NEW MILLENNIUM PROGRAM

An Overview of NASA’s New Millennium Program

American Society of Mechanical Engineers
Western Michigan University
March 17, 2005

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An Overview of NASA’s New Millennium Program

• Why is the New Millennium Program needed?

• What is the New Millennium Program?

• What does the New Millennium Program try to accomplish?

• What is going on now?

• What is coming in the future?
Why Is the New Millennium Program Needed?

- Advanced technology programs seldom are able to carry the technology advances they initiate beyond tests with breadboard hardware in a laboratory environment.
  - Address many topics and funds are limited
  - Testing with more "flight-like" hardware in "relevant" environments is expensive
- Flight project managers are risk adverse
  - Only willing to accept "unproven" hardware if it is essential to their mission
  - Want equipment that has flown on other missions successfully
- The resulting gap means that innovation on flight spacecraft proceeds slowly
- New Millennium Program is intended to bridge that gap and hasten the infusion of technological innovation
Flight Validation of Breakthrough Technologies to Benefit Future Space and Earth Science Missions

Breakthrough technologies
- Enable new capabilities to meet Earth and Space Science needs
- Reduce costs of future missions

Flight validation
- Mitigates risks to first users
- Enables rapid technology infusion into future missions
**New Millennium Program**

**Technology Readiness Levels (TRLs)**

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- TRL 6: System/subsystem model or prototype demonstration in a relevant environment (Ground or Space)
- TRL 7: System prototype demonstration in a space environment
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New Millennium Program
What Is Technology Validation?

• Validation, for the New Millennium Program,
  – Empirical evidence that the physics associated with the technology advance are understood

• Validation characteristics
  – Clear definition of the technology advance being validated
  – A model of the technology advance
    • Model provides ability to predict and to scale to a variety of operational applications
  – Combines data from ground and in-space tests
    • Ground and in-space data combined validate or improve the model and our understanding
    • Data establish a pre-determined level of performance
What is the New Millennium Program?

- New Millennium Program was created to provide opportunities for in-space validation of advanced technologies
  - Three criteria:
    - Is a “Breakthrough” technology advance
    - Has user interest
    - Requires in-space testing
  - Result: mitigates the risk of first use
New Millennium Program
Technology Maturity vs. Development Maturity

- **Technological Maturity**
  - Refers to our ability to understand how to design, build, and operate a device to achieve a desired capability and performance by implementing a specific approach

- **Developmental Maturity**
  - Refers to the degree to which a specific design to achieve a desired capability and performance has been qualified for space flight

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![Diagram showing the relationship between Technological Maturity and Developmental Maturity]
New Millennium Program
Technology Validation Is a Comprehensive Effort

• TRL 4 at end of Concept Definition Phase
  – Site visit and demonstration
  – Overview of validation approach

• TRL 5 at end of Formulation Refinement
  – Technology Review Board
  – Confirmation Assessment Review
  – Approved Technology Validation Plan

• Implementation Phase
  – Demonstrate ability to produce a flight-capable article
  – Execute Technology Validation Plan
    • Ground Tests
    • In-Space Tests
    • Achieve TRL 6
  – Publish Technology Validation Report & Host Workshop

Space Tests are Greatly Constrained

TECHNOLOGY SPECIFIC DATA

SPACE TEST RESULTS

COMPUTER MODELS

VALIDATED TECHNOLOGY

SPACE SCIENCE MISSIONS

SIMULATION DATA

GROUND TEST DATA

Ground Tests are More Comprehensive
The NASA New Millennium Program (NMP) identifies and flight validates breakthrough technologies that will significantly benefit future operational Space and Earth Science missions.

NMP conducts two types of flight validation projects for the Space Science Enterprise:
- Integrated System Validation Projects
- Stand-Alone Subsystem Validation Projects
DS1 and DS2

**DS1**

**12 Advanced Technology Experiments**
- Solar Electric Propulsion
- Fully depleted SOI
- Mini-camera & Spectrometer
- Ion-Electron Spectrometer
- Remote Agent
- Conc. Solar Array
- Multi-Func Stru
- AutoNav
- Pwr. Switching
- Small DS X-ponder
- Ka S-S Amp
- Beacon Monitor

**Launch — October, 1998**

**DS2**

**Validate design principles and practices for direct-entry Impactors (up to 60,000 g)**

**Mission**
- Launch 1/99 on Mars Polar Lander
- Deploy at Mars approach
- No data

**Follow-on experiment to complete validation**
DS3 & DS4

**DS3**
- Project designed to validate the technologies necessary for precision formation flying
- Proved to be premature
  - The necessary technological capability was not sufficiently mature to support an in-space experiment
- Became a focused technology program within NASA’s Origins program

**DS4**
- Project designed to validate the advanced technologies necessary for a comet rendezvous and sample return mission
- Was made a NASA Project called Champollion
- Eventually cancelled due to cost growth.
ST5 and ST6

**ST5**

- Validate the technological capability to conduct scientific investigations from multiple spacecraft
  - Three small spacecraft (25 kg)
  - ’06 Launch to Polar Earth orbit
  - Measure the time varying curl of the Earth’s magnetic field to validate the measurement concept
- Validate the capability to develop small spacecraft capable of making science-quality measurements

**ST6**

- First NMP subsystem-level validation project
- Originally selected 3 exp’ts
  - Inertial Stellar Compass
    - Low mass, low power IMU
  - Autonomous Sciencecraft Exp’t
    - On-board science planning
  - Autonomous Rendezvous Exp’t
    - Cancelled
- ASE validated on EO1 during FY04
- ISC will be hosted on USAF TechSat-2 (’06 Launch)
EO1

– Launched 11/01
– Validated 10 advanced technologies
  • Formation Flying GN&C
  • Pulsed Plasma Thruster
  • Adv. Rec. Processor
  • Adv. Land Imager
  • Hyperspectral Imager
  • Flex Solar Array
  • C-C Radiator
  • Fiber Optic Data Bus
  • Atmospheric Corrector
  • X-Band phased array antenna

– Instruments have been in demand for Earth Observation
– Used in conjunction with AURA to perform coordinated observations
– Hosted ST6 ASE Validation Exp’t

ST7

– Disturbance Reduction System Validation Exp’t
– Spacecraft follows a proof mass
  • Validates ability to control a S/C such that it deviate from a purely gravitational trajectory by less than 
    $3 \times 10^{-14} \text{ m/s}^2/\sqrt{\text{Hz}} \times (1 + [f/3 \text{ mHz}]^2)$
    over a frequency range of 1 mHz to 30 mHz
– Capability needed by LISA (US/European) mission to detect gravitational waves
– Launch in 2008
ST8 and ST9

ST8

- Subsystem Technology Validation Project
- Four Experiments Selected
  - SAILMAST Validation Exp’t
  - COTS-Based High Throughput Computing Architecture
  - Next Generation Ultraflex
  - Miniature Loop Heat Pipe
- In Formulation Refinement Phase
- Expected launch date FY’09

ST9

- System Technology Validation Project
- Five Candidate Experiments
  - Solar Sail
  - Large space Telescopes
  - Precision Formation Flying
  - Terrain-Guided Automatic Landing System
  - Aerocapture
- In Concept Definition Phase
  - At the end of the Concept Definition Study, one will be selected to develop an in-space validation experiment
- Expected launch date FY’10
What Is Coming in the Future?

• Just now beginning: ST10 will be the New Millennium Program’s next technology validation project
  – Third subsystem validation project
  – Initial activities
    • Work with science and user communities to identify candidate areas in which to solicit validation experiments
      – Have high payoff potential
      – Require in-space tests to be validated
    – NASA selects the 3 to 5 areas in which a formal solicitation will be made

• Continue bringing the ongoing projects to launch
  – ST5, ST6, ST7, ST8, ST9
New Millennium Program

• Bridges the gap between advanced technology programs and operational science missions for high-payoff technology advances
  – Hastens the infusion of innovation by mitigating the cost and schedule risks associated with the first operational use of a technology advance

• Addresses the difficulties of simultaneously increasing technological maturity and developing flight hardware and software
  – Accepts higher risks
  – Operates in a lower cost environment
  – Develops special processes and procedures
    • Provide experienced guidance and support
    • Identify difficulties early to contain costs