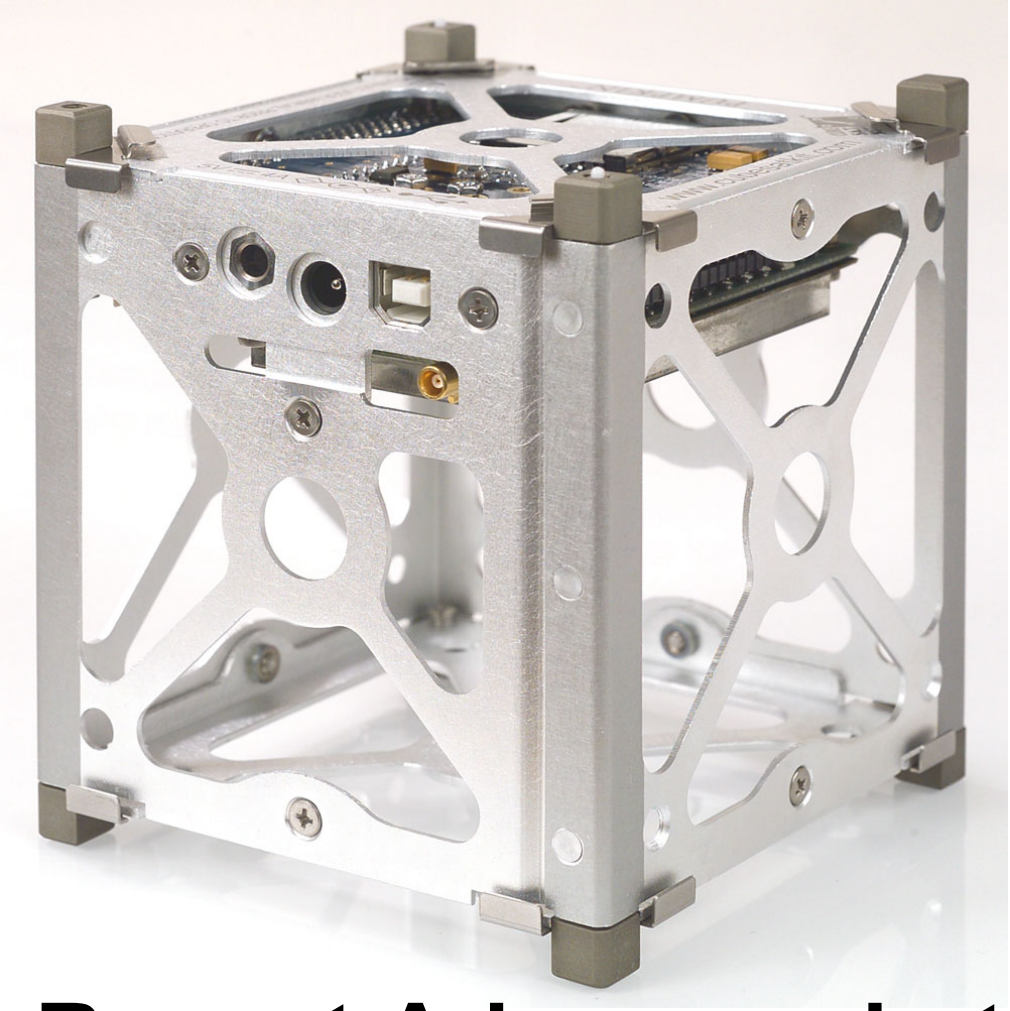

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Recent Advances in the CubeSat Kit™ Family

Andrew E. Kalman, Ph.D.

Introduction

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- Andrew E. Kalman
  - President and CTO, Pumpkin, Inc.
  - Author of Salvo™ The RTOS that runs in tiny places.™
  - Creator of the CUBE SAT KIT
  - 20+ years of embedded systems design and programming experience
  - Contact: aek@pumpkininc.com

Outline

- Part I: State of the CubeSat Kit
- Part II: Structural Components
- Part III: Customer Payloads
- Part IV: IMI-100 ADACS
- Part V: Software
- Part VI: The Future

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State of the CubeSat Kit

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- Delivered to over 40 customers since Dec 2003, with
  - 1U (solid-wall & skeletonized)
  - 3U (solid-wall & skeletonized)
- 4th-generation (Rev D) structural components
- 3rd-generation (Rev C) electronics
- Salvo 4 RTOS now in use
- EFFS-THIN FAT File System for CubeSat Kit
- Linear and Clyde Space EPS now available
- Preserved substantial backwards compatibility
- Improved documentation including datasheets

Part I (cont'd)

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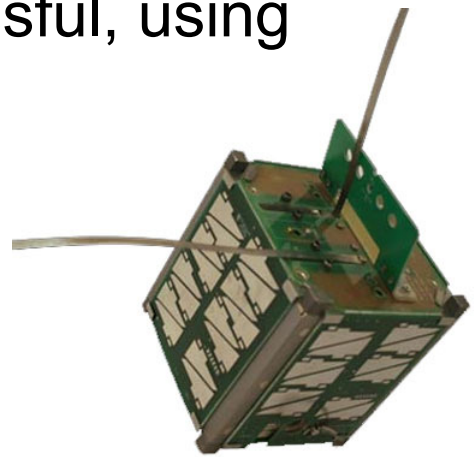
- First customer (Libertad-1) launch successful, using
  - 2nd-generation CubeSat Kit structure
  - 2nd-generation CubeSat Kit electronics
  - Pumpkin Salvo v3 RTOS
  - StenSat Group VHF/UHF Module
  - User-designed EPS, antennas
  - Batteries only (no working Solar Panels)



- Upcoming CubeSat Kit launches:
  - TU-Delft's Delfi-C3
  - KySat
- SSDL's BioLaunch program proving to be low-cost, responsive testbed for recoverable test flights
  - Flying Lippert Cool LiteRunner 2 PC/104 low-power PC-class SBC

Structural Components

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- Newest structures offer several enhancements over prior:

	Rev A, Rev B & Rev C	Rev D
Launch Switch	Partially exposed, direct action	Internal with translating pin
M3x5mm Screws	12	10
Mass	Already best-in-class	-10% on 1U
Wall Cutouts		Greater cutout area
Cross Section	Box with 2 end flanges	Box only (no flanges)
Solar Panel Clips	7 + 1	All 8 identical
Solar Panel PCBs	Top & bottom unique	Top & bottom identical, with more available area
External User Payloads	Complex, must mate in CAD/3D to structure	Simple, via Payload Adapter Plate
Finish / Plating	Non-RoHS (yellow Cad)	RoHS (silver trivalent)

Part II (cont'd)

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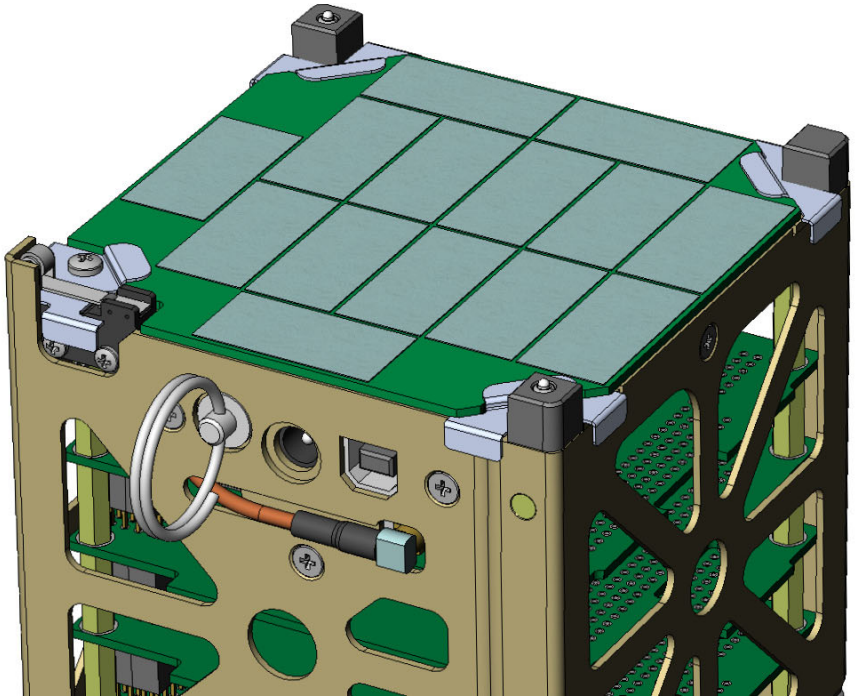

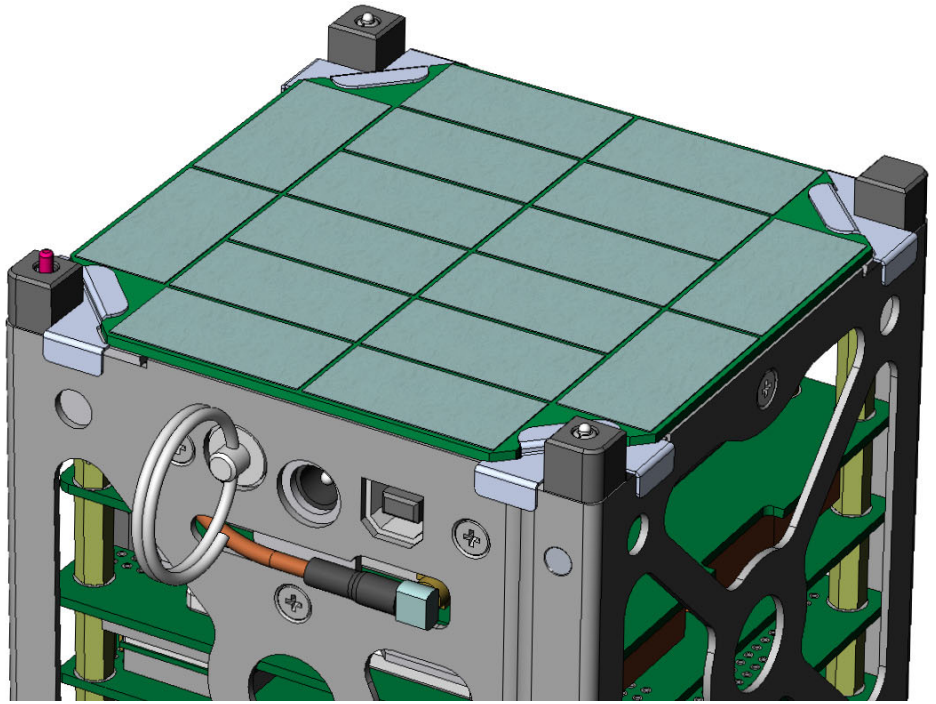

3rd-generation/Rev C (left) & 4th-generation/Rev D (right) skeletonized CubeSat Kits showing changes in cutouts, plating, Launch Switch, Launch Switch foot, Solar Panel Clips & available area on Solar Panel PCB.

Customer Payloads

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- As before, customer can pack *internal* payloads in the 90mm x 96mm x 15mm User Module form factor *inside* complete CubeSat Kit structures.
- Rev D structures can also accommodate *external* customer payloads using the full 100.0mm x 100.0mm cross-section, with:
  - CubeSat Kit Payload Adapter Plate
    - At interface(s) of Chassis Walls and customer payload
  - CubeSat Kit Payload Cover Plate
    - At end of customer payload
  - CubeSat Kit Payload Panel Clips & Solar Panel Clips
    - At Payload Adapter Plate and Payload Cover / Cover Plate Assemblies
- Configurations with *external* payloads:

Length	Payload Size+CSK Size Combinations
3U	2.5U+0.5U 2U+1U 1.5U+1.5U 1U+2U
2U	1.5U+0.5U 1U+1U 0.5U+1.5U
1.5U	1U+0.5U 0.5U+1U
1U	0.5U+0.5U

Part III (cont'd)

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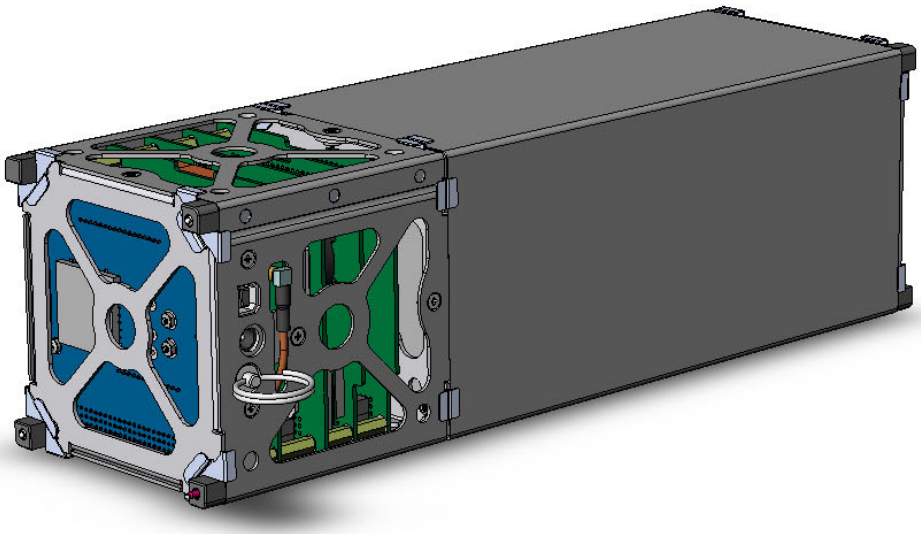
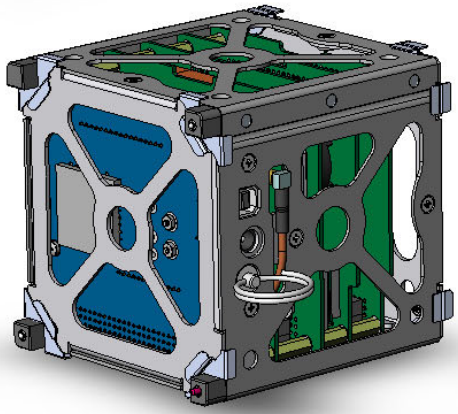
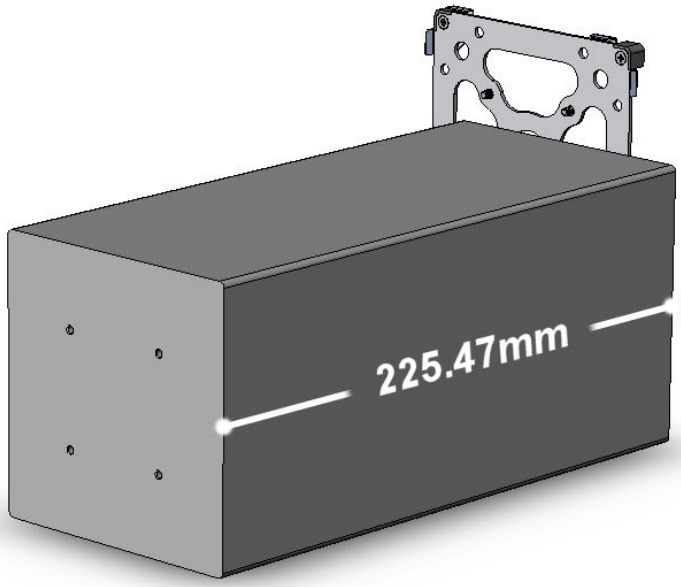


3U CubeSat Kit constructed from a single 1U skeletonized CubeSat Kit (w/ C&DH, radio, EPS & internal payloads) and a 2U external payload (100 x 100 x 225 mm).

Total length is 340.50 mm.





IMI-100 ADACS

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- Modular 3-axis Attitude Determination and Control System (ADACS) from IntelliTech Microsystems, Inc. (IMI)
  - 1 degree pointing accuracy w/external magnetometer & sun angle info
  - Integrated stepper motors and torque coils (for damping)
  - < 4.5W peak power consumption
  - < 1kg mass, < 1U size
  - Designed to interface directly to CubeSat Kit structure Rev D and later
- Complete kit includes:
  - IMI-100 with calibrated magnetometer
  - 2 x CubeSat Kit Payload Adapter
  - 1 x CubeSat Kit ADACS Payload Walls
  - 1 x CubeSat Kit ADACS Interface Module
  - 1 x CubeSat Kit Payload Panels Clips Set
  - Integration support from Pumpkin
  - Configuration and orbital support from IMI

Part IV (cont'd)

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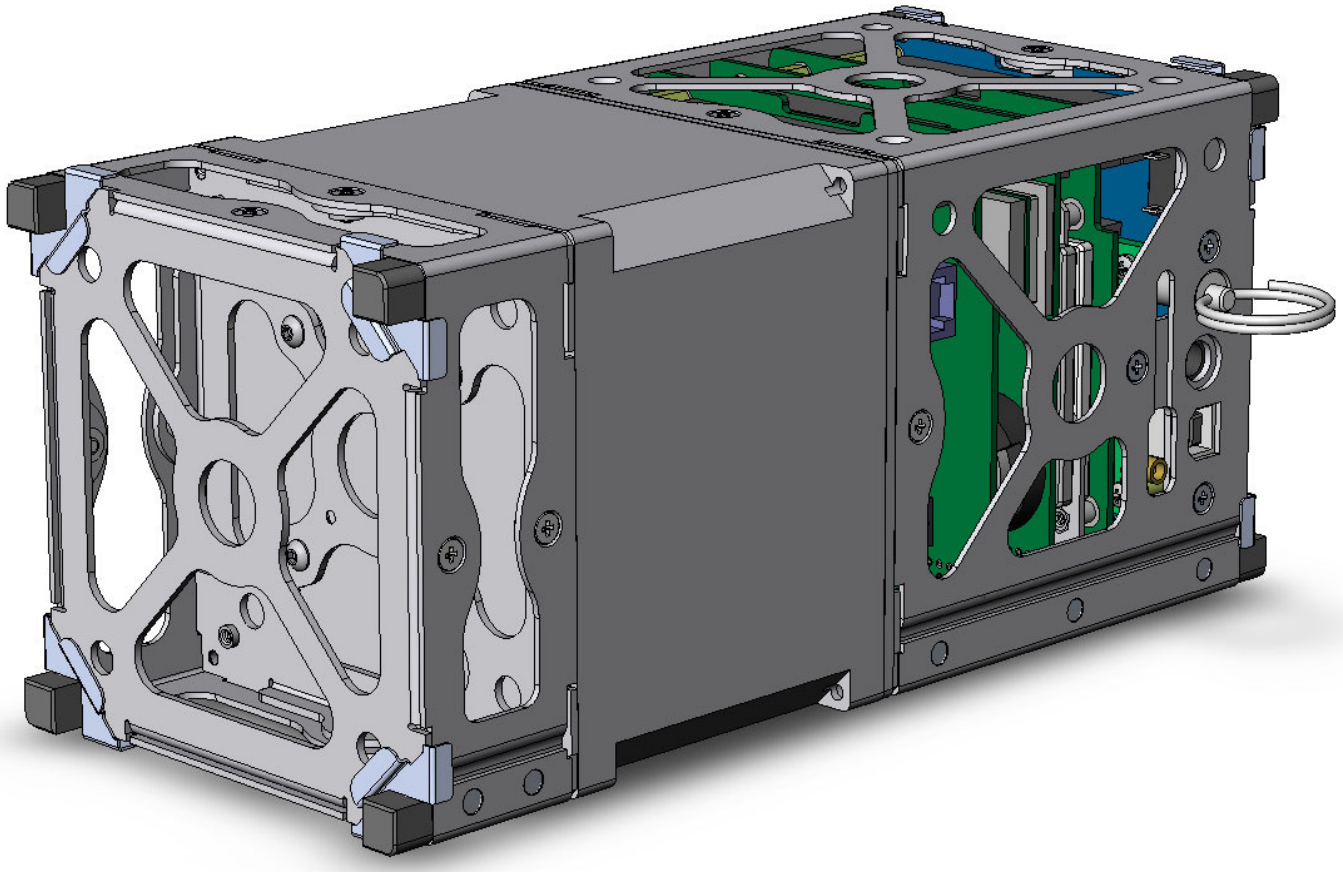

L to R: ADACS Payload Walls, IMI-100 ADACS & 1U skeletonized CubeSat Kit with ADACS Interface Module, internal payload(s), EPS, radio and FM430 Flight Module.

Software

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- CubeSat Kit software growing to provide a library of driver-type routines.
- HCC-embedded EFFS-THIN for CubeSat Kit:
  - Access on-board SD card as a FAT drive
  - Have multiple streams open simultaneously (e.g. read audio data for streaming, write captured data, write to log/error/debug file)
- Salvo 4 RTOS has improvements over Salvo v3 in the areas of:
  - Interrupt latency (now zero)
  - Easier control of interrupts in critical sections (no longer requires source code for configuration)

Future

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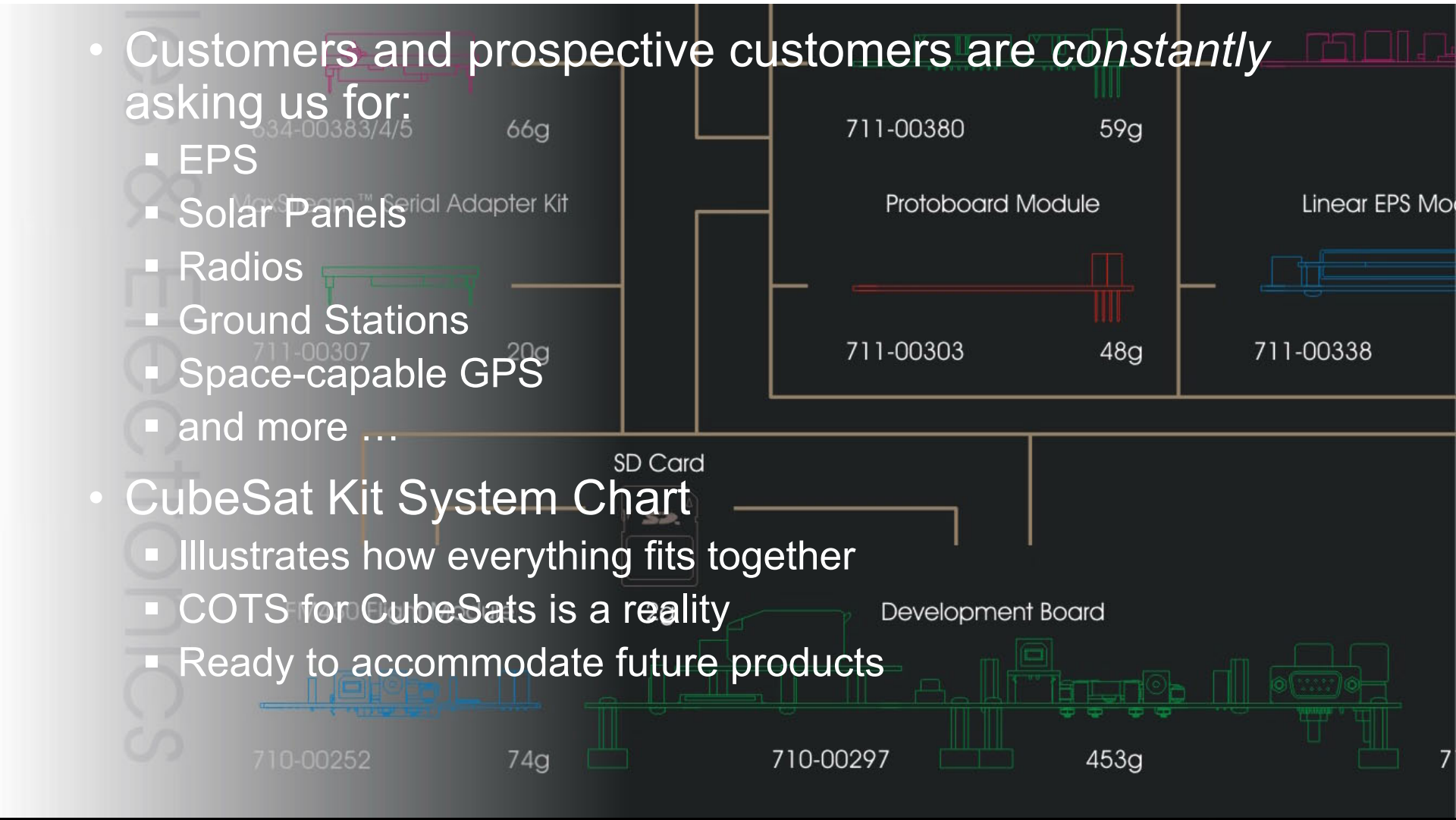
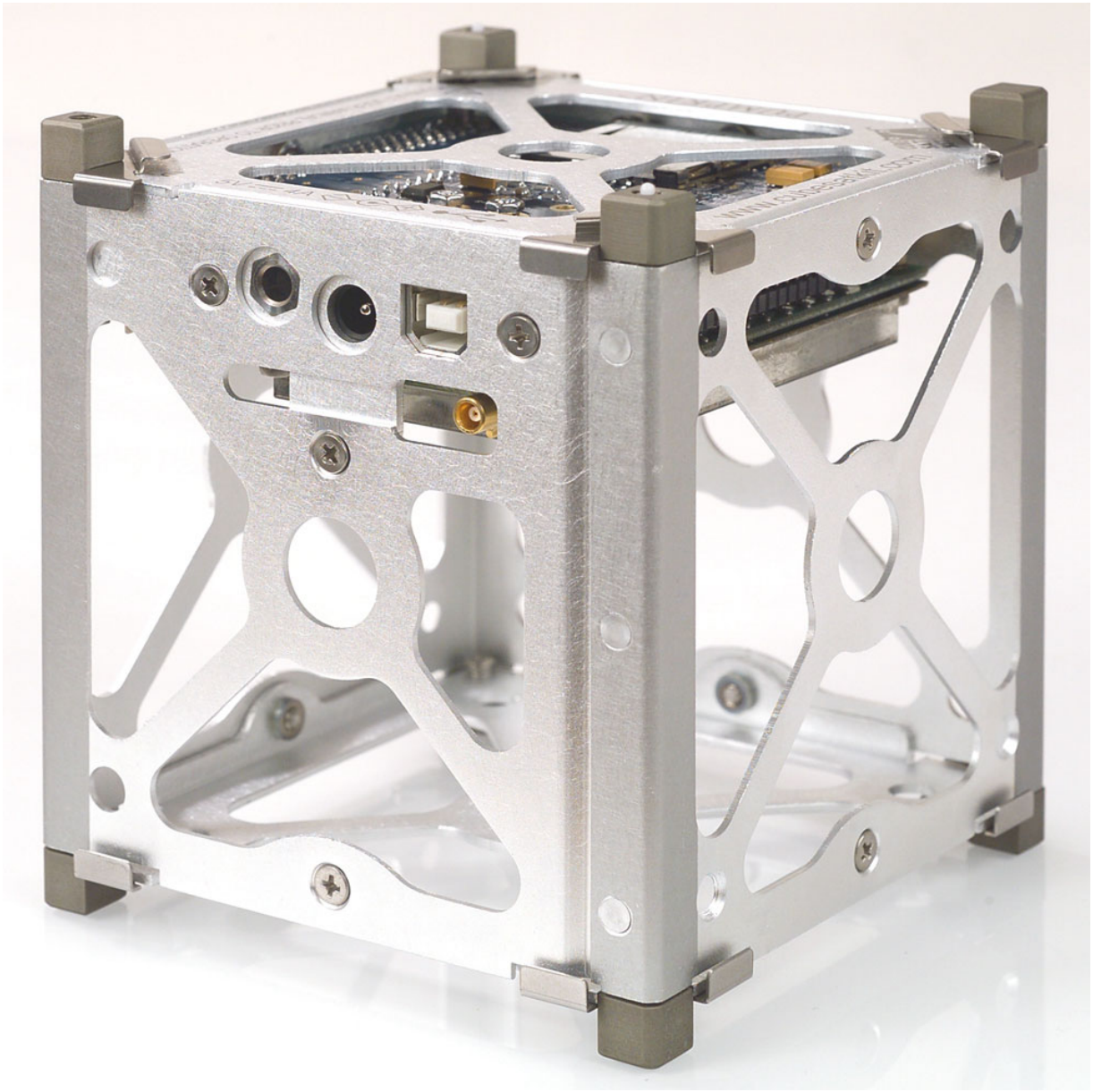
- Customers and prospective customers are *constantly* asking us for:
  - EPS
  - Solar Panels
  - Radios
  - Ground Stations
  - Space-capable GPS
  - and more …
- CubeSat Kit System Chart
  - Illustrates how everything fits together
  - COTS for CubeSats is a reality
  - Ready to accommodate future products





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Q&A Session

Thank you for attending this Pumpkin seminar at the CubeSat Workshop at SmallSat 2007!

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Appendix

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- 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 to explore the feasibility of applying high-level programming paradigms to severely memory-constrained embedded architectures. He holds two United States patents and is a consulting professor at Stanford University.
- Acknowledgements
  - Stanford Professors Bob Twiggs' and Jamie Cutler's continued support for the CubeSat Kit, and their inputs on enhancements and suggestions for future CubeSat Kit products, are greatly appreciated.
  - Pumpkin's Salvo and CubeSat Kit customers, whose real-world experience with our products helps us improve and innovate.
- Salvo, CubeSat Kit and CubeSat information
  - More information on Pumpkin's Salvo RTOS and Pumpkin's CubeSat Kit can be found at http://www.pumpkininc.com/ and http://www.cubesatkit.com/, respectively.
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First presented at the CubeSat Workshop at the 21st Annual Conference on Small Satellites in Logan, Utah on August 12, 2007.