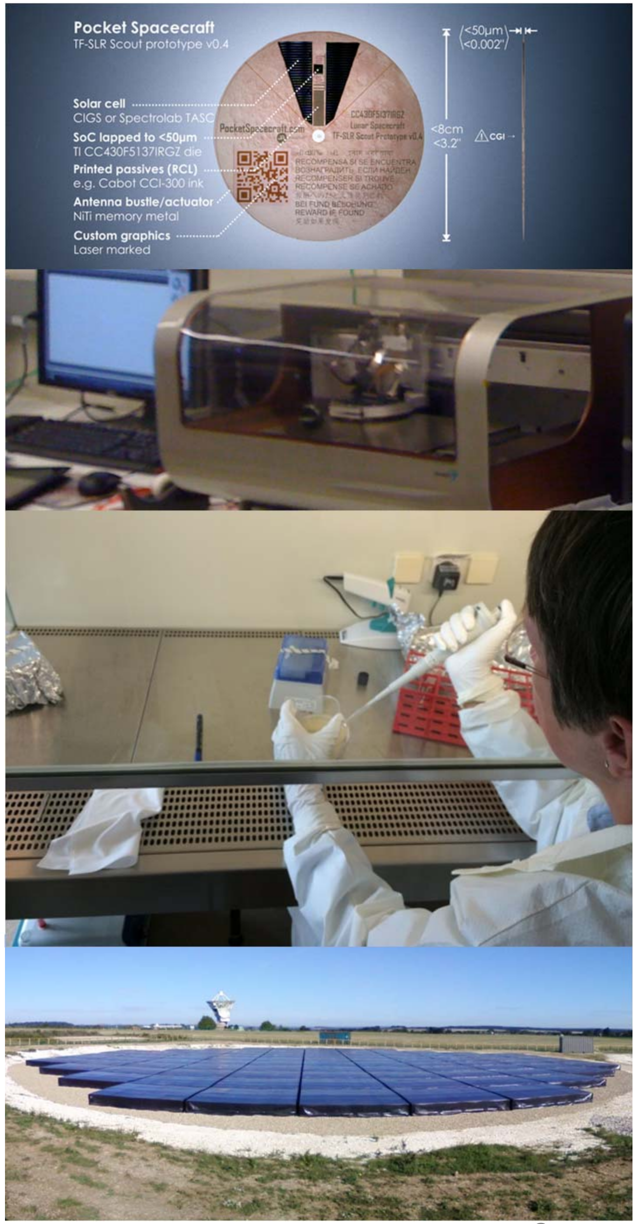
Rideshares on deep space missions



Graphics courtesy: Caltech-NASA/JPL

Thin-Film Spacecraft/Lander/Rovers

- Very thin (<50μm) low mass (<1g) self-sufficient TF-SLR probes designed for large scale (100s-1000s) low overhead (<100g) deployment
- Up to 945mW @ 1AU from solar cells backed by thin film energy storage
- Integrated processing, storage, communications, sensors, imagers
- Can return data to traditional orbiters, deployment device, or each other using custom or CCSDS compatible UHF
- Robust, disposable, customisable
- Designed for COSPAR Class IV PP processes
- Ideal for high risk high return science
- TRL8, path to TRL9 by end of year



Graphics courtesy: JA / PocketSpacecraft.com, STFC

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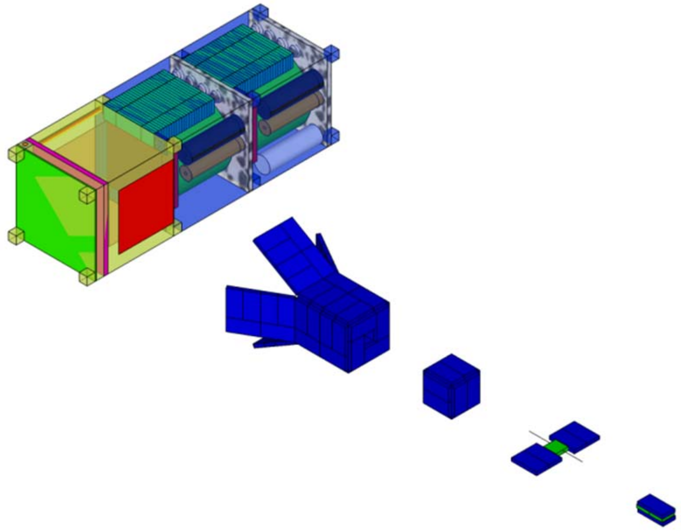
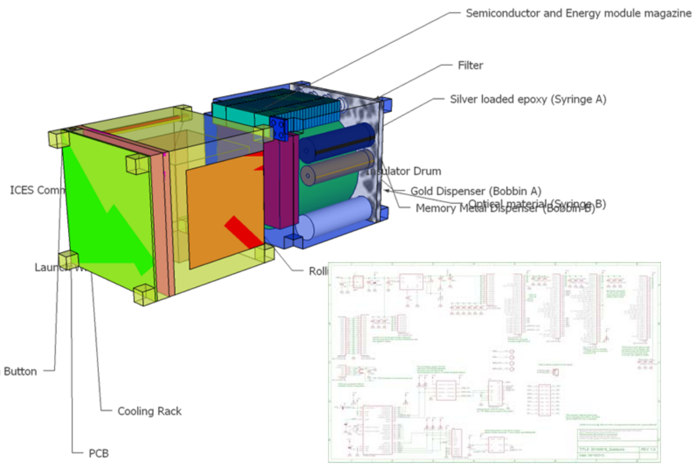
Spacecraft-on-Demand

PocketSpacecraft.com

- A crowd sourced system for the rapid development, deployment and operation of millions of solar system and planetary exploration missions
- Design missions and spacecraft on the ground using easy to use web and iPad apps and library of spacecraft and mission components
- Upload design to Prepositioned Orbiting 3D Printer (POPs) and print it using Insulator, Conductor, Energy and Semiconductor (ICES) cartridges
- Launch and explore
- Parabolic flight test planned 2016, path to TRL 9 (LEO) 2017/18





Graphics courtesy: Anon, JA, N.Gabbani

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The problem

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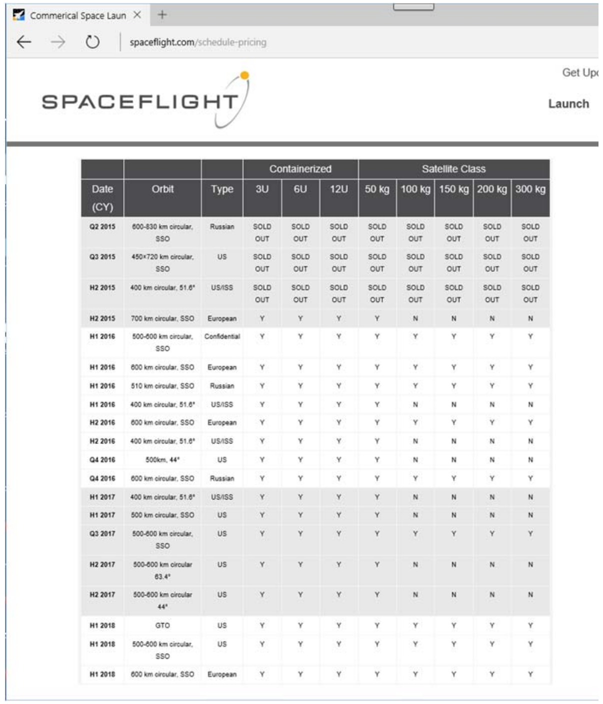
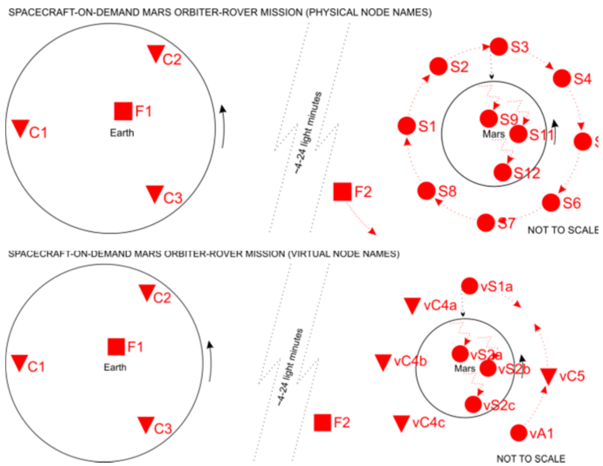
- Identify provision of, or demand for, existing, upcoming or potential trajectories
  - Launch opportunities
  - Deployment opportunities
  - Virtual payload / instrument opportunities
  - Automated and handcrafted solutions
- Platform neutral
- Open decentralized format
- Use existing tools and techniques
  - Manually
  - Automatically
- Reflect realities of fluid mission parameters



			Containerized			Satellite Class				
Date (CY)	Orbit	Type	3U	6U	12U	50 kg	100 kg	150 kg	200 kg	300 kg
Q2 2015	600-830 km circular, SSO	Russian	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT
Q3 2015	450×720 km circular, SSO	US	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT
H2 2015	400 km circular, 51.6°	US/ISS	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT	SOLD OUT
H2 2015	700 km circular, SSO	European	Y	Y	Y	Y	N	N	N	N
H1 2016	500-600 km circular, SSO	Confidential	Y	Y	Y	Y	Y	Y	Y	Y
H1 2016	600 km circular, SSO	European	Y	Y	Y	Y	Y	Y	Y	Y
H1 2016	510 km circular, SSO	Russian	Y	Y	Y	Y	Y	Y	Y	Y
H1 2016	400 km circular, 51.6°	US/ISS	Y	Y	Y	Y	N	N	N	N
H2 2016	600 km circular, SSO	European	Y	Y	Y	Y	Y	Y	Y	Y
H2 2016	400 km circular, 51.6°	US/ISS	Y	Y	Y	Y	N	N	N	N
Q4 2016	500km, 44°	US	Y	Y	Y	Y	N	N	N	N
Q4 2016	600 km circular, SSO	Russian	Y	Y	Y	Y	Y	Y	Y	Y
H1 2017	400 km circular, 51.6°	US/ISS	Y	Y	Y	Y	N	N	N	N
H1 2017	500 km circular, SSO	US	Y	Y	Y	Y	N	N	N	N
Q3 2017	500-600 km circular, SSO	US	Y	Y	Y	Y	Y	Y	Y	Y
H2 2017	500-600 km circular 63.4°	US	Y	Y	Y	Y	N	N	N	N
H2 2017	500-600 km circular 44°	US	Y	Y	Y	Y	N	N	N	N
H1 2018	GTO	US	Y	Y	Y	Y	Y	Y	Y	Y
H1 2018	500-600 km circular, SSO	US	Y	Y	Y	Y	Y	Y	Y	Y
H1 2018	600 km circular, SSO	European	Y	Y	Y	Y	Y	Y	Y	Y



Graphics courtesy: JA, Spaceflight Industries, Inc.

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Solution drivers

PocketSpacecraft.com

- No reinventing the wheel where possible
- Lightweight wrapper for existing tools/standards
  - SPICE ephemeris
  - TLEs
- Platform independent interfaces
  - Launch opportunity databases
  - Orbital parameters
  - Flight dynamics tools

- Capture realities of multiple, often conflicting, sources of information about the same opportunity (e.g. multiple access providers, prices, evolving truth, consumer specific levels of detail)
- Include path to e-commerce

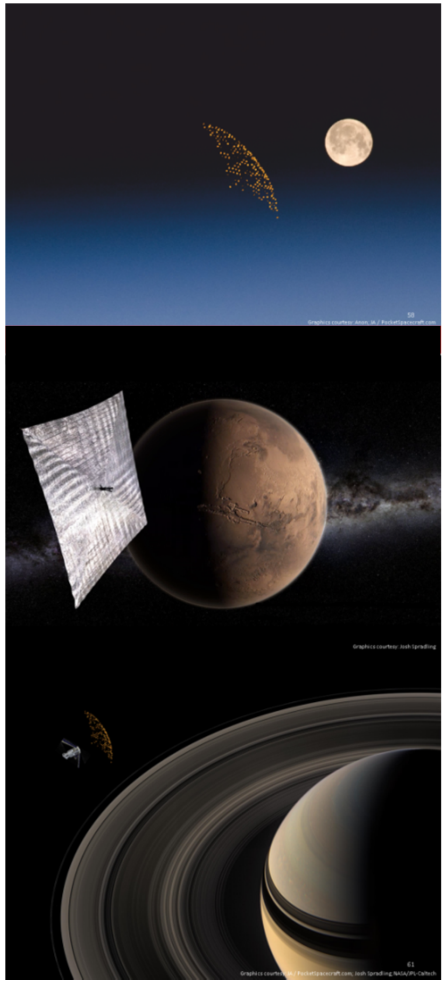
Photos courtesy: JA / OpenMissionControl.org

The solution?

- Trajectory Markup Language (TML)
  - Returned by HTTP(S) RESTful API
  - eXtensible Markup Language (XML) files
  - Captures different levels of truth and detail
  - Can be static files or algorithmically generated
- Level of detail may depend on
  - Source e.g. launch providers, brokers, potential consumers, space situational awareness providers, word of mouth…
  - Server e.g. public/private, physical location,...
  - Other factors e.g. commercial, political, technical, temporal…

Find out more

- http://utl.space
  - Sign up as alpha tester/collaborator
  - Download paper
- Current proof of concepts in development
  - CubeSat launch opportunities
  - CelesTrak integration
  - NAIF SPICE kernels
  - (NB this is all v0.1)



- Support science, education & commerce equally
- What do you want/need from such a system?

 Graphics courtesy: JA / PocketSpacecraft.com; Josh Spradling; NASA/JPL-Caltech

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Questions?

PocketSpacecraft.com

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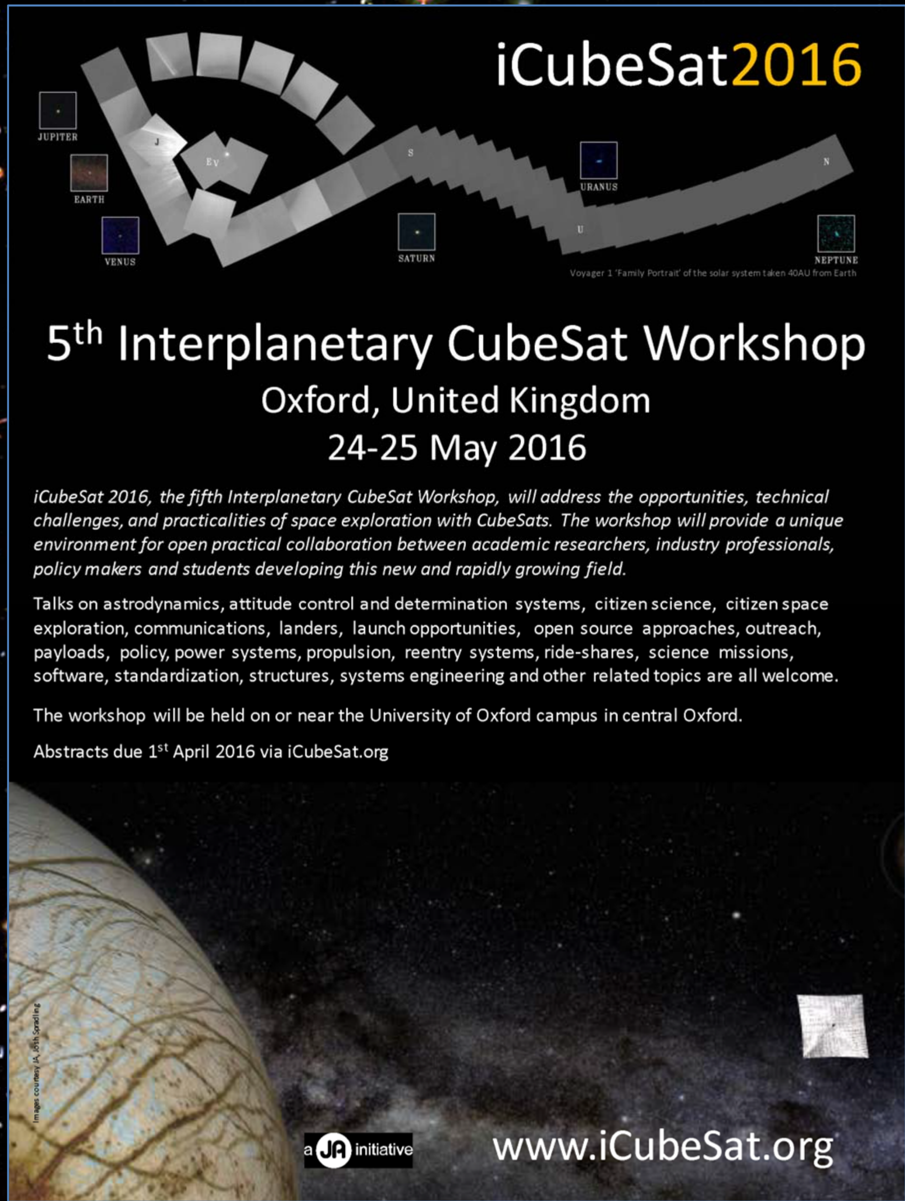
"It's hard to imagine [SpoCs and TF-SLRs] will be capable enough, but that's exactly what people said about CubeSats"

Therese Moretto Jorgensen, Program Director, National Science Foundation
*Nature **508**, 300-301 (17 April 2014)*



Graphics: B.Bishop, JA / iCubeSat.org, NASA, ESA, H. Teplitz and M. Rafelski (IPAC/Caltech), A. Koekemoer (STScI), R. Windhorst (Arizona State University), and Z. Levay (STScI)