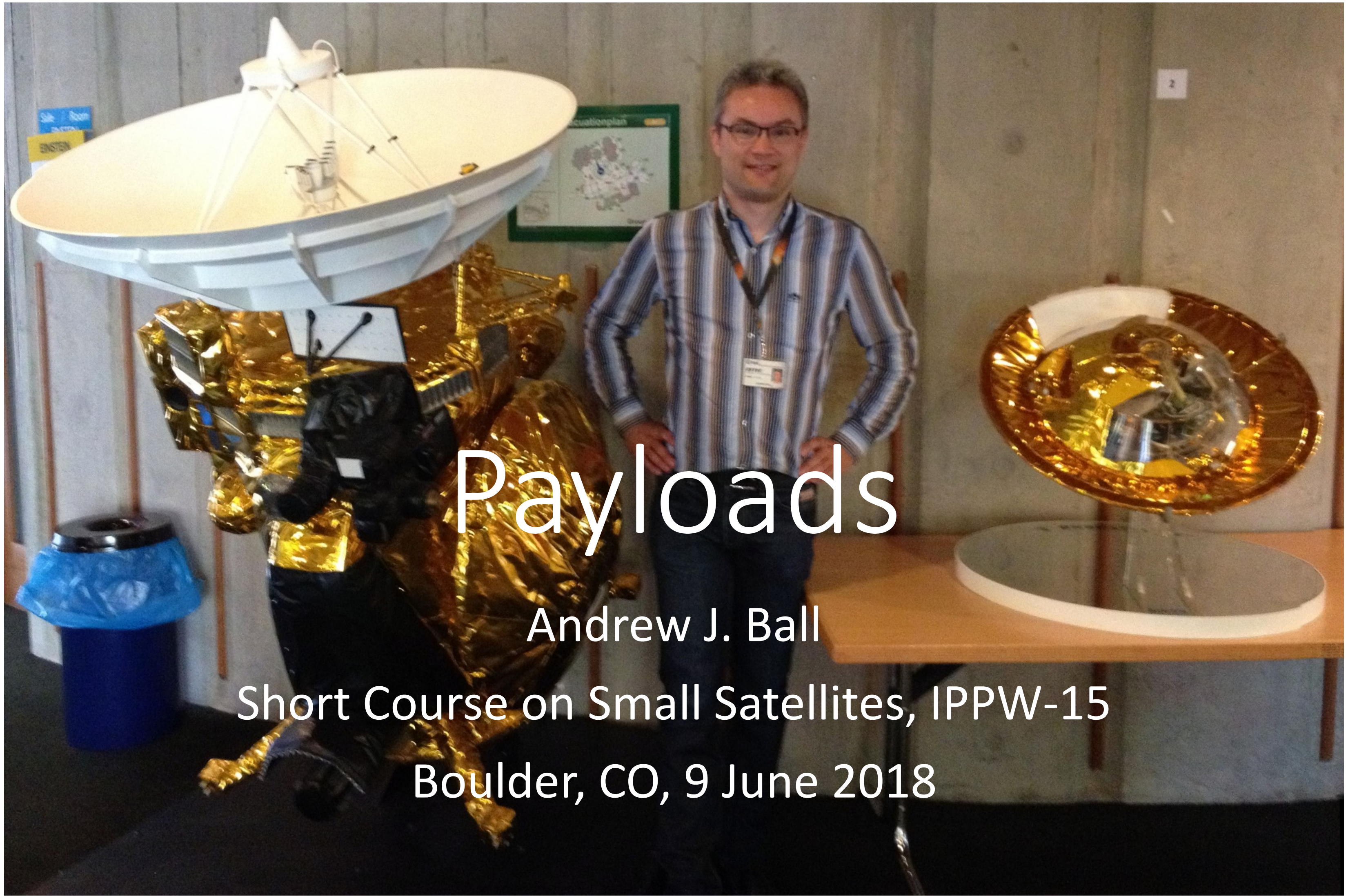


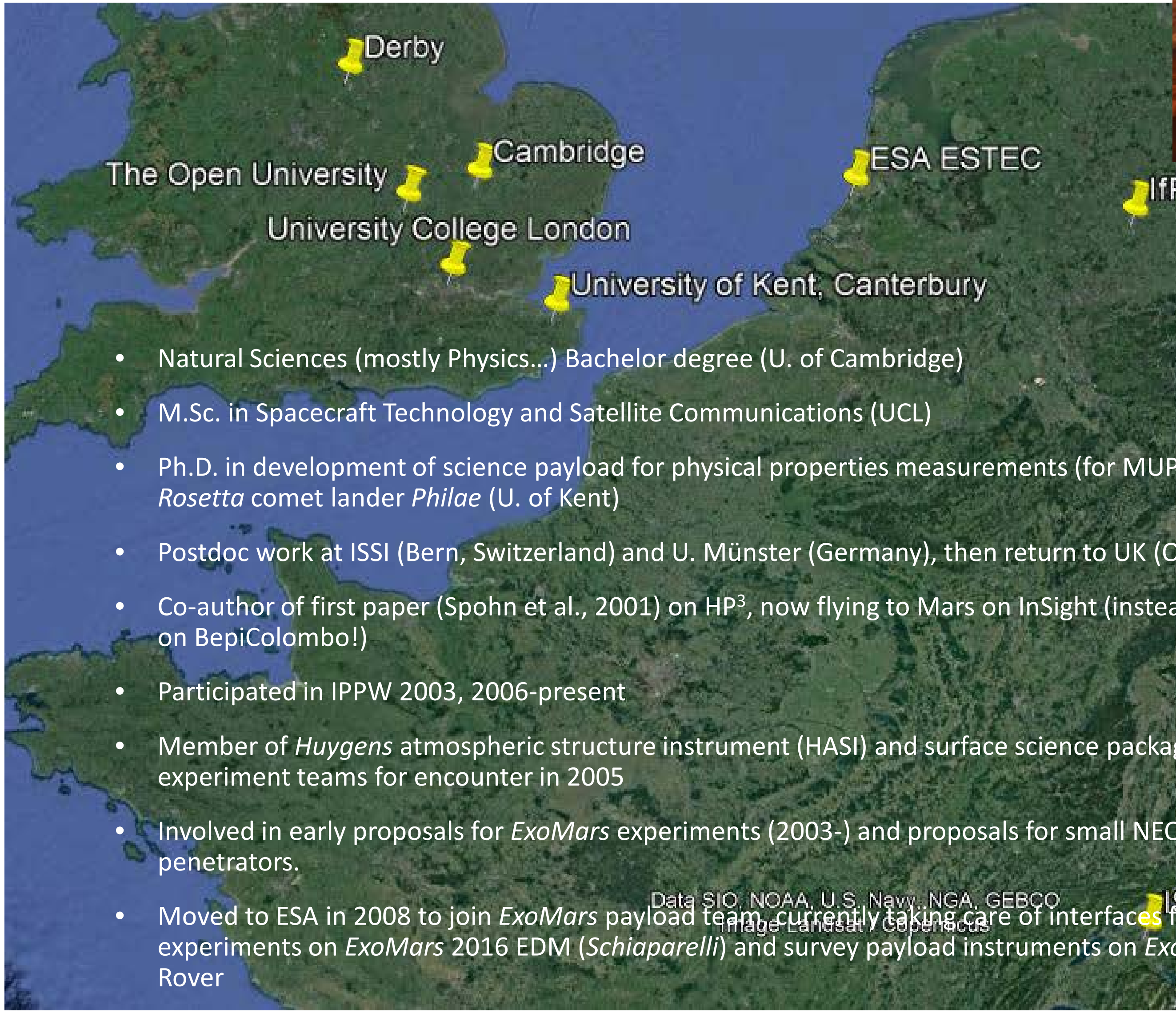
Payloads

Andrew J. Ball

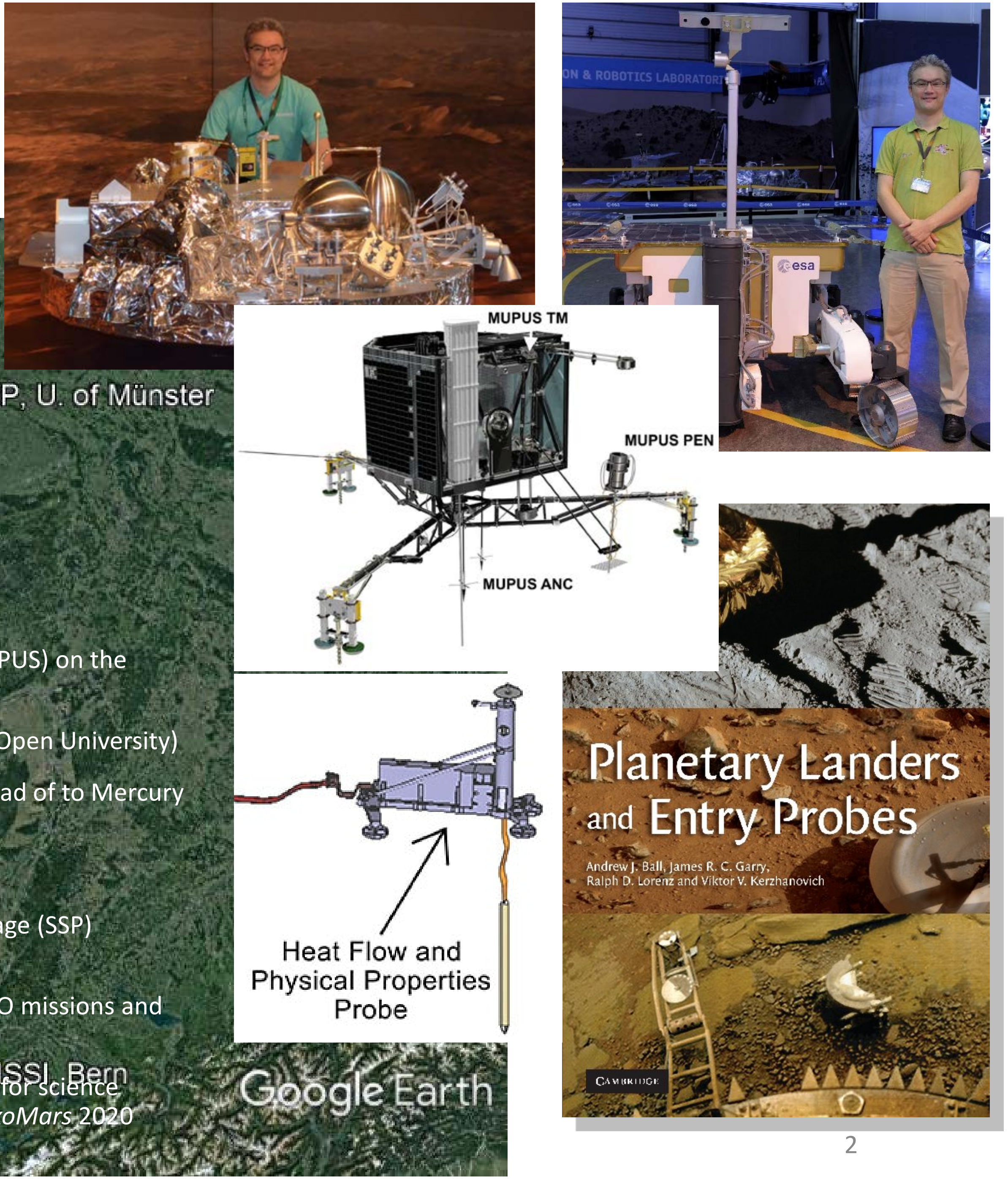
Short Course on Small Satellites, IPPW-15

Boulder, CO, 9 June 2018

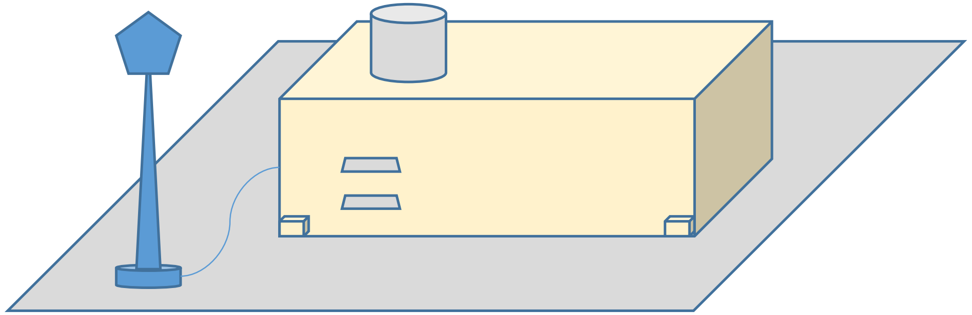
Outline Biography



- Natural Sciences (mostly Physics…) Bachelor degree (U. of Cambridge)
- M.Sc. in Spacecraft Technology and Satellite Communications (UCL)
- Ph.D. in development of science payload for physical properties measurements (for MUPUS) on the *Rosetta* comet lander *Philae* (U. of Kent)
- Postdoc work at ISSI (Bern, Switzerland) and U. Münster (Germany), then return to UK (Open University)
- Co-author of first paper (Spohn et al., 2001) on HP^3, now flying to Mars on InSight (instead of to Mercury on BepiColombo!)
- Participated in IPPW 2003, 2006-present
- Member of *Huygens* atmospheric structure instrument (HASI) and surface science package (SSP) experiment teams for encounter in 2005
- Involved in early proposals for *ExoMars* experiments (2003-) and proposals for small NEO missions and penetrators.
- Moved to ESA in 2008 to join *ExoMars* payload team, currently taking care of interfaces for science experiments on *ExoMars* 2016 EDM (*Schiaparelli*) and survey payload instruments on *ExoMars* 2020 Rover



The ‘usual’ kind of payload



- Enclosed instrument units mounted via base to spacecraft platform structure or deployment mechanism, connected with power and data harness.
- Either highly bespoke (to deliver unique science) and/or reflecting previous heritage (to carry TRL).
- Limited scope for system-level optimisation of payload (resource / performance trades) following initial selection and accommodation (volume, mass, power, data).
- Sized by aperture/baseline or other driving dimension for the measurement, and assembly of electronics involving discrete components
- May rely on platform for access to sample (e.g. robotic arm, drill, crushing and distribution)
- Often requiring support from the platform’s on-board software, e.g. data compression, sub-framing.
- Emphasis on high reliability & low risk commensurate with the high cost of access.
- Likely only one FM built (‘repair kit’ approach for FS)

‘SmallSat’ approaches for payload on conventional lunar & planetary missions

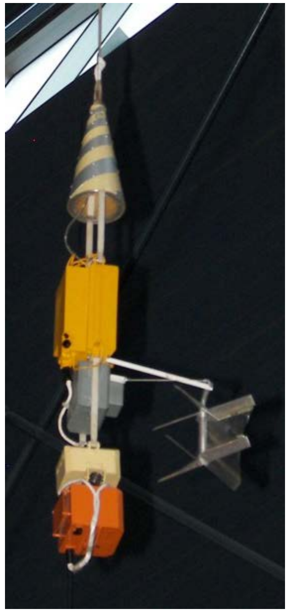
- Smallest payload instrumentation (maybe suited to interplanetary SmallSats?):
  - OTS sensors monitoring a single parameter (T, P, acceleration, photometry, radiometry, radiation dose,…) with analogue output monitored by common electronics
    - Often the mounting hardware and harness are more massive than the sensor itself!
    - Some modern sensors (e.g. MEMS) produce digital output directly
  - High heritage instruments (not needing large aperture) that have achieved miniaturisation over generations (e.g. magnetometers, radiation detectors)
  - Miniaturised devices with built-in digital output (e.g. small cameras)

‘SmallSats’ (<70kg) managed as PI-led ‘instruments’ on a conventional mission

- Particles & Fields Subsatellite on Apollo 15,16 (35.6 kg)
- VeGa AZ balloons on VeGa 1,2 (6.9kg gondola)
- PROP-F on Phobos 2 (50kg)
- DS-2 on MPL (3.6kg)
- Beagle 2 on Mars Express (69kg)
  - 9kg payload: Gas Analysis Package + 5 other instruments
- Philae on Rosetta (98kg)
  - 26.7 kg payload: 9 instruments + sampling drill
- Moon Impact Probe (MIP) on Chandrayaan-1 (29kg, 375×375×470mm^3)
  - Video imaging system, Mass spectrometer, radar altimeter
- MINERVA (-2-1A,1B,2) on Hayabusa (2) (0.591kg, ~1 kg)
- MASCOT on Hayabusa 2 (10kg)
- MarCO on InSight (13.5kg each)
- SLS EM-1 secondary payloads

- Many rely on parent / relay spacecraft for data return.

Smithsonian Inst.



IKI

ISRO

Challenges for planetary missions vs. LEO

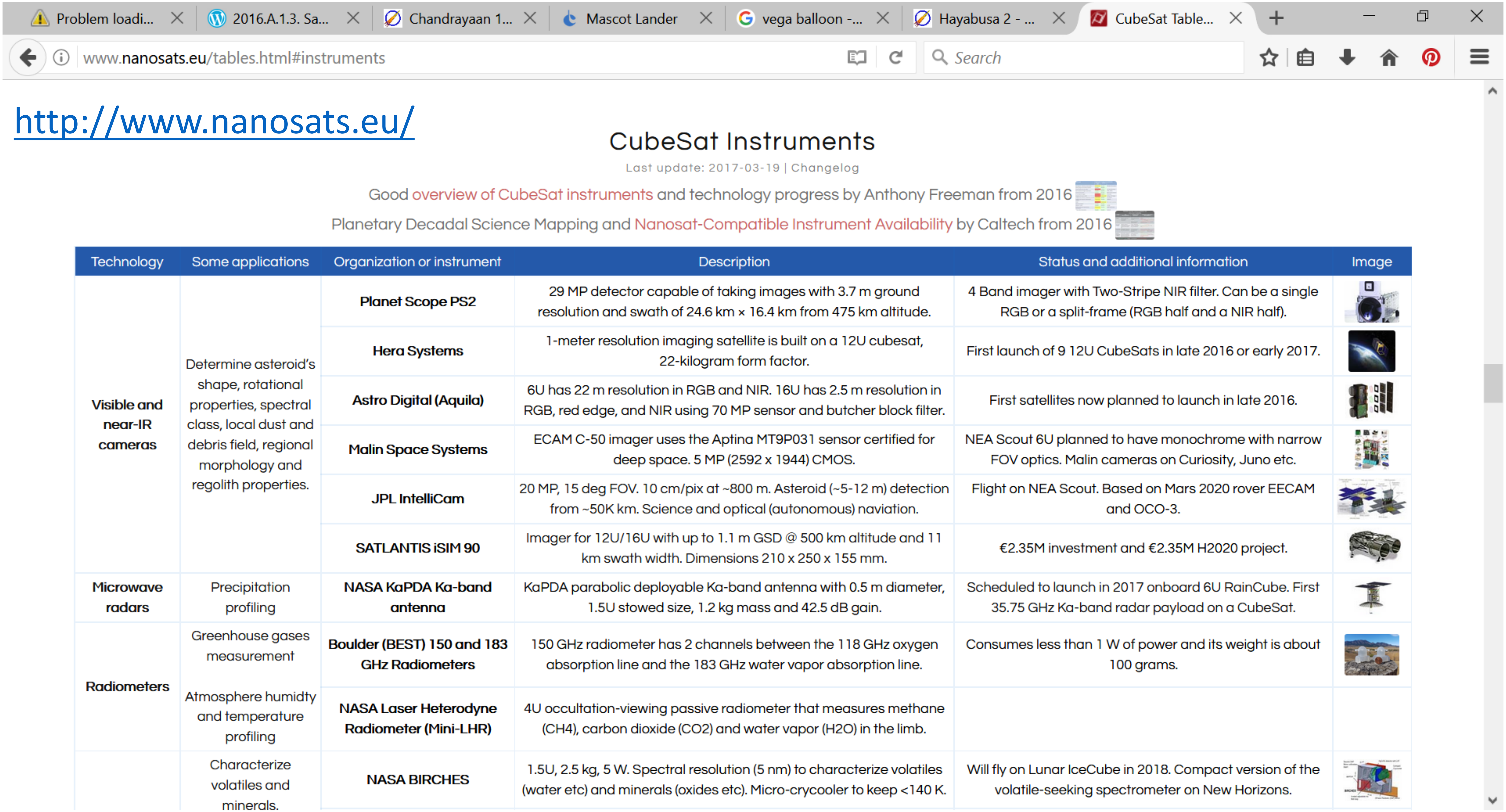
- Delivery (shared launch, upper stage, cruise with parent s/c?)
- Higher radiation dose → constraint on component selection and/or mitigation of effects
- Communication at great distances:
  - Data rate bottleneck (unless relay available)
  - Significant one-way light time
- Interplanetary navigation (no GNSS)
  - Precise targeting
- Precise pointing
- Ground Segment infrastructure and operational complexity
- Thermal environment vs. heliocentric distance – what's optimal at 1 AU probably isn't at <>1 AU
- Planetary Protection (depending on destination)
- Risk management approach

SmallSat payloads

- More highly integrated into the platform (mechanically, thermally, EMC), needing a high level of co-engineering early in development.
- Achieving the miniaturisation possible for consumer electronics is still a challenge.
- Resource constrained in volume (more so than mass), power.
- Unless OTS, need to reach qualification level to justify conventional (<20%) resource maturity margins during development.
- Often include some element of technological demonstration or research rather than purely scientific.

What makes the data return compelling?

- The data should be relevant to a well defined science question
- ×10 more data than before
- ×10 improvement in measurement:
  - temporal resolution
  - spatial resolution / proximity to target
  - sensitivity
- Adding a new dimension to an existing dataset, e.g.:
  - Simultaneous at multiple locations;
  - Extended timebase
- Exploring a new environment
- Making a new kind of measurement



http://www.nanosats.eu/

CubeSat Instruments

Last update: 2017-03-19 | Changelog

Good overview of CubeSat instruments and technology progress by Anthony Freeman from 2016

Planetary Decadal Science Mapping and Nanosat-Compatible Instrument Availability by Caltech from 2016

Technology	Some applications	Organization or instrument	Description	Status and additional information	Image
Visible and near-IR cameras	Determine asteroid's shape, rotational properties, spectral class, local dust and debris field, regional morphology and regolith properties.	**Planet Scope PS2**	29 MP detector capable of taking images with 3.7 m ground resolution and swath of 24.6 km × 16.4 km from 475 km altitude.	4 Band imager with Two-Stripe NIR filter. Can be a single RGB or a split-frame (RGB half and a NIR half).	
		Hera Systems	1-meter resolution imaging satellite is built on a 12U cubesat, 22-kilogram form factor.	First launch of 9 12U CubeSats in late 2016 or early 2017.	
		Astro Digital (Aquila)	6U has 22 m resolution in RGB and NIR. 16U has 2.5 m resolution in RGB, red edge, and NIR using 70 MP sensor and butcher block filter.	First satellites now planned to launch in late 2016.	
		Malin Space Systems	ECAM C-50 imager uses the Aptina MT9P031 sensor certified for deep space. 5 MP (2592 x 1944) CMOS.	NEA Scout 6U planned to have monochrome with narrow FOV optics. Malin cameras on Curiosity, Juno etc.	
		JPL IntelliCam	20 MP, 15 deg FOV. 10 cm/pix at ~800 m. Asteroid (~5-12 m) detection from ~50K km. Science and optical (autonomous) naviation.	Flight on NEA Scout. Based on Mars 2020 rover EECAM and OCO-3.	
		SATLANTIS iSIM 90	Imager for 12U/16U with up to 1.1 m GSD @ 500 km altitude and 11 km swath width. Dimensions 210 x 250 x 155 mm.	€2.35M investment and €2.35M H2020 project.	
Microwave radars	Precipitation profiling	**NASA KaPDA Ka-band antenna**	KaPDA parabolic deployable Ka-band antenna with 0.5 m diameter, 1.5U stowed size, 1.2 kg mass and 42.5 dB gain.	Scheduled to launch in 2017 onboard 6U RainCube. First 35.75 GHz Ka-band radar payload on a CubeSat.	
Radiometers	Greenhouse gases measurement	**Boulder (BEST) 150 and 183 GHz Radiometers**	150 GHz radiometer has 2 channels between the 118 GHz oxygen absorption line and the 183 GHz water vapor absorption line.	Consumes less than 1 W of power and its weight is about 100 grams.	
	Atmosphere humidty and temperature profiling	**NASA Laser Heterodyne Radiometer (Mini-LHR)**	4U occultation-viewing passive radiometer that measures methane (CH4), carbon dioxide (CO2) and water vapor (H2O) in the limb.		
	Characterize volatiles and minerals.	**NASA BIRCHES**	1.5U, 2.5 kg, 5 W. Spectral resolution (5 nm) to characterize volatiles (water etc) and minerals (oxides etc). Micro-crycooler to keep <140 K.	Will fly on Lunar IceCube in 2018. Compact version of the volatile-seeking spectrometer on New Horizons.	

Cubesat instruments developed / flown

- Visible / NIR cameras
- Microwave radars
- Radiometers
- IR imagers
- Hyperspectral imagers / spectrometers
- Neutron spectrometers
- X-Ray spectrometers
- Mass spectrometers
- Gamma ray spectrometers

Payload developments cont’d

- Radar for rainfall measurements
- NIR laser spectrometer for lunar shadows
- ASPECT Multi-spectral imager Vis/NIR/SWIR (for M-ARGO, from VTT) 950g (TRL 6)
- VISION multi-spectral imager with Fabry-Perot Interferometer (VTT)
- DLEM 20 Laser Altimeter (for M-ARGO, from Jenoptik) (COTS, not yet space qualified)
- HyperScout Hyperspectral Imager (COSINE)

- International Workshop on Instrumentation for Planetary Missions (IPM)
  - https://ipm2018.org/
- Interplanetary CubeSat Workshop: http://icubesat.org/
  - E.g. Freeman, A., Deep Space CubeSats and nanosats at JPL. 2017.A.1.1.
- + IPPW!