2015 NASA Cost Symposium

AMES Cost Model
Ames Micro/NanosatellitES Cost Model

August 25th, 2015

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OUTLINE

- Market Assessment –Micro/Nanosatellites
- Development Process
- AMES Cost Model Overview
- Data Collection Plan
- Discussion and Feedback

Observations

- Cubesats are growing in popularity
- Micro/nanosatellite projects cost data are very limited to the available public
- Design and development cost drivers are rapidly changing to adapt to orbiting environments
- Science/Technology, Systems Integration and Testing (SI&T), Mission Operations, and Ground Data Systems (GDS) are specific to each project and there is not enough category cost data to rely on analogous cost yet

AMES Cost Model Characteristics

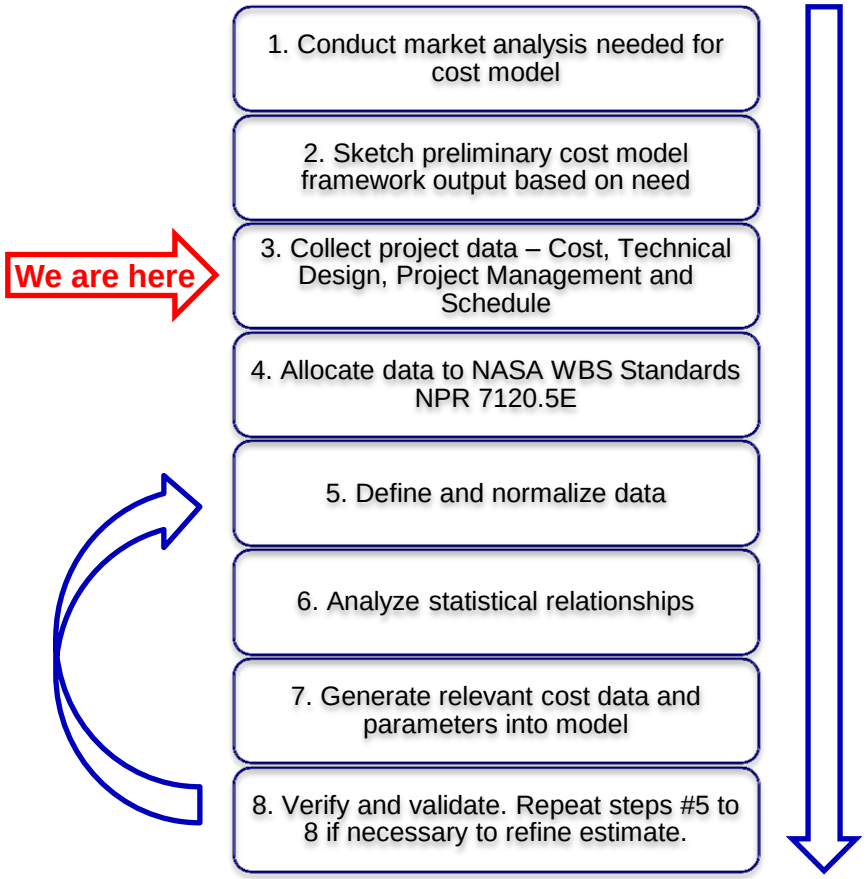
- **Motivation:** Fill in the void for the lack of commercially available micro/nanosatellite (<50 kg) cost model

- **Goal:** Develop an analogous and parametric base cost estimate for micro/nanosatellite development. (up to 14kg and 6U cubesat form factor)

- **Capabilities:**
  - Cubesat spacecraft bus cost estimate
  - Project level cost estimate aligns to NASA's WBS
  - Cost Phasing
  - Risk Analysis
  - Inflation adjustments

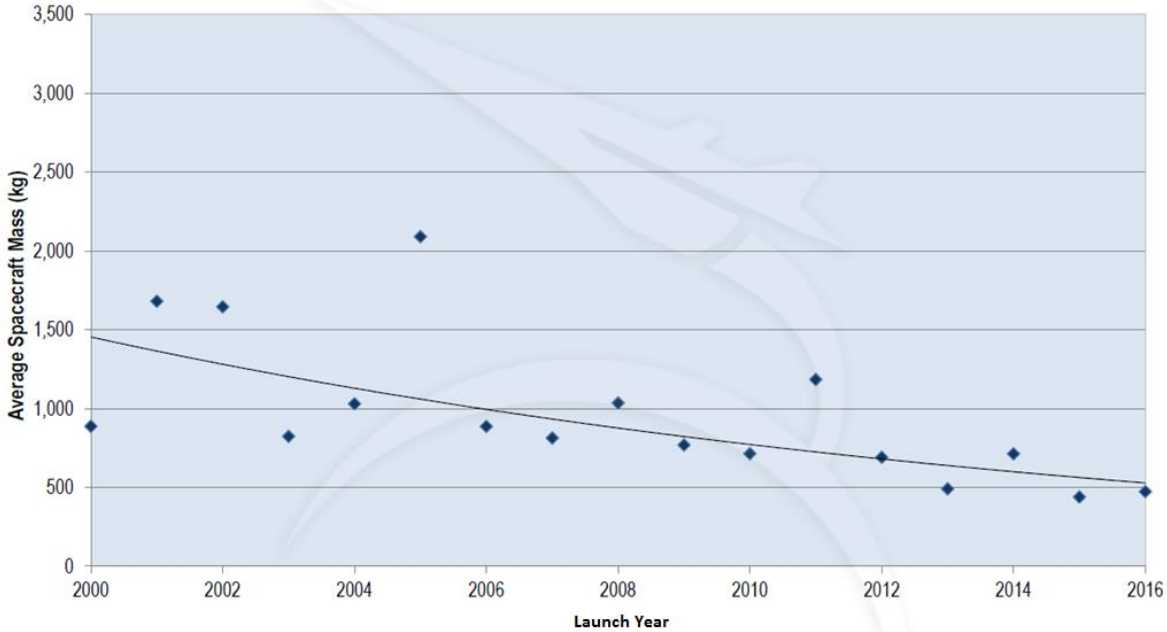
- **Two Types of Cost Estimate:**
  - Self design with user input hardware parameters
  - Preload existing heritage design with options to modify, delete, and/ or add additional components as needed (e.g. Level of Modification (options): no modification, minor, major)

Cost Model Development Methodology and Process



Nano/ Microsatellite Market Overview/Assessment

Low Earth Orbit (LEO) Spacecraft excluding Missions to ISS



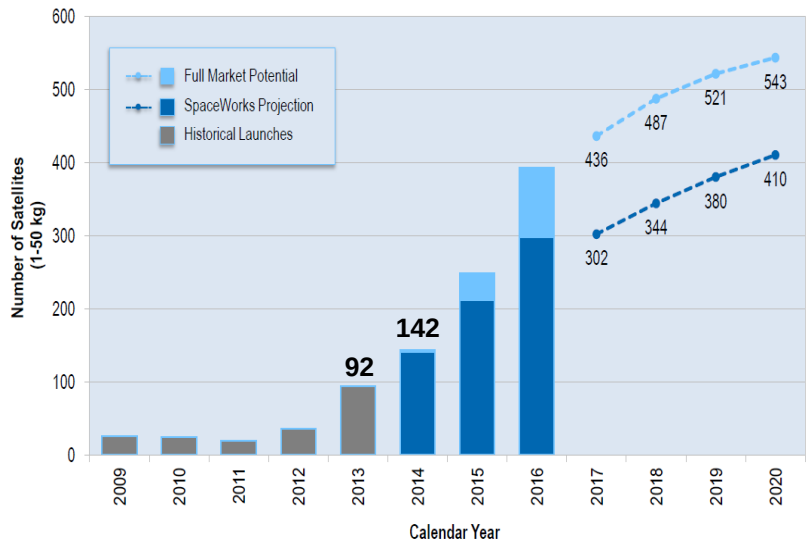
- Average spacecraft mass is significantly reduced when removing missions to ISS
- Still demonstrates the continual decrease in average spacecraft mass

Ref: http://www.spaceworksforecast.com/docs/SpaceWorks_Small_Satellite_Market_Observations_2015.pdf

Nano/ Microsatellite Market Overview/Assessment

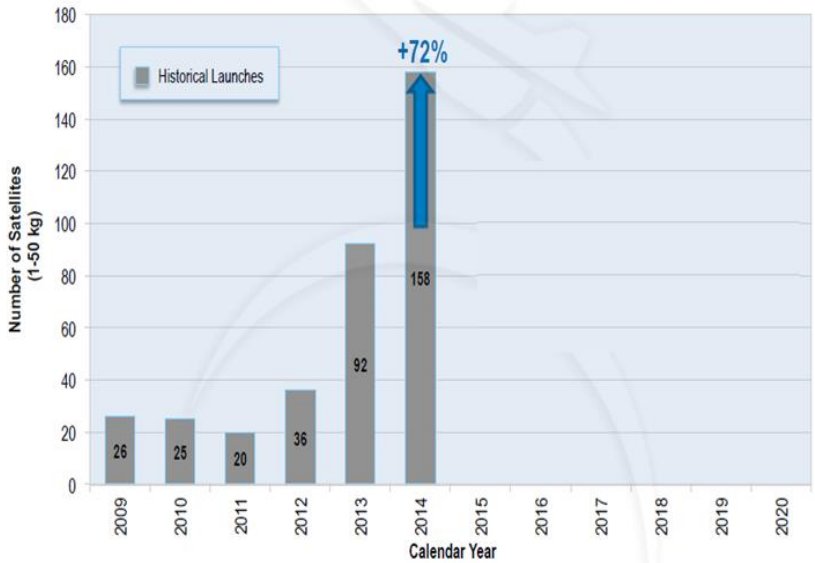
Nano/Microsatellite Launch History and Projection (1 - 50 kg)

Projections based on announced and future plans of developers and programs indicate between 2,000 and 2,750 nano/microsatellites will require a launch from 2014 through 2020



The Full Market Potential dataset is a combination of publically announced launch intentions, market research, and qualitative/quantitative assessments to account for future activities and programs.
The SpaceWorks Projection dataset reflects SpaceWorks' estimate of the total number of satellites that will launch in a given year.

Updated Report January 2015: Follow-up to 2014 forecast, and by comparison from 2014 to 2013 actuals, there was a 72% increase



Historical data includes failed launch attempts.
Historical data may not represent all global nano/microsatellite activities.
The number of satellites may not equal the number of launches since many small satellites are multiple-manifested (i.e. more than one satellite co-manifested on a particular launch vehicle).

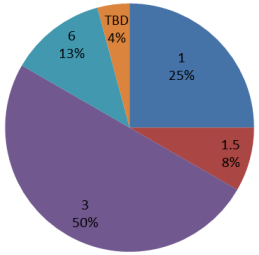
Ref: http://www.sei.aero/eng/papers/uploads/archive/SpaceWorks_Nano_Microsatellite_Market_Assessment_January_2014.pdf

Past and Present NASA ARC Micro/Nanosatellite Missions

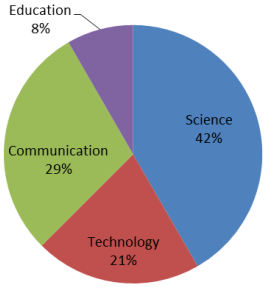
Have Been Launched

Year (CY)	Form Factor (U)	Mission Project
2006	3	GeneSat
2008	3	PreSat
2008	3	NanoSail-D1
2009	6	Pharmasat
2010	3	O/OREOS
2011	1	PhoneSat1beta
2011	3	NanoSail-D2
2012	1	Tech Ed Sat
2013	1	PhoneSat 1
2013	1	PhoneSat 2 beta
2013	1	PhoneSat 2.4
2013	3	Tech Ed Sat 3p
2014	1	PhoneSat 2.5
2014	3	SporeSat-1
2014	3	KickSat
2015	6	EcAMSat
2015	1.5	EDSN
2015	1.5	NODeS
2015	3	SporeSat2
2016	3	KickSat2
2016	3	SLPS-3 (ISS Project)
2016	3	SLPS-4 (ISS Project)
2017	6	BioSentinel
TBD	TBD	Propulsion Pathfinder

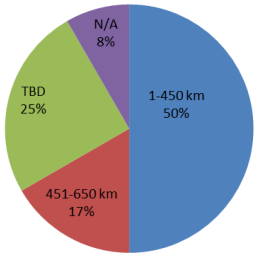
NASA ARC Nano/Microsatellites Cubesat Form Factors (U)



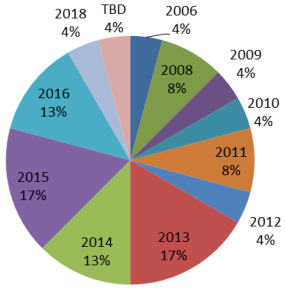
NASA ARC Nano/Microsatellites Applications Types



NASA ARC Nano/Microsatellites Operating Altitudes (km)

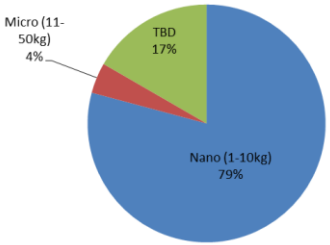


NASA ARC Nano/Microsatellites Launch Year by year

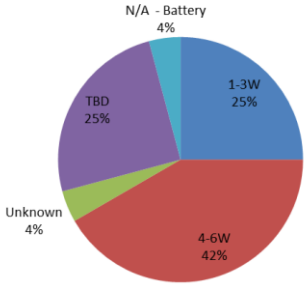


Note: ARC on average launches 3 nanosats/ year

NASA ARC Nano/Microsatellites Classification by Mass (kg)



NASA ARC Nano/Microsatellites Average Orbit Power (W)



Key:
TBD: Project still work in progress
N/A: Not available

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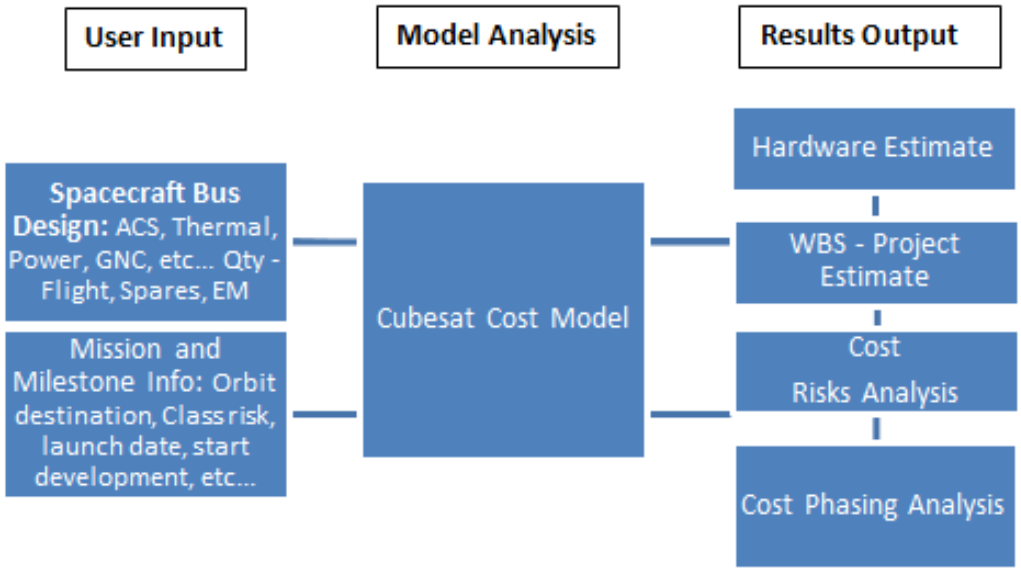
Systems Requirements

- Shall Estimate Cost based on Form Factors (U) – 1U, 1.5U, 2U, 3U, 6U
- Shall Estimate Cost by NASA's WBS Elements: 1-3, 9-10 ("Wraps")
- Shall estimate cost Phase B/C/D
- Shall provide optional Phasing Cost Plan/Funding Profile
- Shall take into account various types of hardware: flight units, engineering units, flatsat, spares
- Shall provide cost risk analysis
- Shall provide cost estimate by: a) build (MEL) b) existing heritage with options to modify
- Shall estimate based on orbit destination (LEO, GEO, L-1, etc…)
- Shall be able to automate inflation based on NASA's inflation rates

AMES Cost Model Flow Architecture*



AMES Cost Model System Level Tool Architecture

*Preliminary design

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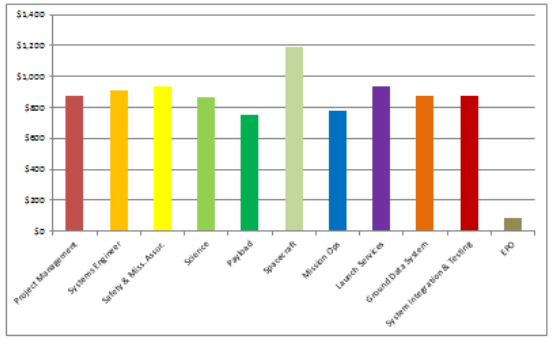
Desired Output Results

NASA AMES Cost Model - Ames Micro/NanosatellitES Cost Model

Project Level Cost

WBS	Description	FY15$ in K
1	Project Management	$874
2	Systems Engineer	$911
3	Safety & Miss. Assur.	$935
4	Science	$862
5	Payload	$750
6	Spacecraft	$1,193
7	Mission Ops	$777
8	Launch Services	$935
9	Ground Data System	$874
10	System Integration & Testing	$874
11	EPO	$90
	Subtotal (B/C/D)	**$9,078**
	Phase A*	$1,816
	Total (Phase A-D)	**$10,893**
	Reserve	$2,723
	Grand Total with Reserve (A	**$13,616**

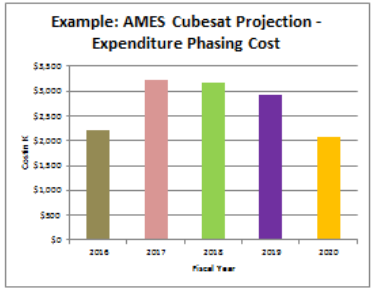
*Parametric Estimate, xx% of B-D



Phasing Expenditure Plan

Expenditure Dollars, not Budget. See other table for Budget.

AO (1) or Directed (0)	1
GFE Hardware	2
Months duration (to last	48
Months from SRR to PDR	5
SRR Date	1/1/2016
Last Launch	1/1/2020
Total Mission (no launch) Cost (BY$M)	13616
Base Year	2015



Fiscal Year	% time (=100% at last launch)	% BY cost (=100% at last launch)	Annual Cost (BY$), K
2016	19%	18%	$2,203
2017	44%	44%	$3,227
2018	69%	70%	$3,165
2019	94%	94%	$2,935
2020	113%	111%	$2,086
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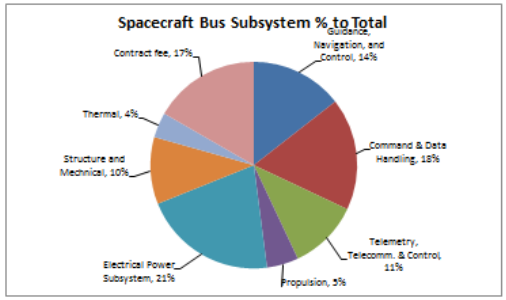
Spacecraft Hardware

Spacecraft Subsystem	Estimated Total Cost, FY15$ in K	% of Total
Guidance, Navigation, and Contro	$172	14%
Command & Data Handling	$209	18%
Telemetry, Telecomm. & Control	$131	11%
Propulsion	$59	5%
Electrical Power Subsystem	$250	21%
Structure and Mechnical	$125	10%
Thermal	$47	4%
Contract fee	$199	17%
Total Hardware Cost	$1,193	



Risk Analysis

Risk and Uncertainty Analysis	
Enter xxth-%tile Cost Here from Simulation	$13,429
Recommended Reserve,	**23%**
Recommended Reserve,	**$2,536**

Cummulative Prob, % and $

%	$, in K
5	$8,100
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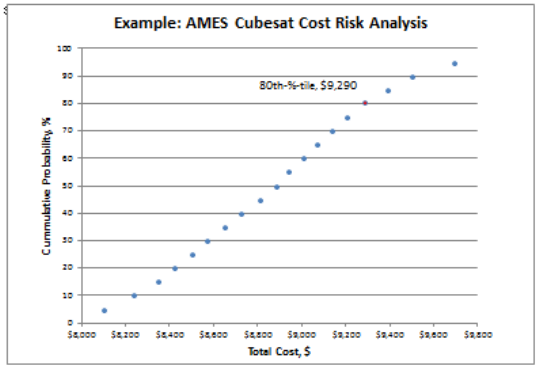

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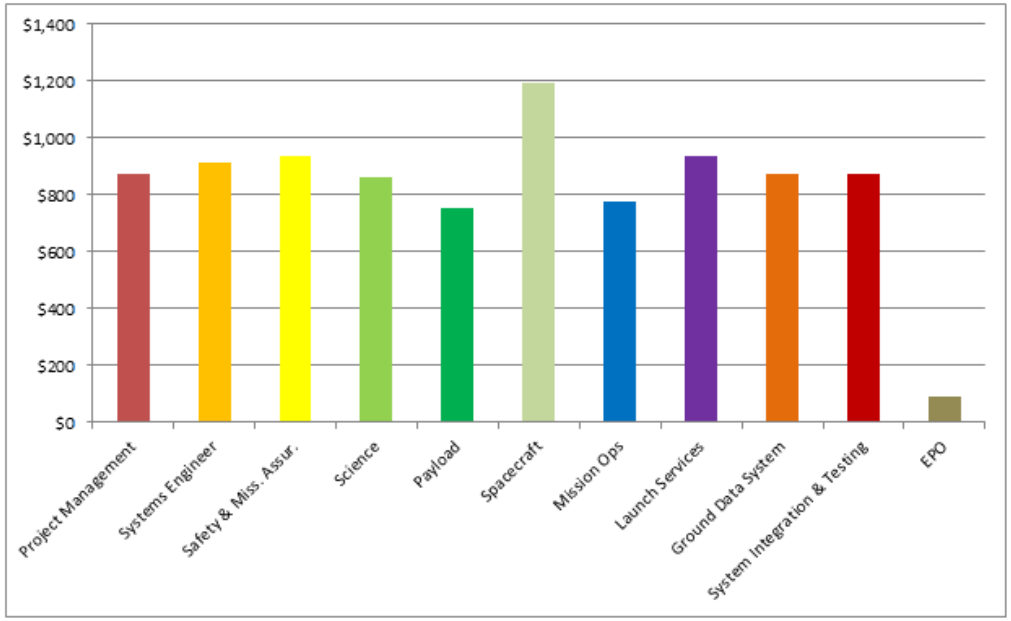

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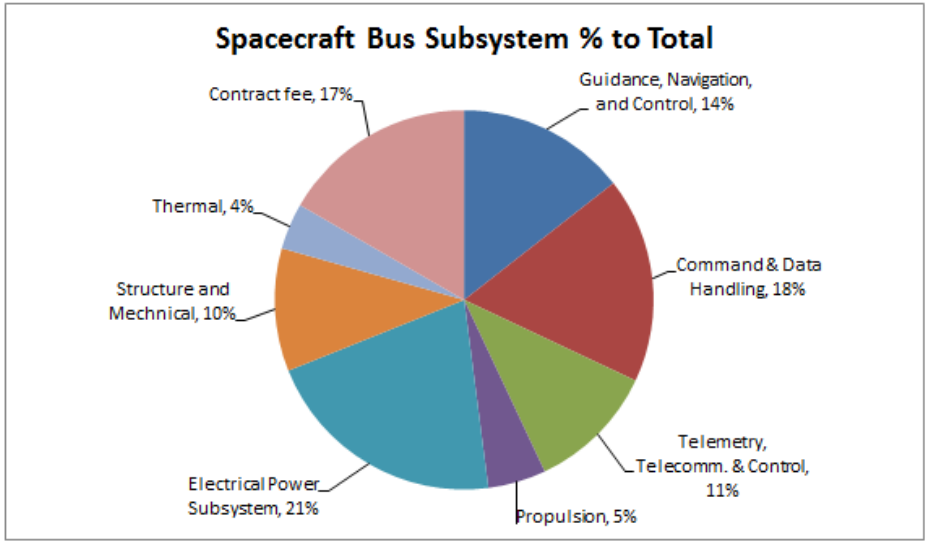

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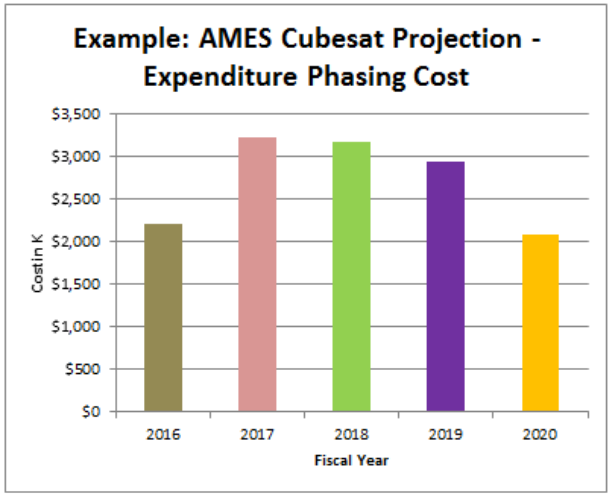

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Desired Output Results
Uncertainty Risk Probability Analysis

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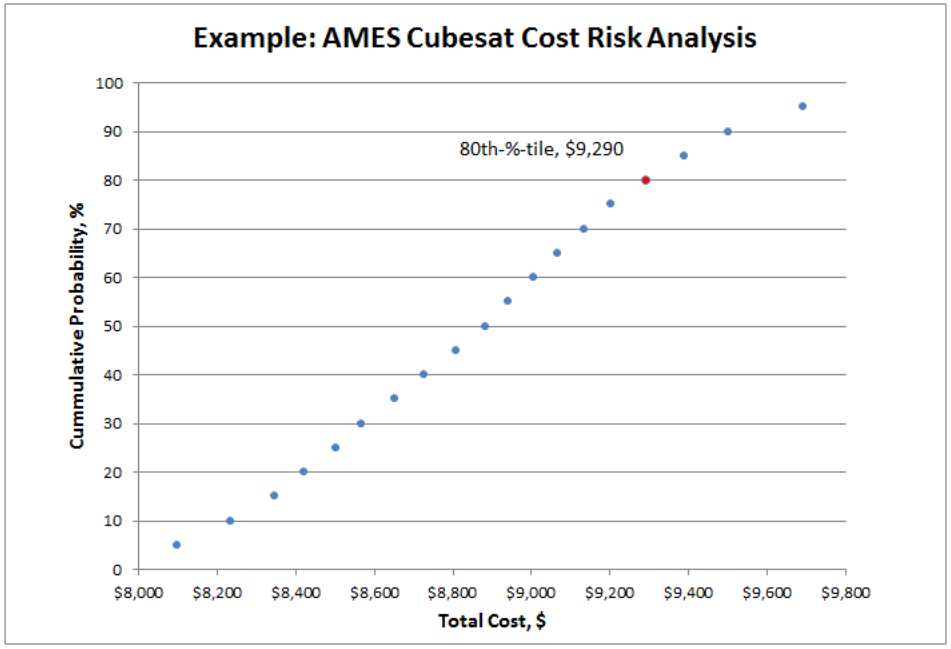

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Data Collection Plan

- Provide an easy input questionnaire template for the project missions for the PM, SE, and or cost resource for the project (such as CM who does the purchase request).
  - To minimize time for the partners, most info request will be filled out as they are publicly available information. Just need them to verify.

- Example of questionnaire for the PM/SE/Cost Resource:
  - Launch Date and Vehicle, Mission Type (Com. Sci., Tech, Edu)
  - Destination – LEO, LEO-ISS, Planetary, etc..
  - Development Time (months) and milestone dates
  - Design Life
  - Form Factor - # of U's
  - "C3PO" – Comm (Up/Down/Cross-Link), Power (EPS), Propulsion, Pointing (ADCS/GNC), Operations (autonomy), Struc. (deployable), C&DH (processors)
  - Total Project Cost, FTE/WYE, Contributions, SC subsystems

Addressing Cost Model Development Challenges

- Determine design and mission parameters to cost relationships
- Determine common cost estimating relationships (CERs) from traditional small spacecraft (>50kg) for application of micro/nanosatellites cost estimate
- Cost factors for different types of orbits – Suborbital, LEO, LEO-ISS, GEO, etc..
- Cost factors for modifying COTS (i.e. Major Modification, Minor Modification, No Modification)
- Determine cost savings from using design heritage
- Determine cost scaling factor pattern (example – cost of 3U will double if designed to 6U).

Development Process

Where we've been:

- Set the requirements
- Began socializing to the Ames, cost community, and subject matter experts
- Explored other parametric tools – PRICE TP (Space Mission Catalog), SEER, NASA's Project Cost Estimating Capability (PCEC), The Aerospace SSCM (Small Satellite Cost Model)

Where we are currently:

- Collecting cost, project, and technical data.
- Continuing to socializing ideas to the Ames and cost community

Path Forward:

- Continuing to gather and collect cost, project, and technical data (10 projects)
- Normalize and analyze collected data results and validity to the cost tool
- Continue to leverage expertise from the cost community
- Generate data into cost model and test preliminary model by Fall 2015 (depending on data collected)

Summary

- Increase Demand of micro/ nanosatellites calls for a need for more efficient and accurate cost estimates
- Development Process
- AMES Cost Model Overview
- Data Collection Plan

Acknowledgement

- **NASA ARC Community:**
  - Paul Agnew, Chief Financial Officer (CFO), Ames Research Center
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  - David Korsmeyer, Director of Engineering
  - Leon Shen, Associate, Booz Allen Hamilton
  - Chad Frost, Division Chief, Mission Design Division
  - Deborah Westley, Program Manager, Chief Scientist Office
  - Elwood Agasid, Chief Technologist, Mission Design Division
  - Andrea Nazzal, Deputy Program Manager, PESS Contract
  - Lynn Hutchison, Senior Cost Analyst, Logical-R
  - Mina Cappuccio, Lead for Spacecraft Projects Office, Engineering Systems Division
  - Michael Henschke, Configuration Manager

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  - Bob Bilbrey, Senior Associate
  - Eric Druker, Chief Technologist
  - Brian Alford, Lead Associate

- **NASA Headquarters:**
  - Charles Hunt
  - Eric Plumer
  - James Johnson
  - COMPACT Team

- **External Community:**
  - Andy Prince (NASA MSFC)
  - Joe Mrozinski (JPL)
  - Mark Jacobs (Victory Solutions)
  - Nani Tosoc (NASA LARC)

Thank You

Questions, Discussions and Feedback

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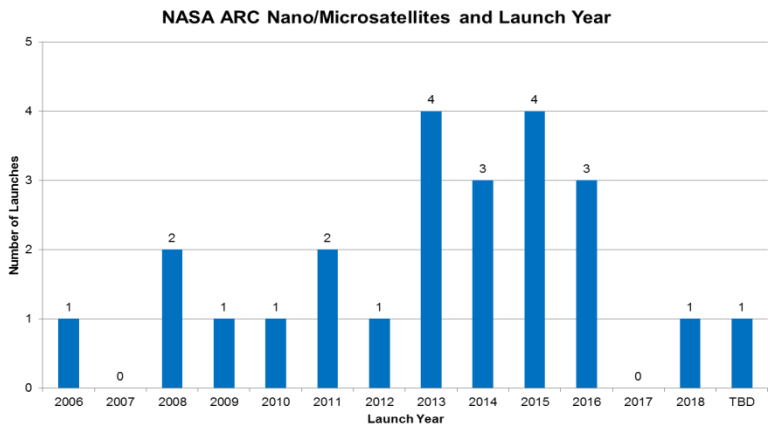
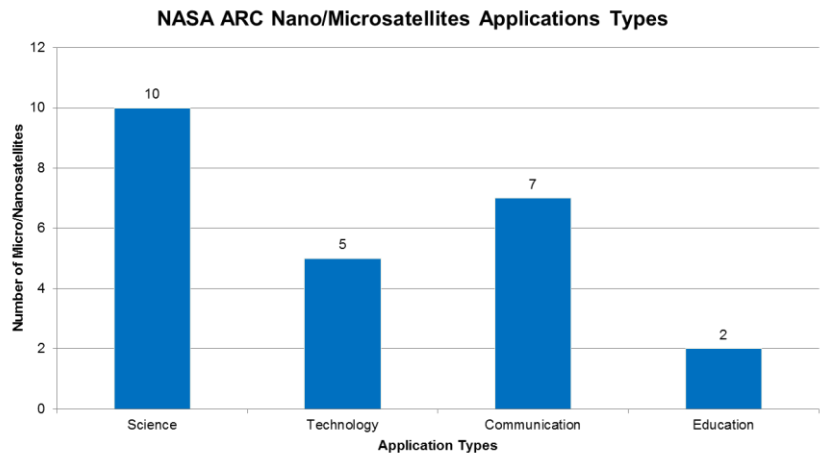
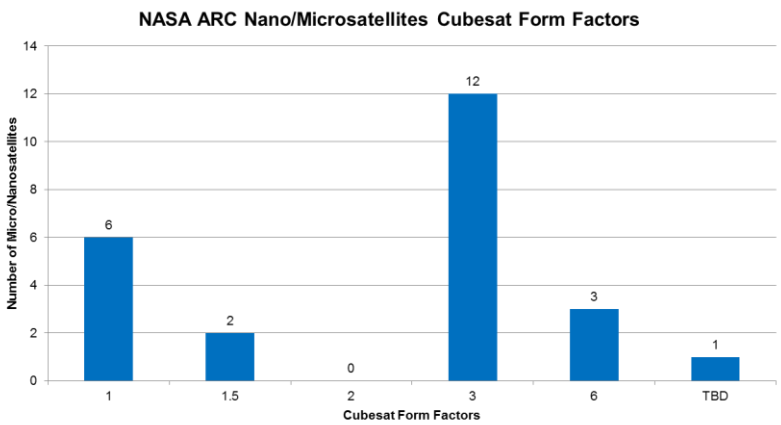
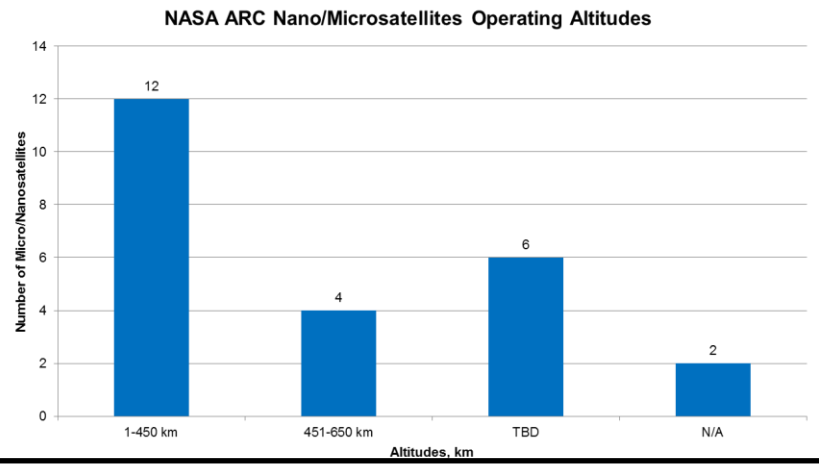
Back-up Slides

Past and Present NASA ARC Cubesats Mission









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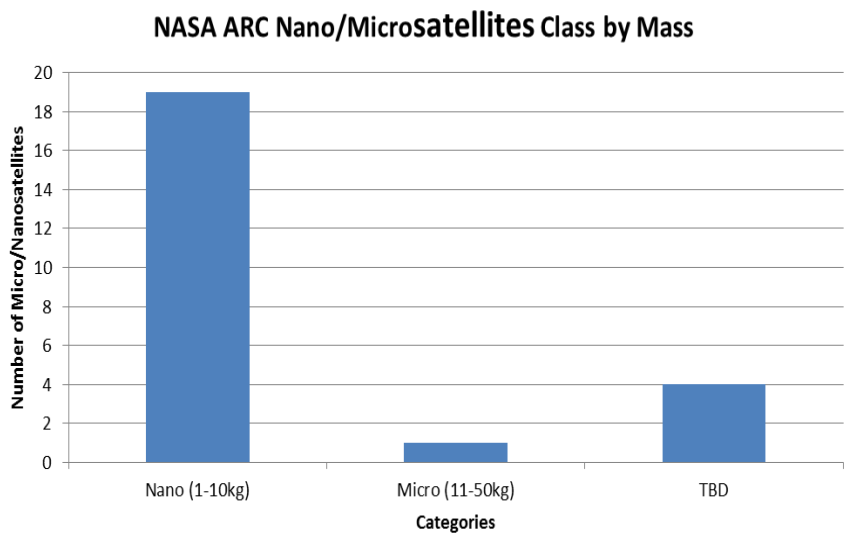
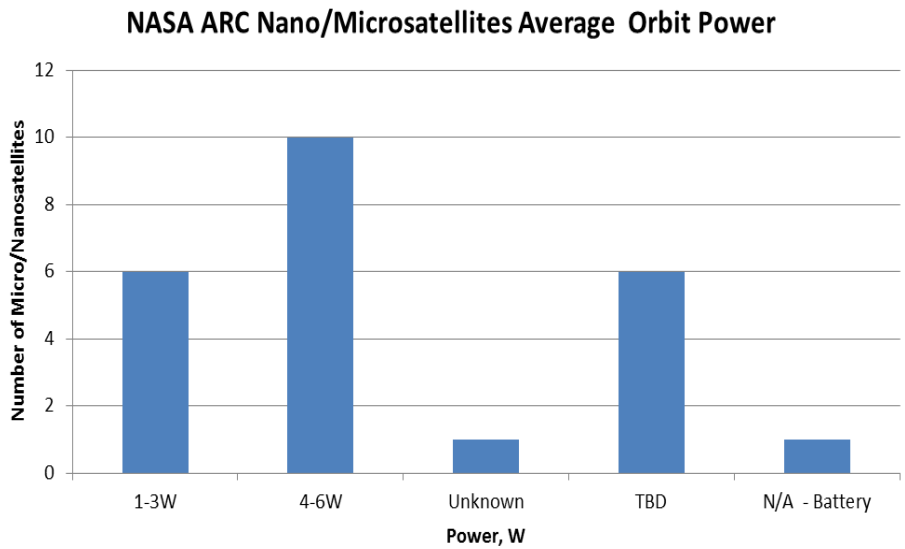
Past and Present NASA ARC Cubesats Mission





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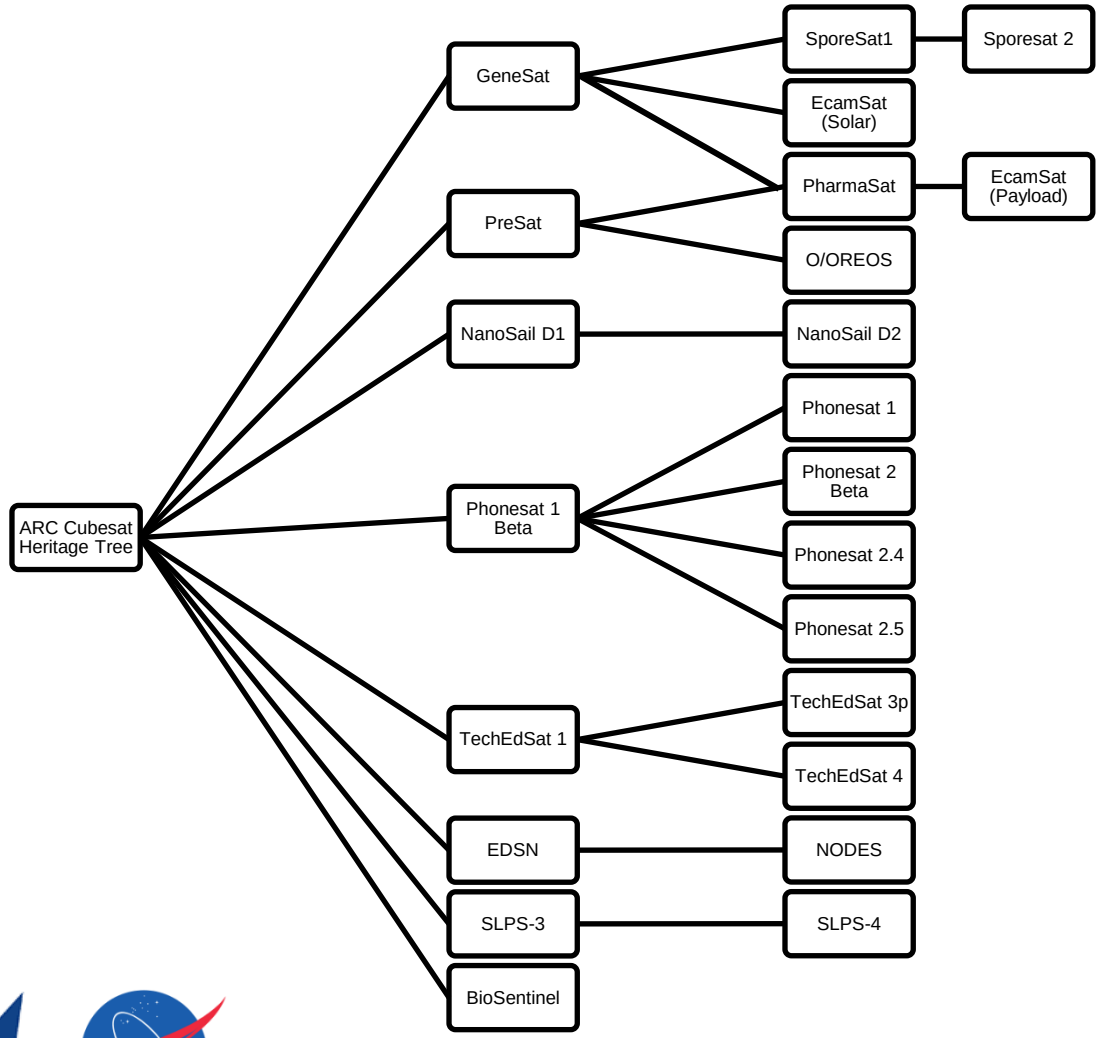
NASA ARC Micro/NanoSatellite Heritage Tree



Top 10 Project Missions to start out with
•GeneSat
•PharmaSat
•O/OREOS
•Nano-Sail D2
•PhoneSat 2.4
•PhoneSat 2.5
•EcAMSat
•EDSN
•NODes
•SporeSat1
•SporeSat2

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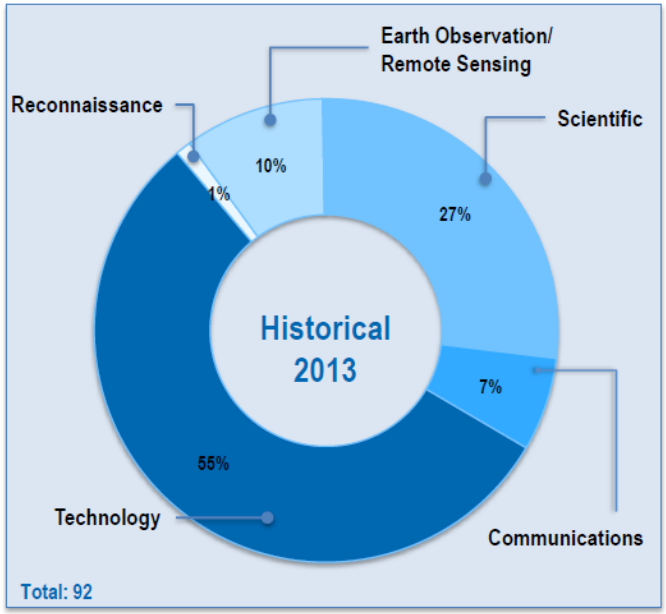
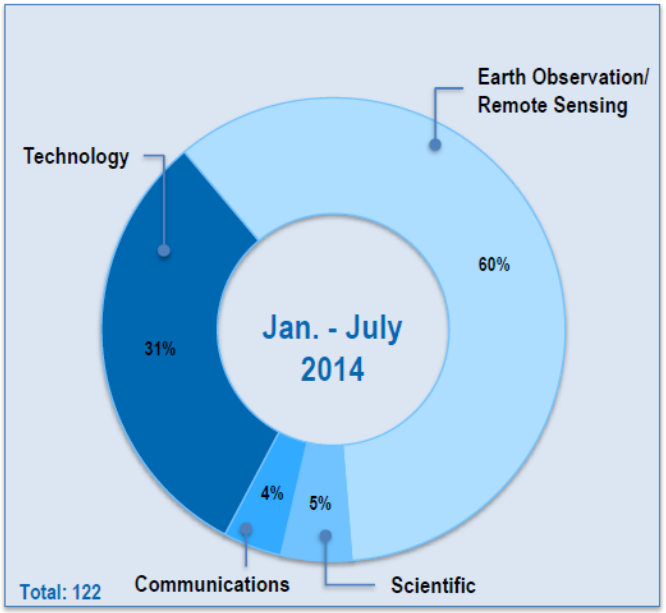
Nano/Microsatellite Market Overview/Assessment

Nano/Microsatellite Trends by Purpose (1 – 50 kg)

More than half of future nano/microsatellites will be used for Earth observation and remote sensing purposes (compared to 10% in 2013)





A smaller proportion of technology development/demonstration nano/microsatellites will be built in 2014 (31% vs. 55% in 2013)

Ref: http://www.sei.aero/eng/papers/uploads/archive/SpaceWorks_Nano_Microsatellite_Market_Assessment_January_2014.pdf