

Nine Years and Counting - A Nanosatellite Designer's Perspective

Andrew E. Kalman aek@pumpkininc.com

President & CTO, Pumpkin, Inc.

Director, SSDL, Stanford University



Don't leave Earth without it

strong light modular scalable customizable affordable
www.cubesatkit.com

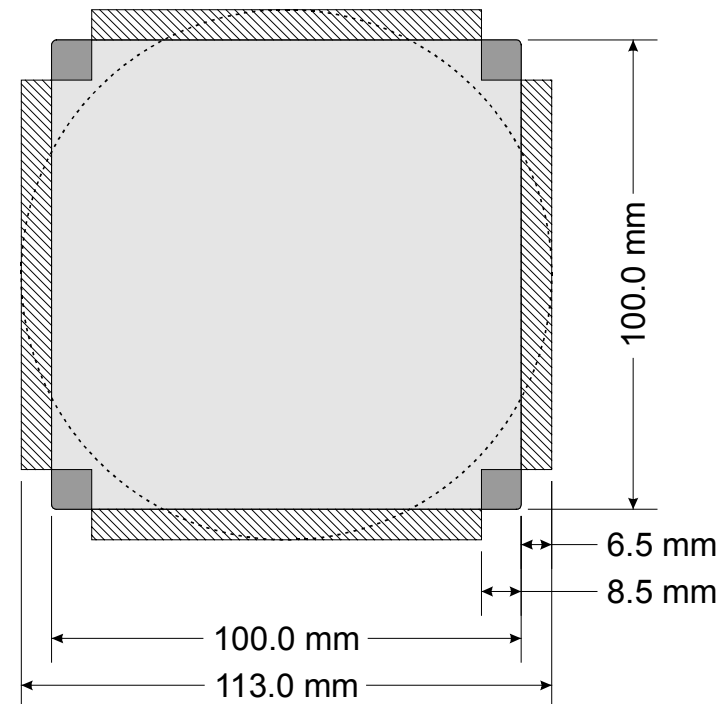
*KISS Small Satellites Workshop
July 16-20, 2012*



Slide 1

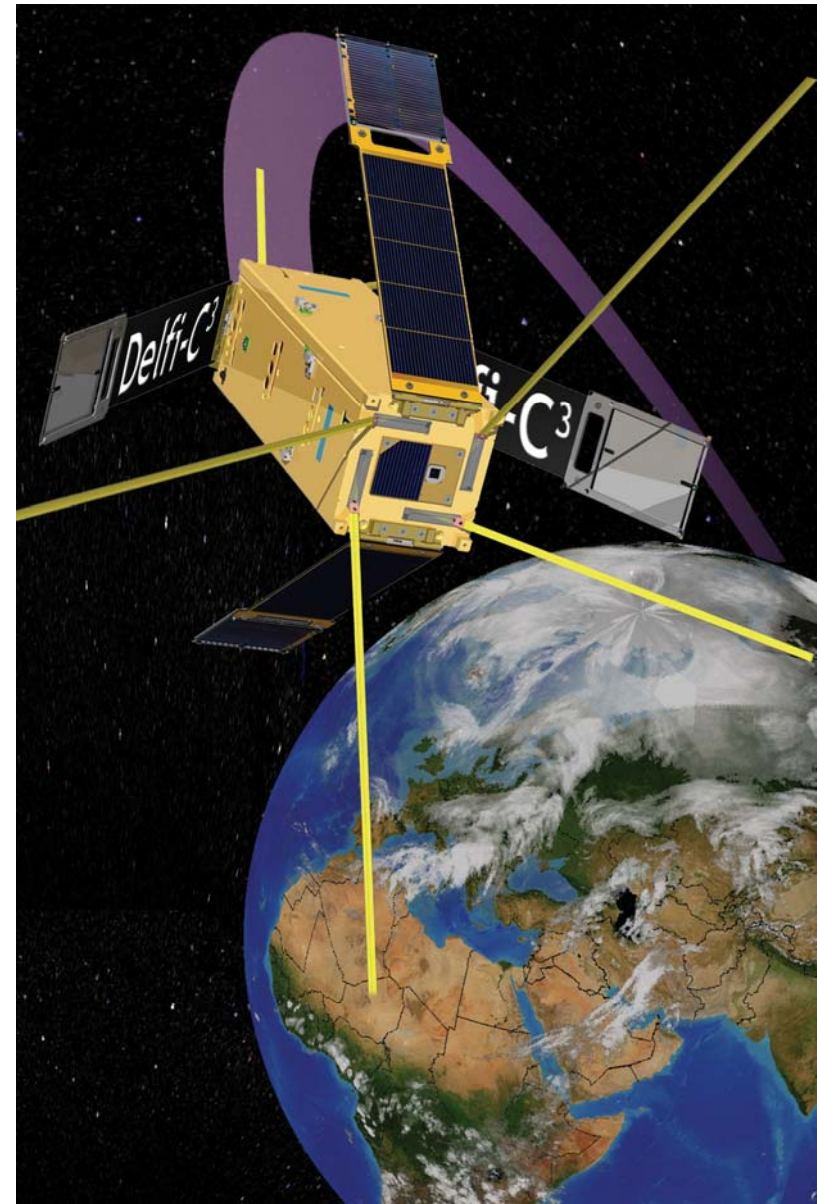
CDS & P-POD

- 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>



CubeSat Generations

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



Don't leave Earth without it

strong light modular scalable customizable affordable
www.cubesatkit.com

KISS Small Satellites Workshop
July 16-20, 2012



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 (vs. iPhone: >100M/year)**
- Limited budgets mean that design decisions have long-reaching implications
- (Not unreasonable?) bias against CubeSats as space debris



Don't leave Earth without it

strong light modular scalable customizable affordable
www.cubesatkit.com

KISS Small Satellites Workshop
July 16-20, 2012

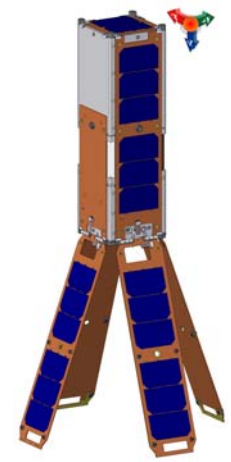
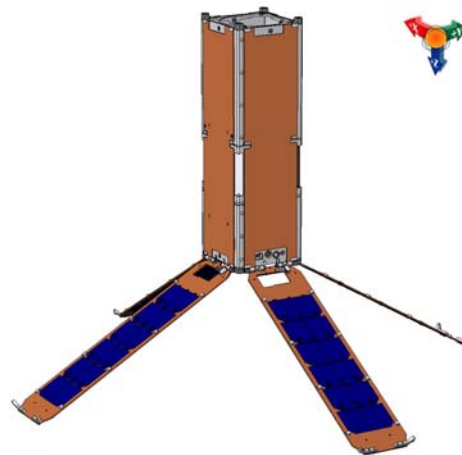


Build vs. Buy

- “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

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



Don't leave Earth without it

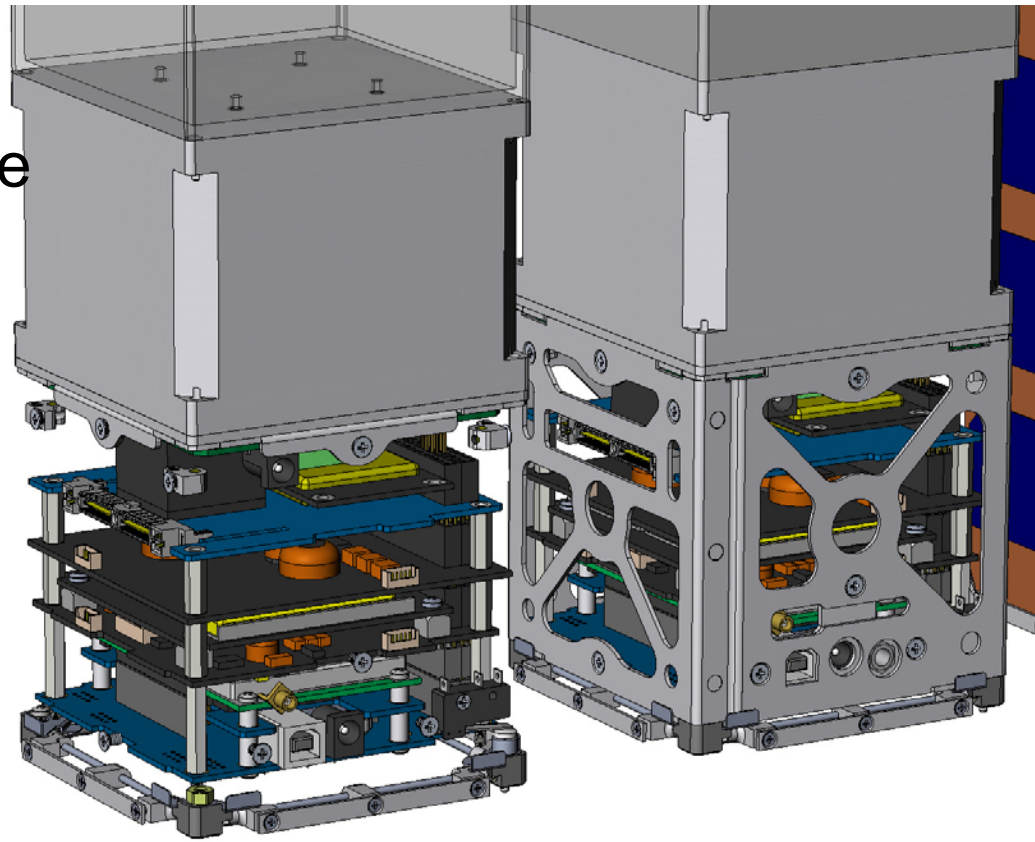
strong light modular scalable customizable affordable
www.cubesatkit.com

KISS Small Satellites Workshop
July 16-20, 2012



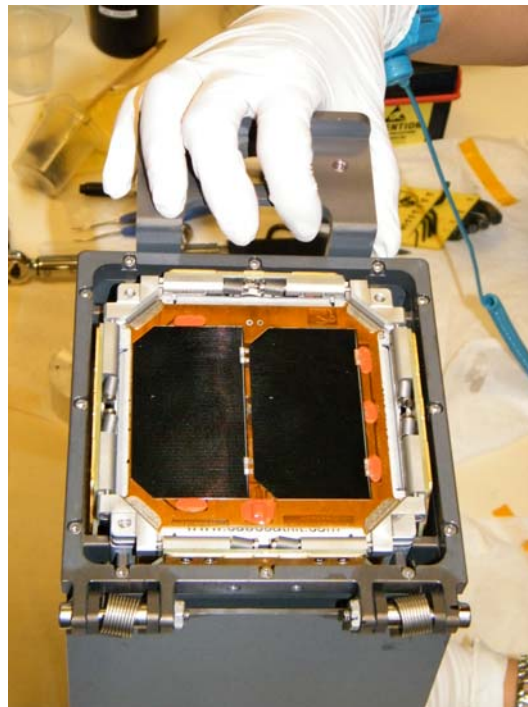
CAD Must be Perfect

- *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



Hardware vs. Software

- Hardware & software co-design required for successful overall system design
- Hardware – once stable – incurs few costs as program progresses. Low-volume hardware design is \$\$\$\$. Good hardware design practices rare amongst unseasoned designers. Requires vendor & inventory management (VIM) for longer-term sustainability. **Hardware obsolescence is extreme within the PC-class world.**
- 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)

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



Don't leave Earth without it

strong light modular scalable customizable affordable
www.cubesatkit.com

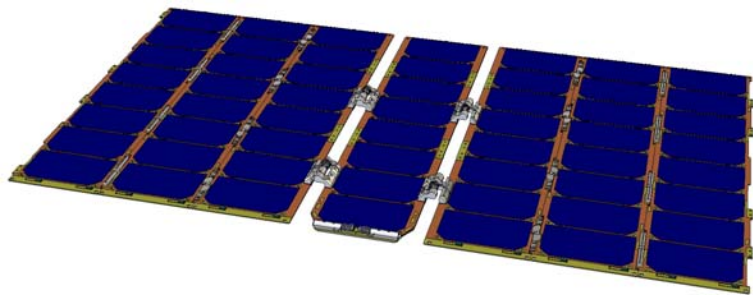
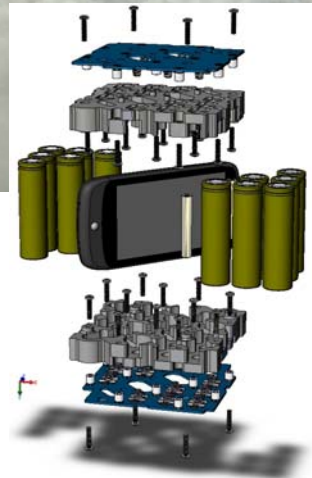
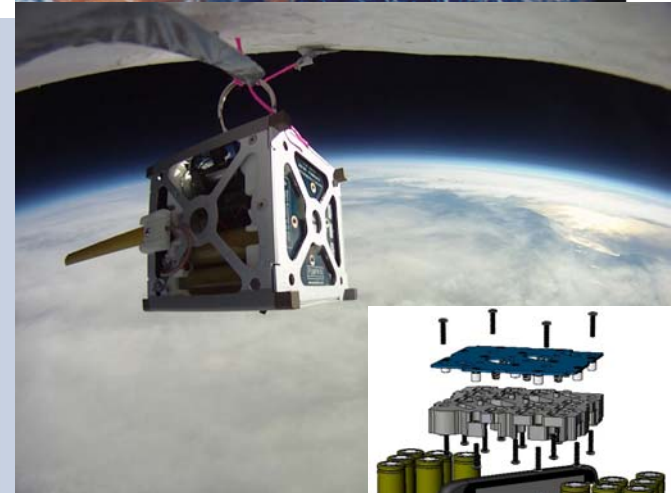
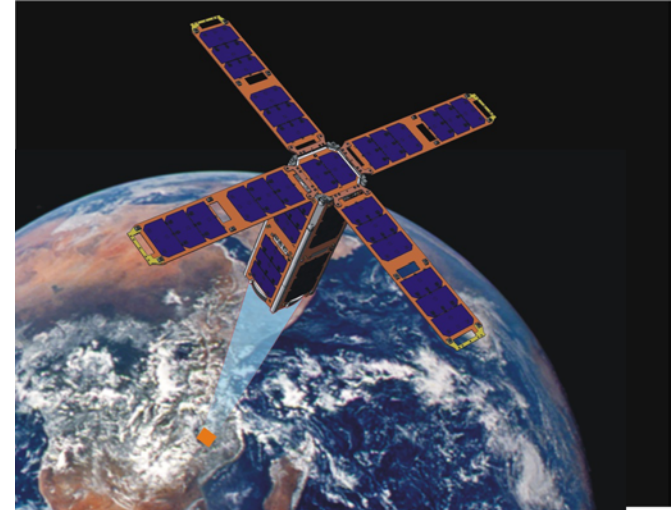
KISS Small Satellites Workshop
July 16-20, 2012

PUMPKIN™

Slide 10

Trends / Hot Topics

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



Hello Kitty
CubeSat!



Don't leave Earth without it

strong light modular scalable customizable affordable

www.cubesatkit.com

KISS Small Satellites Workshop
July 16-20, 2012



On Silicon Valley

“ ... there is a remarkable optimism, and an attitude to try out and explore ideas without the fear of failure.”

“There’s not a sense of looking to generate money, its about having an idea and doing it ...”

- First response to many new unconventional ideas is “That can never work.” Disregard what others are saying.
- You will likely run through many failed designs before you reach one that is ready to release to customers.
- Be modest and listen. **Manufacturing is specialized – in SV, it has to be to survive.** Understand niches and expertise and costs. Manufacturers want to develop new customers, you need new partners.

On the Design Process

Design “ ... is very much about designing and prototyping and making. When you separate those, I think the final result suffers.”

- CAD is great but ultimately your product must leave the computer and be realized. With 3D printing so affordable, hands-on validation and tweaking of designs is a huge advantage. Same goes for electronic circuitry.
- **As a designer, it behooves you to have a fundamental grasp on and experience with a wide range of materials and manufacturing techniques.** Sample sample sample.
- Get your hands dirty. Know how to operate a mill, lathe, saw, welder, file, sanding block, etc. with reasonable skill. This helps you develop a feel for how things are made and can go together.

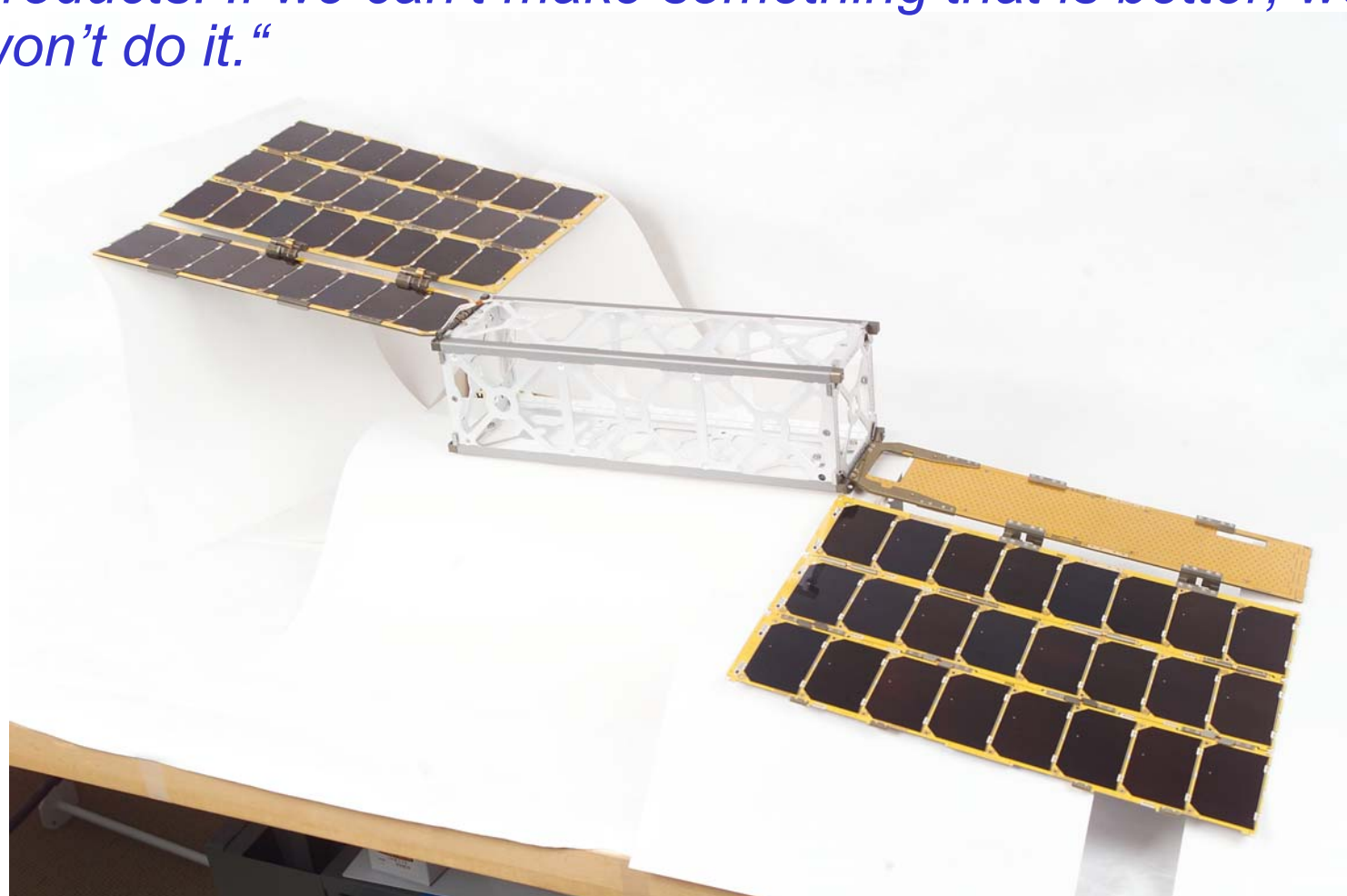
On Being a Nimble Designer

“It is so important to be light on your feet, inquisitive and interested in being wrong.”

- Design requires a real commitment – live and breathe your designs, iterating on them over and over, until an elegant solution emerges. If it’s not good enough, try again. Be able to defend your design decisions. **Some designs take months or years to resolve satisfactorily.**
- If you must compromise your design, understand why, and be able to quantify and explain it. Cost often drives compromise.
- Small, subtle changes to a design-in-process can deeply impact manufacturability, cost, etc. Perturb your design’s trajectory to evaluate your options.

On Goals

“Our goals are very simple - to design and make better products. If we can't make something that is better, we won't do it.”



Don't leave Earth without it

strong light modular scalable customizable affordable

www.cubesatkit.com

Slide 15

KISS Small Satellites Workshop
July 16-20, 2012



On the Working Environment

“A product has to be genuinely better. This requires real discipline, and that’s what drives us - a sincere, genuine appetite to do something that is better. Committees just don’t work, and it’s not about price, schedule or a bizarre marketing goal to appear different - they are corporate goals with scant regard for people who use the product.”

- As a designer, my goal is to make end-users of my products more than just satisfied with their purchase. I want them to be happy with it, and appreciate the thought and care that went into designing and manufacturing it.
- **Committees are about compromise, and good design is about vision, not compromise.** A design must stand on its own merits, and a team will recognize that. Do not share responsibilities – assign them to individuals.

On Knowing what Consumers Want

“We don’t do focus groups - that is the job of the designer.”

- Amen to that.
- A good rule of thumb:
 - The customer drives half of the process
 - You drive the other half

The customer lays out what they need, but it’s up to you to drive the process to that end goal, adding your own mark. You should always be drawing from your “woulda coulda shoulda” ideas you’ve been collecting all along ...



Don't leave Earth without it

strong light modular scalable customizable affordable
www.cubesatkit.com

KISS Small Satellites Workshop
July 16-20, 2012



Slide 17

On Experienced Teams

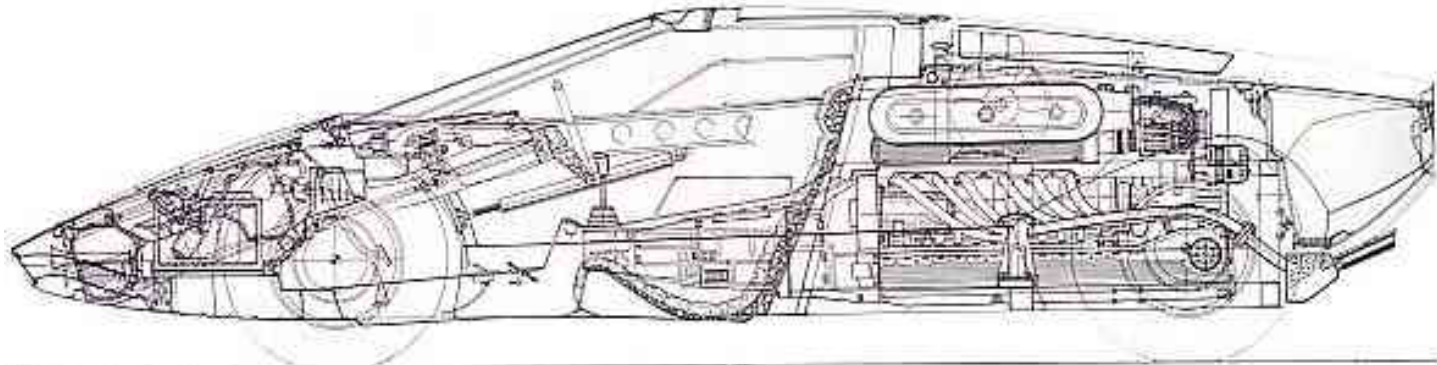
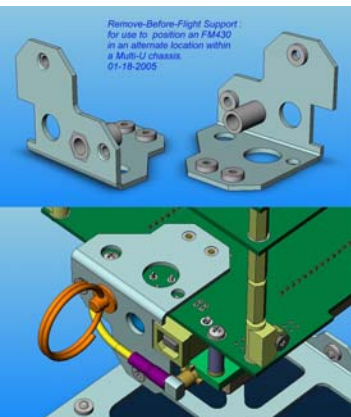
“... the complexity of these products really makes it critical to work collaboratively, with different areas of expertise... We’re located together, we share the same goal, have exactly the same preoccupation with making great products. One of the other things that enables this is that we’ve been doing this together for many years - there is a collective confidence when you are facing a seemingly insurmountable challenge”

- Experience can be in-house or external.
- Experience can be learned, gleaned or purchased.
- Experience can be wrong. Or, at least not up-to-date.

On Obsession with Details

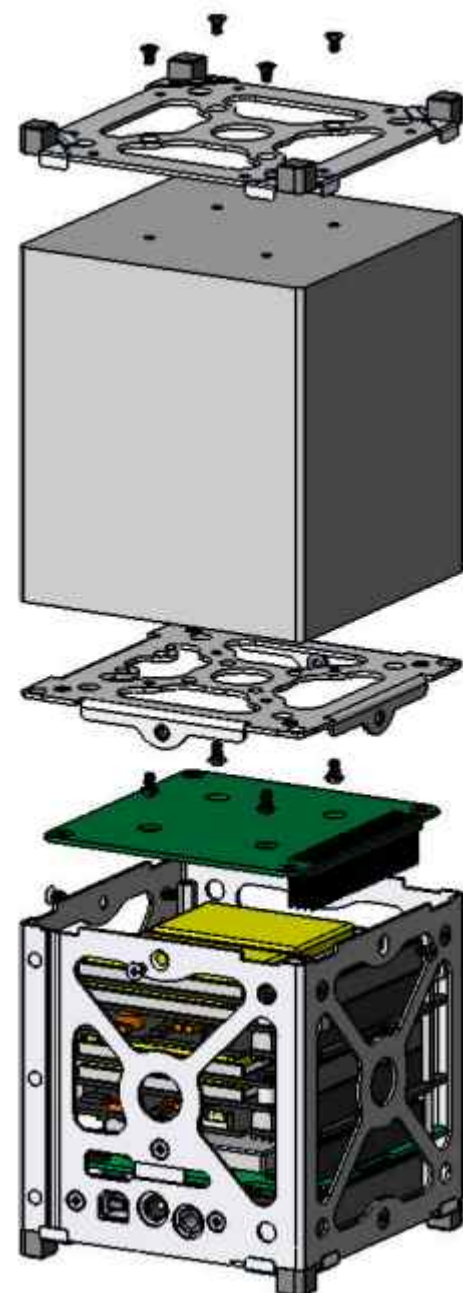
“It’s incredibly time consuming, you can spend months and months and months on a tiny detail - but unless you solve that tiny problem, you can’t solve this other, fundamental product.”

- To a great degree, details can separate a good product from a great one. How does it stand the test of time?
- Details may evolve over the life of a product with more experience, customer feedback, etc. This is natural. **Work this into your manufacturing plan / schedule.**



Underutilized CSK Features

- *External payloads*
- *Off-body / deployed solar arrays*
- *Wiring-free interconnect schemes*
- *Customized structures*
- *“Back doors” via CSK connector*



Don't leave Earth without it

strong light modular scalable customizable affordable
www.cubesatkit.com

Slide 20

KISS Small Satellites Workshop
July 16-20, 2012



Concluding Thoughts

- ITAR continues to damage U.S. space industry, even in nanosats
- Do we really need 20+ different bus architectures, when open launch slots go unused? *Lack of payload focus.*
- COTS in LEO has proven to be eminently capable ... yet end-users exhibit strong reluctance to use it.
- **Balkanization of U.S. gov't initiatives means that market is not reaching critical mass.** Hence development can only be funded through expensive, relatively slow, and application-specific SBIRs, etc. And end-users pay \$\$\$.
- Community has not learned the lesson of PC vs. Macintosh
- Perfect is the enemy of Good Enough ... If you aim for perfect in nanosats, you will miss the cost-effective solution
- *Like PCs, CubeSats are disposable*



Don't leave Earth without it

strong light modular scalable customizable affordable
www.cubesatkit.com

KISS Small Satellites Workshop
July 16-20, 2012



Slide 21



Q&A Session

Thank you for attending this Pumpkin presentation at the 2012 Small Satellites Short Course!



Don't leave Earth without it

strong light modular scalable customizable affordable
www.cubesatkit.com

*KISS Small Satellites Workshop
July 16-20, 2012*



Credits

Quotes from an interview with Sir Jonathan Ives in the London Evening Standard, March 12, 2012.

<http://www.thisislondon.co.uk/lifestyle/london-life/sir-jonathan-ive-the-iman-cometh-7562170.html>



Don't leave Earth without it

strong light modular scalable customizable affordable
www.cubesatkit.com

KISS Small Satellites Workshop
July 16-20, 2012



Slide 23

Notice

This presentation is available online in Microsoft® PowerPoint® and Adobe® Acrobat® formats at:

www.pumpkininc.com/content/doc/press/Pumpkin_KISS_2012.ppt

and:

www.pumpkininc.com/content/doc/press/Pumpkin_KISS_2012.pdf



Don't leave Earth without it

strong light modular scalable customizable affordable
www.cubesatkit.com

*KISS Small Satellites Workshop
July 16-20, 2012*



Slide 24

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.

• Copyright notice

© 2000-2012 Pumpkin, Inc. All rights reserved. Pumpkin and the Pumpkin logo, Salvo and the Salvo logo, The RTOS that runs in tiny places, CubeSat Kit and the CubeSat Kit logo, CubeSat Kit Bus, nanoLab Kit and the nanoLab Kit logo, and MISC are all trademarks of Pumpkin, Inc. Don't leave Earth without it is a service mark of Pumpkin, Inc. All other trademarks and logos are the property of their respective owners. No endorsements of or by third parties listed are implied. All specifications subject to change without notice. Unless stated otherwise, all photographs, images and illustrations are the property of Pumpkin, Inc. and may not be used without permission.

Presented at the Keck Institute for Space Studies' Small Satellite Workshop in Pasadena, California on Monday, July 16, 2012, at the California Institute of Technology.



Don't leave Earth without it

strong light modular scalable customizable affordable
www.cubesatkit.com

KISS Small Satellites Workshop
July 16-20, 2012



Slide 25