



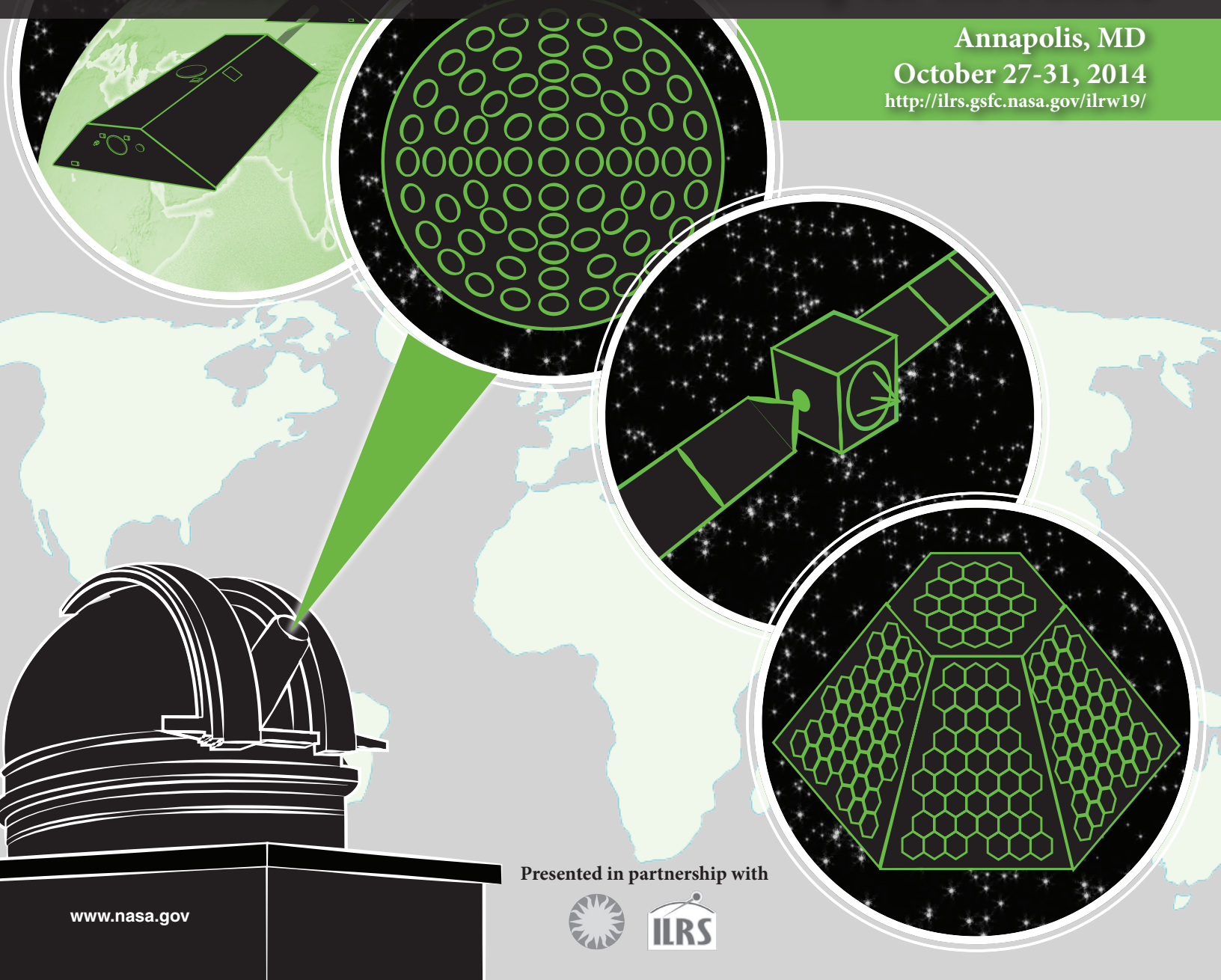
# 19th International Workshop on Laser Ranging

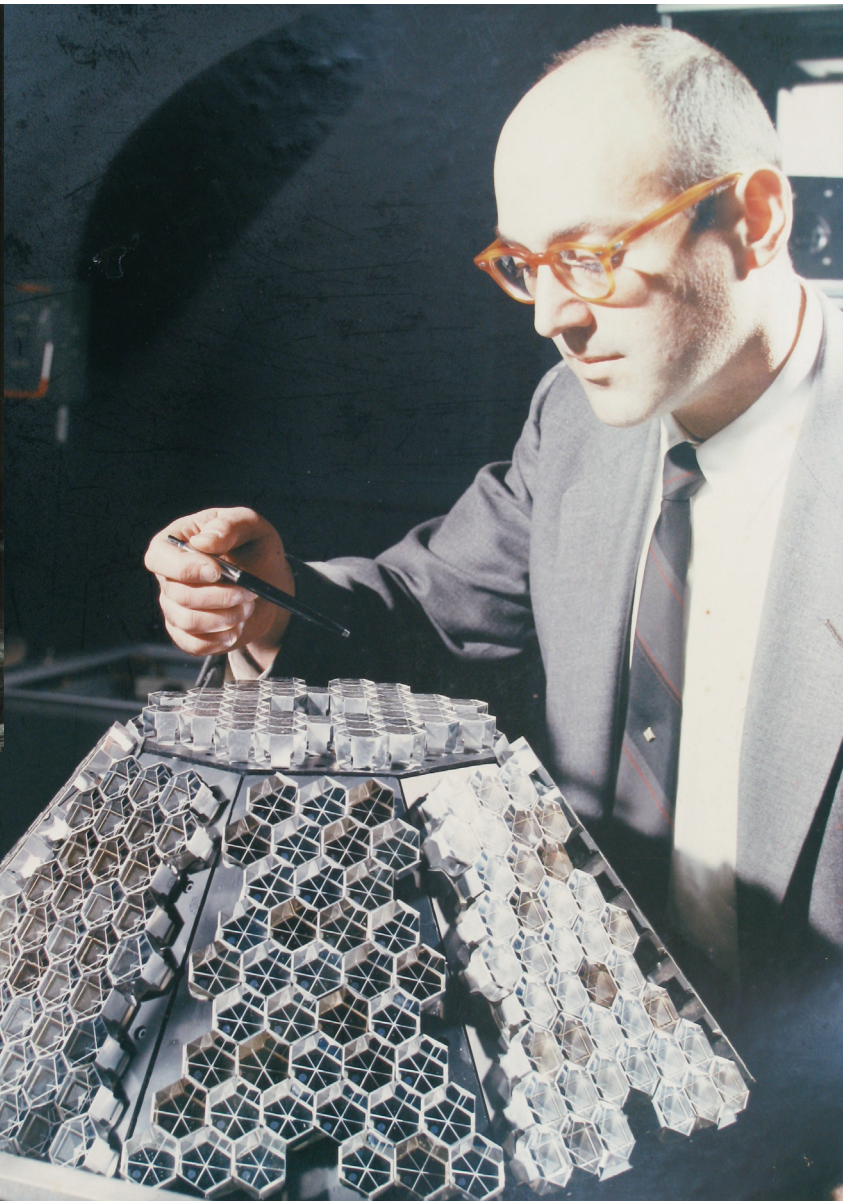
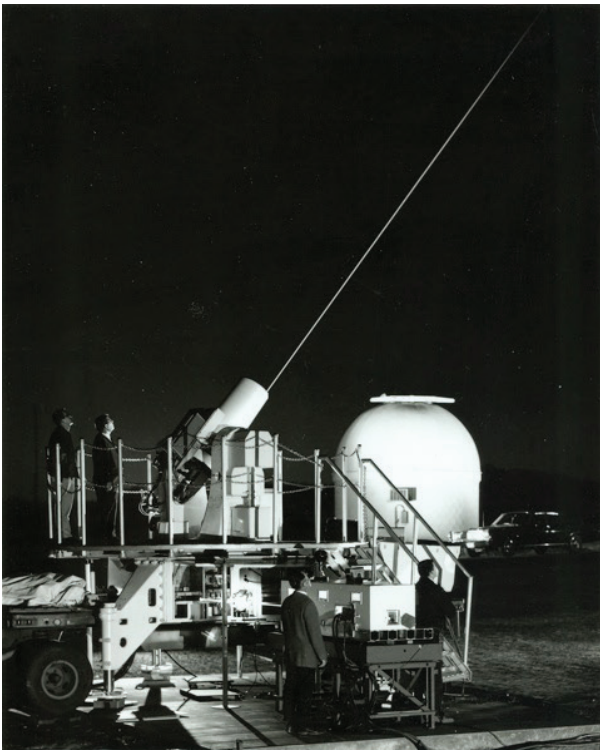
## Celebrating 50 Years of SLR Remembering the Past and Planning for the Future

Annapolis, MD

October 27-31, 2014

<http://ilrs.gsfc.nasa.gov/ilrw19/>





Images: Clockwise from top left

Walter Carrion, Louis Caudill, Peter Minott, and Donald Premo.

Henry Plotkin at the JHU Applied Physics Laboratories in 1964 with the Beacon Explorer A retroreflector array before integration onto the spacecraft.

NASA astronomer, Sol Howard Genatt, and physics co-op student, John Degnan, point and focus the Mobile Optical Telescope System (MOTS) camera along the Beacon Explorer satellite track in order to record the laser returns against the star field on photographic film.

NASA astronomer Sol Howard Genatt and physics co-op student, John Degnan.



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# Introduction

Dear Workshop Attendee,

We are pleased to welcome you to the 19th International Workshop on Laser Ranging, held in historic downtown Annapolis, Maryland. This workshop is sponsored by the National Aeronautics and Space Administration (NASA), along with the Smithsonian Astrophysical Observatory (SAO) and the International Laser Ranging Service (ILRS).

NASA Goddard Space Flight Center (GSFC) is proud to host this event at the birthplace of SLR: October 31, 2014 marks the 50th anniversary of the first successful SLR measurement, which was conducted at what is now the Goddard Geophysical and Astronomical Observatory (GGAO). The theme for this workshop, "Celebrating 50 Years of SLR: Remembering the Past and Planning for the Future" will allow us to look back on our many accomplishments and present plans for future advances in SLR technology and science. Wednesday will be spent at NASA GSFC, where you will tour Goddard facilities as well as NASA's next generation systems at GGAO. The day will conclude with a special GSFC colloquium given by Dr. John Degnan, who participated in that first SLR experiment in 1964.

We have several social events planned for the week: an Icebreaker Reception on Monday evening, a Poster Viewing reception on Wednesday evening (both held at the Workshop venue) and the Workshop Banquet on Thursday evening at a nearby restaurant. Our keynote speaker for the banquet is Dr. Piers Sellers, Deputy Director of the Sciences and Exploration Directorate and NASA astronaut. Breakfast and morning and afternoon breaks will be provided Monday, Tuesday, Thursday, and Friday; lunch will also be provided Monday through Thursday.

The local organizing committee is looking forward to welcoming you to an exciting, informative, week here in Annapolis and wishes you a productive week celebrating our many accomplishments of the past 50 years.

## Local Organizing Committee:

*Carey Noll/NASA GSFC (chair)*  
*John Degnan/ Sigma Space Corporation*  
*Diana Khachadourian/ASRC*  
*Jan McGarry/NASA GSFC*  
*David McCormick/NASA GSFC*  
*Stephen Merkowitz/NASA GSFC*

*Erricos Pavlis/UMBC*  
*Michael Pearlman/SAO*  
*Lynette Queen/USRA*  
*Mark Torrence/SGT Inc.*  
*Scott Wetzel/HTSI*

## Program Committee:

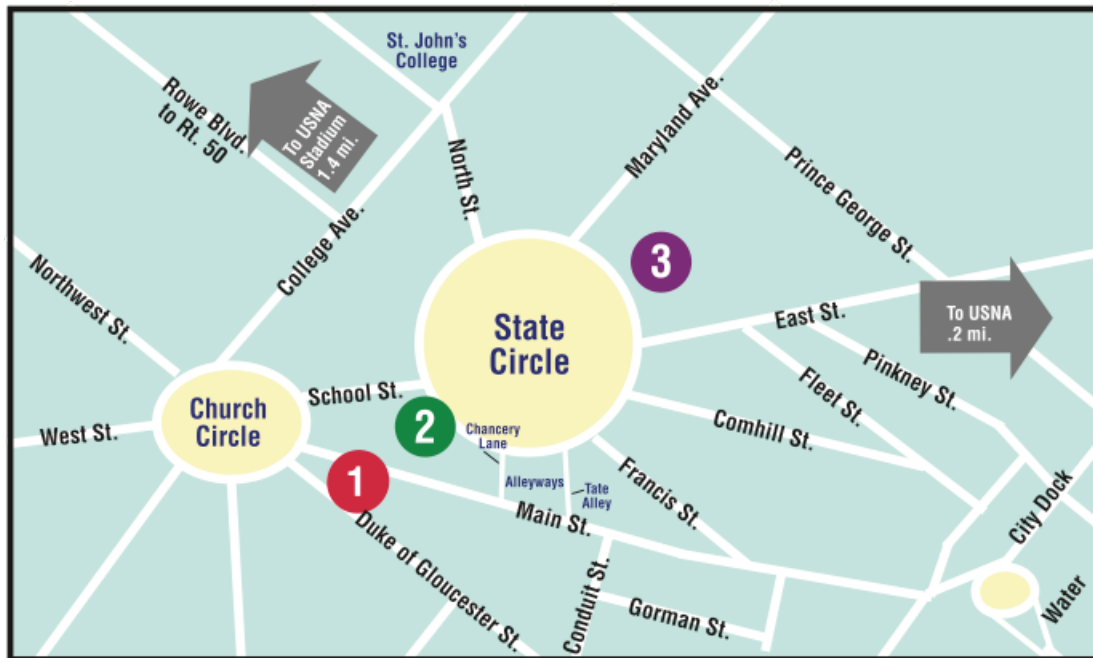
*Jan McGarry, NASA GSFC, USA (Chair)*  
*Graham Appleby, NERC Space Geodesy Facility, UK*  
*Giuseppe Bianco, ASI, Italy*  
*Ludwig Combrinck, HartRAO, South Africa*  
*John Degnan, Sigma Space Corporation, USA*  
*Georg Kirchner, Austrian Academy of Sciences, Austria*  
*Hiroo Kunimori, NICT, Japan*  
*Stephen Merkowitz, NASA GSFC, USA*  
*Chris Moore, Electro Optic Systems Pty Ltd, Australia*  
*Jürgen Müller, Leibniz Universität Hannover, Germany*  
*Shinichi Nakamura, JAXA, Japan*

*Carey Noll, NASA GSFC, USA*  
*Toshimichi Otsubo, Hitotsubashi University, Japan*  
*Erricos Pavlis, UMBC, USA*  
*Michael Pearlman, SAO, USA*  
*Ivan Prochazka, Technical University of Prague, Czech Republic*  
*Ulrich Schreiber, Technische Universität München, Germany*  
*Andrey Sokolov, OJC "RPC" "PSI", Russia*  
*Jean-Marie Torre, OCA, France*  
*Scott Wetzel/HTSI, USA*  
*Matt Wilkinson, NERC Space Geodesy Facility, UK*  
*Zhang Zongping, Shanghai Observatory, China*

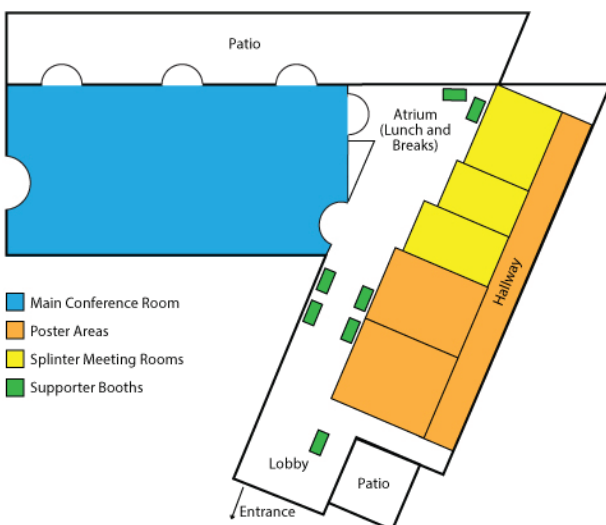
## Workshop Venue



The National Aeronautics and Space Administration (NASA), along with the Smithsonian Astrophysical Observatory (SAO), and the International Laser Ranging Service (ILRS), are hosting the 19th International Workshop on Laser Ranging in Annapolis Maryland at the Historic Inns of Annapolis. The workshop venue is located in the heart of Annapolis, the state capital of Maryland, also known as America's Sailing Capital. Annapolis is located near the Chesapeake Bay, between the cities of Washington D.C. and Baltimore Maryland. Numerous restaurants, quaint shops, historic attractions, and waterfront are all within walking distance of the venue.



The Historic Inns of Annapolis (<http://www.historicinnsofannapolis.com>) consists of three charming individual, historic inns, the Maryland Inn, 16 Church Circle (#1), the Robert Johnson House, 23 State Circle (#2), and the Governor Calvert House, 58 State Circle (#3).



The workshop venue for Monday, Tuesday, Thursday, and Friday is located at the Historic Inns' Governor Calvert House, location 3 on the map above. Oral sessions will be held in the Governor's Hall; posters will be displayed on freestanding boards in the Atrium, adjacent rooms located near the Governor's Hall, and in the hallway behind these rooms. Breakfast, morning, and afternoon breaks for these days will be provided in the Atrium. Lunches on Monday, Tuesday, and Thursday will also be served in the Atrium. Lunch on Friday will not be provided at the venue; attendees can visit one of the local restaurants that day.

## Wireless Internet Access

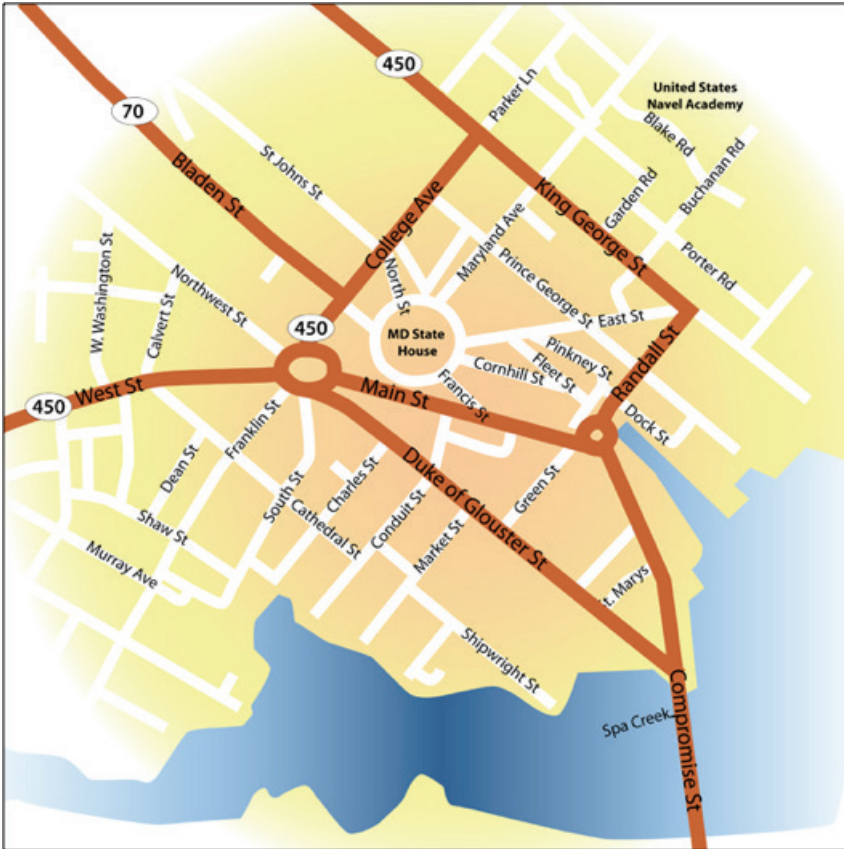
Network name: Calvert House

User name: FALL

Password: FALL

Presentations available during workshop from: <ftp://cddis.gsfc.nasa.gov/pub/ilrw19>

## Local Area



Map of downtown Annapolis MD  
 (map courtesy of Main Street Maryland website:  
<http://www.mainstreetmaryland.org/visit/annapolis/>)

Map of Annapolis MD area showing parking garages and lots  
 (map courtesy of the Annapolis Maryland government website:  
<http://www.annapolis.gov/government/city-departments/transportation/shuttle-service>)

# Social Events

Icebreaker Reception  
Monday, October 27  
18:00-21:00 (Open bar from 18:00-20:00)

Governor Calvert House  
Atrium

Poster Viewing and Wine and Cheese Reception  
Wednesday, October 29  
18:00-21:00 (Open bar from 18:00-20:00)

Governor Calvert House  
Atrium

Workshop Banquet  
Keynote speaker: Dr. Piers Sellers  
Thursday, October 30  
19:00-22:00 (Open bar from 19:00-21:00)

Pusser's Caribbean Grille  
80 Compromise Street  
Annapolis, MD 21401



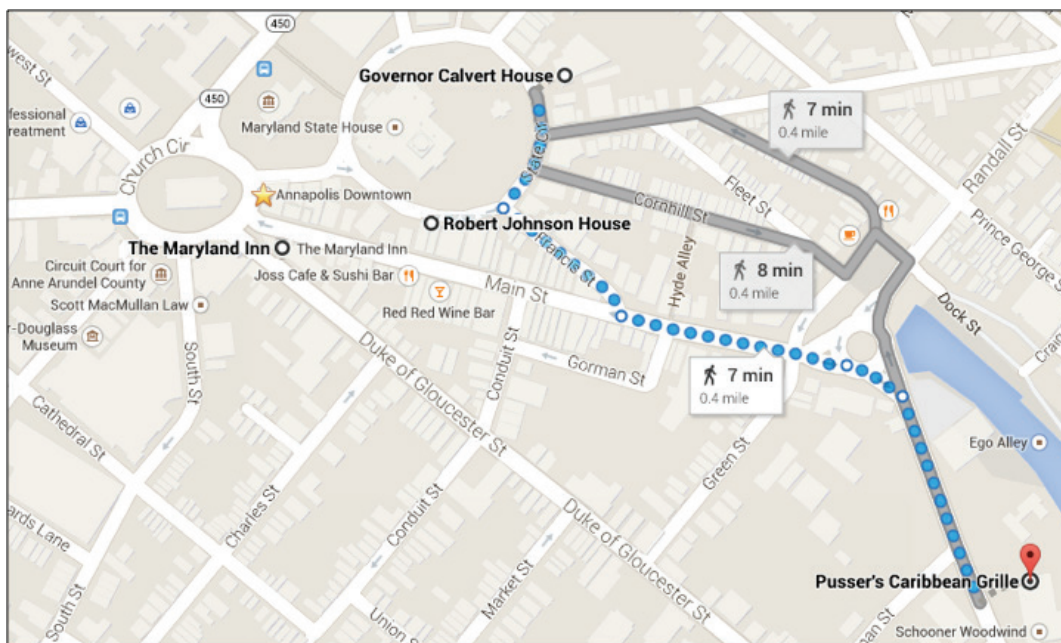
Piers Sellers is currently the Deputy Director of the Sciences and Exploration Directorate and Acting Director of the Earth Sciences Division at NASA GSFC.

Dr. Sellers was born and educated in the United Kingdom and moved to the U.S. in 1982 to carry out climate research at NASA GSFC. From 1982 to 1996, he worked on global climate problems, particularly those involving interactions between the biosphere and the atmosphere, and was involved in constructing computer models of the global climate system, satellite data interpretation and conducting large-scale field experiments in the USA, Canada, Africa, and Brazil.

He served as project scientist for the first large Earth Observing System platform, Terra, launched in 1998.

Dr. Sellers joined the NASA astronaut corps in 1996 and flew to the International Space Station (ISS) in 2002, 2006, and 2010, carrying out six spacewalks and working on ISS assembly tasks. He returned to GSFC in June, 2011.

Directions to Workshop Banquet (Pusser's Caribbean Grille):





# Week at a Glance

Date	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Date	
Time	26-Oct-2014	27-Oct-2014	28-Oct-2014	29-Oct-2014	30-Oct-2014	31-Oct-2014	Time	
06:30							06:30	
07:00				Depart Annapolis			07:00	
07:30		Registration	Arrival	Travel	Arrival	Arrival	07:30	
08:00			S4: SLR and Service Organizations	Arrive GSFC	S9: Networks and Core Sites	S15: Operations	08:00	
08:30							08:30	
09:00		S1: Welcome	S5: Role of SLR in TRF Development	GSFC/GGAO Tours	Break	Break	09:00	
09:30		S2: Hist. Persp.						09:30
10:00		Break	Break		S10: New Apps: Space Debris	S16: Workshop wrap-up and closing	10:00	
10:30	AWG Meeting				S11: New Apps: Time Transfer			10:30
11:00		S2: Historical Perspective	S6: Role of SLR in Gravitational Earth Modeling	Lunch (box)				11:00
11:30					Lunch+Posters		11:30	
12:00		Lunch+Posters	Lunch+Posters			Lunch on your own	12:00	
12:30							12:30	
01:00					S12: From GNSS to Lumar	S17: Station Clinics	13:00	
01:30		S3: Science through Missions	S7: Advanced Technologies I	GSFC/GGAO Tours	Break			13:30
02:00							14:00	
02:30	GB Meeting	Group Photo	Break	Break	S13: Lunar Laser Ranging	Break	14:30	
03:00		Break					15:00	
03:30			S8: Advanced Technologies II	Joint Scientific/Engineering Colloquium	S14: Planetary Ranging	S17: Station Clinics	15:30	
04:00		S3: Science through Missions						16:00
04:30	Pre-Registration & Poster Set-Up			Depart GSFC	DFPWG Meeting and TWG Meeting		16:30	
05:00	Program Committee Meeting	Poster Set-Up	MWG Meeting	Travel				17:00
05:30				Arrive Annapolis			17:30	
06:00							18:00	
06:30							18:30	
07:00		Icebreaker Reception	NEWG Meeting	Poster Viewing Reception			19:00	
07:30							19:30	
08:00							20:00	
08:30					Banquet		20:30	
09:00							21:00	
09:30							21:30	
10:00							22:00	

	Presentations
	Breaks/activities
	Other topics/meetings

# Workshop Agenda: Monday, October 27

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## Session 01: Welcome

Stephen Merkowitz/NASA GSFC, Chair  
Michael Pearlman/SAO, Co-Chair

- 09:00-09:50 Workshop Welcome and Introduction  
Stephen Merkowitz, Manager, NASA Space Geodesy Project  
Michael Pearlman, Director, ILRS Central Bureau  
Giuseppe Bianco, Chair, ILRS Governing Board  
Hansjörg Kutterer, Chair, GGOS Coordinating Board  
Dr. Jack Kaye, Associate Director for Research, Earth Science Division, NASA Headquarters  
Dr. Colleen Hartman, Acting Director, Sciences and Exploration Directorate, NASA Goddard Space Flight Center  
Dr. John Kress, Interim Under Secretary for Science, Smithsonian Institution  
Dr. Charles Alcock, Director, Smithsonian Astrophysical Observatory
- 09:50-10:00 J. McGarry, C. Noll, Workshop Logistics
- 

## Session 02: Historical Perspectives

*A review of 50 years of Satellite Laser Ranging, highlighting early technical and scientific achievements and international cooperation.*

Michael Pearlman/SAO, Chair  
John Degnan/Sigma Space Corporation, Co-Chair

- 10:00-10:20 H. Plotkin/NASA GSFC retired,  
Genesis of Laser Satellite Tracking at the NASA Goddard Space Flight Center (3128)
- 10:20-10:40 C. Lundquist/University of Alabama in Huntsville,  
Evolution of Optical Satellite Tracking (3019)
- 10:40-11:00 **Break**
- 11:00-11:20 G. Veis/National Technical University of Athens,  
From Optical Tracking to Laser Tracking - The Early Years of Satellite (3023)
- 11:20-11:40 F. Barlier/Observatoire de la Cote d'Azur,  
Early Satellite Laser Ranging for Geodesy at CNRS, CNES and ONERA in France (3108)
- 11:40-12:00 J. Bosworth/NASA GSFC,  
The NASA Crustal Dynamics Project's Use of Satellite Laser Ranging to Meet its Multiple Objectives (3132)
- 12:00-12:20 J. Faller/JILA,  
Lunar Laser Ranging (3127)
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- 12:30-13:30 **Lunch**
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# Workshop Agenda: Monday, October 27 (continued)

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## Session 03: Science through Missions

*Presentations on the impact of satellite laser ranging support of missions through the last 50 years.*

Giuseppe Bianco/ASI, Chair  
Graham Appleby/NERC Space Geodesy Facility, Co-Chair

- 13:30-13:50 G. Neumann/NASA GSFC  
Interplanetary Spacecraft Laser Ranging: The Quest for 1 AU (3143)
- 13:50-14:10 P. Exertier/CNRS-UNS-OCA  
Time Transfer by Laser Link (T2L2) : A Way to Synchronize Laser Ranging Observatories at the ns Level (3083)
- 14:10-14:30 G. Beutler/Astronomical Institute of Bern  
GNSS for Positioning, Navigation, Timing, and Science (3135)
- 14:30-14:50 R. Beard/Naval Research Laboratory  
The NAVSTAR 35 and 36 Laser Retro-reflector Experiments (3142)
- 14:50-15:10 B. Tapley/University of Texas/CSR  
Space Geodesy Contributions to Gravity Model Development (3129)
- 15:10-15:40 **Group Photo**
- 15:40-16:10 **Break**
- 16:10-16:30 Z. Altamimi/Institut National de l'Information Géographique et Forestière  
ITRF 2013 Analysis and SLR Contribution (3035)
- 16:30-16:50 J.P. Berthias/CNES  
SLR and Altimetry: A Success Story and a Lasting Partnership (3153)
- 16:50-17:10 B. Schutz/University of Texas/CSR  
The NASA Ice, Cloud and land Elevation Satellite (ICESat) Series: Science, Data Products and Operations (3120)
- 17:10-17:30 T. Murphy/University of California San Diego  
Lunar Laser Ranging: Science and Status (3057)

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## Poster Set-up

17:30-18:00 **Governor Calvert House Atrium**

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## Icebreaker Reception

18:00-21:00 **Governor Calvert House Atrium**

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# Workshop Agenda: Tuesday, October 28

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## Session 04: SLR and Service Organizations

*Presentations on the importance of satellite laser ranging to the IAG and GGOS.*

Carey Noll/NASA GSFC, Chair

- 08:00-08:20 G. Bianco/Agenzia Spaziale Italiana  
The International Laser Ranging Service: Past, Present and Future (3168)
- 08:20-08:40 H.J. Kutterer/Federal Agency for Cartography and Geodesy (BKG)  
GGOS and the Importance of the Combination of Space Techniques (3164)
- 08:40-09:00 P.E.O. Opseth/Norwegian Mapping Authority  
Status in the UN-GGIM Initiative on a Resolution for a Global Geodetic Reference Frame (3026)
- 

## Session 05: The Role of SLR in the Terrestrial Reference Frame Development

*Presentations that highlight the use of laser ranging data for geophysical, planetary and fundamental physics research and classical areas of reference frame development and maintenance, precision orbit determination, gravitational modeling, and calibration of other techniques or instruments.*

Erricos Pavlis/UMBC, Chair

Vincenza Luceri/e-GEOS S.p.A, ASI/CGS Matera, Co-Chair

- 09:00-09:15 V. Luceri/e-GEOS S.p.A, ASI/CGS Matera  
The ILRS Contribution to the Development of ITRF2013 (3157)
- 09:15-09:30 E. Pavlis/UMBC  
Modeling Improvements in the ILRS Reprocessing for ITRF2013 Using the LAGEOS Satellites to Assess the Accuracy of ILRS Stations (3146)
- 09:30-09:45 G. Appleby/NERC BGS  
Using the LAGEOS Satellites to Assess the Accuracy of ILRS Stations' Observations During The Last Decade (3052)
- 09:45-10:00 S. Kopeikin/University of Missouri  
Relativistic Aspects of SLR/GPS Geodesy (3144)
- 10:00-10:15 D. Thaller/BKG  
Pre-Combined GNSS-SLR Solutions for the ITRF2013 (3079)
- 10:15-10:30 F. Deleflie/GRGS  
Impact of 25 Years of Etalon-1 and Etalon-2 Data (3081)
- 10:30-11:00 **Break**

# Workshop Agenda: Tuesday, October 28 (continued)

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## Session 06: The Role of SLR in Gravitational Earth Modeling

*Presentations that highlight the use of laser ranging data for geophysical, planetary and fundamental physics research and classical areas of reference frame development and maintenance, precision orbit determination, gravitational modeling, and calibration of other techniques or instruments.*

Horst Müller/DGFI, Chair  
Shinichi Nakamura/JAXA, Co-Chair

- 11:00-11:15 J. Ries/University of Texas at Austin  
Satellite Laser Ranging Applications for Gravity Field Determination (3117)
- 11:15-11:30 R. Gross/JPL  
Mass Transport and Dynamics in the Earth System (3015)
- 11:30-11:45 K. Matsuo/Kyoto University (T. Otsubo/Hitotsubashi University)  
Geocenter Motion Driven by Large-Scale Mass Redistribution (3088)
- 11:45-12:00 L. Petrov/ADNET Systems, Inc.  
The Use of Numerical Weather Models for SLR Data Analysis (3011)
- 12:00-12:15 W. Qu/Shanghai Astronomical Observatory, CAS  
The Study on the Coefficients of the Earth's Gravity Using Scaled Sensitivity Matrix Method (3002)
- 12:15-12:30 R. Govind/University of Cape Town  
Assessing Orbit Quality Using SLR (3110)

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12:30-13:30 **Lunch**

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## Session 07: Advanced Technologies I

*Presentations on new hardware, software and techniques for improvements in SLR performance and automation.*

Zhongping Zhang/Shanghai Astronomical Observatory, CAS, Chair  
John Degnan/Sigma Space Corp., Co-Chair

- 13:30-13:45 Z. Fan/NAO, CAS (Z. You/NAO, CAS)  
Millijoules High Master-Slave Pulse Ratio 532 nm Picosecond Laser (3126)
- 13:45-14:00 T. Murphy/University of California San Diego  
TBAD: Transponder-Based Aircraft Detector (3058)
- 14:00-14:15 I. Blinov/FSUE VNIIFTRI (I. Ignatenko)  
Metrological Provision Uniformity of Measurements of Time and Frequency in the Satellites Laser-Ranging Systems (3041)
- 14:15-14:30 M. Sadovnikov/OJC "RPC "PSI"  
SLR Station of the New Generation for Time Transfer with Sub-nanosecond Accuracy and Ranging with Sub-millimeter Accuracy in Night and Daytime (3025)

## Workshop Agenda: Tuesday, October 28 (continued)

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- 14:30-14:45 Z. Zhang/Shanghai Astronomical Observatory, CAS  
Laser Measurement to Space Targets by Using Dual-Receiving Telescopes and Transmitted from One of Systems (3032)
- 14:45-15:00 A. Kloth/SpaceTech GmbH  
Development of a Full SLR Software Stack Based on Real-Time Linux and a New Version of the Potsdam Range Gate (3089)
- 15:00-15:30 **Break**
- 

### Session 08: Advanced Technologies II

*Presentations on new hardware, software and techniques for improvements in SLR performance and automation.*

Georg Kirchner/Austrian Academy of Sciences, Chair  
Matt Wilkinson/NERC Space Geodesy Facility, Co-Chair

- 15:30-15:45 M. Wilkinson/NERC Space Geodesy Facility  
Upgrading kHz SLR at the SGF, Herstmonceux (3104)
- 15:45-16:00 J. Degnan/Sigma Space, Inc.  
A Proposed Multifunctional Multichannel Receiver for SGSLR (3020)
- 16:00-16:15 Z. Li/Yunnan Observatories, CAS  
The Research of Rotating Shutter Control Method for 1.2m Telescope SLR System (3051)
- 16:15-16:30 S. Riepl/BKG  
First Results from the Satellite Observing System Wettzell (3131)
- 16:30-16:45 C. Courde/Laboratoire Geoazur/OCA  
Ideas of New Technological Developments for Future French SLR Stations (3091)
- 16:45-17:00 E. Hoffman/GFZ  
Upgrades and New Capabilities of the GFZ SLR Timing System (3085)  
Modernization and Characterization of the Riga SLR Timing System (3086)
- 

### Working Group Meetings

- 17:00-18:30 Missions Working Group Abram Claude Room
- 18:30-20:00 Networks and Engineering Working Group Abram Claude Room
-

# Workshop Agenda: Wednesday, October 29

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## Buses Depart

07:00 Governor Calvert House

## Buses Arrive

07:45 NASA GSFC Visitor Center

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## Tours of NASA Goddard Space Flight Center (GSFC) and Goddard Geophysical and Astronomical Observatory (GGAO)

08:30-11:30

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11:30-12:30 Lunch provided in Building 8 Auditorium

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## Tours of NASA Goddard Space Flight Center (GSFC) and Goddard Geophysical and Astronomical Observatory (GGAO) Continue

12:30-15:00

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15:00-15:30 Break in Building 8 Auditorium

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15:30-15:45 Joint GSFC Engineering and Scientific Colloquium  
Welcome: Chris Scolese, Director, NASA Goddard Space Flight Center

15:45-17:00 John Degnan/SigmaSpace, NASA GSFC Retired  
A Celebration of Fifty Years of Satellite Laser Ranging

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## Buses Depart

17:00 NASA GSFC Building 8 Auditorium

## Buses Arrive

18:00 Governor Calvert House

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## Poster Viewing Reception

18:30-21:30 Governor Calvert House Atrium

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## Workshop Agenda: Wednesday, October 29 (continued)

### Tours of NASA Goddard Space Flight Center (GSFC)



NASA's Goddard Space Flight Center (GSFC), located in Greenbelt, MD, is home to the nation's largest organization of combined scientists, engineers and technologists that build spacecraft, instruments and new technology to study Earth, the Sun, our solar system, and the universe. Goddard manages many of NASA's Earth observation, astronomy, and space physics missions.

Named for American rocketry pioneer, Dr. Robert H. Goddard, the center was established in 1959 as NASA's first space flight complex.



The GSFC Visitor Center demonstrates Goddard's innovative and exciting work in Earth science, astrophysics, heliophysics, planetary science, engineering, communication, and technology development. Visitors can browse the unique, informative exhibits and learn about climate change, view a Gemini capsule model, and explore informative mission displays. The data visualization exhibit, Science on a Sphere, projects video onto a floating, 6-foot-wide white globe. A gift shop is located next to the Visitor Center and offers post cards, publications, patches, models, space-related educational toys, games, clothing and other NASA souvenirs.



Goddard spacecraft testing facilities include the High Bay Clean Room and the Thermal Vacuum Chamber. Most spacecraft components built by Goddard are cleared for launch by undergoing final checkout in these facilities. Goddard's High Bay Clean Room is one of the largest facilities of this type in the world. To simulate the extreme heat and cold of space, spacecraft undergo tests in one of the center's thermal vacuum chambers. The largest is 40 feet tall and can run tests on large spacecraft such as the James Webb Space Telescope (JWST). JWST, planning for launch in 2018, is a large infrared telescope with a 6.5-meter primary mirror.



# Workshop Agenda: Wednesday, October 29 (continued)

## Tours of Goddard Geophysical and Astronomical Observatory (GGAO)



## Workshop Agenda: Wednesday, October 29 (continued)

### Tours of Goddard Geophysical and Astronomical Observatory (GGAO)



**NGSLR** is the prototype for NASA's Next Generation Satellite Laser Ranging System, designed to replace the aging NASA SLR network. The system will operate semi-autonomously and provide ranging performance for all retroreflector-equipped satellites in both day and night. NGSLR is also the primary laser ranging ground station for one-way ranging to the Lunar Reconnaissance Orbiter (LRO), which has been orbiting the Moon since 2009.



**MOBLAS-7** is the flagship station in NASA's SLR network and a key contributing station to the International Laser Ranging Service (ILRS). Operating at GGAO since the late 1970s this station is capable of tracking retroreflector-equipped satellites from low Earth orbiting to GNSS altitude. MOBLAS-7 provides centimeter level ranging accuracy to geodetic satellites and performs ranging operations during the day and the night.



The **1.2-meter (48") telescope** was built in the early 1970s and has been performing laser ranging R&D since that time. Laser transponder ranging was pioneered at this facility. In 2005, the longest successful two-way asynchronous laser ranging experiment took place between this telescope and the Mercury Laser Altimeter (MLA) onboard MESSENGER (24 Mkm). That same year, one-way laser ranging (80 Mkm) occurred from the 1.2-meter telescope to the Mars Orbiter Laser Altimeter (MOLA) onboard MGS orbiting Mars. Multiple on-orbit calibrations of the Lunar Orbiter Laser Altimeter (LOLA) onboard LRO have taken place from the 1.2-meter telescope.

## Workshop Agenda: Wednesday, October 29 (continued)

### Tours of Goddard Geophysical and Astronomical Observatory (GGAO)



To improve **Very Long Baseline Interferometry (VLBI)** data to meet increasingly demanding requirements, an end-to-end redesign called VLBI2010 Global Observing System (VGOS) has been developed. The fast 12-m Patriot antenna was erected in October 2010 as a major component of VLBI2010. The cryogenic broadband (2 – 12 GHz) receiver along with four digital back ends and high speed (2 Gbps) recorders will replace the current VLBI equipment built in the 1970s and 1980s. The MV-3 system was originally a mobile VLBI station supporting the Crustal Dynamics Project that began in 1980. Since 1993, MV-3 has been a fixed antenna at GGAO and part of the global network supporting the International VLBI Service for Geodesy and Astrometry (IVS).



Two **Global Navigation Satellite System (GNSS)** receivers (GPS and GPS+GLONASS) share a common antenna at GGAO and have been operational since the early 1990s. Both receivers are key contributors to the International GNSS Service (IGS). JPL provides installation and infrastructure support for receiver, antenna, and data download. Two additional multi-constellation GNSS antenna/receiver pairs (GODN and GODS) were installed with deep-drilled brace monuments and have been collecting data since early 2012. The GGAO site is also used for engineering tests of various GNSS antennas.



The GGAO **Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)** beacon is part of a global network of ~57 stations. DORIS has been operational at GGAO since June 2000. French-developed DORIS receivers are located on altimeter satellites (TOPEX/Poseidon, Jason-1, Jason-2, Envisat, Cryosat-2, HY-2A) and remote sensing satellites (SPOT-4 and -5); future satellites include: SARAL/Altika, Jason-3, SWOT & SENTINEL-3. DORIS data are used for precision orbit determination, and contribute to IERS reference frame realizations. DORIS activities are coordinated through the International DORIS Service (IDS).



One of the fundamental issues with the co-location between techniques is the measurement of the vector between the invariant reference points on the co-located systems. The combination of space geodetic solutions is critically reliant on the availability of local tie vectors. It is necessary for integrated/co-located stations to implement an economical approach to routinely measure and/or monitor the inter-system vectors. At GGAO, a **Vector Tie System (VTS)** is being tested where vectors are measured from a central survey pillar (i.e., the origin of the local reference frame) to survey points at co-located space geodetic stations and ground control pillars.

# Workshop Agenda: Thursday, October 30

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## Session 09: Networks and Core Sites

*Presentations on new or improved SLR stations that will be co-located with the other space geodetic techniques. Included in this topic area is how the different techniques will work together (scheduling, RFI, etc.), surveying techniques for the sites, how the site ties will be obtained and maintained, and how the new Core Site Networks may be run.*

Michael Pearlman/SAO, Chair  
Stephen Merkowitz/NASA GSFC, Co-Chair

- 08:00-08:15 M. Pearlman/SAO  
The Role of CORE and Co-location Sites and the Activities Underway to Improve the Global Space Geodesy Network (3044)
- 08:15-08:30 M. Sadovnikov/OJC "RPC "PSI"  
Stages of Development of Stations, Networks and SLR Usage Methods for Global Space Geodetic and Navigation Systems in Russia (3068)
- 08:30-08:45 Z. Zhang/Shanghai Astronomical Observatory  
The Status and Plan of the Chinese SLR Network (3165)
- 08:45-09:00 J. McGarry/NASA GSFC  
Developing and Deploying NASA's Space Geodesy Satellite Laser Ranging (SGSLR) Systems (3018)
- 09:00-09:15 T. Varghese/Cybioms  
Testing and Benchmarking the NASA SGSLR Systems at the 1mm Level Prior to Field Deployment (3119)
- 09:15-09:30 J. Esper/NASA GSFC  
NASA's Next Generation Space Geodesy Network Typical Core Site Requirements and Layout (3151)
- 09:30-09:45 P.E.O. Opseth/Norwegian Mapping Authority  
Status of the Establishment of a Core Site in Ny-Ålesund (3027)
- 09:45-10:15 **Break**
- 

## Session 10: New Applications: Space Debris

*Presentations on synergies between SLR and orbital debris.*

Chris Moore/Electro Optic Systems Pty Ltd, Chair  
Ivan Prochazka/Technical University of Prague, Co-Chair

- 10:15-10:30 B. Greene/Space Environment Research Centre  
Laser Ranging for the Precision Orbit Determination and Remote Maneuver of Space Debris (3094)
- 10:30-10:45 H. Wirmsberger/Austrian Academy of Sciences  
Space Debris Orbit Predictions using Bi-static Laser Observations. Case Study: ENVISAT (3017)

## Workshop Agenda: Thursday, October 30 (continued)

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10:45-11:00 G. Kirchner/Austrian Academy of Sciences  
Infrared Laser Ranging to Space Debris – a Chance for ILRS (3009)

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### Session 11: New Applications: Time Transfer

*Presentations on synergies between SLR and time transfer.*

Pierre Exertier/OCA/CERGA/GRGS, Chair  
Hiroo Kunimori/NICT, Co-Chair

11:00-11:15 A. Schlicht/Technische Universität München  
Concept for a Geodetic and Time Reference in Space (3075)

11:15-11:30 I. Prochazka/Czech Technical University in Prague  
Calibration of SLR System Delays for the European Laser Timing Reaching 20 ps Accuracy (3006)

11:30-11:45 J. Kodet/ Technische Universität München  
SLR and GNSS Co-location and Delay Control for the Application of Laser Time Transfer (3005)

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11:45-12:45 **Lunch**

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### Session 12: From GNSS to Lunar

*Presentations related to the ground or space segments of satellite laser ranging from GNSS altitude satellites, through geosynchronous.*

Andrey Sokalov/OJC “RPC “PSI”, Chair  
Scott Wetzel/HTSI, Co-Chair

12:45-13:00 M. Pearlman/SAO  
Early Results from New Initiatives on SLR Tracking of GNSS and Synchronous Satellites (3114)

13:00-13:15 A. Sokolov/OJC “RPC “PSI”  
New ideas in retroreflector array development (3024)

13:15-13:30 L. Thomas/Naval Research Laboratory  
Status of the GPS III Laser Retroreflector Array (3053)

13:30-13:45 S. Kasho/JAXA  
Accuracy Evaluation of QZS-1 Precise Ephemerides with Satellite Laser Ranging (3067)

13:45-14:00 A. Boni/INFN-LNF  
Thermal and Optical characterization of a GNSS Retroreflector Array at the SCF Lab (3082)

14:00-14:15 K. Sosnica/University of Bern  
Processing 20 Years of SLR Observations to GNSS Satellites (3070)

## Workshop Agenda: Thursday, October 30 (continued)

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14:15-14:45      **Break**

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### Session 13: Lunar Laser Ranging

*Presentations related to advances in Lunar Laser Ranging.*

Jürgen Müller /Leibniz Universität Hannover, Chair  
Ludwig Combrink/HRAO, Co-Chair

14:45-15:00      T. Murphy/University of California San Diego  
APOLLO: Performance and Findings (3061)

15:00-15:15      C. Courde/Laboratoire Geoazur/OCA  
French LLR Station Status and New Project (3016)

15:15-15:30      J. Müller/Leibniz Universität Hannover  
Earth Orientation and Relativity Parameters Determined from LLR Data (3033)

15:30-15:45      M. Martini/INFN  
Test of General Relativity Using Lunar Laser Ranging Data and the Planetary Ephemeris Program (3148)

15:45-16:00      A. Bourgoïn/Observatoire de Paris/SYRTE  
New dynamical relativistic modeling of the Moon in POLAC group (SYRTE, Observatoire de Paris) (3092)

16:00-16:15      D. Currie/University of Maryland  
Atmospheric Effects and the Ultimate Ranging Accuracy for Lunar Laser Ranging (3055)

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### Session 14: Planetary and Transponder Ranging

*Presentations on synergies between SLR and planetary and transponder ranging.*

Ulrich Schreiber/BKG/Geodaetisches Observatorium Wettzell, Chair  
Jan McGarry/NASA GSFC, Co-Chair

16:15-16:30      S. Bauer/DLR  
Application of one-way laser ranging data to LRO into orbit determination (3124)

16:30-16:45      D. Dirkx/Delft University of Technology  
Simulated Comparative Analysis of One- and Two-Way Planetary Laser Ranging Systems (3101)

16:45-17:00      S. Dell'Agnello/INFN-LNF  
NASA-SSERVI and INFN Partnership "Springlets": Solar system Payloads of laser Retroreflectors of INFN for General reLativity, Exploration and planeTary Science (3100)

# Workshop Agenda: Thursday, October 30 (continued)

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## Working Group Meetings

17:00-18:30	Data Formats and Procedures Working Group	Abram Claude Room
17:00-18:30	Transponders Working Group	Sara Bell

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## Workshop Banquet

19:00-22:00	<b>Pusser's Caribbean Grille</b> Keynote Speaker: Dr. Piers Sellers/NASA GSFC Deputy Director, Sciences and Exploration Directorate, NASA Astronaut
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# Workshop Agenda: Friday, October 31

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## Session 15: Operations

*Presentations on the best practices for station engineers and operators, solution to common station problems, how to maintain station stability, and how to interact with the analysts in determining station bias and RMS.*

- Toshimichi Otsubo/Hitotsubashi University, Chair  
David McCormick/NASA GSFC, Co-Chair
- 08:00-08:10 R. L. Ricklefs/University of Texas at Austin  
ILRS Station Configuration Tracking (3123)
- 08:10-08:20 T. Otsubo/Hitotsubashi University  
Two-fold Quality Assessment of Global SLR Data (3036)
- 08:20-08:30 M. Wilkinson/NERC Space Geodesy Facility  
Plotting NP range residuals - SGF web development (3125)
- 08:30-08:40 E. Pavlis/UMBC  
Station Performance Assessment Tools for the ILRS Stations (3160)
- 08:40-08:50 G. Appleby/NERC Space Geodesy Facility  
Satellite Interleaving and Real-time Normal Point Data-Quantity Monitoring (3059)
- 08:50-09:00 J. Woo/Excelis  
Station Procedures (3029)
- 09:00-09:10 J. Torre/OCA  
Station best practice and requests (3130)
- 09:10-09:20 G. Kirchner/Austrian Academy of Sciences  
SLR Calibration Issues - Example: Graz (3154)
- 09:20-09:30 I. Prochazka/Technical University of Prague  
Geometry bias in a short baseline ground calibration (3097)

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9:30-10:00 **Break**

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## Session 16: Workshop Closing

*Session summaries, issues, resolutions, and actions.*

- Michael Pearlman/SAO, Chair  
Jan McGarry/NASA GSFC, Carey Noll/NASA GSFC, Co-Chairs
- 10:00-11:00 Session Summaries
- 11:00-12:00 Working Group Summaries
- 12:00-12:30 Workshop Closing



## Workshop Agenda: Friday, October 31 (continued)

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12:30-13:30      **Lunch**

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### Session 17: Station Clinics

*Interactive sessions with station operators and analysts.*

David McCormick/NASA GSFC, Chair  
Toshimichi Otsubo/Hitotsubashi University, Co-Chair  
Jean-Marie Torre/OCA, Chair  
Mark Torrence/SGT, Co-Chair

13:30-15:00      Station Clinic I

15:00-15:30      **Break**

15:30-17:30      Station Clinic II

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17:30              **Workshop End**

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# Posters

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## Session 02: Historical Perspectives Posters

- C. Schwatke, Historical Development of the SLR Data Holdings at EDC Between 1976 and 2014 (3010)
  - J. Kostelecky, 1970 - First Laser Ranging in the Czechoslovakia (3022)
  - E. Kattimuthu, 40 Years of SLR in India (Remembering the Past) (3034)
  - Ya. Blagodyr, History of the "Lviv-1831" SLR station at Lviv, Ukraine (3039)
  - C. Noll, Satellite Laser Ranging Tracking Through the Years (3046)
  - M. Abele, Satellite Laser Ranging in the University of Latvia since 1975 (3102)
  - M. Ploner, History of the Laser Observations at Zimmerwald (3116)
  - P. Dunn, Arequipa's Contribution to the ILRS Network (3121)
  - P. Yanyachi, Arequipa Satellite Tracking Station (3122)
- 

## Session 05 and 06: Science Posters

- A. Pacheco, Earth Orientation Parameters (EOP's) using SLR data from ILRS 7406 station at San Juan - Argentina (3013)
- E. Park, Preliminary Performance Analysis for the Korean SLR Station "DAEDEOK-73592601" (3064)
- Y. Kim, Precise Orbit Determination and Measurement Bias Analysis for Starlette with Satellite Laser Ranging of The Korean SLR Station "DAEDEOK-73592601" (3071)
- K. Sosnica, Earth Rotation and Gravity Field Parameters from Satellite Laser Ranging (3072)
- M. Bloßfeld, LOD systematics from SLR observations (3074)
- K. Ebauer, Impact of Atmospheric Effects on SLR-derived Parameters (3078)
- K. Ebauer, Geodetic Parameters Estimation from Processing of LAGEOS and LEO SLR Data (3080)
- I. Fausk, Combining SLR with VLBI, DORIS and GPS in the GEOSAT Software (3096)
- P. Dunn, Etalon and Ajsai Observations from NASA's SLR Network (3138)
- D. Kucharski, Submillimeter SLR: Ajsai as the Zero-Signature Geodetic Satellite (3021)
- T. Otsubo, Systematic Range Error 2013-2014 (3141)
- D. Lucchesi, Testing Fundamental Physics with Satellite Laser Ranging: Perspectives and Goals of the LARASE Experiment (3109)
- E. Tcyba, Associate Analysis Center of VNIIFTRI (3103)
- X. Wang, Introduction on ILRS SHAO Analysis Center and Products (3112)

H. Oh, Orbit Determination of Korea Regional Navigation Satellite System by Using Satellite Laser Ranging (3145)

P. Yanyachi, Laser Ranging and GPS Measurements to Misti, Chachani, Pichu Pichu Volcanoes and Surrounding Hills, and Applications of Precise Positioning to Monitoring of Volcanic Deformation and Seismic Risk (3155)

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### Sessions 07 and 08: Advanced Technologies Posters

L. Combrinck, Development of a High Accuracy, User Friendly Lunar Laser Ranging Telescope Steering and Pointing Software Package at HartRAO (3004)

I. Prochazka, Dark Count Rate Reduction of the SPAD Detection Package for SLR (3007)

R. Ricklefs, Software Reuse in the ILRS Network (3008)

S. Ndlovu, An Estimation of the Number of Expected Returned Photons for the HartRAO Lunar Laser Ranging System (3012)

H. Zhang, The Research on Key Technology of 1064nm Wavelength SLR and Measurement Experiment (3030)

A. Goncharov, The Laser Station Synchronization and Reference Frequency System and Its Metrological Support (3042)

D. Arnold, Final Transfer Function of the LARES retroreflector array (3047)

M. Choi, Development of the Automatic Transmitter/Receiver Alignment System (ATRAS) for ARGO-M (3063)

J. Näränen, A New Toolset for Passive Monitoring of Air Traffic and Sky Conditions at Metsähovi Station, Finland (3073)

S. Bang, A-RGG development for 10 kHz Laser Ranging of Daedeok station (3077)

V. Vedin, New USB version of the Riga Event Timer and additional Software Support for Linux (3098)

M. Wilkinson, ADS-B in-Sky Safety - Making Listen2Planes Package Available to Download (3099)

C. Clarke, Background Noise Suppression for Increased Data Acceptance (3118)

J. Horvath, Automating NASA's Space Geodesy Satellite Laser Ranging (SGSLR) Systems (3136)

C. Moore, Laser Development for Kilohertz Ranging at the US Naval Research Laboratory (3149)

R. Preston, Analysis of ILRS data from STPSat-2 Retro-reflector (3156)

H. Kunimori, Range Gate Generator with Pulse Position Modulation Capability (3159)

J. Kilmer, Lasers for Satellite Laser Ranging (SLR) Applications (3162)

V. Vasiliev, Retroreflector Using a Birefringent Wedge for Efficient Velocity Aberration Compensation (3167)

## Posters (continued)

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### Session 09: Networks and Core Sites Posters

- R. Podestá, Local Ties to Determine the Co-location Vector from the SLR Telescope and GPS Antenna in San Juan, Argentina (3014)
- C. Noll, SLR, GNSS, VLBI, and DORIS Networks: ILRS+IGS+IVS+IDS (3048)
- A. Raja-Halli, Progress Report on the New SLR System of GGOS's Core Site Metsähovi, Finland (3090)
- J. Cheek, SGSLR Computer Design (3093)
- G. Appleby, Relative Height Surveying of Geodetic Monuments at the SGF Herstmonceux, UK (3105)
- S. Merkwitz, NASA's Next Generation Space Geodesy Network (3150)
- 

### Session 10: New Application: Space Debris Posters

- M. Shappirio, Tracking Orbital Debris in a Busy Airspace Environment (3115)
- Q. Li, Space Debris Laser Ranging at Yunnan Observatories (3049)
- C. Liu, Laser Ranging on Space Debris with the Changchun SLR station (3066)
- S. Lakshminarayana, Send off to Space Debris using LASER Techniques (3003)
- 

### Session 11: New Applications: Time Transfer Posters

- D. Mao, Time-transfer Experiments Between Satellite Laser Ranging Ground Stations via One-Way Laser Ranging to the Lunar Reconnaissance Orbiter (3060)
- C. Courde, Comparison Campaigns of Time Transfer Techniques Between Calibrated Observatories (3161)
- 

### Session 12: From GNSS to Lunar Posters

- Zhao Chunmei, BDS Satellite Orbit and Clock Determination based on MGEX Data (3037)
- X. Hani, Daylight Tracking GNSS in the Changchun SLR station (3065)
- D. Currie, Science Trades for Weight and Deployment of the LLRRA-21 (3106)
- V. Glotov, Some Results of the GLONASS SLR Data Analysis in IAC PNT (3140)
- S. Dell'Agnello, "Laser Ranging to Galileo", an ASI-INFN Project of the Italian Ministry of Research (3147)
- 

### Session 13: Lunar Laser Ranging Posters

- Yu. Kokurin, LLR (Lunar Laser Ranging) in the Physical Institute of the USSR Academy of Sciences (3040)
- M. Aimar, ODISSEE, a Promising Tool for Lunar Laser Ranging (3113)

### Session 14: Planetary and Transponder Ranging Posters

- D. Dirkx, Influence of Atmospheric Turbulence on Planetary Transceiver Laser Ranging (3087)
  - D. Mao, Summary of Ground Station Performance in 5 years of Laser Ranging Operation to Lunar Reconnaissance Orbiter (3158)
- 

### Session 15: Operations Posters

- J. Woo, Developments at the NASA SLR OC (3028)
- Z. Wu, Current status in Shanghai SLR station (3031)
- F. Qu, Comparison of Different Frequency Laser Ranging (3038)
- C. Noll, Recent CDDIS Developments (3043)
- C. Noll, The ILRS Website's Site Log Viewer Application (3045)
- Y. Xiong, The Status and Plans of Satellite Laser Ranging at Yunnan Observatories (3050)
- J. Griffiths, Preliminary Bias Estimates for SLR Observations at Stafford, Virginia (3054)
- W. Smith, Status of SLR upgrades at the U.S. Naval Research Laboratory's Optical Test Facility (3056)
- R. Carman, Remote Control and Safety Upgrades at the Yarragadee MOBLAS-5 Station (3069)
- S. Yu, Daekdeok Station Receive Optical System Upgrade (3076)
- F. Deleflie, Dissemination of SLR data-related products through a Virtual Observatory: developments 2014-2015 (3084)
- J. del Pino, A Format Proposal for Reporting SLR-Airspace interaction Events (3107)
- J. del Pino, A Spreadsheet Tool for the Visualization of Long Term Calibration Series Parameters (3111)
- C. Moore, Start Detector Time Walk Compensation (3133)
- J. Luck, The Importance of Minicos (3134)
- Y. Kim, A Status Report on KASI Prediction Center (KAS) (3137)
- E. Pavlis, A Multi-platform Package for the Visualization of the ILRS QC Reports (3139)
- M. Torrence, The ILRS "Global Report Card" (3163)
- J. Woo, Tracking Statistics for High Performing SLR Stations (3166)

## Posters (continued)

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### Session 18: New Applications: Laser Communications (Poster Only)

G. Vallone, Quantum Communications Demonstrated For Satellite Downlink At MLRO (3062)

D- Phung, DOMINO: Laser Communication Between SOTA, Onboard SOCRATES Satellite, and MEO Optical Ground Station (3095)

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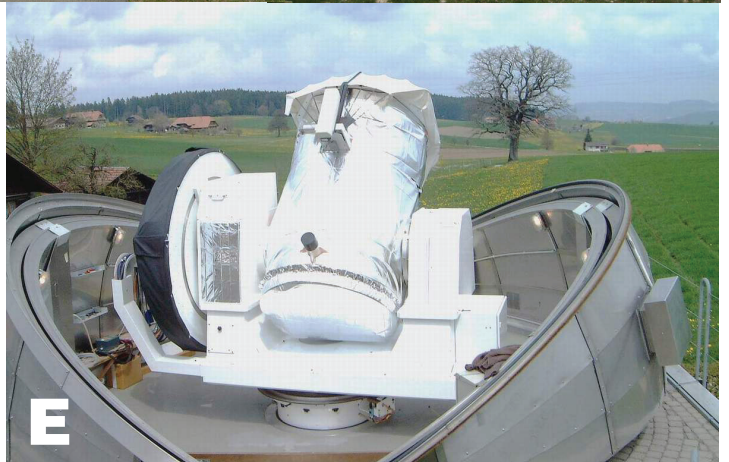












**A.** Matera

**B.** Mt. Stromlo

**C.** NGSLR at Greenbelt

**D.** Grasse

**E.** Zimmerwald

**F.** Graz

**G.** ARGO system at Daedeok

**H.** Badary



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