The Lunar Reconnaissance Orbiter and Our New View of the Moon

John W. Keller, NASA’s Goddard Space Flight Center

Abstract: The Lunar Reconnaissance Orbiter (LRO) has been in orbit about the Moon for over five years. During that time, a remarkable transformation of our understanding of Earth’s nearest neighbor has taken place. Prior to LRO and other recent missions, both from NASA and other space-faring nations, the Moon was thought to be inactive, with changes taking place over long time scales as a result of the solar wind and meteoric impacts. We now know that the Moon is still geologically active; that it contains sufficient water to be used as a resource for future explorers; that areas of the poles are sufficiently cold to trap volatiles over geological timescales; the trapped volatiles may provide a record of volatile delivery to the Earth. Likewise, the Moon retains the impact history of the Earth-Moon system, and provides clues to formation of the Earth and the evolution of the Solar System.
Reminder

After the meeting, everyone is invited to join us at Plato's Diner in College Park. Plato's is located at 7150 Baltimore Ave. (US Rt. 1 at Calvert Rd.), just south of the university's campus. What if it's clear and you want to stick around and observe? No problem -- just come over when you're through. This is very informal, and we fully expect people to wander in and out.

LROC’s Views of the Moon

The Lunar Reconnaissance Orbiter Camera (LROC) system takes high-resolution photos of the Moon's surface. LROC captured images of Chang'e & Yutu (China) at different Sun angles from February – May 2014 in Mare Imbrium. Yutu's shadow and tracks from Chang'e are evident in following image.

An image of the Lunar Module of Apollo 11 (US) in Mare Tranquilitatis was also captured. There’s a trail (the dark line) that leads 50 meters to the east of the module where Neil Armstrong ran over to get an impromptu look inside a crater.

LRO – continued from page 1

human exploration of Mars and other destinations. The mission was part of NASA’s Exploration Systems Mission Directorate (ESMD). The ESMD goals were to produce accurate maps and high-resolution images of future landing sites, assess potential lunar resources, and characterize the radiation environment. The mission was completed after one year. Since then, LRO has transitioned from being a reconnaissance to being a science mission, under NASA’s Science Mission Directorate.

Major accomplishments from the LRO mission include:

- Discovery that the Moon is shrinking, based on the analysis of small widely distributed tectonic features.
- Discovery of geologically recent volcanism on the Moon, as recent as 50 million years ago instead of over 1 billion years ago as previously thought.
- Determination of the shape and topography of the Moon more accurately than any planet (including the Earth), and use of these measurements to characterize, globally, the Moon's tidal motions.
- Discovery of numerous impacts on the Moon occurring during the LRO mission.
- Characterization of lunar pits, which are thought to be collapsed volcanic vent tubes (these are places with relatively benign environments, where outposts may be constructed in the future).
- Accurate determination of areas at the lunar poles that are in permanent shadow and relevant temperatures. These areas were found to be colder than any previously measured place in the Solar System. They can be as cold as 25 K.
- Mapping the distribution of hydrogen, thought to be in the form of water, at the lunar poles. Some of the water, but not all, is concentrated in the permanently shadowed areas.

The LRO mission has been extended for an additional two years. During the extended mission, the orbiter will continue to explore the Moon, building on prior observations from LRO and other missions. The five themes of focus will be: 1) Transport of Volatiles, 2) Contemporary Surface Change, 3) Regolith Evolution, 4) Probing the Interior from Observations of the Surface, and 5) Interactions with the Space Environment.

Biographical Sketch:

John Keller is the project scientist for the Lunar Reconnaissance Orbiter Mission. Prior to LRO he worked on instrument development on numerous missions, including WIND, POLAR, and DSCOVR. His training is in physical chemistry, with a Ph.D. from the University of Maryland. He maintains an active laboratory research effort in which he simulates the interaction of the solar wind with planetary surfaces.
February 2015
Vol 7
3, Iss 6

Sky Watchers

February

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
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<tbody>
<tr>
<td></td>
<td>the Constellation Leo. <em>Best Washington DC viewing time is 12:30 am</em></td>
</tr>
<tr>
<td>18-9</td>
<td>Overnight – <strong>Deep Sky</strong>, N. Hemisphere. <em>Bode’s Galaxy</em> (M81, NGC 3031) in the</td>
</tr>
<tr>
<td></td>
<td>Constellation Ursa Major. <em>Best Washington DC viewing time is midnight</em></td>
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<tr>
<td>19</td>
<td>2:28 am – <strong>Planets</strong>, N. &amp; S. Hemispheres. Moon (at perigee, only 221,826 miles</td>
</tr>
<tr>
<td></td>
<td>from Earth)</td>
</tr>
<tr>
<td>20</td>
<td>8:00 pm – <strong>Planets</strong>, N. Hemisphere. Venus 2° south of Moon</td>
</tr>
<tr>
<td>26-7</td>
<td>9:17 pm-3:02 am – <strong>Occultation/Eclipse Combo</strong>, N. Hemisphere. Features: <strong>Io</strong>,</td>
</tr>
<tr>
<td></td>
<td><strong>Ganymede &amp; Callisto</strong></td>
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March

<table>
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<tr>
<th>Date</th>
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<tbody>
<tr>
<td>5</td>
<td>1:06 pm – <strong>Full Moon</strong>, Global. Other Moon Names: <strong>Full Crow Moon</strong>, **Full Sap</td>
</tr>
<tr>
<td></td>
<td>Moon, <strong>Full Worm Moon</strong> (worms reappear for spring birds)</td>
</tr>
</tbody>
</table>

Times EST

The NCA Star Dust Scanning Project: a 15-Year Effort

Wayne H. Warren, Jr.

The *Star Dust* publication of the National Capital Astronomers (NCA) is quite different from most other publications in that there is only one copy of the complete run in the world. This collection is housed in the library of the U.S. Naval Observatory in Washington, DC (USNO). No private collection that even approaches completeness exists. In 1998 while looking through some old issues of *Star Dust* at the USNO, I thought about the fact that if anything happened to the USNO collection, our publication would be lost forever. Therefore, I decided to compile an index of all issues as a starter
Star Dust Scanning Project – continued from page 3

to ensure that at least a record of all meetings and guest speakers would be preserved, with the idea that a project to scan the actual paper copies would eventually be undertaken. At the time, such a project seemed a daunting task. However, the indexing was begun and worked on over the next several years whenever I was at USNO for some other purpose such as colloquia, library usage, to visit other astronomers, etc. Through the kindness of librarians Brenda Corbin and Sally Bosken, I was able to take my laptop computer to the USNO library and work in the room that houses the Star Dust collection. After I had compiled most of the index, I discussed the scanning of Star Dust with Sally Bosken. It was clear that I couldn’t very well remove the collection from the library, so the scanning would need to be done there. Sally informed me that she sometimes had students working in the library on a temporary basis and that we could discuss the project the next time that a student was available.

During the holiday season of 2007-8, Sally Bosken informed me that a student was working at the USNO library and could spend some time on the scanning project. The library has a photocopying machine that can scan and produce PDF images only. The machine can’t do the Optical Character Recognition (OCR) work that I wanted; however, once the images are available, OCR is a fairly simple procedure. The student, Nick Kutchak, was assigned the task of scanning the early issues and was able to complete the work up through 1969. Since issues of Star Dust for 2000 and newer were being produced in PDF format, we needed to scan and OCR all issues between 1970 and 1999, including certain other issues that had not turned out properly during their initial scans. An announcement was made at an NCA meeting asking for volunteers to help with the work and a computer file was designed to keep track of the assignments and dates of dispersal and return. Although I had a collection of Star Dust issues going back to the early 1990s, I did not have issues back to 1970. Collections of issues from Leith Holloway, Bob McCracken, Jay Miller, Jerry Schnall, and Morton Schiff were donated and used to complete the hardcopy inventory destined to be scanned by the volunteers. Issues were dispensed by whole years and the resulting scans were checked and OCRd if necessary. The table on page 6 contains information about the completed scanning assignments.

The issues scanned at the USNO were not OCRd initially and that job had to be done by me. It was important to produce a finished product that can be searched by users. Automated searches work for the most part, but certain text such as handwritten material can’t be found by machine. Following the scanning, checking, and any other work needed, the issues were sent to Elizabeth Warner for transfer to the NCA website, where they are available to anyone who wants them. The final set of issues will be committed to archival-quality CDs and the NCA meeting/lecture index will be transferred to the website so that it will be available to everyone.

continued on page 6
Occultation Notes

- D following the time denotes a disappearance, while R indicates that the event is a reappearance.
- When a power (x; actually, zoom factor) is given in the notes, the event can probably be recorded directly with a camcorder of that power with no telescope needed.
- The times are for Greenbelt, MD, and will be good to within +/-1 min. for other locations in the Washington-Baltimore metropolitan areas unless the cusp angle (CA) is less than 30 deg., in which case, it might be as much as 5 minutes different for other locations across the region.
- Some stars in Flamsteed's catalog are in the wrong constellation, according to the official IAU constellation boundaries that were established well after Flamsteed's catalog was published. In these cases, Flamsteed's constellation is in parentheses.
- Further explanations & more information can be found on the main IOTA Web site.
- Notes following a /.

Mid-Atlantic Occultations

David Dunham

Asteroidal and Planetary Occultations

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<thead>
<tr>
<th>Date</th>
<th>Day</th>
<th>EST/EDT</th>
<th>Star</th>
<th>Mag</th>
<th>Iota</th>
<th>dmag</th>
<th>dur.</th>
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<tr>
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<td>Sun</td>
<td>5:01</td>
<td>SAO 160928</td>
<td>9.8</td>
<td>1</td>
<td>3</td>
<td>1</td>
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<td>18:47</td>
<td>2UC31273915</td>
<td>12.5</td>
<td>5</td>
<td>6</td>
<td>8</td>
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<td>M  b</td>
<td>5:24</td>
<td>BAO 27984</td>
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<td>3</td>
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<tr>
<td>Mar 2</td>
<td>Mon</td>
<td>4:01</td>
<td>4UC66305216</td>
<td>12.9</td>
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<td>7</td>
<td>8</td>
<td>10SNF</td>
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<td>2UC29480870</td>
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<td>3</td>
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Lunar Grazing Occultations

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<th>% alt</th>
<th>CA</th>
<th>Sp.</th>
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<td>Wed</td>
<td>21:04</td>
<td>ZC 1753</td>
<td>6.7</td>
<td>98</td>
<td></td>
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<tr>
<td>Feb 28</td>
<td>Sat</td>
<td>0:14</td>
<td>20 Geminorum</td>
<td>6.9</td>
<td>74+</td>
<td>33</td>
<td>11N</td>
<td>Damascus, APL, Gambrills, MD</td>
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<tr>
<td>Feb 28</td>
<td>Sat</td>
<td>15:21</td>
<td>Gem</td>
<td>6.3</td>
<td>74+</td>
<td>33</td>
<td>11N</td>
<td>Dullies, Anandal, VA; Brndwyln, MD</td>
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Total Lunar Occultations

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<th>Ph Star</th>
<th>Mag</th>
<th>% alt</th>
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<td>Feb 22</td>
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<td>19:19</td>
<td>PPisci um</td>
<td>8.2</td>
<td>21+</td>
<td>35</td>
<td>88N</td>
<td>ZC 274</td>
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<tr>
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<td>22:13</td>
<td>SAO 110215</td>
<td>7.8</td>
<td>23+</td>
<td>80</td>
<td>80A</td>
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</tr>
</tbody>
</table>

Further explanations & more information is at [http://iota.jhuapl.edu/expخد.htm](http://iota.jhuapl.edu/expخد.htm)

David Dunham, dunham@starpower.net, phone 301-526-5590

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Acknowledgments

This project could not have been done without the cooperation and help of the USNO librarian, Sally Bosken, who is also an NCA member. The help of Nick Kutchak with the actual scanning work is greatly appreciated. The work of the NCA volunteers listed in the table allowed the completion of the project on a reasonable timescale, as there was far too much scanning to be done by any one person. I am grateful for their work and dedication to the project. I am also indebted to Elizabeth Warner for moving issues to the NCA website and for proofing the early PDF files. Several archival-quality CDs were donated by Alan Bromborsky for transfer of the final set of Star Dust issues to permanent media.

Table of Scanning Assignments and Work Completed *

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<thead>
<tr>
<th>Name</th>
<th>Year(s)</th>
<th>Done</th>
<th>#</th>
<th>Remark(s)</th>
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<td>Bromborsky Alan</td>
<td>1992</td>
<td>2010</td>
<td>1</td>
<td>Complete year scanned; OCRed by WHW</td>
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<tr>
<td>Peterson Norman</td>
<td>1995</td>
<td>2009</td>
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<tr>
<td>Warner Elizabeth</td>
<td>1943-1955</td>
<td>2009-12</td>
<td>13</td>
<td>USNO PDF files checked and edited</td>
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<tr>
<td>Weissberg Marjorie</td>
<td>1979-80, 1983, 1986</td>
<td>2010-11</td>
<td>4</td>
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<tr>
<td>Wing Simon</td>
<td>1985</td>
<td>2010</td>
<td>1</td>
<td>Images only; OCRed by WHW</td>
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</table>

* Approximately 620 issues of Star Dust were scanned, including some issues that did not scan well on the first attempt and had to be redone. All issues were processed by OCR so that the text can be searched for strings of characters. An index of all issues was prepared, containing meeting dates, speaker identifications, topics, affiliations, and miscellaneous information. In fact, the index was started way before any scanning took place. The index will be kept up to date and put onto the NCA website periodically.
Orion – continued from page 3

The Hearth and the Flame

called K’ak (M42, the Orion Nebula). Many K’iche’ Maya still call these stars “the hearth stones” and refer to M42 as “the smoke from the hearth.”

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Calendar of Events

- **NCA Mirror- or Telescope-making Classes:** Tuesdays and Fridays, from 6:30 to 9:45 pm at the Chevy Chase Community Center (intersection of McKinley Street and Connecticut Avenue, N.W.) Contact instructor Guy Brandenburg at 202-635-1860 or email him at gfbbrandenburg@yahoo.com.

- **Open house talks and observing at the University of Maryland Observatory** in College Park on the 5th and 20th of every month at 8:00 pm (Nov.-Apr.) or 9:00 pm (May-Oct.). Details: [www.astro.umd.edu/openhouse](http://www.astro.umd.edu/openhouse)

- **Phoebe Waterman Haas Public Observatory** at the National Air & Space Museum, Solar viewing, Wed. - Sun., 12 - 3 pm (weather permitting).

- **Mid-Atlantic Senior Physicists Group:** “Quantum Entanglement” with James Franson (Univ. of MD-Baltimore County), Wed. Feb. 18, at 1 pm at the American Center for Physics (1st floor conference room). [http://www.aps.org/units/maspg/](http://www.aps.org/units/maspg/)

- **Smithsonian’s Stars Lectures:** “Tracing the Structure of the Universe with Galaxy Surveys” with Cameron McBride (Harvard-Smithsonian Center for Astrophysics), Sat. Feb. 21, 5:15 pm at the Einstein Planetarium, National Air & Space Museum. [http://airandspace.si.edu/events/lectures/smithsonian-stars/](http://airandspace.si.edu/events/lectures/smithsonian-stars/).

- **Upcoming NCA Meetings at the University of Maryland Observatory:**

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Clear Skies!

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National Capital Astronomers Membership Form

Name: ___________________________________________________________ Date: ___/___/___

Address: _________________________________________________________ ZIP Code: _____

Home Phone: _____-____-____ E-mail: ___________________ Print / E-mail Star Dust (circle one)

Membership (circle one): Student….. $5; Individual / Family…..$10; Optional Contribution…..$__

Please indicate which activities interest you:

- Attending monthly scientific lectures on some aspect of astronomy
- Making scientific astronomical observations
- Observing astronomical objects for personal pleasure at relatively dark sites
- Attending large regional star parties
- Doing outreach events to educate the public, such as Exploring the Sky
- Building or modifying telescopes
- Participating in travel/expeditions to view eclipses or occultations
- Combating light pollution

Do you have any special skills, such as videography, graphic arts, science education, electronics, machining, etc.?

Are you interested in volunteering for: Telescope making, Exploring the Sky, Star Dust, NCA Officer, etc.?

Please mail this form with check payable to National Capital Astronomers to:

Henry Bofinger, NCA Treasurer; 727 Massachusetts Ave. NE, Washington, DC 20002-6007
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Next NCA Meeting:
2015 February 14th
7:30 pm
@ UMD Observatory

Dr. John Keller