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Nano-Satellites as Disruptive Technology

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Boeing IDS / Advanced Systems

- Responsible for Innovative Products Across Boeing

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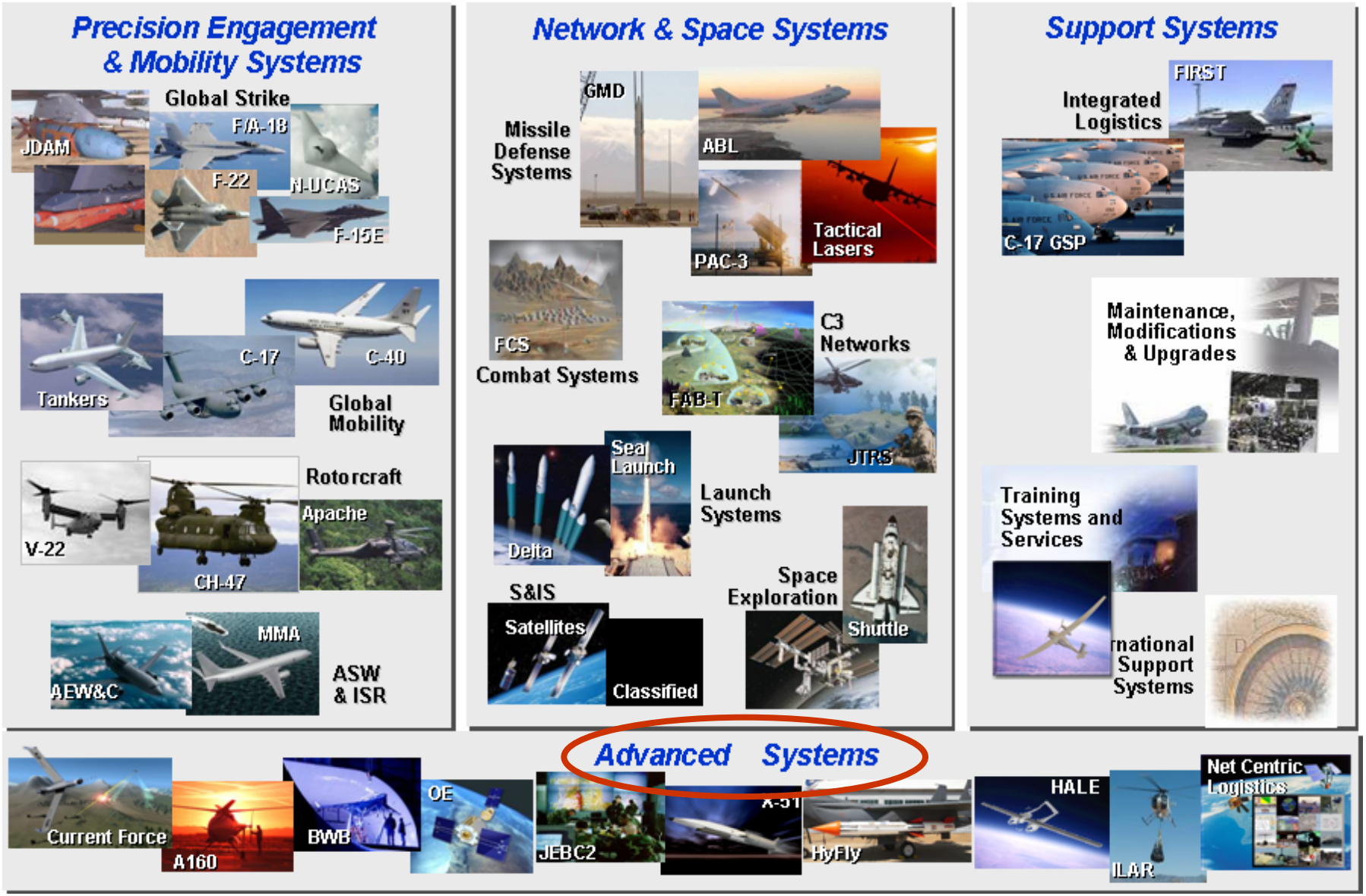


What is a Disruptive Technology?

- ***Sustaining technologies*** improve performance of established products, along dimensions of performance that mainstream customers in major markets have historically valued
  - *Breakthrough* sustaining technologies substantially improve product performance

Ref: http://www.tonh.net/museum/3flopsizes.jpg

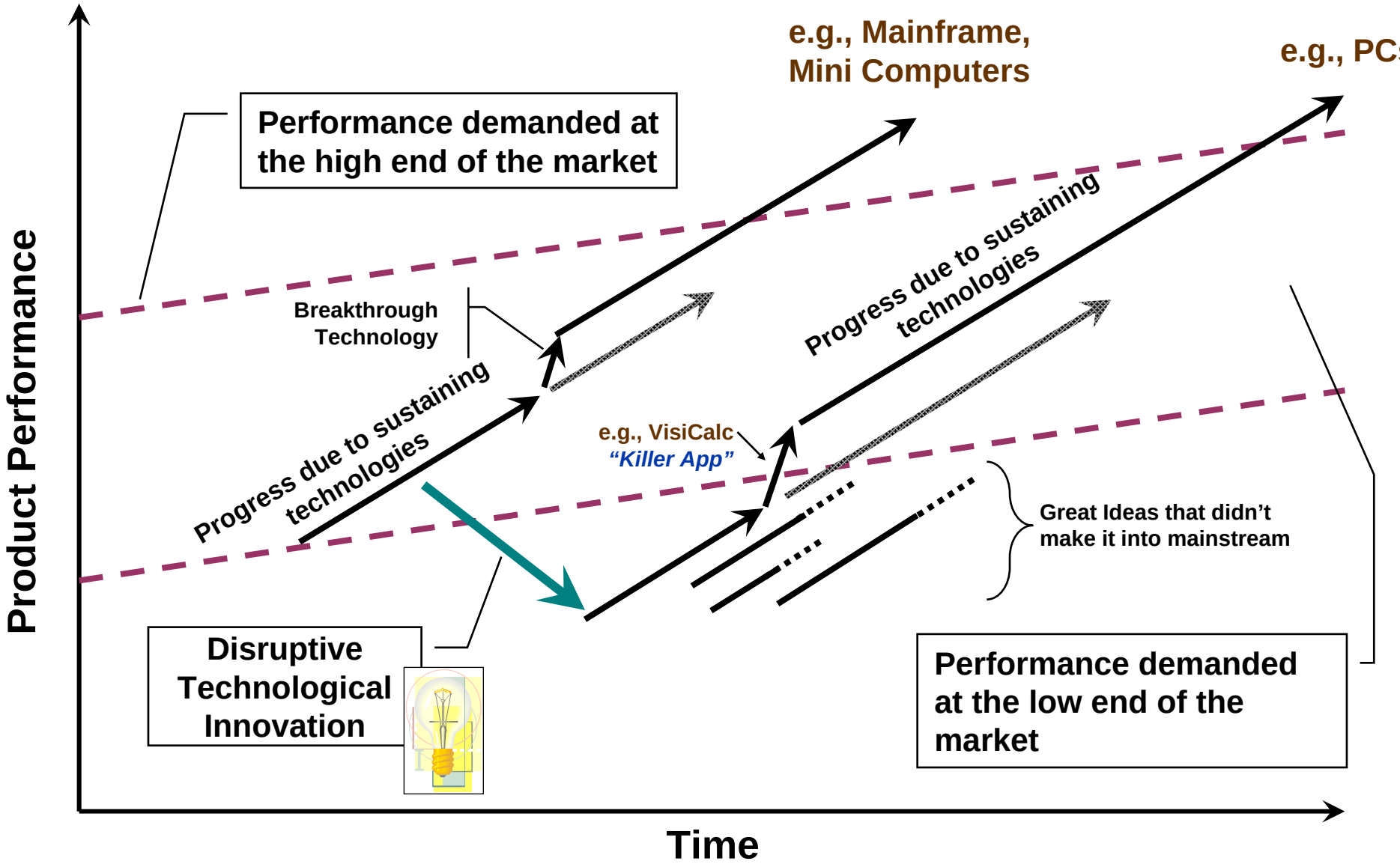
Ref: http://www.sharp.com

- ***Disruptive technologies*** bring to a market a very different value proposition that had not been available previously
  - Generally, disruptive technologies underperform established products in mainstream markets
  - But they have other features that a few fringe (and generally new) customers value
  - Products based on disruptive technologolies are typically cheaper, simpler, smaller, and frequently more convenient to use
  - Archetypical Examples:
    - Personal Desktop Computers
    - Transistors
    - HMOs

Ref: Christensen, Clayton M. The Innovator's Dilemma

Disruptive & Sustaining Technologies

- *Disruptive Technology Shifts Market*



Response to Disruptive Technology

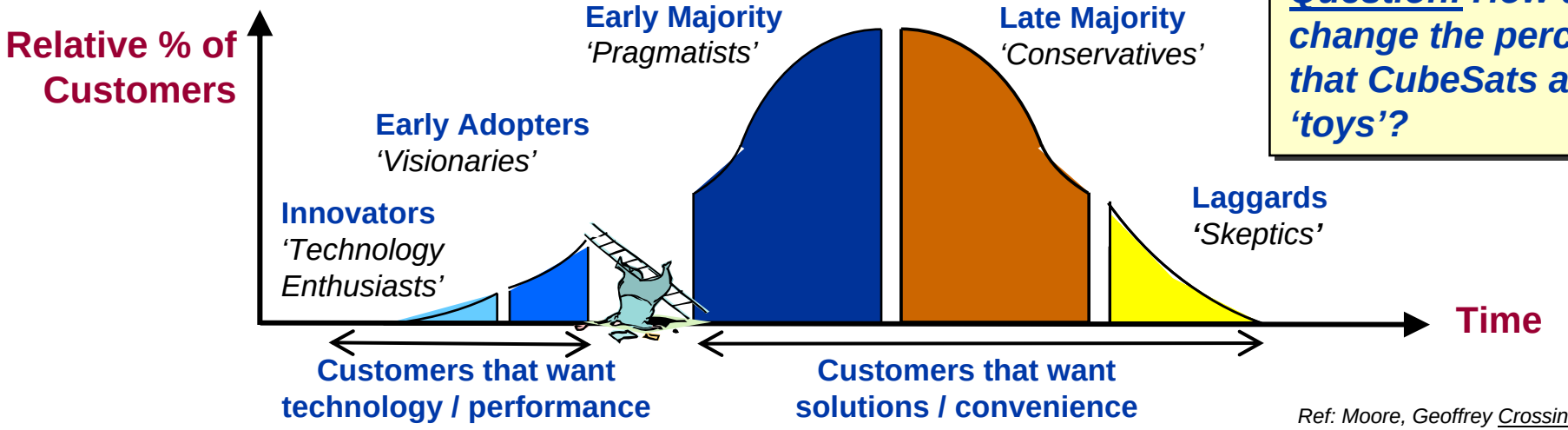
- Customer Reactions Vary Depending on Their Needs

- Disruptive technologies, though they initially can only be used in small markets remote from the mainstream, are disruptive because they subsequently can become performance-competitive within the *mainstream* market against established products

- Current Representative NanoSat Customers:
  - Universities
  - R&D organizations to test new components
  - Generally, leading edge "fringe" customers

By Definition, Disruptive Technologies are Defined by Their Influence on the Market

***Question:* How do we change the perception that CubeSats are 'toys'?**

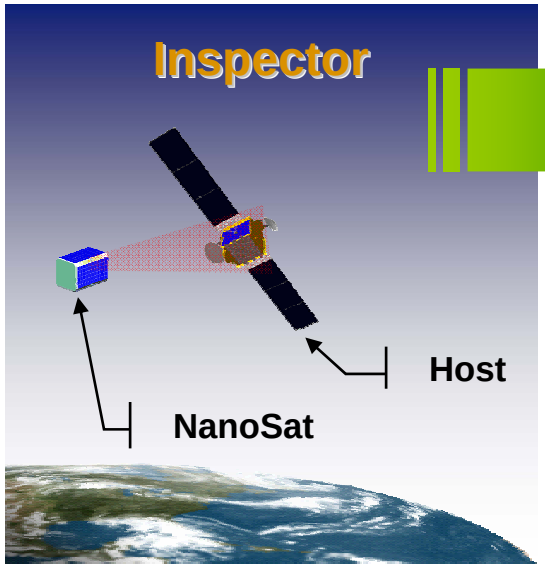


Ref: Moore, Geoffrey Crossing the Chasm

Representative NanoSat Missions

- Mainstream Missions will Define Technology Needs

NanoSats Currently Perform Unique Missions:



Inspector Mission:
- Anomaly Resolution and Assessment
- Additional Camera View During On-Orbit Operations

Other Candidate Missions:
- Space Situational Awareness
- Large Arrays & Formations
- Specialized Space Science

- Low Cost Launch [e.g., $/kg]
- Frequent Launch Opportunities

Small Technologies for Spacecraft:
- Development of Miniature Components
  - Application to all Space Vehicles; not just NanoSats

Low-Cost Space Access Helps Drives Innovation

- Renewed Focus on Innovation

- **Launch Costs Often Prohibitive for Satellite Missions**
  - **Even the cheapest dedicated launches approaching $10Ms**
- **Forces Significant Pressure to be "Risk Adverse"**
- **Results in Path Towards Larger, Higher-Reliability and More Expensive Satellites**

- **NanoSats Bring a New Paradigm**
  - Ultra low-cost space access to space
  - CubeSat standard, launch brokering service, and regular launches
- Permits Higher Risk with Low Cost of Failure
- Leads to New Approach to Satellite Development
  - Inspires creative, 'out-of-box' thinking
  - Smaller systems facilitate rapid development cycles


"Asteroid" CubeSat

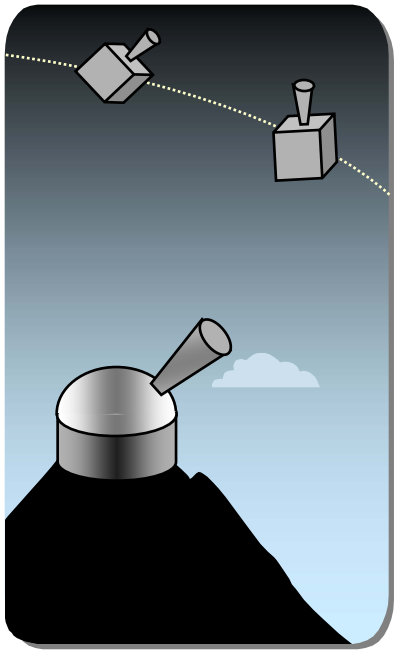
How Do We Measure the Utility of NanoSats?

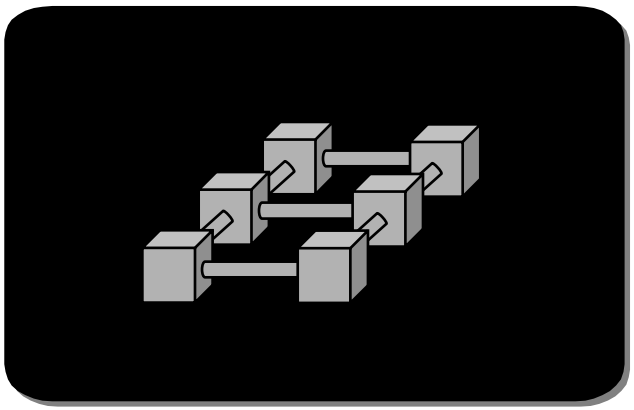
- How Do We Exploit the Strengths of NanoSats?

- Utility is Measured the Same Way We Do For Larger Satellites
  - Availability
  - Coverage
  - Resolution
  - Etc.
- Key Attributes of NanoSats
  - Cheaper to build and launch
  - Deploy in quantity
  - Small size

Operate in Proximity
- **Resolution**
- **Availability**

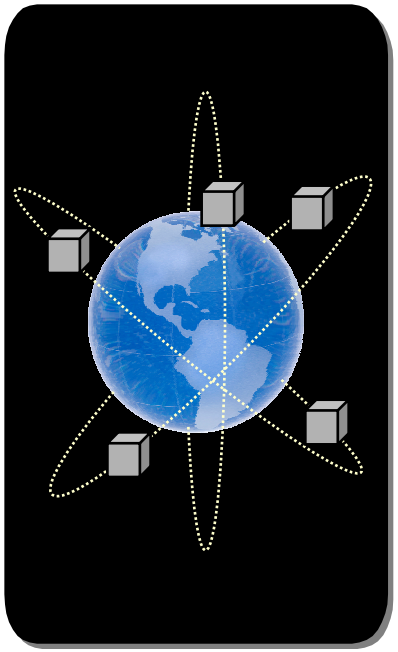
"A 5 inch television looks like a big screen when you are sitting 15 inches away"





Modular, Reconfigurable Vehicle
- **Adaptability**
- **Flexibility**

"Lego-Sats"

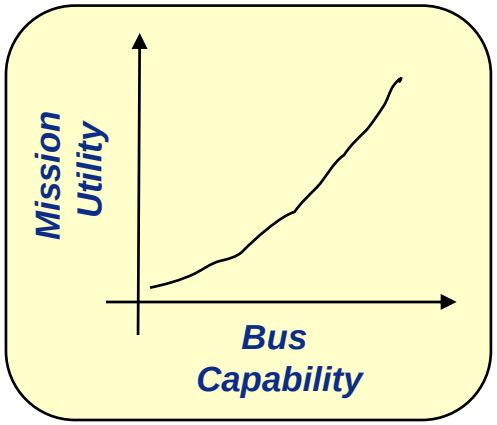


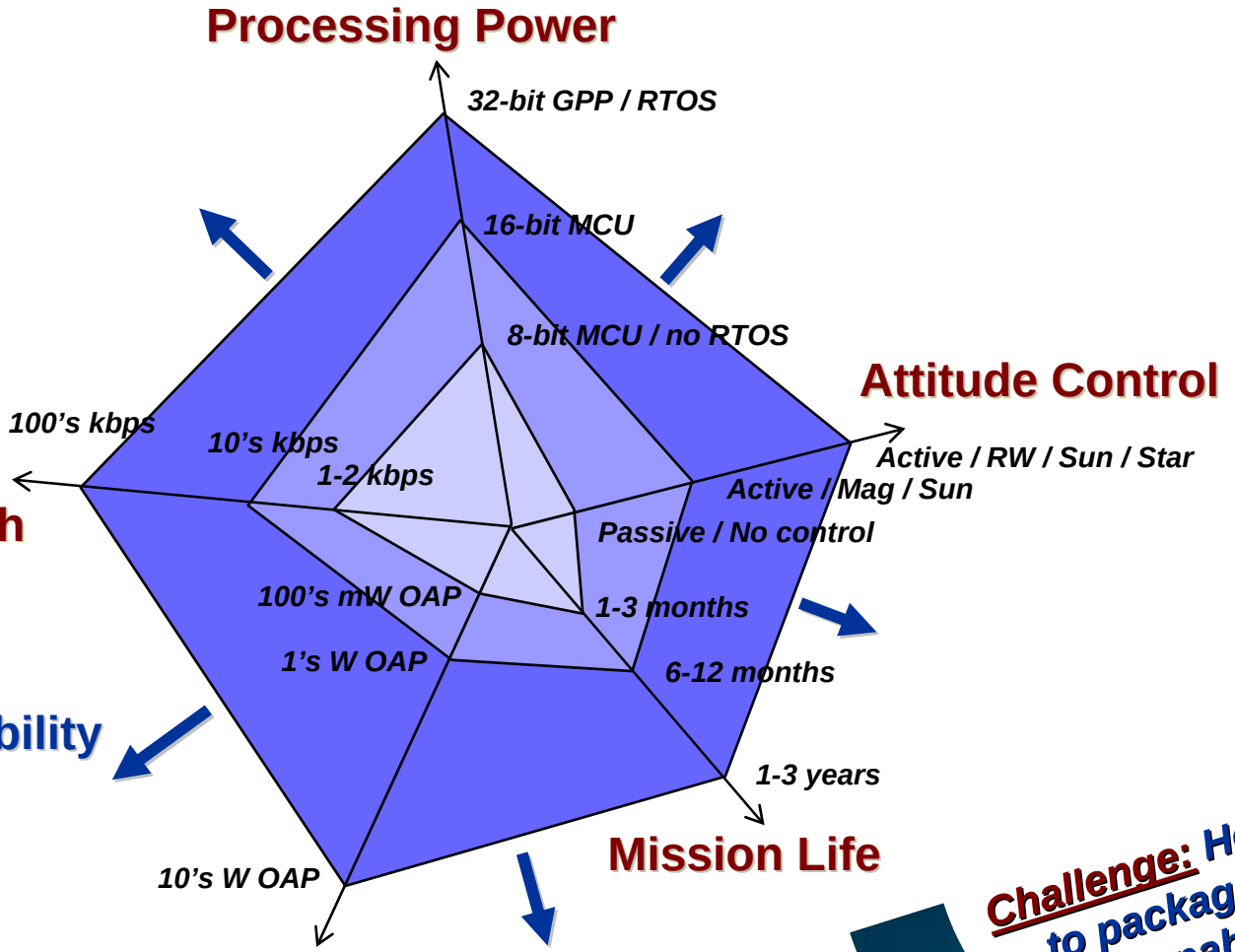
Deploy Constellations of Vehicles
- **Coverage**
- **Availability**

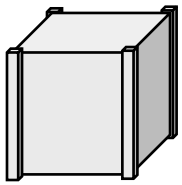
"Timely coarse data can sometimes be more important than high-fidelity, dated data"

Evolution of Nano-Satellites

- Growth in Capability is Inter-Related







Challenge: How to package more capability into CubeSat envelope

Note: Values are Notional

Needed Technology Development

- What We See Needed to Support Mainstream …

Needed NanoSat Capabilities:

Subsystem/ Requirement	Parameter	[units]	Current	Mid-Term	Far-Term
			[Today]	[3 - 5 years]	[5 -10 years]
Propulsion	Delta-V	[m/s]	~ 5 ?	< 30	> 200
	Thrusters	[#]	1 - 2?	4 - 6	> 12
	I_{sp}	[s]	~ 50 ?	> 50	> 200
Communications	Frequency		Amateur/ ISM/ S-Band	S-Band	S- & X-Band
	Bandwidth	[kbps]	< 10 ?	> 25	> 100
Attitude	Knowledge	[deg]	~ 1 ?	< 0.1	< 0.001
	Control	[deg]	~ 5-10 ?	< 1.0	< 0.01
Mission Assurance	Redundancy		0	Selective	Multi-String
	Reliability		< 50%	> 75%	> 95%
Mission Life		[yrs]	0 - 3+	3 - 5	> 8

If You're Interested in Being Part of the Team that's Going to Create the NanoSat "Killer App", Come Talk to Me ☺

Questions?