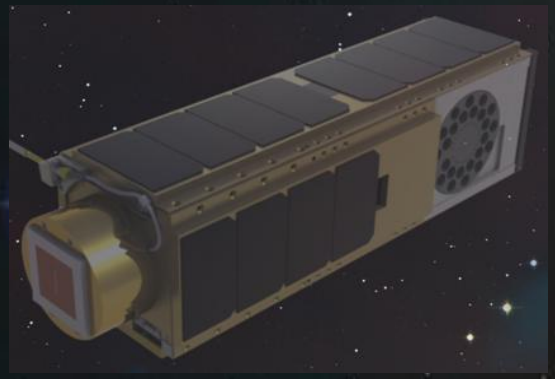
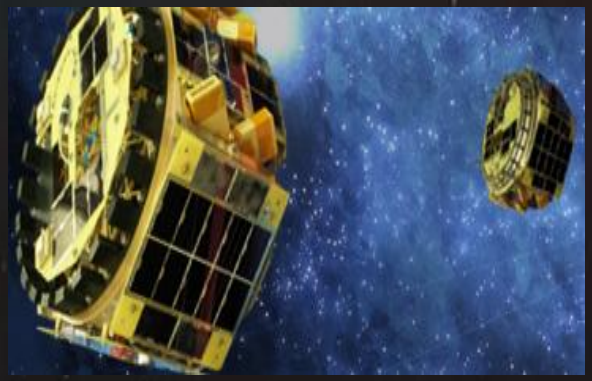
National Aeronautics and Space Administration



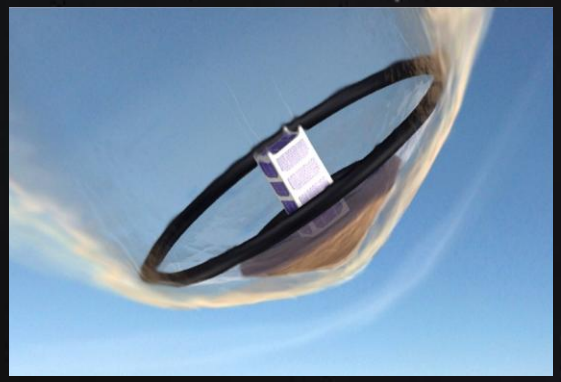


OFFICE OF THE CHIEF TECHNOLOGIST

SMALL SPACECRAFT PROGRAMS

24th Annual AIAA/USU Conference on Small Satellites

August 9, 2010



Agenda

- Overview
- Franklin Small Satellite Subsystem Technologies
- Edison Small Satellite Demonstration Missions
- Virtual Institute and Nano-Satellite Launch Challenge
- Q&A
- In-Room Breakout Discussions

Office of the Chief Technologist Overview

Space Tech Research Grants

NIAC

SBIR/STTR

Centennial Challenges

Center Innovation Fund

Idea

Idea

Idea

Idea

Idea

Idea

Idea

Franklin Small Satellite Subsystem Technologies

Game Changing Development

Possible Solution

Possible Solution

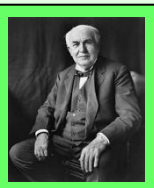
Possible Solution

Possible Solution

Possible Solution

Technology Demonstration Missions

Edison Small Satellite Demonstration Missions



Flight Opportunities

Crosscutting Capability Demonstration

Industry

Academia

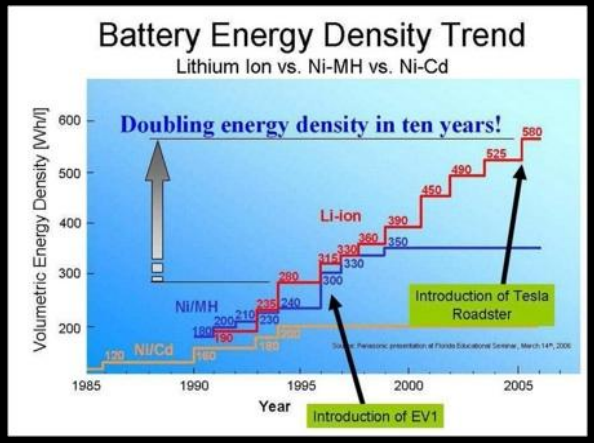
Govt

1	2	3	4	5	6	7

Technology Readiness Level (TRL): See http://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf.

Why Small Spacecraft? (1 of 3)

Innovation Rapidly Making Technology Smaller, More Powerful and Less Costly



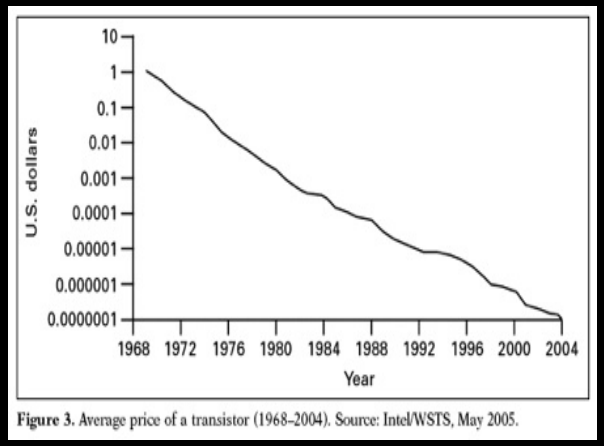
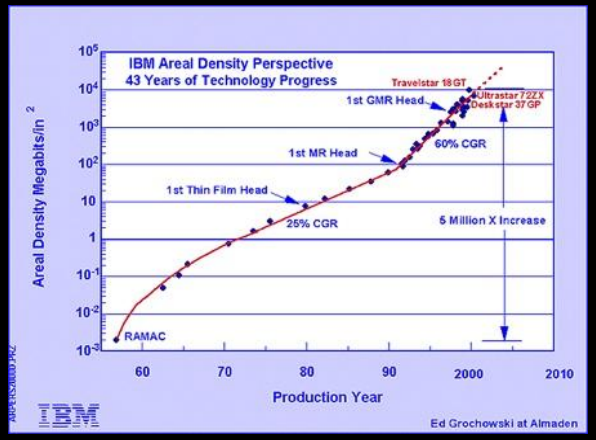
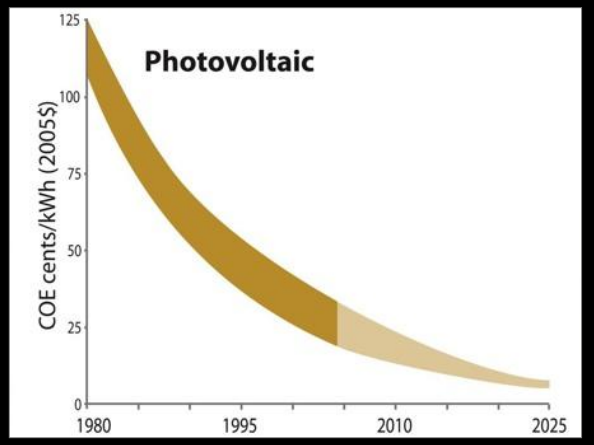
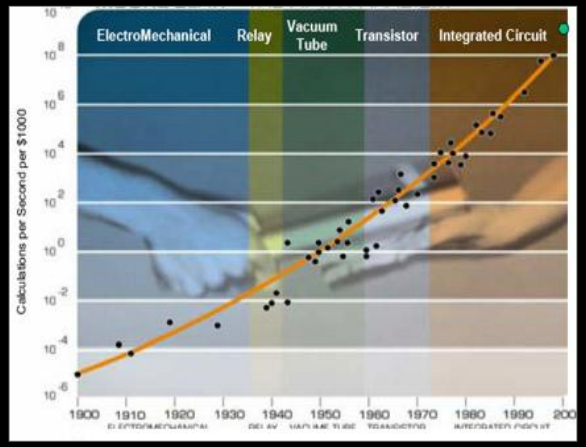
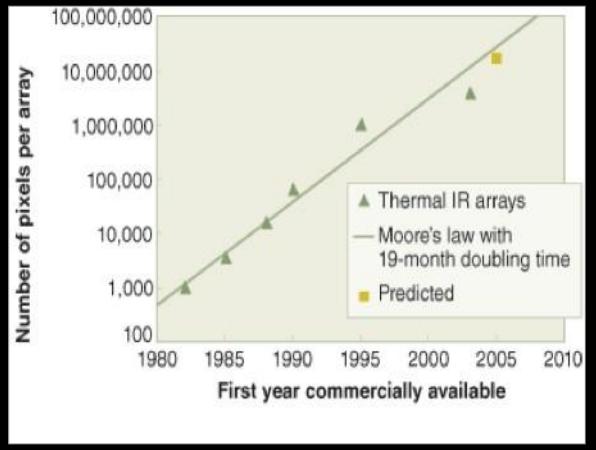


Figure 3. Average price of a transistor (1968–2004). Source: Intel/WSTS, May 2005.





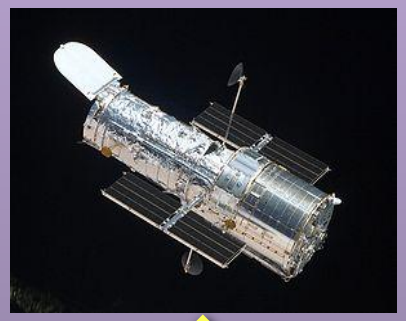


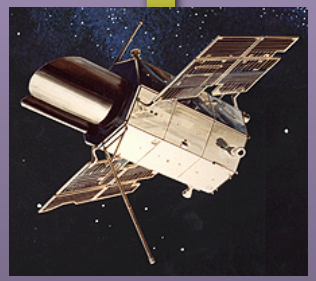


Infuse Technology Faster and Perform Missions Better and More Affordably

Why Small Spacecraft? (2 of 3)

Enable New Approaches to Satellite Communications and Remote Observation

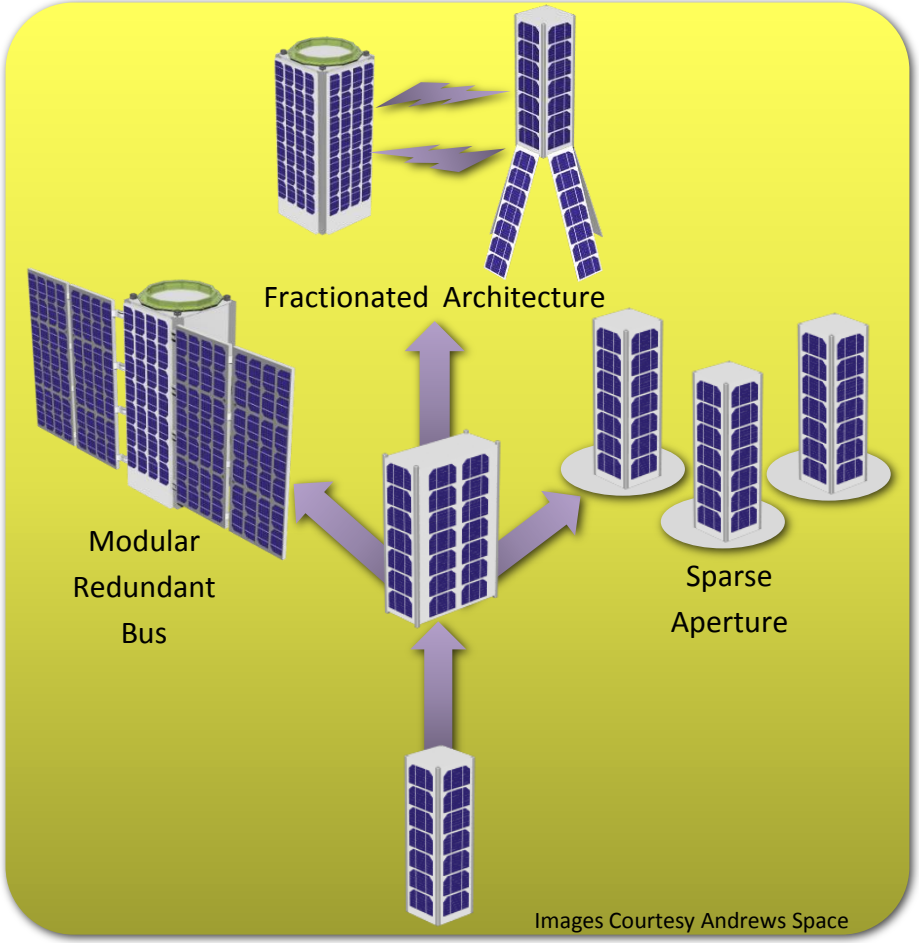




OAO to HST

TDRS-1 to TDRS-10

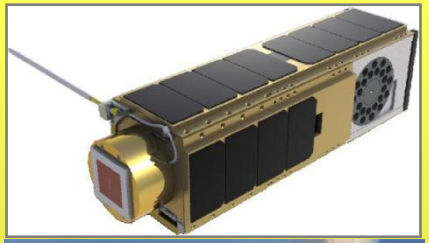
Spacecraft Evolution Usually Starts Large and Gets Larger

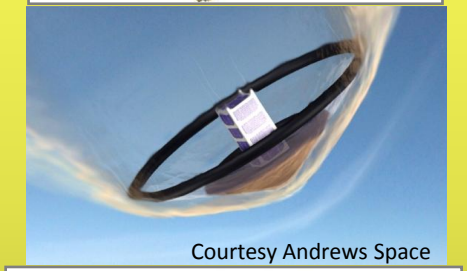


Radically Rethink Design Fundamentals By Starting Small

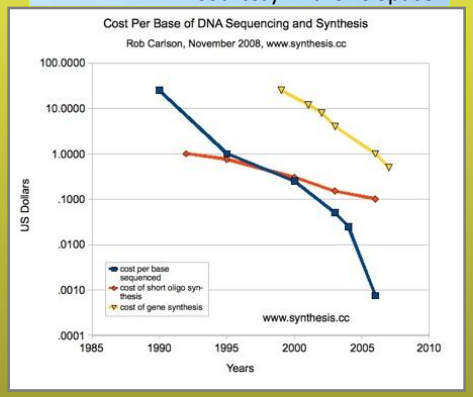
Why Small Spacecraft? (3 of 3)

Take Risks on New Applications

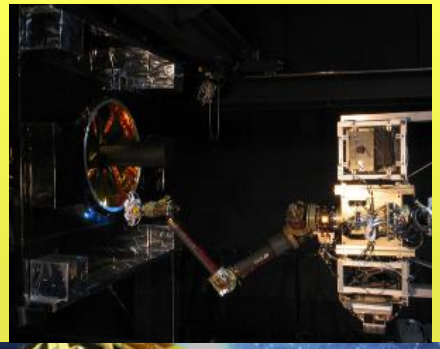


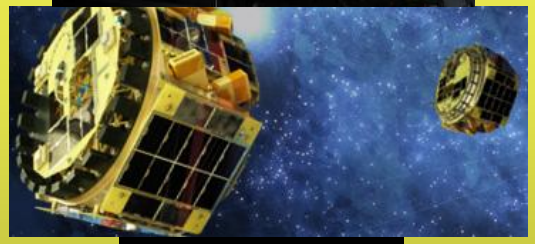


Courtesy Andrews Space

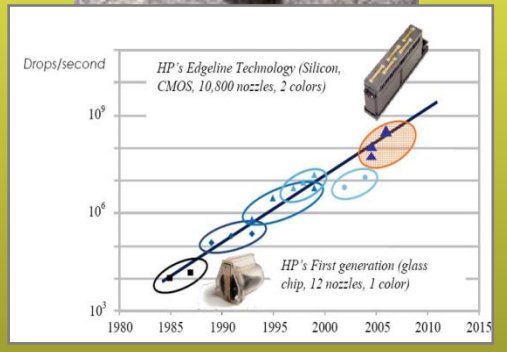


Biological and Physical Research





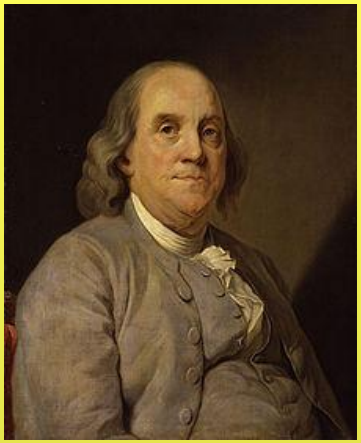
In-Space Servicing And Orbital Debris

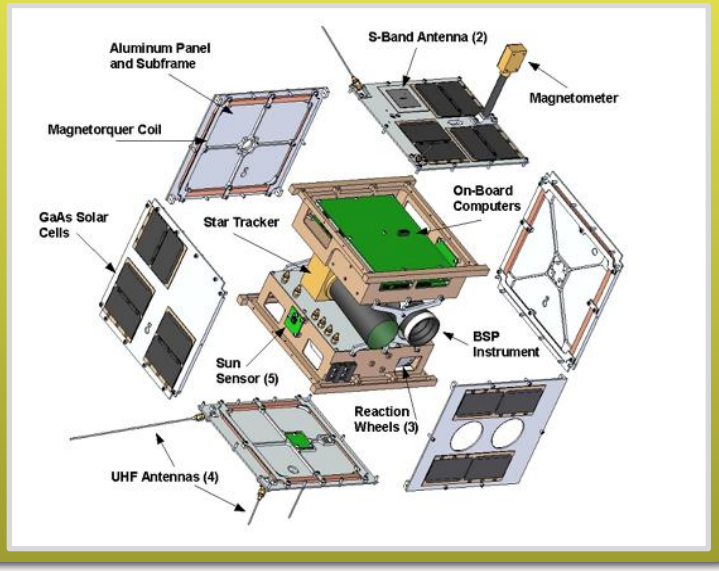


Planetary Research and Resources

Franklin Small Satellite Subsystem Technologies

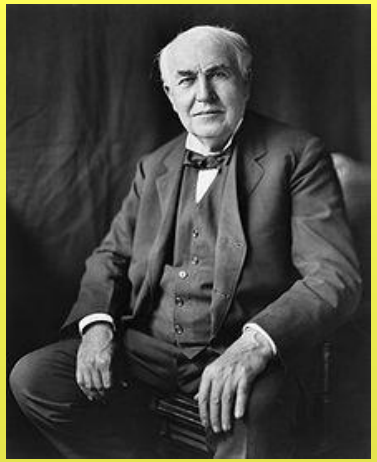
- **Objectives:** The Franklin Program will mature technologies that enable small satellites to provide game changing capabilities for the government and commercial sectors. At completion, the subsystem deliverables should be ready for demonstration in space.
- **TRL Maturation:** From TRL 3-4 to TRL 5-6
- **Solicitation:** Annual BAA. At least 2-8 competitively selected awards.
- **Awards:** One-year base activity with two, one-year options. Approximately $100 thousand to 3 million per year.
- **Collaboration:** Competitions open to academia, industry, and federal laboratories with partnering strongly encouraged.

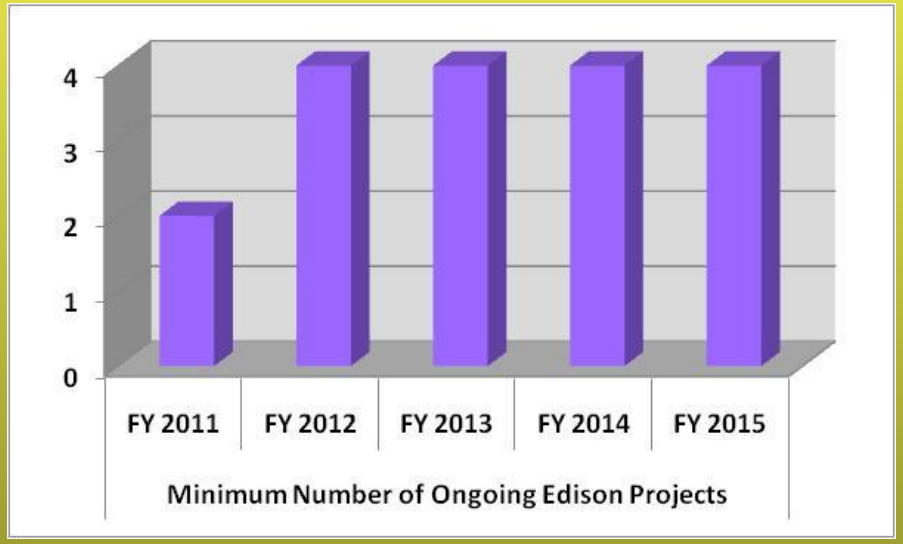




Edison Small Satellite Demonstration Missions

- **Objective:** Develop and operate a series of small satellite technology demonstration missions with game-changing and crosscutting potential for government and commercial sectors.
- **TRL Maturation:** From TRL 5-6 to TRL 6-7
- **Solicitation:** Annual BAA. At least 1-2 competitively selected awards.
- **Awards:** Subsystem Validation Missions – 2 years to launch readiness and $1-10 million mission cost. Mission Capability Demonstrations – 3 years to launch readiness and $1-20 million mission cost.
- **Collaboration:** Competitions open to academia, industry, and federal laboratories with partnering strongly encouraged.





Franklin/Edison Joint Program Management

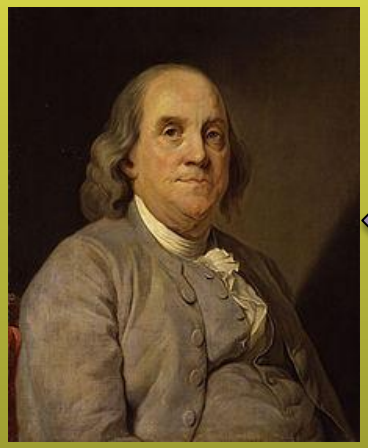
One Joint Program Office for Both Franklin and Edison Programs

- Resides at NASA Ames Research Center
- Firewall with proposing NASA organizations
- Franklin Program Lead: Kimberly Hines, ARC
- Edison Program Lead: Bruce Yost, ARC

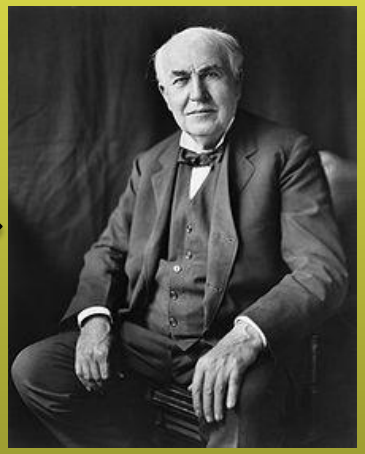
One Program Executive for Both Franklin and Edison Programs

- Resides in NASA Headquarters Office of the Chief Technologist
- Small Spacecraft PE: Brant Sponberg, HQ OCT

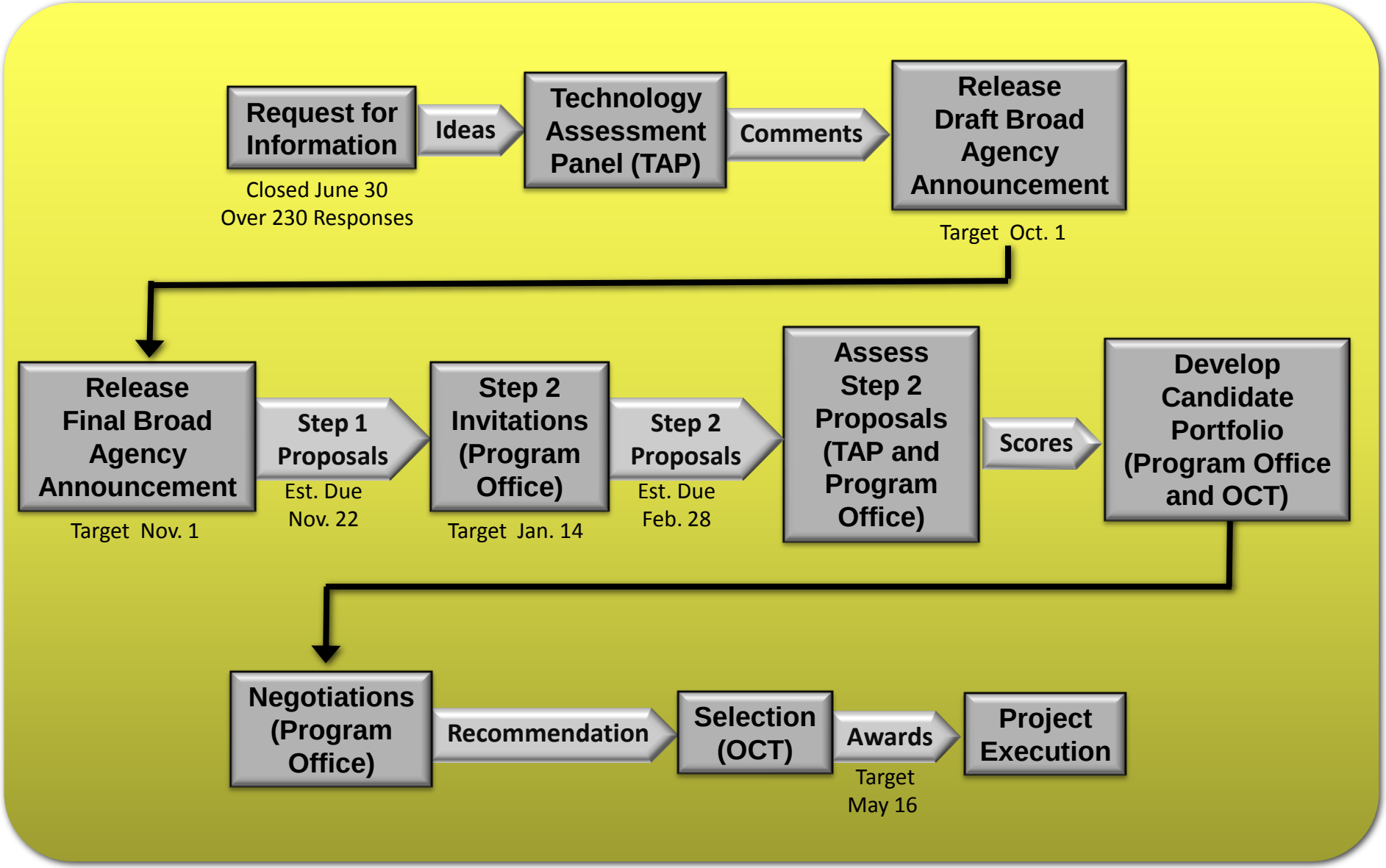
One Annual Solicitation for Both Franklin and Edison Programs



Joint Management



Planned Franklin/Edison Annual Solicitation Process



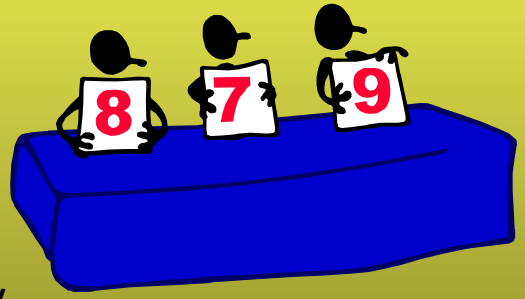
BAA and TAP

Planned Solicitation Is a Broad Agency Announcement (BAA)

- Three Potential Types of Awards
  - Contracts
  - Grants
  - Cooperative Agreements

BAA Process Advised by Technology Assessment Panel (TAP)

- Help set technology and mission priorities in the BAA
- Provide proposal peer review function
- Avoid duplication of other federal small spacecraft activities
- Membership Will Be ~10 Non-Proposers With Experience From:
  - NASA
  - DOD
  - Academia
  - Industry
- Augment with NASA technical experts, as necessary



Likely Key Evaluation Criteria

Step 1
~5 pages

Technical Concept

- Game-Changing, Crosscutting or Both
- Relevant TRL and Not Duplicative of Other Efforts

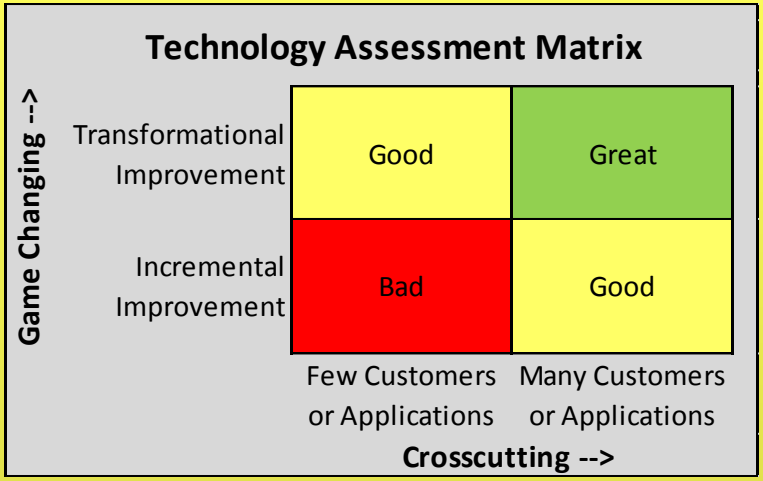
Step 2
~20 pages

Technical Merit

- Degree of Game-Changing or Crosscutting Potential (or Both)
- Suitability of Approach, Including Criteria for Subsequent Phases and Evaluating Success
- Maturity of Risk Assessment

Project Viability

- SOW
- Proposed Costs
- Key Personnel



Final selection decisions made considering cost, available funding, and the best overall portfolio to meet the program objectives with respect to providing for a broad range of innovative activities and participation

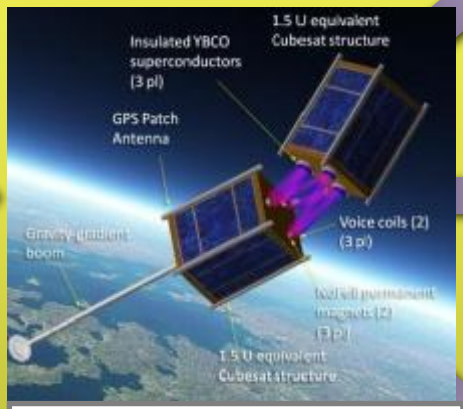
Game Changing/Crosscutting Example

Flux-Pinned Spacecraft

NIAC
NASA Institute for Advanced Concepts

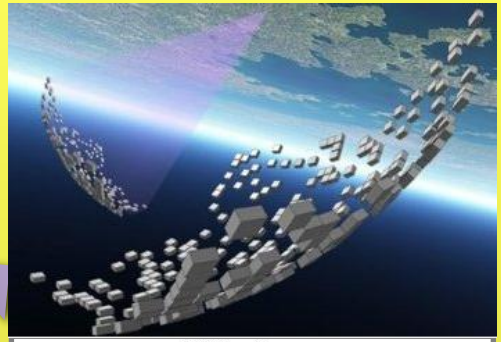
FAST

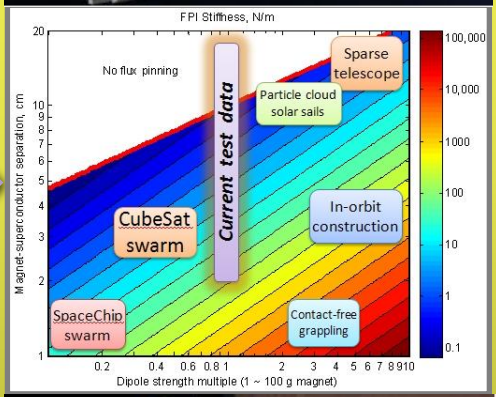
Facilitated Access to the Space Environment for Technology



TBD:

Small Spacecraft Demonstration





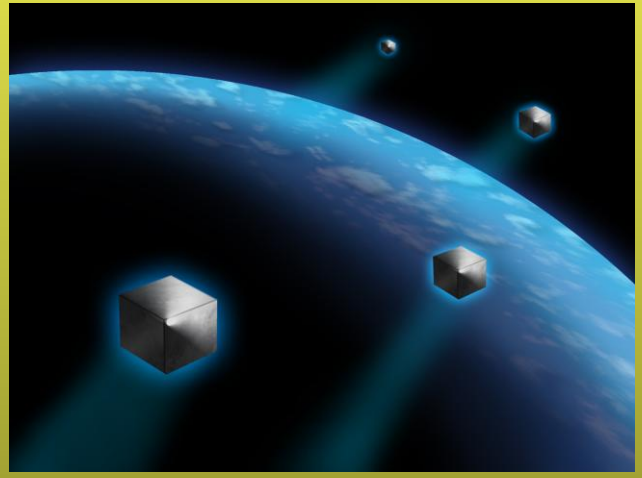
Space Access

Now:

- Government-Furnished Secondary and Hosted Payloads Accommodations
  - BAA will provide orbits, adaptors, and accommodations/interfaces on common Government launches for proposers to design to
  - If selected, mission will be placed in queue for future flight
- Proposer-Furnished Secondary and Hosted Payload Accommodations
  - Can propose own or partner's accommodation

Future:

- Dedicated Small Spacecraft Launch
  - Nano-Satellite Launch Challenge
  - Follow-on launch service procurement
- Interplanetary
  - Upper-stage reuse or host spacecraft



Federal, Commercial, Science, and Education Opportunities

Cost Sharing

- Encouraged but not a requirement or selection criterion
- Enables programs to make more awards and develop/demonstrate more technology

Coordinate With, Not Duplicate, Other Federal Small Spacecraft Programs

- USAF ORS, DARPA F6, NSF Cubesats
- Proposals building on funding from other federal programs are welcome

Programs Will Work Flexibilities on Commercially Important Issues

- Intellectual property
- Data rights
- Title to rights and property

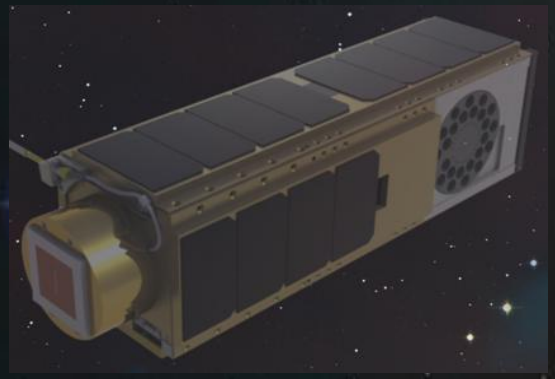
Science Opportunities

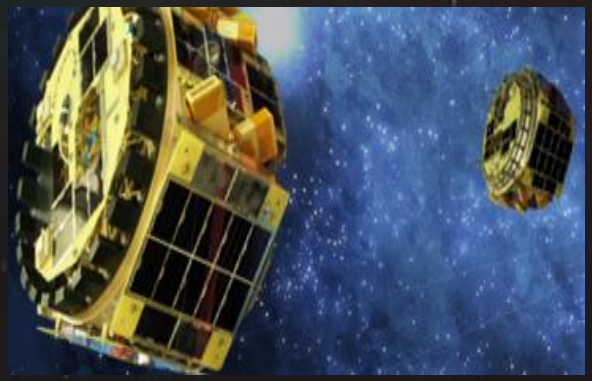
- Anticipate that scientific investigations will be performed in the course of many Edison demonstrations
- Some Edison missions may also be become platforms for peer-reviewed SMD and ESMD missions of opportunity

Educational Opportunities

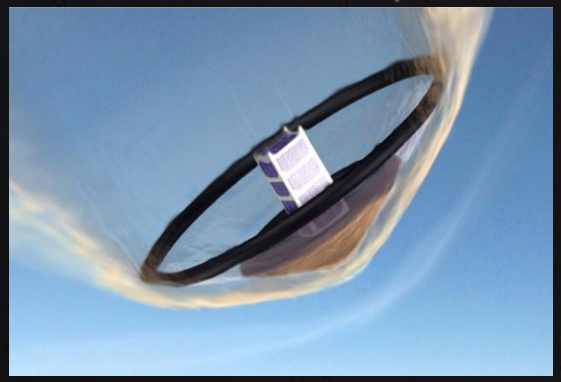
- Anticipate hands-on university student involvement in many Edison and Franklin Projects
- Formulating complementary virtual institute

National Aeronautics and Space Administration





FRANKLIN SMALL SATELLITE SUBSYSTEM TECHNOLOGIES



Candidate Franklin Subsystem Technologies

Advanced Bus Architectures
- Plug-and-Play
- Spacecraft-on-a-Chip/Spacecraft-on-a-Circuit-Board

Data Handling
- Lightweight Cabling
- Wireless Intrasatellite Networks
- Miniaturized Atomic Clock
- Multi-Sensor Signal Processor
- Proactive Health Management
- Radiation-Tolerant Processors, Memory, and Ops
- Space Ethernet Switch
- Space Flash Memory
- Virtual Ground Networks

Communications
- Crosslink Communications
- Intersatellite Networking
- Optical Communications
- Software-Defined Radios

Entry, Descent and Landing Systems
- Reliable, Lightweight Deorbit Capabilities
- Payload Return
- Small-Scale Surface Systems

Guidance, Navigation and Control
- MEMS Accelerometers and Gyroscopes
- Miniaturized GPS Devices
- Propellantless Attitude Control
- Small-Scale CMGs and Reaction Wheels
- Small-Scale Thrusters

Multifunctional Systems
- Sensors for Payload/Nav/Comm/FormFlt/Power
- Solar Arrays Incorporating Comm/Thermal
- Structure for RadShielding/Thermal/Propellant

Multisatellite Operations
- Cluster Formation Flight
- Electromagnetic Formation Flight
- Fractionated Spacecraft
- Proximity Operations
- Self-Assembly
- Swarm Operations
- Tether Formation Flight

Payload
- Electromagnetic Payload Isolation and Steering
- Miniaturized Instruments for Remote Observation
- Miniaturized Instruments for Space-Based Research
- Long-Life Microcryocooler
- Small-Scale Steering Mechanisms

Power
- Long-Life, High-Density, Scalable Power Storage
- High-Density, Scalable Solar Arrays
- Intersatellite Power Transfer
- Wireless Intrasatellite Power Transfer

Propulsion
- Small-Scale, Non-Toxic Chemical Propulsion
- Small-Scale, Highly Efficient Ion Propulsion
- Propellantless Propulsion
- Small-Scale, Solar-Thermal Propulsion

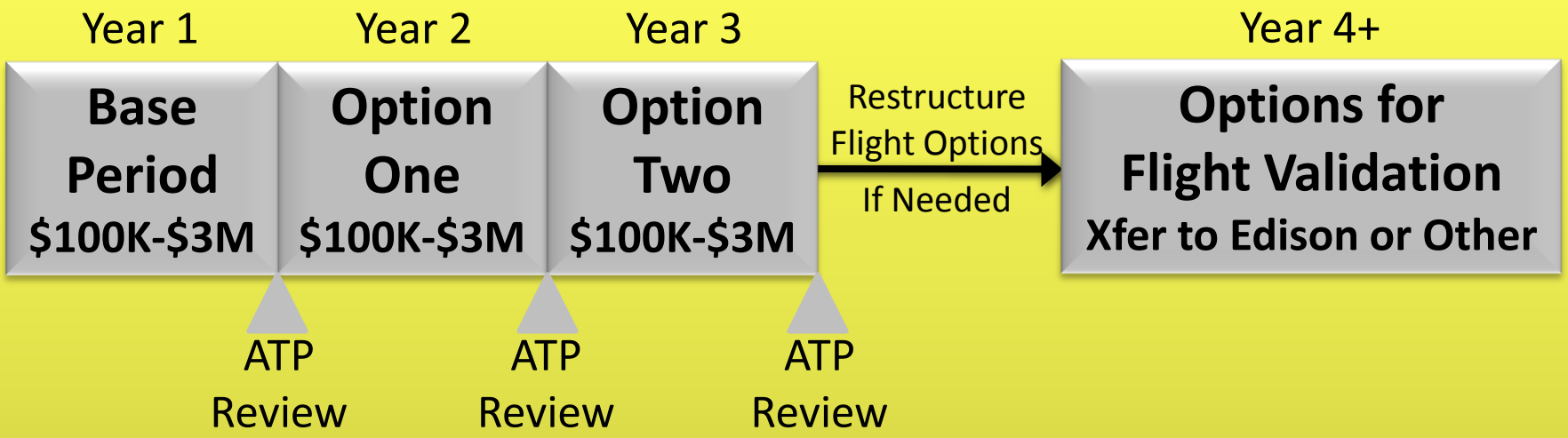
Structure
- Deformable Apertures
- Deployable Collecting Areas

Thermal Management
- MEMS-based
- Miniaturized Heat Pipes
- Thermally Conductive Structures
- Variable Emmissivity Surfaces

Proposer-Generated

Drawn From RFI Responses
Subject to TAP Review

Likely Franklin Award Structure

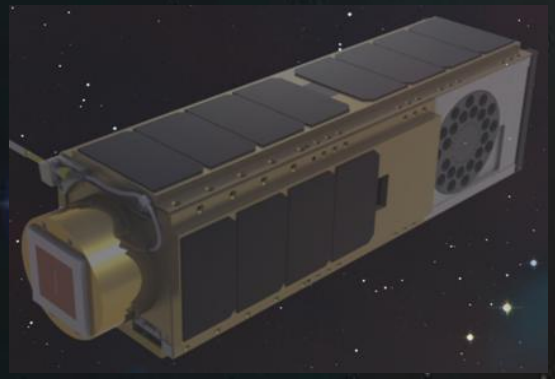


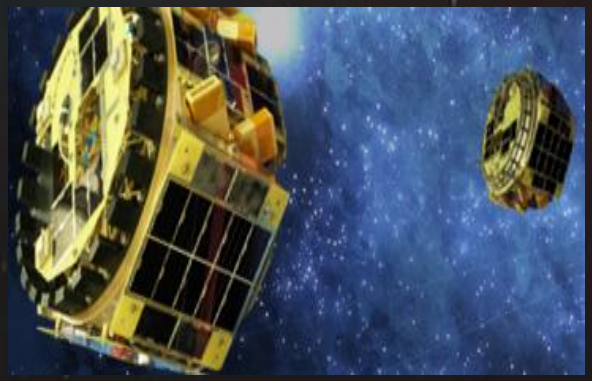
Depending on Need, Franklin Activities Can Encompass:

- **Base**
- **Base Plus One Option**
- **Base Plus Two Options**
- **Any Combination of Above with Options for Flight Validation**

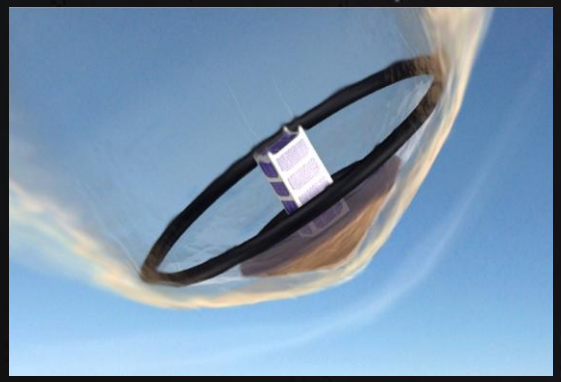
ATP = Authority To Proceed

National Aeronautics and Space Administration





EDISON SMALL SATELLITE DEMONSTRATION MISSIONS



Two Types of Edison Missions

Subsystem Validation Missions

- Leverage accessibility and affordability of small spacecraft to rapidly flight validate new subsystem technologies
- Example: 1U cubesat to flight validate a new electrochromic thermal panel, microthruster, radiation-tolerant processor, rechargeable battery, and solar panel
- Demonstrates no overall mission capability for future spacecraft, even if the individual subsystems are incorporated in future spacecraft.

Mission Capability Demonstrations

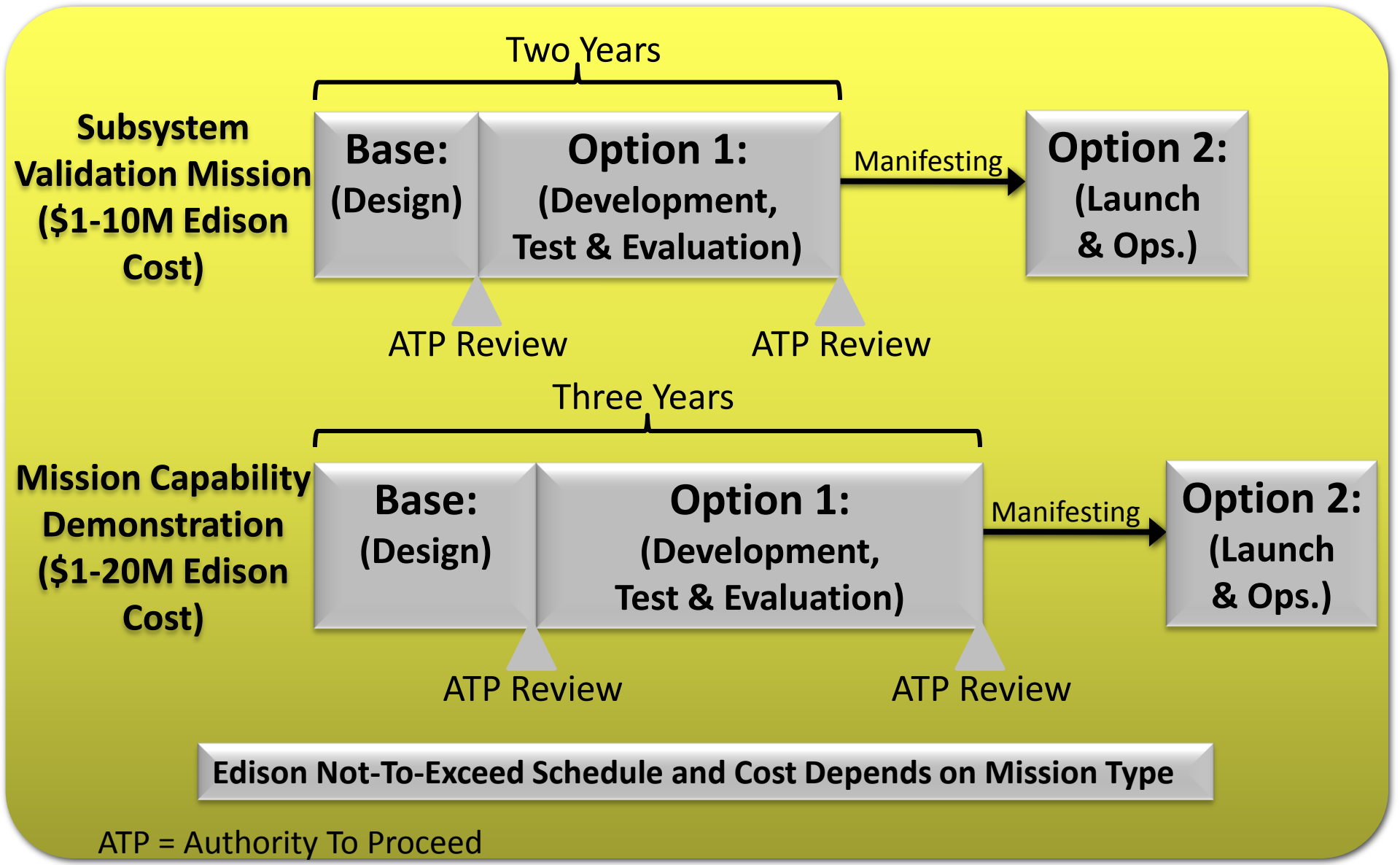
- Advance the state-of-the-art in small spacecraft, demonstrating how small spacecraft can be perform more capable or less costly missions than larger spacecraft or to perform non-existent mission capabilities
- Example: 3U cubesat to demonstrate a low-cost precision pointing capability
- Example: 3U cubesat to demonstrate a non-existent payload return capability
- May flight validate several new subsystems, but the primary purpose is to demonstrate an overall mission capability

Candidate Mission Capability Demonstrations

- Deformable Aperture for Remote Observation
- Distributed Aperture for Communications or Remote Observation
- Extended Space-Based Research Mission (such as beyond Van Allen Belts)
- Femtosatellite
- Fractional Space-Based Research Satellite (such as payload switchout on-orbit)
- Fractional Space-Based Telescope (such as separated occulter)
- Inspection and Servicing Satellite
- Large Deployable Aperture for Communications, Power Collection, or Remote Observation
- Modular Satellite
- Orbital Debris Mitigation
- Payload Return
- Precision Pointing for Remote Observation
- Secondary or Hosted Planetary Research Mission
- Sensor Swarm
- Proposer-Generated

Drawn From RFI Responses
Subject to TAP Review

Likely Edison Award Structure



Launch for Edison Missions

Proposer-Furnished Secondary and Hosted Payload Accommodations

- Can propose own or partner's accommodation

Government-Furnished Secondary and Hosted Payloads Accommodations

- If selected, mission will be placed in queue for future flight
- Standard Government orbits are as follows:

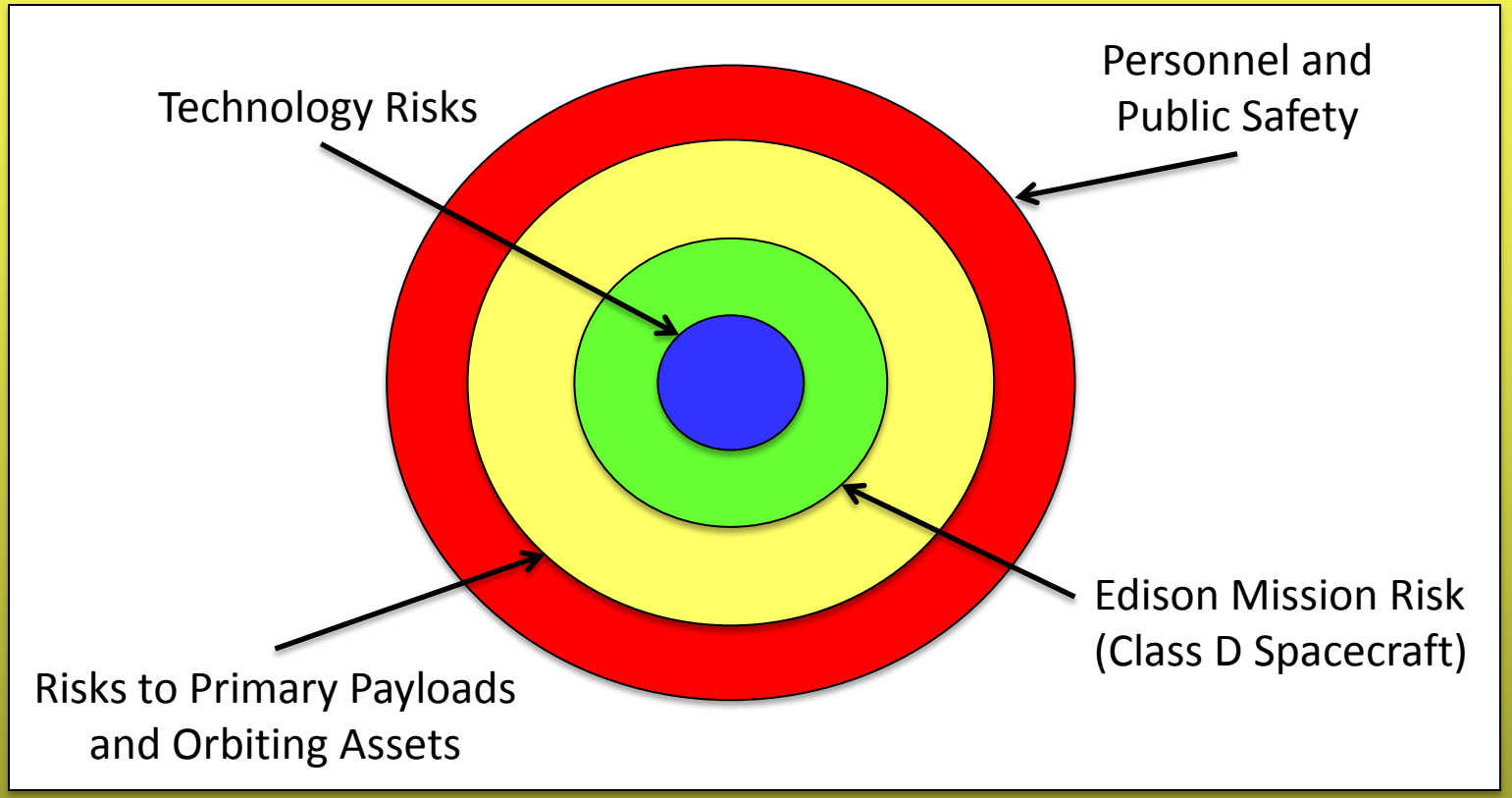
Mission Type	Altitude	Inclination	Comments
DoD (Minotaur I)	350 – 500 km	40- 45°	Launched from Wallops Flight Facility
DoD (Minotaur IV)	685 km	72°	Launched from Kodiak Alaska
NASA CRS	300 km	51°	Cargo Resupply – for ISS. Launched from KSC.
EELV	300 x 23,000 km	<28°	GTO "drop-off" orbit
Sun-Synchronous	500 – 1000 km	98°	Sun-synchronous Earth monitoring orbit ("A-train")

- LEO orbits typically have a 90 minute period.
- Higher inclination orbits are generally in the radiation belts more than lower inclinations.
- Inclinations between 35 – 60° will likely fly through the South Atlantic Anomaly which is a radiation hazard for spacecraft.
- Low altitude orbits (<300 km) will expose spacecraft to atomic oxygen, which can be reactive to certain spacecraft materials.
- Atmospheric drag becomes significant around 250 – 300 km.
- The Sun plus Earth's albedo result in a relatively warm orbital environment.

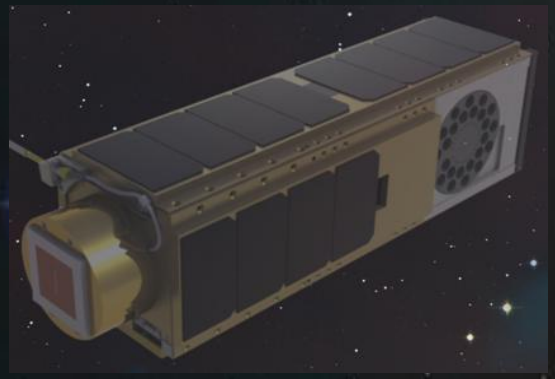
Draft Risk Approach for Edison Missions

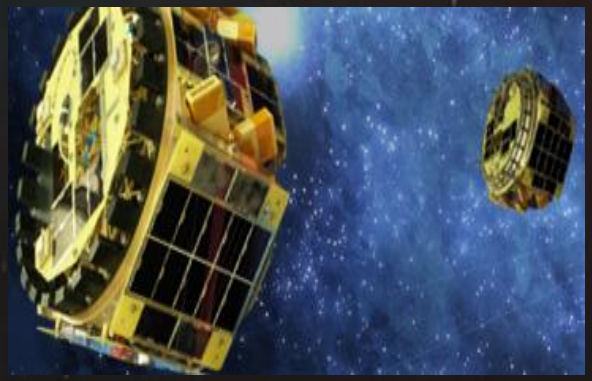
Avoid Propagating Technology Risks Outward

- Take Smart Risks To Demonstrate New Technologies and Capabilities
- But Minimize Risk of New Technologies to Other Mission Demonstration Objectives, Primary Payloads, Orbiting Assets, Personnel, and the Public

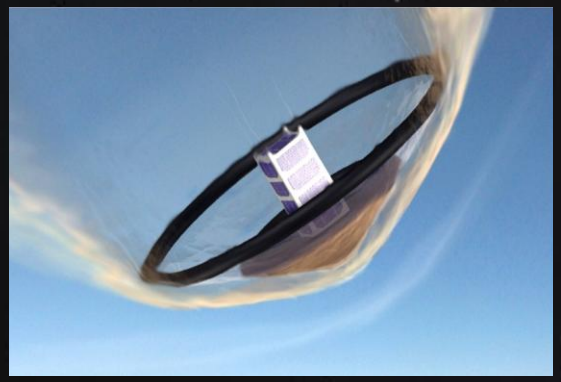


National Aeronautics and Space Administration





VIRTUAL INSTITUTE AND NANO-SATELLITE LAUNCH CHALLENGE



Small Spacecraft Virtual Institute Outline

Purpose

- Complement Franklin and Edison Programs Technically
- Boost Student Involvement
- Increase Industry Partnerships
- Leverage International Collaboration

Models

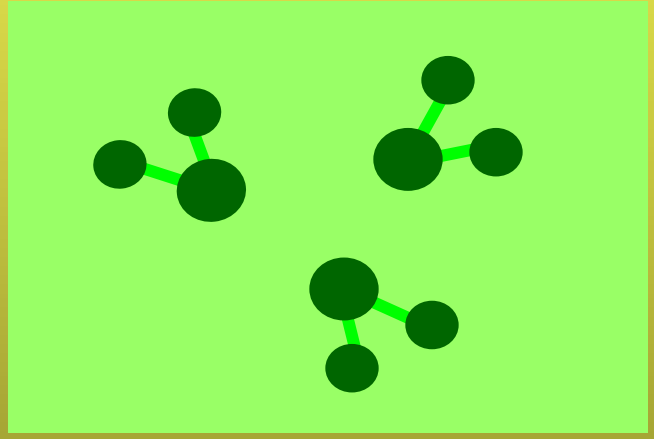
- NAI/NLSI
- URETIs
- NSF I/UCRC

Small Spacecraft Technical Areas

- Advanced Components (Bio, Nano, Robotics, Other Low-TRL)
- Standards Maintenance and Advocacy (Systems, S/C, Ops)
- Applications Development (Bio, Comm, Info, GIS, Robotics, Other)

Funded Members

- At Least One University for Each Technical Area
- At Least 3-Year Awards w/ Reviews
- Outcome-Oriented Tasking
- Must Have One Industry Partnership and/or One International Collaboration



Unfunded Members

- Franklin/Edison Award Winners
- Additional U.S. and International Applicants

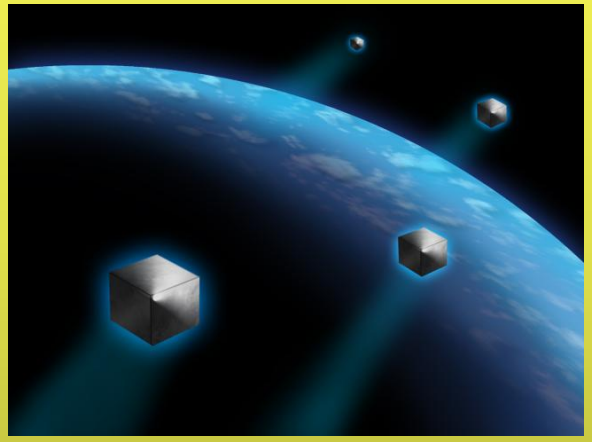
Nano-Satellite Launch Challenge

New $2 Million Prize Competition Under NASA's Centennial Challenges Program

- Safe, low-cost, small payload delivery system for frequent access to Earth orbit
- Innovations with broader implications for future launch systems
- Commercial dedicated launch capability at cost comparable to secondary launches (follow-on launch service procurement planned)

Preliminary Rules

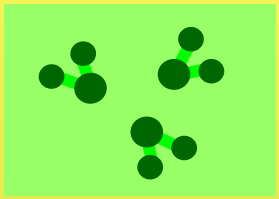
- Deliver a payload at least 1 kilogram in mass and at least 10x10x11 centimeters in volume (1U cubesat equivalent)
- Complete at least one orbit past launch site
- Repeat with second payload within one week
- http://www.nasa.gov/offices/ipp/innovation_incubator/centennial_challenges/nano_satellite/index.html



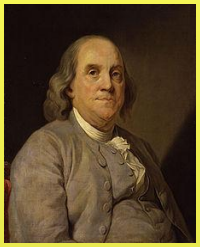
Seeking Proposals for Allied Organization to Manage Competition

- NASA covers $2 million prize purse
- Allied organization responsible for planning, sponsor and competitor recruitment, administration and execution, publicity
- Responses to Announcement of Opportunity due September 13
- http://prod.nais.nasa.gov/cgi-bin/eps/synopsis.cgi?acqid=142445

Filling Out the Small Spacecraft Value Chain



Virtual Institute



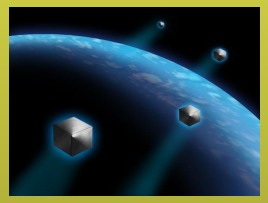
Franklin Program

Components

Subsystems

Launch

Nano-Sat Launch Prize

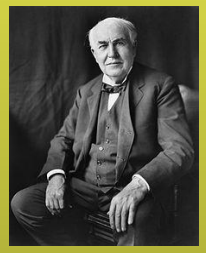


Spacecraft

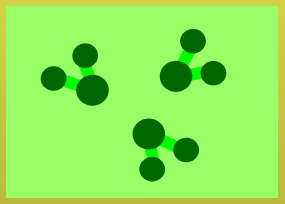
Operations

Applications

Edison Program



Virtual Institute



Upcoming Events

Nano-Satellite Launch Challenge

- Responses to Announcement of Opportunity for Allied Orgs due Sep. 13

Draft Franklin/Edison BAA Release

- Targeting October 1
- Comments from potential proposers due October 8

Final Franklin/Edison BAA Release/Step 1 Proposals

- Targeting October 22
- Step 1 proposals estimated due November 22

Franklin/Edison Step 2 Invitations/Awards

- Targeting January 14
- Step 2 proposals would be due February 28/Target awards May 9

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Nano-Satellite Launch Challenge: andrew.j.petro@nasa.gov