

# Summary

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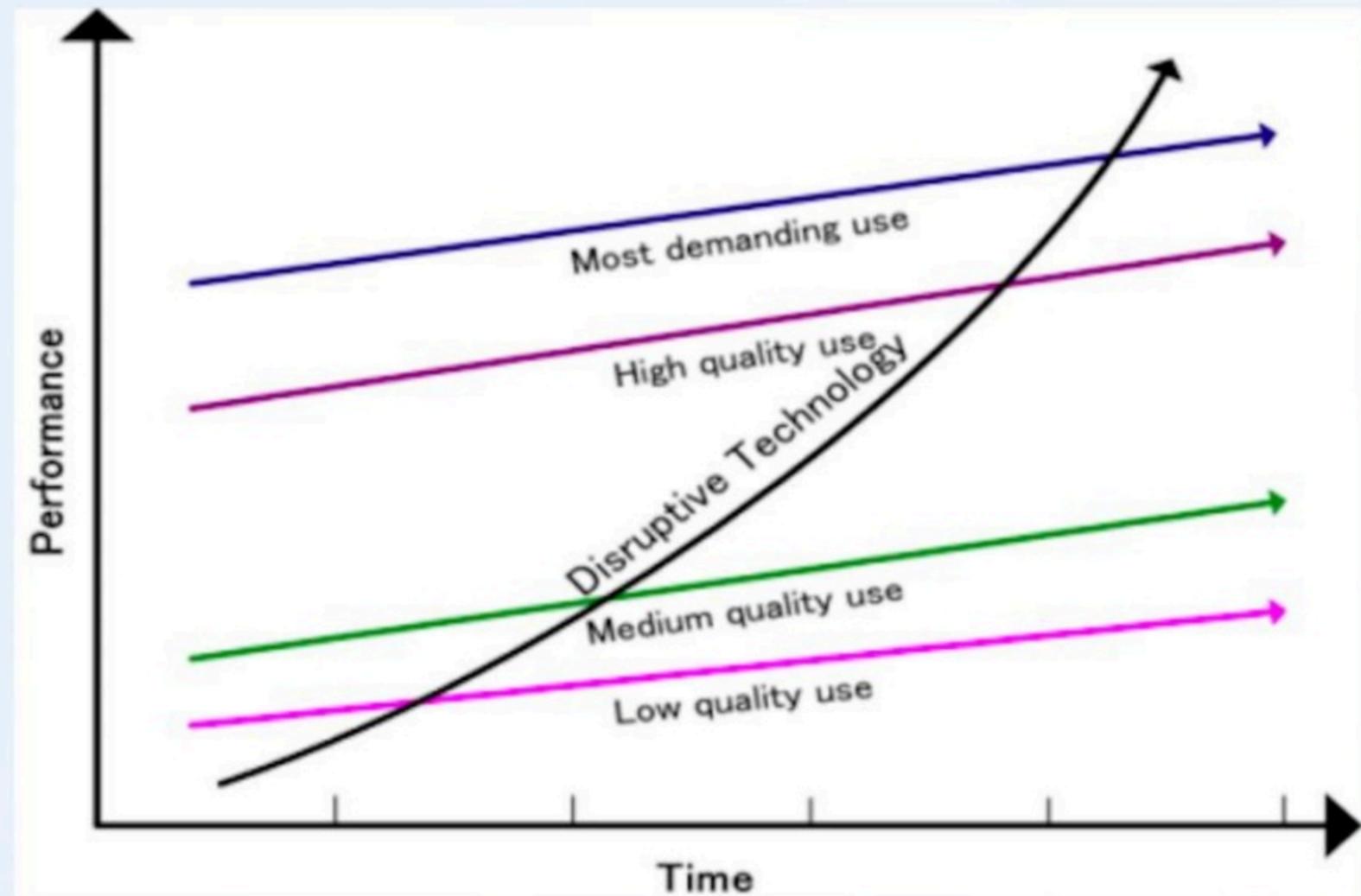
1. Nano-satellites based on the CubeSat standard are exponentially improving, creating counter-intuitively large increases in capabilities
2. This creates attractive solutions for communication and weather applications (which are less limited by the laws of physics as imaging, SAR and LIDAR applications)

# Disruptive Technologies Surprise

*A disruptive innovation creates a new market disrupting (destroying) an existing market sometimes within years.*

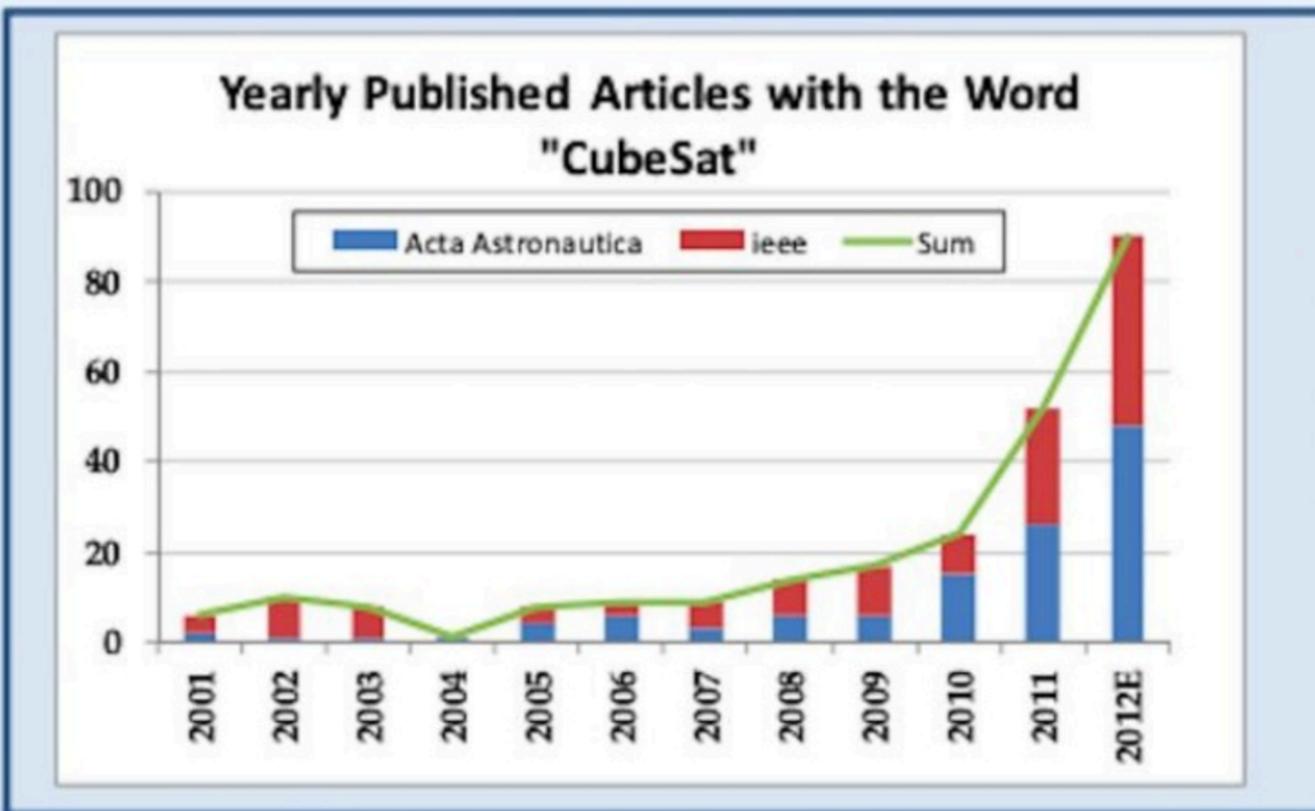
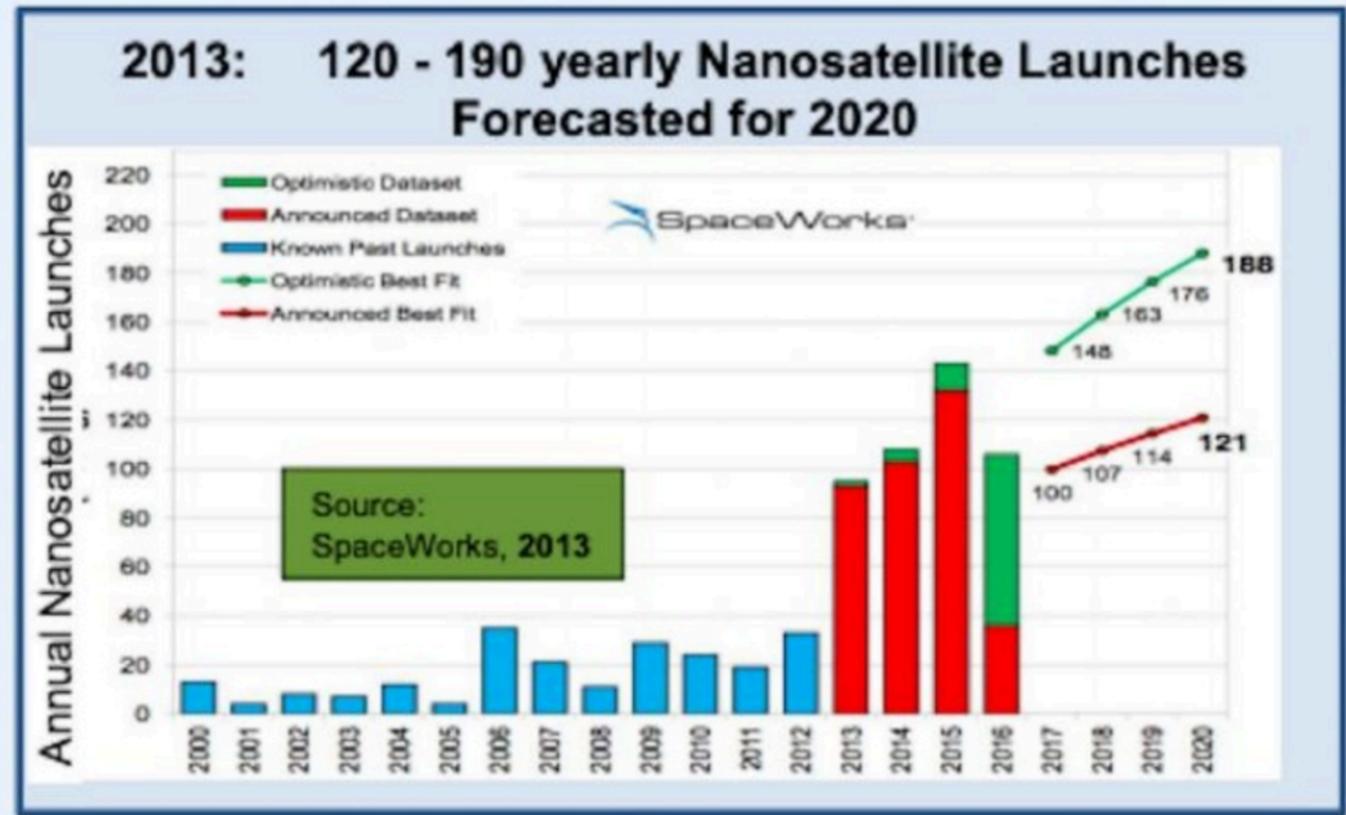
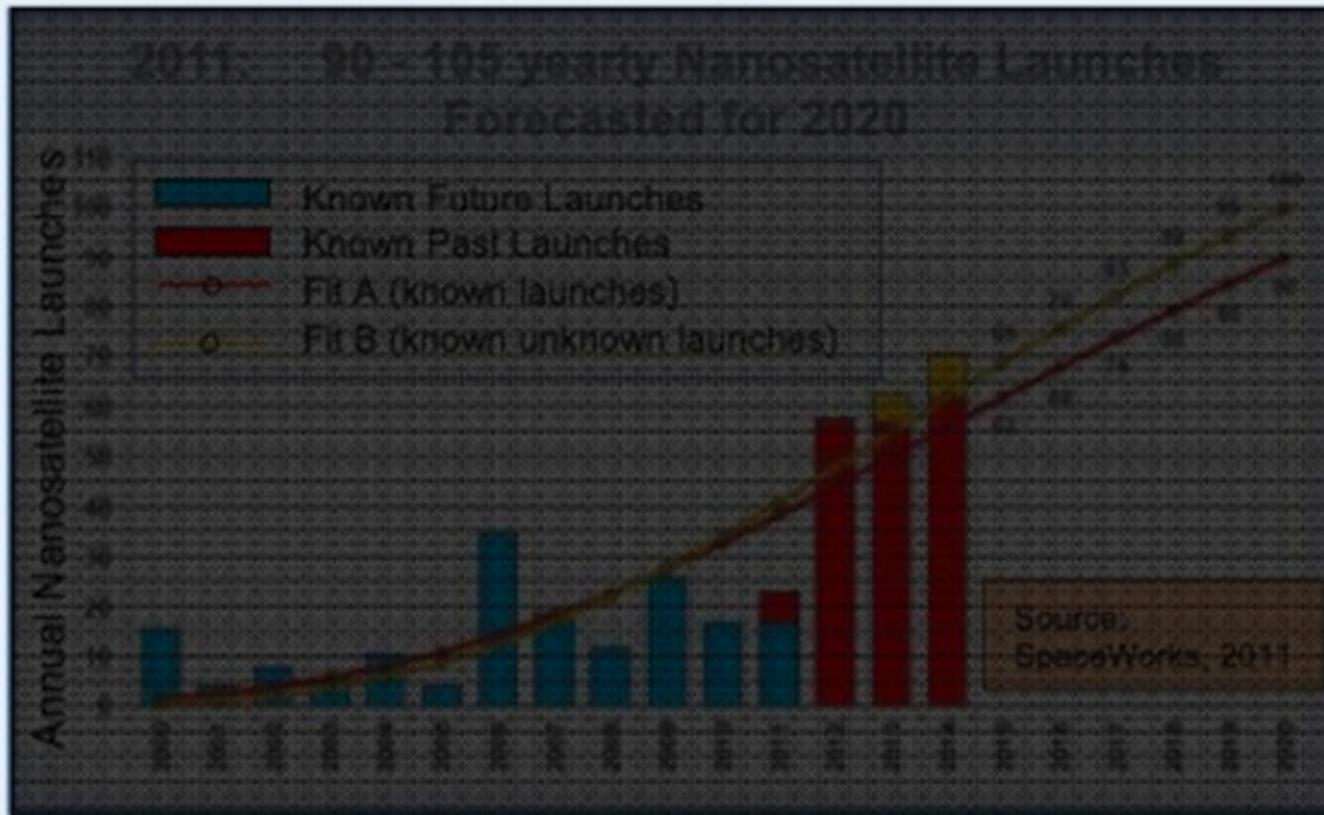
*The term describes innovations that improve a product or service in ways that the market does not expect, typically first by designing for a different set of consumers for lower prices than in the existing market.*

**Introduced by Clayton Christenson in 1995**



*Disruptive Technologies generally are improving exponentially and/or being adopted exponentially (e.g. via network effects)*

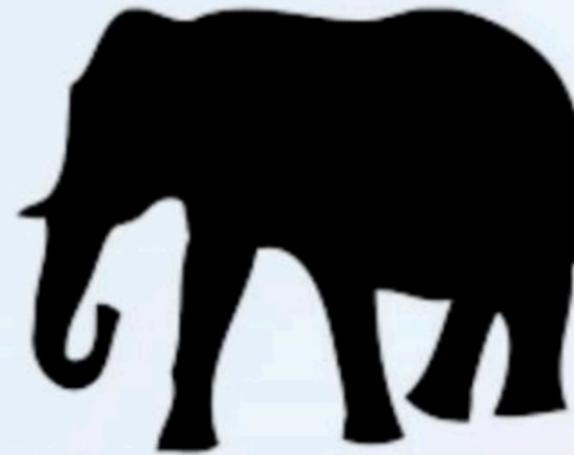
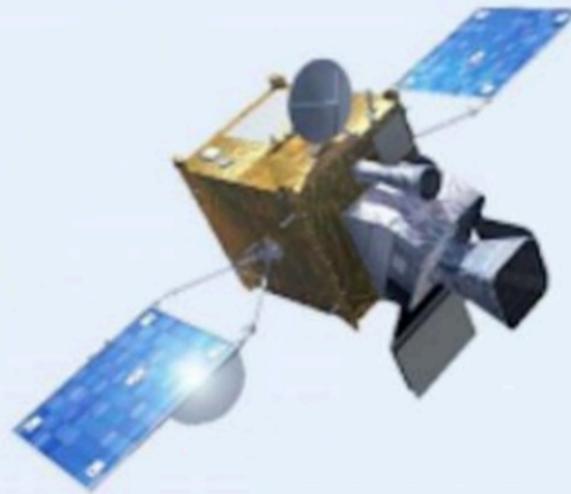
# Nanosatellites – A Disruptive Exponential Technology



- Typical for exponential technologies, forecasts have to be continually revised upward
- Use of and research in CubeSat technology is increasing exponentially

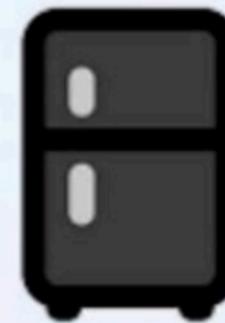
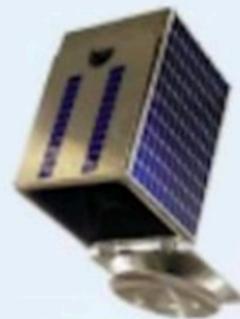
# Nano-Satellites have 1,000x lower cost

Traditional Satellite



\$500,000,000

Mini Satellite



\$25,000,000

Nano Satellite



\$500,000

\*Includes Launch Costs

# CubeSat Standard Solves Launch Bottleneck

## CubeSat Standard



- Size of a bottle of good wine
- Public standard invented in 2001 at Stanford and CalPoly
- More satellites launched (~125) with this standard than any other satellite standard
- Exponentially growing use, research and products

## P-POD Container



- Similar to shipping container in shipping industry
  - Certified on 12+ launch vehicles (more than any other launch container)
  - Enables “piggy-back” launch dozens of times per year
- **No dedicated launch needed!**

# Available Launch Capacity: Many 100s CubeSats/yr

Launch Vehicle	Demonstrated Annual Launch Capacity
Rokot	8
<b>Dnepr</b>	<b>26</b>
Delta-II/Delta-IV	7
Atlas-V	16
<b>Falcon</b>	<b>10</b>
Minotaur	4
H-IIA	8
Vega	10
<b>PSLV</b>	<b>10</b>
Taurus-XL	3
<b>Long March II</b>	<b>6</b>
<b>H2B/HTV</b>	<b>7</b>
<b>Antares/Cygnus</b>	<b>10</b>
Soyuz/Progress	10

- Launch negotiations started
- Launch purchased / performed

**U.S. Army, NASA Working on Low-Cost Nanosat Launcher**  
Nov. 19<sup>th</sup>, 2012

**LauncherOne: Revolutionary Orbital Transport for Small Satellites**  
Aug. 10<sup>th</sup>, 2013

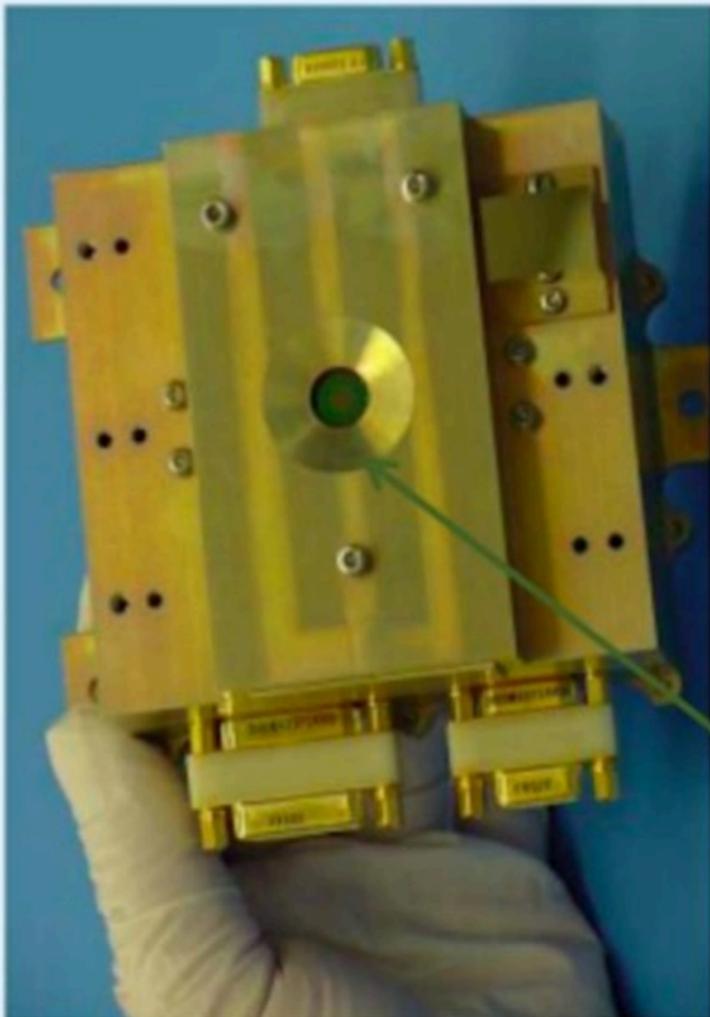
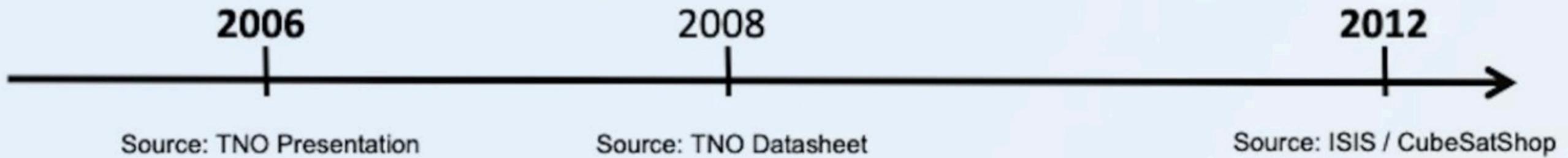
**NASA selects small businesses to build nanosatellite launchers with funding of up to \$39m for 2013 alone**  
Apr. 4<sup>th</sup>, 2013

**NASA's NEXT Step for Cubesats Is a Dedicated Launcher**  
Aug. 22, 2013

Launches limited by demand so far – approx. 125 CubeSats launched total.

Especially international launch providers are happy to replace dead ballast with paying CubeSats

# Exponential Sensor Improvements



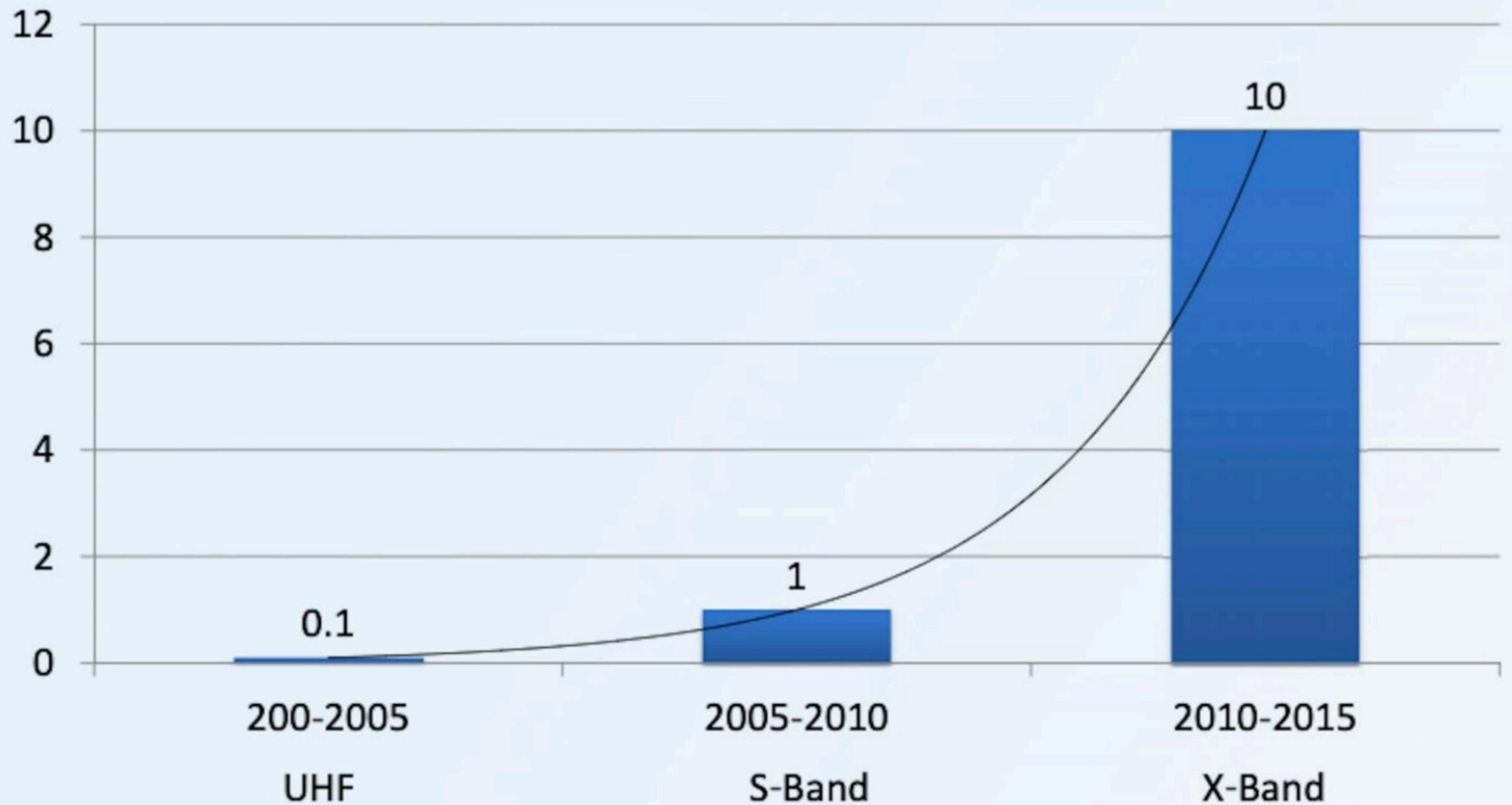
At least 1,000x price/performance improvement

Model:	TNO Digital Sun Sensor	TNO Fine Sun Sensor	www.CubeSatShop.com
Weight:	475g	365g	5 g
Price (1FM)	n/a	est. €15,000	€ 2,500
Size:	900.9 cm <sup>3</sup>	560.9 cm <sup>3</sup>	2.2 cm <sup>3</sup>

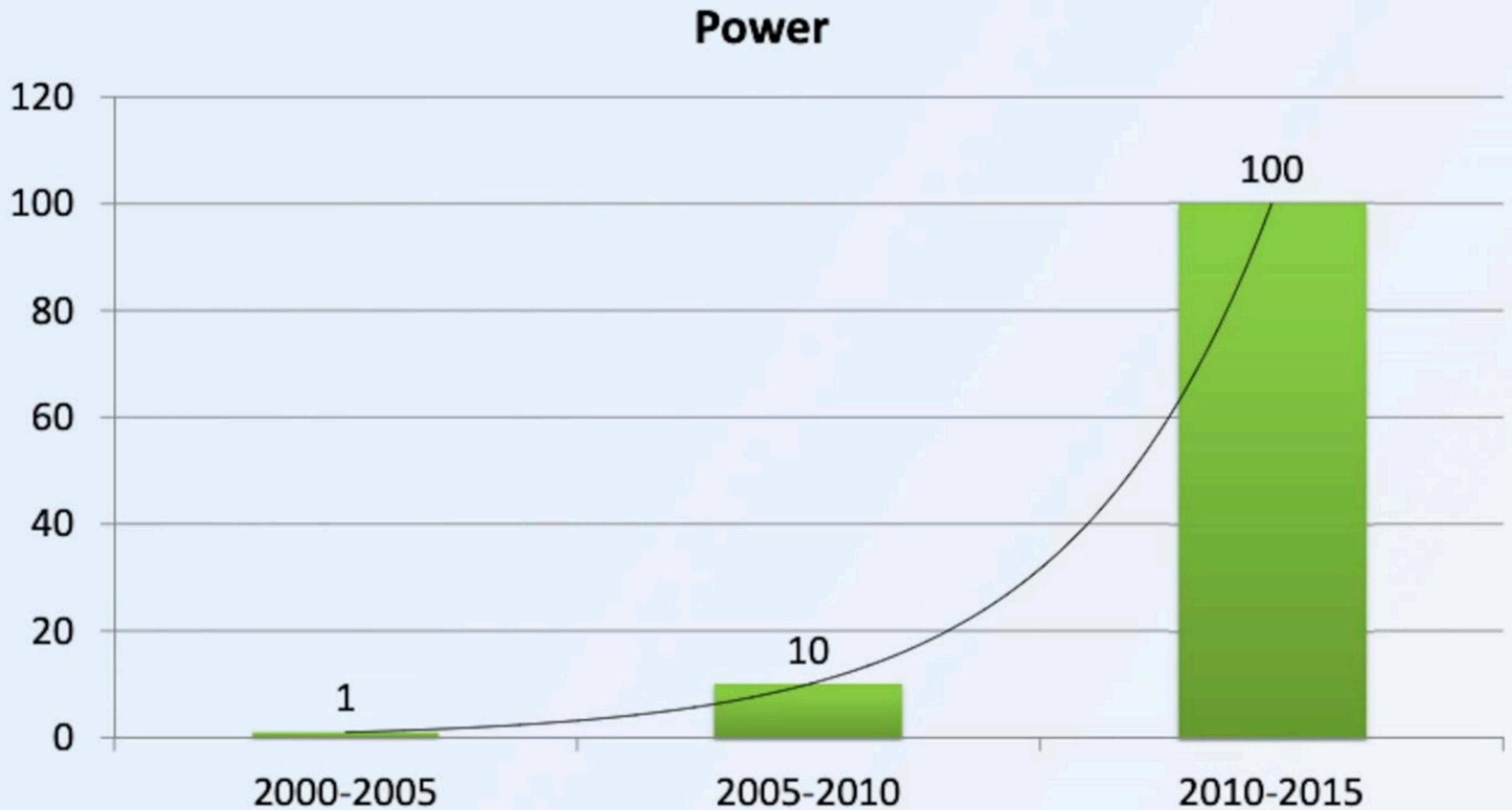
# Available Bandwidth of CubeSats

Microsoft PowerPoint - Exponential Nano-Satellite Technologies v1.pptx

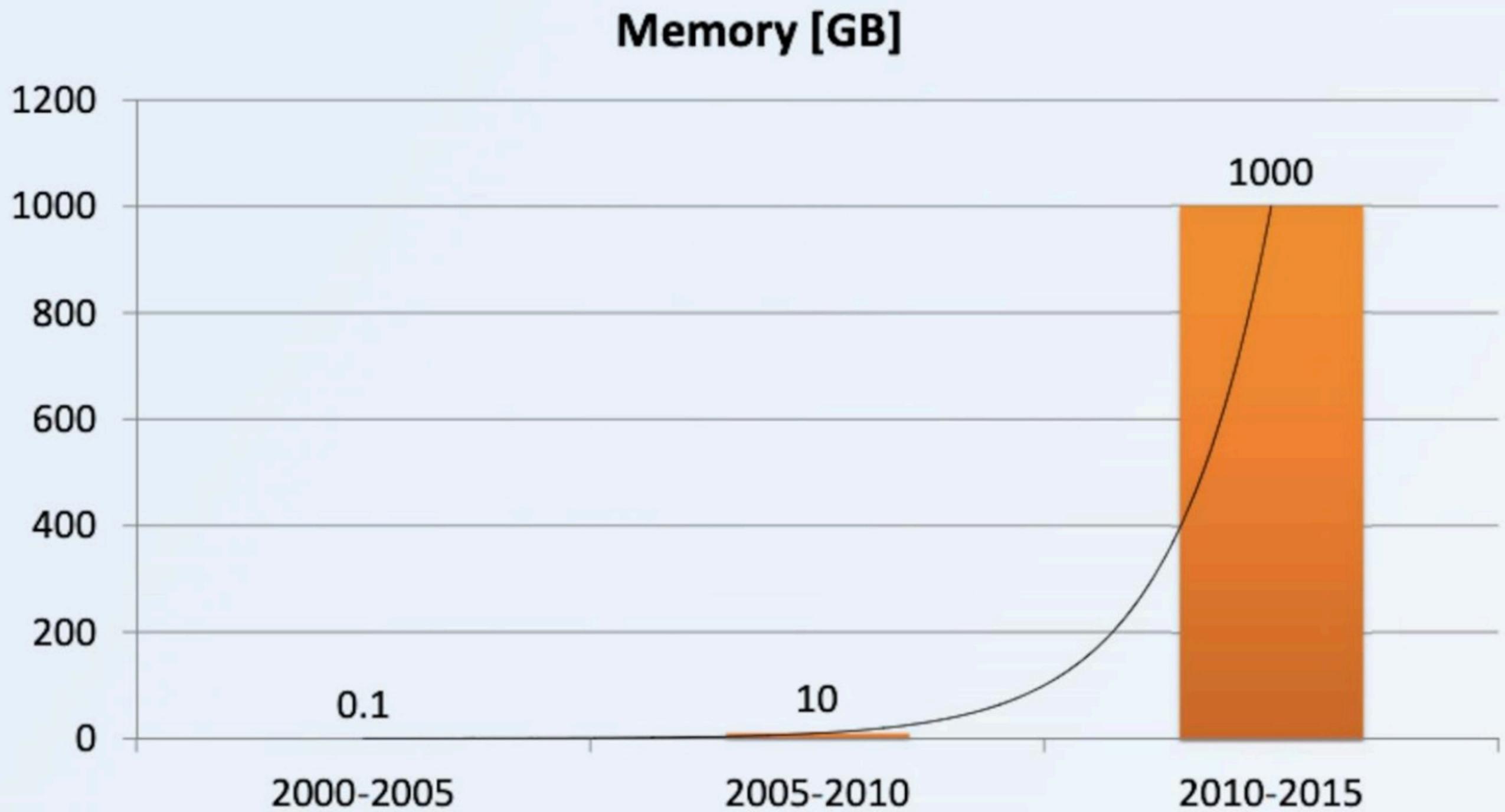
Bandwidth [Mbit]



# Available Power on CubeSats

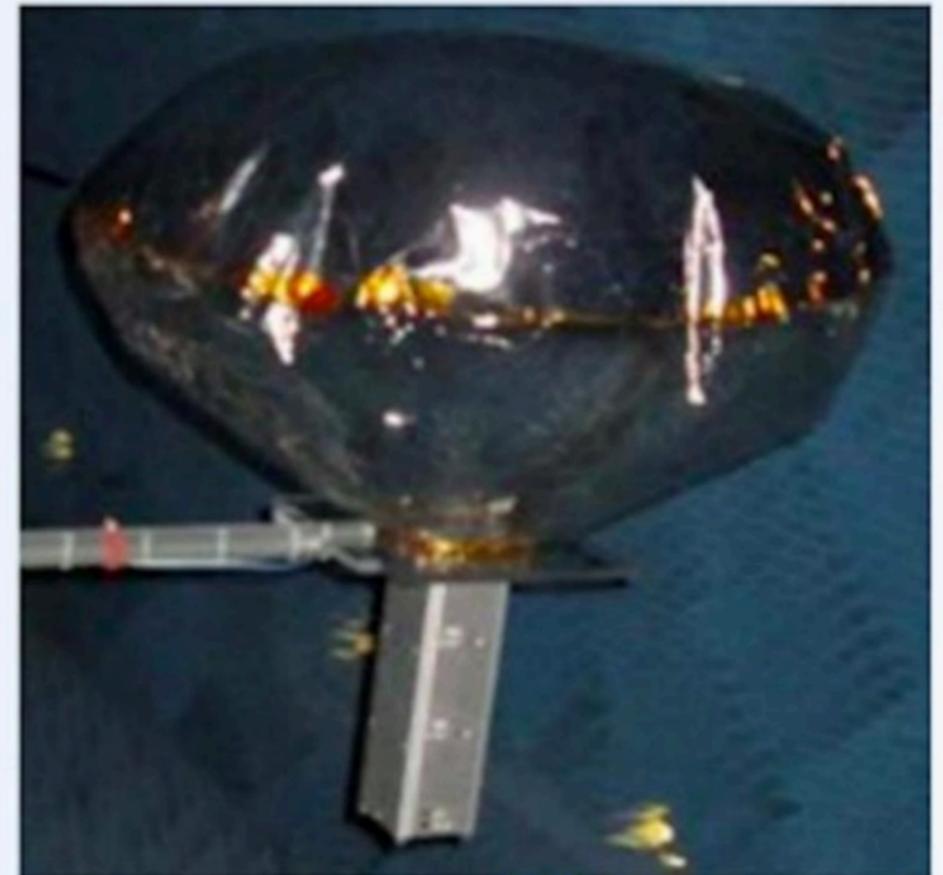
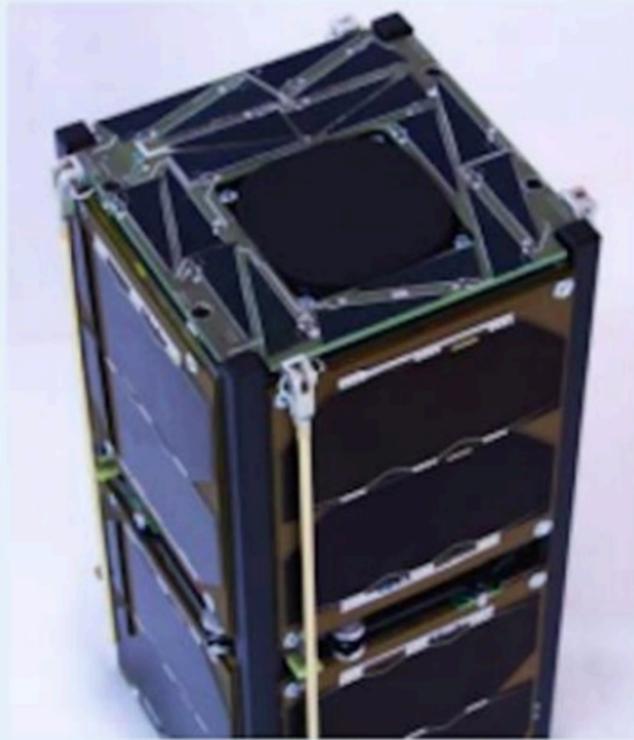
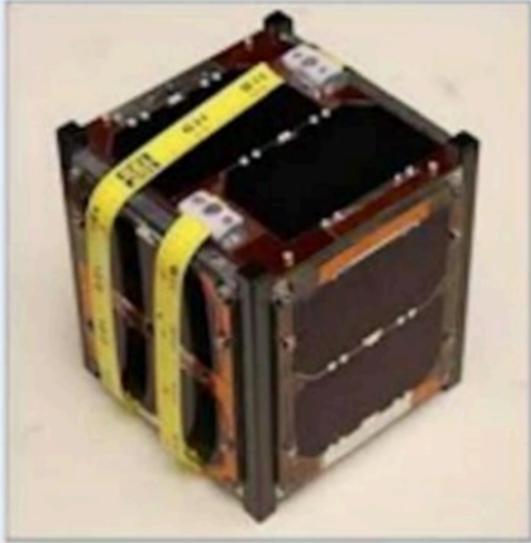


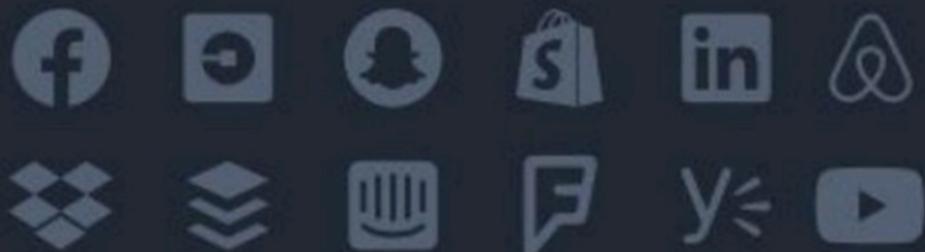
# Available Memory on CubeSats



# Exponential Antenna Capabilities

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