THE VALUE OF CUBESATS TO NATIONAL INNOVATION SYSTEMS

Some thoughts for policy makers

“1 unit” cubesat and a Mark III P-POD

Kirk Woellert, Interorbital Systems

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Cubesats: Cost-effective science and technology platforms for emerging and developing nations

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Abstract

The development, operation, and analysis of data from cubesats can promote science education and spur technology utilization in emerging and developing nations. This platform offers uniquely low construction and launch costs together with a comparative ubiquity of launch providers; factors that have led more than 80 universities and several emerging nations to develop programs in this field. Their small size and weight enables cubesats to "piggyback" on rocket launches and accompany orbiters travelling to Moon and Mars. It is envisaged that constellations of cubesats will be used for larger science missions. We present a brief history, technology overview, and summary of applications in science and industry for these small satellites. Cubesat technical success stories are offered along with a summary of pitfalls and challenges encountered in both developed and emerging nations. A discussion of economic and public policy issues aims to facilitate the decision-making process for those considering utilization of this unique technology.

Keywords: Cubesat; Developing countries; Innovation; Capacity building; Space technology; Nanosatellite

1. Introduction

People from developing and emerging nations often struggle to obtain clean water, sufficient nutrition, adequate healthcare, effective education, economic stability, and basic security. Expenditures on space science and satellite technology in such countries may, therefore seem inappropriate because of the need for diverting resources from near-term social programs. Nevertheless, long-term economic prosperity depends in part on intellectual capital, the advancement of which requires scientific training as well as the use, and eventually the development, of new technology. We posit that a recent technological advance, the cubesat, can contribute on a politically attractive and economically viable basis to the expansion of an emerging nation's intellectual capital. Cubesat technology offers a uniquely inexpensive pathway to the study of scientific phenomena and the advancement of novel engineering concepts in the unique environment of outer space.

Primarily for economic reasons, satellite development has been dominated heretofore by the United States, Russia, members of the European Union, Japan, Canada, China and India. Satellites in general, and the smallest of them in particular, are less expensive to develop and build than full-size spacecraft. A growing number of private commercial and public (both military and civilian) space launches carry ever more small "secondary" payloads into orbit at far lower cost than the dedicated missions required by conventional satellites.

Smallsats including cubesats have spawned significant commercial activity, including providers of complete satellites, components, and launch services, many of them starting as academic spin-offs (Table 1). An early success story is the collaboration between Pumpkin, Inc., and Stanford University leading to the development of the Cubesat Kit. Commercial success has undoubtedly been furthered

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Cubesat Program Assessment

Lewis Groswald, Stephanie Wan and Kirk Woellert

Abstract

Many countries are considering the role of space technology in their science and technology portfolios. Countries with no previous or expressed interest in space technology are now assessing potential applications of space technology. National space agencies through bi-lateral agreements, the United Nations (UN), NGOs, and some private entities are extolling the benefits of space technology, products and services for the emerging and developing world. Some countries contemplate strategies to develop indigenous space technology capacity. The range of space technology capacity contemplated may include goals such as developing a cadre of STEM 21st century workforce, increasing utilization of space data products and services, establishment of a satellite manufacturing base, purpose-built space launch facilities, or even developing space launch capability.

A new paradigm in the satellite community is the practice of developing satellites weighing less than 500 kilograms with capabilities comparable to much larger satellites. Small satellites have been described as a disruptive technology due to their significantly lower costs and faster development cycles. In particular cubesats have attracted considerable interest from academic, government and industry. Potential utility of these platforms has reached a level where industry is beginning to commercialize the technology. How may cubesat programs contribute to national priorities? How do government science and technology policy makers measure success of these programs? A methodology is presented which classifies the objectives of various cubesat projects and relates them to an internationally recognized socioeconomic index. Based on outcomes of this analysis recommendations are offered on the role of cubesats in science and technology policy of emerging and developing countries.

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Prof. Nicholas S. Vonortas

May 3, 2010

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The Space Policy Institute

NASA Ames Research Center

The Big Picture & national issues

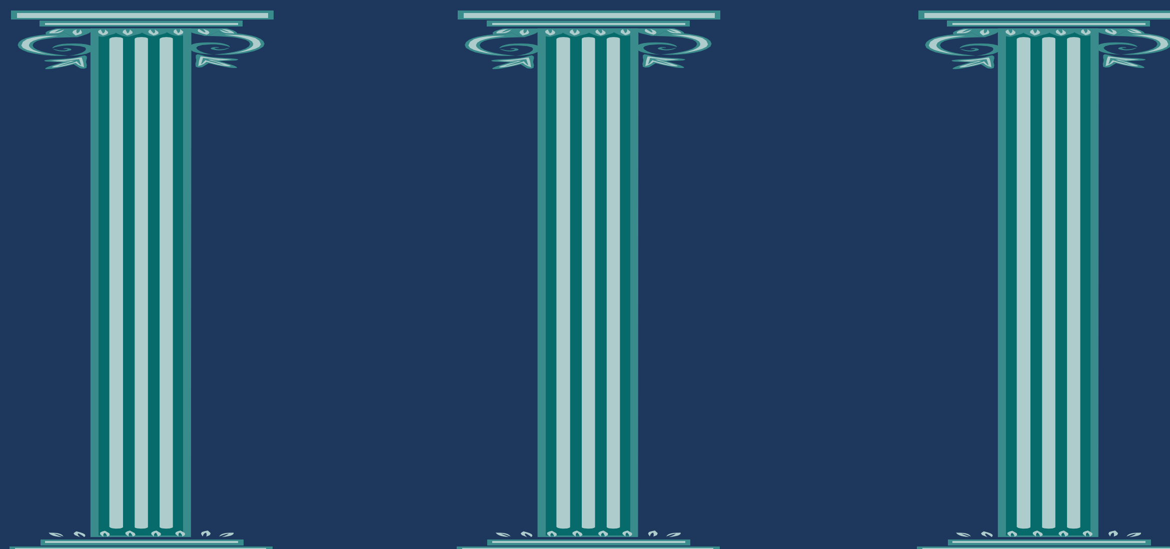
Where does the CubeSat fit in?

The Knowledge-Based Economy

production, distribution and use of knowledge

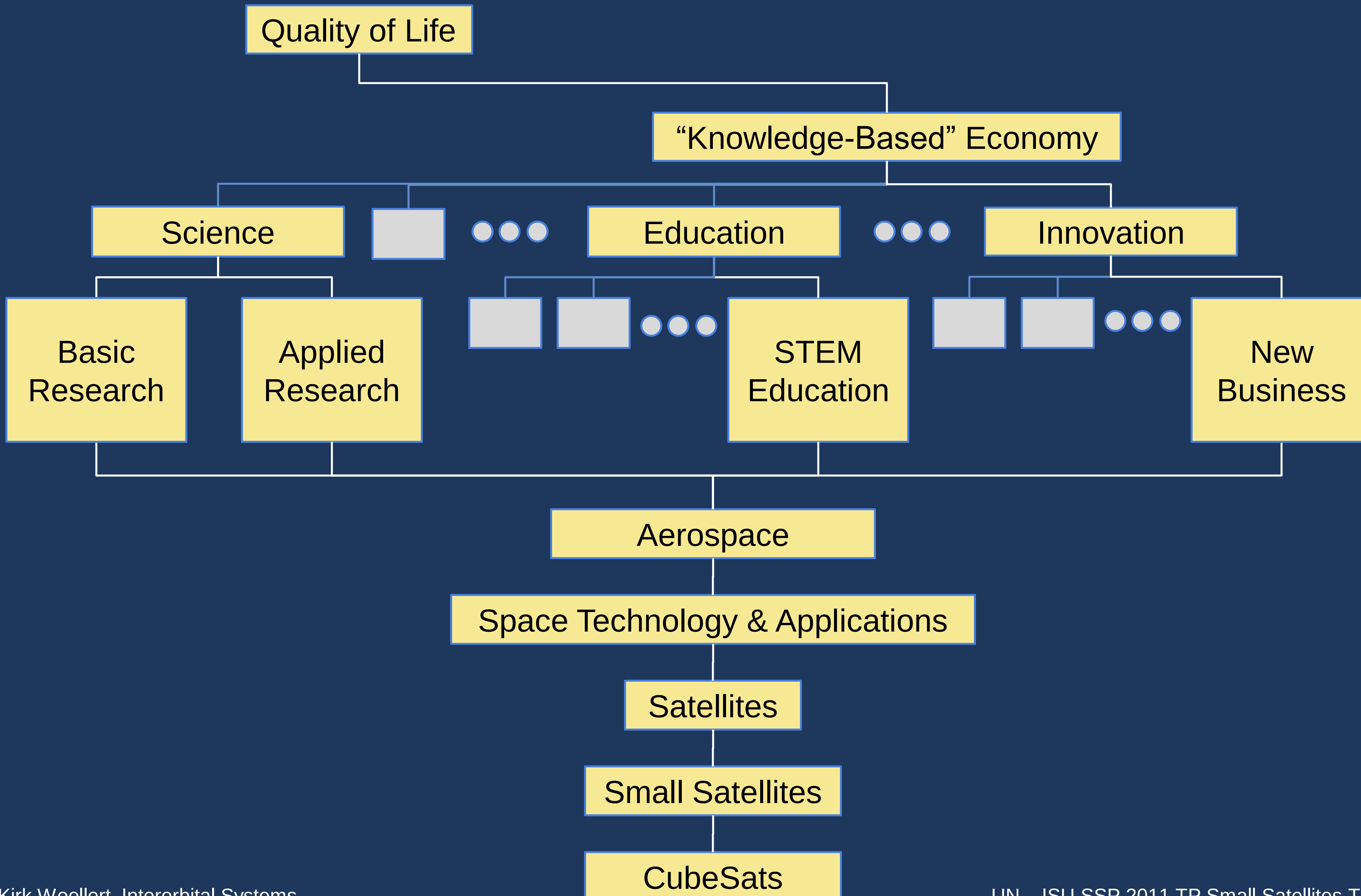
"Know-how"

"Know-what" "Know-why" "Know-who"



Science Education Innovation

The Big Picture and CubeSats



SCIENCE

Science/Technology Missions(1 of 2)

Sampling of completed and proposed nanosatellite science and technology missions			
Category	***Mission***	***Sponsor/Lead Agency***	***Status***
Astrobiology	O/OREOS: UV-visible spectral monitoring: organic materials; space radiation effects on survival/growth of 2 microbes	NASA ARC	In progress, L = 10/2010
Astronomy	BRITE/CanX-3/TUGSAT-1: Constellation of nanosatellites for asteroseismology	CSA/U. Vienna/Austrian Research Promotion Agency (FFG)	In progress, L = 2011
Atmospheric Science	SwissCube: telescopic investigation of atmospheric airglow phenomena AtmoCube: Interaction between space radiation and upper atmosphere	Ecole Polytechnique Federale de Lausanne Univ. Trieste and commercial sponsors	L =9/2009 nominal operation L = 9/2011 In progress
	FIREFLY: Terrestrial gamma-ray flashes induced by lightning	NSF	In progress L=2011
	RAX: Plasma interactions of the thermosphere	NSF	L = 11/2010 partial mission
Biology	GeneSat-1: E. coli gene expression via fluorescent reporters in microgravity	NASA/ARC	L = 12/2006, full mission success
Earth Observation	QuakeSat: Measure extra-low frequency magnetic waves from earthquakes in space	Stanford University Quakefinder Inc.	L = 6/2003, nominal operation
	PRISM: Validation of medium-resolution earth observation	University of Tokyo	L = 1/2009, nominal operation

Science/Technology Missions (2 of 2)

Sampling of completed and proposed nanosatellite science and technology missions

Category	***Mission***	***Sponsor/Lead Agency***	***Status***
Ecology	NCube2: Large ship AIS; reindeer tracking (NCube1 destroyed at launch)	Norwegian U. of Science and Technology	L = 10/2005, no comm. established
Pharmaceutical Efficacy	PharmaSat: Antifungal agent dose response of yeast in microgravity	NASA/ARC, U. Texas Medical Branch	L = 5/2009; full mission success
Technology Demonstration	CANX-2: Tech. eval.: propulsion system, radios, attitude sensors/actuators, GPS receiver, IR spectrometer for pollution	UTIAS/SFL, CSA	L = 4/2008, technology demo. success
	Libertad-1: Columbia's 1st satellite; test of basic systems	Universidad Sergio Arboleda	L = 4/2007, successful; deactivated
	MAST: Electromagnetic tether technology demonstration	Tethers Unlimited	L = 4/2007; partial comm. only
	NANOSAIL-D: 3U cubesat to demonstrate solar sail propulsion	NASA/Marshall Spaceflight Center	L = 11/2010 In progress
Space Weather	CINEMA: detection of sub-atomic particles from space magnetic storms	UC Berkeley Space Sciences Lab/Imperial College/NSF	L= 4Q2011 In progress
Telecommuni-cations	OUFTI-1: first satellite to test D-STAR communication protocol in space	University de Liege, BG	L=9/2011 In progress

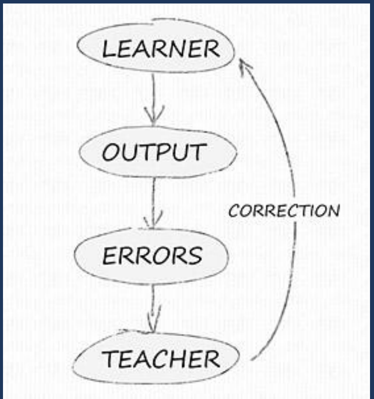
Science Missions

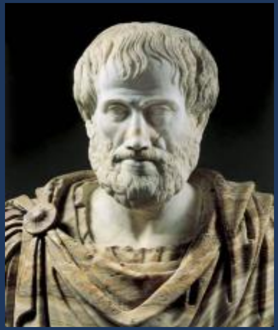
- “Big Science” on the cheap
  - CAUTION: Hubble Space Telescope capability in a CubeSat?….not likely
- In-situ observations not practical with larger satellites
- Replicative experiments

STEM EDUCATION

Experiential Learning; Learning from Your Mistakes

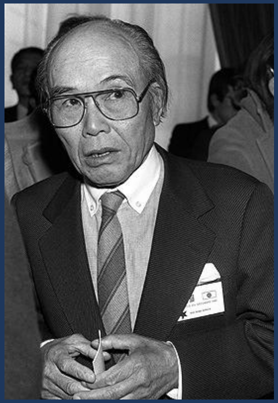
- A more intense mental imprint process
- Develops problem solving mindset





"For the things we have to learn before we can do them, we learn by doing them."

Aristotle
Philosher and Thinker



"Success can only be achieved through repeated failure and introspection"

Soichiro Honda
Founder, Honda Motors

Examples of two trends in satellites

		
Satellite	Inmarsat 4 series 2005, 2008	DTU-1
Mass	5900 kg (13,137 lb)	< 1 kg
Height	7 meters (22.8ft)	10 cm
Cost	$ 1.5 billion for 3 units ($500M/unit)	$200,000
Development	10 years for 3 units	2 years

Source: http://images.businessweek.com/ss/08/06/0603_efficacy/source/5.htm;
Bynum, W.F. and Porter, R. (eds) (2005) Oxford Dictionary of Scientific Quotations. Oxford University Press. 21:9.

Hands-On STEM Experiences

- FIREFLY, U.S. Cubesat
  - Student assembled/tested Gamma ray detector
  - Student assembled/tested VLF receiver
  - Mission operations include local high school students
- STUDSAT, Indian CubeSat
  - Student inspired IAC 2007
  - Launched 2011 on ISRO PSLV
  - Undergraduates from seven institutions developed all subsystems
  - Technical Assistance from ISRO

Source: www.thehindu.com Photo: K. Gopinathan

Photo credit-teamstudsat.com

Brazilian Elementary School TubeSat Project



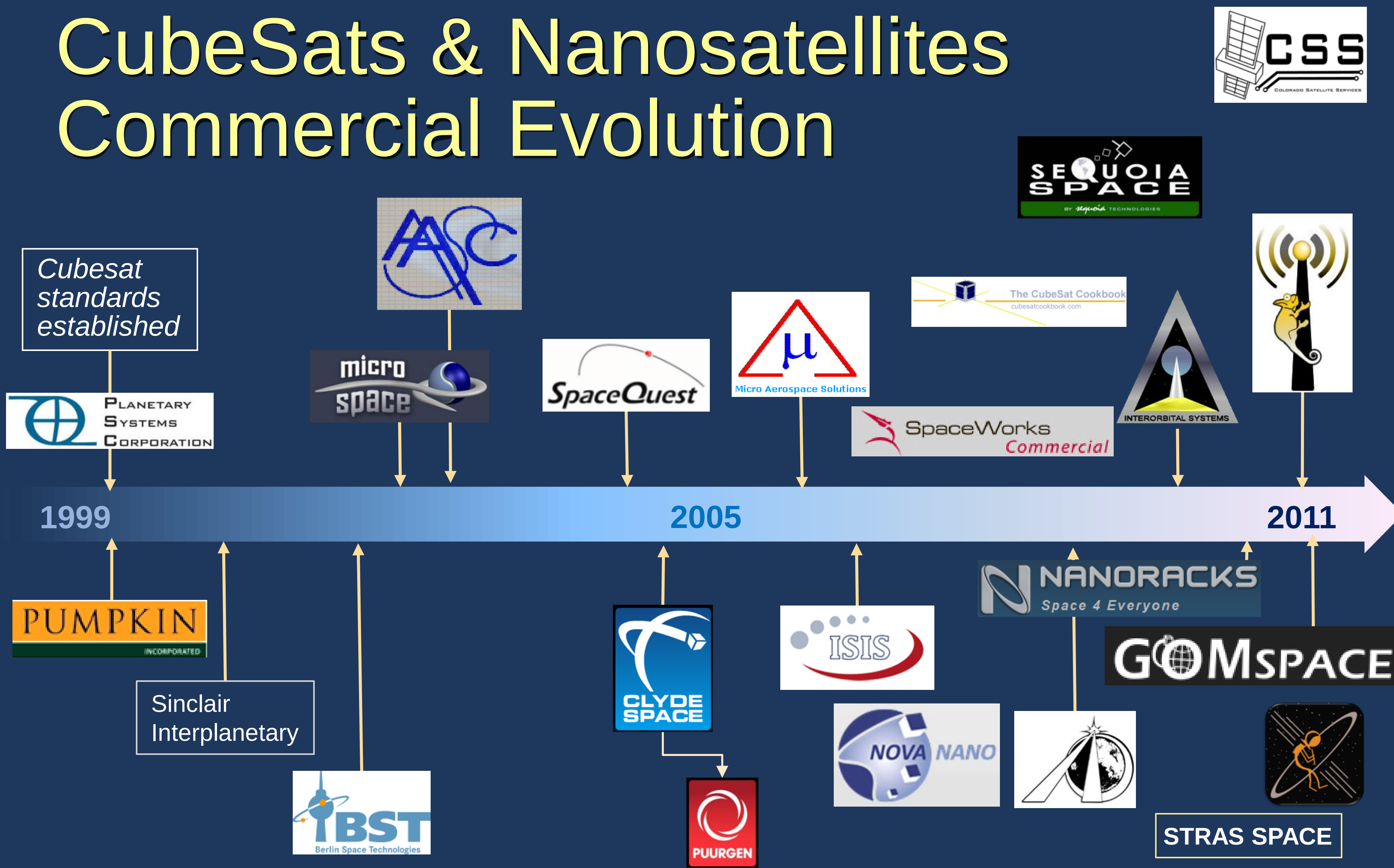



Presidente Tancredo de Almeida Neves EM
Ubatuba, Brazil

•-108 elementary school students
•-5 teams

INNOVATION

CubeSats & Nanosatellites Commercial Evolution



CubeSat Technology & Missions

Technologies

- Architectures
- Nano propulsion
- Deorbit Technologies
- Communications
- Structures
- Manufacturing, Fabrication, Integration
- Power
- Fempto Orbital Deployer (FOD)
- Sensors

Applications (an example)

- “6U CubeSat design for Earth observation with 6.5m GSD, five spectral bands and 14Mbps downlink.”
  TSITAS S. R. (1) ; KINGSTON J. (1) ;
  Aeronautical Journal ISSN 0001-9240

CubeSats & Collaborative Networks

- CINEMA, NSF CubeSat
- Kentucky Space
  Morehead State University
  University of Rome
- TUGSAT-1

Small Teams Mindset

"...The number one thing I learned through the CubeSat program is **how to work on a team** creating many different subcomponents and integrating those subcomponents together. Most all industry projects are larger than one person can accomplish so teams are essential. CubeSat has also taught me the importance of networking and never being afraid to call on or expand your network when you need anything. Weather that be help on a project, looking for co-team members or just looking for someone to hang out with. Contrary to what some may tell you in school, you don't have to have all the answers in your head, you just need to know where to find them. That may be a book, but more commonly it's your team mates or your larger network.“

Student Testimonial
CubeSat Worldwide
Facebook

OECD INDEX

Organization for Economic Co-operation and Development (OECD)

OECD Scorecard
Investing in the Knowledge Economy

- Responding to the Economic Crisis
- Targeting New Growth Areas
- Competing in the World Economy
- Connecting to Global Research
- Investing in the Knowledge Economy

OECD Scorecard
Investing in the Knowledge Economy

Table 5 OECD Investing in the Knowledge Economy relation to cubesats*			
OECD Scorecard Metric	**STEM Education**	**Science**	**Innovation**
New university graduates	●		
New doctoral graduates	●		
Human resources in science and technology	●		
Employment of tertiary-level graduates	●		

OECD Metric: New University Graduates

Delft University of Technology nanosatellite program

OECD Scorecard
Connecting to Global Research

Table 6 OECD Connecting to Global Research relation to cubesats

OECD Scorecard Metric	STEM Education	Science	Innovation
International co-operation in research	●	▲	■
International research co-operation among regions			
International co-operation in science		▲	
Cross-border inventions			
Technology balance of payments			
R&D funding from abroad			
Internationalization of R&D			
International collaboration on innovation			■
International mobility of doctoral students			
Foreign scholars in the United States			

OECD Metric: International Cooperation in Research

CINEMA

OECD Scorecard
Competing in the World Economy

Table 7 OECD Competing in the World Economy relation to cubesats

OECD Scorecard Metric	STEM Education	Science	Innovation
International trade			■
International trade by technology intensity			
Manufacturing trade balance by technology intensity			
International trade in ICT goods and services			■
Activity of foreign affiliates			
Activity of foreign affiliates			
Electronic commerce			■
Innovation and firm performance			
Innovation within companies			
Non-technological innovation			■
Product and marketing innovation using trademarks			■
Internet access and use by businesses			■
Entrepreneurship			■

<u>OECD Metric: Entrepreneurship</u>

E.g. GOMspace, ISIS Space, Pumpkin

OECD Scorecard
Targeting New Growth Areas

Table 8 OECD Targeting New Growth Areas relation to cubesats

OECD Scorecard Metric	STEM Education	Science	Innovation
Patents in environment-related technologies			
Environmental sciences	●	▲	■
Telecommunication networks			■
Health-related R&D		▲	
Health-related patents			
Biotechnology R&D		▲	
Public-sector biotechnology R&D			
Biotechnology patents			
Biosciences		▲	
Nanotechnology patents			
Nano-sciences			
Government R&D budgets	●	▲	■
Public-private cross-funding of R&D	●	▲	■
Tax treatment of R&D			
Collaboration by innovating firms			■

OECD Metric: Environmental Sciences

CanX-2 3U cubesat with IR spectrometer payload

OECD Scorecard
Responding to the Economic Crisis

Table 9 OECD Responding to the Economic Crisis relation to cubesats

OECD Scorecard Metric	STEM Education	Science	Innovation
Venture capital in the economic crisis			■
R&D in the economic crisis	●	▲	■
R&D growth over the business cycle			
Financing R&D during a recession			
Trends in business R&D			
Business R&D by technology intensity			
Business R&D by firm size			
Patent intensity over the business cycle			■
Trademarks over the business cycle			
Trends in researchers			
Foreign direct investment flows			
Trends in the employment of foreign affiliates			
Labor productivity growth over the business cycle			
ICT Investment over the business cycle			

OECD Metric: Patent Intensity Over the Business Cycle

Tethers Unlimited
Dobson Space Telescope (DST)
PRISM, the first remote sensing nanosatellite to achieve 30 meter
Micro-propulsion and Nanotechnology Laboratory of The George Washington University

OCED Mapping Conclusions

- Organization for Economic Cooperation and Development (OECD)
  - Socioenconomic indices
- In less than 10 years cubesat have achieved correlation to half of the OECD variables
  - Real world examples that qualitatively map to OECD variables
- “Cubesat projects demonstrate relevance to 25 of 57 variables”
- Empirical-based rationale that cubesats can contribute to national innovation systems

STEM Education Recommendations

- Building a skilled STEM workforce
  - Provide hands-on activities that develops skills to be utilized in the workforce
  - Example: Cubesats- a mechanism for learning various processes in satellite development
- Invest in robust STEM education programs
  - Universities collaborating with industry and government programs to develop the needs of all parties
  - Example: Texas A&M University AggieSat 2
- Ongoing learning tool that leads to economic transformation and innovation
  - While curriculum is set, need to build institutional knowledge for continuous growth of knowledge

Science Policy Recommendations

- Countries can emulate the grant-award approach of the National Science Foundation’s cubesat program:
  - Clear goals
  - Address national needs
  - Importance of government funding to provide stability to nascent technology platform (committed end-user)
- Government, industry, and academia need to work together to form regional and national organizations to both formalize and optimize sharing of intra-national knowledge and human capital
  - Example: Kentucky Space Grant Consortium
  - Promote regional cooperation in a field (data sharing, etc)
- Universities should pursue relationships both in and outside of their country
  - Leverage technologies like the Internet for sharing data and seeking out new information

Innovation Policy Recommendations

- Bi-lateral agreements with mature space actors
- Incentivize risk taking
  - Robust IPR system
  - X-prizes
  - National Competitions
- Growth and new businesses
  - Seed funds and university incubators
  - “Technology parks” on orbit
- Improve global collaborative networks
  - Environments conducive to grass-roots organizations

Conclusions, CubeSats…

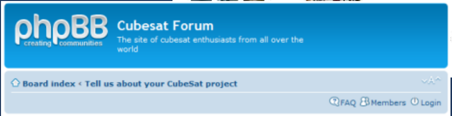
- …development mirrors the multi-disciplinary nature of traditional satellite development but at a fraction of the cost and time
- …are proven STEM education platforms
- …are viable science platforms and the fidelity and range of applications will continue to grow
- …excellent vehicle for international collaborations
- …are an viable element of national science and technology capacity-building portfolios, including nations with limited economic resources for such activity

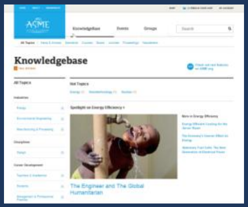
Thank You!

WHERE TO START

Ways to obtain knowledge

- CubeSat.org
- Collaborative Projects
  - U2U, U2Industry
- Social Media
  - CubeSat Worldwide, facebook
  - Many CubeSat projects are on facebook
  - Dedicated websites
- Professional Societies
  - AIAA, ASME, IEEE, etc.
- Amateur Societies
  - Amateur Radio
  - AMSAT
  - Rocketry associations





Entry Level Field Work

- Balloons
- Hobby/Amateur Rockets

"We are constantly developing new concepts for scientific instruments. We test those instruments on rockets or balloons and bootstrap our way into space"

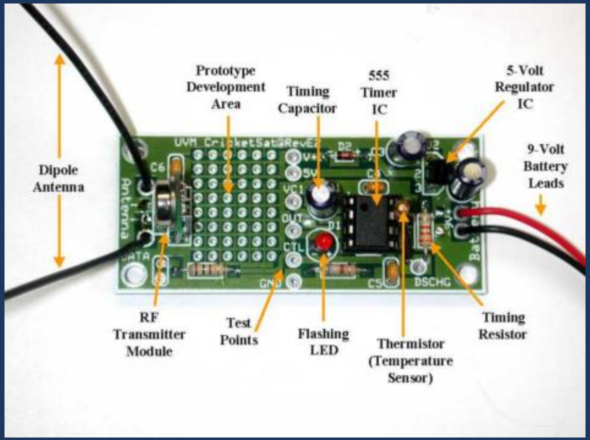
Stuart Bale
Director, Space Sciences Laboratory
University of California, Berkeley

http://space.1337arts.com/

CREDIT: Quest for Stars

Resources: Hardware

- Microcontrollers and Payload Components
  - CricketSat (stanford space systems laboratory)
  - Arduino Boards < $50
  - NetMedia Basic < $50



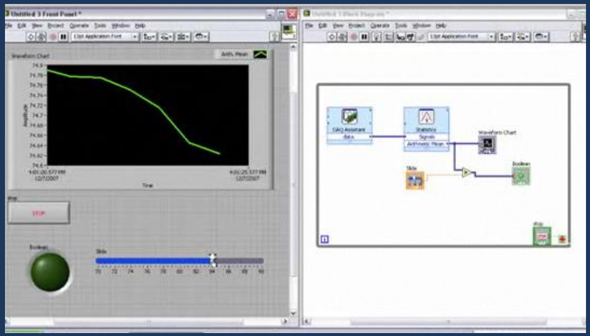
Source: Mike Fortney and Jeff Frolik, University of Vermont, Adaptation of a Low-cost Wireless Sensor for Freshman and Outreach Programs
Retrieved at http://vtspacegrant.org/cricketsatfortney.htm

Resources

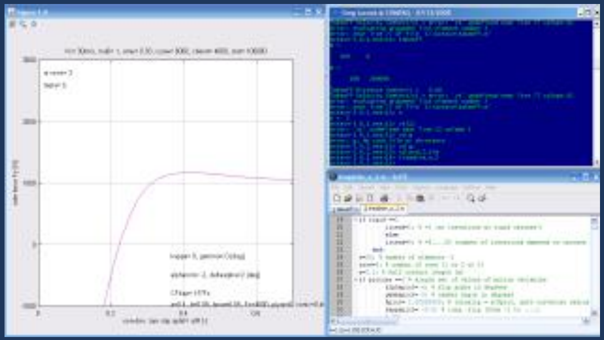
- Computer Aided Design (CAD)
  - Numerous (too many to list) open source alternatives for mechanical, structureal, and electrical circuit design
- Computer Aided Manufacturing
  - 3D Printing Technology
  - NetFabb- 3D Printing pre-processor
  - RepRap / MakerBot $1,200 (USD)

Resources: Bench Analysis

- MatLab
  - Student Edition < $100 (USD)
- LabView
  - Student Edition <$100 (USD)

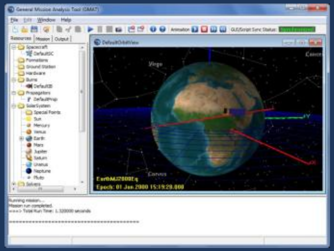


- Octave- open source, free

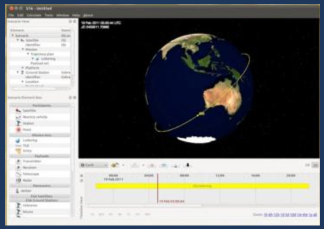


Resources: Astrodynamics and Trajectory Analysis

- AGI Satellite Tool Kit (STK)= $
- GMAT
  - NASA software, free!



- Space Trajectory Analysis (STA)
  - ESA software, free!



Backup Slides

New Space Faring Nations (1)

- Argentina
  - Pehuensat-1, (launch 2007) still on orbit; enable students to broadcast messages in Spanish, Hindi, and English
- Brazil
  - Developing its first cubesat, the 1U NanosatC-BR, to study the geomagnetic field in the region of the South Atlantic Magnetic Anomaly
- Colombia
  - First space mission, the Libertad-1 cubesat, excellent example of a cubesat developed by a very small team
- Mexico
  - Mexican consortium of universities is participating in the UN HUMSAT project through development of SATEX-2
  - University of Mexico is collaborating with a number of Russian institutions to develop UNAMSAT-3, a 10-kg nanosatellite that will attempt space-based earthquake prediction
- Peru
  - Aspires to its first satellite, Chasqui-I, a cubesat with a remote sensing payload, encourage international collaboration (Chasqui-1 2010). The Chasqui-1 team includes faculty and student collaborators from the U.S. and Taiwan
- Croatia's
  - launch of its first satellite, the CROPSAT cubesat, to conduct upper atmospheric research and space technology capacity building

New Space Faring Nations (2)

- Romania
  - First satellite, the cubesat Goliat on the European VEGA launcher. Goliat primary mission is education and workforce development but also has science payloads including a micrometeoroid detector and sophisticated Earth imaging camera
- India
  - First indigenous picosatellite, STUDsat, launched in July 2010 and developed exclusively by undergraduates from seven Indian academic institutions, STUDsat's primary mission is education; it includes a camera with stated lateral resolution of 90m for Earth imaging
- Pakistan
  - ICUBE-1 from the Institute of Space Technology is an education and training project to develop space technology capacity
- Tunisia
  - development of its first picosatellite, ENIS REGIM pico
  - satellite 1. ERPSat-1 has three basic missions: ground station communication, intersatellite communication, and remote sensing using a low-resolution CMOS camera
- Turkey
  - first native satellite, the ITUpSAT1 cubesat, operating now for nearly a year, with a primary mission of education and aerospace technology development
- South Africa
  - F'SAT1, a 3U cubesat led by the Cape Peninsula University of Technology; three payloads a camera, a repeater/transponder, and a high-frequency beacon in the calibration of its radars in the Antarctic

Recent Cubesat Launches 1

- Japan, Negai, reentered atmosphere June 26, 2010, H-2*
- Japan, WASEDA-SAT2, reentered atmosphere June 26, 2010, H-2
- Japan, KSAT, status unknown, H-2
- Norway, AISSat1, July 2010, PSLV*
- Switzerland, TiSAT-1, July 2010, PSLV
- India, STUDSat, July 2010, PSLV
- ExoPlanetSat nanosatellite

*AISSat1 is a nanosatellite, mass of 6 Kg, of cubic form factor 20x20x20 cm

Recent Cubesat Launches 2

- Perseus 000,001,002,003, 1.5U, Falcon 9, 12/8/2010
- Mayflower-Caerus, 3U, Falcon 9, 12/8/2010
- QbX1, 3U, Falcon 9, 12/8/2010
- QbX2, 3U, Falcon 9, 12/8/2010
- SMDC-ONE, 3U, Falcon 9, 12/8/2010
- RAX 11/2010, 3U, Minotaur 4, 11/19/2010
- O/OREOS, 3U, Minotaur 4, 11/19/2010
- NanoSail-D, Minotaur 4, HAPS, 11/2010
- FASTRAC 1/2*, Minotaur 4, HAPS, 11/2010

* Univ of Texas, a nanosatellite but not a cubesat

CROPSAT Case Study

Croatian path to space capacity

- 2002-2003 – Decision to pursue a satellite
- 2003-2007 – Concept Development and integration with educational programs
- 2007-2008 – Concept and Project Team Definition
- 2008-2010 – Fundraising
- 2010-2012 – Systems Engineering
- 2013-2014 – Launch of first satellite

Croatia's Cubesat Program Homepage

The ultra-low barriers to entry afforded by cubesats permits a newly independent nation, population about 4.5 million people, to establish a space program…

Space Access

Launch Vehicle	***Country/Provider***	***Secondary Payload Accommodation***
Atlas V	US (NASA/ULA)	EELV Secondary Payload Adapter (ESPA)
Delta IV	USAF (ULA)	
Dnepr	ISC	P-POD
Falcon 1*	SpaceX	Ride Share Adapter; P-POD
Minotaur I	USAF (OSC)	P-POD
Minotaur IV	USAF (OSC)	P-POD
Nanolauncher Black	US-Japan (SWC, IHI)	P-POD
Neptune30	US (Interorbital)	10 Cubesats
PSLV, GSLV	ISRO	P-POD
Vega	ESA	P-POD

* Falcon 1 retired. Falcon 1e future availability unclear

The Bad News…ultra-low mass satellites often accept sub-optimal orbits…at least for now;
The Good News….established launch providers are accommodating secondary payloads while new launch vehicles are on the horizon;

CubeSat Demographics

Cubesat Demographics Post & P-POD Standard Release (2000)		
	2010	**2011**
Total # of cubesats launched	46[5,6]	61
Total # universities with cubesat programs	80[7]	??
Total # of cubesat-related businesses/new startups since 2000	12	13
# countries whose first satellite was or planned to be a cubesat	6	8

Cubesat Economics

Average Costs for Cubesats		
Sponsor	***Satellites***	***Average cost per kg***
National Science Foundation[1]	RAX, FIREFLY, DICE, FIREBIRD, CINEMA, & REPTile (all 3U cubesats)	$385,000
NASA[2]	Genesat-1, PharmaSat, O/OREOS (all 3U cubesats)	$870,000 $590,000 $455,000
Other cubesats	XaTcobeo, QuakeSat, MAST, Libertad-1, NRO, DTU-1 (1 U and 3U cubesats)	$510,000
Overall Average		**$560,000**

[1]*excludes* integration & launch costs

[2]*includes* integration, launch, and ground operations costs

The Point: cubesats don't offer advantages on a cost-per-kilogram basis. However overall cost is much less than historical costs while substantial utility and tacit benefits are derived.

International Satellite Development

First satellite * Cubesat

Country	*Satellite*	*Primary Mission*
Argentina	Pehuensat-1*	Education, multi-lingual transponder
Austria	UniBRITE	Asteroseismology
Azerbaijan	AzerSat 1	Communications
Bangladesh	Proposed	Communications and/or EO
Brazil	NanosatC-BR*	Earthquake Detection
Colombia	Libertad-1*	Education
Croatia	CROPSAT*	Education
Ecuador	NEE-01*	Education; live video from space
India	STUDsat-1*	Low-resolution remote sensing
Latvia	Venta-1	Nanosatellite (1Q 2011)

International Satellite Development

First satellite * Cubesat

Country	*Satellite*	*Primary Mission*
Mexico	SATEX-2 UNAMSAT-3*	HUMSAT contribution Earthquake precursors
Tunisia	ERPSat1*	Chip-based image processing
Romania	Goliat*	Micrometeoroid detection
Pakistan	ICUBE-1*	Education
Peru	Chasqui-1*	Low resolution imaging
Portugal	VORsat	Rentry capsule
Turkey	ITUpSat-1*	low resolution imaging
South Africa	F'SAT-1*	Cooperative radar calibration
Spain	XaTcobeo*	Software Defined Radio
Switzerland	SwissCube* TISat-1*	Investigate air glow phenomena Technology validation

Space Program or Space Applications?

- Countries seeking benefits of developing space technology have choices
- A Space Program? Or a Space Applications Program?
  - The space programs of the established space actors (i.e. US, Russia, Europe, China, India, etc) may not be applicable or sustainable for emerging space actors
- Countries should strive to tailor their space aspirations so that activities are synergistic to:
  - Cultural
  - Economic
- Some countries rely on eco tourism
  - hence maybe emphasis should be on developing applications of small satellites for wildlife conservation

Citizen Satellites

Personal Satellite Project

By an

American Astronomer