Highly Integrated Design Approach For High Performance CubeSats

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Tyvak™ Company Background and Overview

- **Tyvak™ was Created to Address Unfulfilled and Growing CubeSat Needs**
  - Feedback From Customers Concerned that Needed Performance and Complete Solutions Were Not Supported by Existing Component & Kit Focused Suppliers
  - Advanced "Next Generation" CubeSat Components & Complete Vehicles To Support Operational and Scientifically Relevant Missions
  - Provide Complete Program Life-Cycle Expertise and Mission Development
- **The Tyvak™ Team Brings Experience and Unique Skills in CubeSats**
  - Co-Founders Scott MacGillivray and Jordi Puig-Suari Leaders in CubeSat Community
  - Experienced Developing, Testing, Operating and Launching "First Generation" CubeSats
- **Tyvak™ is Currently Undergoing Start-Up Operations**
  - Defining Details of Initial Products
  - Initial R&D and Consulting Services Work
- **Wide Range of Products and Services**
  - Complete CubeSat Bus and Vehicles for Advanced Missions
  - Direct Sales of Key Components and Product Suites to Support Other Organization's In-House Projects
  - Research and Development of Advanced "Next Generation" Products
  - Consulting Services for Mission and Vehicle Design
  - Launch Integration Services
- **Quick Response and Low Cost Solutions**
  - Experienced in Rapid Turn-Around Projects
  - Focus on Value-Added Work to Maintain Low Operating Cost Infrastructure
- **Blend of Creativity and Proven Engineering Expertise**
  - Custom Products and Services From Advanced Components to Full Space Vehicles
  - New Mission and Space Vehicle Approaches that Leverage the Unique Features and Capabilities of CubeSats

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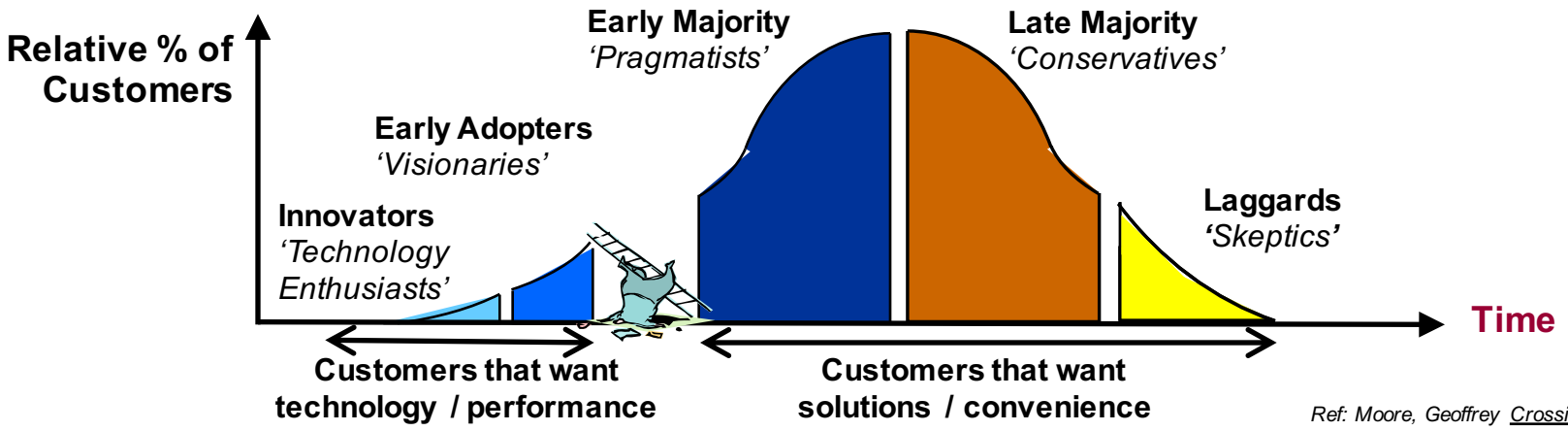
Diversification and Maturing of the CubeSat Marketplace

- CubeSat Principles Were Built Upon Keeping It Low Cost and Therefore Accessible on University Budgets
- As With Most New Technologies, It Is Morphed by Other Parties Who See Its Potential (Visionaries)
- CubeSat Technologies Are Moving To The Point Where People Are Thinking of Real Applications (Pragmatists)
  - Have we crossed the technology chasm?
- Diversification is Evident with Wider Variation of Educational and Industry Applications (e.g., NSF, Colony II, SENSE, GAINSTAM)



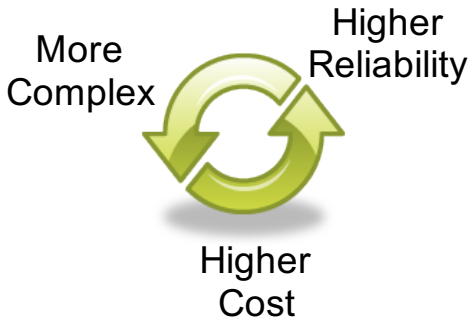
Ref: Moore, Geoffrey Crossing the Chasm

Growing Need for Mission Assurance and Advanced Capability

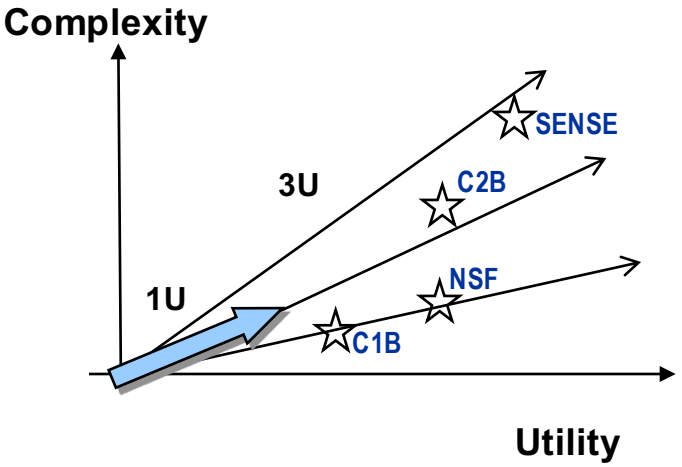
- Need to Balance with Keeping CubeSats Simple and Low Cost

- **As a Natural Progression of Technology, Things Become Increasingly Complex and More Diversified**

- **In The Beginning…**
  - Predominantly 1U CubeSats
  - Simple payloads
  - Mission life of weeks to months
  - Simple attitude control
  - Simple communications leveraging amateur equipment
  - 'Disposable'



- **… Progressing To …**
  - Numerous 3U CubeSats
  - Multiple payloads on a single CubeSat
  - Mission life of greater than a year
  - Precision 3 axis attitude control
  - Higher frequencies, larger bandwidth, and increasing COMSEC requirements
  - 'Higher Reliability'



Subsystem Performance Will Continue to Increase

- Driven by Mission Needs and Technology Development

Subsystem/ Requirement	Parameter	[units]	Current *	Mid-Term	Far-Term
			[Today]	[3 - 5 Years]	[5 - 10 Years]
C&DH	Performance	[MIPS/W]	< 500	<1000	>2,000
	Storage	[GB]	< 4?	< 24	> 64
TT&C	Frequency	[Band]	UHF/ ISM	S-Band	X-Band
	Bandwidth	[kbps]	< 50	< 500	> 2,000
	Data Security		AES/256	NSA Type 1	NSA Type 1
ADCNS	Knowledge	[deg]	<0.02	< 0.005	< 0.001
	Control	[deg]	< 0.5	< 0.05	< 0.01
	Navigation	[m]	> 200	> 50	< 10
Propulsion	Delta-V	[m/s]	< 25 ?	< 600	> 1,000
	Thrusters	[#]	1 - 2?	<= 8	> 8
	I_{sp}	[s]	< 60	< 280	> 320
EPS	Storage	[W-hr]	< 50	> 100	> 200
	P/L OAP	[W]	< 4?	> 10	> 20
Special Needs	Prox Ops		No	< 5km	< 200 km
	Re-Docking		No	Simple	Complex
	Re-Fueling		No	Yes	Yes
Mission Assurance	Redundancy	[strings]	None - Minimal	Selective	Multi-String
	Reliability	[%]	< 80 %	> 80%	> 95 %
Mission Life		[yrs]	< 1	< 3	< 7

* Generally known to have flown

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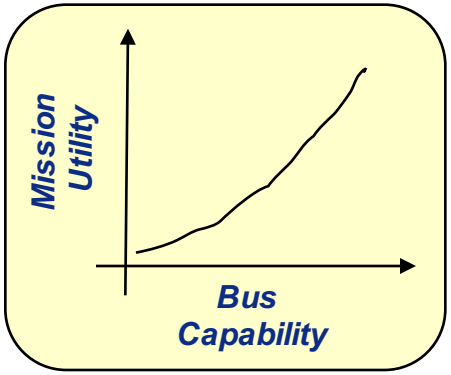
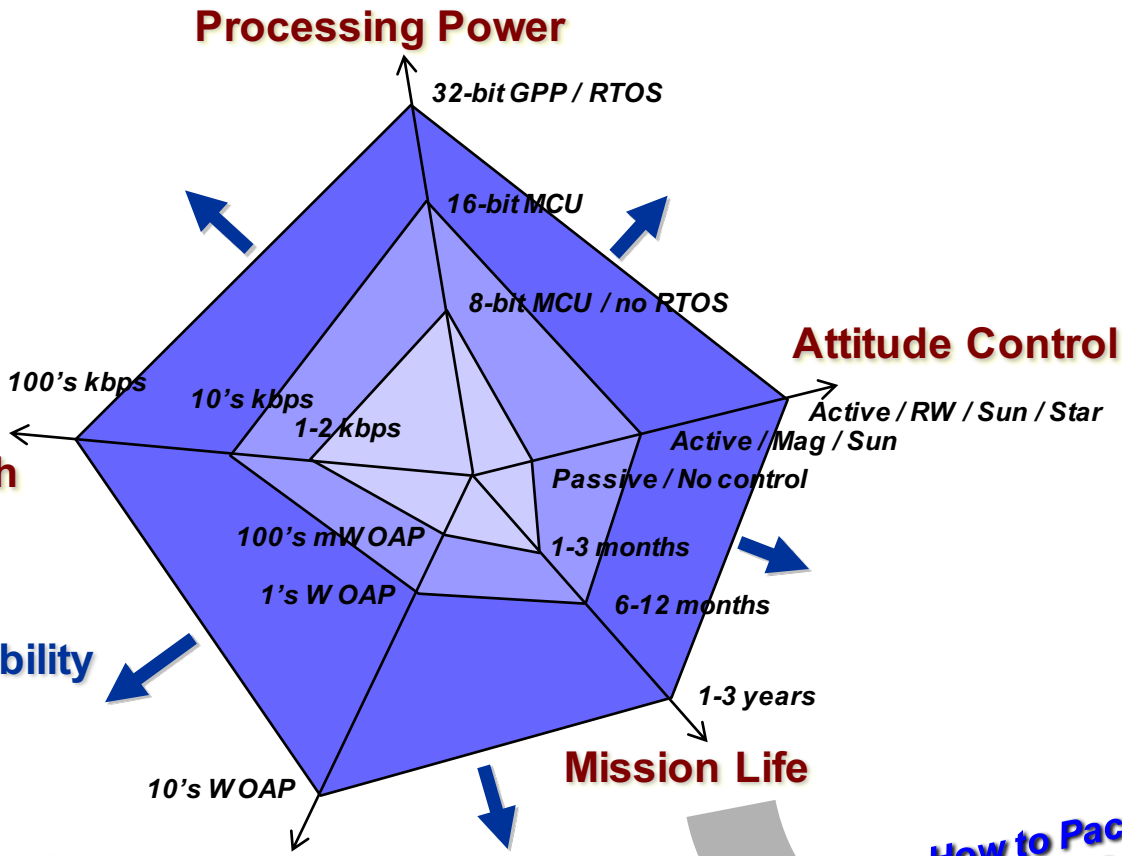
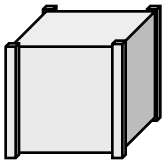
Technology Needs are Inter-Related

- Additional Capability Needed to Enable New CubeSat Missions

Evolution of Nano-Satellites-
Capability Growth is Inter-Related







Challenge: How to Package More Capability into CubeSat Envelope

Note: Values are Notional

New Approach Needed to Support Highly Integrated Systems

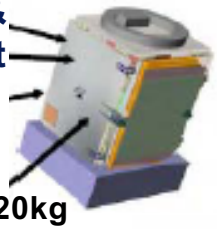
Current Approach to Small Satellites

SoA Space-Rated Boxes / Components
(smallest mass, power, and size)

Collection of Subsystems
(Integration of boxes and systems)

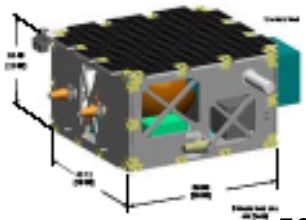
Examples:

AFRL Plug & Play Sat



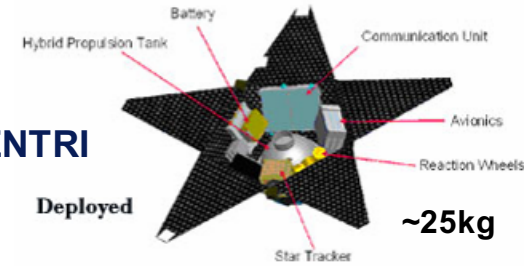
~120kg

LM ANGELS



~50kg

SpaceDev SENTRI



~25kg

Needed Approach to Get To Ultra Low Power & Size

SoA Space and Commercial Components
(smallest mass, power, and size)

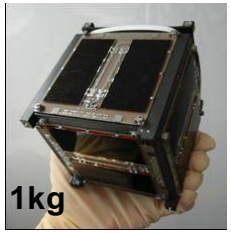
Highly Integrated System
(Integration of lower level components)

Examples:

Boeing Colony II Bus

4 kg

Cal Poly CP2 CubeSat



1kg

SSTL Snap

6-12kg

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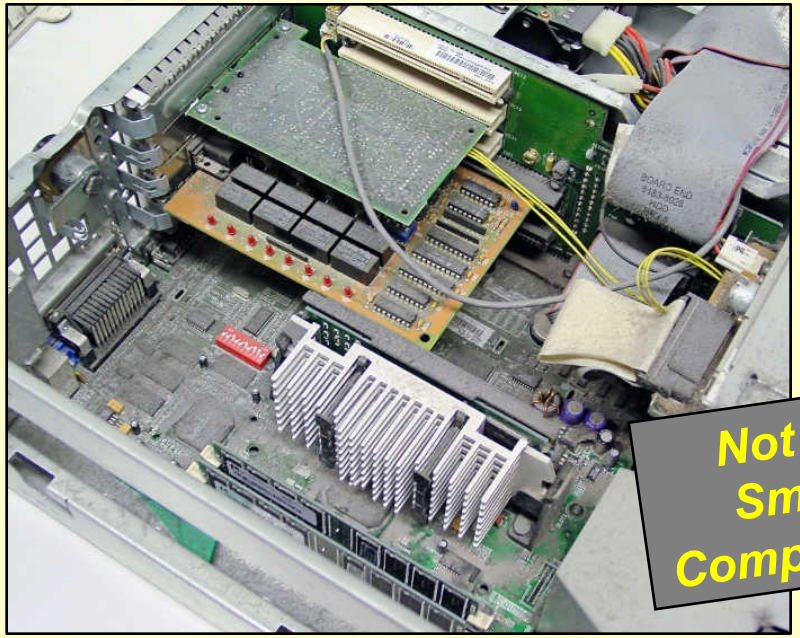
Unique Needs of Miniature, High Performance Systems

- A Different Design Approach is Required

- **Miniaturization Requires a Highly Integrated System Solution Approach**
  - Can't just bolt together group of disparate components
  - Need to be designed as an Integrated System
  - Kit and modular approach can support low tech needs, but not high performance

- **Personal Computer**
  - Plug and Play allows for rapid customization by end user, however is highly inefficient packaging



- **Laptops and Smartphones**
  - Specialized components and design approach needed to provide highly efficient packaging

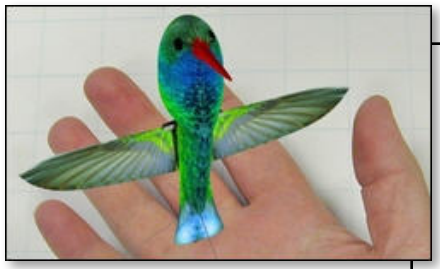
Not Just Smaller Components!

Examples of Other Complex Miniature Systems

- Utilize Different & New Approaches to Fabrication and Assembly

- **Use of Novel Manufacturing Technologies**
  - Printed Circuit Boards as Structural and Multi-Functional Elements
  - MEMS Technology
  - Rapid Prototyping; plastics and metals
  - Other Manufacturing Materials and Processes
    - Etched Ceramics, Layered Metal Foils, etc.

- **Require Many Similar Functions to Space Vehicles**
  - Attitude Determination and Control
  - Power Storage
  - Ultra-Low Power Use
  - Communication Interfaces



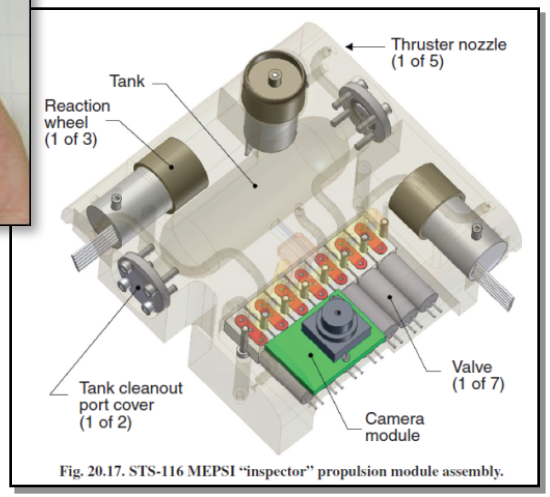


Fig. 20.17. STS-116 MEPSI "inspector" propulsion module assembly.

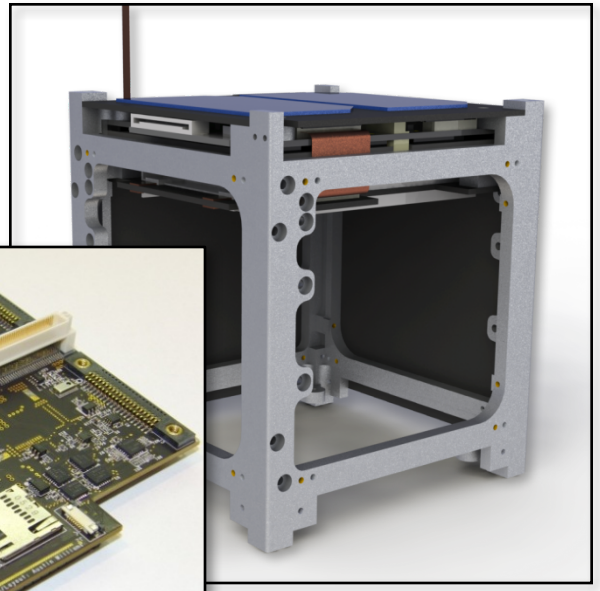
Courtesy of Aerospace Corp

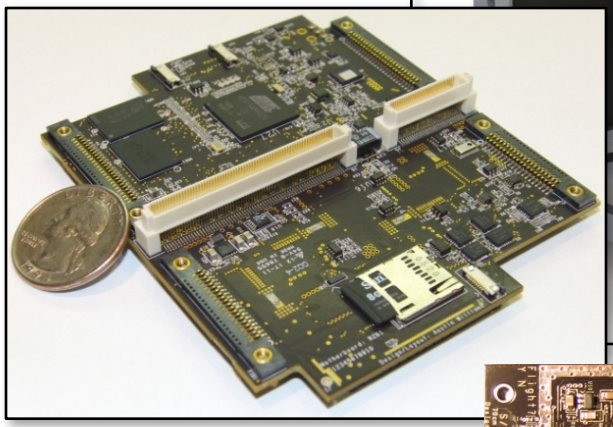
- **Modularity Becomes Less Beneficial**
  - The "Module" May Now Be at The System Level

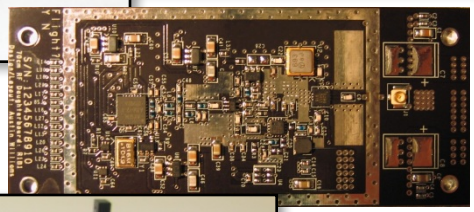
The Tyvak™ *Intrepid* Pico-Class CubeSat Suite

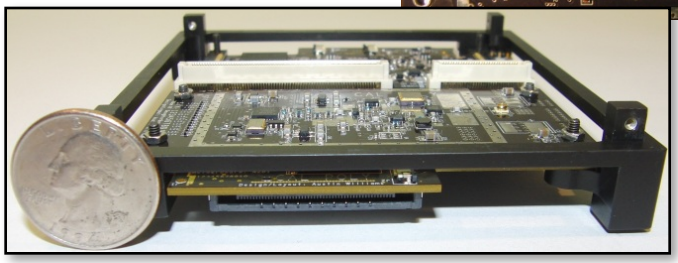
- *Integrated High Performance System Bundle*

- ***Intrepid* System Board**
  - 400Mhz ARM Processor; >512MB of Storage, 64MB RAM at <0.3 Watts
  - Embedded Linux
  - Integrated Power Regulation System and Sensor Suite
- **Low Profile UHF Radio Daughterboard**
  - 1W RF Out, Up to 250 kbps
- **Multi-Functional Side Panels**
  - 28% Solar Cells, Sensors, Torque Coils
- **High Strength Aluminum Structure**
  - "Pegboard" of Mounting Holes
- **Software Tools**
  - Open Source OS and Drivers
  - Simple Development Platform Available
- **Minimal Bus Volume**
  - Core Avionics, EPS, Communication, and Payload Interface in a 9 x 9 x 3 cm Package









For The Latest Tyvak™ *Intrepid* System Board and Suite Info:

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Tyvak™ CubeSat Product Family

- Suites of Highly Integrated High Performance Products

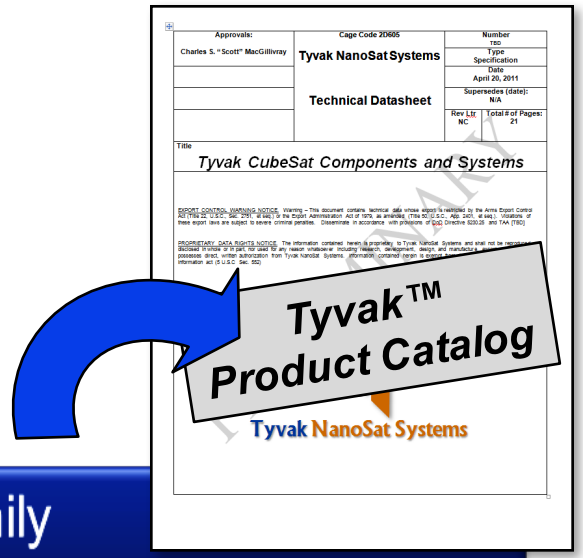
Two Complementary Product Groups

– ***"Pico-Class"*** **CubeSats**

- **Advanced Core Capabilities: System Board & Suite**

– ***"Nano-Class"*** **CubeSats**

- **Cutting Edge Capabilities: Higher Power, Precision Attitude Knowledge & Control, Radiation Tolerant, High Bandwidth, Fault Handling**



Tyvak™ CubeSat Product Family

Structural and Mechanical			EPS and Thermal Management					C&DH			ADCNS	
3U Frames	Custom Enclosures and Mounting Hardware	Deployable Hold-Down and Release Mechanism	PMAD PCBs	Battery Modules	Body Mounted Solar Arrays	Deployable Solar Arrays	Tracking Solar Arrays	Processor Daughter board	Rad Tolerant Option	Software Libraries	Adv Star Tracker	Reaction Wheels / Adv RWA

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Thank You !

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