Environmental Diagnostic Package for NMP Technology Validation Flights

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Note: This open discussion is to be conducted consistent with ITAR restrictions. Only open-literature technology is to be discussed.

INTRODUCTION

PURPOSE: Before preparing an RFP, assemble sensor builders, sensor integrators, and potential users *to prioritize the sensors and requirements and to identify the availability of the sensors* for a small, low-cost, environmental diagnostic package for the NMP/ST8 set of technologies.

OUTLINE:

- NMP Overview and ST8 and ST9 Technologies
- Environments
- Example/Historical Costs
- Diagnostic Requirements
- Process Steps

Environmental Diagnostics Package: CONCEPT

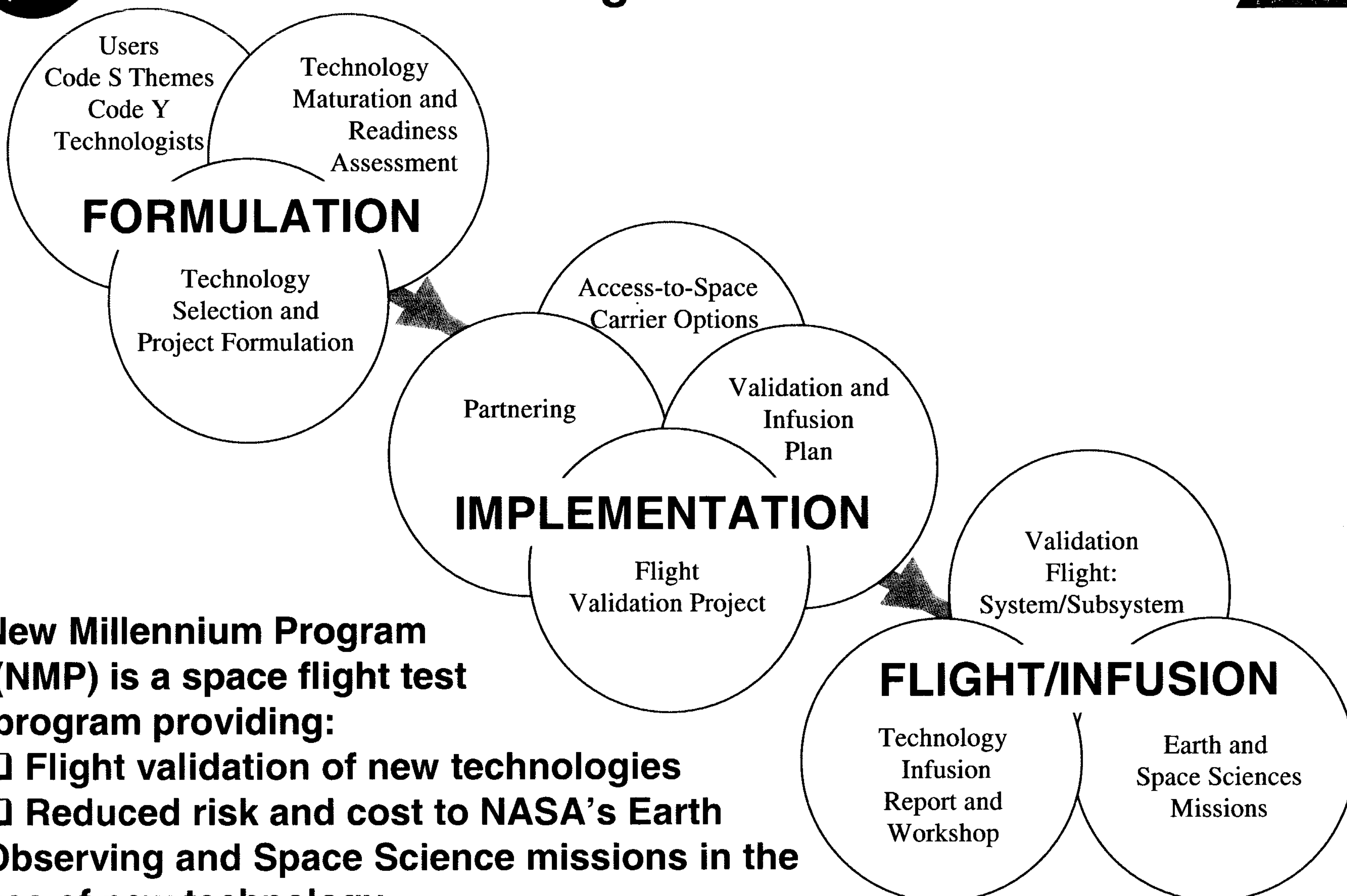
NMP is exploring the possibility of making an environmental diagnostic package available for inclusion on its validation flights.

The *raison d'etre* for this effort follows from the need to characterize the validation-flight environment so that future users can extrapolate or scale NMP test results to the end-use environment.

Short-Term Objective: To develop four hockey-puck size diagnostic packages to be included with the ST8 technology validation flights for a total cost of about $1M that is $250K each.

Long-Term Goal: To include an Environmental Diagnostic Package with every NMP validation flight from a commercial source for about $5,000 each.

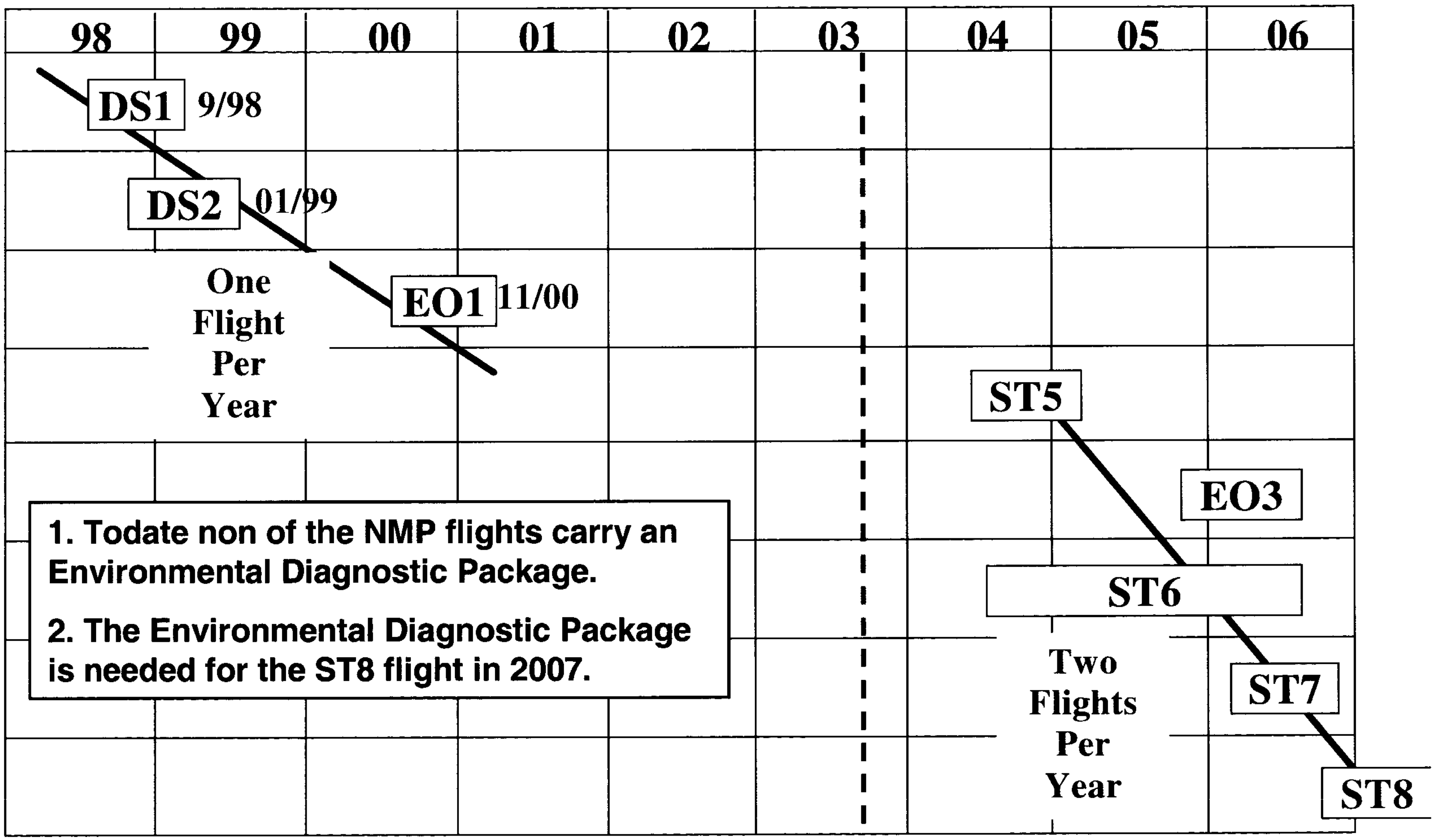
NMP Program Overview



New Millennium Program (NMP) is a space flight test program providing:

- **Flight validation of new technologies**
- **Reduced risk and cost to NASA's Earth Observing and Space Science missions in the use of new technology.**

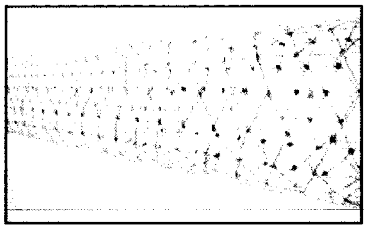
NMP Flight History and Prospects

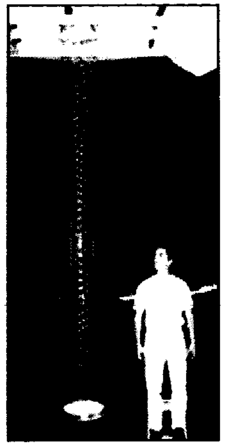


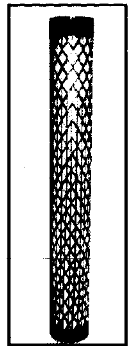
1. Todate non of the NMP flights carry an Environmental Diagnostic Package.

2. The Environmental Diagnostic Package is needed for the ST8 flight in 2007.

ST8-1: Deployment of Ultra-Lightweight Booms







Flight Validation Objective: The objectives of an investigation directed to this technology area should be:

•Validation of boom deployment, including the dynamics and uniformity of the deployment action and the completeness with which the boom secures into its final state of deployment;

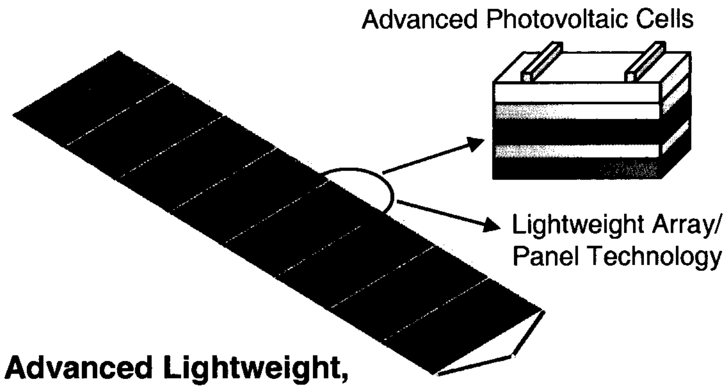
•Characterization of the structural mechanics and dynamics of the deployed booms; and

•Validation of design approach and predictive methods for deploying ultra lightweight booms by *correlating flight measurements with analytical models developed through ground testing.*

Measurements, Parameters, and Model Verification:
This in-space investigation will provide *relevant environment test results* that can be used to validate the performance models. Hence, the deployed subsystem should be adequately instrumented to verify successful deployment and to quantify predicted structural characteristics of the booms as follows:

- Deployment dynamics and reaction forces imparted to the experiment platform during deployment;
- Time required to execute the deployment (and *rigidization*, if inflatable);
- Power required over the deployment period;
- Deployed boom length, straightness, and uniformity;
- Mechanical stability in response to quasi-static loads and *temperature* changes; and
- *Structural dynamics*, including natural frequency, mode shape, and damping.

ST8-2: Deployment of Lightweight Solar Array



Advanced Lightweight,

High Performance Solar Array

***Flight Validation Objectives*:** The overall objectives of an investigation directed to this technology area should be:
- Characterization of the deployment, controllability, and structural dynamics of a lightweight solar array assembly;
- Verification of the predicted structural and *photovoltaic performance* of the deployed solar array, including the *behavior and durability of the photovoltaics, any supplemental optics, and panel materials in the space environment;*
- Verification of secure deployment after the solar array is deployed;
- Verification that the deployed solar array is dynamically stable;
- Validation of photovoltaic cell, blanket, and solar array technology that is capable of being qualified for future NASA missions; and
- Validation of all structural and electrical performance models used to scale up to 7 kW (if flight demonstration is subscale and/or not fully power producing).

Measurements, Parameters, and Model Verification: The principal objective for this in-space experiment is to provide relevant environment information that can be used to *validate the performance models*. Hence, the deployed subsystem should be adequately instrumented to verify successful deployment and to quantify predicted power generation characteristics of the array. The instrumentation should measure parameters that characterize the solar array performance in terms of:

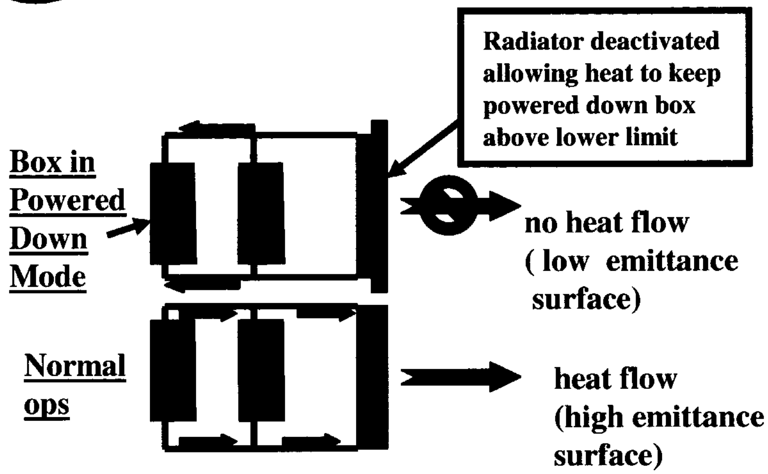
- Deployment dynamics and reaction forces imparted to the experiment platform during deployment;

- Structural dynamics of deployed array, including natural frequencies, mode shapes, and damping;

- Dimensional stability and change in array pointing angle in response to *temperature* changes; and

- *Variation of voltage and current output as a function of time, temperature, and environmental conditions as measured at the spacecraft.*

ST8-3: Thermal Management Subsystem for Small Spacecraft



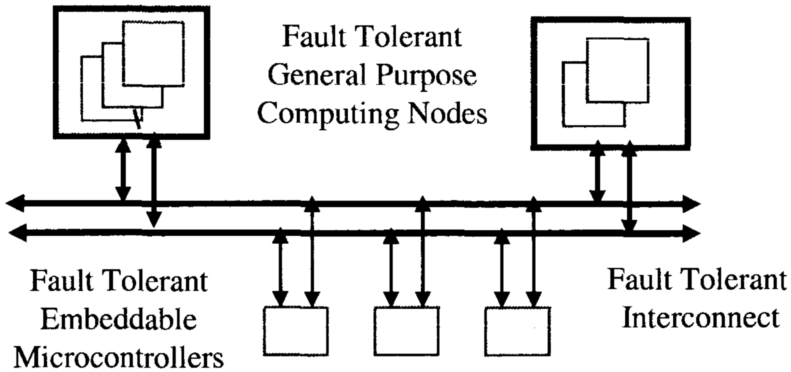
Flight Validation Objectives: The objectives of an investigation directed to this technology area should be:

- Validation of the performance of a thermal control subsystem designed specifically for small (< 150 kg) spacecraft having a total power generation of ≤250 W and corresponding power dissipation of ≤200 W
- Validation of analytically predicted savings in spacecraft mass, power, and volume of thermal control system designed for small spacecraft when compared with conventional thermal control techniques; and
- Validation of analytical models used to predict thermal performance of optimized component locations enabled by new thermal control system.

Measurements, Parameters, and Model Verification: The thermal management subsystem is to be instrumented to the extent required to quantify all necessary parameters that characterize subsystem performance, including but not limited to:

- Component power dissipations;
- Component *temperature*, including temperature measurements of spacecraft surfaces that may affect the performance of the subsystem; and
- Any electrical power associated with control of the subsystem.

ST8-4: COTS Based High Performance Computing



Flight Validation Objectives: The general objective of this experiment is to verify the feasibility of flying a high performance COTS-based data processing system onboard NASA spacecraft. Specific objectives are:

Validation of the radiation fault models, system models, laboratory testing procedures, design tools and fault tolerance techniques with respect to system level predicted fault rates and representative locations in *natural space radiation environments*; and

Validation that low cost fault tolerance techniques can provide predictable and acceptable levels of reliability for space based COTS onboard data processors while maintaining orders of magnitude performance improvement over state of the art radiation hardened systems in a minimal overhead, scalable architecture.

Measurements, Parameters, and Model Verification: The ultimate goal of this investigation is to validate and/or calibrate the underlying technology models proposed for this experiment, as well as to validate the efficacy of the fault tolerance techniques and system design methods and tools. In order to accomplish this, the following parameters are suggested as a minimum set to be measured by the investigation:

•Fault rates;

•Fault locations where fault sites are identified with sufficient physical (hardware) granularity to aid in diagnosing the system;

•*Radiation environment*;

•Number of successful recoveries from recoverable faults;

•Recovery time; Number of system failures which cause the system to cease operating due to unrecoverable faults; and

•Effective MIPS/Watt at the system level in the presence of recoverable faults.

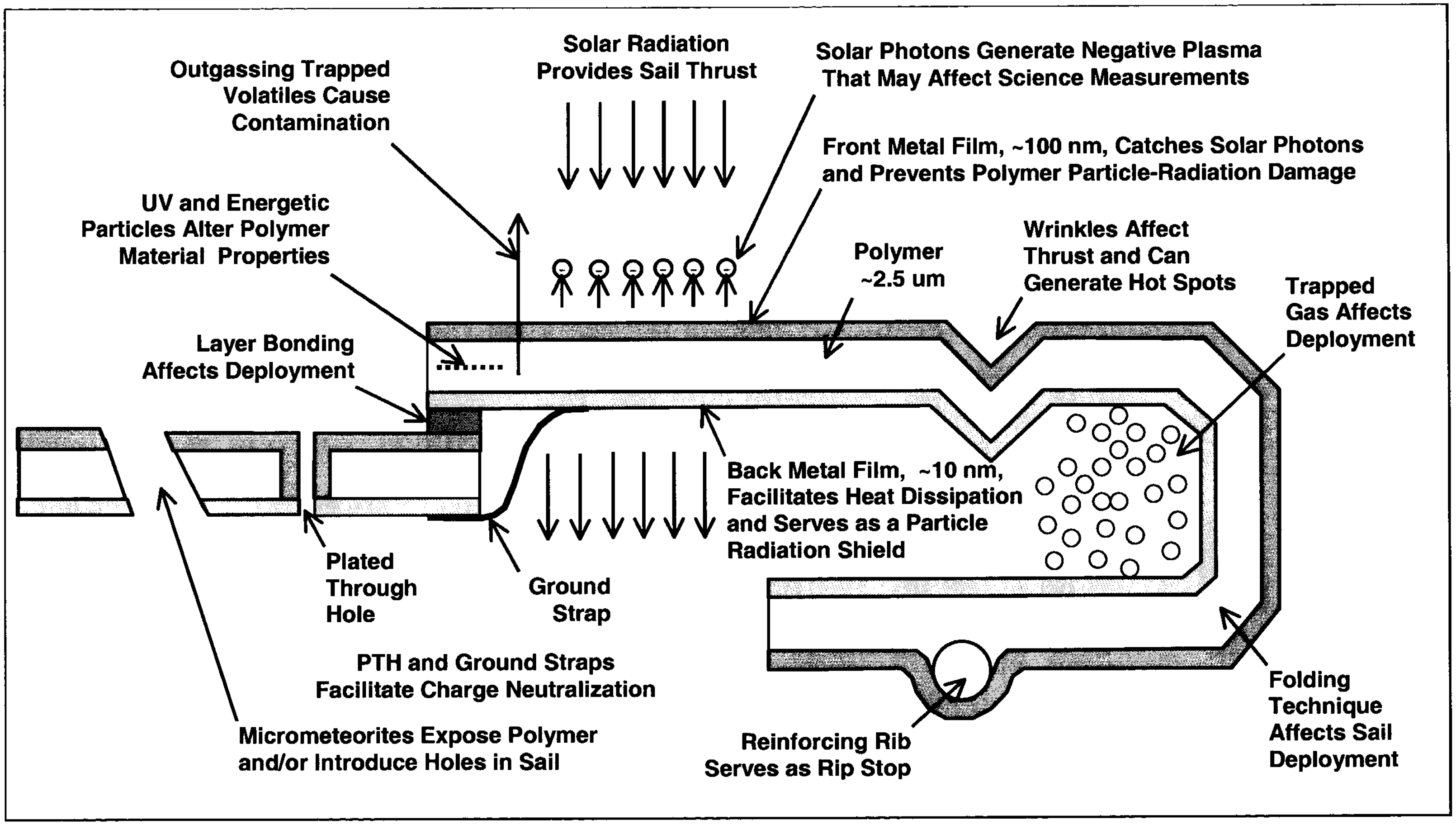
Environmental Diagnostic Package

Sensitivity of Technology to Space Environment

	ST8-1	ST8-2	ST8-3	ST8-4	ST9-1	ST9-2	ST9-3	ST9-4	ST9-5
Environment	Ultra-Light-weight Booms	Light-weight Solar Arrays	Thermal Management	COTS Computing	Solar Sail	Aerocapture	Large Space Telescope	Precision Landing	Precision Formation Flying
1.0 Mechanical									
1.1 Deploy. Motion	X	X			X		X		
1.2 Launch Vibration	X	X	X		X	X	X	X	X
1.3 Gravity Gradient	X				X				
2.0 Contamination									
2.1 Outgassing	X	X	X	X	X	X	X	X	
2.2 Thruster		X	X		X	X	X	X	X
3.0 Radiation									
3.1 Electrons/Protons	X	X		X	X		X		X
3.2 Cosmic Rays				X					X
3.3 UV	X	X		X	X		X		
3.4 Plasmas	X	X			X	X			
3.5 Neutrals				X					
3.6 Magnet Field	X	X		X	X		X		
4.0 Particulate									
4.1 Orbital Debris		X	X		X		X		X
4.2 Micrometeorites	X	X			X		X		X
4.3 Atomic Oxygen	X	X			X		X		X
5.0 Temperature									
5.1 High T	X	X	X	X	X	X	X	X	X
5.2 Low T	X	X	X	X	X	X	X	X	
5.3 Transient T	X	X	X	X	X	X	X	X	
6.0 Atmospherics									
6.1 Aerodynamic Drag						X		X	X
6.2 Atm. Heating						X		X	
6.3 Pressure						X		X	

Currently the ST9 technologies are in the formulation phase which will define their capability needs.

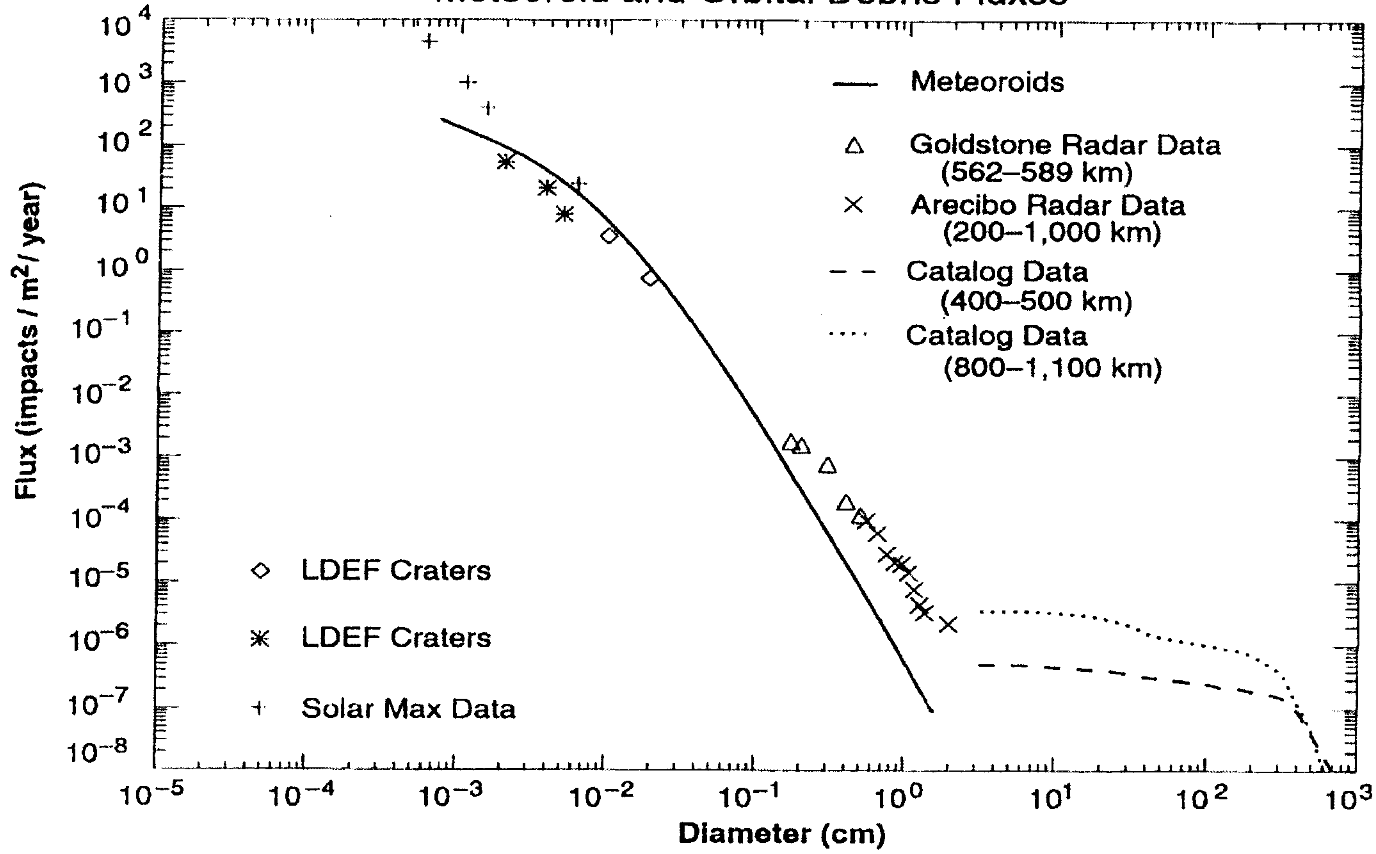
Space Environmental Effects on Membrane Materials



Based on: C. R. McInnes, "Solar Sailing: Technology, Dynamics and Mission Applications", Praxis Publishing (Chichester, UK, 1999)

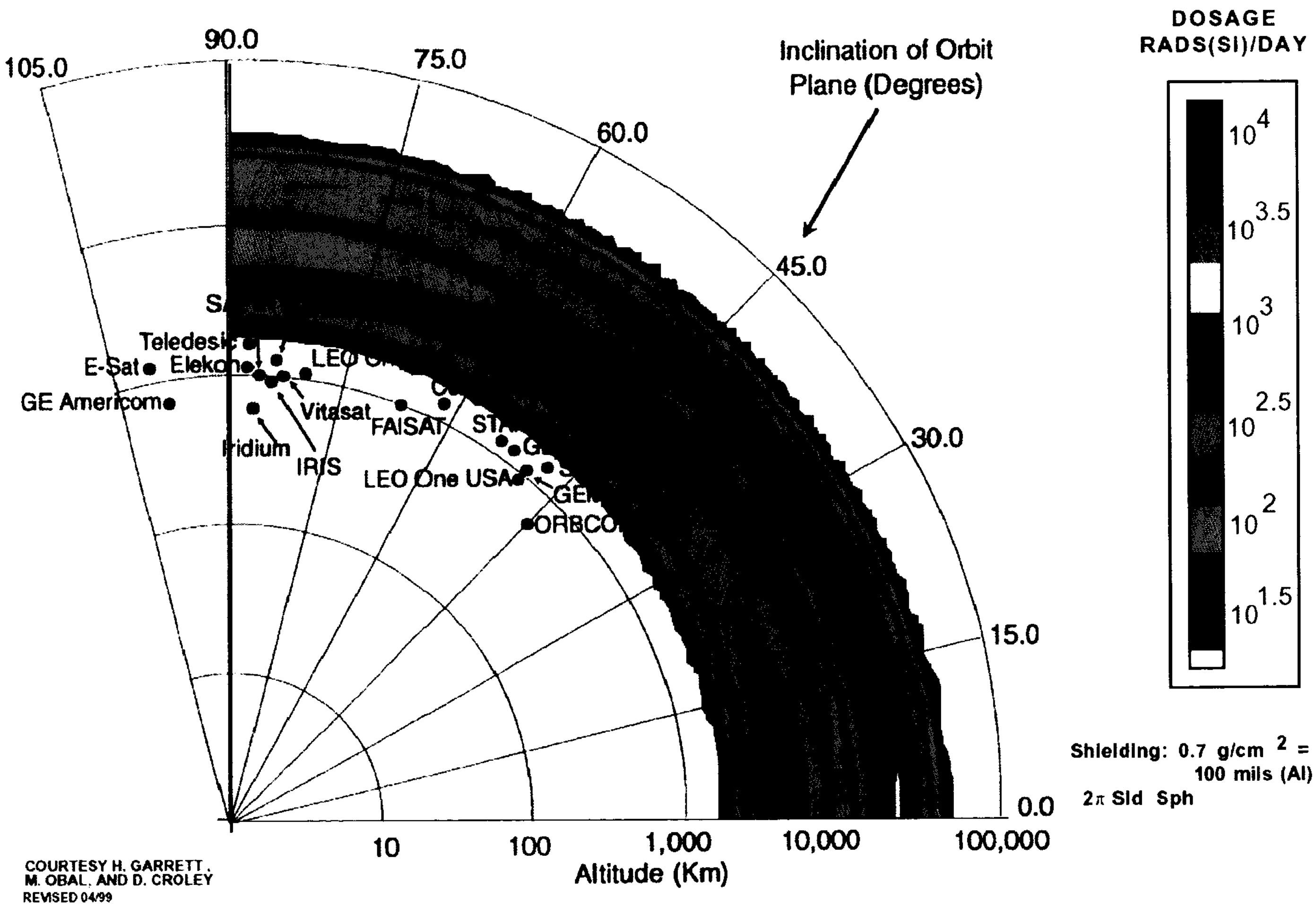
Environmental Diagnostic Package

Meteoroid and Orbital Debris



After: J. R. Wertz and W. J. Larson, "Space Mission Analysis and Design," Microcosm Press, El Segundo, CA 1999).

Total Ionizing Dose for Circular Orbits



NMP space validation flights will be found in orbits between the Earth-Moon. The duration will be between days to months.

Environmental Diagnostic Package

Environmental Instrumentation: Example

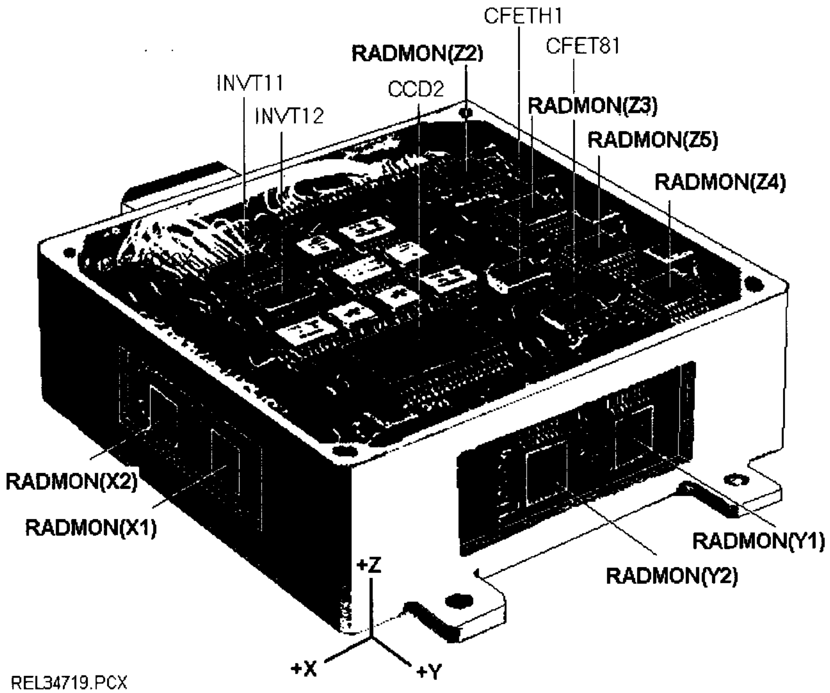
Detector	Purpose	Range	Mass (kg)	P (W)	Data (Bits/s)	Size (cm)	Vol cm^3
1. Dosimeter* (per unit)	Total Ionizing Dose at selected locations	0.1 to 1000 kRad	0.1	0.05*	1	5x5x2.5 per unit	62.5
2. SEU Monitor**	Single Event Upsets	NA	0.7	1	10	5x5x2.5	62.5
3. Surface Potential Monitor	Measure surface potentials	.01 to -20 kV	0.5	1	5	5x5x10	250
4. Electron Telescope***	Electron Spectrum	0.03-3 MeV	0.25	0.5	100	17x7x3	357
5. Proton Telescope***	High Energy Proton Spectrum	0.5-200 MeV	0.25	0.5	100	17x7x3	357
6. Magnetometer****	Vector Magnetic Field (Fluxgate)	10 to 4x10e5 nT	0.5	2	50	4x4x6	96
7. Cosmic Ray Spectrometer***	Heavy Ion Spectrum	H to Fe/>20 Mev/nucleon	2.5	1	100	5x5x2	50
8. Calibration Dosimeter	Calibrated Dosimeter for detailed *dosimetry studies*	0.1 to 1000 kRad	2.5	4	100	12x12x20	2880
9. Low Energy Electron Detector	Measure lower energy electrons	0.01 -100 keV	2.5	3	100	10x10x15	1500
10. Low Energy Proton Detector	Measure lower energy protons	0.01-100 keV	2.5	3	100	10x10x15	1500
11. Discharge Monitor	Monitor discharges on surface and inside spacecraft	1-100 V/pulse	0.5	0.5	10	5x5x2.5	62.5
12. Micrometeoroid Detector	Micrometeoroid and Debris fluences	1-10 ug	0.5	0.1	10	100x100x0.2	2000
TOTALS			13.3	16.6		21x21x21	9177.5

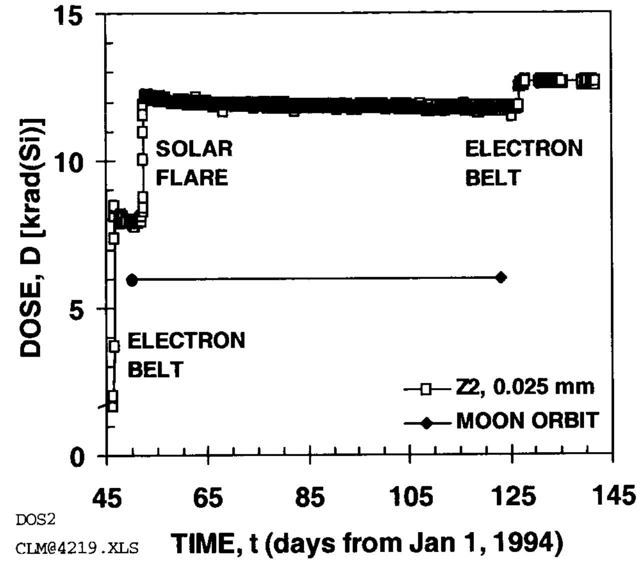
*Per Unit: Probably want 5-10 units; Power only when turned on to read accumulated dose
**Might be able to monitor RAM or SSDR memory upsets instead; may want to measure LET/pulse height instead of upsets; Could replace with CEASE
***Replace all with AFRL CEASE: 1.5 kg, 3 W, 7.5x7.5x7.5
****Assumes magnetically clean spacecraft, no boom....

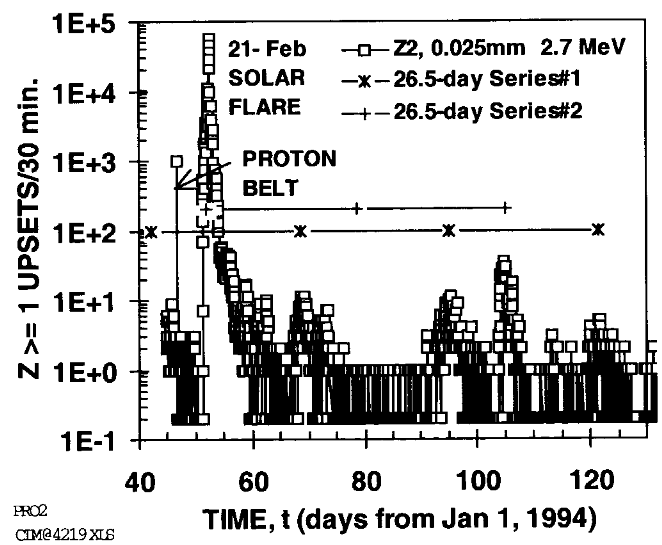
Instrument package costs ~$4M which is too high.

After: H. B. Garrett, JPL

Radiation Test Package Flown on Clementine







RRELAX is a 624 g, 2.4 watt, 10.2 cm x 10.2 cm x 3.8 cm box used to characterize 166 test devices and the electron, proton, solar flare environment.

After: M. G. Buehler, G. A. Soli, B. R. Blaes, J. M. Ratliff, and H. B. Garrett, “Clementine RRELAX SRAM Particle Spectrometer”, IEEE Trans. on Nuclear Science, Vol. 41, No. 6, 2404-24011, December 1994

Attributes Of
The Environmental Diagnostic Package

1. SMALL: Diagnostic package is to be the size of a hockey puck.
2. INEXPENSIVE: When developed and commercially available, the package should cost about $5,000 each excluding integration costs.
3. SAME: The package will be the same for all NMP flights. The package will not be customized for a particular NMP flight.
4. MONITOR: Data from this package are not intended to be used to update environmental models. Thus, the package is a monitor-grade not scientific-grade device.

Environmental Diagnostic Package: PROCESS STEPS

1. Assemble sensor builders, sensor integrators, and potential users to *prioritize* sensors and requirements for a small low-cost diagnostic package for the NMP/ST8 set of technologies.

2. Prepare an RFP using results from step 1.

3. Inform ST8 providers in late August 2003 at their Phase A review that a diagnostic package is being developed and needs to be integrated into their development plans.

RFP Outline

1. Environmental Diagnostics:
    1.1 Diagnostic Measurement Capability
    1.2 Mass, Volume, Power
    1.3 Data Storage
    1.4 Interface Standards

2. Business Plan:
    2.1 Device Cost Projections
    2.2 Flight Qualification
    2.3 Availability

Environmental Diagnostic Package

NMP Environmental Diagnostic Package Technology Priority and Requirement

ENVIRONMENT	CONTAMINATION	RADIATION	PARTICULE
1.0 Mechanical			
1.1 Deploy. Motion			
1.2 Launch Vibration			
1.3 Gravity Gradient			
2.0 Contamination			
2.1 Outgassing			
2.2 Thruster			
3.0 Radiation			
3.1 Electrons/Protons			
3.2 Cosmic Rays			
3.3 UV			
3.4 Plasmas			
3.5 Neutrals			
3.6 Magnetic Field			
4.0 Particulate			
4.1 Orbital Debris			
4.2 Micrometeorites			
4.3 Atomic Oxygen			
5.0 Temperature			
5.1 High T			
5.2 Low T			
5.3 Transient T			
6.0 Atmospherics			
6.1 Aerodynamic Drag			
6.2 Atm. Heating			
6.3 Pressure			
7.0 **Other**			

Requirement (first choice):

Requirement (second choice):

Requirement (third choice):

Indicate first (1) second (2), and third (3) choices along with requirements.

EXPERT NAME: ______________, AFFILIATION: _____________, PHONE: _______________,

E-MAIL: ______________

E-mail this form to martin.g.buehler@jpl.nasa.gov by 1 August 2003.