Science & Technology Office

Small Lean Science, Technology and Exploration Missions and Access to Space

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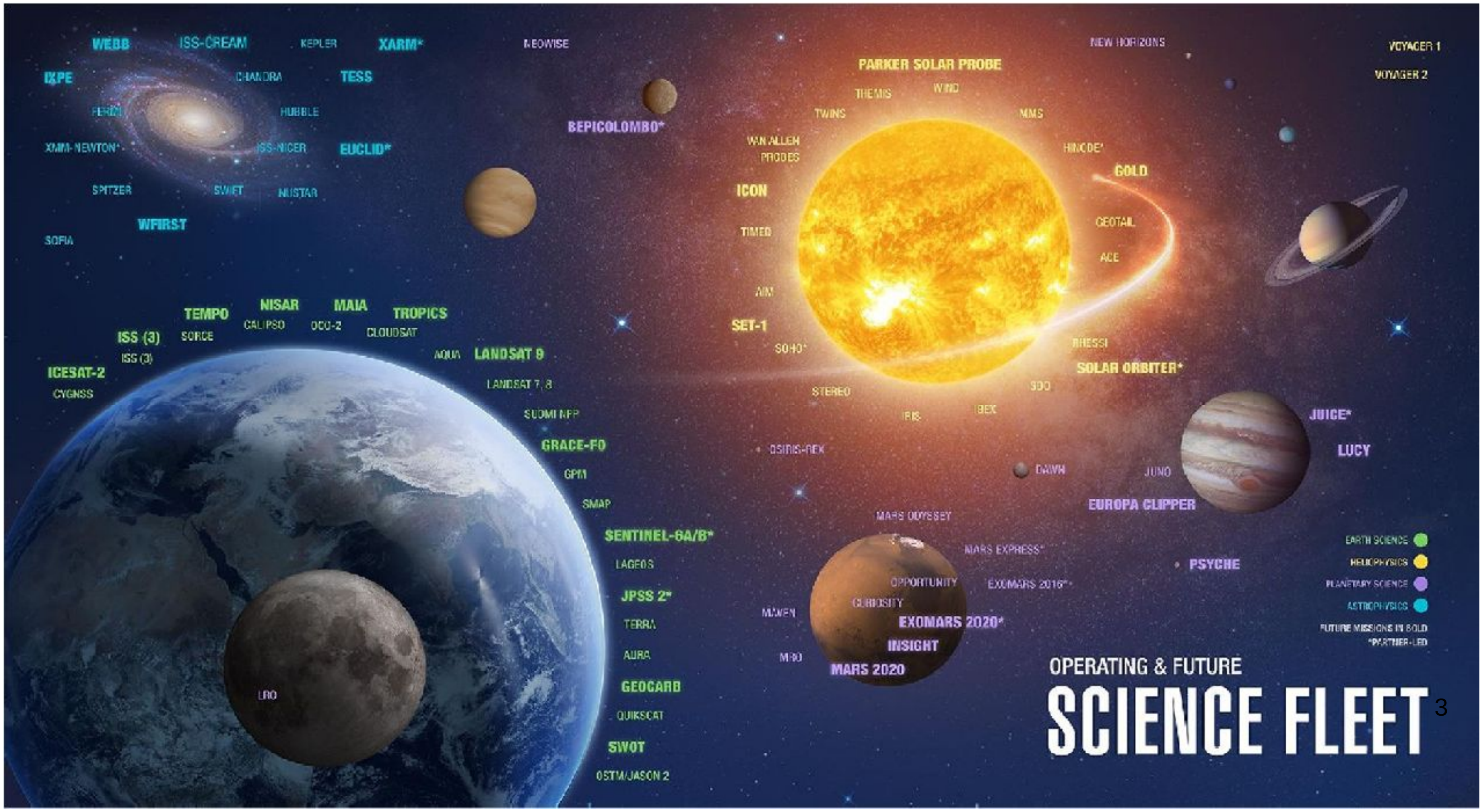
Outline

Context of Use of Space for Small Missions

Reliability Management Approach Considerations

Launch Access

Context of Space Use

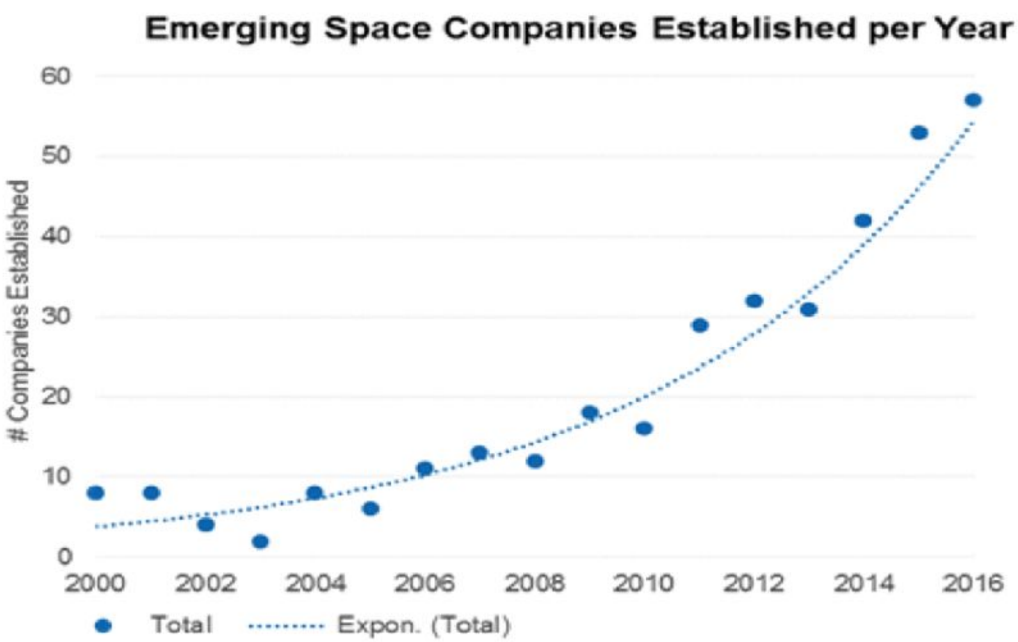


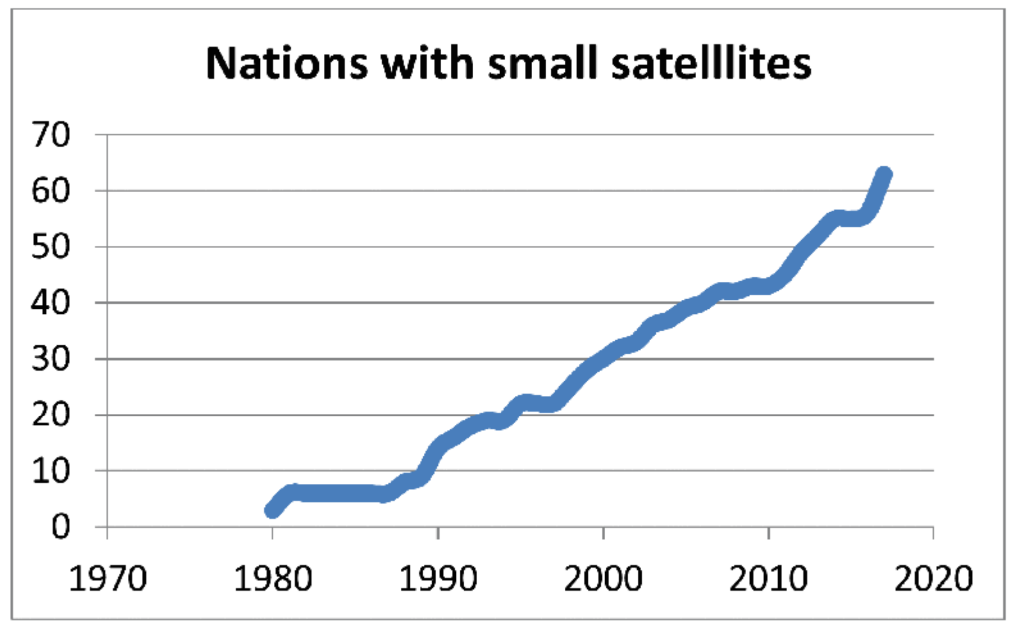
Context of Space Use

- Over the past several decades of years the small satellite mission market has been experiencing an advanced rate of growth in capabilities, number of missions and user investments due to the increasing demand of small satellite applications among end users within academia, commercial, defense, and government.
- This higher scale of growth on an international basis in both interest level and actual participation within the space communities is subsequently influencing the development of small satellite spacecraft technologies, payload instruments, approaches to mission development and launch vehicle systems.
- Within this growth of the small satellite user missions, a new range of experiments, projects, programs, organizations and businesses are being created to advance the use of small missions for scientific research, technology development, data services, exploration and operational capabilities.
- Three of the major factors effecting this growth in the use of the space environment are
  - the size of the spacecraft,
  - the reliability management approach
  - and the availability of a wide variety of lower cost launch accommodations

Context of Space Use

- The global small satellite market size in USA dollars was valued at $2,045 million USD in 2015, and is expected to reach at a compound annual growth rate (CAGR) of 19.8% with the revenue of $7,179 million USD by 2022.





Source: NSR

Context of Space Use

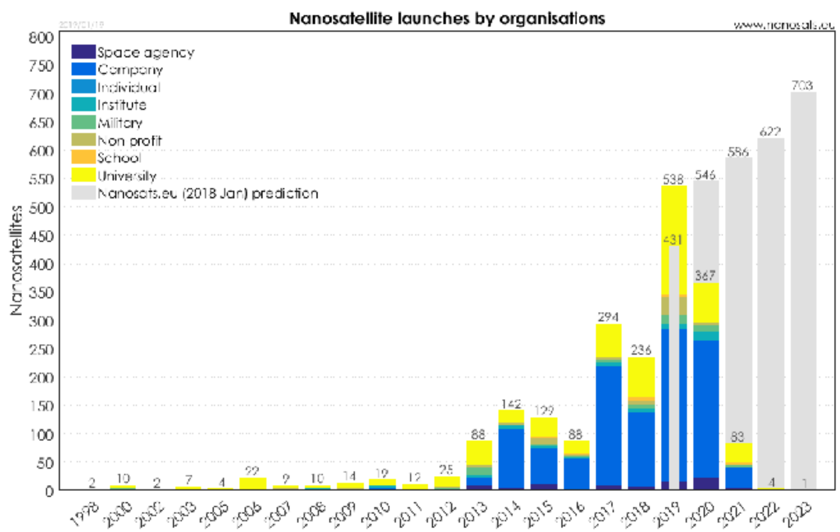
- Small satellites are used to conduct missions both in earth orbit , cis-lunar and planetary . Small satellites are categorized into mini-satellites (mass of 100-500 kg), microsatellites (10-100 kg), and nanosatellites (1-10 kg). The fastest growth in number of small satellite recently is in the size category of less than 50-kilogram in mass.

Context of Space Use

- This growing market in the number of small satellites reflects increases in the use of spacecraft for various applications such as Earth observation, communication, scientific research, and technology demonstration

Context of Space Use

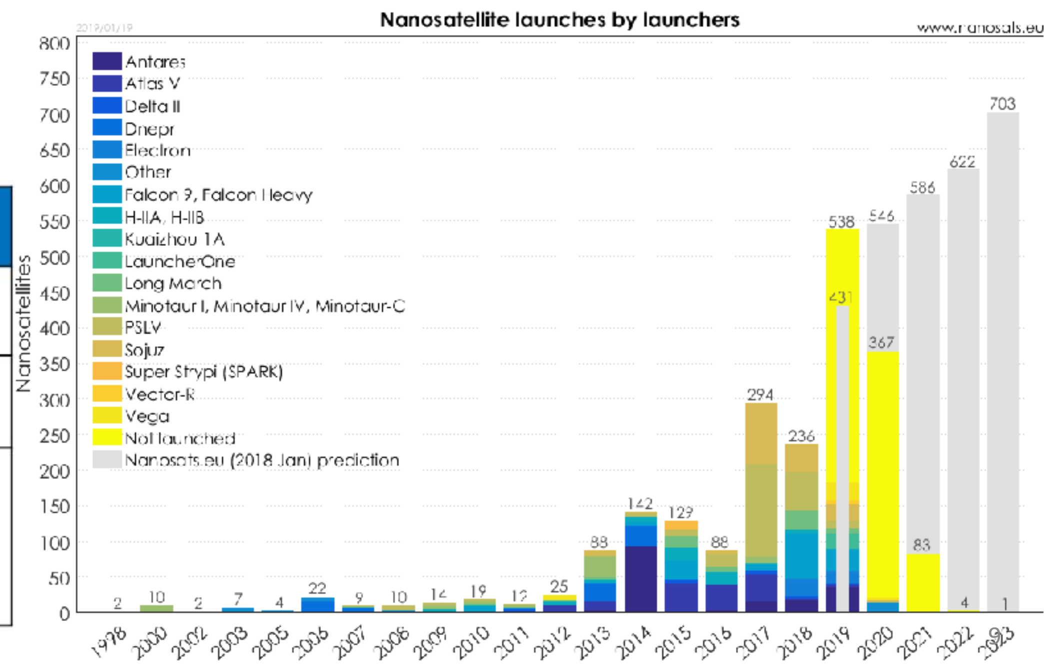
- The growing demand for access to space by small satellite mission users and the increasing use of constellations for experimental and operational applications, such as remote sensing, navigation, communication, Internet of Things(IoT) and observations missions has created driving factors of interest, opportunities and sometimes concerns within the small satellite communities of interest.
- These communities of interest are involved as users, developers, suppliers, consumers of services, investors, regulators and legislators



Context of Space Use

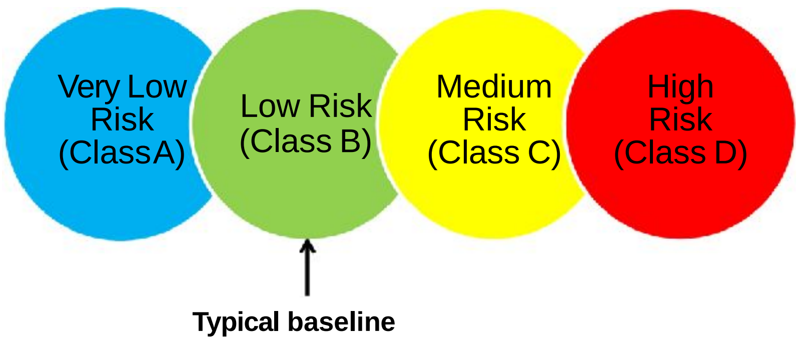
- As in many technological oriented markets, many factors influence the growth of the small satellite market and the characteristics of the market sectors.
- Two of the major factors driving both interest and concerns addressed in this paper are in the areas of
  - reliability management approac
  - launch access

	High Risk Approach*	Additional ISS Safety-related Requirement
Single Point Failures	"…single string approaches may be used."	Critical SPFs may be permitted if there are no safety impacts (per NSTS 1700.7B)
Materials	"..based on applicable safety requirements"	All materials shall be verified as specified in ICDs, NSTS 14046 and NSTS 1700.7B/SSP 50021
Test Program	"..only for verification of safety compliance and interface compatibility"	Payloads will be required to be proven structurally safe and compatible with the ISS for all expected flight environments. This process will include verification of payload structural strength and life integrity as well as strength verification for selected materials.



Reliability Management

- In general NASA* divides all airborne/space science equipment into one of four risk classifications-



- Determining the risk classification for a particular payload is an *inexact,* iterative process
  - Classification is finalized prior to Preliminary Design Review through a combination of various NASA offices/organizations/ councils

*- NPR 8705.4, "Risk Classifications for NASA Payloads" 33

Risk Classification Considerations*

	Class A (Very Low Risk)	Class B (Low Risk)	Class C (Medium Risk)	Class D (High Risk)
Priority (Criticality to Agency Strategic Plan) and Acceptable Risk Level	High priority, very low (minimized) risk	High priority, low risk	Medium priority, medium risk	Low priority, high risk
National Significance	Very high	High	Medium	Low-to-medium
Complexity	Very high to high	High to medium	Medium to low	Medium to low
Mission Lifetime (Primary Baseline Mission)	**Long >5yrs**	**Medium 2-5 yrs**	**Short(~3)**	**Short (<2 yrs)**
Cost	High	High to Medium	Medium to low	Low
Launch Constraints	Critical	Medium	Few	Few to None
In-flight Maintenance	N/A	Not feasible or difficult	May be feasible	May be feasible and planned
Alternative Research Opportunities or Re-flight Opportunities	No alternative or re-flight opportunities	Few or no alternative or re-flight opportunities	Some or few alternative or re-flight opportunities	Significant alternative or re-flight opportunities
Achievement of Mission Success Criteria	All practical measures are taken to achieve minimum risk to mission success. The highest assurance standards are used.	Stringent assurance standards with only minor compromises in application to maintain a low risk to mission success.	Medium risk of not achieving mission success may be acceptable. Reduced assurance standards are permitted.	Medium or significant risk of not achieving mission success is permitted. Minimal assurance standards are permitted.

-NPR 8705.4

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Reliability Management

Example- Deep Space Science Mission

	Class A (Very Low Risk)	Class B (Low Risk)	Class C (Medium Risk)	Class D (High Risk)
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Reliability Management

Example- Earth Science Orbiter (3 yr mission)

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Example- Science Instrument for Mars Lander

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Example- Space Station Science Demo

	Class A (Very Low Risk)	Class B (Low Risk)	Class C (Medium Risk)	Class D (High Risk)
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Cost	High	High to Medium	Medium to low	Low
Launch Constraints	Critical	Medium	Few	Few to None
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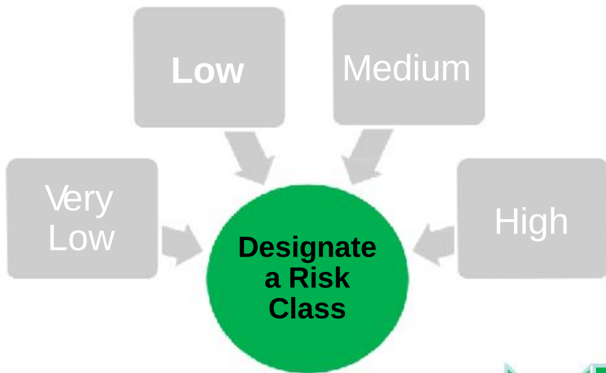
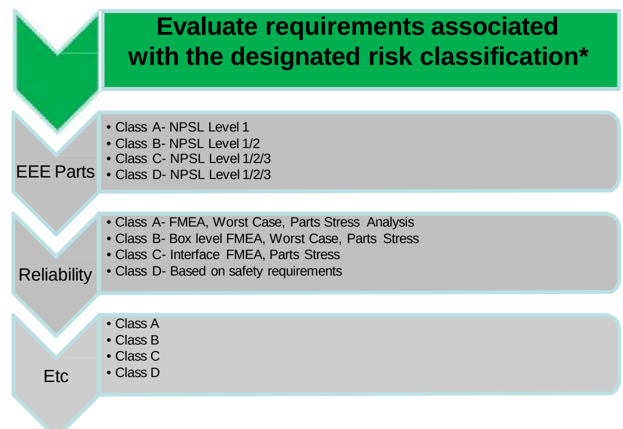
Recap- It’s a Two Step Process

STEP 1



STEP 2

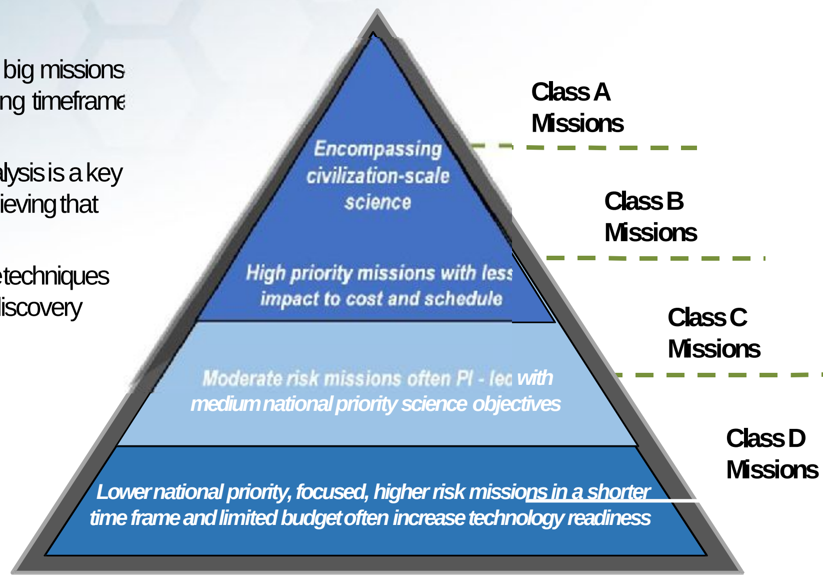


*- per NPR 8705.4

Reliability Management

The Value of a Balanced Portfolio

- Importance of the big missions but recognizing long timeframe to achieve results
- Research and Analysis is a key component of achieving that balance
- Employ innovative techniques to grow scientific discovery



Class D Strategy

Innovative Techniques to Inspire Learners

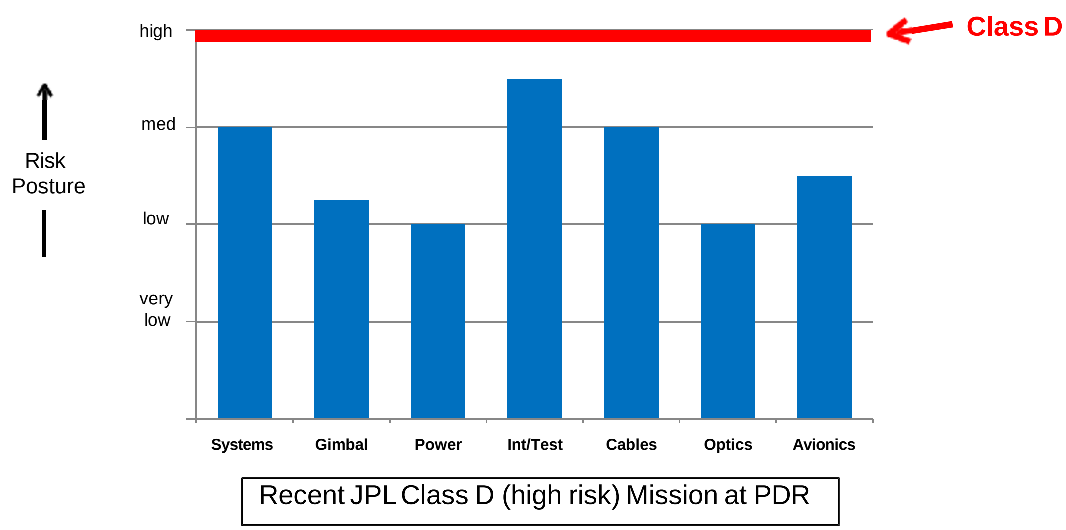
- **Expand** science programs to take advantage of Class D and small satellite rapid innovation to achieve breakthrough science
- **Enable** fast access to space for focused science measurements that fill a critical gap between large flight projects
- **Leverage** technology investments to further improve potential of science instruments
- **Partner** with international agencies and commercial entities to acquire new capabilities of small satellite platforms

Class D Strategy Implementation

Accepting higher risk for scientific gain by implementing a tailored, streamlined classification approach

Medium/High Risk Payload Challenges

- The willingness to assume "additional" risk, versus normal practice(s), is typically uneven throughout an organization



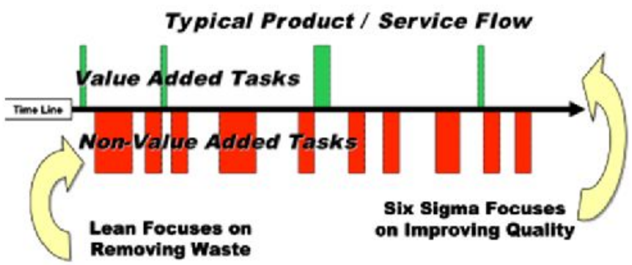
- "Medium/high risk is OK in other areas, but not mine"

Main Challenges

- At NASA, there are generally two challenges in dealing with NASA's multiple science payload risk classifications-
  1) Science payloads with a lower risk posture than the traditional NASA "low risk" Institutional baseline- i.e., "very low" risk missions, for example Lean Missions ?
     - Meeting these guidelines requires unique add-ons to the way NASA typically performs work
       - – Impact of SIX SIGMA approach is usually largely programmatic- increases in cost and cycle time (full qualification & acceptance test programs, separate prototype and flight models, etc)
  2) Science payloads that adopt a higher risk posture than the NASA "low risk" Institutional baseline- "medium/high" risk missions
     - In our experience, more effort (than expected) is required to actually execute a science payload mission with less than traditional rigor and penetration
  3) Opportunities for use of Lean SIX SIGMA approaches

"Lean" Small Satellite Missions Concept

- The concept of "lean satellite missions" was born from the creation and evolution of the practices of lean manufacturing, lean engineering, lean satellites , lean launch and lean operations
- "Lean" is a both technical and management approaches to the "risk and reward" considerations, it is not a standard by itself
- Lean and Six Sigma are widely used in industry as continuous improvement best practices
  - They can also be very **complementary** in nature and, if performed properly, can produce unprecedented results
  - Lean focuses on eliminating non-value added activities in a process and Six Sigma focuses on reducing variation from the remaining value-added steps
  - Lean provides speed ensuring products and services flow without interruption while Six Sigma ensures that critical product / service characteristics are completed correctly the very first time we do them.



Launch Access to the Environment of Space

Atlas V

Space Shuttle

Zero G Flight

High-altitude balloon

Sounding rocket

Minotaur IV

- More than 100 organizations world wide are thought to be currently developing launch vehicles
- More than 30 small launch vehicles are being developed (< 500kg Payloads)
- Ridesharing opportunities have increase by a factor of 10 in the last 5 years

Lean Access to Space

- Improved CubeSat manifesting via NASA's CubeSat Launch Initiative (CSLI)
- As reliability is demonstrated, some providers may be appropriate for future less risk-tolerant NASA missions
- Milestones-based payment structure; ***limited*** LSP insight through milestone reviews
- A ***single demonstration*** flight was awarded to Firefly, Rocket Lab, and Virgin Galactic
- Statement of Work: Minimum 60kg to LEO (425km), orbit inclination 33 to 98 degrees, launch date no later than April 15, 2018
- Companies are responsible for LV development costs

Comparison Only

VECTOR (new)

Specification *	Alpha 1.0 (Firefly)	Electron (Rocket Lab)	LauncherOne (Virgin Galactic)	Pegasus XL (Orbital)
Length	23 m	17 m	20 m	16.9 m
Payload Mass	200 kg	150 kg	300 kg	Up to 443 kg to LEO
Payload Diameter	1.45 m	1.1 m	1.3 m	1.18 m
Orbit	500 km (Sun Synchronous)	500 km (Sun Synchronous)	500 km (Sun Synchronous)	Multiple
LV Certification	No certification High risk-tolerant spacecraft			Certified; Low risk-tolerant spacecraft

* LSP recommends a 25% reduction from published specifications for vehicles of this size and maturity until successfully demonstrated


SLS CAPABILITY AVAILABILITY
SLS Block 1
As Early As 2020
Provides
Initial Heavy-Lift Capability
Enables
Orion Test
SmallSats to Deep Space
SLS Block 1B Crew
As Early As 2023
Provides
105 t to LEO capability via Exploration Upper Stage
Co-manifested payload capability in Universal Stage Adapter
Enables
Deep Space Gateway
Larger CubeSat- and ESPA-Class Payloads
SLS Block 1B Cargo
As Early As 2023
Provides
8.4-meter fairings for primary payloads
Enables
Europa Clipper/Lander
Deep Space Transport
Ice or Ocean Worlds Missions
Large-Aperture Space Telescopes
SLS Block 2
As Early As 2028
Provides
130 t to LEO capability via advanced boosters
10-meter fairings for primary payloads
Enables
Crewed Mars Orbit Missions
Crewed Mars Surface Missions
SLS
www.nasa.gov/sls
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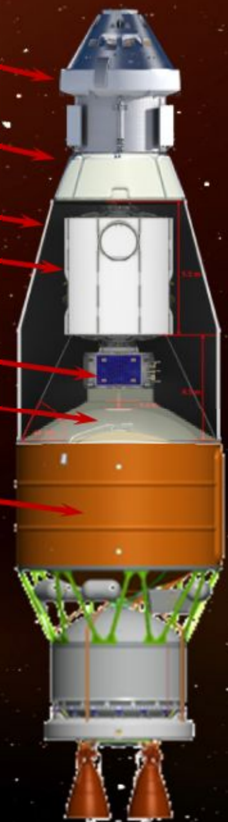
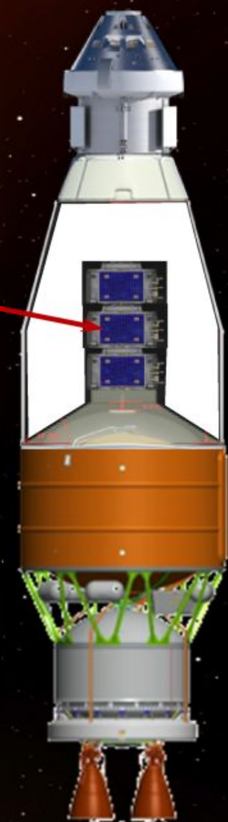
SLS Crew Launch Configurations

A Propulsive Payload Carrier as a Rideshare Capability for Secondary Payloads with a Co-Manifested Payload



or

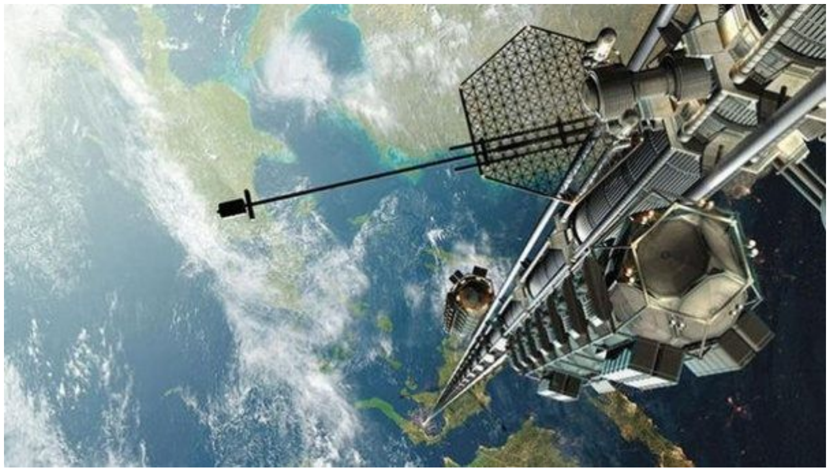
Multiple Propulsive/ESPA Payload Carriers with Secondary Payloads as a Dedicated Co-Manifested Payload



SLS B1B Secondary Payload Accommodation Concept

- Mounting on the Payload Adapter and Universal Stage Adapter (USA)
- Possible Complement
  - 22 – 6U
  - 2 – 12U
  - 2 – 27U
- Mounting on the aft portion of the Payload Adaptor has been shown to be the optimal mounting location

What does the Future Hold for Opportunities to Gain Access to Space ?

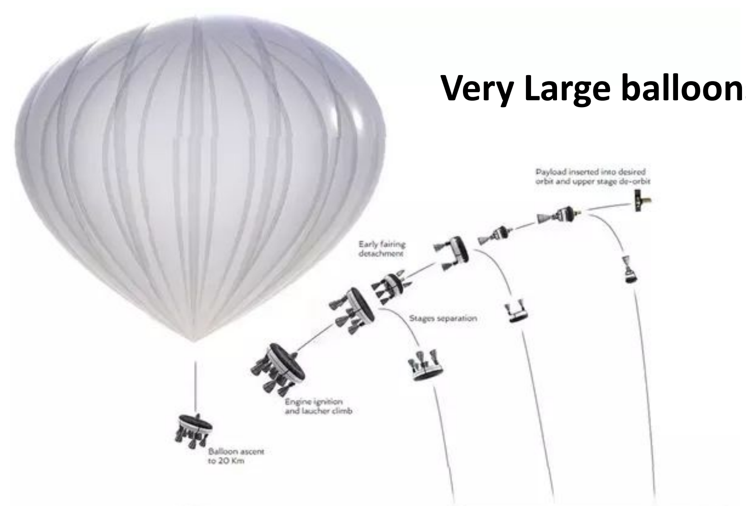


Space elevator -

Mega Rail Gun

Space Planes

Very Large balloons



QUESTIONS PLEASE ?

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References

Presentations;
Kenneth W. Ledbetter NASA, Science Mission Directorate Implementation of Spacecraft Risk Classifications;

Kim Plourde Caltech , Challenges in Implementing Medium & High Risk NASA Payloads and

Thomas Zurbuchen and Gregory Robinson, Science Mission Directorate Class D Strategy

Agenda

- NASA management process for determining mission and science payload* risk classification
- Examine the management implications of mission science risk classification
- Typical challenges with implementing science payloads of varying risk classifications
- The value of balancing our science and technology missions approach portfolio
- Observations/suggestions going forward

*-Science payload- Any airborne or space equipment or sensor that is not an integral part of the carrier vehicle and contributes to the science objectives. Small Satellite Missions ?