








## The Optical Fiber Array Bundle Assemblies for the NASA Lunar Reconnaissance Orbiter

Melanie N. Ott, Rob Switzer, William Joe Thomas, Richard Chuska, Frank LaRocca, Shawn Maemurphy






**CODE 562**  
**PHOTONICS**  
Group @ GSFC

Melanie N. Ott  
NASA Goddard Space Flight Center  
Applied Engineering & Technology Directorate,  
Electrical Engineering Division,

301-286-0127, [melanie.n.ott@nasa.gov](mailto:melanie.n.ott@nasa.gov)  
301-286-8813, [william.j.thomas@nasa.gov](mailto:william.j.thomas@nasa.gov)  
[misspiggy.gsfc.nasa.gov/photronics](http://misspiggy.gsfc.nasa.gov/photronics)  
[NEPP.nasa.gov](http://NEPP.nasa.gov)  
[Photronics.gsfc.nasa.gov](http://Photronics.gsfc.nasa.gov)











## Outline


- Introductions
- LRO (LOLA & LR) Introduction & Requirements
- LRO Solutions
- Design to Integration
  - Lessons Learned
  - Integration
- Conclusions

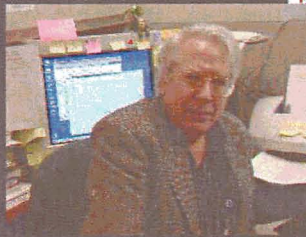
## Mentorship Mapping




**Arnold Sommerfeld**  
Russia, 1868 - 1951  
German Physicist  
Quantum Theory



**Karl F. Herzfeld**  
Vienna, 1892 - 1978  
John's Hopkins University Professor, 1926  
Catholic University Professor, 1936





**Henning Leidecker, USA,**  
Catholic University Professor, 1967  
NASA Goddard Space Flight Center, 1985  
NASA GSFC Chief Parts Engineer, Currently



Melanie N. Ott


**Students/Nobel Laureates**

- 1) Werner Karl Heisenberg, 1901-1976, Quantum Mechanics
- 2) Wolfgang Ernst Pauli, 1900 - 1958, Theoretical Physics, uncertainty principal
- 3) Peter Joseph William Debye, 1884 - 1966 Physics, Physical Chemistry
- 4) Hans Albrecht Bethe 1906 - 2005, Physics
- 5) Herbert Kroemer, 1928 -
- 6) Linus Carl Pauling, 1901 - 1994

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Group @ GSFC

Melanie N. Ott, Group Leader, 1994-2008  
Applied Engineering Technologies Directorate, Electrical Engineering Division



Rob Switzer, Frank LaRocca, W. Joe Thomes, Melanie Ott, Richard Chuska



*A Decade of Service from the Photonics Group for Photonics & Optical Fiber Components and Assemblies Code 562, Electrical Engineering Division of AETD, NASA GSFC*

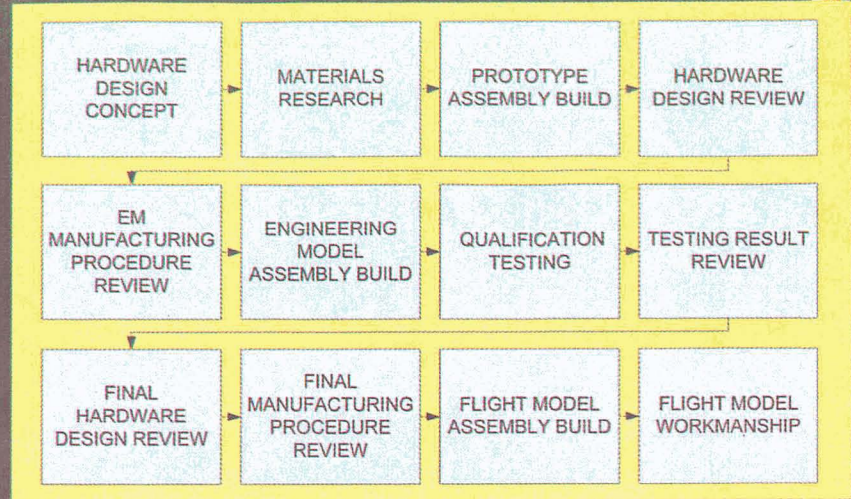


Project	Dates	Design	Qualification Performance over Harsh Environment	Manufacturing	Integration	Failure Analysis
ICESAT, GLAS,	1997 - 2005	X	X	GSE		Prototype
ISS	1998 - 2008					Vendor/ Flight
ISS - HDTV	2003	X	X	FLIGHT		
Fiber Optic Data Bus	1997 -2000	X	X			
Messenger - MLA,	2001 - 2004	X	X	FLIGHT	X	
Sandia National Labs (DOE)	1998 -2008			FLIGHT		Vendor/ Flight
ISS-Express Logistics Career	2006 -2009	X	X	FLIGHT	X	
Air Force Research Lab	2003, 2008		X			
Shuttle Return To Flight	2004 -2005			FLIGHT		
Lunar Orbiter Laser Altimeter	2003 -2008	X	X	FLIGHT	X	Prototype
Mars Science Lab ChemCam	2005 -2008	X	X	FLIGHT	X	Vendor
Laser Ranging, LRO	2005 - 2008	X	X	FLIGHT	X	Prototype
Fiber Laser IIP/IRAD	2003 - 2006	X	X	QUAL		
ESA/NASA SpaceFibre	2008 (TBD)		X	QUAL		

Upcoming is the 3<sup>rd</sup> Event in coordination with ESA/CNES/JAXA/NASA on optics for space Publications from work noted above can be found @ [misspiggy.gsfc.nasa.gov/photonics](http://misspiggy.gsfc.nasa.gov/photonics)



*How Does the Photonics Group Go from Ideas to Flight?*



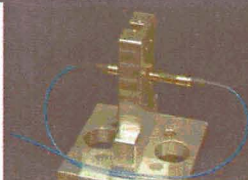
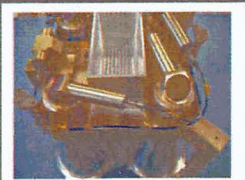
BASIC PRODUCT LIFE CYCLE



*Mercury Laser Altimeter 2001-2003*

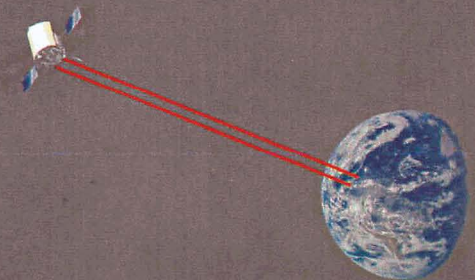


Receiver telescopes focused into optical fiber assemblies that route to different detectors. The MLA is aboard MESSENGER currently sending data from Mercury!



*The 24 Million Km Link with the Mercury Laser Altimeter*

- Jay Steigelman
- Dave Skillman
- Barry Coyle
- John F. Cavanaugh
- Jan F. McGarry
- Gregory A. Neumann
- Xiaoli Sun
- Thomas W. Zagwodzki
- Dave Smith
- Maria Zuber



MOLA Science Team Meeting  
Bishop's Lodge, Santa Fe, NM  
August 24-25, 2005



REPORT

### Laser Altimeter Observations from MESSENGER's First Mercury Flyby

Maria T. Zuber,<sup>1\*</sup> Daniel E. Smith,<sup>2</sup> Scott C. Solomon,<sup>3</sup> Bruce J. Phillips,<sup>4</sup> Stanton J. Peck,<sup>5</sup> James W. Head III,<sup>6</sup> Gwenaël R. Mehall IV,<sup>7</sup> Rachel E. Millard,<sup>8</sup> Jeffrey Blum,<sup>9</sup> Gregory A. Neumann,<sup>10</sup> Frank G. Tomblin,<sup>11</sup> Xueli Sun,<sup>12</sup> Orlan Karawane Jia,<sup>13</sup> John K. Harmon<sup>14</sup>

A 3200-km orbit was kept precise by the Mercury laser altimeter on the MESSENGER spacecraft's eight-year mission. The altimeter's range and accuracy were characterized by a 5.2-km range and 30-cm accuracy. The altimeter's range and accuracy were characterized by a 5.2-km range and 30-cm accuracy. The altimeter's range and accuracy were characterized by a 5.2-km range and 30-cm accuracy.

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SPECIAL SECTION



Altitude by the variability of the ranging process. The wide accuracy of LOLA is limited by uncertainties in the geometry associated with errors in the spacecraft's position and velocity. The ranging process is a function of the spacecraft's position and velocity. The ranging process is a function of the spacecraft's position and velocity.

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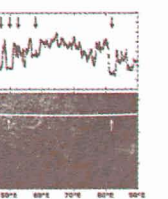


Fig. 1. The altimeter's range and accuracy were characterized by a 5.2-km range and 30-cm accuracy. The altimeter's range and accuracy were characterized by a 5.2-km range and 30-cm accuracy.

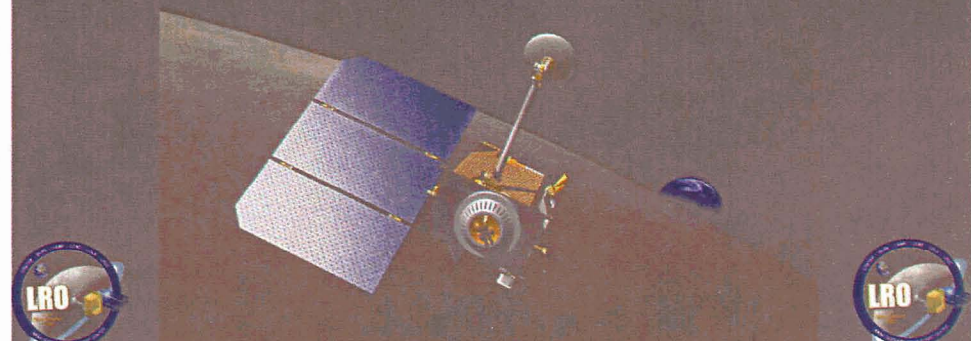


## Lunar Reconnaissance Orbiter NASA Goddard Space Flight Center

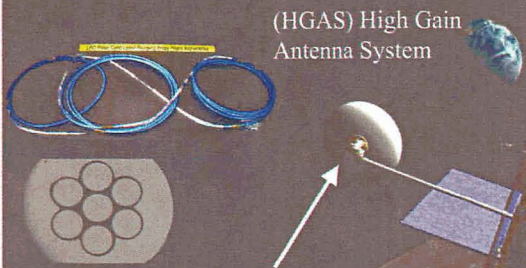


The Concept Challenges:

- 1) LOLA: For the Lunar Orbiter Laser Altimeter (LOLA) Reduce size and weight of previous MLA hardware design from four telescopes into one telescope with fiber based array in a precise compressed pattern.
- 2) LASER RANGING: For the Laser Ranging Application from Earth, carry the signal from the telescope located on the High Gain Antenna system (HGAS) - Traverse three subsystems, to given detector on LOLA, with high reliability and compactness - Several interconnections would have to be accommodated for integration subsystem ease.



## The Lunar Reconnaissance Orbiter; The Laser Ranging Mission and the Lunar Orbiter Laser Altimeter



Receiver Telescope mounted on antenna and a fiber array to route signal from HGAS to LOLA

(HGAS) High Gain Antenna System



LRO Fiber Optic LOLA Flight Assembly



Lunar Orbiter Laser Altimeter (LOLA)



Presentation Slide Courtesy of Dr. Dave Smith, NASA GSFC, 19th International Laser Ranging Workshop, Canberra Australia, Oct 16-20 2006



### Ranging Products Overview

1. Distance range from Earth to LRO spacecraft as a function of time

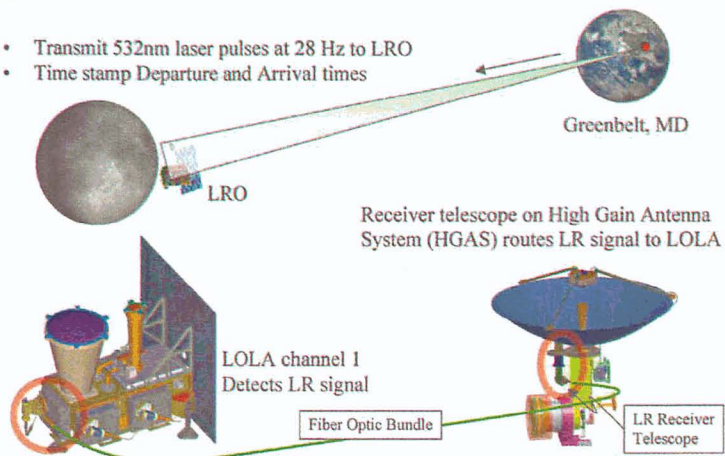
2. Accuracy of ranging with different ranging techniques

3. Accuracy of ranging with different ranging techniques



## LR Operations Overview

- Transmit 532nm laser pulses at 28 Hz to LRO
- Time stamp Departure and Arrival times

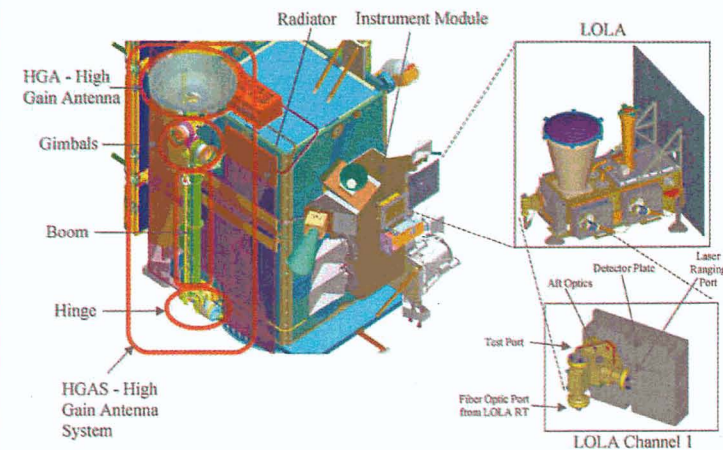


19th International Laser Ranging Workshop

R. Zellar/Sep2006  
Canberra, Australia, Oct 16-20, 2006



## LR Flight System Components

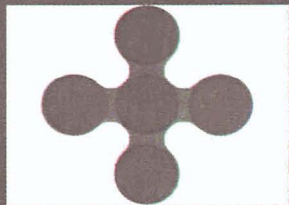


19th International Laser Ranging Workshop

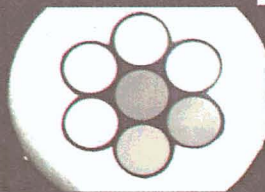
R. Zellar/Sep2006  
Canberra, Australia, Oct 16-20, 2006



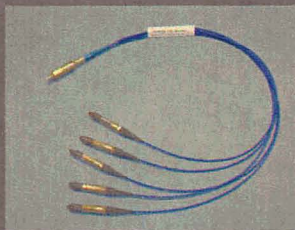
## The Solution; NASA GSFC Fiber Optic Array Assemblies for the Lunar Reconnaissance Orbiter



Array Side End Face Picture at 200X magnification



End Face Picture of both assembly ends at 200X magnification



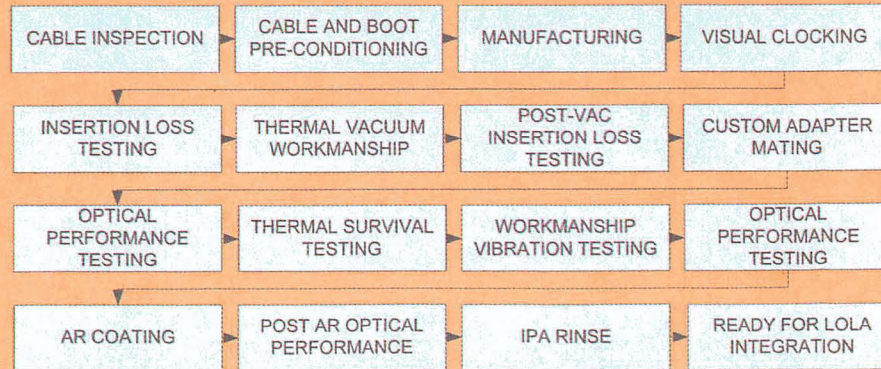
**Lunar Orbiter Laser Altimeter (LOLA) Assemblies**  
Description: 5 Fiber Array in AVIM PM on Side A, Fan out to 5 individual AVIM connectors Side B  
Wavelength: 1064 nm  
Quantity ~ 3 Assemblies Max ~ 0.5 m long



**Laser Ranging (LR) for LRO Assemblies**  
Description: 7 Fiber Array on both Sides in AVIM PM Connector  
Wavelength: 532 nm  
Quantity ~ 9 Assemblies ~ 1 to 4 m long each



## LOLA Assembly Flight Flow





## LOLA Documentation for Configuration Management



Document Name	CM Documentation Number
LOLA Fiber Optic Flight Assemblies	LOLA-OPTICS-WOA-0338
Thermal pre-conditioning on Flexlite 200/220 $\mu\text{m}$ fibers for flight application	562-PHOT-WI-LOLA-TP-001
Preconditioning Procedure for AVIM Hytrel Boots for LOLA fiber optic assemblies	562-PHOT-WI-LOLA-VAC-001
Procedure for Diamond AVIMS PM Kit Pre-Assemble Inspection	LOLA-PROC-0104
Assembly and Termination Procedure for the Lunar Orbiter Laser Altimeter Five Fiber Custom PM Diamond® AVIM Array Connector for the Lunar Reconnaissance Orbiter	LOLA-PROC-0098
Insertion Loss Measurement Procedure For LOLA 5-Fiber Assembly (Open Beam Configuration)	562-PHOT-WI-LOLA-IL-001
Integration of the LOLA Fiber Optic Bundle to the Telescope Adapter	LOLA-PROC-0140
LOLA Fiber Bundle Inspection and Test Procedure	LOLA-PROC-0099



## Laser Ranging on Lunar Recon Orbiter 2006-2008



Document Name	CM Documentation Number
Thermal Pre-conditioning on Flexlite 200/220 $\mu\text{m}$ fibers for flight application	LOLA-PROC-0137
Preconditioning Procedure for AVIM Hytrel Boots for LOLA fiber optic assemblies	LOLA-PROC-0138
Diamond AVIM PM Kit Pre-Assembly Inspection	LOLA-PROC-0104
Ferrule Polishing & Ferrule/Adapter Matching Procedure	LOLA-PROC-0139
Assembly and Termination Procedure for the Laser Ranging Seven Fiber Custom PM Diamond AVIM Array Connector for the Lunar Reconnaissance Orbiter	LOLA-PROC-0112
Compression Test Procedure for Fiber Optic Connector	LOLA-PROC-0141
Active Optical Power Optimization Procedure for The Laser Ranging Optical Fiber Array Assemblies	LOLA-PROC-0110
Laser Ranging Fiber-Optic Bundle Optical Test Procedure	LOLA-PROC-0107
Insertion Loss Measurement Procedure for The Laser Ranging Optical Fiber Array Bundle Assemblies	LOLA-PROC-0111
Mating of Two LR 7-Fiber Optical Fibers Using Cleanable Adapter	LOLA-PROC-0142
Cutting Back The Kynar Strain Relief For Integration	LOLA-PROC-0143
Fiber Optic Bundle Inspection and Insertion Loss Measurement	LOLA-PROC-0148



## Qualification Testing on Engineering Models



- Array Compression Testing.
- Thermal Vacuum Workmanship Testing, 8 cycles
- Vibration Launch Conditions.
- Thermal Cycling with Active Monitoring (accelerated life)
- Cold Gimbal Motion Testing, 20,000 Mechanical Cycles with Active Monitoring
- Gimbal Life Testing, 20,000 Motion Cycles.
- Gamma Radiation Testing with Active Monitoring.

## Qualification Testing on Flight Models

Array Compression Testing.  
Thermal Vacuum Workmanship Testing, 8 cycles.  
Vibration Launch Conditions, Instrument Levels.



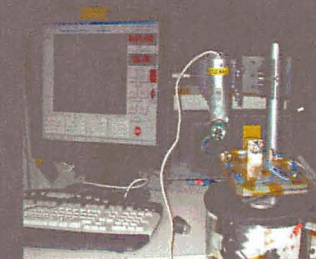
## Qualification of Engineering Models



### Random Vibration Testing for EMs

Launch vehicle vibration levels for small components (GEVS) (based on box level established for EO-1) on the "high" side.

Frequency (Hz)	Protoflight Level
20	0.052 $\text{g}^2/\text{Hz}$
20-50	+6 dB/octave
50-800	0.32 $\text{g}^2/\text{Hz}$
800-2000	-6 dB/octave
2000	0.052 $\text{g}^2/\text{Hz}$
Overall	20.0 grms

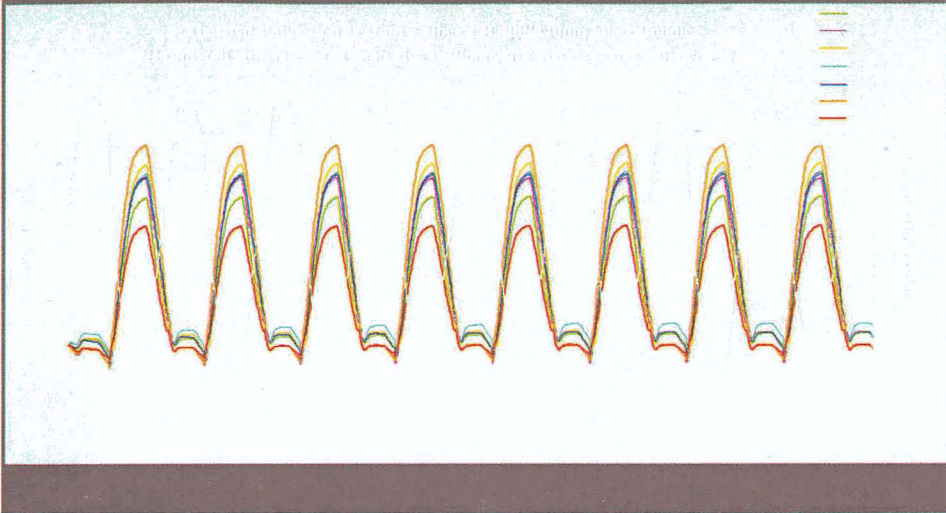


3 minutes per axis, tested in x, y and z

Both LR and LOLA Assemblies



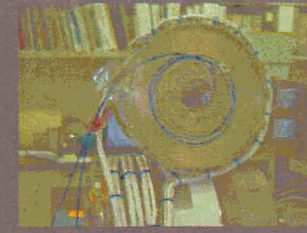
# Thermal Qualification Data on Laser Ranging Optical Assemblies



# LRO Laser Ranging Cold Gimbal Motion Life Testing



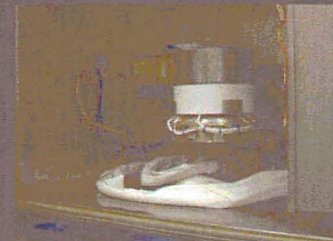
Gimbals



Window inside gimbal;  
Flexlite cable inside



Window inside gimbal;  
Bundle cable inside.



Gimbals w/ single flexlite in thermal chamber

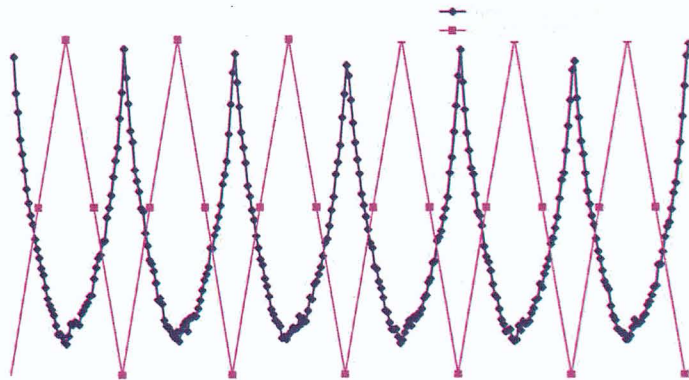


Gimbals w/ bundle in thermal chamber

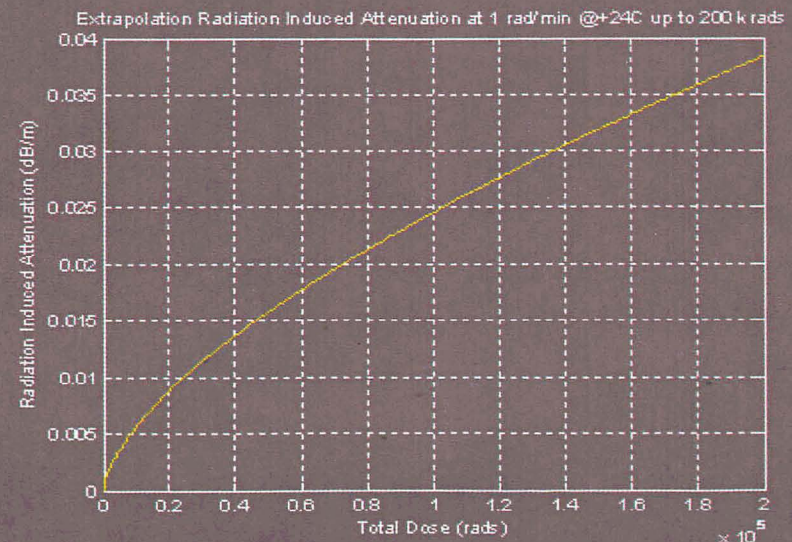


# LRO Laser Ranging Bundle Cold Gimbal Motion Testing Results

End of Test, relative IL ~ 0.50 dB, @ 850 nm, -20°C, 400/440 FV flexlite in Bundle



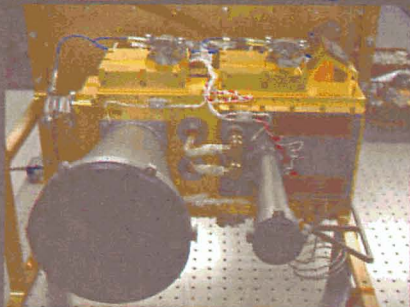
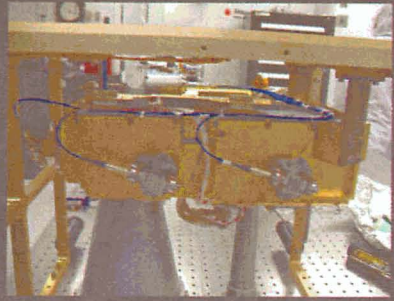
# Radiation Testing and Modeling



$$A(D) = 1.4516 * 10^{-4} \phi^{1-0.6412} D^{0.6412}$$



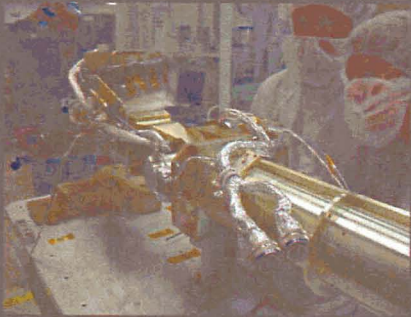
# LOLA Integration, October 2007



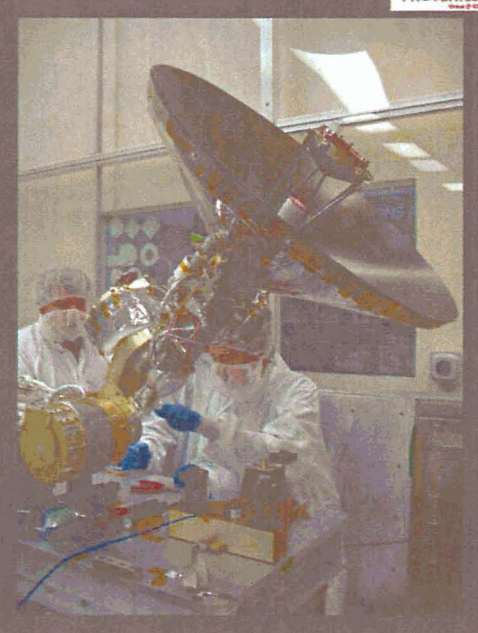
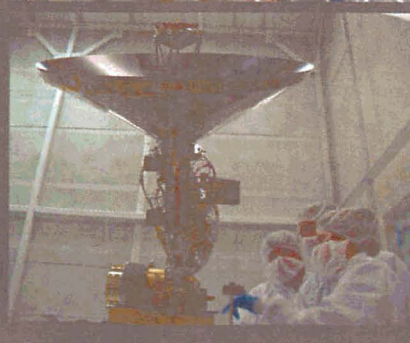
# Gimbal Integration, December 2007



# LRO Integration HGAS, 02-2008

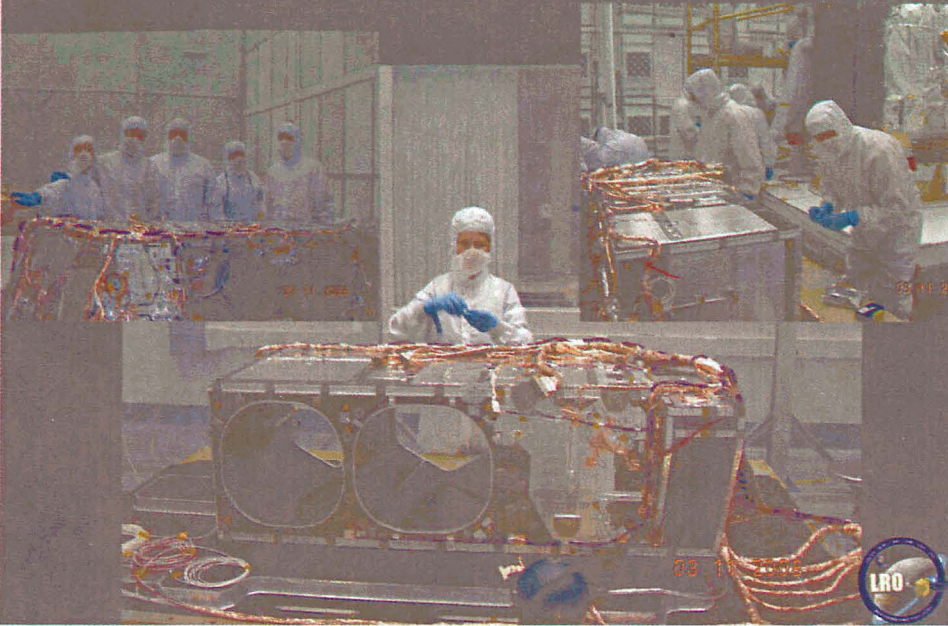


# Lunar Recon. Orbiter - LRT & HGAS, 02-2008

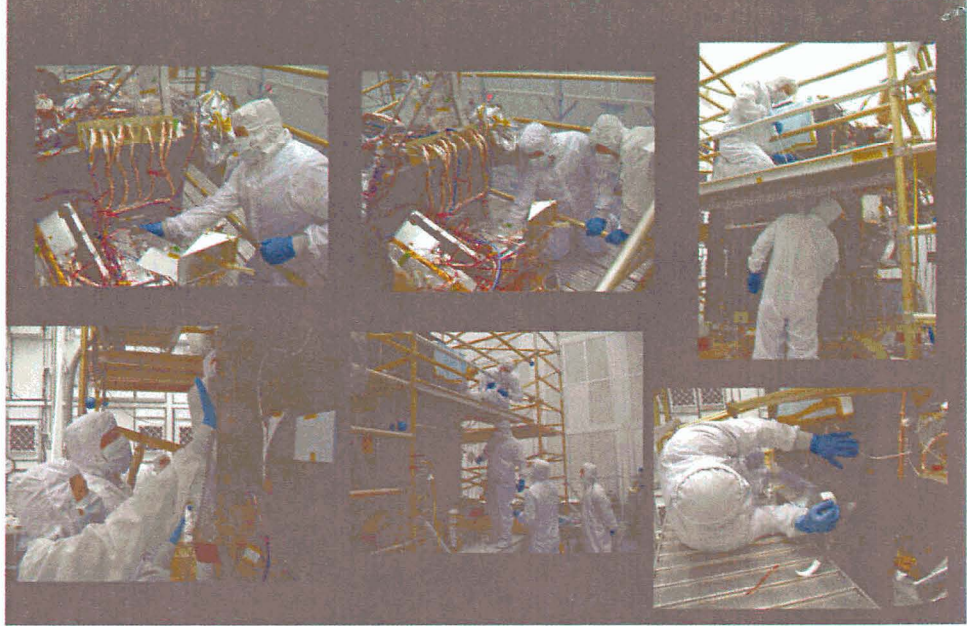




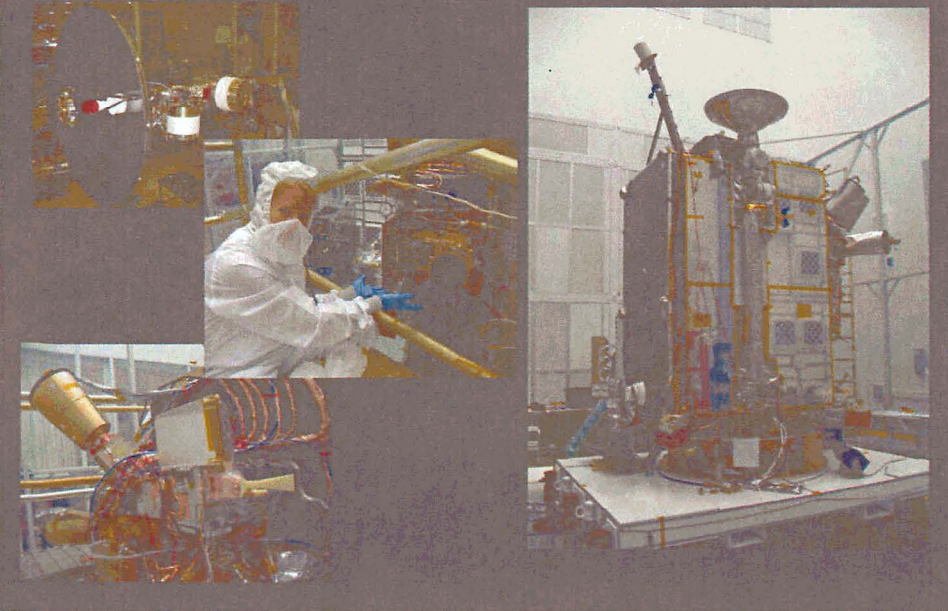
# LRO Integration @ IM Deck, 03-2008



# LR Segment 3 Flight Routing, April 2008



# Additional Pictures of LRO, June 2008 Integration Complete







## 2008 New Capability

### 19 Fiber Arrays with Linear to Bundle Mapping



## Conclusion

Do Not Go Where the Path May Lead,  
Go Instead Where There Is No Path  
and Leave a Trail....

- Ralph Waldo Emerson

*Thank you  
for the invitation!*

For more information please visit the website:

[misspiggy.gsfc.nasa.gov/photronics](http://misspiggy.gsfc.nasa.gov/photronics)  
[NEPP.nasa.gov](http://NEPP.nasa.gov)