ADVANCED EXPLORATION TECHNOLOGIES

MICRO AND NANO TECHNOLOGIES
ENABLING SPACE MISSIONS IN THE 21ST CENTURY

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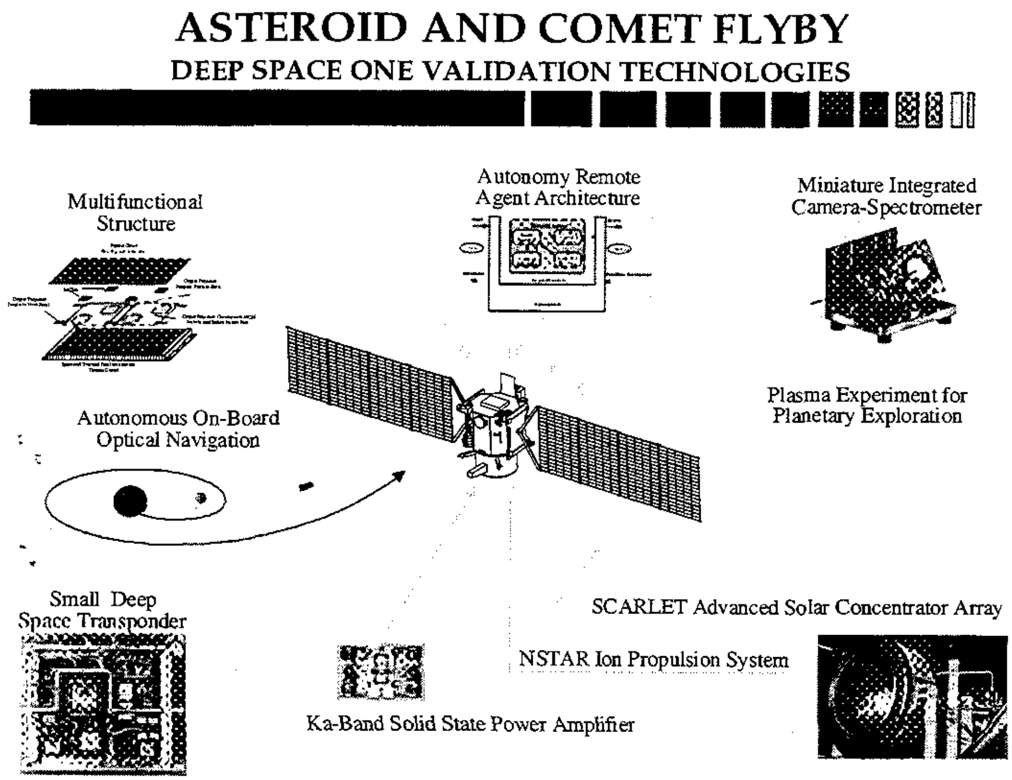
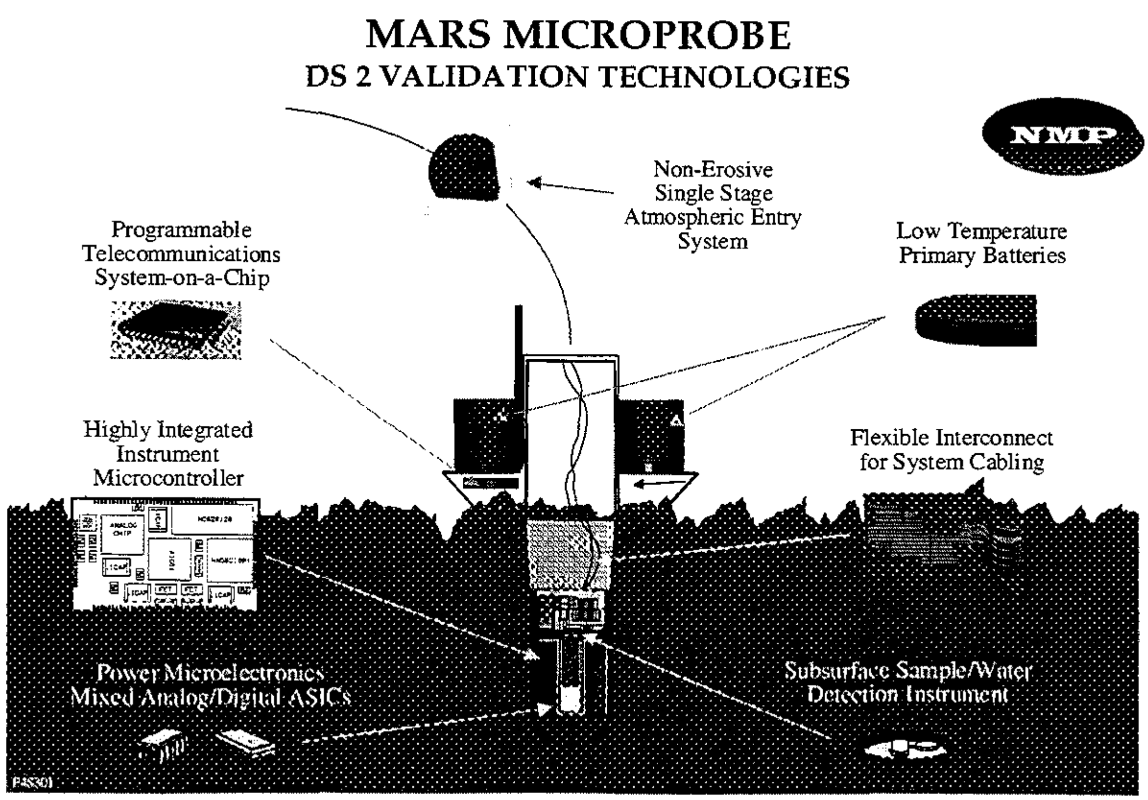
- NASA and ISAS have agreed to Collaborate on the MUSES C Mission.
- In Exchange for DSN, Navigation and Recovery Support, ISAS will carry a NASA/JPL Rover to the Asteroid.
- The Rover is enabled by NASA technology investments in robotics.

Pathfinder

Nano Rover

NASA New Millenium Program
Technology Validation through Space Flight

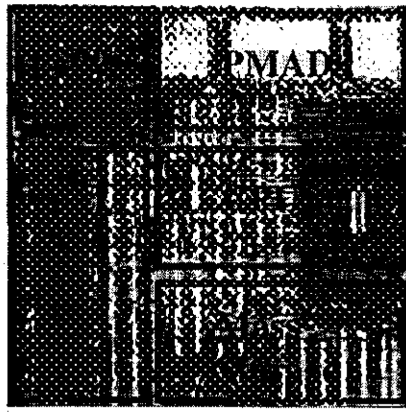




System on a Chip
Technical Challenges

•Miniaturization-RF
•Integration-RF
•Integration of optical com.

•Integration of devices and integrated circuits with MEMS.



•Miniaturization
•Passive components
•Low power

•Integration of processors and memory devices.
•Merging of individual designs

General challenges:
•Different design techniques and design tools (digital, analog, mixed, rf, optical, MEMS)
•Ultra low power devices and architectures
•Unified device fabrication technology-SOI CMOS, SOI MOSFET, SOI SI based memories, SiGe
•Testing of the system on a chip
•Reliability
•Intellectual Property related issues
•Successful partnership with industry for system on a chip fabrication

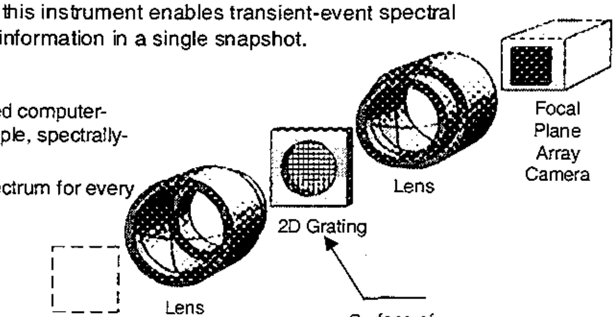
NASA
Cross - Cutting Technology Program
Examples

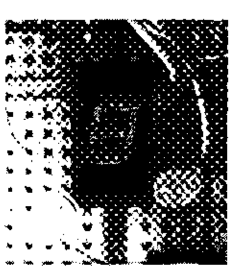
Computed-Tomography Imaging Spectrometer

A new concept in imaging spectrometers, this instrument enables transient-event spectral imaging by capturing spatial and spectral information in a single snapshot.

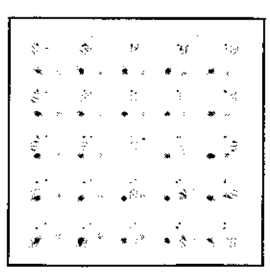
Principle of Operation
- JPL designed and electron-beam fabricated computer-generated hologram splits scene into multiple, spectrally-dispersed images
- Tomographic reconstruction yields the spectrum for every pixel in the scene

Advantages
- Does not employ scanning of any type
- Multiple spatial-spectral data cubes having different dimensionality can be reconstructed from the same frame

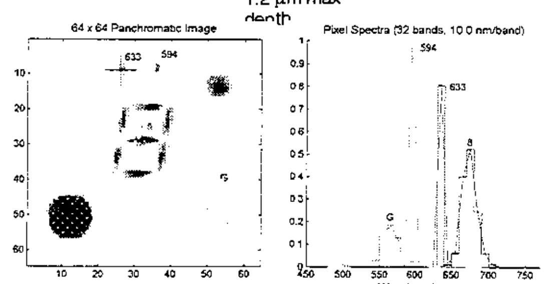




Experimental Scene
(633 nm and 594 nm
laser spots not shown)



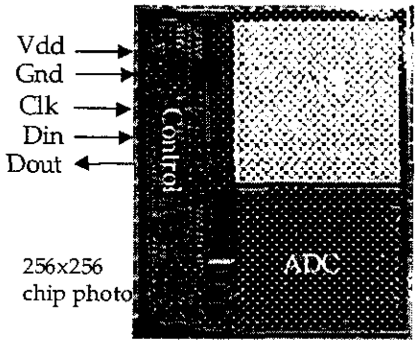
Intensity on Focal Plane Array
(Image taken in dark ambient)



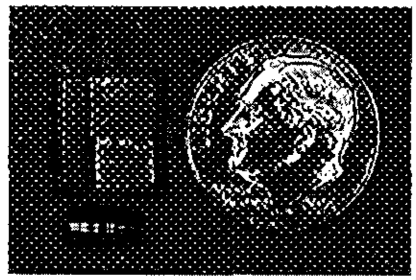
Reconstructed Spatial-Spectral Scene

DIGITAL APS CAMERA-ON-A-CHIP

First fully digital camera-on-a-chip: needs only FIVE wires for operation



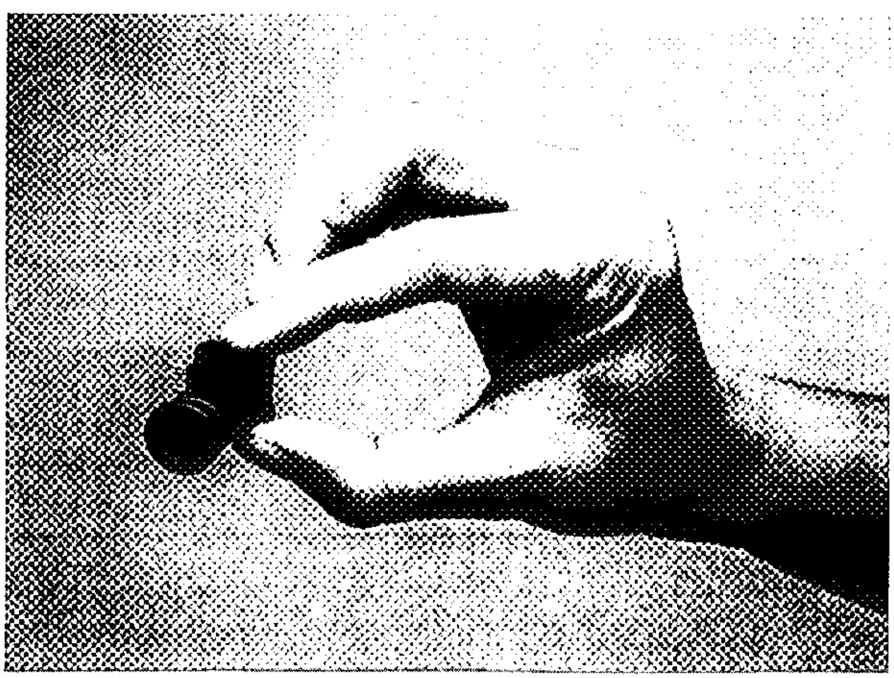
256x256
chip photo



picture of "george" at video rate (30 fps)

- ⇨Fully **digital** interface
- ⇨Requires **single** bias supply (5V)
- ⇨Fully **programmable**: resolution, speed, electronic pan & zoom, exposure, and data-reduction
- ⇨**256** Column-parallel **ADC**
- ⇨On-chip bias generation
- ⇨Total chip area: **9.7 mm x 8.9 mm**
- ⇨Supports parallel or serial interface
- ⇨Provides on-chip **offset correction**

ULTRA-LOW POWER, MINIATURIZED FULLY DIGITAL, 256 x 256 APS CAMERA



Palmcorder size QWIP Infrared Camera

Low Cost Camera for Scientific, Defense, and Commercial Applications

Detector Technology	=	QWIP
Focal Plane Array Size	=	256 x 256
Spectral Bandpass	=	8 - 9 mm
Optics	=	f1.3 Ge
Output	=	Standard Video-analog
Power Requirements	=	5.5 Watts
Battery Life	=	3 hours from Sony camcorder battery
Weight	=	2.5 pounds
Dimensions (with 50 mm lens)	=	5.3 in. x 9.7 in. x 2.5 in.
NEDT	=	30 - 50 mK
MRTD	=	10.5 mK
Instantaneous Dynamic Range	=	1024 (10 bits)

COMPARISON WITH HAND HELD CAMERA

WEIGHT – X4 LESS

VOLUME – X 4 LESS

POWER – X10 LESS

MEMS
(Micro - Electro - Mechanical System)
Technology for Space

Silicon Micromachined Microgyroscope

Present Gyroscope Technologies

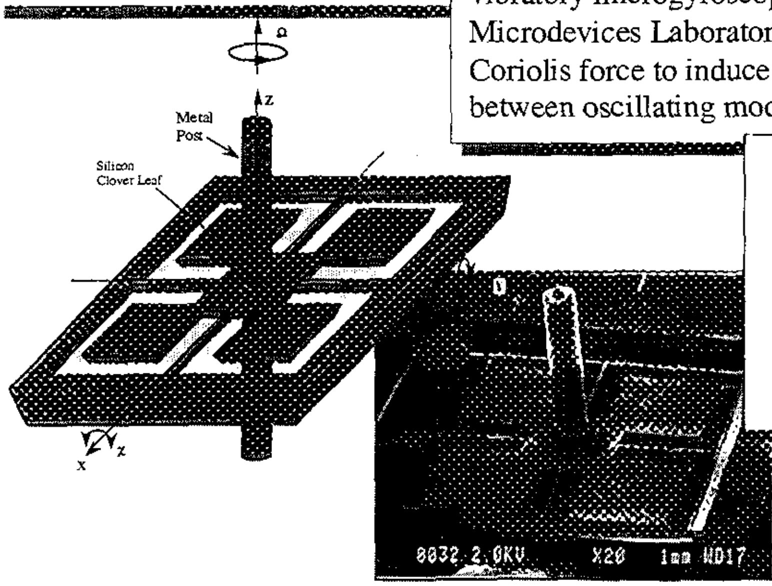
- Too Expensive
- Too bulky (volume, mass)
- Too high power consumption
- Limited Lifetime

Concept

The JPL/UCLA silicon micromachined vibratory microgyroscope fabricated at the Microdevices Laboratory depends on the Coriolis force to induce energy transfer between oscillating modes to detect rotation.

JPL Advantages

- Inexpensive
- Compact
- Low power consumption
- Non-wear/Long lifetime
- Negligible turn-on time
- Large dynamic range



NASA X-33 Advanced Technology Demonstrator
JPL Avionics Flight Experiment (AFE)

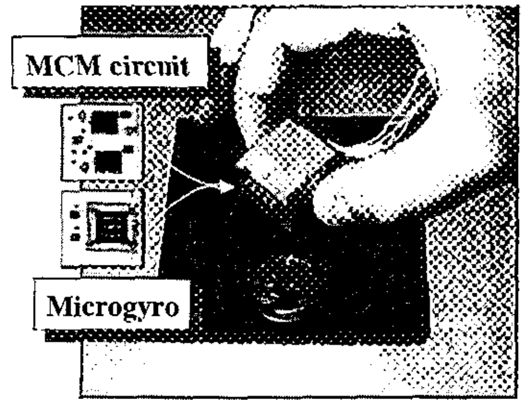
Present Performance:

1) ~17-29deg/hr bias stability,
   ~1.5 deg/root-hr ARW.
2) Electronics packaged in MCM format

Predicted Performance Goals:

1) Bias stability: 1-10 deg/hr.
   ARW: <0.1 deg/root-hr.
2) Operate at matched frequencies condition.
3) Improved electronics.
4) Package: 3 yrs operation.
5) Qualification: shock,vibration,thermal.

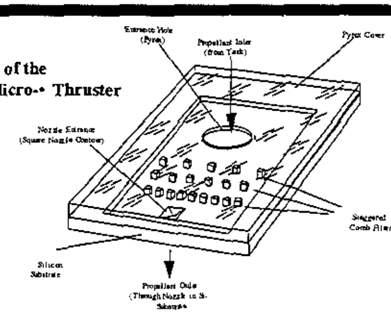
MICROGYROSCOPE

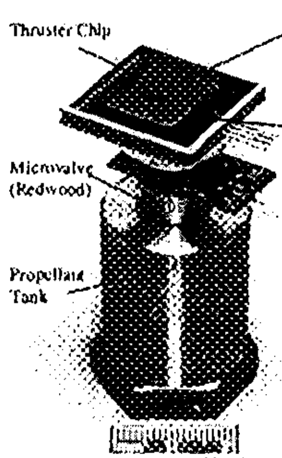


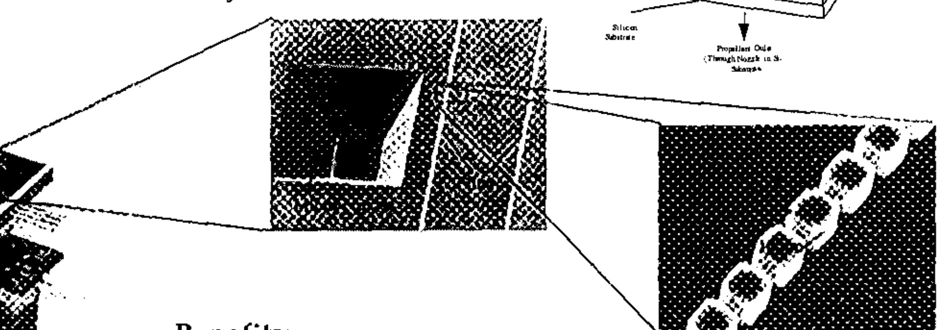
Subliming Solid Micro-Thruster

Principle of Operation:

- Store propellant (ammonium salt) in solid form.
- Propellant sublimes when heated, building up pressure in tank (~10-15 psia)
- Vent gaseous propellant through micro-valve, micro-filter and micro-nozzle assembly to produce thrust.







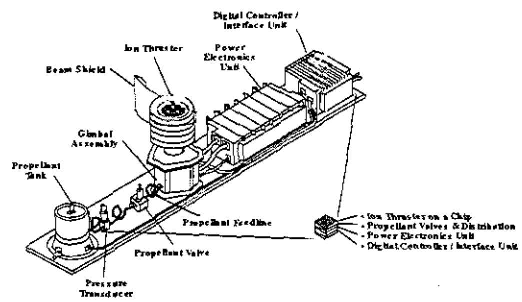
Benefits:

- Phase-change thruster concept, reduces leakage problem.
- Very small thrust and I-bit capability for microspacecraft attitude control through the use of MEMS technologies.
- Benign temperature and pressure conditions compatible with MEMS materials.

Performance Goals:

- Isp : 50-75 sec
- Thrust: 0.5 mN
- Power: < 2 W/mN
- Mass: few grams
- Size: 1 cm^2

Micro - Ion Thruster



Principle of Operation:

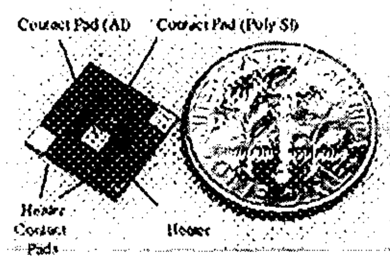
- Create micro-sized plasma to generate ions to be accelerated in micro grid accelerator system.
- Study feasibility of radio-frequency (RF) inductive coupling, cold cathode technology or hollow cathode discharges for plasma generation.
- Pursue miniature conventional and MEMS based approaches for micro-grid accelerator fabrication.

Benefits:

- Many interplanetary missions require large velocity increments, demanding large propellant masses using conventional propulsion technology.
- Ion engine technology provides high specific impulses,requiring less propellant for the same mission.
- Fuel-efficient micro-ion engine technology enables micro-sized spacecraft for demanding interplanetary missions.

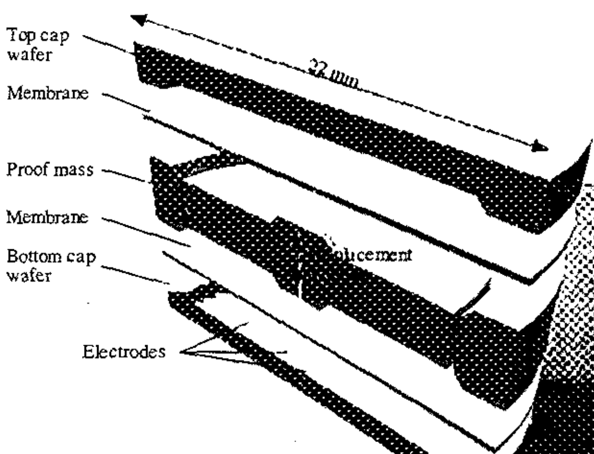
Performance Goals:

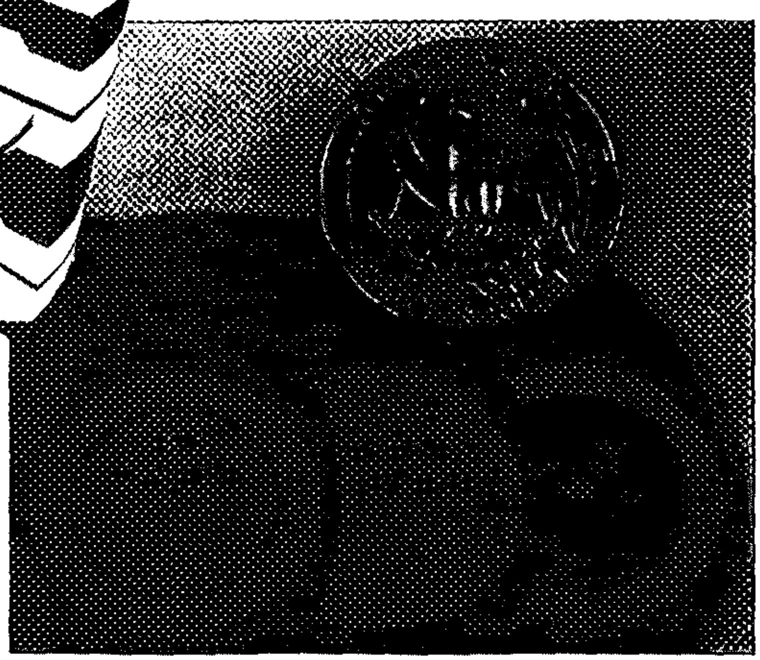
- Isp: ~ 3000 sec
- Thrust: μN to mN
- Power: < 10 W
- Mass: few grams (MEMS)
  tens of grams (conventional)
- Size: 1-3 mm dia (MEMS)
  1-3 cm dia. (conventional)



Grid Breakdown Test Chip

Micromachined Silicon Seismometer





- Use micromachining techniques (etching and photolithography) to produce tightly toleranced structures
- Continuous 10 μm membranes used as springs to maximize robustness
- Sandwich structure distributes mass/spring structures vertically rather than laterally - produces most compact geometry
- Coupled with ultrasensitive position transducer for 1 ng/√(Hz) resolution

SAW Dewpoint Microhygrometer

Features of SAW Dewpoint Microhygrometer

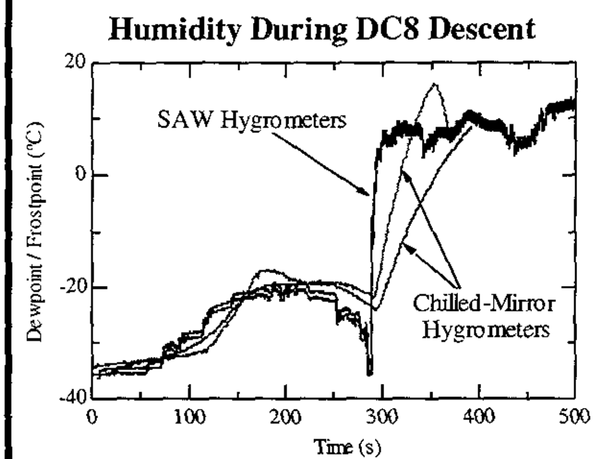
- 100x higher sensitiviy and >10x faster response compared to chilled mirror dewpoint hygrometers
- Reduction in size, mass, and power

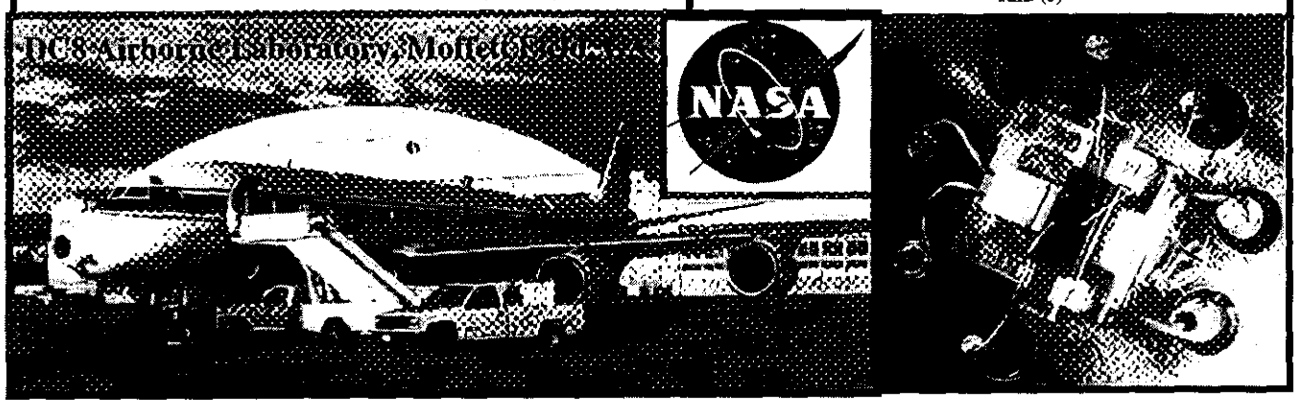
Applications of Microhygrometer

- Humidity in Earth and planetary atmospheres: Micro weather stations, Airplanes, Balloons, UAVs
- Environmental and process monitoring in space: Shuttle, X33, RLV, Space Station

Flight Tests for NASA Code YS

- NASA DC8 Airborne Laboratory (FY'95)
- Balloon-borne reference radiosonde (FY'97)

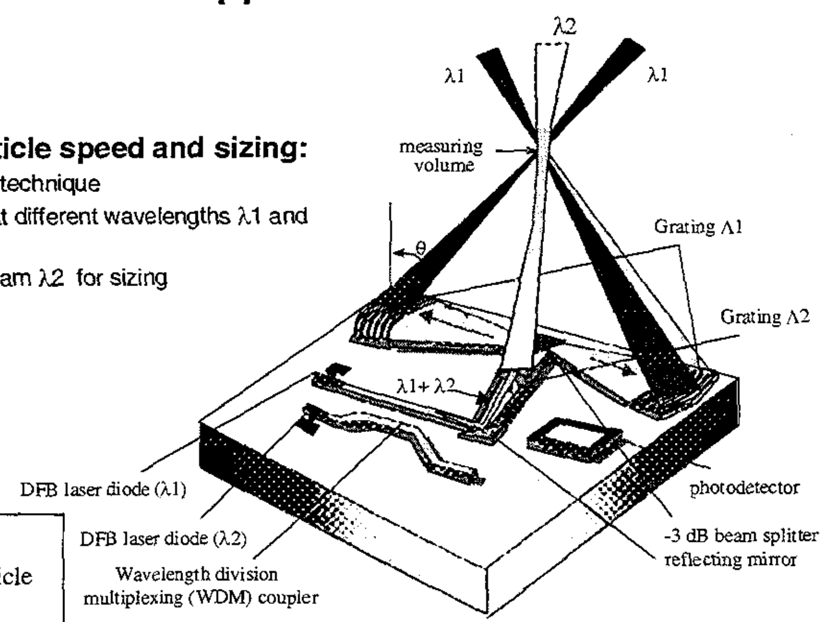




Micro Laser Doppler Anemometer

A wind sensor for particle speed and sizing:

- Combining LDA and Imax technique
- Two DFB lasers emitting at different wavelengths λ1 and λ2
- beam λ1 for speed and beam λ2 for sizing



A JPL Innovative Integrated Micro Laser Doppler Anemometer for particle speed and sizing sensor

NASA Applications

- Mars surface dust particle characterization
- Planetary boundary layer wind sensor

JPL

Tunable Diode Laser (TDL) Sensors

CSMT

New generation of TDL's operating at specific wavelengths to perform in-situ gas monitoring of Earth and planetary atmospheres

Typical laser diode package for instrument use

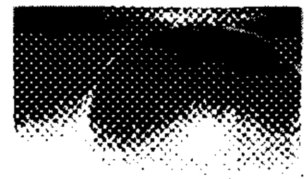
Instrument features

- High Sensitivity
- Gas discrimination
- Corrosion resistant
- Robust
- Low mass
- Low power consumption

Applications

- Measurement of atmospheric species
- Medical (breath analysis)
- Mine safety monitors
- Toxic gas monitoring

The Mars Volatiles and Climate Surveyor (MVACS) mission (1999 launch)



MVACS will carry four TDLs

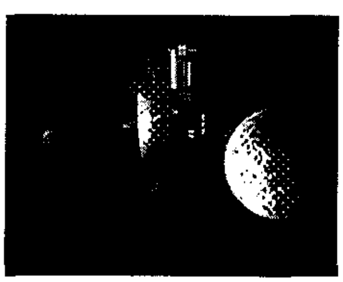
- Metrology package to measure water content of Mars atmosphere
- Thermally Evolved Gas Analyzer (TEGA) package to measure volatile contents of the soil

REMOTE EXPLORATION AND EXPERIMENTATION

HPCC

Vision:

Move Earth-based Scalable Supercomputing Technology into Space



Background

Funded by Office of Space Science (Code S) as part of NASA's High Performance Computing and Communications Program
Started in FY1996
Guidelined at $102M over 8 years

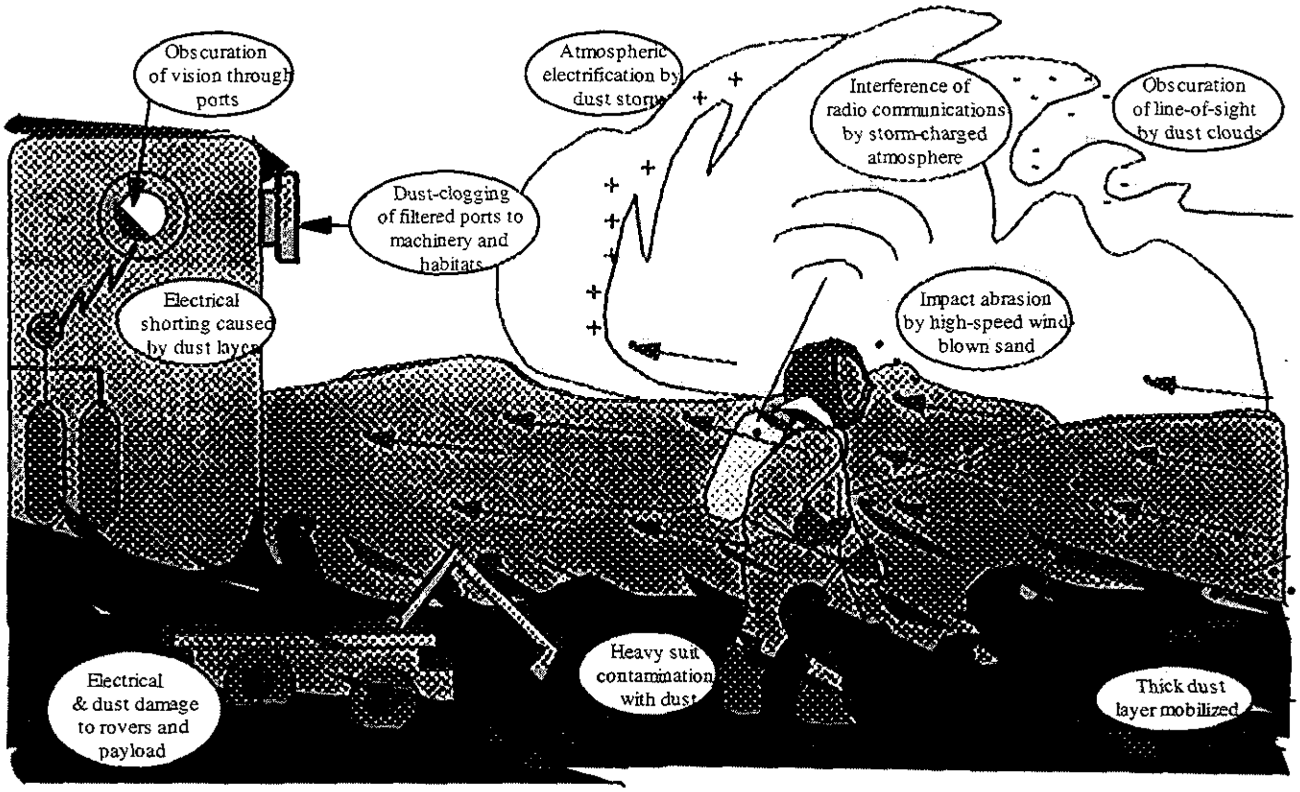
REE Impact on NASA and DOD Missions by FY03

Faster - **Fly State-of-the-Art Commercial Computing Technologies within 18 month of availability on the ground**

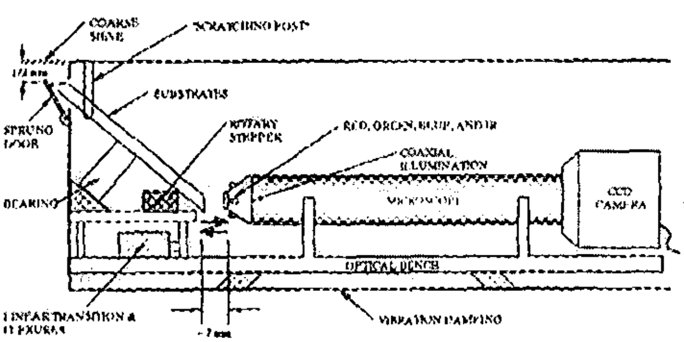
Better - **Onboard computer operating at > 300MOPS/watt scalable to mission requirements *(> 100x Mars Pathfinder power performance)***

Cheaper - **No high cost radiation hardened processors or special purpose architectures**

Interaction of Dust & Soil with Human Explorers



What's in MECA?

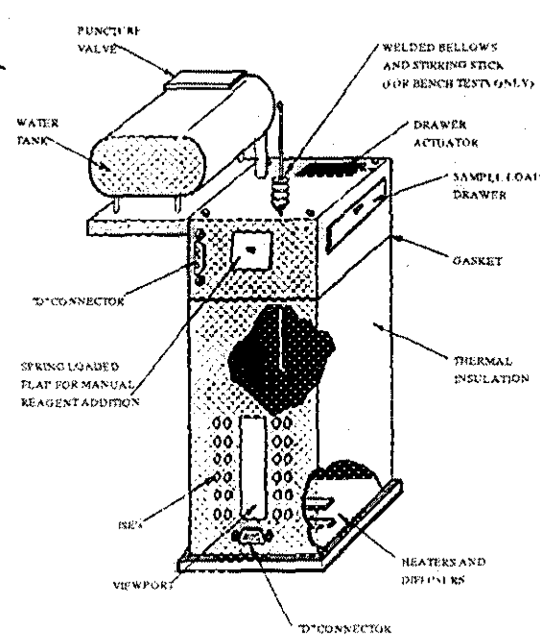


An imaging facility to observe the size, shape, and hardness of dust and soil which clings to selected targets. Particles such as quartz and asbestos can cause abrasion and lung damage. An Atomic Force Microscope (AFM) complements the optical microscope.

Also

- **An Electrometer to measure Triboelectric Charging in the dry, irradiated Martian environment**
- **Material patches to measure wear and adhesion**

A Wet Chemistry Laboratory (WCL) to measure what happens when the Martian soil is exposed to water in the human environment. The WCL measures pH, dissolved ions, and potential toxins.



CSMT Board of Governors, 1/27/98

Summary

Advanced Technology insertion is critical for NASA

- **Decrease mass, volume, power, and mission cost**
- **Increase functionality, science potential, robustness**

The Next Frontier