



En masse, on demand, on orbit: Interplanetary Pocket Spacecraft licensing and regulatory challenges

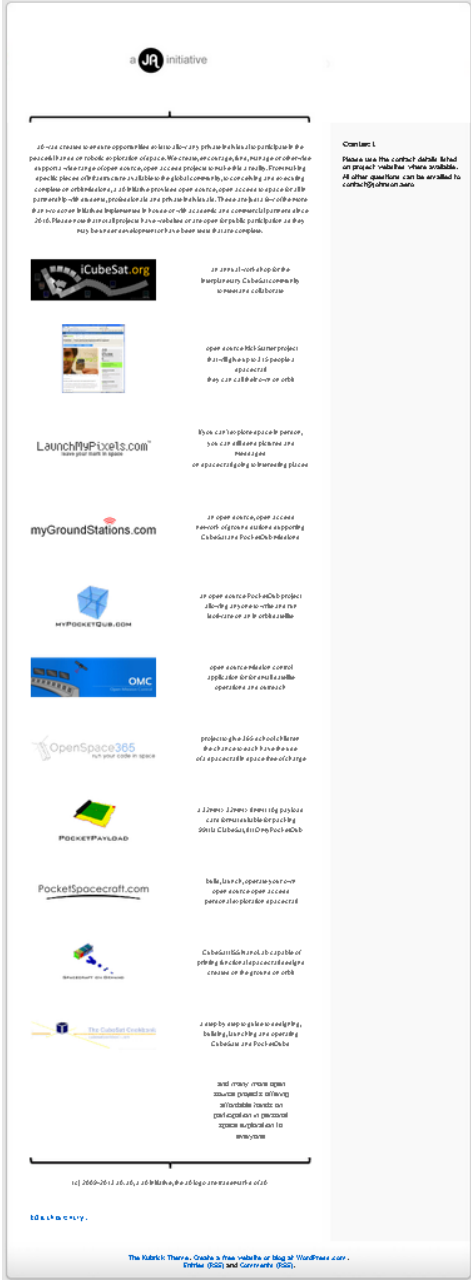
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ITU Symposium and Workshop on Small Satellite
Regulation and Communication Systems

Prague, Czech Republic
3rd March 2015

- Founded 2010
- Ops in China, IoM, UK & USA
- Creates, encourages, funds, manages or otherwise supports more than two dozen open source open access space exploration infrastructure projects
- Seven flight projects
- Collaborate with academia, enthusiasts, government, industry and non-profits
- >300 volunteers, >30 countries



goal

send spacecraft to orbit and/or land on
the surface of every body in the solar
system over the next ~~25~~ 21.1 years

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$>10^1 > \sim 5000\text{km}$ radius

$>10^2 > \sim 100$ km radius

$>10^4 > \sim 20$ km radius

$>10^6 > \sim 0.5\text{km}$ radius in asteroid belt alone

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

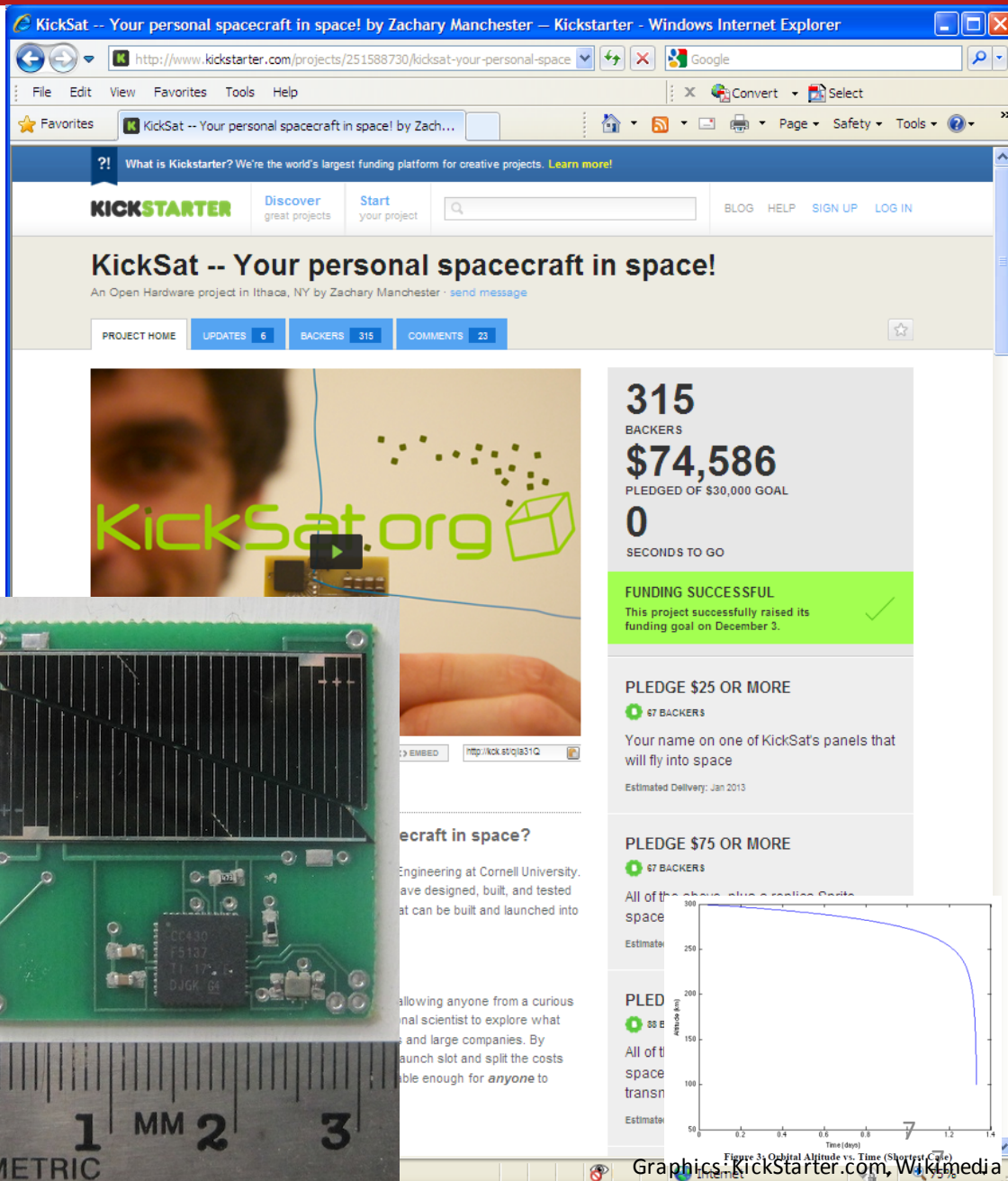


- science goals
 - be useful, be responsible
 - work within existing frameworks and systems where possible
 - enable many of the >95% of missions not down selected
- consumer goals
 - support 10^6 participating explorers
 - video game size quantum of exploration
 - instant gratification and mass customisation
 - appeal to everyone from collectors to citizen space engineers
- easy to use for everyone
 - point and click/touch design, collaboration and autonomous operation
- sustainable
 - fun, interactive, immersive for years or decades
 - spread risk, be comfortable not knowing where it may lead
 - legal, honest, decent and truthful
 - make affordable - crowd source, fractionate and automate everything
- symbiotic and respectful
 - scientists need explorers, explorers need scientists
 - everyone needs engineers
 - all skill levels can contribute something – apps/money both ways

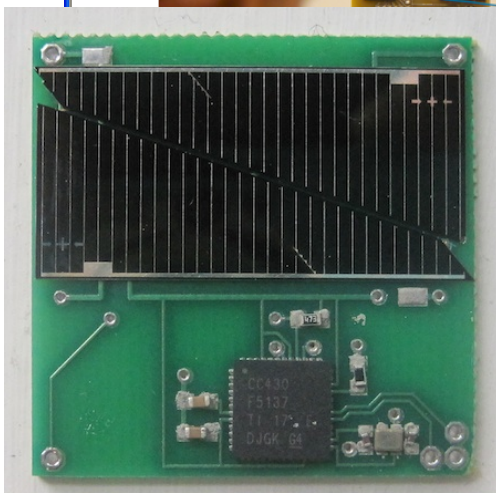
- Crowd sourced funding via 315 KickStarter backers

- 67 @ \$25
- 67 @ \$75
- 88 @ \$300 ←
- 26 @ \$1000 ←
- 0 @ \$5000
- 1 @ \$10000

- NASA ELaNa 5 launch April 2014
- Student labour
- Reuse existing open source systems
- Very inexpensive
- Very short lived



The screenshot shows the KickSat Kickstarter page in a Windows Internet Explorer browser. The page title is "KickSat -- Your personal spacecraft in space! by Zachary Manchester". The main statistics are: 315 BACKERS, \$74,586 PLEDGED OF \$30,000 GOAL, and 0 SECONDS TO GO. A green banner indicates "FUNDING SUCCESSFUL". Below this, there are pledge options: "PLEDGE \$25 OR MORE" (67 BACKERS) and "PLEDGE \$75 OR MORE" (67 BACKERS). A graph titled "Figure 3: Orbital Altitude vs. Time (Shortest Case)" shows orbital altitude in km over time in days. The graph shows a curve that starts at approximately 300 km and drops to about 100 km after 1.2 days. A ruler is placed over the bottom part of the page for scale, showing centimeters and millimeters.





Pocket Spacecraft

TF-SLR Scout prototype v0.4

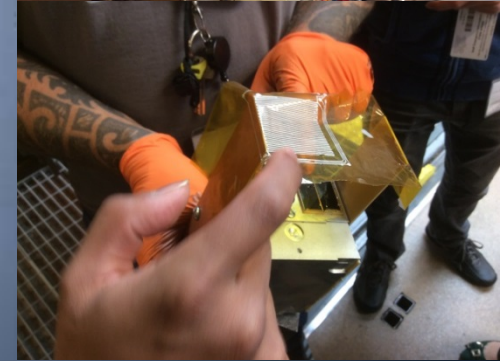
Solar cell
CIGS or Spectrolab TASC

SoC lapped to <math><50\mu\text{m}</math>
TI CC430F5137IRGZ die

Printed passives (RCL)
e.g. Cabot CCI-300 ink

Antenna bustle/actuator
NiTi memory metal

Custom graphics
Laser marked



Resistance:

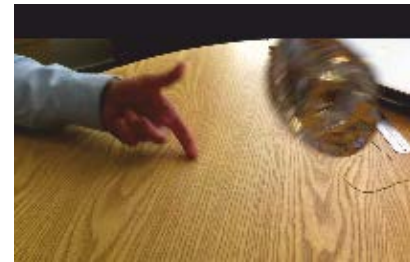
- ‘They will never work’
- ‘You can’t do anything useful’
- ‘They are just for students’
- ‘You can’t do real science’
- ‘You can’t fit real instruments’
- ‘You can’t do useful imaging with such small apertures’
- ‘They don’t have enough power’
- ‘They’re unreliable’



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“It’s hard to imagine [ChipSats 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)*

PocketSpacecraft.com

LOFAR Configuration

Observation: PS86X1/O2
 Start: T+93:00:00.00
 Duration: 00:10:12.00
 Channel(s): 235
 Centre: 145.8984375 MHz
 Mode: Complex Voltage
 Sub-mode: Fly's eye
 Reference: 20141019/7.1.7.3.19

- Antenna
- Network link
- Data centre

SE607HBA - Onsala
 3370272.092, 712125.596, 5349990.854
 57.39875746, 11.93087904, 41.358
 Delay compensation: OFF

CS002LBA - Superterp
 3826577.462, 461022.624, 5064952.526
 52.91511897, 6.86983284, 49.350
 Delay compensation: ON

DE604HBA - Potsdam-Bornim
 3796380.254, 877613.809, 5032712.272
 52.43785922, 13.01648194, 75.843
 Delay compensation: OFF

PS-DC44A - Bristol

DE605HBA - Jülich
 4005681.407, 450968.304, 4926457.940
 52.91511897, 6.86983284, 49.350
 Delay compensation: OFF

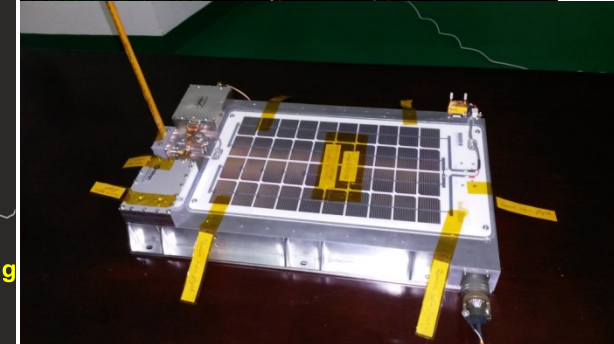
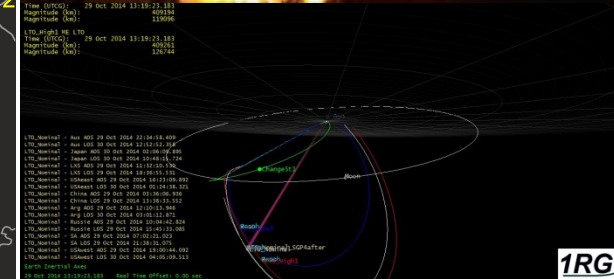
UK608HBA - Chilbolton
 4008462.280, -100376.948, 4943716.600
 51.14354266, -1.43445876, 177.05
 Delay compensation: OFF

DE601HBA - Effelsberg
 4034101.901, 487012.401, 4900230.210
 50.52260408, 6.88365595, 365.993
 Delay compensation: OFF

DE603HBA - Tautenburg
 3940296.126, 816722.532, 4932394.152
 50.97939457, 11.71012829, 376.426
 Delay compensation: OFF

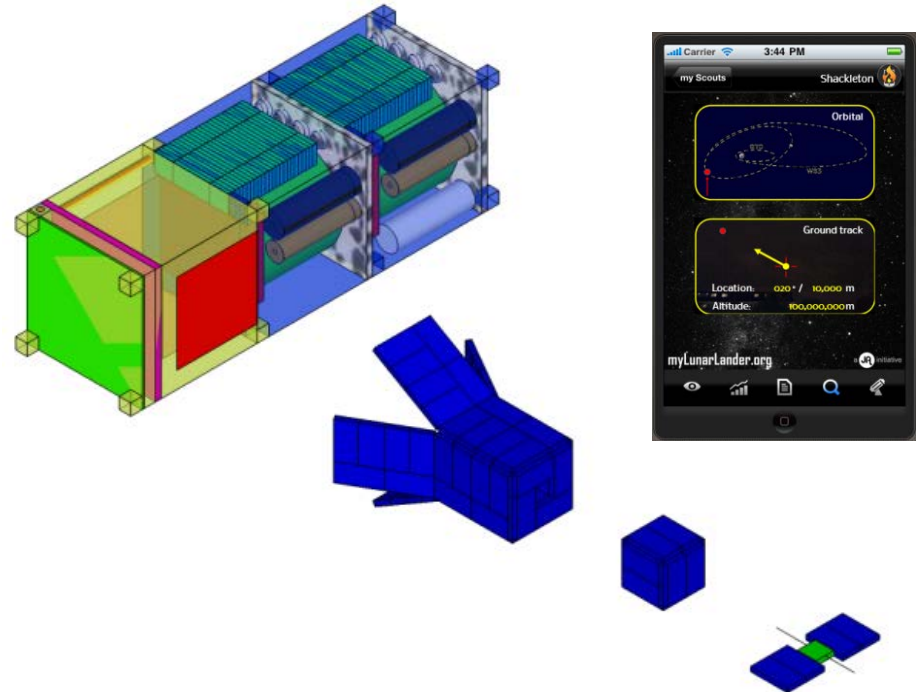
FR606HBA - Nançay
 4324017.054, 165545.160, 4670271.072
 47.37552429, 2.19250034, 182.091
 Delay compensation: OFF

DE602HBA - Unterweilenbach/Garching
 4152568.416, 828788.802, 4754361.926
 50.97934787, 11.71126745, 378.840
 Delay compensation: OFF

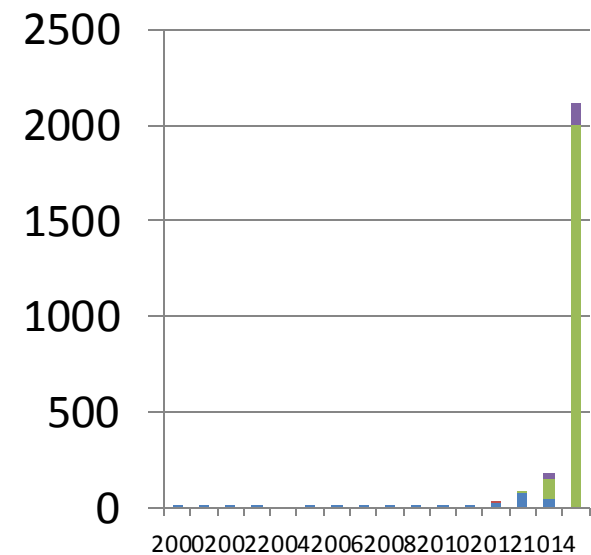


Graphics courtesy: ASTRON, JA, LuxSpace, STFC

- Purpose may not be known at launch
- Spacecraft can be launched speculatively
- Potential clashes with existing frameworks (e.g. amateur vs scientific vs commercial)
- Design to deployment can be minutes



- 3881 payloads catalogued on orbit by U.S. Space Surveillance Network
- KickSat proof of concept low earth orbit mission launched 2014: >100 spacecraft
- Pocket Spacecraft interplanetary proof of concept mission 2015/16: >1000 spacecraft
- Potentially >1 million TF-SLRs to come over next two decades
- Number of spacecraft printed per mothership may be unknown at launch and could vary by orders of magnitude



- Current regulatory fees for spacecraft that can profitably be manufactured, launched and operated for less than \$99 each can be disproportionate (>\$10,000 per spacecraft)
- License application fee (no guarantee of success):
UK: £6,500- £13,000 per mission (£0 in China, Spain, USA, etc.)
- €60 million third party insurance cover per mission:
UK: €600,000 per year indefinitely (£0 in China, Spain, USA, etc.)



- Pocket Spacecraft interplanetary proof of concept mission has spacecraft backed by participants from >40 countries
- Spacecraft could be designed, manufactured, launched, deployed, managed or operated by different children and adults with multiple citizenships with ownership changing at every step and over time



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* if your question is about an open source project:
- no restrictions

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iCubeSat2015


4th Interplanetary CubeSat Workshop
South Kensington, London, United Kingdom
26-27 May 2015

iCubeSat 2015, the fourth Interplanetary CubeSat Workshop, will address the opportunities, technical challenges, and practicalities of space exploration with CubeSats. The workshop will provide a unique environment for open practical collaboration between academic researchers, industry professionals, policy makers and students developing this new and rapidly growing field.

Talks on astrodynamics, attitude control and determination systems, citizen science, citizen space exploration, communications, landers, launch opportunities, open source approaches, outreach, payloads, policy, power systems, propulsion, reentry systems, ride-shares, science missions, software, standardization, structures, systems engineering and other related topics are all welcome.

The workshop will be held on or near the Imperial College London campus in South Kensington.

Abstracts due 1st April 2015 via [iCubeSat.org](http://www.iCubeSat.org)

 initiative

www.iCubeSat.org