Nanosatellite Development from a CubeSat Designer's Perspective

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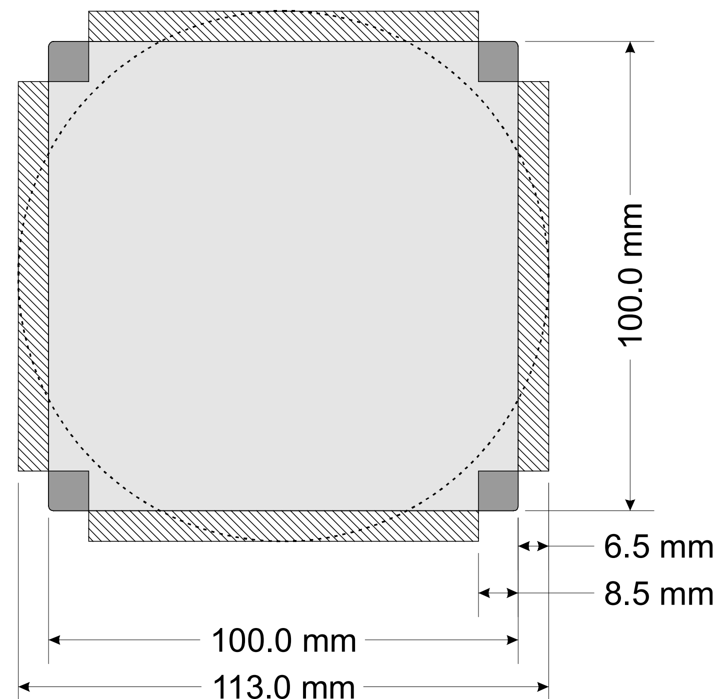
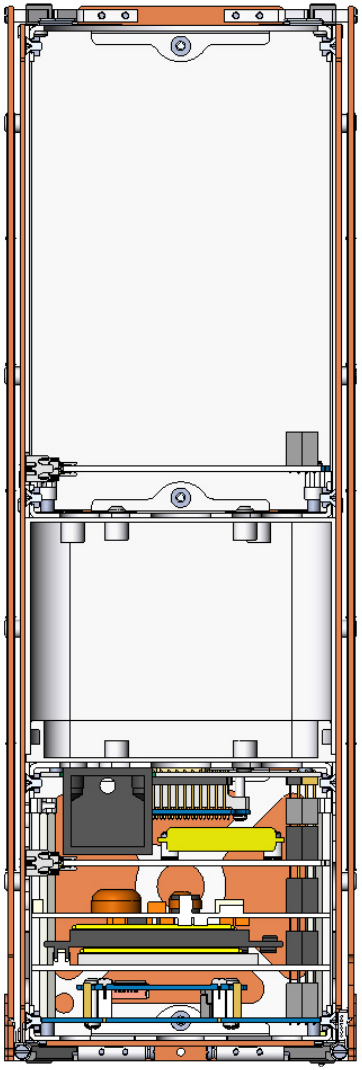
CDS & P-POD

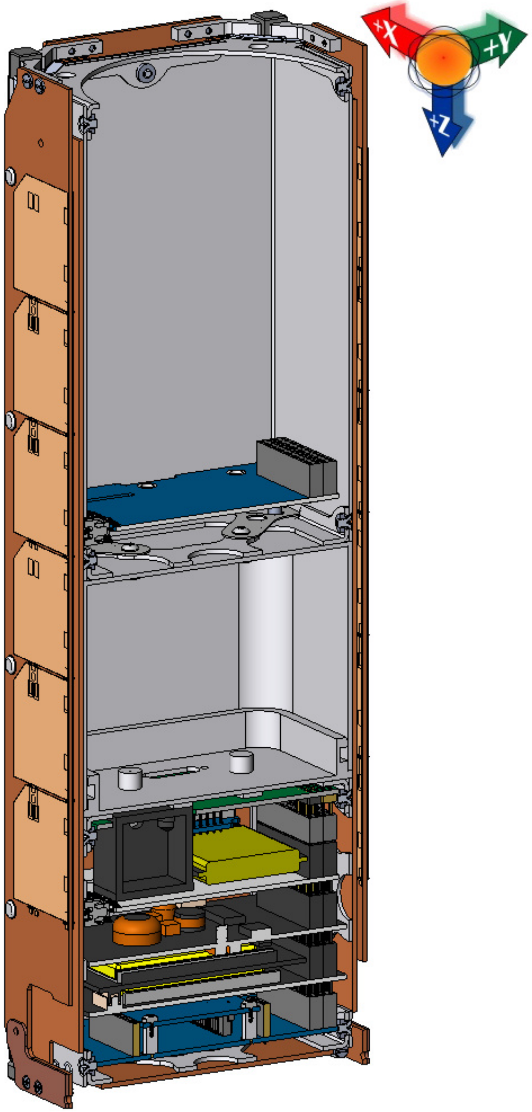
- Twiggs @ Stanford: original CubeSat idea
- Puig-Suari @ Cal-Poly: formalized idea, and developed deployer (P-POD)
- CDS: Few-page standard
- KISS: 10 x 10 x 10cm, few additional requirements
- CDS now maintained at Cal Poly, http://www.cubesat.org



Major CubeSat Components

- Structure
- Mechanisms
- EPS
- Batteries
- Solar Panels & Arrays
- C&DH
- ADCS
- COMM
- Payload(s)
- GSE
- Software!





Challenges in CubeSat Designs

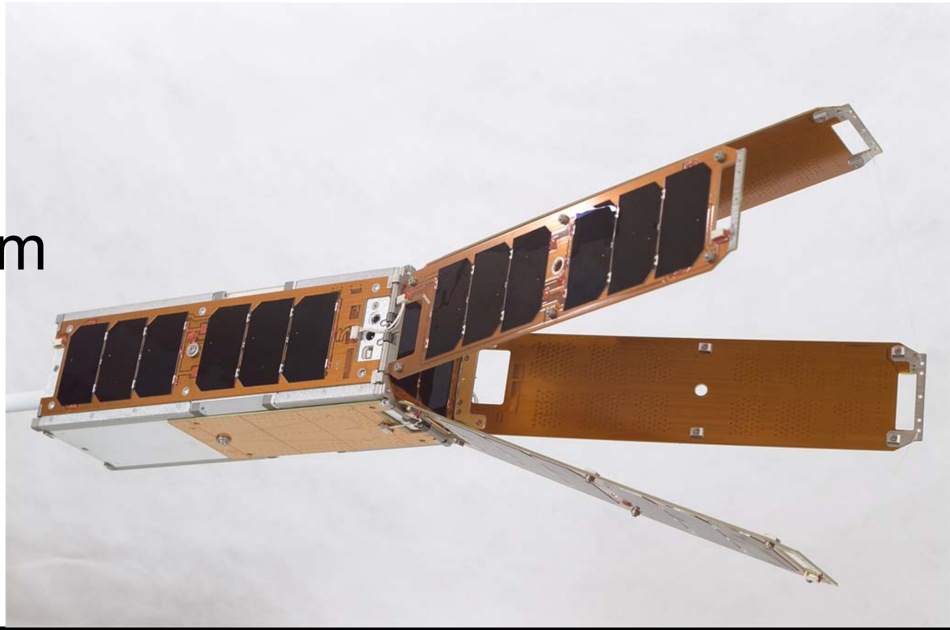
- Appearances can be deceiving – the small scale of CubeSats complicates many design issues, rather than simplifies them
- Volume envelope is severely constrained
- Available power was severely constrained – impact on architectures, software, etc.
- "Integer sizes" of various components (e.g., solar cells) don't play well with certain CubeSat dimensions
- No buying power, low volume
- Limited budgets mean that design decisions have long-reaching implications
- Bias against CubeSats as space debris

Build vs. Buy

- "Build a satellite" vs. "fly an experiment and get data"
- Lots to learn in many disciplines when building
- The more transparency (i.e., datasheets, CAD models, test results, responsiveness) the better, though said transparency, ISO9000, etc. do not guarantee quality or results
- "Non-gifting" partners will often want to have clearly visible contributions
- Value of free labor adds up quickly – difficult for successful small commercial entities to compete against this, both at the beginning (viewed as too expensive) and end of a project (when it's too late to correct, no funds left)
- Constraints due to ITAR

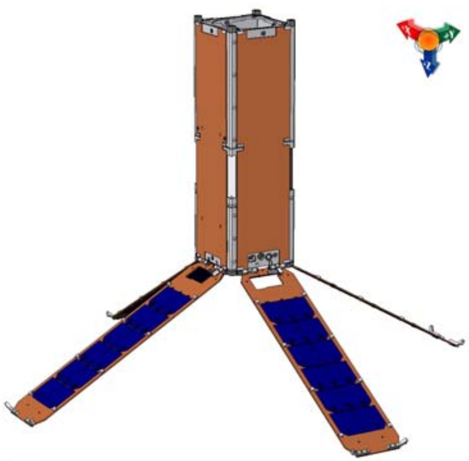
Costs & Schedules

- 1U kit (Pumpkin): $7500
- 1U launch: was $40k, now ???
- 1U mission (complete): $<200k in 2007
- 3U kit (Pumpkin): $8750
- 3U bus with ADACS, power & panels: $250k
- 3U launch: $125k-$500k
- 3U mission: $1-2M + launch
- 3-4 years used to be the norm
- 18-36mos now the norm



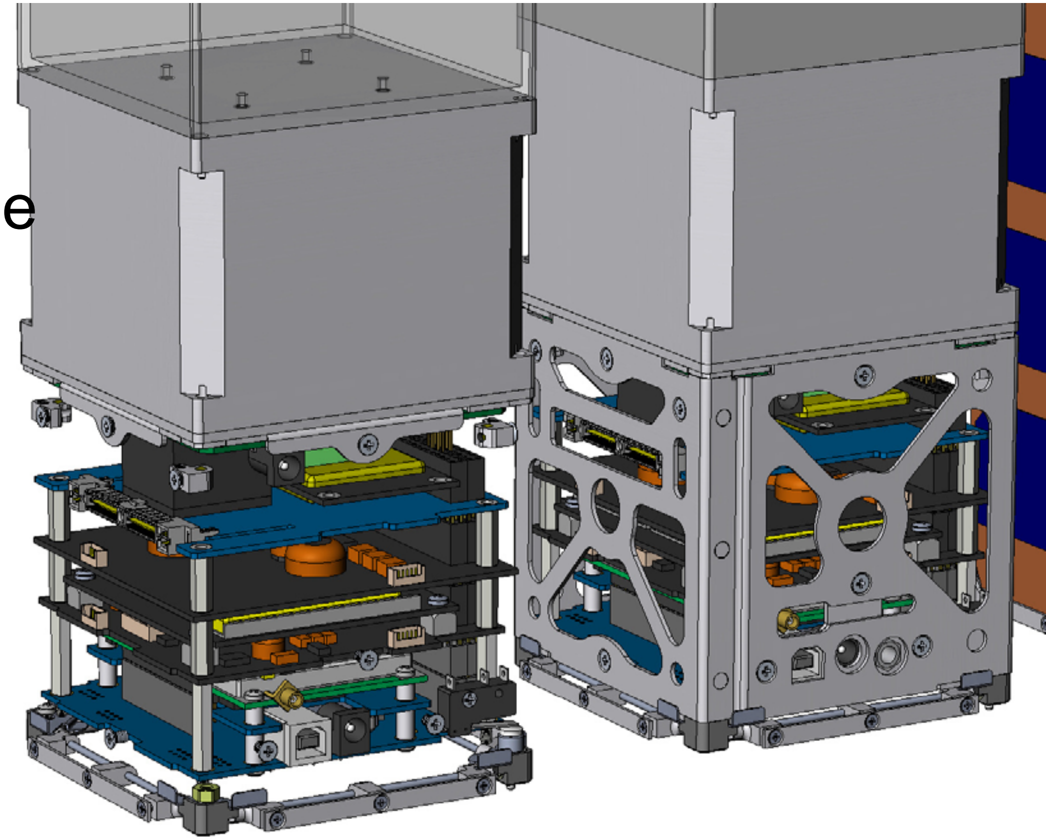
Iterating Towards a Solution

- 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, but not every solution is simple



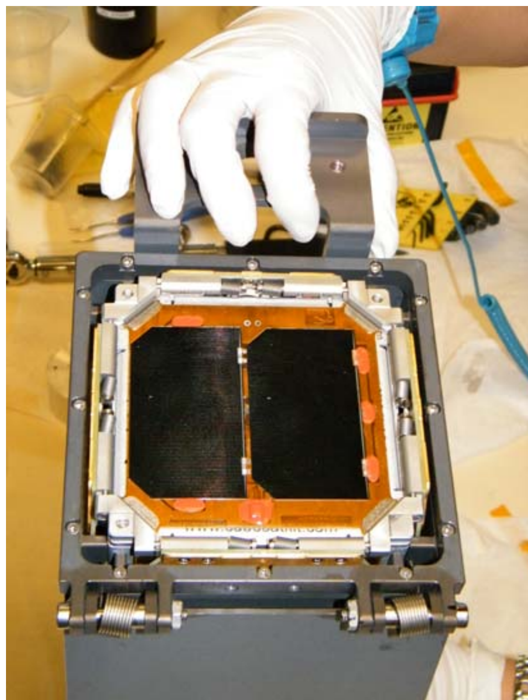
CAD Must be Perfect

- *Everything* gets modeled in 3D CAD … don't take anything (e.g., price, specs, availability, etc.) 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
  - Scale independence



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



CubeSat Architectures

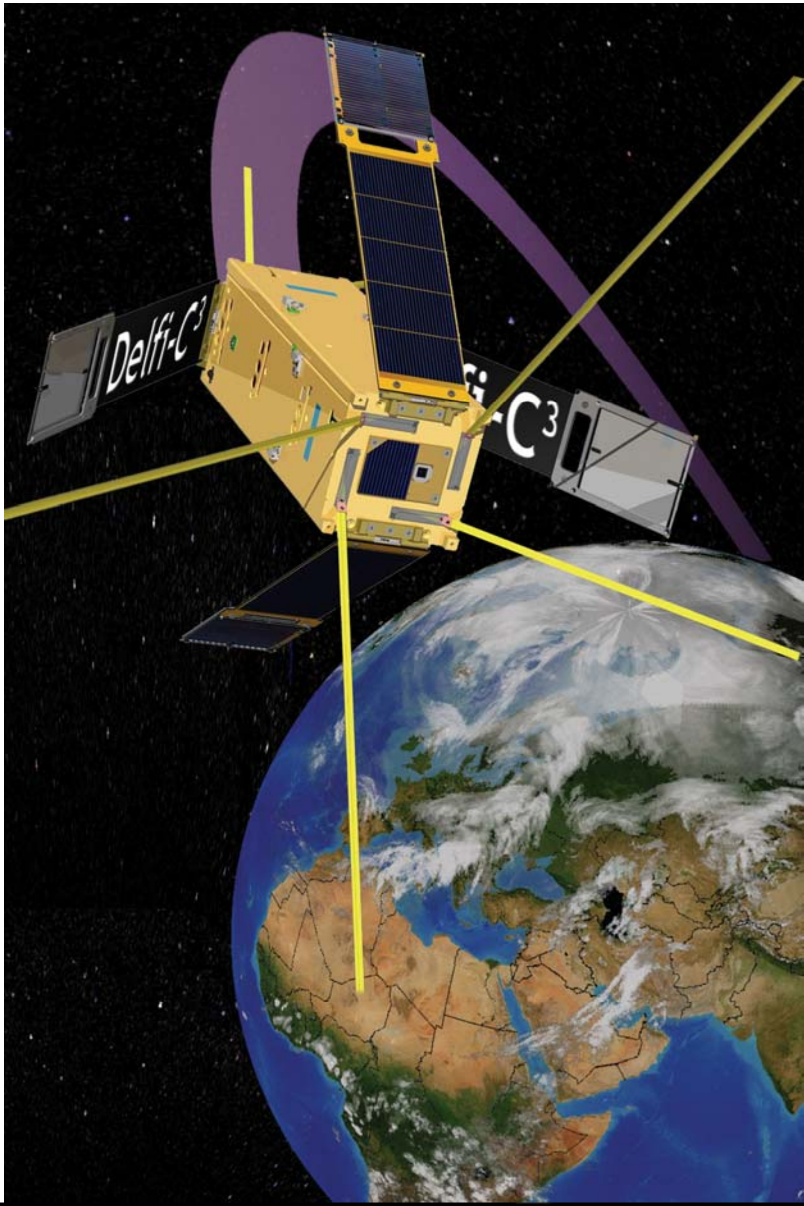
- Hardware:
  - Microcontroller-based (CP, GeneSat, CSK, etc.)
  - Microprocessor-based
  - Proprietary (CSTB)
  - SBC-based (QuakeSat)
  - General-purpose (CSK)
  - Specific-purpose (LANL)
  - FPGAs & rad-hard
  - Concentrated or distributed processing
- Software
  - C programming
  - Simply embedded vs. PCs
  - Multi-processor or multitasking (RTOS)
  - Reliance on libraries, etc.

Hardware vs. Software

- Hardware & software co-design required for successful overall system design
- Hardware – once stable – incurs few costs as program progresses. Good hardware design practices rare amongst unseasoned designers. Requires vendor & inventory management (VIM) for longer-term sustainability
- Modularity and well-defined ICDs can mitigate problems & isolate design efforts
- Software creep must be aggressively managed
- Software deliverables should be tested & vetted incrementally (e.g., N x per quarter)

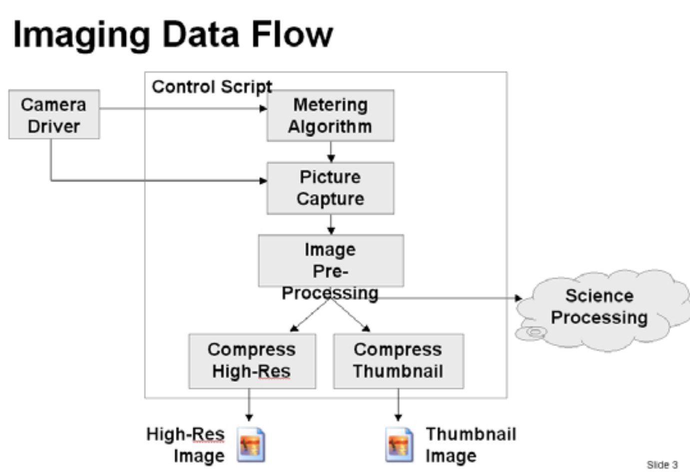
CubeSat Generations

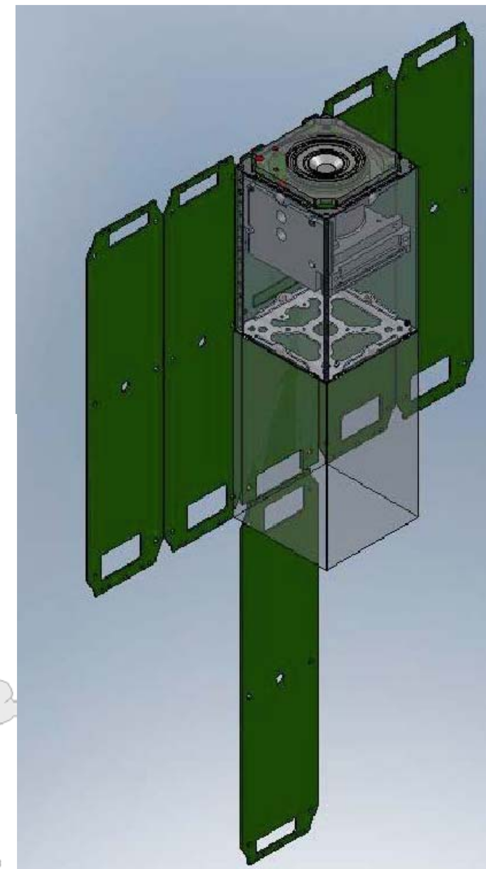
- 1st: Modern Sputniks
- 2nd: Utility of the 3U is demonstrated
- 3rd: More power, attitude control & determination, propulsion
- 4th: Constellations

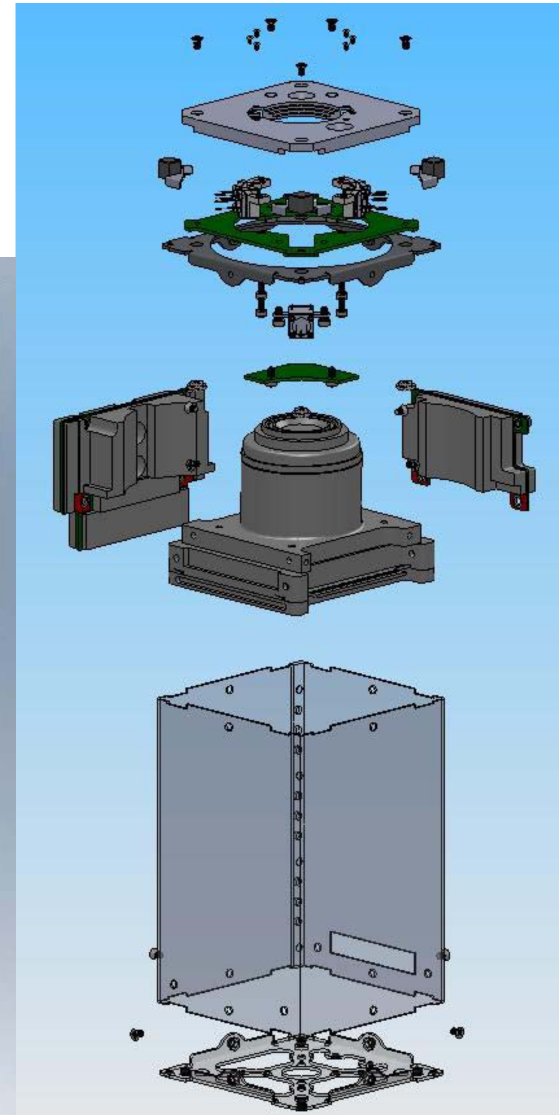


Interdisciplinary Development

- SSDLCAM:
  - CAD Team
  - Electronics Team
  - Embedded f/w team
  - SBC (Linux) team
  - Camera Integration Team
  - Experiments Teams
  - Applications Team
  - Etc.

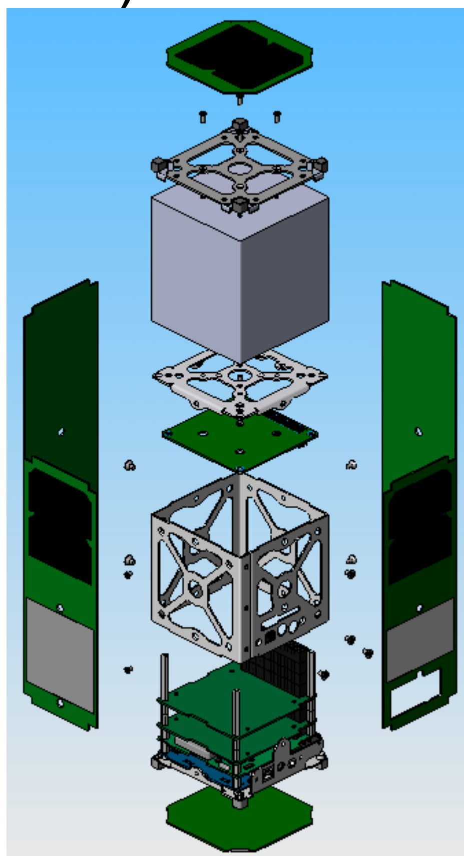


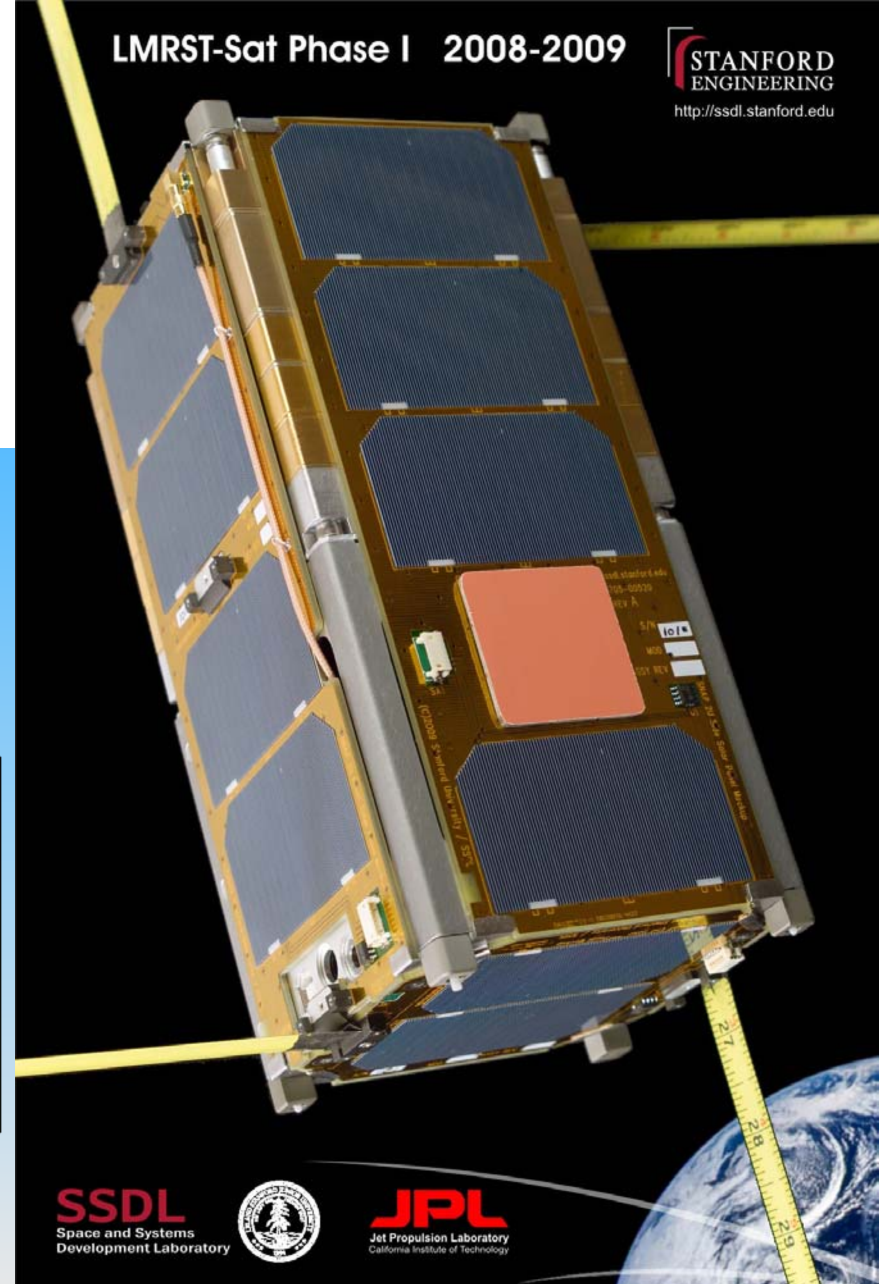




Interdisciplinary Teaming (External)

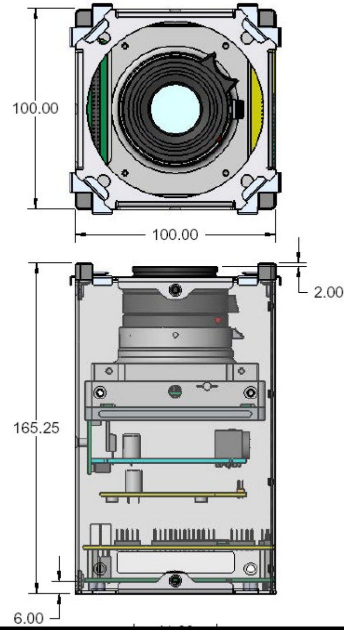
- SSDL (bus)
- JPL (ITAR payload)

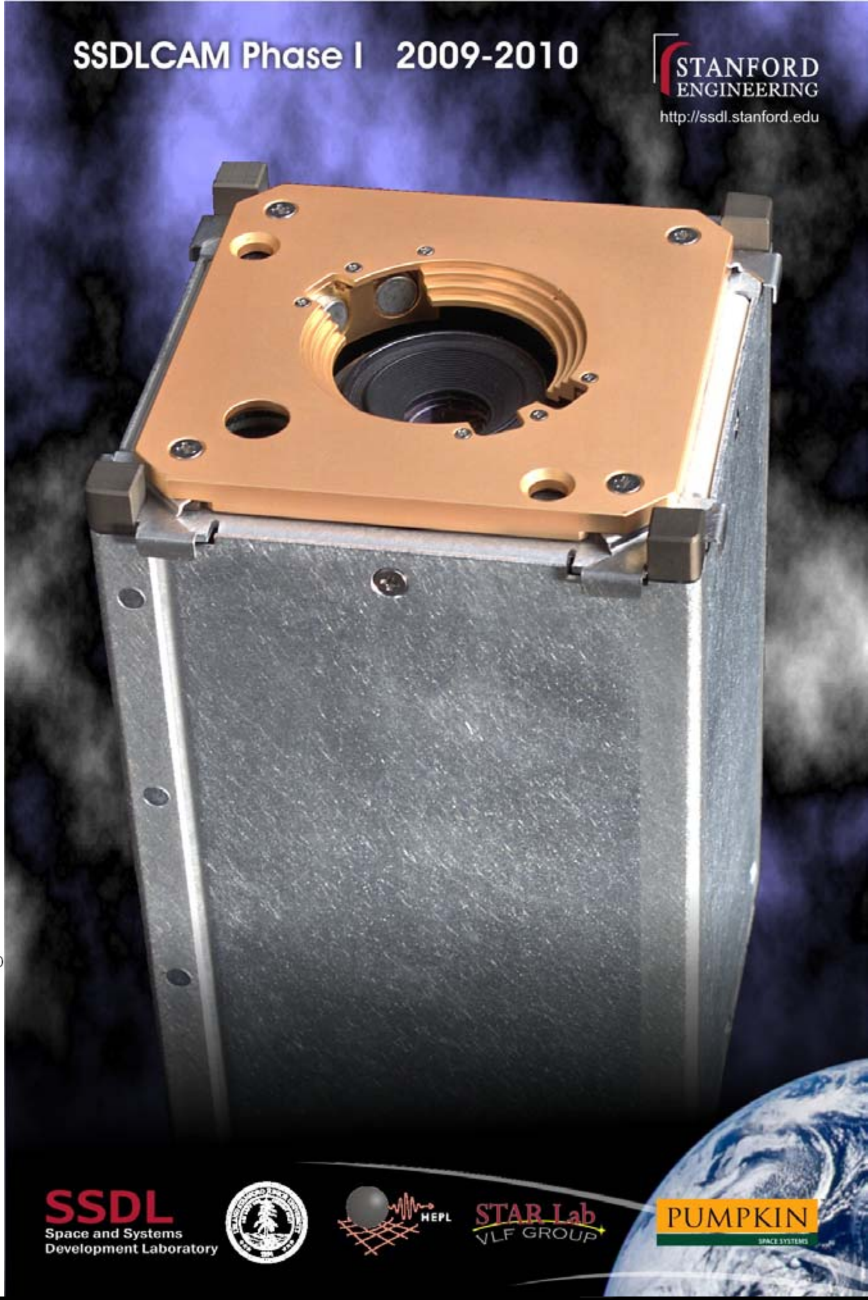




Interdisciplinary Teaming (Internal)

- SSDL (camera + FMR exp.)
- HEPL (UV LED exp.)
- STARLab (EED exp.)
- Pumpkin: equipment donations, advising





Interdisciplinary Teaming (Summer)

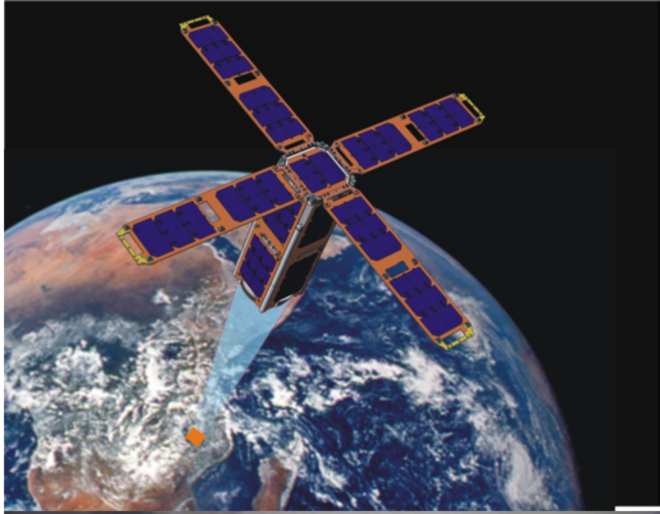
- SSDL (payload)
- Aeropac & ARLISS (sponsors)

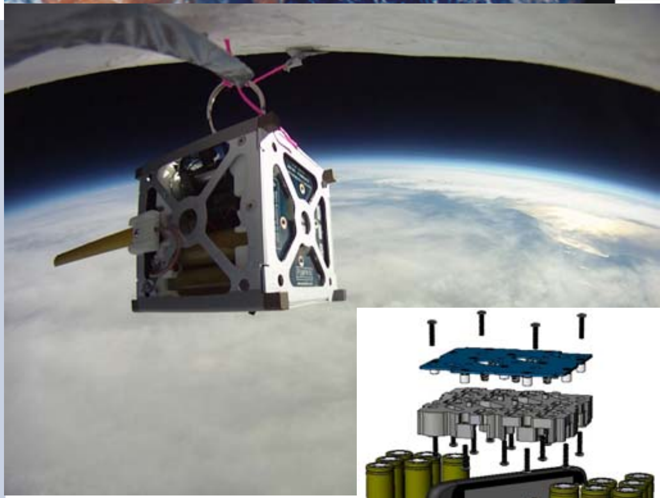
Why CubeSats drive Tech Innovation

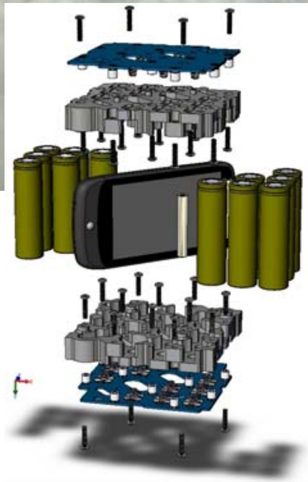
- Short development timeframes – ride the wave
- Proven use of mass-produced components – antithesis of "approved space components" builds
- Relatively low cost means launch & other failures not a major obstacle
- Dynamic response to problematic issues (e.g., deorbit)
- Currently protected by "LEO or lower" orbits

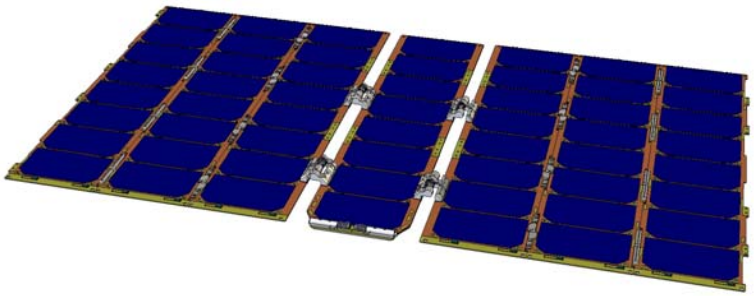
Trends / Hot Topics

- Earth Imaging
- Space Weather
- (Android) PhoneSats
- More & Better Power
- Faster Comms
- Propulsion at Last!
- What is the killer app?









Q&A Session

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

Notice

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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 Andrew 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.
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First presented at the CubeSat Developers' Workshop in Logan, Utah on Sunday, August 7, 2011, prior to the 25th Annual AIAA/USU Conference on Small Satellites.