PIXE 2019: PocketSpacecraft
Integrated eXploration Environment

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8th Interplanetary CubeSat Workshop
iCubeSat 2019

Milan, Italy
28th May 2019
goal
send spacecraft to flyby, orbit or land on the surface of every body in the solar system over the next 25 17 years
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>10 > ~ 5000km radius
>100 > ~ 100 km radius
>10,000 > ~ 20 km radius
>1,000,000 > ~ 0.5km radius in main 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
Crowd sourced funding via 315 Kickstarter backers
- 67 @ $25
- 67 @ $75
- 88 @ $300
- 26 @ $1000
- 0 @ $5000
- 1 @ $10000

104+1 s/c -> ELaNa 5 launch April 2014
Pocket Spacecraft
TF-SLR Scout prototype v0.4

- Solar cell
- CIGS or Spectrolab TASC
- SoC lapped to <50 µm
- TI CC430F5137IRGZ die
- Printed passives (RCL)
  e.g. Cabot CCl-300 ink
- Antenna bustle/actuator
- NiTi memory metal
- Custom graphics
- Laser marked

Graphics courtesy: JA / PocketSpacecraft.com
• Create a system to permit close to instant creation of new missions based around minimum useful quantum of exploration
  Represent > Fractionate > Synthesize > Operate

• Demonstrate that missions objectives can be captured in a computer language / data format

• Demonstrate that the format can be used to automatically fractionate monolithic mission requirements into quanta of exploration

• Demonstrate that the quanta of exploration can be used to manufacture / synthesize swarms of small spacecraft to perform the mission

• Demonstrate that a viable system can be automatically operated in space
Design/refine → Print in lab → Collect data → Analyse/Report

- **D1.** Traceability matrix driven
- **D2.** Automatic systems design
- **D3.** Automatic mission and trajectory design
- **P1.** Laboratory spacecraft printer
- **P2.** Thin-film spacecraft bus
- **P3.** Thin-film micrometeoroid sensor
- **P4.** Virtualised sensing/relay orbiters
- **C1.** Deep space weather probes
- **C2.** Virtualised sensing/relay orbiters
- **C3.** Mars weather station lander

**10^5+ bodies => 10^5+ thin-film spacecraft/landers/rovers @ <1g each = ~100kg total**

New missions in hours instead of decades

Graphics: B. Bishop, JA/PocketSpacecraft.com, J. Spradling, kokogiak.com
PIXE 2019 Workflow

Design/refine ➔ Print in space ➔ Collect data ➔ Analyse/Report

D1. Traceability matrix driven

D2. Automatic systems design

D3. Automatic mission and trajectory design

E A R T H S P A C E

C1. Deep space weather probes
C2. Virtualised sensing/relay orbiters
C3. Mars weather station lander

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Exploration challenges = Software challenges

— Represent (XML based) **Done**
  • Science Traceability Matrix Language (TML) = requirements
  • Uniform Trajectory Language (UTL) assists discovery
  • Spacecraft Markup Language (SML) captures systems

— Fractionate **Done**
  • TML inputs used to break mission requirements down into intermediate ‘minimal measurements’ (MMX)
  • UTL and TML inputs used to search for candidate ‘measurement opportunities’ (MOX)

— Synthesize **Partial**
  • Libraries of spacecraft subsystems are searched to build MMX compatible ‘minimal viable spacecraft’ (MVS)
  • Spacecraft-on-Demand CPX scheduler searches for optimal solutions to deliver a swarm of MVS to a MOX and return data, merging multiple MVS is appropriate

— Operate **In progress**
  • Synthesizer generates g-code and communications scheduling scripts to send to spacecraft printers and communications
Progress

- Proof of concept end to end toolchain implemented **Done**
- Viable sample mission designs produced **Done**
  - Solar Sail Test Bed / Deep Space Weather Buoy
  - Mars Meteorological Microlander
- Minimum viable spacecraft concept & designs generated **Done**
- Refactored 1U spacecraft printer testing **Partial**
- Spacecraft printer printed spacecraft testing **Partial**
- Support systems sourced and installed **Done**
- Spacecraft licensing (still) in progress **Partial**
Microlander Weather Station

- Very thin (<20 μm) low mass (<100 mg) TF-SLR lander for direct insertion from orbit from CubeSat or as ‘breadcrumbs’ from rover based printer
- Up to 200 mW @ 1.67 AU from solar cells backed by thin film energy storage
- Integrated processing, storage, communications and sensors (humidity, pressure and temperature)
- Can return data to traditional orbiters, deployment device, or each other using custom or CCSDS compatible comms
- Robust, disposable, customisable
- Designed for COSPAR Class IVc planetary protection processes
• CRESST COMET
• Example of synergy and 15 minute design with a <5g bus
• In-orbit demonstration of COMET electrospray thruster (and possible printer material)
• <GBP 10K build-test budget, <GBP 50K to launch and operate

KickSat Sprite bus

+ SUPER-SHARP piezo driver
+ COMET thruster

= CRESST COMET

= CRESST COMET

= CRESST COMET

ROUGHLY TO SCALE
Planetary protection
Acknowledgements

>4000 private individuals in >45 countries

and many others
“It’s hard to imagine [TF-SLRs] will be capable enough, but that’s exactly what people said about CubeSats”

*Therese Moretto Jorgensen, Program Director, National Science Foundation*

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