Lessons Learned from the First Wave of Common-architecture CubeSats

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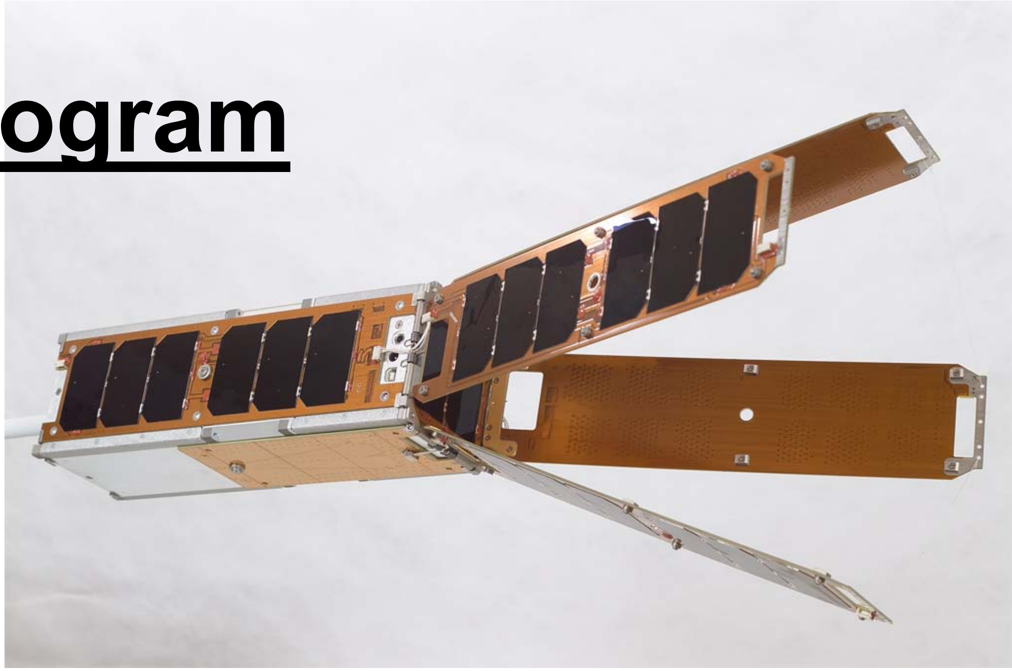
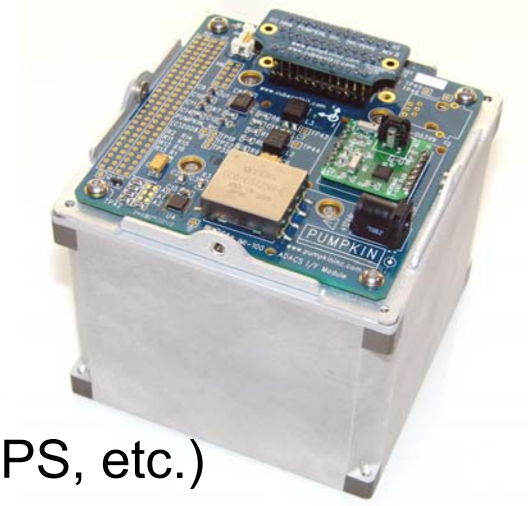
Colony I (C1B) Program

- Overview
  - First FFP contract for two units (XS-25a)
  - Follow-on FFP contract for ten more (XS-25b)
- Timeline:
  - Approached by customer at SmallSat August 2008
  - Under contract by September 2008
  - Kickoff in October 2008
  - Five EMs delivered in January 2009
  - First two units delivered March 2009
  - Option for ten more exercised April 2009
  - Last of twelve units delivered August 2009
  - 13th unit ordered April 2010
  - 13th unit delivered June 2010



Preface

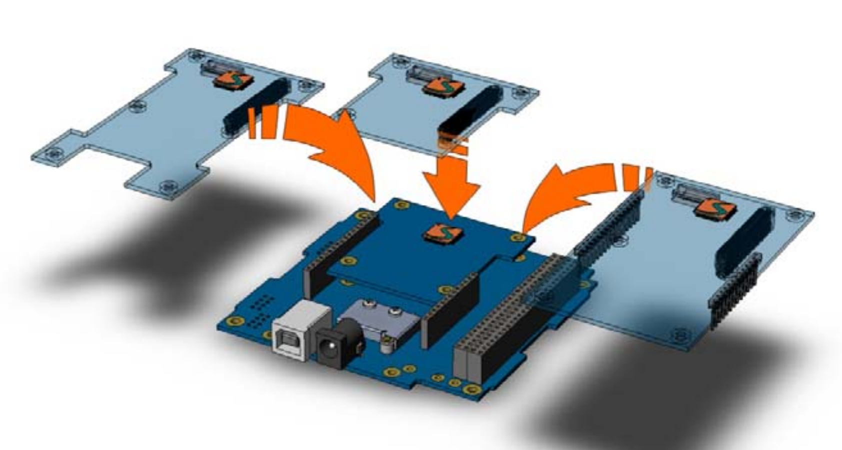


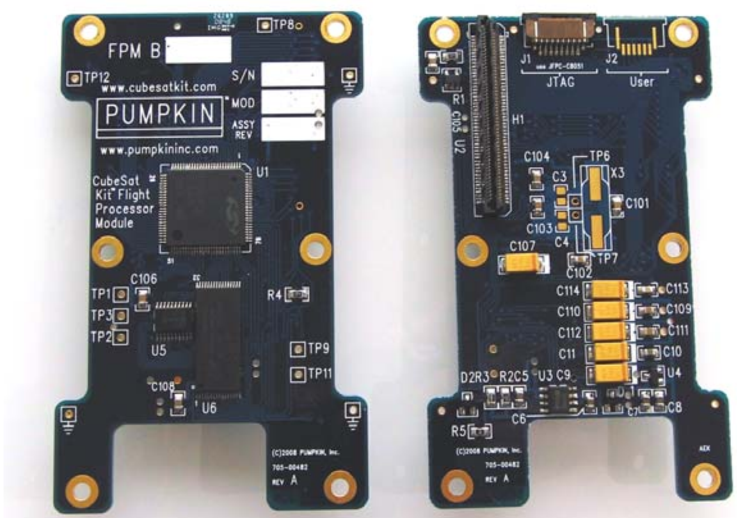
- 4th-gen CubeSat Kit (CSK) structure
  - Developed to accommodate external payloads
  - First external payload: IMI-100 & IMI-200 ADACS
  - Other detail improvements (Separation Switch, MPS, etc.)
- 4th-gen CSK electronics
  - Introduced Motherboard (MB) + Pluggable Processor Module (PPM)
  - Additional features (RTC, VBACKUP, beacon connector)
  - EFFS-THIN SD Card software
- Pumpkin focus on processors supported by Salvo RTOS:

MSP430	8051	ARM7
PIC24	dsPIC33	AVR
TMSC2000	S1C17	PIC32

Lesson 1 – Adapt to Customer

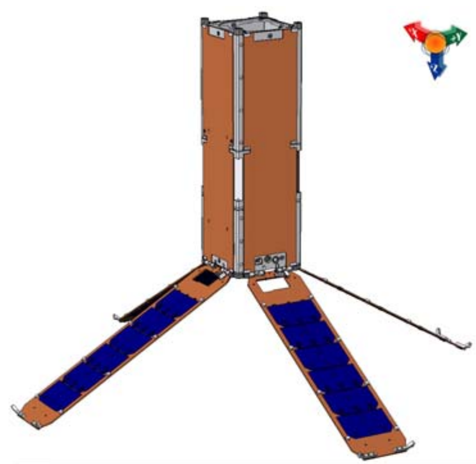
- IEI awarded October 2008 to develop new PPMs
- In Q3 2008 only Pumpkin PPMs were MSP430-based
- Kickoff revealed that customer had well-developed codebase for 8051 – *software is a schedule killer, so*
- Solicited customer input on choice of 8051 (C8051F120), on PPM peripherals and on PPM-to-bus routing





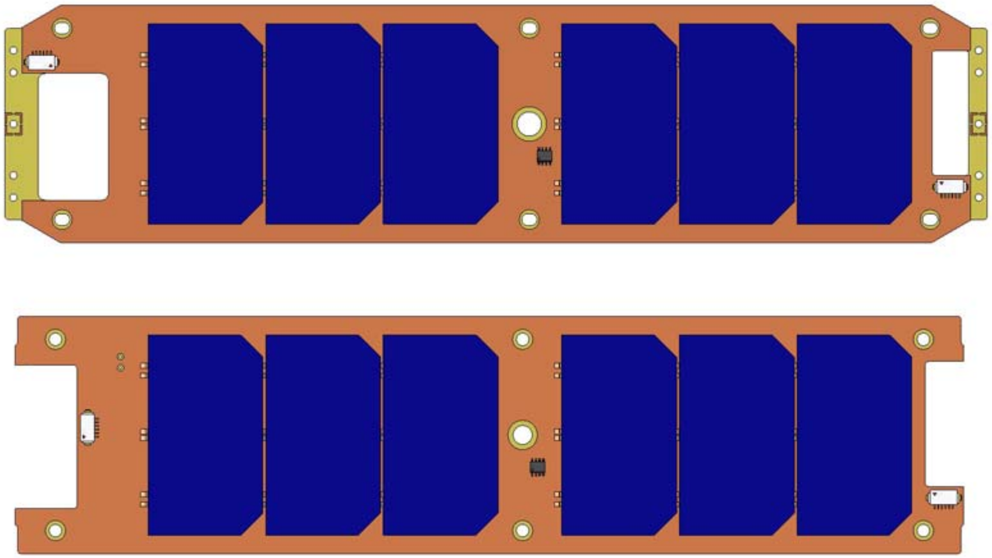
Lesson 2 – Iterate Towards Solution

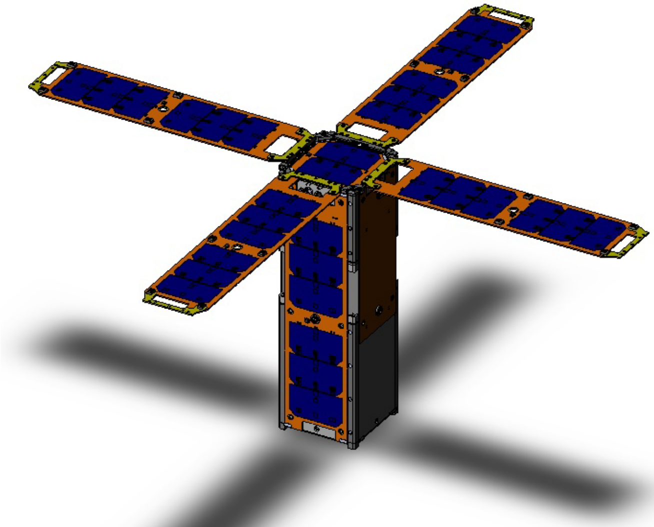
- Must always consider the *entire* system – holistic design has many dimensions and drivers
- C1B spec was relatively open, therefore requirements that affected "free" portions of design were fluid and took time to converge
- Version history becomes an institutional asset
- Simpler is better



Lesson 3 – Benefits of Modularity

- All C1B-unique structural parts interface to standard CSK parts
- Satisfy specific requirements, while designing in as much flexibility as possible
- Example: deployable solar panels on twelfth QbX

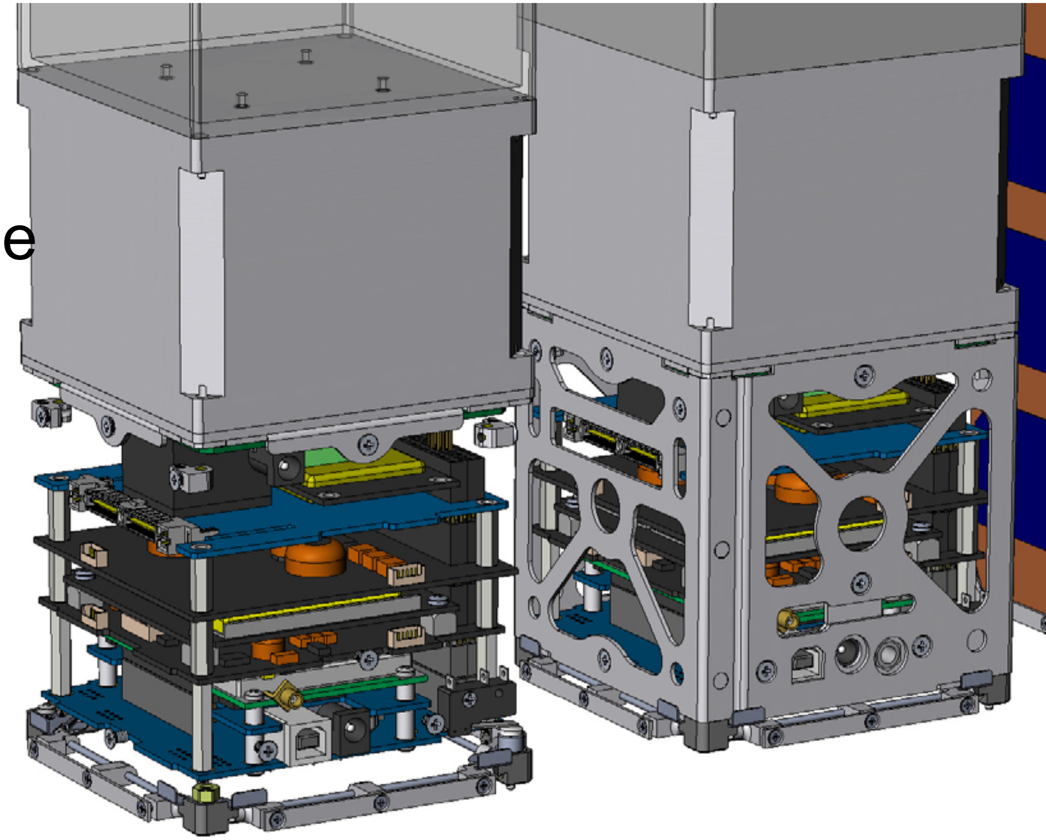




MISC2 / QbX 3U Satellite
90 (Reverse) Deployables

Lesson 4 – CAD Must be Perfect

- *Everything* gets modeled in 3D CAD
- Don't take anything for granted
- Nothing goes into production until CAD is fully vetted … too dangerous to do otherwise
- Permits many "what if" scenarios
- Has additional benefits:
  - Illustrations
  - Mass estimates
  - Models for customer use
  - 3-D printing



Lesson 5 – Money Buys Schedule

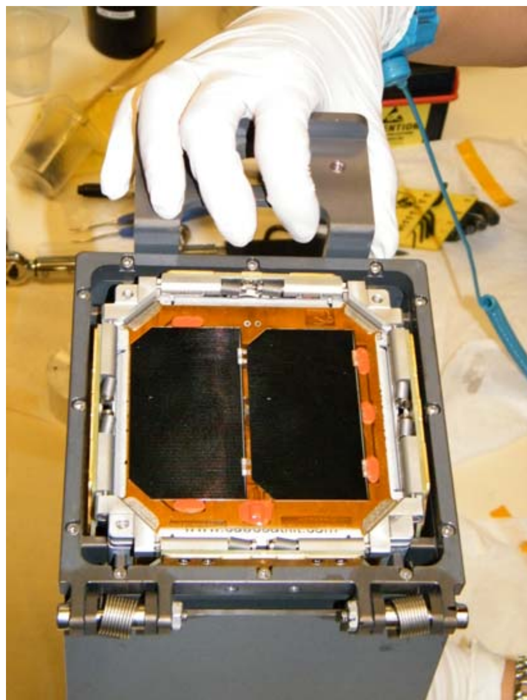
- Nearly everyone prefers to work on a normal schedule
- JIT often makes sense because of the rapid, parallel development of many interrelated components
- Comprehensive CAD-based design guarantees correctness of JIT parts
- For a small program like C1B, JIT really means “at the last possible moment”, and that adds (vendor) expense
- Size of typical vendor production run will affect vendor’s willingness to bump your job to front of production queue
- The ability to do R&D via development contracts (e.g., via SBIRs) is very different from the IRAD possibilities from (profitable) sales

Lesson 6 – Supplier Relationships

- Mistakes can and will happen
- Might be detected during design, integration or testing phases
- Everyone is working towards a common goal
- When problems occur, remain objective & responsive
- Personal touch helps
- Some solutions are expedient, others are longer-term
- Keep customer informed

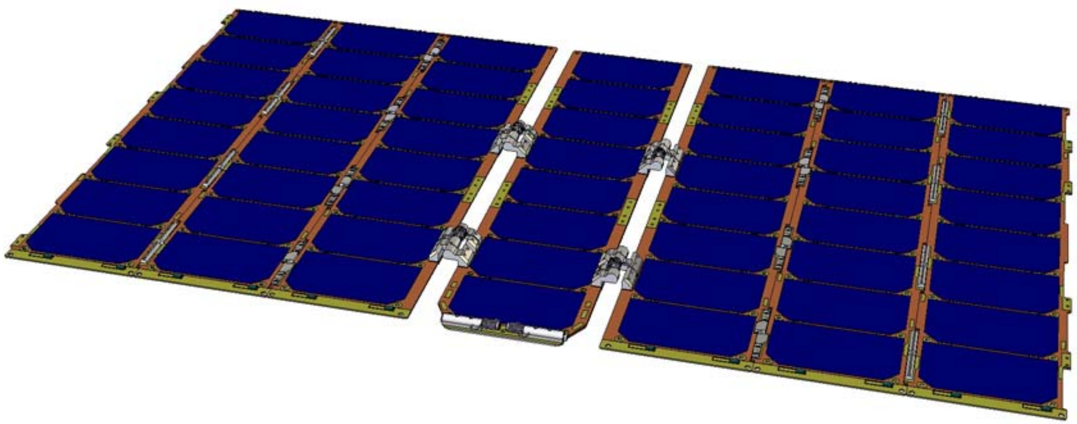
Lesson 7 – Quality Matters

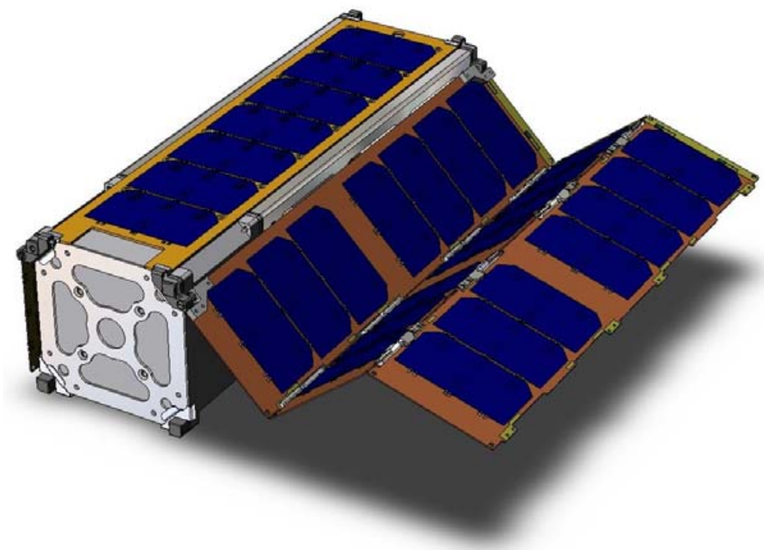
- No changes or mods to any Pumpkin-designed or produced component required over life of C1B program
- Good design is fundamental to quality
- Concurrent builds ease quality assurance



Lesson 8 – Think to the Future

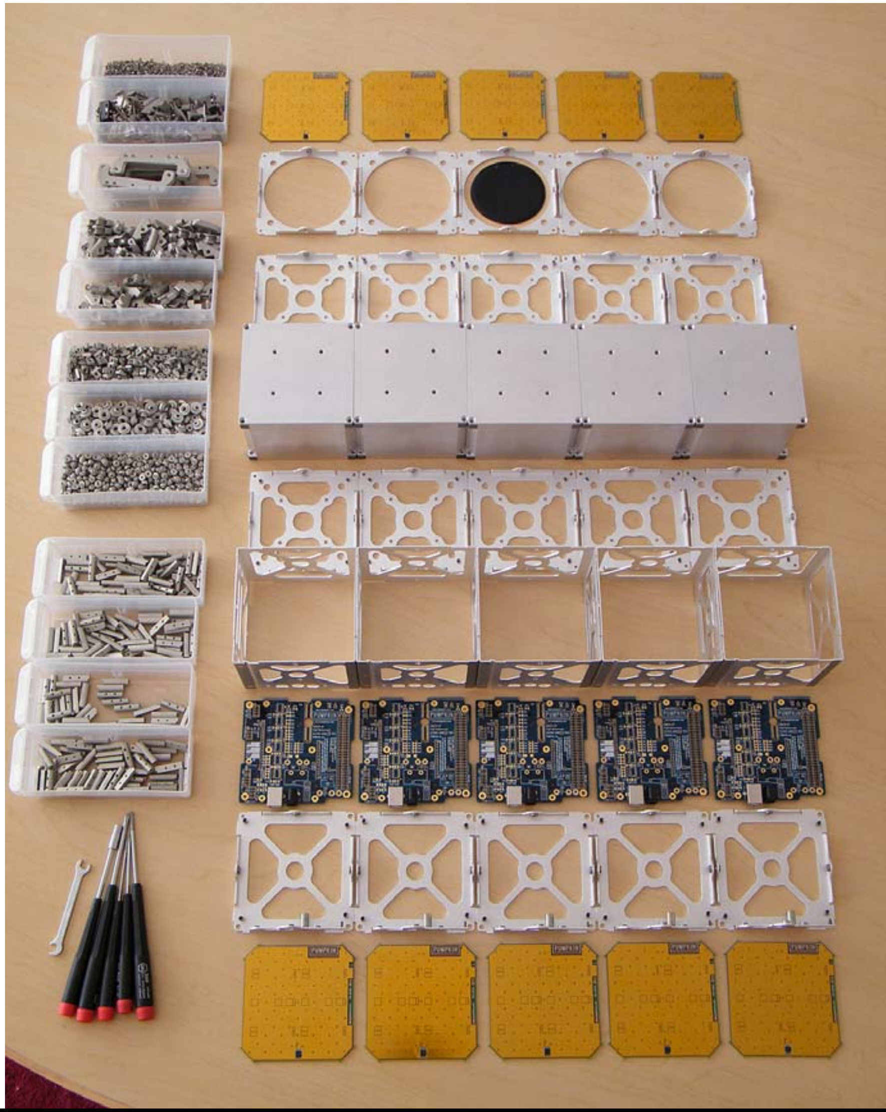
- Market demands innovation, but is very small relative to required costs and investment
- Modularity retains customer and Pumpkin's investments in prior generations
- Adapt to new technologies and customer requirements





Lesson 9 – Get the Word Out

- Things that are obvious to us about our products may not be obvious to the customer
- Leverage your time by providing comprehensive documentation



PUMPKIN™

SPACE SYSTEMS

Q&A Session

Thank you for attending this Pumpkin presentation at the 2011 CubeSat Spring Developers Workshop!

Appendix

- Speaker information
  - Dr. Kalman is Pumpkin's president and chief technology architect. He entered the embedded programming world in the mid-1980's. After co-founding Euphonix, Inc – the pioneering Silicon Valley high-tech pro-audio company – he founded Pumpkin, Inc. to explore the feasibility of applying high-level programming paradigms to severely memory-constrained embedded architectures. He is the creator of the Salvo RTOS and the CubeSat Kit. He holds several United States patents. He is a consulting professor in the Department of Aeronautics & Astronautics at Stanford University and directs the department's Space Systems Development Laboratory (SSDL). Contact Dr. Kalman at aek@pumpkininc.com.
- Acknowledgements
  - Pumpkin's Salvo, CubeSat Kit and MISC customers, whose real-world experience with our products helps us continually improve and innovate.
- CubeSat Kit information
  - More information on Pumpkin's CubeSat Kit can be found at http://www.cubesatkit.com/. Patented and Patents pending.
- Copyright notice

Presented at the CubeSat Developers Workshop in San Luis Obispo, California on Thursday, April 21, 2011.