

Fiftieth Anniversary of the First SLR Measurement Celebrated at the 19th International Workshop on Laser Ranging

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The 19th International Workshop on Laser Ranging was hosted by NASA Goddard Space Flight Center from October 27-31, 2014 in Annapolis, Maryland. October 31 marked the 50th anniversary of the first successful Satellite Laser Ranging (SLR) measurement, which occurred at the Goddard Geophysical and Astronomical Observatory (GGAO) in 1964. The theme for this workshop, "Celebrating 50 Years of SLR: Remembering the Past and Planning for the Future" allowed the community to look back on its many accomplishments and to present plans for future advances in SLR technology and science. Sponsors for the workshop were NASA, the Smithsonian Astrophysical Observatory (SAO), and the International Laser Ranging Service (ILRS). The workshop was organized by Carey Noll (NASA GSFC, CDDIS Manager), Jan McGarry (NASA GSFC), Mike Pearlman (SAO), and Stephen Merkowitz (NASA GSFC); many others contributed to making the conference a success. Over 180 people from 23 countries participated in the meeting.



Participants in the 19th International Workshop on Laser Ranging, Annapolis Maryland, October 27-31, 2014. *(Photo by Deborah McCallum, NASA GSFC)*

The participants were welcomed by several dignitaries including Giuseppe Bianco, Chair of the ILRS Governing Board, Hansjörg Kutterer, Chair of the GGOS Coordinating Board, Jack Kaye, the Associate Director for Research, Earth Science Division of NASA

Headquarters, Prof. Charles Alcock, Director of the Harvard-Smithsonian Center for Astrophysics, Dr. John Kress, Interim Under Secretary for Science at the Smithsonian Institution, and Victor Shargorodsky, Russian network representative.

The first session included a brief history of SLR through invited talks by six pioneers in the field. Henry Plotkin, head of the GSFC 1964 SLR team, recalled the events that led to the first successful laser ranging measurement on October 31, 1964, including all of the obstacles that had to be overcome to secure the necessary resources to fire those early laser pulses. Chuck Lundquist presented the early SAO program that established the international network of Baker-Nunn cameras and laser ranging systems. George Veis discussed the early recognition of the need for an international reference frame and the improved accuracy that SLR could provide. Francois Barlier reviewed the history of the CNES laser ranging program and its cooperation with SAO. John Bosworth reported on the contributions of the NASA Crustal Dynamics Project, including the formal organization of a large multinational program on space geodesy. The session concluded with a presentation on the early lunar laser ranging activities by Jim Faller, including some of the groundbreaking technologies that would later provide impetus for the evolution of the SLR systems.

The workshop included sessions on the role of laser ranging in science and international programs, advanced technology, current developments in networks, new applications of laser ranging, advances in GNSS ranging, and lunar, planetary, and transponder ranging.

Some of the highlights of the meeting were:

- Successful two-way optical links to the Mercury Laser Altimeter and optical/radio two-way links with MOLA, LOLA, and LCCD show the promise of interplanetary two-way optical transponders.
- Time transfer by laser link to Jason-2 (T2L2) has demonstrated the way to synchronize laser-ranging observatories to the nanosecond level; continued improvement is anticipated.
- The ILRS Analysis Centers have submitted their contribution to the IERS for the ITRF2013 development, which could be issued as early as the second quarter of 2015; some consideration is being given to extending the series through 2014, thereby making the ITRF model more current (ITRF2014).
- SLR remained a key contributor to POD and validation of ocean-altimeter missions including ERS-2, GFO, Jason-1 and -2, and Envisat, to the newer missions CryoSat-2, SARAL and HY-2a, and the upcoming Jason-3. Global coverage of the oceans has revealed large-scale dynamics and smaller-scale eddy transport. SLR has played an important role in the validation of the GPS derived orbits for ICESat-1 and would play such a role in future ice-altimeter missions.
- Lunar Laser Ranging currently provides many of the best tests of gravity that are available: strong equivalence principle, $G\dot{m}/G$, gravito-magnetism, geodetic precession, inverse square law, preferred frame effects, etc.; the availability of

the once-lost Lunokhod-1 reflector has provided an additional reflector to aid libration studies.

- A number of initiatives underway will address some of the large geographic gaps and technology voids in the ILRS network. The Russians have deployed an SLR system in Brasilia and are in the process of deploying one in Havana. Several more station installations are scheduled over the next few years. The NASA Space Geodesy Program is planning up to ten CORE sites beginning with McDonald Observatory and Hawaii. New CORE sites are also underway on Sejong (Korea), Metsahovi (Finland), and Ny Ålesund.
- Many groups are implementing the new technology SLR hardware and software, enabling them to enhance data acquisition, pass interleaving, single photon operation, and different levels of automation; improved methods for aircraft spotting safety are also being implemented at several stations.
- While GRACE is providing an unprecedented insight into the time variations in the Earth's gravity field, the longest wavelength gravity field components and their time variations are provided by SLR, helping to put observations from GRACE into the proper context of long-term changes.
- New-generation SLR system designs in both Russia and China offer promise of improved signal-to-noise performance and less susceptibility to the introduction of range biases.
- Several stations have begun to include space debris tracking in their activities; the ILRS has formed a study group to organize a test program and interface with user agencies that are interested in the data products; concern was expressed that this activity may interfere severely with the ILRS satellite tracking priorities.
- A recent SLR tracking campaign on the GNSS constellations demonstrated that some stations were able to track more than thirty GNSS satellites over the course of a week without significantly decreasing coverage of other satellites; however, sampling along the passes and daylight ranging are still lacking. A second campaign is now underway. Five stations participated in short campaigns on the Indian IRNSS geosynchronous satellites.
- Many new and creative ideas on retroreflector array development are being explored to increase cross-section and reduce weight.

On the final day of the workshop, a new format for a station operations session was introduced, where ILRS experts met in small groups with station engineers and operators to provide: solutions to common station problems, information on maintaining station configuration stability, and guidelines for interacting with the analysts in determining station biases. These station clinics were well attended and well received by workshop attendees.

In addition to the events in Annapolis, the participants were transported by bus to GSFC, for a full day visit to Goddard facilities and GGAO, including tours of the Goddard Visitor's Center, spacecraft and instrument Integration and testing facilities, the James

Webb Space Telescope (JWST) integration and testing chambers, and tours of the NASA next generation space geodesy systems at GGAO. A Goddard Joint Engineering and Scientific Colloquium featured a seminar by John Degnan, "A Celebration of Fifty Years of Satellite Laser Ranging." John's talk was introduced with a few words from GSFC Center Director, Chris Scolese.



Jan McGarry leading a tour of the NASA's Next Generation SLR prototype system during the visit to GSFC. *(Photo by Mark Torrence/SGT Inc.)*

A highlight of the workshop was an entertaining talk and question and answer period at the Thursday evening banquet by Dr. Piers Sellers, GSFC Deputy Director of the Sciences and Exploration Directorate and a NASA astronaut. Sellers related some of his humorous experiences prior to and during his three Shuttle journeys and six space walks (not clear why they call them walks since they do little walking). Pippo Bianco, chair of the ILRS Governing Board, presented the ILRS Pioneer Award to John Degnan and Michael Pearlman during the banquet, citing their leadership and contributions to the field of SLR.



John Degnan, Henry Plotkin, and Michael Pearlman, recent and past recipients of the ILRS Pioneer Award. (Photo by Felipe Hall/HTSI)

The workshop concluded with several resolutions:

- Because of the importance of the Etalon satellites to the reference frame and other Earth dynamic properties, the ILRS should organize, monitor, and analyze a three-month tracking campaign on these satellites.
- To support the great potential for laser time transfer, the ILRS encourages the SLR stations to support laser time transfer activities such as T2L2 and address error sources and accuracy in their ranging systems.
- Future workshops should include speakers with a broad historical perspective to stress the importance of multi-generational history and information exchange.
- The participants acknowledged and thanked the local organizers and corporate sponsors who made the workshop a great success

The workshop program included 81 oral presentations and over 70 posters. The Program section of the workshop website includes links to all abstracts, presentations, and posters; papers for the proceedings will be published electronically only through this website. The workshop program book is also available through this link.

This workshop in Annapolis and GSFC proved to be a very successful gathering of international experts in the field of satellite laser ranging. The workshop website is hosted by the CDDIS and available at: <http://cddis.gsfc.nasa.gov/lw19/>. This website will soon be updated with additional presentations, posters, summaries, and photos from the week.



A beautiful fall day in Annapolis Maryland. *(Photo by Deborah McCallum, NASA GSFC)*