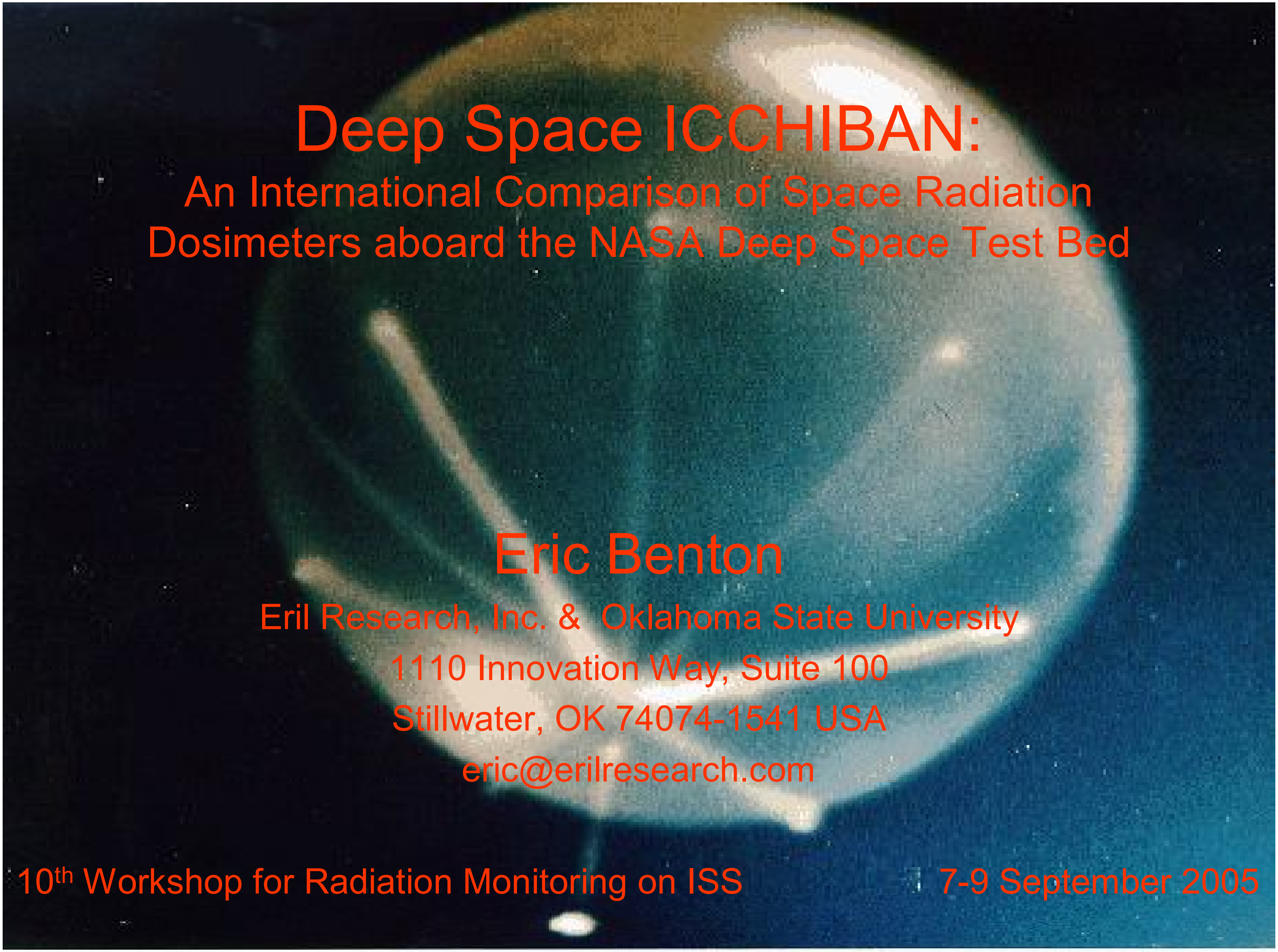

Deep Space ICCHIBAN:

An International Comparison of Space Radiation Dosimeters aboard the NASA Deep Space Test Bed

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10th Workshop for Radiation Monitoring on ISS 7-9 September 2005

Introduction

- NASA’s focus has shifted away from LEO and ISS, and towards Exploration
  - return to the Moon
  - human missions to Mars
- Radiation Environment in deep space (beyond Earth’s Magnetosphere) differs from that in LEO
  - no trapped radiation
  - no geomagnetic cutoff imposed on GCR and SPE
- Easiest access to “Deep Space” radiation environment is by high altitude balloons flying at polar latitudes

NASA Deep Space Test Bed (DSTB)

- Managed from NASA Marshall Space Flight Center and National Space Science & Technology Center (NSSTC) as part of NASA's Space Radiation Shielding Project
- High altitude (~37 km or ~125,000 ft) balloon platform to fly at polar latitudes
- Proposal for Deep Space ICCHIBAN submitted in Nov. '04 and accepted in May '05
- Will be carried out in parallel with another DSTB grant: "Space Radiation Shielding Testing on the NASA DSTB"

DSTB Objectives

- Provide a platform for direct exposure to the full composition and energy spectra of Galactic Cosmic Rays (GCR)
- Enable experimental validation of NASA's radiation transport codes in a realistic GCR environment
- Test shielding effectiveness of typical spacecraft materials as well as novel materials in the GCR flux
- Test new radiation monitoring instrumentation

DSTB Implementation

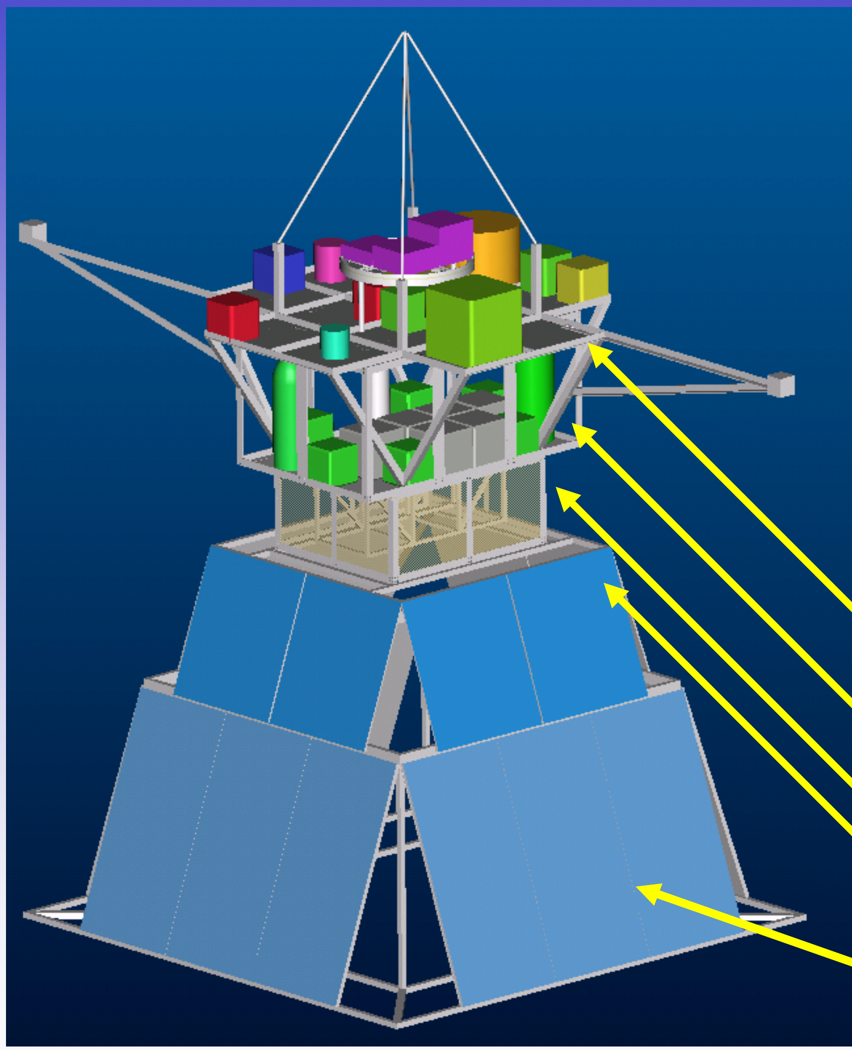
- Utilize NASA's scientific balloon program to provide high-altitude exposures:

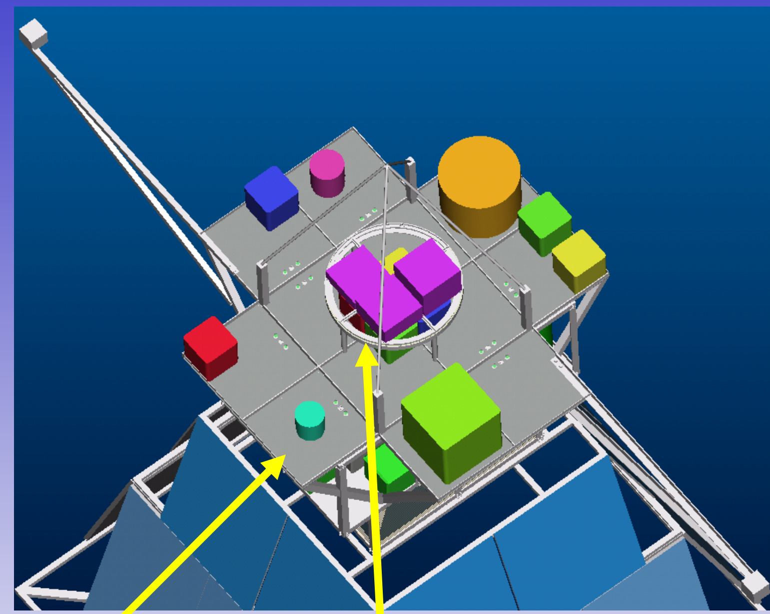
  <5 g/cm^2 atmospheric overburden

  15-20 days of exposure

  Operates under reduced restrictions compared to flight experiments: reduced costs, shorter schedules and reviews
- Conduct multiple flights (one flight per year)
- Develop an architecture to conduct multiple experiments on each flight
- Accommodate changes in the payload configuration from year to year

DSTB Design





Shielding Turntable

Exposure Deck

Electronics Deck

SIP Deck (Balloon Equip.)

SIP Solar Arrays

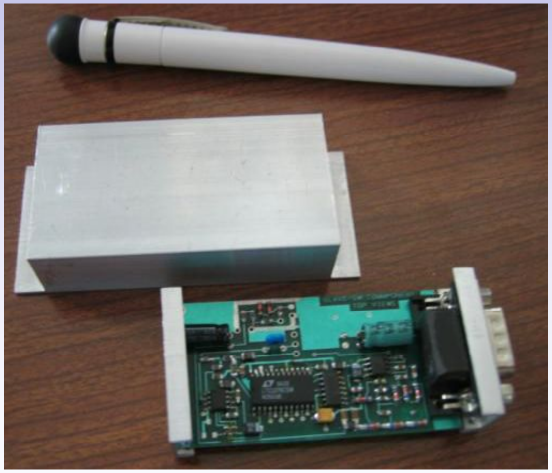
DSTB Solar Arrays

DSTB Specifications

- Gondola dimensions: height 19.6 ft., width 11.7ft.
- Maximum science payload: 4000 lbs./ 5500 lbs. with balloon equipment (shared resource)
- Power: 600 watts at 28 VDC (shared resource)
- Omni-directional or pointed gondola
- Telemetry: 6 kbits/second
- Experimental interface: RS-232, parallel, DIO, smart-port (LAN)
- Average of 10 experiments per flight:
  – Average mass: 150 lbs. per experiment
  – Average power: 60 watts per experiment

DSTB Standard Radiation Instrument Suite

- Passive Dosimetry System *(Eril Research, Inc.)*
  - CR-39 Plastic Nuclear Track Detectors *(ERI)*
  - PorTL Portable TLD System *(KFKI AERI, Hungary)*
  - Liulin-4 Mobile Dosimetry Units *(STILBAS, Bulgaria)*
  - Al_2O_3:C OSL *(OSU)*
  - Thermal/Resonance Neutron Detectors *(ERI)*
- Tissue Equivalent Proportional Counter
  (CARR, Prairie View A&M University)
- Neutron Monitoring System *(NSSTC)*
- Charged Particle Spectrometer *(NSSTC)*

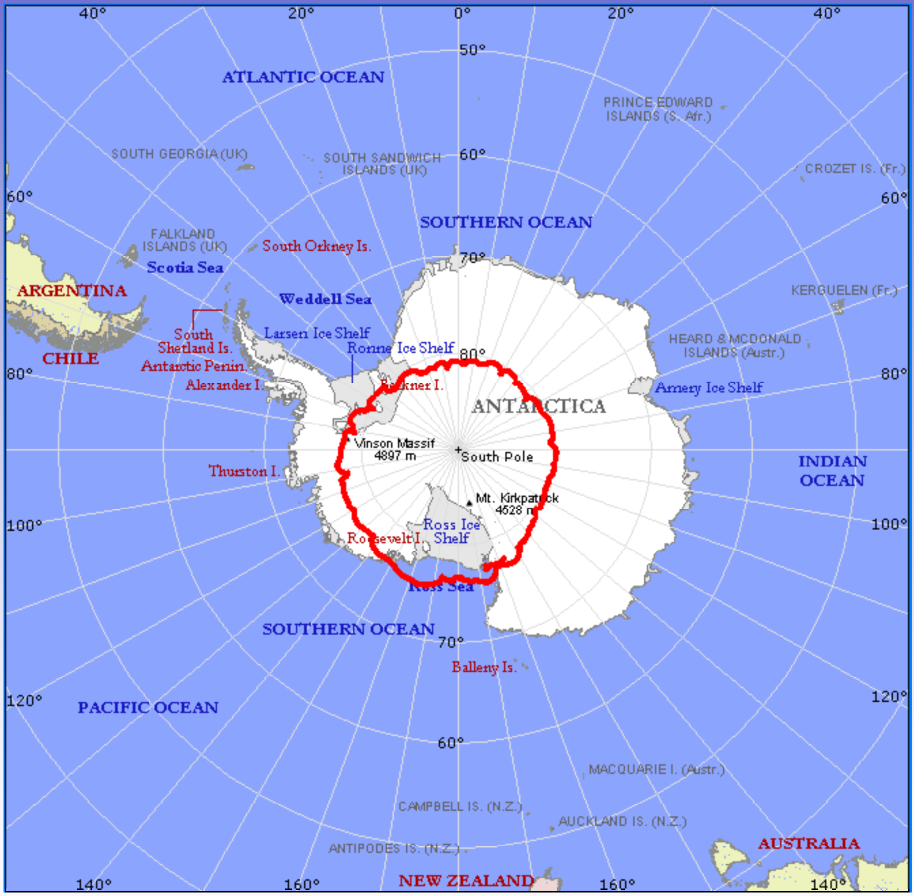


DSTB Preliminary Experiments

- Characterization of radiation environment at ~37 km, polar latitudes by piggyback experiments on previous Antarctic balloon missions
  - ATIC (2002/03)
  - TIGER (2003/04)
  - TRACER (2003/04)
  - CREME (2004/05)
- Test of PDS on DSTB Certification Flight in June 2005 from Fort Sumner, New Mexico

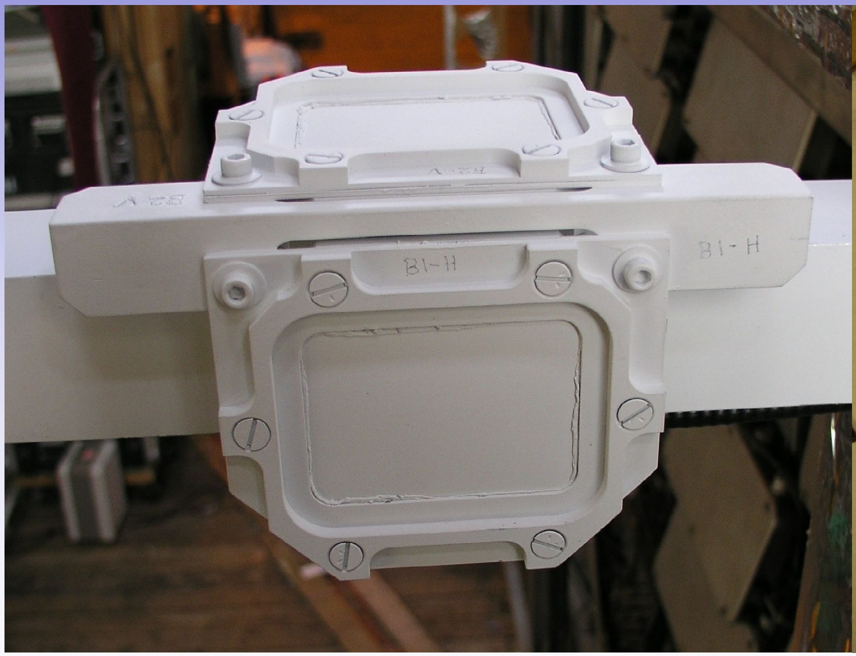
TRACER (Transition Radiation Array for Cosmic Energetic Radiation) Piggyback Experiment

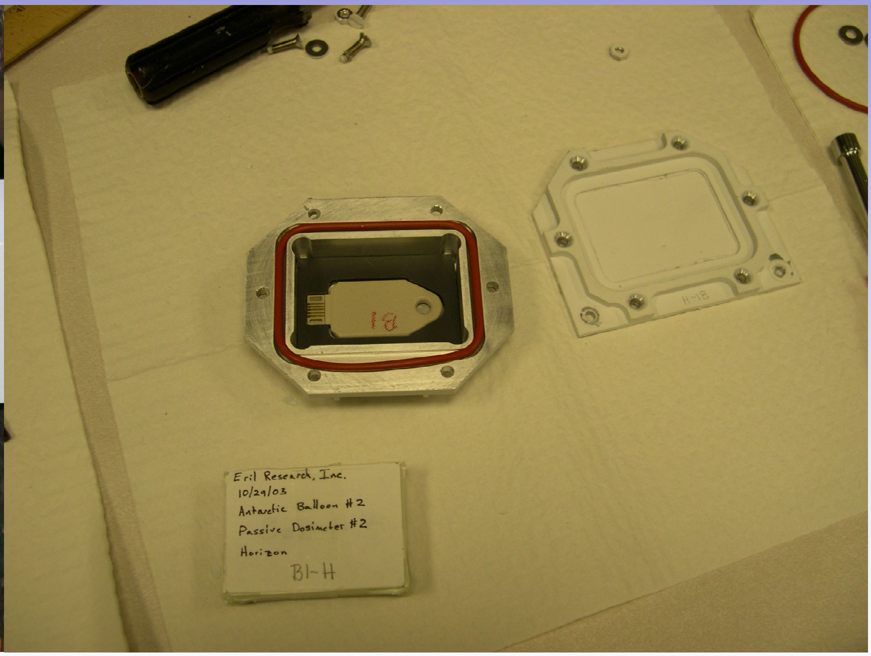
- U. of Chicago
- Dec. 12-27, 2003
- 324 hours
- 36-39 km



TRACER Piggyback Detectors

- CR-39 PNTD (ERI), TLD-700 (ERI), OSLD & TLD-100 (OSU)
- One Detector pointing towards Zenith
- One Detector pointing towards Horizon

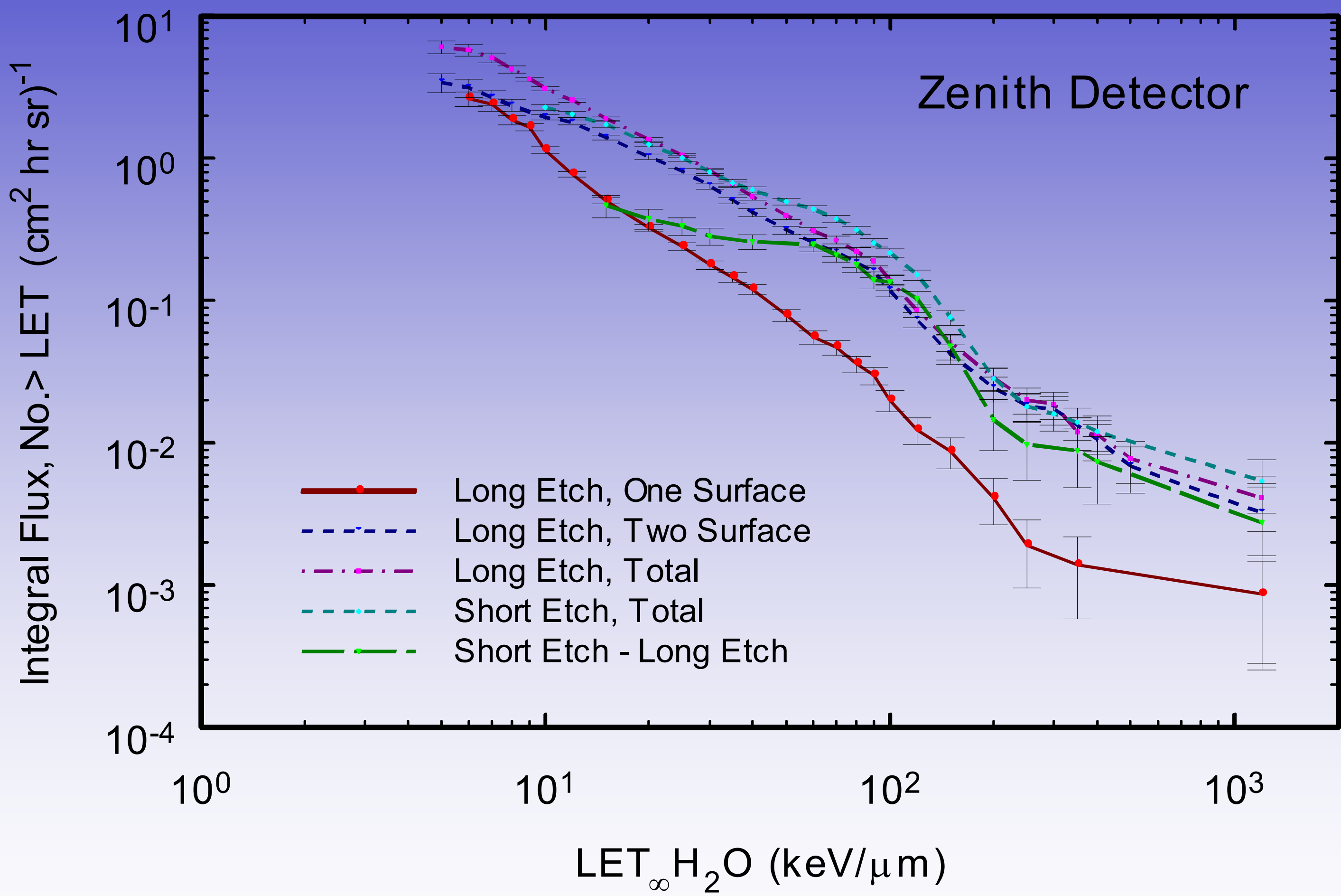




TRACER TLD/OSLD Results

	Dose (mGy)	Average Dose Rate (μGy/hour)
TRACER Zenith Detector		
ERI TLD-700 (^{7}LiF:Mg,Ti)	1.58 ± 0.05	4.88 ± 0.15
OSU TLD-100 (LiF:Mg,Ti)	1.66 ± 0.15	5.12 ± 0.46
OSU TLD-300 (CaF_2:Tm)	1.59 ± 0.02	4.91 ± 0.06
OSU Al_2O_3:C OSL chips	1.33 ± 0.03	4.10 ± 0.09
OSU Luxel Al_2O_3:C OSL	1.745 ± 0.002	5.386 ± 0.006
TRACER Horizon Detector		
ERI TLD-700 (^{7}LiF:Mg,Ti)	1.60 ± 0.05	4.94 ± 0.15
OSU TLD-100 (LiF:Mg,Ti)	1.72 ± 0.11	5.31 ± 0.34
OSU TLD-300 (CaF_2:Tm)	1.68 ± 0.04	5.19 ± 0.12
OSU Al_2O_3:C OSL chips	1.34 ± 0.05	4.14 ± 0.15
OSU Luxel Al_2O_3:C OSL	1.787 ± 0.003	5.515 ± 0.009
1997 Arctic Balloon Mission		
Detector 1	2.37 ± 0.07	8.00 ± 0.24
Detector 2	2.39 ± 0.07	8.07 ± 0.24
1994 JACEE-13	2.33 ± 0.07	7.74 ± 0.23

TRACER Integral LET Flux Spectra



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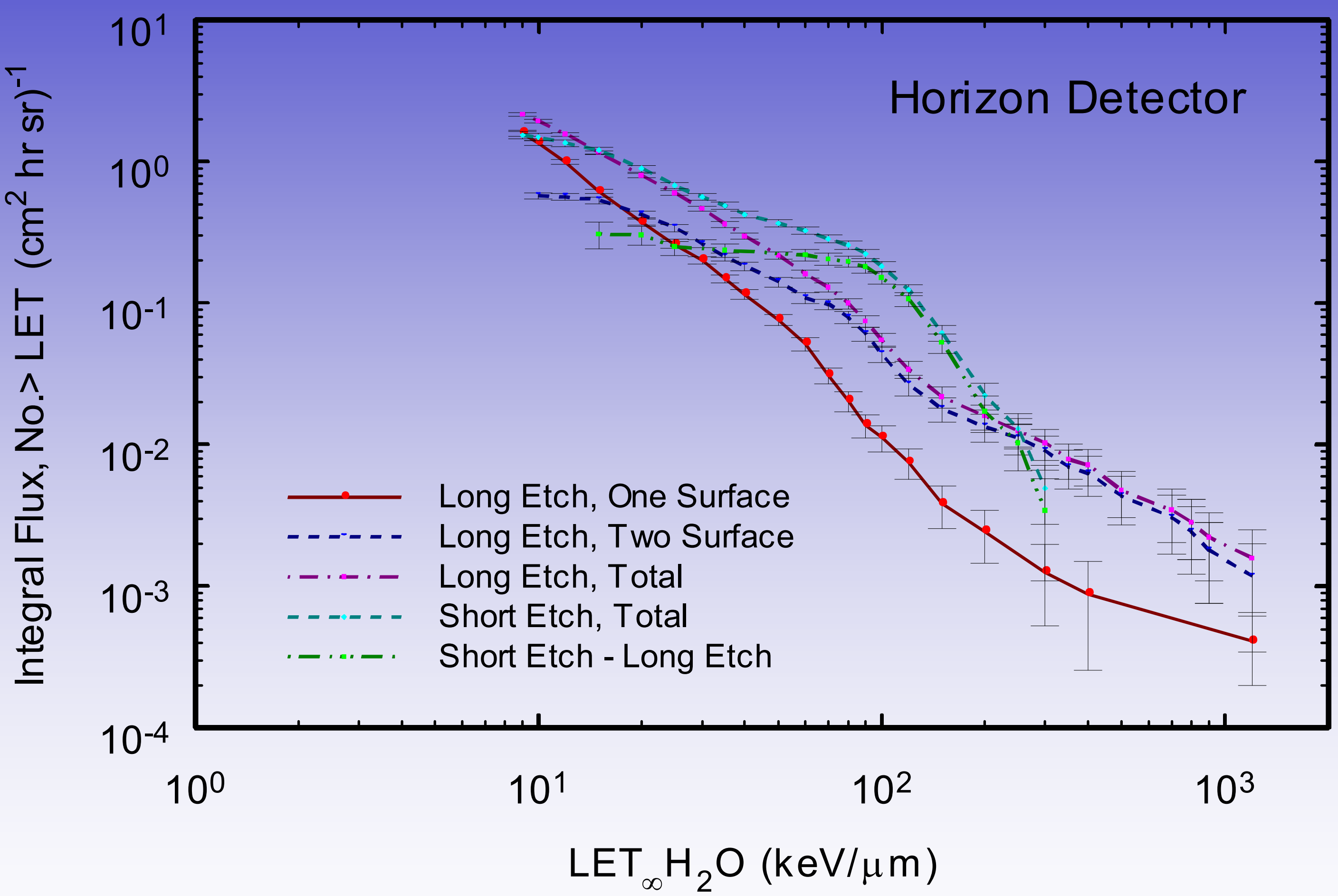
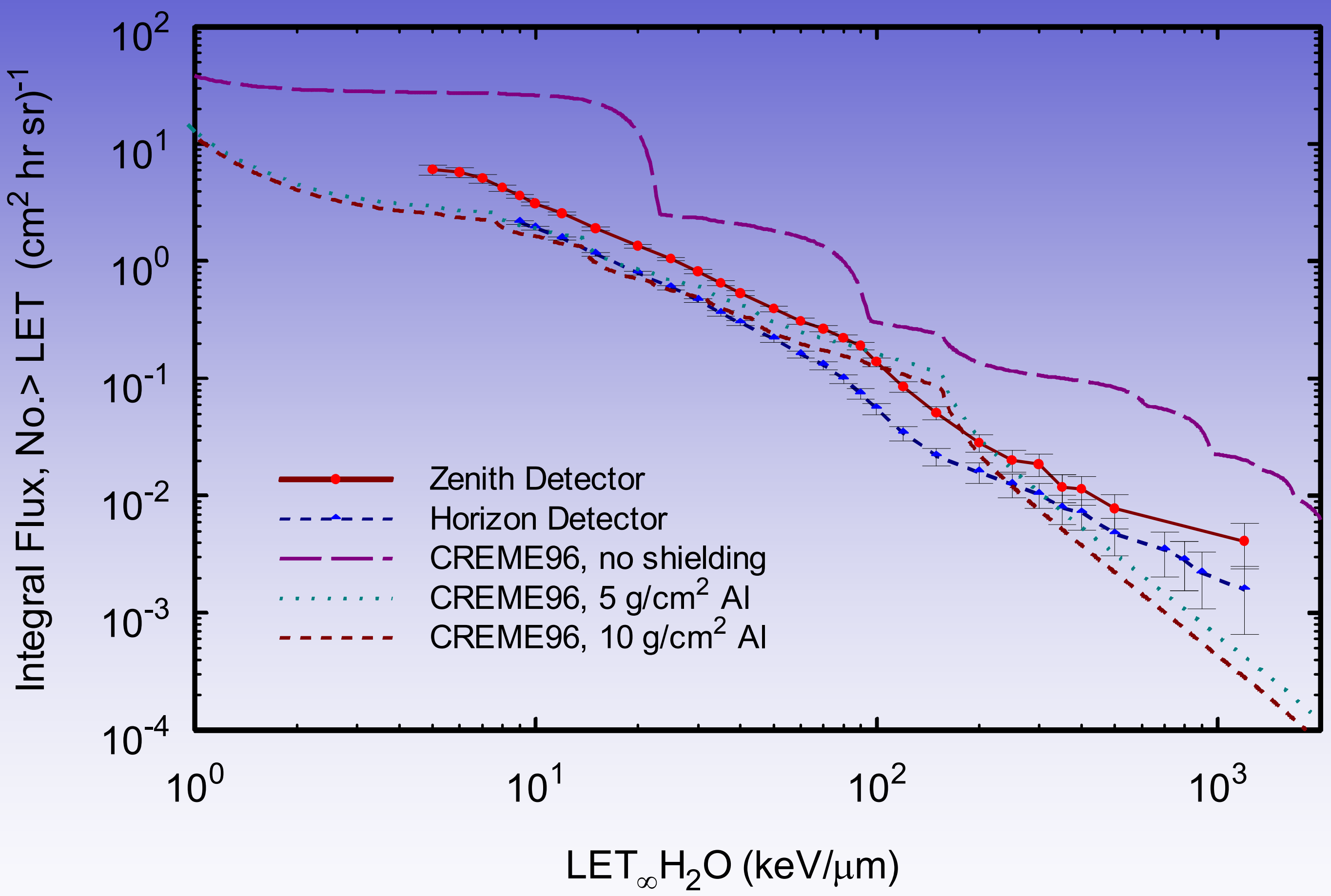
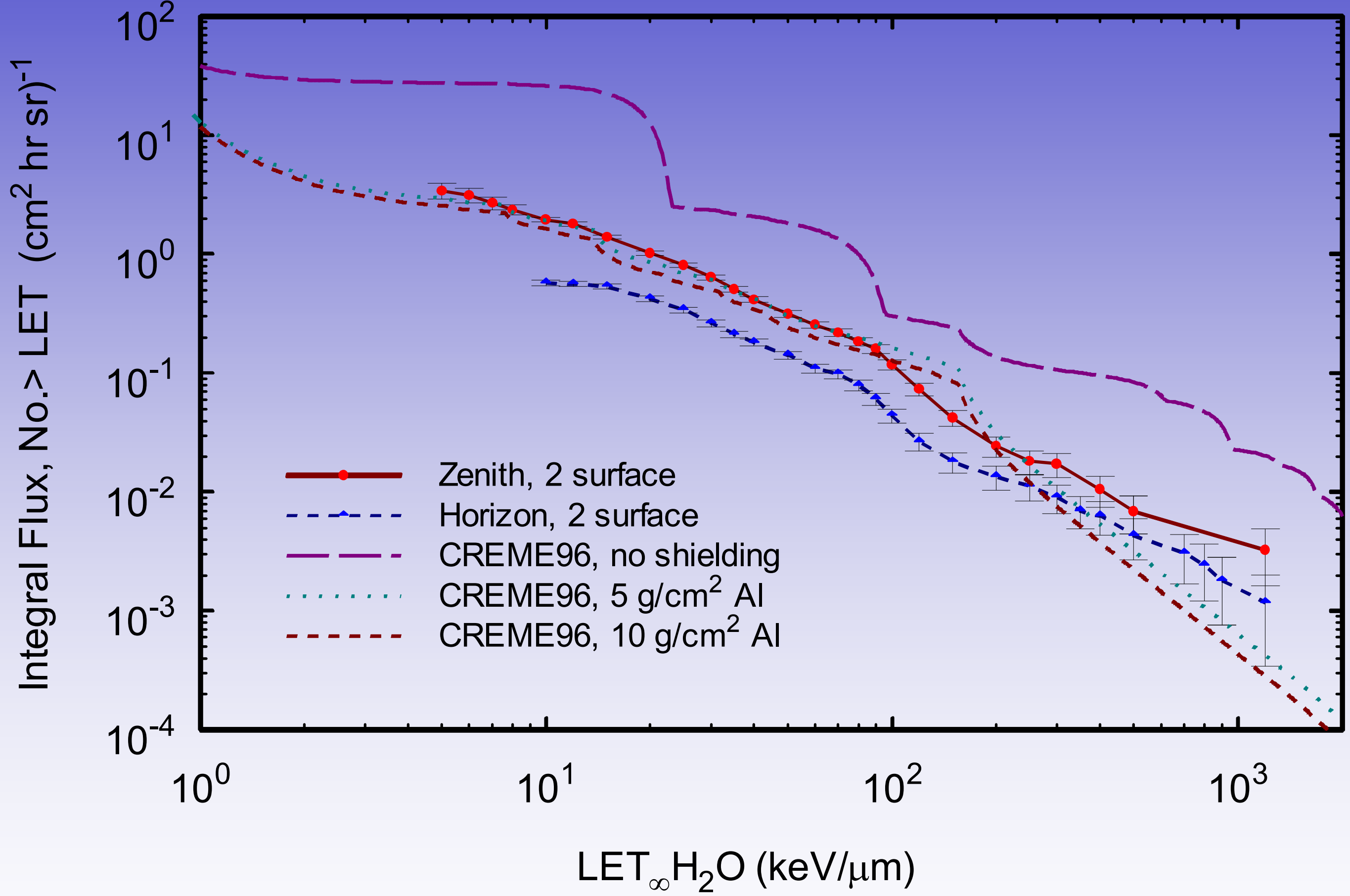
TRACER Integral LET Flux Spectra



TRACER Total Integral LET Flux Spectra
CREME96 Calculation



TRACER Primary GCR Integral LET Flux Spectra
CREME96 Calculation

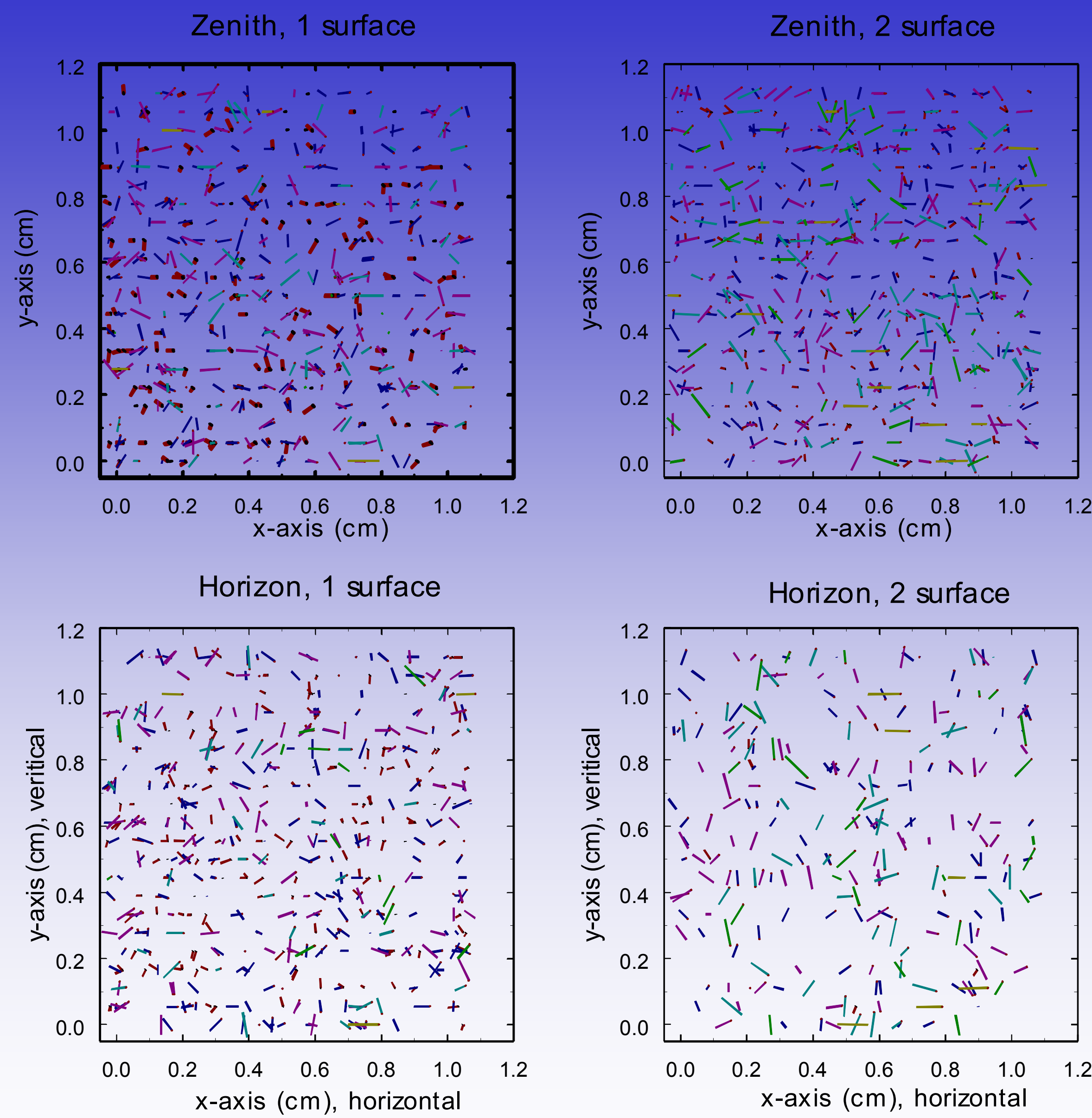


TRACER Total Dose & Dose Eq. Results from combined CR-39 PNTD & TLD

	Dose Rate <10 keV/μm (μGy/hr)	Dose Rate ≥10 keV/μm (μGy/hr)	Total Dose Rate (μGy/hr)	Dose Eq. Rate ≥10 keV/μm (μSv/hr)	Total Dose Eq. Rate (μSv/hr)	Average Quality Factor ≥10 keV/μm	Total Average Quality Factor
2003 TRACER							
Zenith	3.64 ± 0.15	1.83 ± 0.07	5.47 ± 0.31	22.34 ± 1.09	25.98 ± 1.68	12.21 ± 0.76	4.75 ± 0.36
Horizon	4.21 ± 0.18	1.05 ± 0.04	5.26 ± 0.31	11.47 ± 0.63	15.68 ± 1.09	10.92 ± 0.75	2.98 ± 0.24
2002 ATIC*							
Zenith	na	0.83 ± 0.04	na	7.31 ± 0.07	na	8.81 ± 0.05	na
Horizon	na	0.56 ± 0.04	na	3.39 ± 0.06	na	6.05 ± 0.07	na
1997	7.79 ± 0.25	0.43 ± 0.01	8.21 ± 0.25	4.54 ± 0.17	12.33 ± 0.29	10.56 ± 0.47	1.50 ± 0.04
1994 JACEE-13	6.64 ± 0.58	1.79 ± 0.15	8.44 ± 1.04	22.09 ± 1.36	28.74 ± 3.08	12.33 ± 1.30	3.41 ± 0.47
CREME96							
no shielding	2.38	14.31	16.69	126.44	128.81	8.84	7.72
5 g/cm^2 Al	2.20	1.46	3.66	20.91	23.11	14.32	6.31
10 g/cm^2 Al	2.11	1.18	3.29	16.61	18.71	14.08	5.69

*TLD was not included in the 2002 ATIC passive detector experiment.

TRACER: Vector Plot of Track Distributions in CR-39 PNTD



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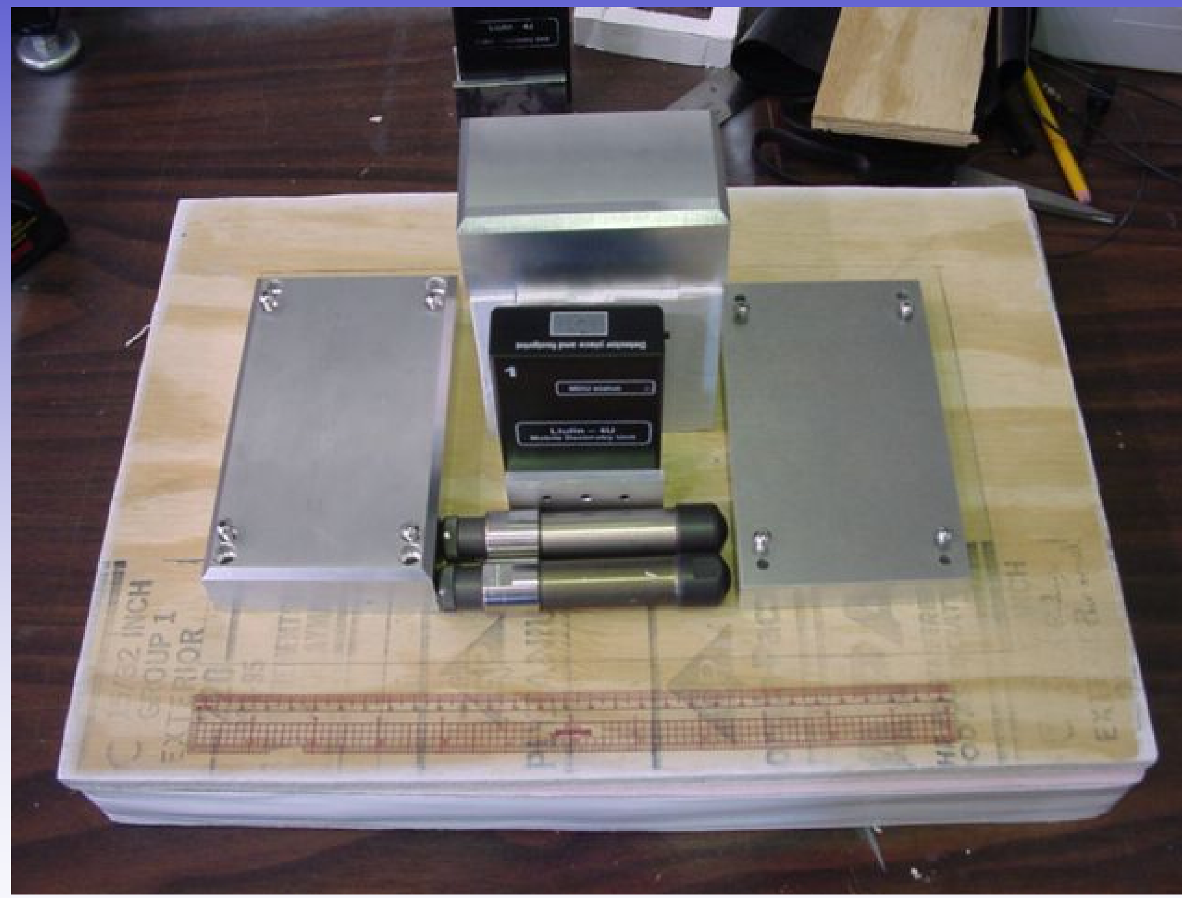
TRACER Piggyback Experiment: Conclusions

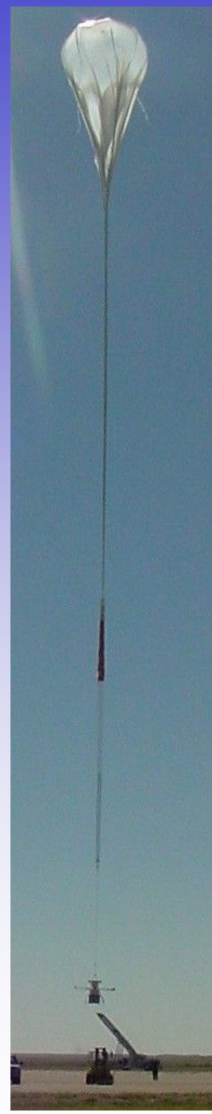
- Radiation environment at 37 km, polar latitudes is same as “Deep Space” environment only for particles with trajectories nearly perpendicular to the Earth’s surface...i.e. field is highly directional
- Significant secondary component
  - probably albedo neutrons and protons
  - secondary neutrons from the mass of the gondola could also be significant source
  - need to conduct “tether” experiment to find out.

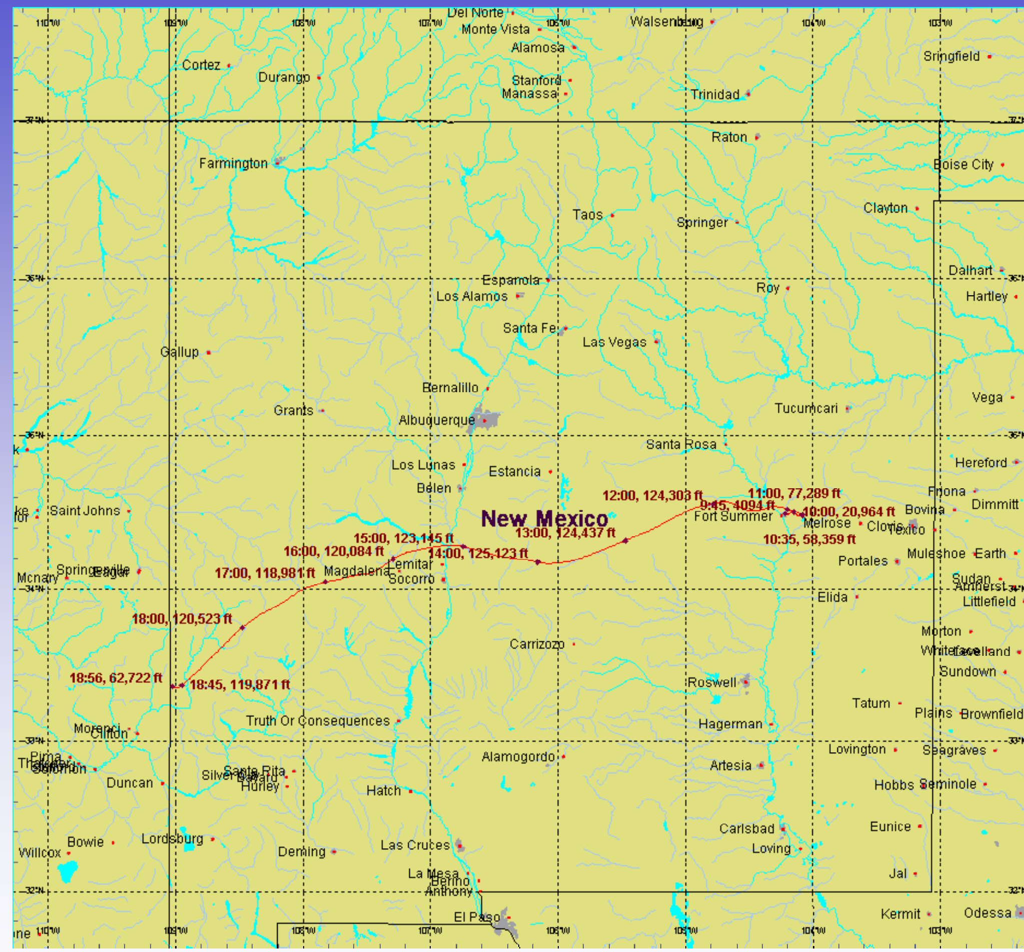
DSTB Certifcation Flight: Overview

- June 10, 2005 from Ft. Sumner, NM
- 9.5 hr duration
- ~37 km avg. alt.
- Detectors
  - 3 Liulin-4 MDUs
  - PorTL TLD Cells
  - Pille TLD Cells
  - OSL (no data)
  - TLD-600/TLD-700 (no data)
  - CR-39 PNTD not flown



DSTB Certification Flight





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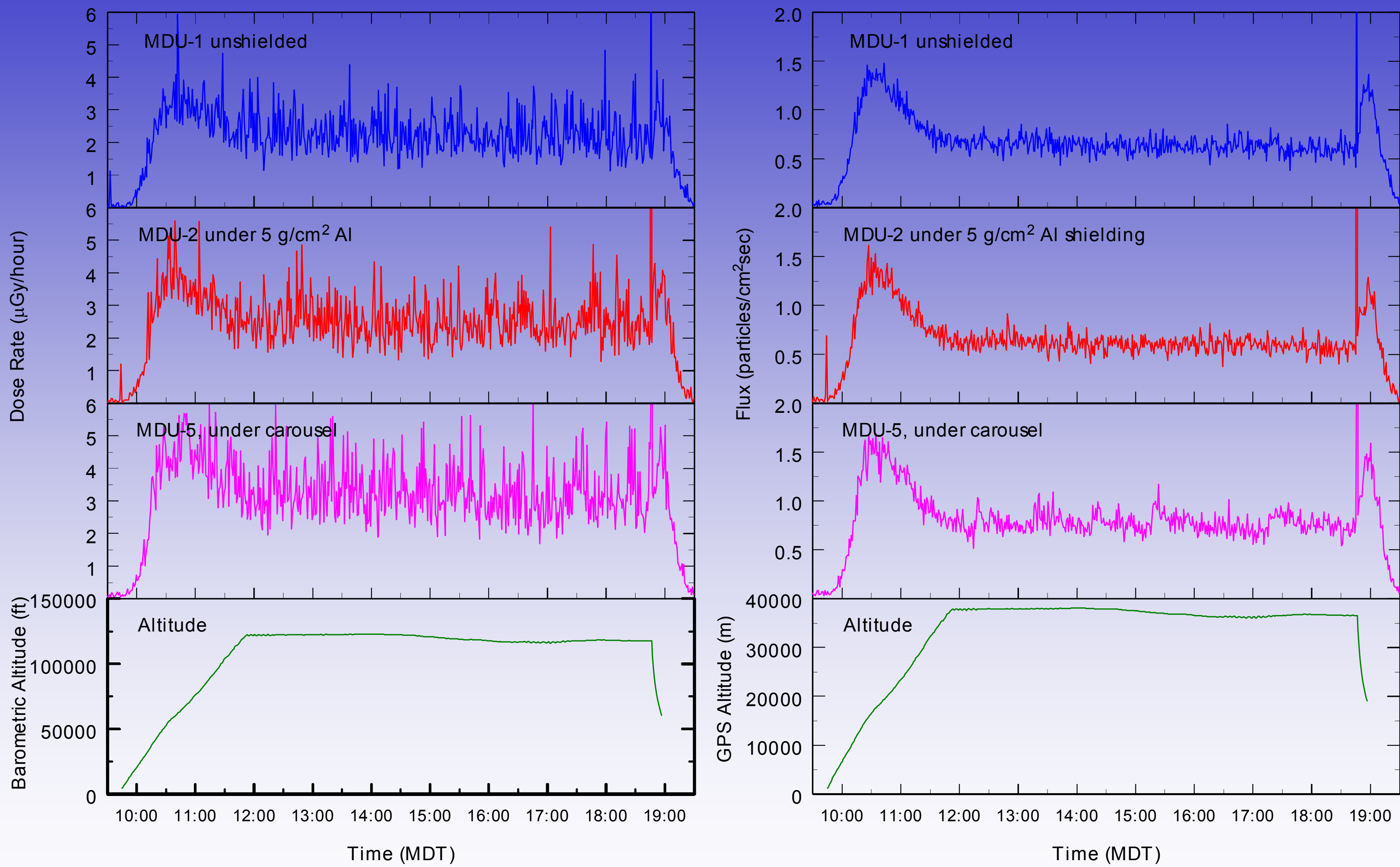
DSTB Certification Flight: Liulin-4 MDUs



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DSTB Certification Flight: Dose Results

Detector	Dose (μGy)	Average Dose Rate (μGy/hr)	Average Flux (particles/cm^{2}s)
Liulin-4U MDU #1, bare	20.6	2.28 ± 0.78	0.69 ± 0.22
Liulin-4U MDU #2, 5 g/cm^2 Al	23.0	2.55 ± 0.86	0.66 ± 0.22
Liulin-4J MDU #5, carousel	29.5	3.27 ± 1.07	0.82 ± 0.25
MDU #5, bare		3.00 ± 0.76	0.71 ± 0.07
MDU #5, 5 g/cm^2 Al		3.32 ± 0.80	0.79 ± 0.08
MDU #5, 15 g/cm^2 Al		3.64 ± 0.88	0.89 ± 0.09
MDU #5, 15 g/cm^2 PE		3.05 ± 0.76	0.73 ± 0.08

		Dose (μGy)	Average Dose Rate (μGy/hr)
PorTl	Bare	27.4 ± 1.7	2.88 ± 0.18
	5 g/cm^2 Al	29.3 ± 0.6	3.08 ± 0.06
	Control	11.7 ± 0.2	0.07 ± 0.00
Pille	Bare	22.8 ± 0.8	2.40 ± 0.08
	Control	11.4 ± 0.7	0.08 ± 0.00

DSTB Certification Flight: Conclusions

- Portable TLD systems like Pille and PorTL permit measurement of lower doses than TLD annealed and analyzed in the laboratory
- Effect of shielding on dose is highly complex:
  - competing effects of ionization and fragmentation
  - depends not only on shielding depth, but on shielding composition
- One can obtain useful data from an extremely short, balloon experiment at easily accessible altitudes... "Near Space"

Deep Space ICCHIBAN: Objectives

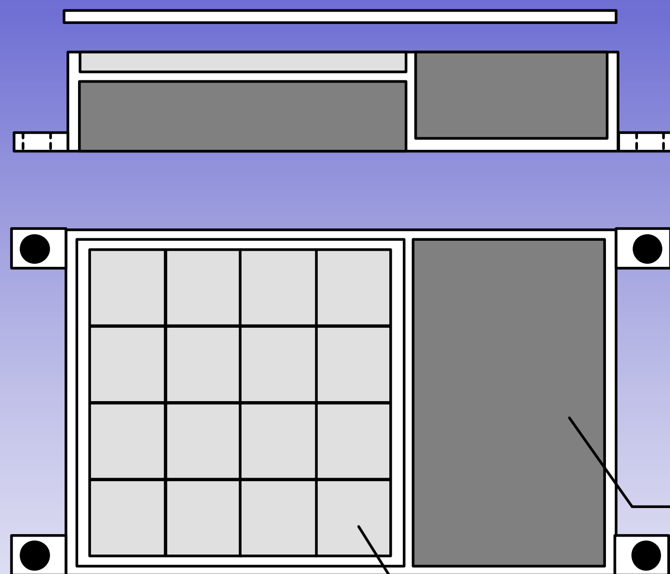
1. Intercompare the response of space radiation detectors used for crew and area dosimetry aboard piloted spacecraft in the deep space galactic cosmic ray (GCR) environment aboard a circumpolar DSTB balloon flight.

2. Provide *in situ* measurements for use in assessing the ability of space radiation transport models and space radiation environment models, including models of geomagnetic cut-off rigidity.

3. Compare and reconcile dosimetric measurements from the Deep Space ICCHIBAN experiment with results from accelerator-based ICCHIBAN experiments in order to assess the efficacy and improve the design of the space radiation simulations conducted as part of the accelerator-based ICCHIBAN experiments.

Deep Space ICCHIBAN: Passive Detectors

- TLD
- OSLD
- CR-39 PNTD
- Bubble Detector
- Other



Deep Space ICCHIBAN: Active Detectors

- Tissue Equivalent Proportional Counter (DSTB standard radiation instrument suite)
- Liulin-4 MDU (DSTB standard radiation instrument suite)
- DOSTEL (U. of Kiel, old unit flown on Shuttle)
- HETn High Energy Telescope (Southwest Research Institute)

Deep Space ICCHIBAN: Environmental Sensor Package

Sensor/Component	Part No.	Mfg.
3-axis Magnetometer	CXM113	Crossbow Technologies
3-axis accelerometer	CXL10HF3	Crossbow Technologies
PRV-0858X-01 Dual Pressure Sensor/Temperature Sensor	PRV-0858X-01	Parvus
Orbitrak 8R PC/104 8 channel GPW w/Trimble Lassen LP Receiver	PRV-5033X-01	Parvus
Athena 400 MhZ 128 Mb DAQ	ATH400-128	Diamond Systems
Jupiter 50W power supply	JUP-MM-SIO	Diamond Systems

Deep Space ICCHIBAN: Conclusions

- Same format as accelerator-based ICCHIBAN experiments.
- Open to all investigators who have previously participated in the ICCHIBAN project, as well as other laboratories participating in dosimetry in space.
- First flight scheduled for June 2006 from Sweden to Alaska.
- Second flight tentatively scheduled for Dec. 2007 in Antarctica.
- Contact me (eric@erilresearch.com) if you have not previously participated in the ICCHIBAN project and want to participate in Deep Space ICCHIBAN

Deep Space ICCHIBAN

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Eddie Semones, *NASA JSC,*
Arik Posner, Donald Hassler, *SwRI,*
Brad Gersey, *PV A&M U*,
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