Cross Enterprise Technology Development Program

Revolutionary Technology Enables Revolutionary Missions: Recent Success Stories

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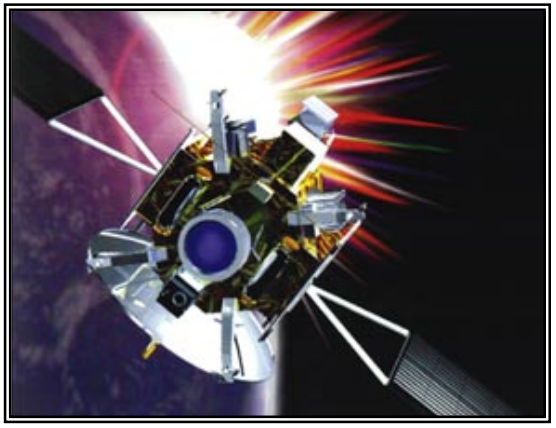
Solar Electric Propulsion Flies on New Millennium DS-1 Mission

Operation of 2.6 KWe ion engine (NSTAR) in space with advanced solar concentration PV array (SCARLET)

- First NASA use of SEP in mission
  - Culmination of years of research
- First application of solar concentrator array
  - Highest efficiency MBG.PV cells ever flown (23%)
  - Increased w/Kg, low cost
- Opens the door for widespread use of electric propulsion
  - Increased mobility
  - Reduced trip times
  - Smaller launch vehicles

SCARLET

NSTAR



Formation Flying Autonomous Navigation and Control
EO-1 Flight Experiment

NMP Autonomy IPDT

- EO-1 flight experiment with Landsat-7 in 1999

Co-funded by NASA Code S Cross Enterprise Technology Development Program

- Increased level of autonomy through expert systems/AI technologies

Goal

- Improve space science data return through simultaneous observations from multiple satellites

Objectives

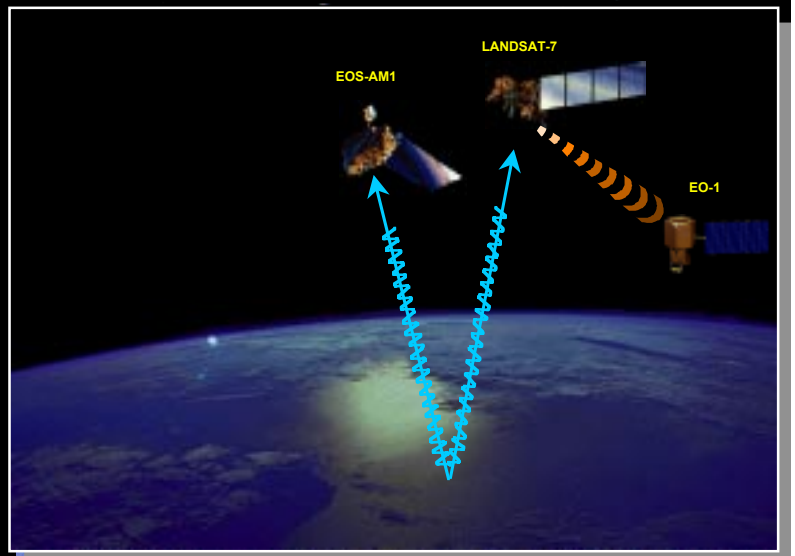
- Demonstrate the capability of gathering collaborative science data from multiple spacecraft whose navigation and orbit control functions are executed cooperatively and autonomously as part of a coordinated network

Benefits--Technology will enable

- Synchronous science measurements on multiple spacecraft
- Weather and land-imaging collection 8-16 times faster than current Lansat or TIROS satellites
- Autonomous operations will allow large numbers of satellites to fly with minimum ground support

Partners: GSFC, JPL, Stanford University, AI Solutions, Hammers Company

Distributed Spacecraft Thrust



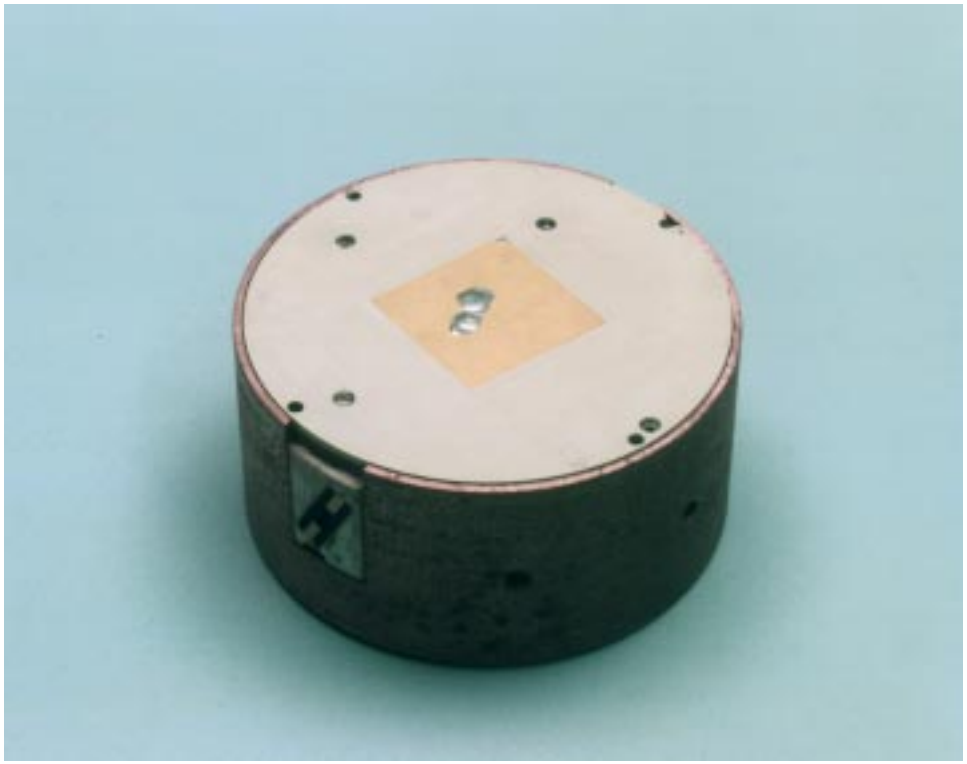
EO-1 Formation Flying Experiment

- **Onboard autonomous maneuver control to maintain EO-1/LS-7 formation**
- **EOS-AM1 Flies nominal mission**
- **Landsat-7 Flies in a constellation with EOS-AM1**

μ/ν Sciencecraft Thrust Area

Successful Flight of Three Free-Flying Magnetometers Paves Way for Future Mapping of Magnetosphere with 100-Spacecraft Constellation

- **Free-Flying Magnetometer flight demonstrated ability to make simultaneous magnetosphere measurements from multiple spacecraft constellation in CY'98**
  - Four "hockey puck" sized magnetometer spacecraft
  - Magnetically "clean"
  - Enstrophy Mission, joint with UNH and Cornell, measured Curl-H on short spatial scales
  - Sub-orbital trajectory used BB-X rocket launched from Poker Flats, AK
- **Proposed for ST-5 a part of demonstration of other needed technological capabiities to accomplish a 100-spacecraft constellation**



Enabling precursor to 100-spacecraft SEU mission to map the magnetosphere

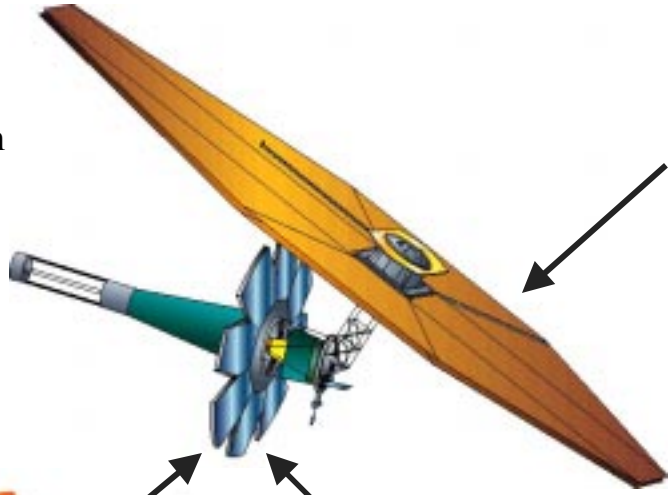
OES selects CloudSAT mission to fly in 2003

- The enabling technology for CoudSat mission - a 94GHz high power transmitter - developed under 632 program (1993 - 1996)
  - CSMT Sensor Technology Program jointly funded technology development of the Airborne Cloud Radar with NASA Code Y Atmospheric Dynamics & Remote Sensing Branch (R. Kakar)
  - Collaboration: University of Mass, Colorado State University, JPL Lead Fuk Li
- 1996
  - Continued Joint Development of the Cloud Radar with Code Y Cloud & Radiation Program (Bob Curran)
- April 1999
  - NASA Awarded CLOUDSAT Mission to JPL with Colorado State University as PI ($110 M)
  - Collaborator: Canadian Space Agency, USAF; (~$25M Commitment); Major Industrial Partner – Ball Aerospace

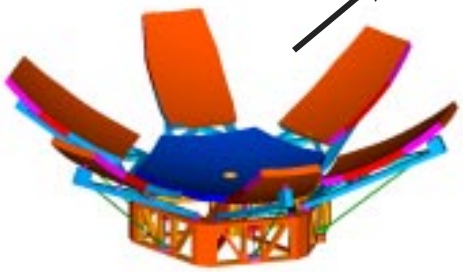
Ultra-Lightweight Structures and Space Observatories Thrust Success Story

CETDP Revolutionary Technology Has Enabled Revolutionary Missions

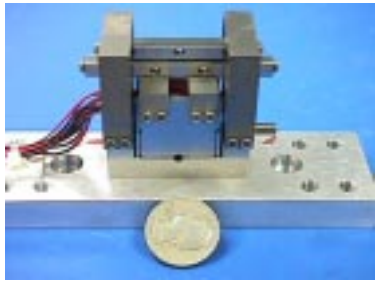
The Next Generation Space Telescope (NGST) will study the origins of galaxies at the edge of the universe. NGST will have 2x greater resolution than the Hubble Space Telescope at infrared wavelengths, and cost 1/4 as much.



Inflatable sunshield developed by CETDP will passively cool telescope to cryogenic temperatures. Inflatable structure enables 10x reduction in launch volume and 2x reduction in sunshield weight. Shown is a 1/2-scale model of the inflatable NGST sunshield.



Precision deployable telescope technology developed by CETDP will enable large apertures to be flown on smaller, lower-cost launch vehicles. Deployable primary mirror enables 3x increase in aperture size. Shown is one petal of a deployable reflector testbed with sub-micron deployment precision.



Cryogenic actuators developed by CETDP will control shape of NGST primary mirror to nanometer precision. Actuators will operate at 30 ^{o}K. Shown is prototype piezoceramic linear actuator.

Advanced Radar Technology Program Contribution to CloudSat

Technology Need

- **95 GHz high power transmitter is the most critical technology challenge to enable spaceborne cloud profiling radar**

Technology Development

- **Feasibility study of using EIK (Extended Interaction Klystron) for a spaceborne cloud profiling radar (1993)**
- **Develop enabling EIK technologies with CPI-Canada**
  - **Conduction cooling**
  - **Use of depressed collector for higher efficiency**
  - **Innovative packaging for space environment (vibration, shock, thermal)**
  - **Innovative application of reservoir cathode for longer lifetime operation under space environment**
- **Technology Validation**
  - **Vibration Engineering Model delivery in March 1999**
  - **Thermal Vacuum Engineering Model delivery in December 1999.**

CHARACTERISTICS

- **F = 95 GHz**
- **Po = 1.5 kW min**
- **Duty = 3 %**
- **Efficiency = 30%**
- **Conduction cooled**

Code S FY99 PIDDP (Planetary Instrument Definition and Design Program) awards enabled by 632 BSICT development

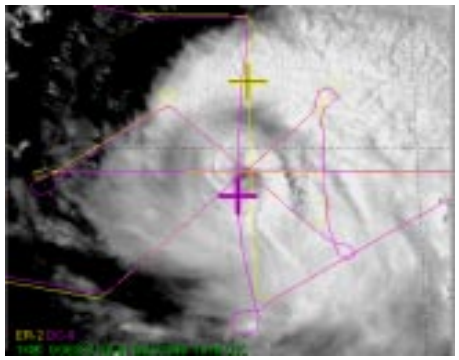
- "Miniature In situ Geochronology Instrument for Surface deployment on Mars: Breadboard development" Brian Stewart (U of Pitt)
- "Miniature Solid State Spectrometer for in situ Applications" William Smythe (JPL)
- "Atmospheric Electron X-ray Spectrometer (AEXS): Breadboard Instrument Development" Jaroslava Wilcox (JPL)
- "Spectrometer-on-chip Using Surface Plasmon Tunable Filter and Active Pixel Sensor Technologies" Yu Wang (JPL)
- "A low noise, Ultra-Broadband Heterodyne Sensor for Studies of Planetary Atmospheres and Comets" William R. McGrath (JPL)

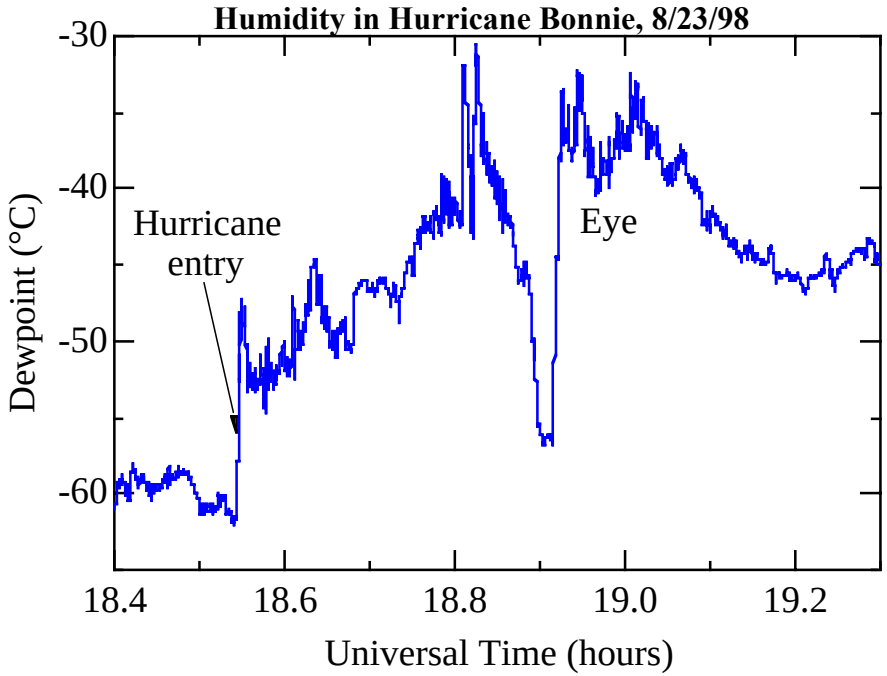
Flight Validation of Micro Weather Station

Micro Weather Station Objective: Develop unique microsensors for accurate in situ monitoring of weather in Earth and planetary atmospheres.

- **Flight validated a miniaturized SAW hygrometer on the NASA DC8.**
- **Generated high-resolution humidity data in Atlantic hurricanes (Third Convection & Moisture Exp't.)**
- **Sponsor is evaluating possible use as a national standard for in situ atmospheric humidity.**

Hurricane Bonnie, 8/23/98
Satellite image with flight tracks

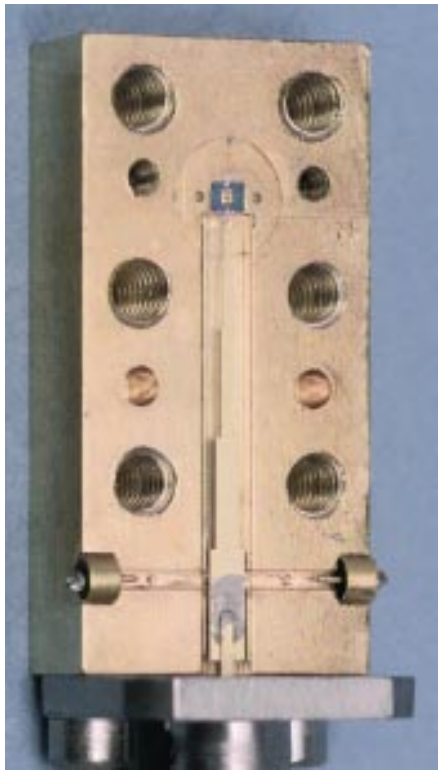




SAW Hygrometer data, CAMEX-3

Submillimeter-Wave Radiometer Components MOMED Mixer

OBJECTIVE: **Developed all-planar GaAs-based mixer for use at 2.5 THz (118 microns)**
CUSTOMER: **Earth Observing System Microwave Limb Sounder - 2.5 THz radiometer for measurement of atmospheric OH**

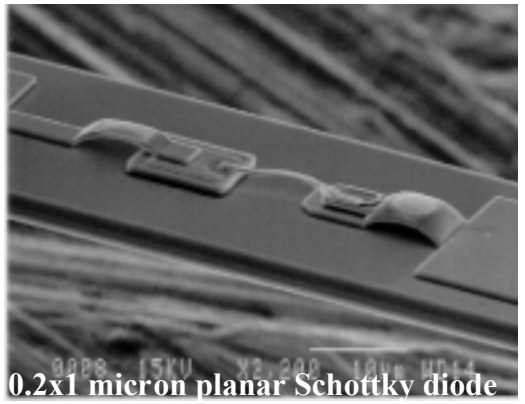


2.5 THz Mixer Block

ACCOMPLISHMENTS:

- **Invented a novel MEMS-like circuit composed totally of GaAs & incorporating state-of-the-art planar submillimeter-wave devices & filters**
- **Device is now baselined for EOS-MLS, replacing less reliable "point-contact" structure with robust space-qualifiable component**
- **RF performance is competitive with any semicond. radiometer at this frequency**
- **New MOMED technology enables other RF & electro-mechanical applications not realizable with traditional silicon MEMS structures**

MOMED Structure



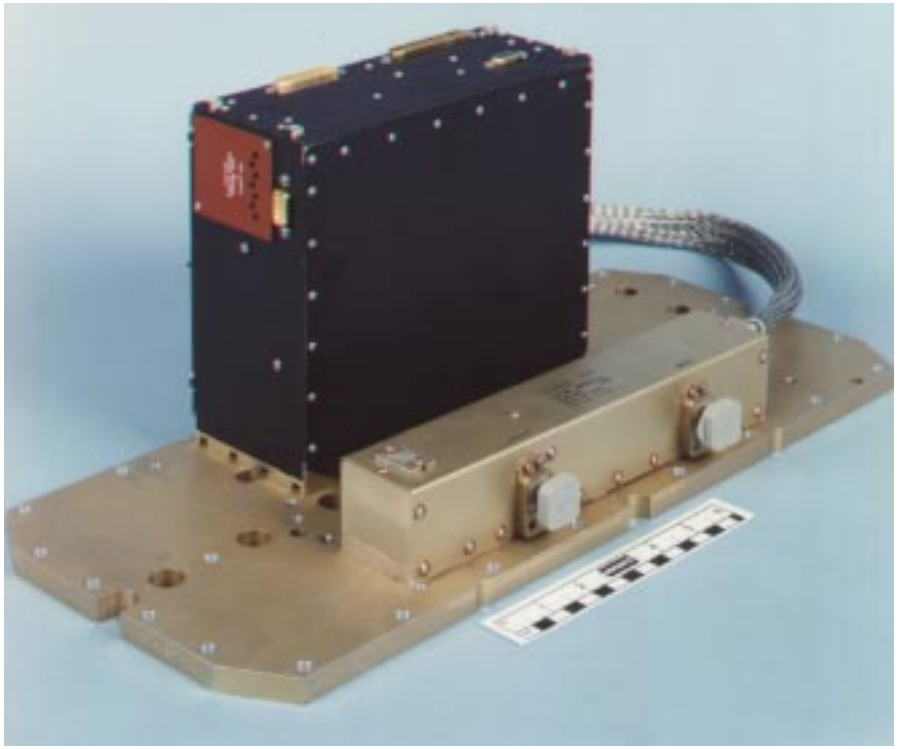
0.2x1 micron planar Schottky diode

Performance at 2.5 THz:Trec=16,500K DSB; Tmixer<9000K; LO Power Required: <3mW!

Recent Success Story for High Rate Data Delivery Thrust

CETDP Technology Enabled Cassini Mission Experiment

- First Ka-band TWTA for Deep Space Mission
- Enables Cassini Ka-band gravity wave experiment
- Technology doubles efficiency of 32 GHz TWTA
- Two flight TWT's and EM TWTA produced
- GRC Impact
  - Designed TWT collector and helix circuit
  - Textured collector surfaces with unique GRC process



10-Watt, 32-GHz TWTA

Remote Agent AI Software Flies on New Millennium DS-1

•REMOTE AGENT software experiment aboard the Deep Space 1 spacecraft shows how robotic explorers of the 21st century can be built to be less costly, more capable and more independent from ground control.

•Planner and Scheduler (PS)--produces flexible plans, specifying the basic activities that must take place in order to accomplish the mission goals.
•Smart Executive (EXEC)--carries out the planned activities.
•Mode Identification and Recovery (MIR)--monitors the health of the spacecraft and attempts to correct any problems that occur.

•REMOTE AGENT successfully controlled the spacecraft for a two day period, planning and executing its actions, and recovering from simulated faults that were injected by the ground team.

Surface Systems Thrust Success Story

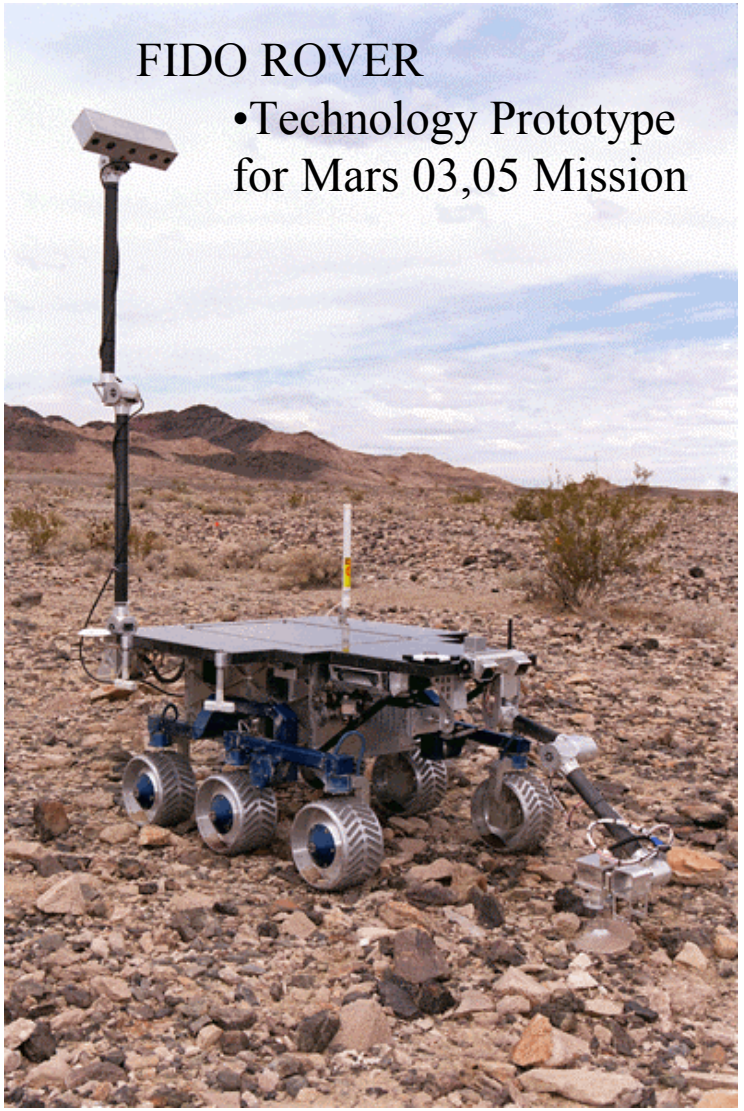
Rover Technology Enables Sample Return Missions

•Rover and science payload technology for NASA 03,05 Mars Sample Return Missions

•Multiple Science Instruments (Raman, Mossbauer, Mini-Corer, etc.)

•Complete science acquisition and return sequence field simulations (April 1999)

•Built on earlier success of Sojourner (97) Rover and Mars Volatiles and Climate Surveyor (MVACS 99) robot arm technology



Surface Systems Thrust Success Story

The Giant Rover that Could

Key Technologies

•Autonomous hazard avoidance & navigation
•6-Wheel rocker-bogie mechanism
• APXS instrument deployment
•Miniaturized rover system

In-Space Robotics Performance

•~100 m traverse
•~15 APXS measurements
•~20 Soil mechanics measurements
•Deployment Maneuver from Lander

Surface Systems Thrust Success Story

MUSES CN ~1 kg Rover Technology

- NASA Flight Experiment in Muses C Asteroid Mission (02)
- Self-Righting Mechanism
- Embedded Point Spectrometer