



## Nano/Microsatellite Launch Demand Assessment 2011

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Acknowledgements to Mr. Jeff Denis for contributions to this assessment

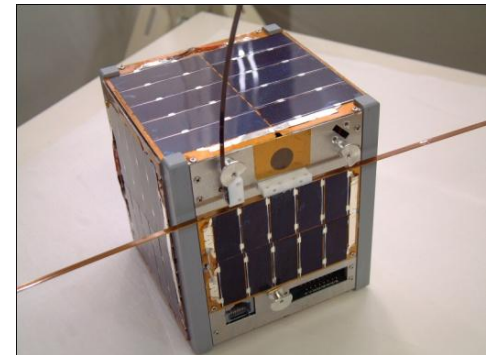
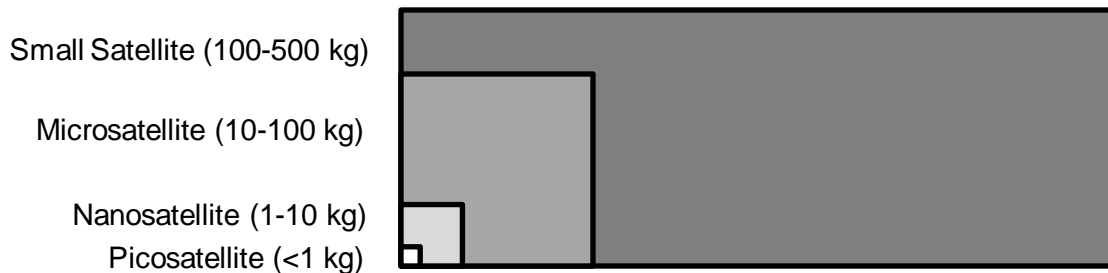
Note: External image sources are used for educational purposes only.

- **SpaceWorks Commercial presents its ongoing study of nano/microsatellite launch demand and future projections of such demand**
  - Objective to periodically present to global community
  - Subset of SpaceWorks Commercial **Orbital Satellite Database (OSD)**
- **For this study, nano/microsatellites refer to those with masses between 1 kg and 50 kg**
  - Combination of nanosatellites and the smaller half of microsatellites
  - Allows the study to be more applicable to the nano/microsatellite launch market
- **SpaceWorks Commercial has aggregated a database of known nano/microsatellites, both launched and planned**
  - Includes all known nano/microsatellites between now and 2014
  - Currently 180 known future nano/microsatellites in above database
- **Using quantitative estimates as well as reasonable qualitative adjustments, SpaceWorks Commercial has projected global launch demand in the nano/microsatellite market according to a Gompertz logistic curve to 2020**
  - Launch demand projection based on publicly announced plans
- **Projections indicate a strong increase in nano/microsatellite launch demand, with an estimated range of 100 to 142 nano/microsatellites (1-50 kg) that will need launches globally in 2020 (versus 23 in 2011)**

## Executive Summary

- **Generally accepted definitions of satellite mass classes under 500 kg**
  - **Small (100-500kg), Micro (10-100 kg), Nano (1-10 kg), and Pico (<1 kg)**
- **Many nanosatellites are based on the “CubeSat” standard**
  - **Developed in by California Polytechnic State University and Stanford University in 1999**
  - **Consists of any number of 10 cm x 10 cm x 10 cm units with mass of 1 kg (e.g. a 3U CubeSat has mass of 3 kg)**
  - **Standard allows for ease of design and integration**

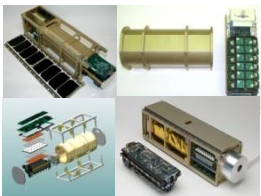
Visual Display of Small to Pico Satellite Scale



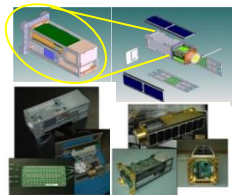
University of Tokyo's XI-IV CubeSat

## Definitions

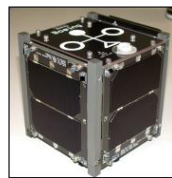
Characteristic	Value
Advantages	<ul style="list-style-type: none"> <li>Existing standard(s) such as CubeSats</li> <li>Lower cost of manufacture</li> <li>Easiness of mass production</li> <li>Lower overall cost of launch</li> <li>Ability to be launched in groups or "piggyback"</li> <li>Ideal test bed for new technologies</li> <li>Minimal financial loss in case of failure</li> <li>Faster building times</li> <li>Faster Innovation</li> </ul>
Developers	<ul style="list-style-type: none"> <li>Universities (100+ globally)</li> <li>Commercial industry</li> <li>NASA</li> <li>NSF</li> <li>DoD (AFRL, Army, DARPA, NRL, etc.)</li> </ul>



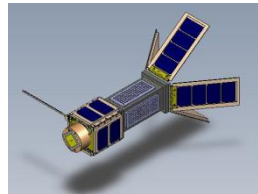
GeneSat-1



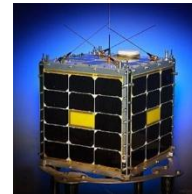
PharmaSat-1



Boeing CSTB1



Nanosail-D2

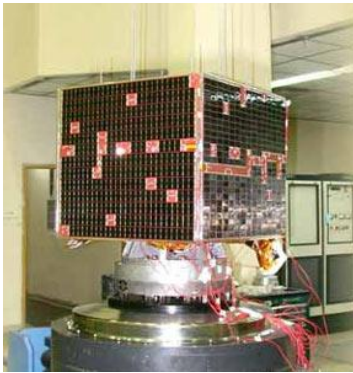


AprizeSat



Mayflower-Caerus

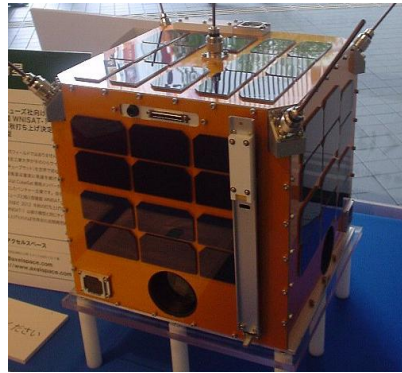
## Nano/Micro Satellite Characteristics



**Communications**

**HAMSAT**

Mass: 46 kg



**Remote Sensing**

**WNISAT**

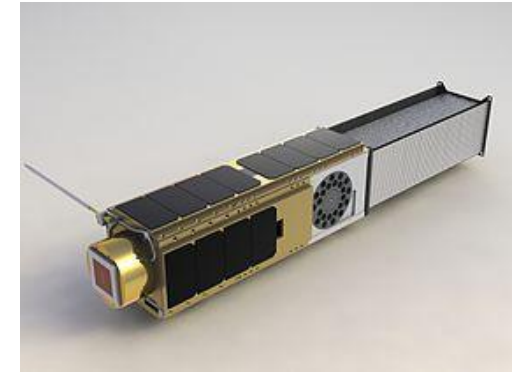
Mass: 10 kg



**Scientific Research**

**UNISAT**

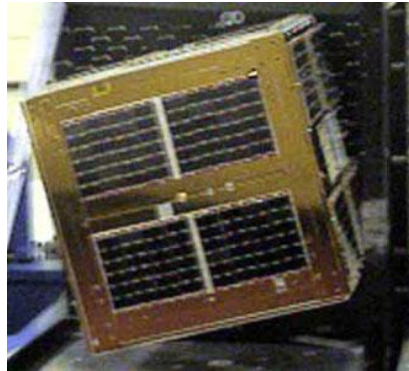
Mass: 1.5 kg



**Biological Experiments**

**O/OREOS**

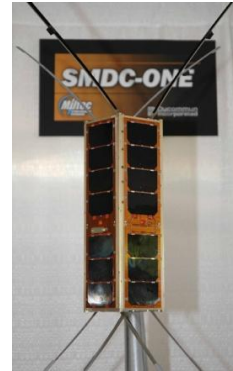
Mass: 5.5 kg



**Technology Demonstration**

**FalconSat 1**

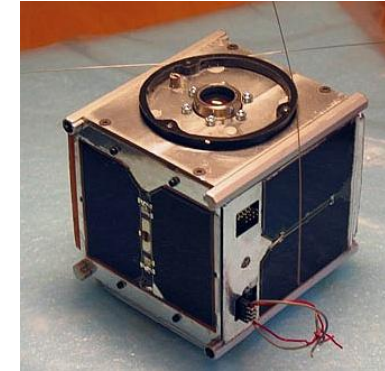
Mass: 50 kg



**: Military Application**

**SMDC-One**

Mass: 4 kg



**Academic Training**

**AAUSAT 2**

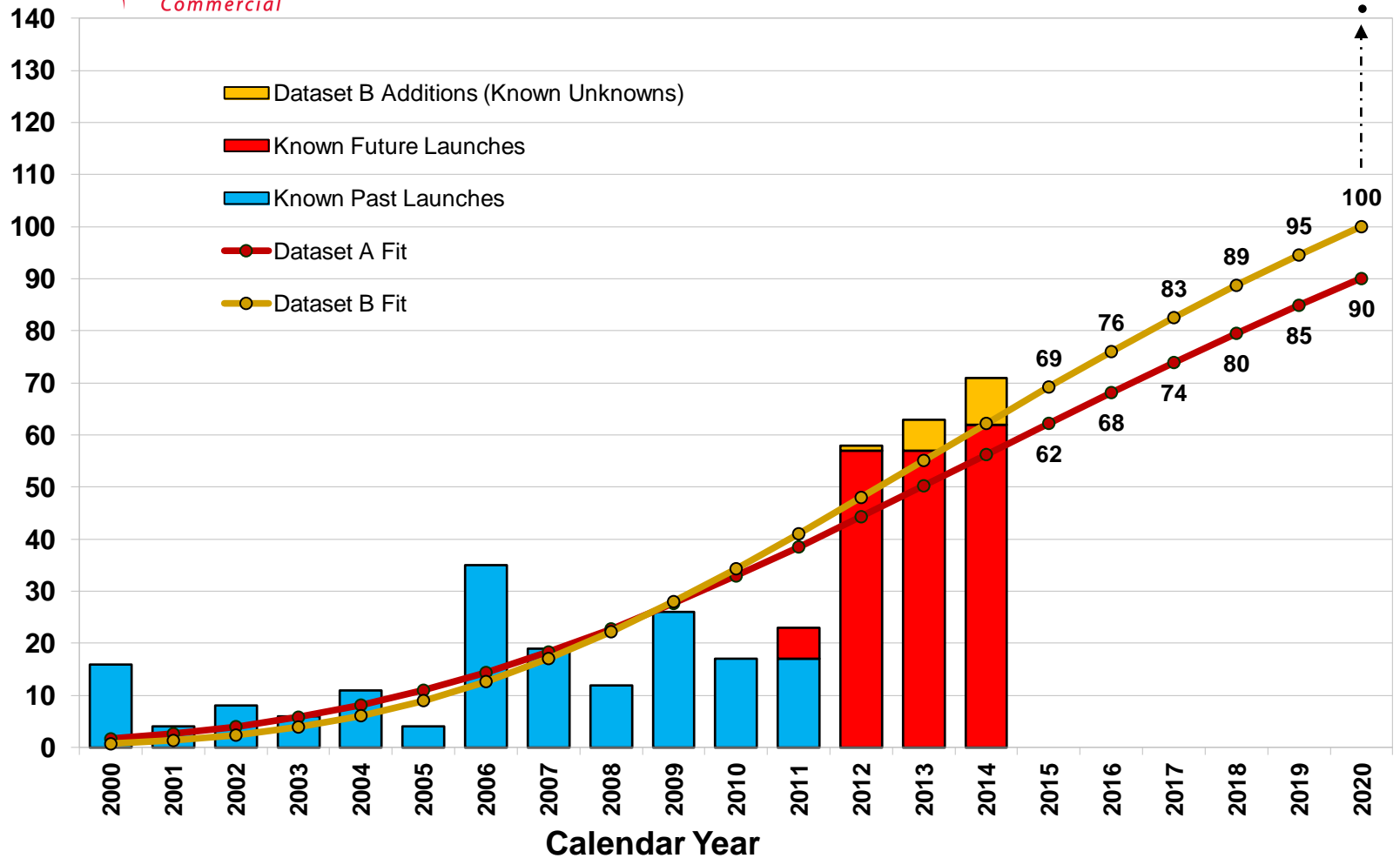
Mass: 1 kg

## Nano/Micro Satellite Applications and Associated Examples

- **SpaceWorks Commercial is actively tracking all future global nano/microsatellite projects for its Orbital Satellite Database (OSD)**
  - SpaceWorks Commercial has generated a launch demand based on both observations and quantitative data
- **Observations on new programs**
  - QB50 is an international project to launch a network of 50 CubeSats between 2013 and 2014
  - NRO Colony I will launch 12 CubeSats over the next few years
  - NRO Colony II will launch an additional 20-50 CubeSats following Colony I
  - DARPA Airborne Launch Assist Space Access (ALASA) plans to launch approximately 36 microsatellites beginning in 2015
  - Additional nano/microsatellite initiatives are underway, such as Innovative NanoSat Experimental Series (INXS) and DARPA F6
  - **There is a global nanosatellite movement, encouraged by the emergence of COTS solutions, turnkey solutions, launch brokers, nano/micro technology development, and overall non aerospace technology advancement that may account for bringing in new customers for new applications (including more commercial operators)**

## Nano/Microsatellite Market Observations

Number of Satellites (1-50 kg)



Notes: Source: DePasquale, D., Charania, A., "Nano/Microsatellite Launch Demand Assessment 2011", Revision A, 22 November 2011. www.spaceworkcommercial.com.

•Data values refer to attempted launches, and may include failures.

•The number of satellites "launched" may not equal the number of launches since many satellites are multiple-manifested (i.e. more than one satellite on a particular launch).

•The term "launch" or "launches" may refer to the number of satellites launched (even though they may be multiple-manifested).

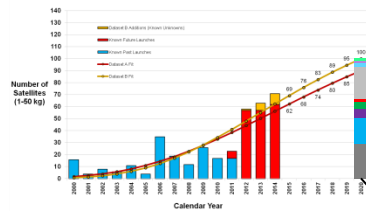
•Based on projections from past (blue) and future known "launches" (red) as analyzed by SpaceWorks Commercial's Orbital Satellite Database (Q4 2011 version), includes satellites with mass between 1-50 kg.

•Future projections from 2015-202 based upon Gompertz logistic curve regression estimate with market saturation point (launch demand asymptote in 2030) set at 150 nano/micro satellites in a year.

•Dataset contains all currently known past and future nano/microsatellite launches from the SpaceWorks OSD, with an inflating factor to account for the "known unknown" satellites.

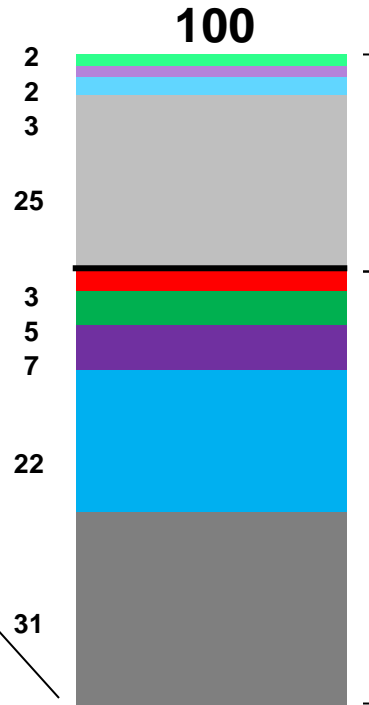
## Nano/Microsatellite Launch Demand History and Projections (Global)

**Nano/Microsatellite orbital launch demand is projected to increase to over 100+ satellites needing launches in 2020**

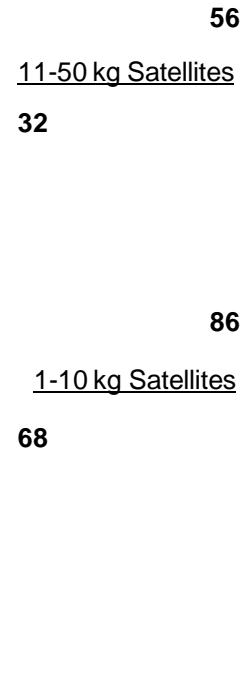


**SpaceWorks Commercial Nano/Micro Satellite Launch History and Projections (2000-2020)**

- Commercial
- Military
- Civil
- Academic
- Foreign (all types)



**2020 Projection Breakdown No. 1 Dataset B**



**2020 Projection Breakdown No.2 Dataset B + addition/sustainment of new programs**

**Notes:**

- The number of satellites "launched" may not equal the number of launches since many satellites are multiple-manifested (i.e. more than one satellite on a particular launch). Data may include failures.
- Many times in this presentation, the term "launch" or "launches" may refer to the number of satellites launched (even though they may be multiple-manifested).
- Based on breakdown between 2007 and 2011 according to the SpaceWorks Orbital Satellite Database, applied to the total satellites predicted for 2020 by the Gompertz logistic curve using Dataset B
- Breakdown No. 2 includes additional assumed QB50, Colony, ALASA, and F6 nano/microsatellites

# Breakdown by Type of Nano/Microsatellites Needing Launches in 2020 (Global)

- **The nano/microsatellite market has grown considerably with the adoption of the CubeSat standard, technology development, entrance of new developers, and furthering of applications**
- **Nano/Microsatellite launch demand has grown by an average of 4.38% per year since 2000, with an expected 22.5% growth per year over the next 3 years (2011-2014)**
- **In 2020 the global nano/microsatellite market may demand 100-142 launches per year**
- **The nano/microsatellite market is dominated by academic and non-U.S. satellites, but the military and civil markets are growing (especially in the U.S.)**
- **SpaceWorks Commercial will continue to update its Orbital Satellite Database (OSD) and Nano/Microsatellite launch demand assessment**
  - **Plan for twice yearly public update of nano/microsatellite launch demand**
  - **Database and more detailed assessment available for purchase for certain customers**

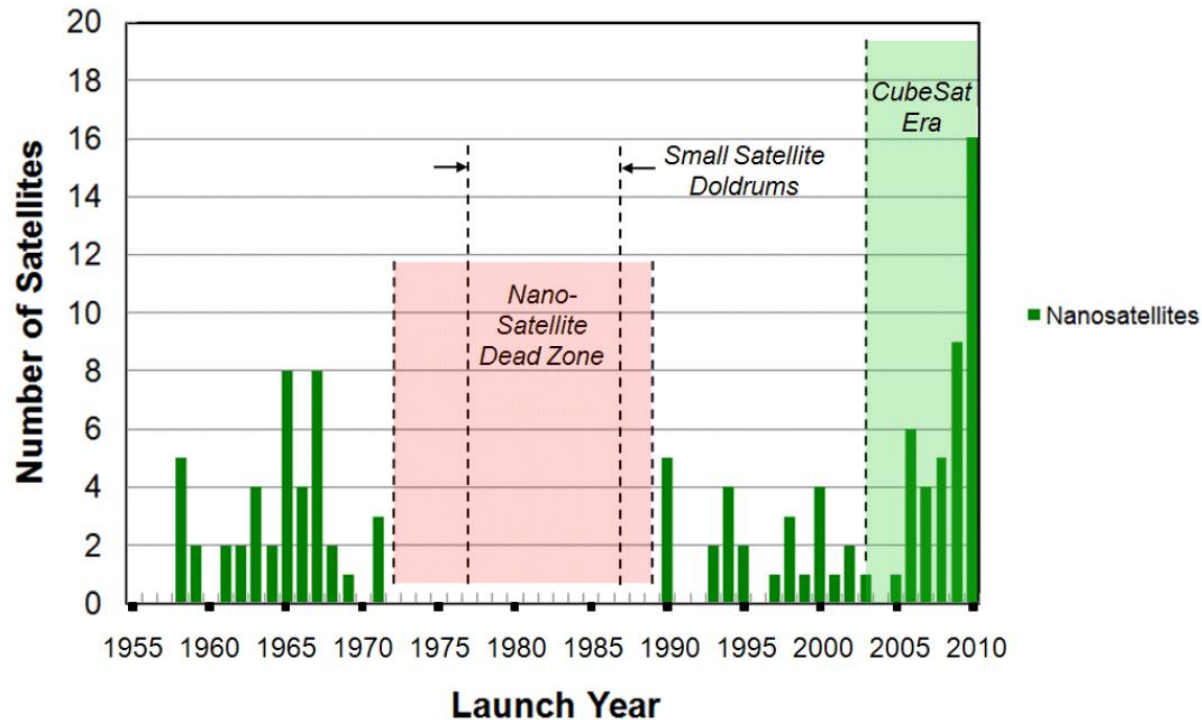
## **Conclusions**



## **NANO/MICROSATELLITE LAUNCH DEMAND: ASSESSMENT BACKGROUND**

- **Nanosatellites have existed since the beginning of spaceflight**
  - Many of the first satellites for the U.S. were nanosatellites
  - While not technically a nanosatellite, Explorer 1's mass was only 14 kg
- **No “active” nanosatellites were launched between 1972 and 1989**
- **CubeSat standard has driven an increase and resurgence in nanosatellites**

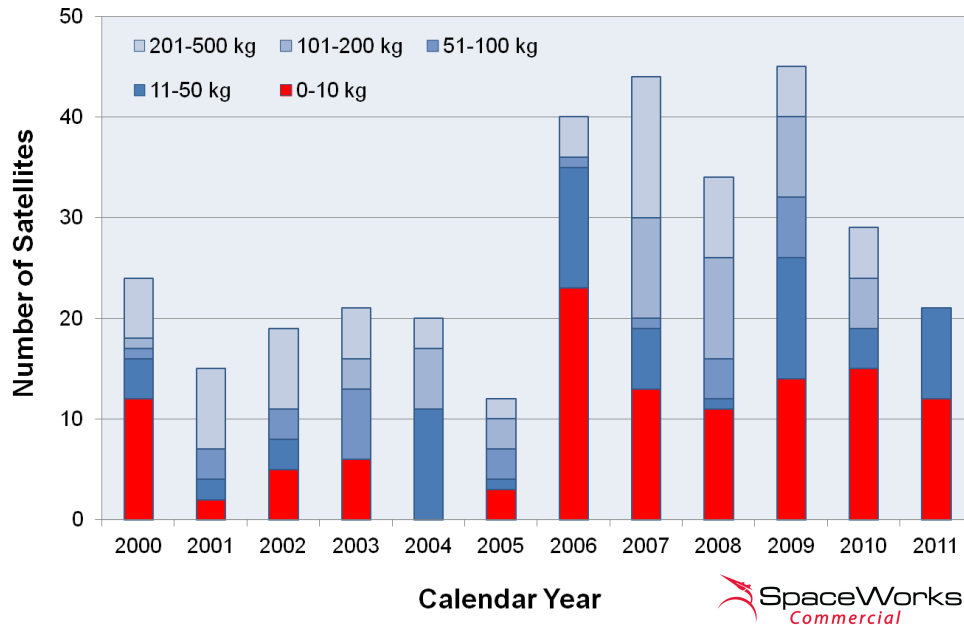
### Global Nanosatellite (1-10kg) Launch History (Successful Launches)



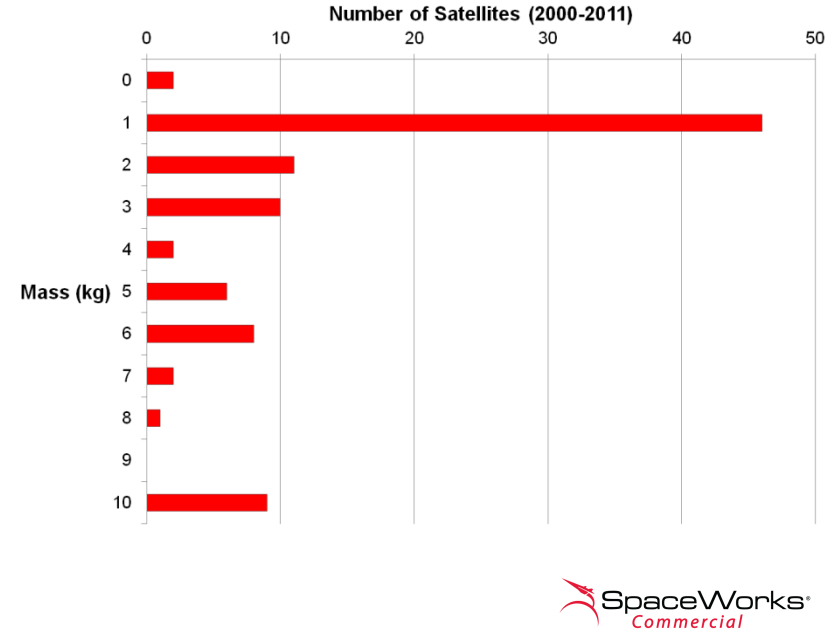
Source: Janson, Siegfried. "25 Years of Small Satellites." The Aerospace Corporation. 9 Aug 2011. Notes: Nanosatellites in chart are 1-10 kg (as opposed to 1-50 kg nano/microsatellites class referenced in other parts of this presentation), Does not include Russian Romb nanosatellites due to their passive nature.

## History

## Signs of an emerging and sustained launch market



## 1U (1 kg) CubeSat popularity is evident



### Number of Attempted Small Satellite Deliveries: 2000-2011 for 1-500 kg Satellite Class (Global)

### Distribution of Orbital Satellite Mass: 2000-2011 for 0-10 kg Satellite Class (Global)

- Notes:
- Data values refer to attempted launches, and may include failures
  - The number of satellites “launched” may not equal the number of launches since many satellites are multiple-manifested (i.e. more than one satellite on a particular launch)
  - Many times in this presentation, the term “launch” or “launches” may refer to the number of satellites launched (even though they may be multiple-manifested)
  - Data aggregated by SpaceWorks Commercial from its Orbital Satellite Database

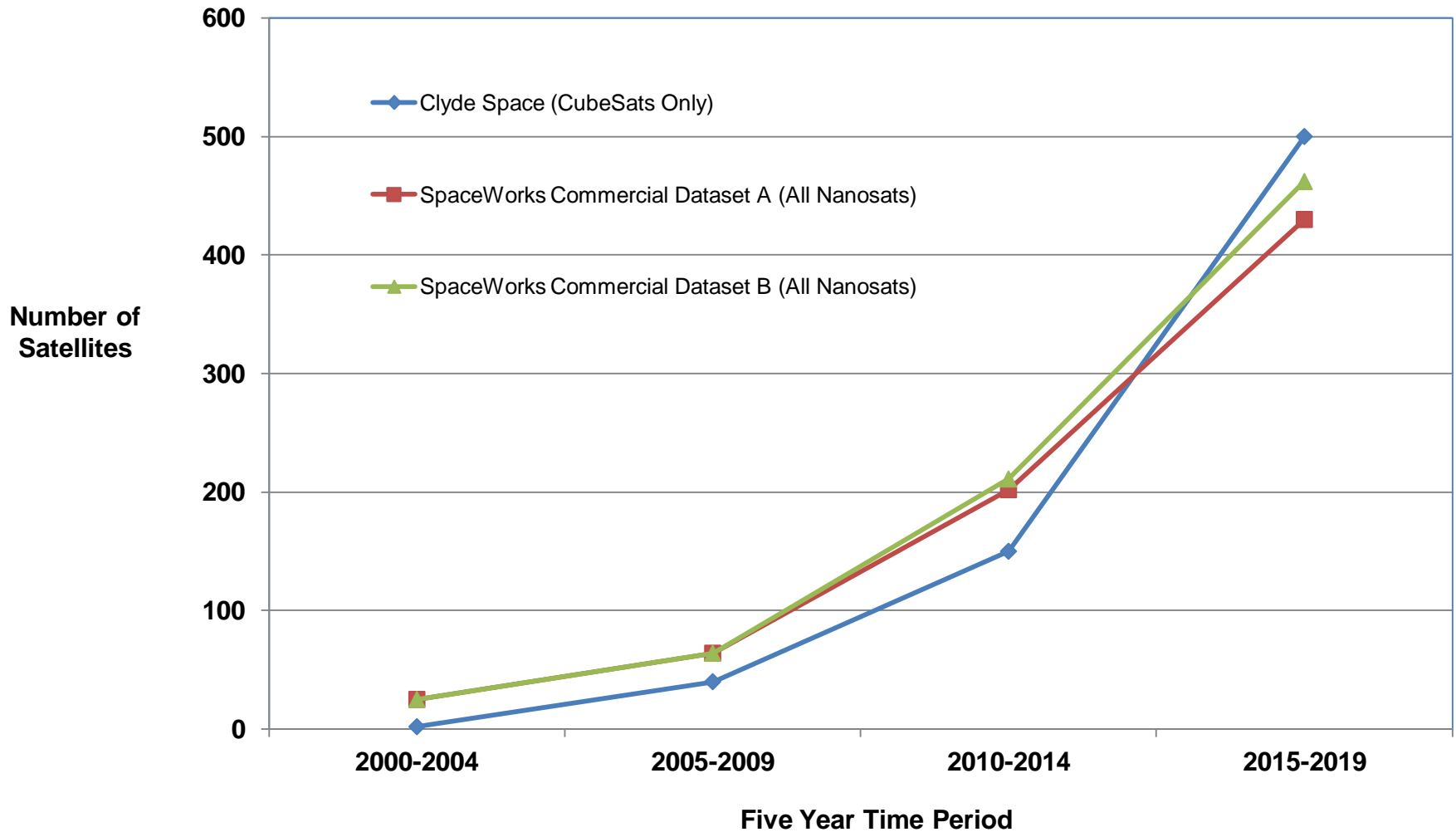
## Global Small Satellite Launch Demand: 2000-2011

- **Nano/microsatellite launch demand was projected through 2020 using the combination of historical launches and known future launches from the SpaceWorks Commercial Orbital Satellite Database (OSD)**
  - Market projection given there that is demand based
  - Projection based on the publicly announced plans of small satellite operators, launch vehicle providers, government agencies, etc.
  - Potentially several of these needing dedicated launch options
  - Potentially missing several commercial nano/microsatellite projects (harder to obtain data)
  - Price elasticity of demand not included here
- **The number of launches per year was fit to a Gompertz logistic regression**
  - The Gompertz logistic regression provides an accurate market growth prediction for many industries, particularly high tech
  - Regression curve based upon best fit to data while still accounting for a market saturation point
- **Market saturation point (launch demand asymptote in 2030) set at 150 nano/micro satellites in a year, limited by:**
  - Realistic number of manufacturers
  - Limits imposed by requiring a shared launch with a larger satellite
  - Note: others within CubeSat industry have proposed that total market just for CubeSats is over 600 CubeSats per year that will need launches
- **Methodology risks**
  - Assumes launches will occur as planned
    - Launches are often delayed
    - Projects may not launch due to lack of funding
  - Dependent on market saturation assumption
  - Datasets contains an inflating factor based on unknown satellites that could potentially not exist

## **Nano/Micro Satellite Launch Demand Projection: Methodology**

- **Two datasets were used to develop two different future projections of nano/micro satellite launch demand (each is global in nature)**
- **Dataset A contains all currently known past and future nano/microsatellite launches from the SpaceWorks OSD**
- **Dataset B contains Dataset A with an inflating factor to account for the “known unknown” satellites**
  - **Inflating factor is a percentage of known future launches in that year that are assumed missing (“known unknowns”)**
  - **Dataset B differs from Dataset A by adding a percent increase to the total number of satellites in a given year, with 2% in 2012, 10% in 2013, and 15% in 2014. It increases due to increased likelihood of not knowing satellites that are further in the future, with such a small percentage in 2012 because most satellites that are launching within a year seem to be known.**
- **Dataset B is used to determine how the 2020 projection is broken out among various customer classes, in order to project current known launch demand to 2020**
  - **Two projection types for the year 2020 are shown (1 and 2)**
    - **2020 Projection No. 1 uses the aggregate breakdown between 2007 and 2011 and projects it onto the 100 satellites in the Dataset B projection in the same ratios**
    - **2020 Projection No. 2 adds additional Von Karman Institute QB50, NRO Colony, DARPA ALASA, and DARPA F6 satellites assuming the sustainment of existing programs and creation of these new, identified programs (best estimate)**

## **Nano/Micro Satellite Launch Demand Projection: Datasets and 2020 Demand**



Notes:

- Data values refer to attempted launches, and may include failures
- The number of satellites "launched" may not equal the number of launches since many satellites are multiple-manifested (i.e. more than one satellite on a particular launch).
- Many times in this presentation, the term "launch" or "launches" may refer to the number of satellites launched (even though they may be multiple-manifested).
- Based on 2010 ClydeSpace analysis and 2011 SpaceWorks Commercial analysis from its Orbital Satellite Database, using satellites with masses of 1-10 kg

## Correlation of SpaceWorks Projections (1-10 kg)



## NANO/MICROSATELLITE APPLICATIONS AND EXAMPLES

Application	Name	Mass (kg)	Launch Date	Power (W)	Orbit	Inclination	Description
<b>Telecommunications</b>	AprizeSat 1	12	6/29/2004	1 W	SSO	98.00	Constellation to achieve a global communication system of data transmission and fixed and mobile asset tracking and monitoring
	<b>HAMSAT</b>	42.5	5/5/2005	1 W	SSO	98.87	Amateur radio communications satellite
	SaudicomSat-4	12	4/17/2007		SSO	98.07	Constellation of low orbit micro-communication satellites (12 kg each) for commercial use
<b>Earth Observations / Remote Sensing</b>	<b>WNISAT</b>	10	2012	12.6W	670 km SSO	97.5	Monitoring of Atmospheric CO <sub>2</sub> levels
	K-SAT	1.5	5/20/2010		200 km LEO	30	Observation experiments of atmospheric vapor distribution for predicting localized heavy rain
	PRISM	5	1/23/2009		650 km SSO	98	Technical experiments on Ground Image Acquisition using a refracted optical system with an extensible boom
<b>Scientific Research</b>	ION	2	7/26/2006		510 km SSO	97.4	Utilizes a Photomultiplier Tube (PMT) to observe airglow phenomenon in the Earth's upper atmosphere
	<b>UniSat 2</b>	12	12/20/2002		620 km LEO	65	A series of small satellites to perform technology experiments and to check the use of non space rated equipment in space
	MUNIN	6	11/21/2000		698 km x 1800 km polar orbit	96.5	Auroral research satellite using a combined electron-ion spectrometer and a solid state detector for high energy particles
<b>Biological Experiments/ Pharmaceuticals</b>	GeneSat-1	4	12/16/2006	5 W	410 km LEO	40	To study the effects of the microgravity environment on biological cultures
	PharmaSat-1	5	05/19/2009		390 km LEO	40	To test and validate autonomous, in-situ bio-analytical and sample management technologies to implement a Principal Investigator-defined science experiment to evaluate the efficacy of an antifungal drug agent on a biological specimen
	<b>O/OREOS</b>	5	11/20/2010	1 W	650 km LEO	72	An experiment exposing selected organisms and organic compounds to the space environment, and monitoring or assessing changes to them induced by space exposure

## Nano/Micro Satellite Application Examples (1)

Application	Name	Mass (kg)	Launch Date	Power (W)	Orbit	Inclination	Description
<b>Technology Demonstrations</b>	<b>FalconSat-1</b>	50	1/27/2000	24 W	733 km SSO	100.19	An analysis of ion current collection in plasma wake
	3CSat 1	16	12/21/2004		105 km (180 km x 240 km planned) Rapid Decay	13.48	One of three satellites to demonstrate stereoscopic imaging, formation flying, and end-to-end command and data handling
	Nanosail-D2	4	11/20/2010		650 km LEO	72	Solar sail demonstration
<b>Military Applications</b>	<b>SMDC-One</b>	4	12/8/2010		300 km LEO	34.5	Military communications satellite
	Atmospheric Neutral Density Experiment (ANDE) Pollux Sphere	25	7/15/2009		330 km LEO	51.64	To measure the density and composition of the low Earth orbit atmosphere while being tracked from the ground
	MEPSI 1A	1.5	11/23/2002		800 km SSO	100.2	Has aim of developing autonomous small sub-spacecraft that can be carried for remote inspection and servicing
<b>Academic Training</b>	CanX-2	3.5	4/28/2008	2 W	640 km SSO	98	To gain experience for students and to evaluate new technologies for future missions
	AggieSat-2	3.5	7/30/2009	1 W	350 km Rapid Decay	51.64	To gain experience for students and to test a GPS unit
	<b>AAUSAT 2</b>	1	4/28/2008	1 W	640 km SSO	98	To gain experience for students and carries a radiation sensor

## Nano/Micro Satellite Application Examples (2)

**Satellite: Nanosail-D2**

**Type: Technology**

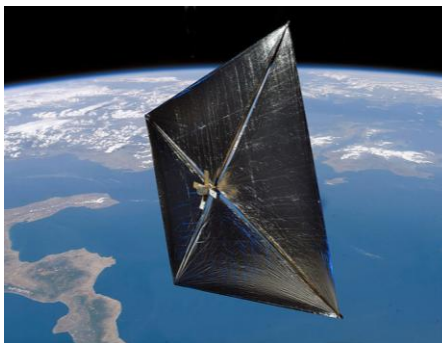
**Launch Vehicle: Minotaur-IV HAPS**

**Operator: NASA Ames Research Center**

**Mass: 4 kg (3U)**

**Orbit: LEO**

**Launch Date: 20 November 2010**



### **LOW COST SYSTEM REDUNDANCY**

NanoSail-D2 is a nanosatellite studying the deployment of a solar sail in space. The first attempt, Nanosail-D, failed in a Falcon 1 launch. Nanosail-D2 was a backup which they had made due to the low cost of this small satellite.

**Satellite: GeneSat-1**

**Type: Biological Experiments**

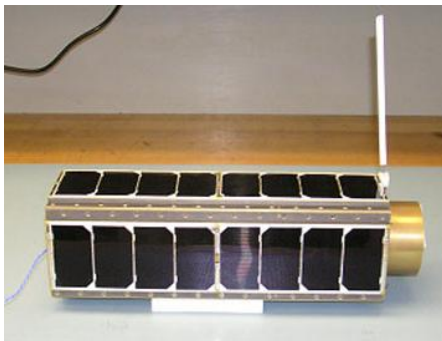
**Launch Vehicle: Minotaur-I**

**Operator: NASA**

**Mass: 5 kg (3U)**

**Orbit: LEO**

**Launch Date: 16 December 2006**



### **EXQUISITE APPLICATION**

GeneSat-1 was NASA's first fully automated, self-contained biological spaceflight experiment on a satellite of its size. The cost was far less than a typical experiment of this nature, but still a significant investment of \$3-5 M. GeneSat-1 shows the potential of these small satellites.

**Satellite: FASTRAC**

**Type: Technology**

**Launch Vehicle: Minotaur-IV HAPS**

**Operator: NASA Ames Research Center**

**Mass: 15 kg each (2 Satellites)**

**Orbit: LEO**

**Launch Date: 20 November 2010**



### **ENABLING CONSTELLATION**

FASTRAC investigates using a constellation of satellites and the communication between them for a single mission. These types of missions are much more feasible with the lower cost of small satellites and ability to launch multiple payloads on one launch vehicle.

## **NASA Case Studies**



## ABOUT SPACEWORKS

- An engineering services firm with offices in Atlanta, Georgia (HQ) and Washington, D.C.
  - Spin-off from the Georgia Institute of Technology founded in 2000
  - Approximately +\$2M annual revenues from sales of engineering services and software
  - #39 fastest growing Engineering firm in 2011 Inc. 500/5000 list
  - Three major divisions: Engineering, Commercial, and Software
- Core Competencies
  - Advanced concept synthesis for launch and in-space transportation systems
  - Technology impact analysis and quantitative technology portfolio optimization
  - Commercial development of space
  - Media materials related to space
  - Engineering software development
- Clients: NASA, U.S. DoD, commercial, and international space companies



## SpaceWorks Enterprises, Inc. (SEI)

- **Advancing innovative ideas, solutions, and partnerships to mature near and far term commercial and international space ventures**
  
- **Services:**
  - **FutureAssist**: Work with entrepreneurial companies, to enhance existing or to facilitate new business opportunities
    - Provide technical and business services (concept design, visualization/media, program management, business plan development)
    - Open to direct and delayed compensation as well risk-sharing for appropriate ventures
    - Liaison for services of other divisions (Engineering, Software) for commercial customers
  
  - **FutureLab**: Incubate and accelerate SpaceWorks Commercial-led ventures
  
  - **GlobalAssist**: Facilitate global aerospace projects
    - Aerospace agent and broker services
    - ITAR compliant aerospace project services
    - International project experience with Japan and Republic of Korea (South Korea)
  
- **SpaceWorks Commercial has recent small satellite experience**
  - NanoLauncher study (air-launch market analysis)
  - Working with small satellite providers (domestic U.S. and international)
  - Satellite demand modeling for government clients

## SpaceWorks Commercial



**SpaceWorks Commercial**

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