# A Multinational Lunar Research and Development Park

## Lunar-based R&D, Education and Training

2010 JUSTSAP Symposium

Greg Schmidt
Deputy Director, NASA Lunar Science Institute

# Topics for discussion

- What is a research park?
- The "new Moon" (things are different this time around)
- Research on the Moon – to understand:
  - The Moon itself
  - The solar system
  - The universe
- NLSI – a quick update
- Public engagement and participation
- Summary
- A vision

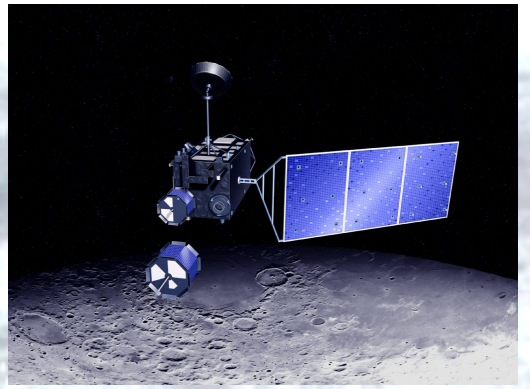
# What is a research park?

- Wikipedia:
  - A Research park is a research facility which is often linked with a major research university
  - More than 170 research parks throughout North America
  - Exist to create linkages between the university(-ies), industry and the community [government]
  - First research park was Stanford, created in 1951 – numerous success stories have included Hewlett Packard, Varian and many others
    - "Cornerstone of Silicon Valley"

- Can a research park environment be created on the Moon? What would be the benefits? What are the necessary ingredients?

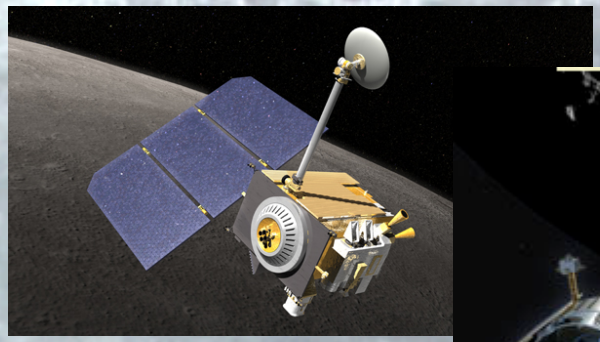
# What's different #1: The World Returns to the Moon

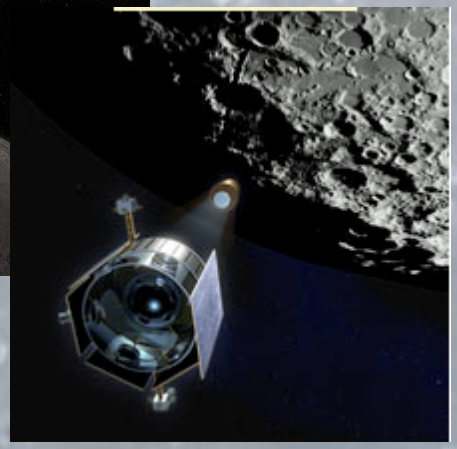
**Chang'e 1:** China
(**Chang'e 2** launched September 2010)



**Selene / Kaguya:** Japan (JAXA)

**Chandrayaan-1:** India





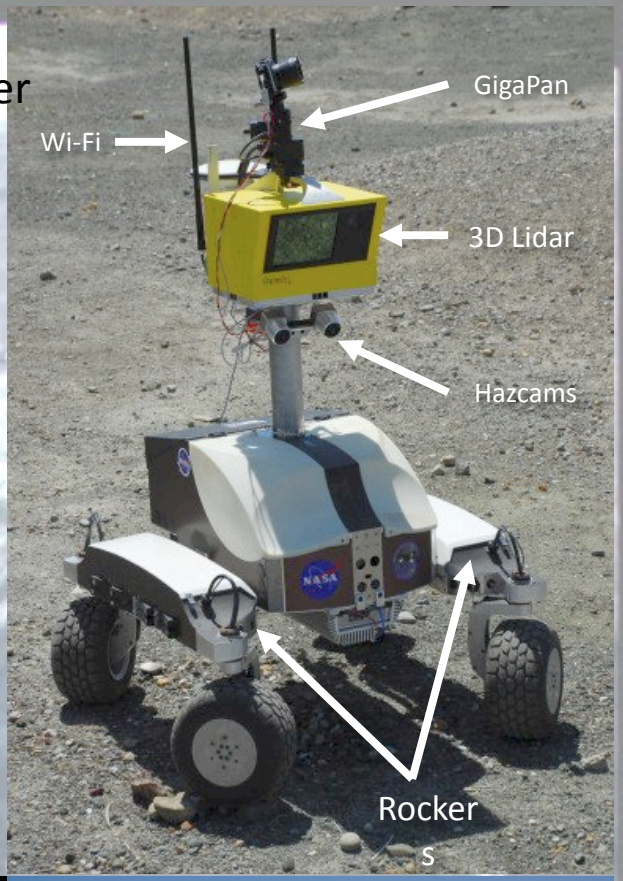
**LRO & LCROSS**
USA (NASA)
(LADEE, GRAIL in Waiting)

# What's different #2: The Moon – a new era of commerce?

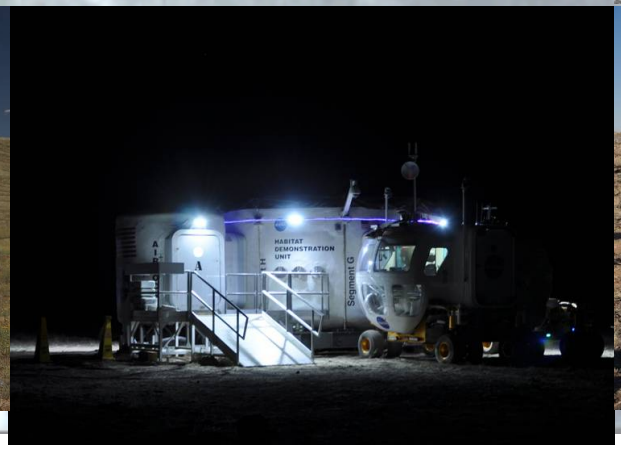
Google
LUNAR
X PRIZE

# What's different #3: Robots and Analogs

K-10 Rover




- Analog environments can provide excellent testbeds for science, technology and procedures
- Desert RATS – a yearly robotic/human study effort conducted in the Arizona desert – has given many insights into robotic/human cooperation during space missions
- **Robotics has reached a level of maturity to deliver first class research results**



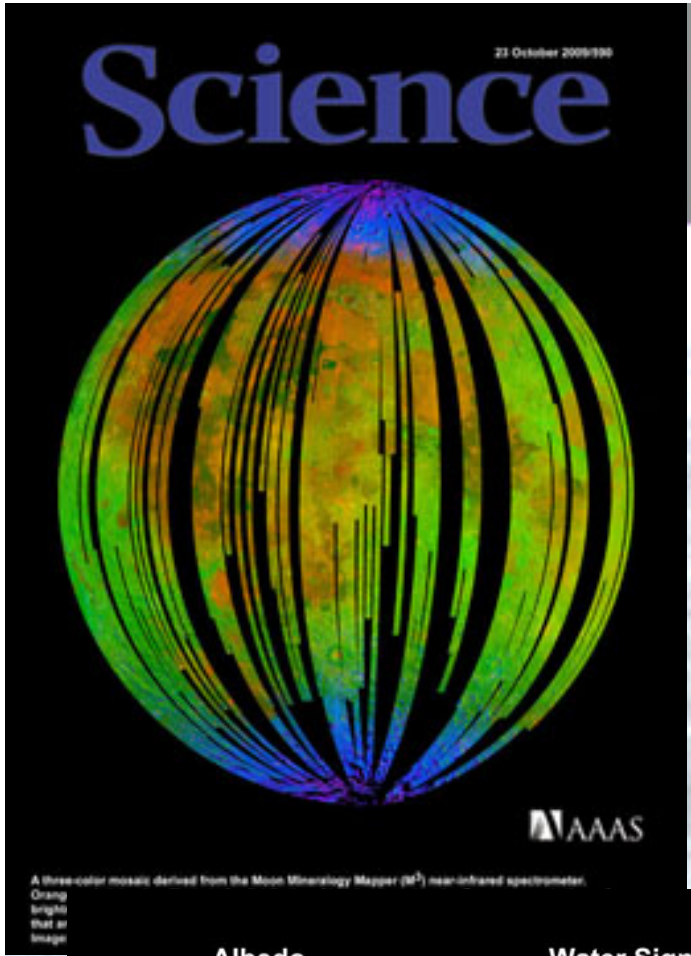
# Why the Moon?

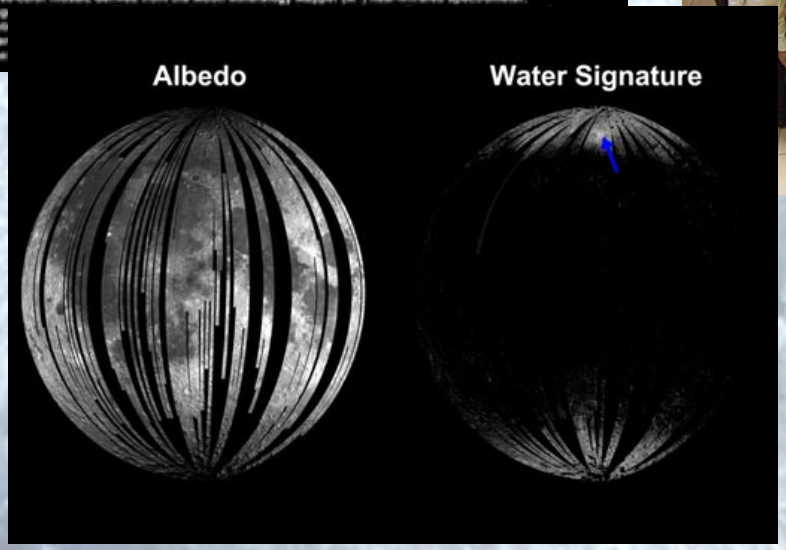
- It isn't your grandfather's Moon!
- Water – on the Moon?

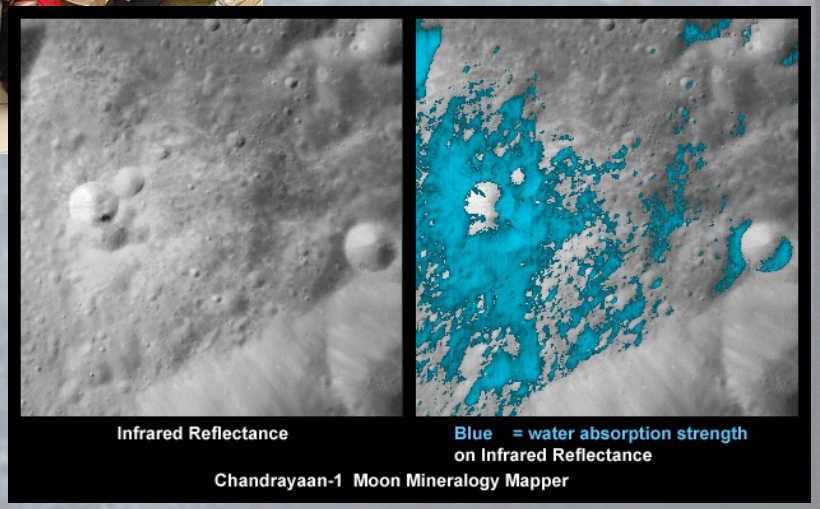
*Maybe not quite like this, but..*

# Water on the Moon

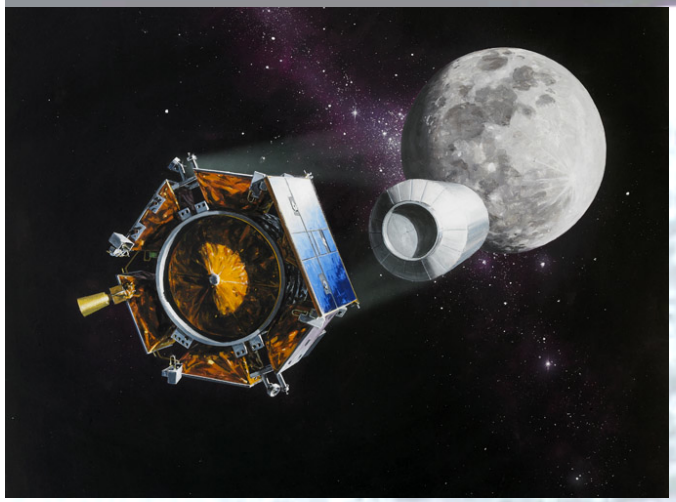
- World astounded by discovery of surface water using Chandrayaan-1 M3 instrument (verified with other data)



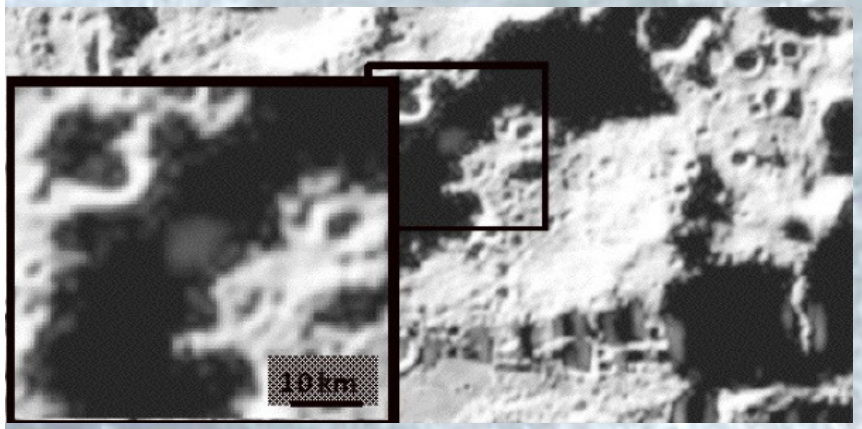


# Water on the Moon



- World astounded by discovery of surface water using Chandrayaan-1 M3 instrument (verified with other data)
- LCROSS impact on permanently shadowed crater Cabeus definitively proved existence of major amounts of water
  - Where did the water originate?



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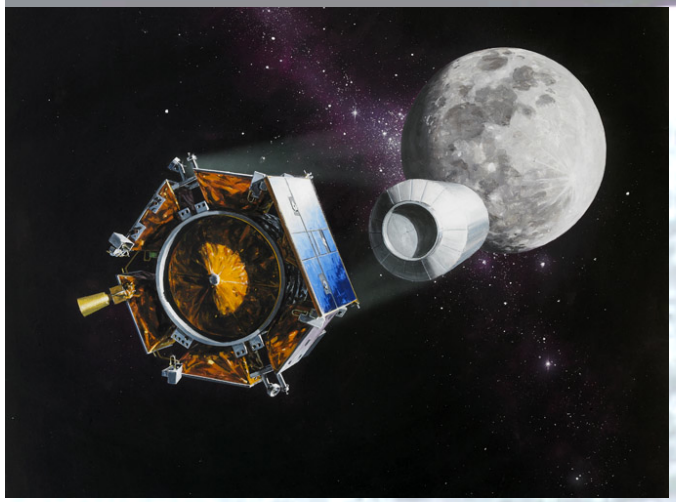
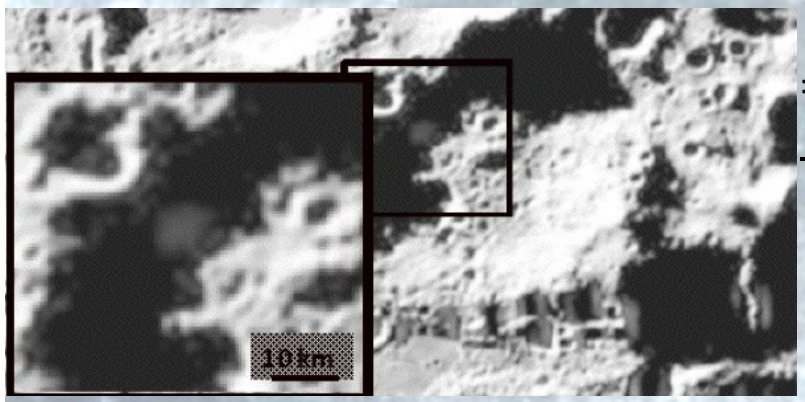


- World astounded by discovery of surface water using Chandrayaan-1 M3 instrument (verified with other data)
- LCROSS impact on permanently shadowed crater Cabeus definitively proved existence of major amounts of water
  - Where did the water originate?
- How much water?
  - Up to 2 m depth in polar regions (est from current radar data)

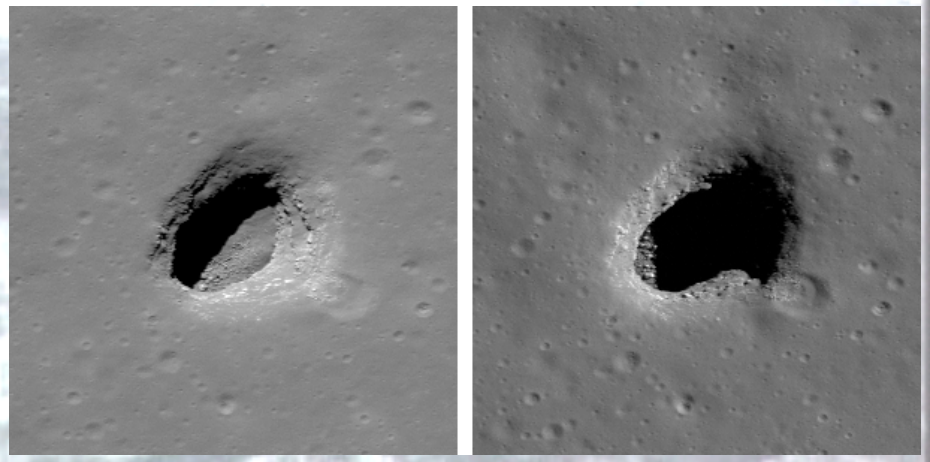
= one shuttle launch per day for 2,300 years

  - Getting the water? Support Gerry Sanders and ISRU!



# A few more discoveries

- New, strange images from Lunar Reconnaissance Orbiter show similarities to Earth features
  - *Shown: "pit crater" roughly 70 meters deep showing individual lava flows*



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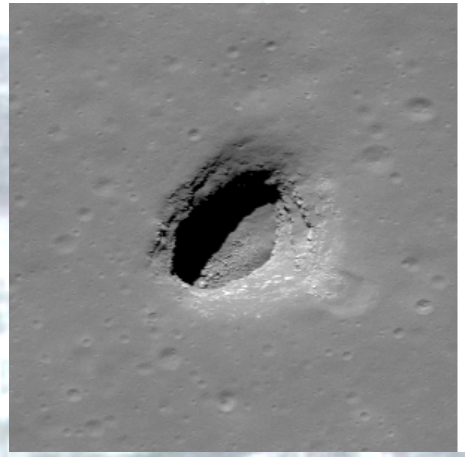
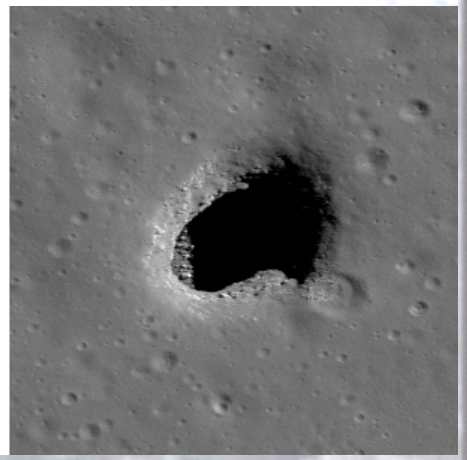
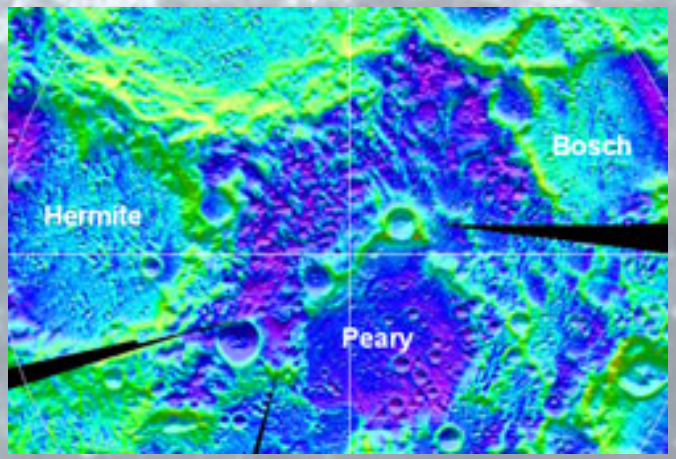




- The Moon has the coldest place measured in the Solar System
  - Diviner (LRO's temperature measuring instrument) measured an astounding -248 Celsius (25K) in the Hermite crater
  - By comparison, Pluto's surface temperature is a relatively balmy -184 Celsius

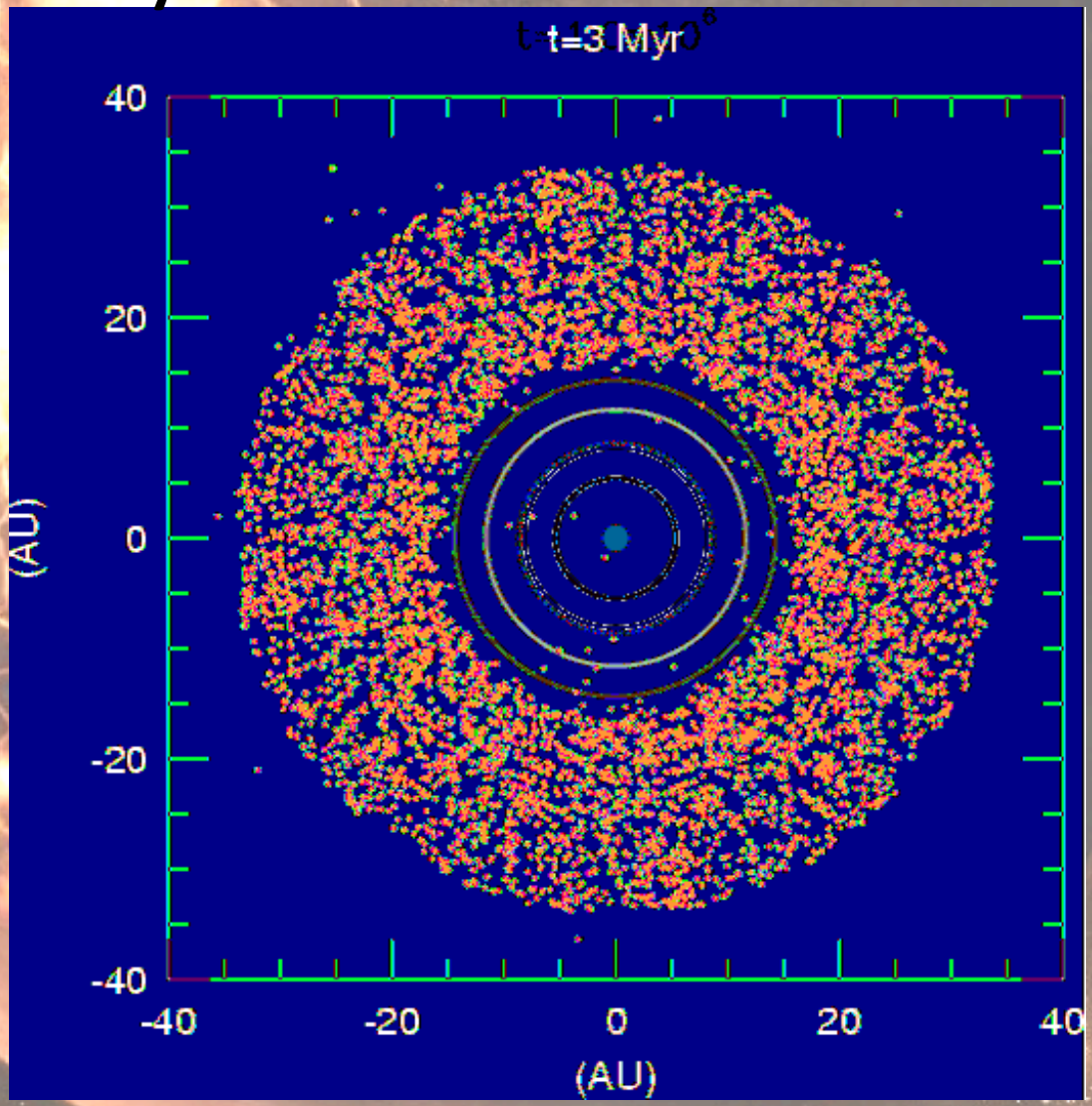


# The Moon: teaching us about the solar system

- Current theory, supported by 30+ years of evidence, says that the Moon arose from a giant impact by a Mars-sized planet with the early Earth
  - Recent modeling results supported by NASA Lunar Science Institute using more than 1M elements support this theory
- So, the Moon has been the Earth's cosmic companion for its entire 4 billion year history
- Unlike the Earth, the Moon preserves its entire ancient impact record
  - Including that of a "late heavy bombardment" whose origins are only now coming to light

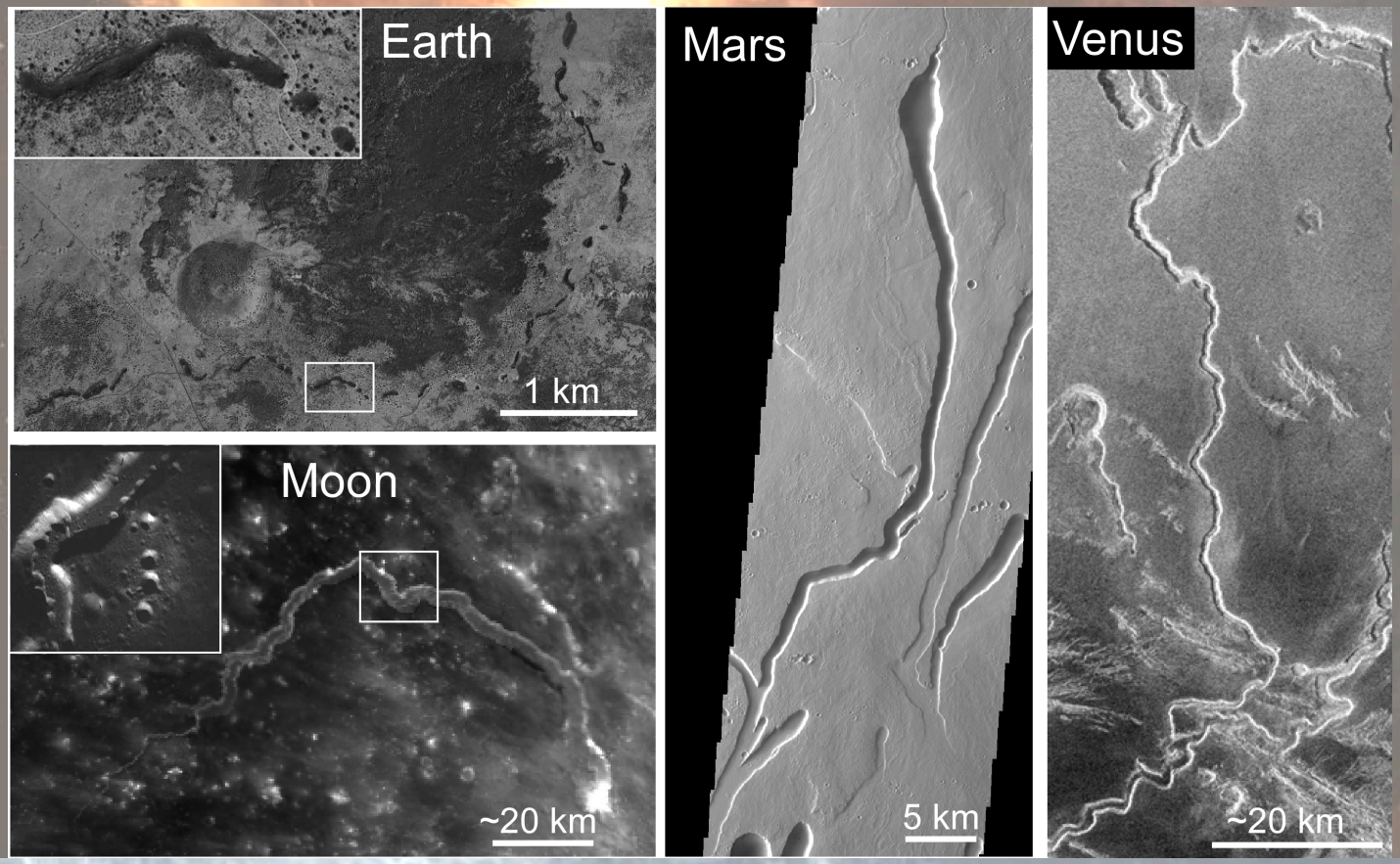
# The Moon: teaching us about the solar system

- Simulations of the early Solar System support the late heavy bombardment hypothesis
- An instability in Jupiter and Saturn's orbits leads to a 2:1 resonance
- Causes an orbital change of the giant planets and disruption of the early asteroids
- The record is preserved on the Moon!



# The Moon: teaching us about the solar system

- Inner planets and Moon have similar geological features
  - Growing evidence that what Moon has recorded can be used to broadly interpret geology of inner Solar System

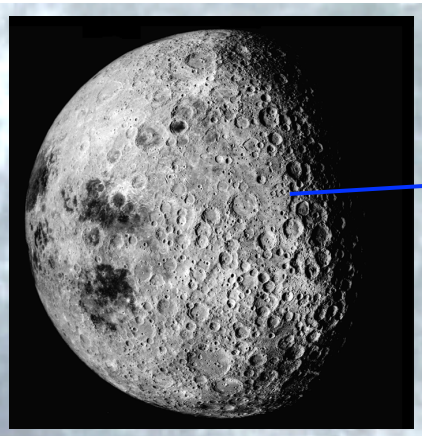


# The Moon: Peering into the universe's history

- Observations since the 1950s have been done of the era of the universe immediately following the big bang through ground and space microwave antennae
  - 2 Nobel prizes awarded for this work, including the first to a NASA scientist (John Mather)
- Additionally, observations have been done back in time from the present to the distant, "red-shifted" past using optical and infrared telescopes
- However, no significant observations have been done of the "Dark Ages" when the universe had cooled to the point where atoms could form, and at the point where the first stars were forming – an essential step to the first life

# The Moon: Peering into the universe's history

- What's special about the Moon?
  - In the required area of the radio spectrum, the far side of the Moon is the quietest area in the inner solar system
  - A far side radio observatory would be able to reveal the time when the first stars turned on - as well as some potentially exotic physics



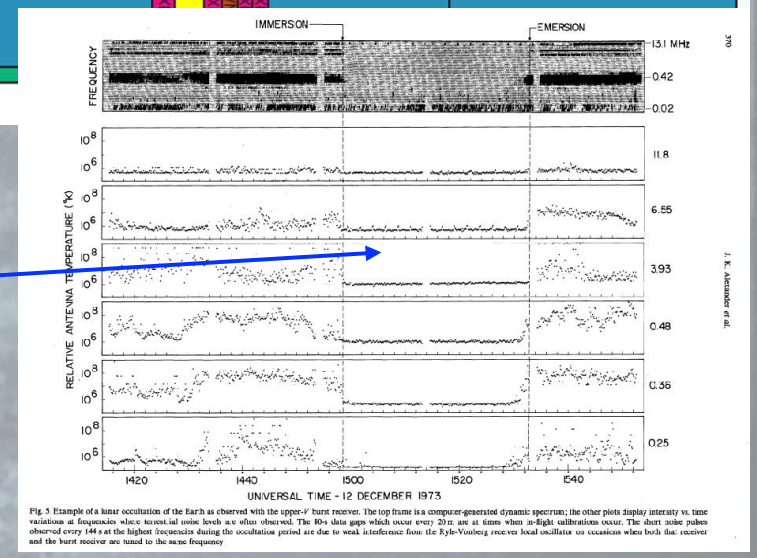
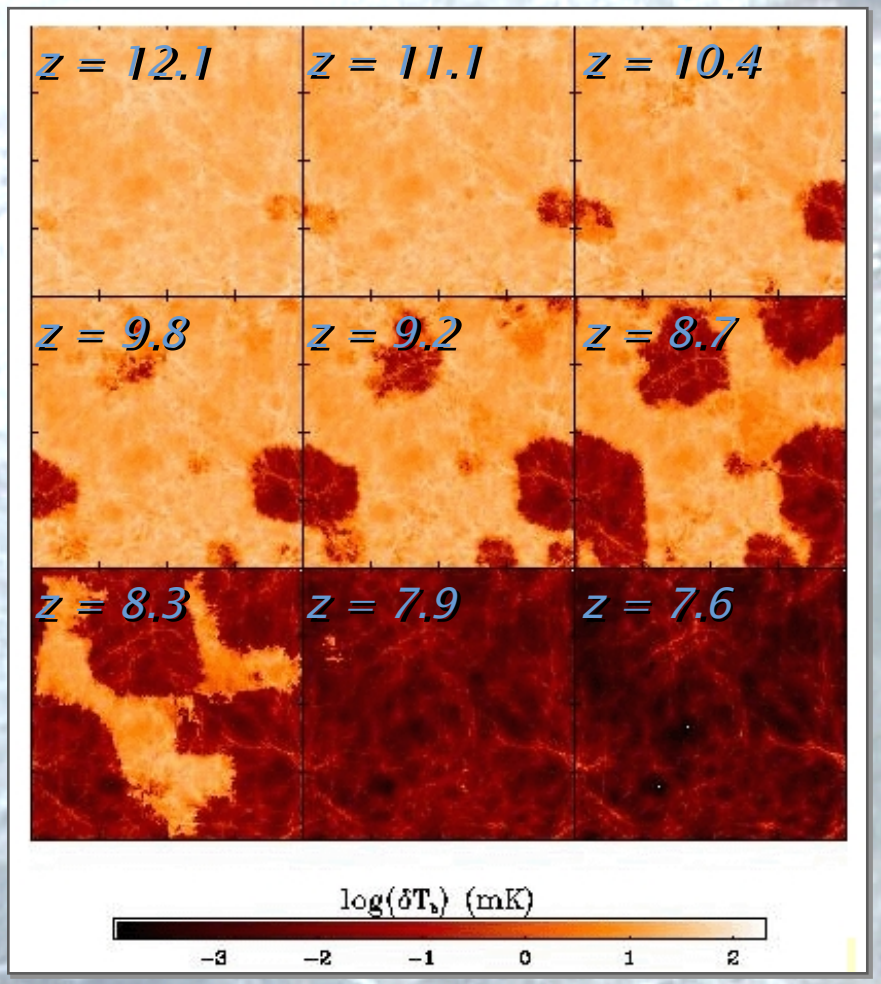
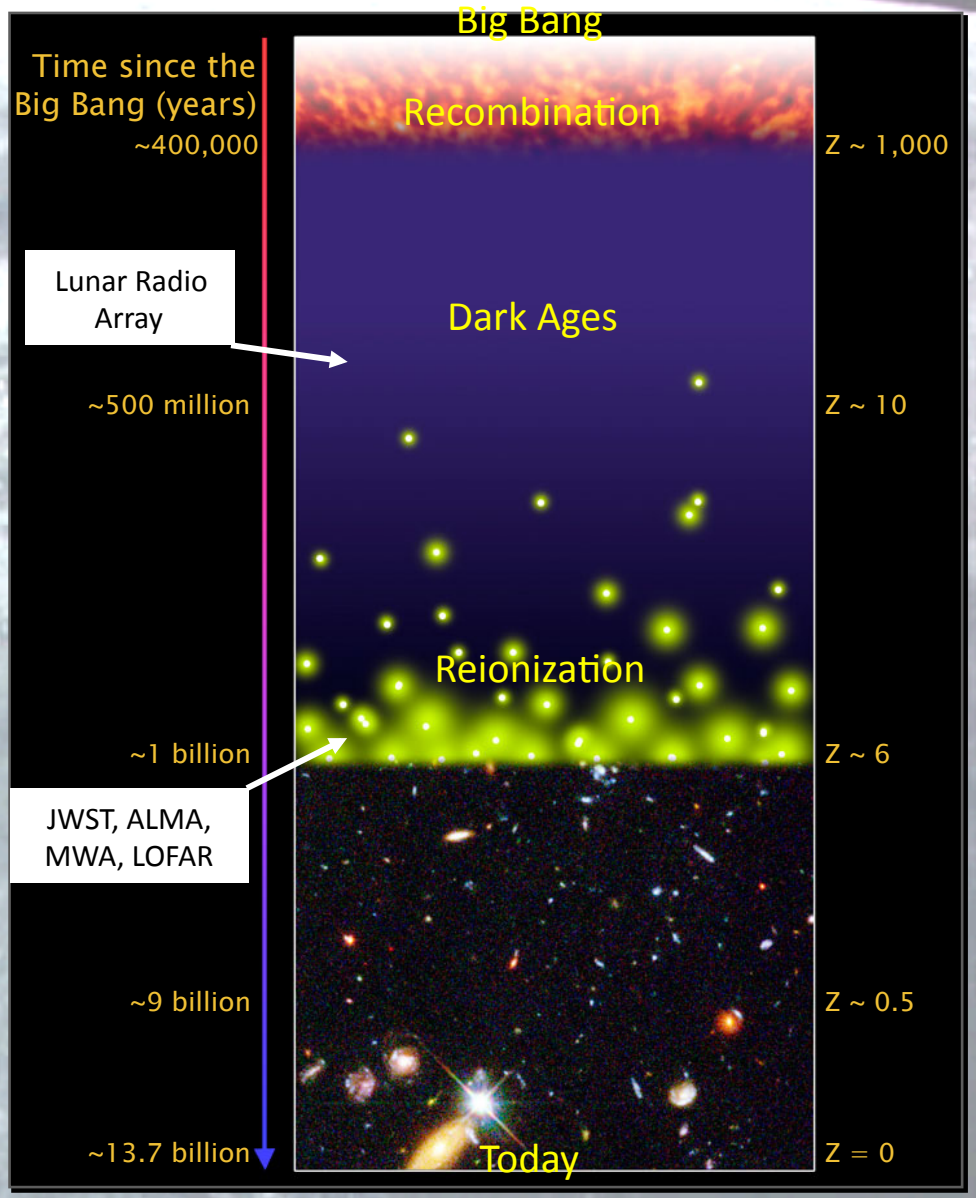



Fig. 3. Example of a lunar occultation of the Earth as observed with the upper-V burst receiver. The top frame is a computer-generated dynamic spectrum; the other plots display intensity vs. time variations at frequencies where terrestrial noise levels are often observed. The 80-s data gaps which occur every 20 m are at times when in-flight calibrations occur. The short noise pulses observed every 144 s at the highest frequencies during the occultation period are due to weak interference from the Ryle-Vonberg receiver local oscillator on occasions when both the receiver and the burst receiver are tuned to the same frequency.

# The Moon: Peering into the universe's history

- What might we see?



# The NLSI: a renewed emphasis on lunar science

NASA LUNAR SCIENCE INSTITUTE

**NLSI Mission**

- Carry out and supporting **collaborative research** in lunar science, investigating the Moon itself and using the Moon as a unique platform for other investigations
- Provide **scientific and technical perspectives** to NASA on its lunar research programs, including developing investigations for current and future space missions
- Support and catalyze the lunar science community and **train the next generation** of lunar science researchers
- Support education and public outreach by providing scientific content for K-14 education programs, and communicating directly with the public

# A new kind of institute – a new kind of research park?

NASA LUNAR SCIENCE INSTITUTE

- Virtual institutes bring together the very best of an existing research community
  - No new buildings
  - Small central office for institute administration and institute-wide programs
- Academic institutions within the virtual institute are ideal for educating the next generation of scientists, while connecting them with NASA and the broad community
- The direct connection to NASA ensures responsiveness to NASA strategic needs
- Virtual institutes have a proven history
  - Operationally, NLSI is modeled on the successful NASA Astrobiology Institute (NAI)
  - An NRC review of the NAI gave it very high marks for successfully implementing the virtual institute model

NASA LUNAR SCIENCE INSTITUTE

# *U.S. Teams*

**Understanding the Formation and Bombardment History of the Moon**
PI: Bill Bottke, Southwest Research Institute

**Impact Processes in the Origin and Evolution of the Moon: New Sample-driven Perspectives**
PI: David Kring, USRA/LPI

**Dynamic Response of the Environment At the Moon (DREAM)**
PI: Bill Farrell, NASA Goddard Space Flight Center

**Colorado Center for Lunar Dust and Atmospheric Studies (CCLDAS)**
PI: Mihaly Horanyi, University of Colorado – Boulder

**The Moon as Cornerstone to the Terrestrial Planets: The Formative Years**
PI: Carle Pieters, Brown University

**Scientific and Exploration Potential of the Lunar Poles**
PI: Ben Bussey, Johns Hopkins University

**Lunar University Node for Astrophysics Research (LUNAR): Exploring the Cosmos from the Moon**
PI: Jack Burns, University of Colorado - Boulder

# CURRENT INTERNATIONAL AFFILIATE TEAMS

**Canada**
PI: Gordon "Oz" Osinski,
University of Western Ontario

**Korea**
PI: Im Yong-Taek,
Korean Institute for Advanced Science & Technology (KAIST)

**United Kingdom**
PI: Mahesh Anand,
Open University

**Kingdom of Saudi Arabia**
PI: Haithem Altwaijry
King Abdulaziz City for Science and Technology (KACST)

**Israel**
PI: Shlomi Arnon
Ben-Gurion University at the Negev

**Netherlands**
PI: Wim van Westrenen
VU University Amsterdam

# Engaging the Public

# Exploration Uplink

*Participatory Exploration Using Tele-robotic Systems*

Ames Research Center

## International Demonstrations

- South African Astronomical Observatory, Cape Town South Africa 5/5
- University of Toronto Space Design Contest, Toronto Canada 5/15

## Traveling Space Museum

- McNair Academy, East Palo Alto, CA 4/2
- California School for the Blind, Fremont, CA 5/18
- Burnett Academy, San Jose, CA 5/20
- American Indian Public Charter School, Oakland, CA 5/25
- Cesar Chavez Middle School, Union City, CA 5/27
- Toyon Elementary School, San Jose, CA 5/27

## NASA Explorer Schools

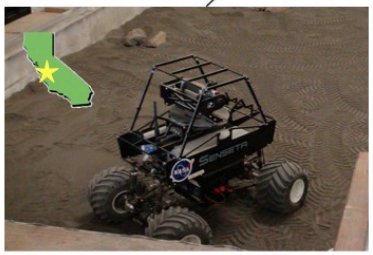
- Key Peninsula Middle School, Lakebay, WA 4/21
- Sequoia Middle School, Porterville, CA 5/13
- Vintage Math Science Tech. Magnet, North Hills, CA 6/11

## Special Events/Fairs

- Yuri's Night, Moffett Field, CA, 4/9-4/10
- Makers Fair, San Mateo, CA 5/22-5/23

## Local CA Schools

- Eastside College Prep. School, East Palo Alto, CA 3/5
- Eastside College Prep. School at NASA Ames 5/14
- Westmont High School, Campbell, CA, at NASA Ames 5/24



*NASA Research Park Test-bed*

*Eastside College Prep. School*

# FIELD TRAINING & RESEARCH PROGRAM AT METEOR CRATER

***2010 Participants***

Jeffrey Balcerski *(Case Western Reserve University)*
David Blair *(Purdue University)*
Matthew Chojnacki *(University of Tennessee)*
Patrick Donohue *(University of Notre Dame)*
Sarah Drummond *(University of Tennessee-Knoxville)*
Joshua Garber *(University of California-Davis)*
Michelle Hopkins *(University of Colorado-Boulder)*
Matthew Huber *(University of Vienna)*
Steven Jaret *(Harvard University)*
Anna Losiak *(University of Vienna)*
Analisa Maier *(University of Colorado)*
Julie Mitchell *(University of Houston-Clear Lake)*
Lissa Ong *(University of Arizona)*
Lillian Ostrach *(Arizona State University)*
Katie O'Sullivan *(University of Notre Dame)*
Ross Potter *(Imperial College London)*
Stuart Robbins *(University of Colorado-Boulder)*
Bhairavi Shankar *(University of Western Ontario)*
Erin Shea *(Massachusetts Institute of Technology)*
Kelsi Singer *(Washington University)*
Michael Sori *(Massachusetts Institute of Technology)*
Sebastian Sturm *(Westfälische Wilhelms-Universität Münster)*
Malte Willmes *(Westfälische Wilhelms-Universität Münster)*
Michael Zanetti *(Washington University)*

**19 PhD candidates**
**5 MS candidates**

COMING TO YOU 09.18.2010 ← *The Date*

# International Observe the Moon Night

*SEEING THE MOON IN A WHOLE NEW LIGHT*

NASA LUNAR SCIENCE INSTITUTE

LRO

LUNAR AND PLANETARY INSTITUTE

# MOON ZOO

## Citizen Science in Action

* Directly engages the public in identifying geological (& sometimes technological) features on the Moon.

* Users can explore educational content, including video tutorials, articles, glossary terms, and flash interactive activities.

•There also is a blog and a forum to encourage collaboration and social learning, and a twitter feed.

Over 2 million craters / areas of interest annotated as of June 15, 2010

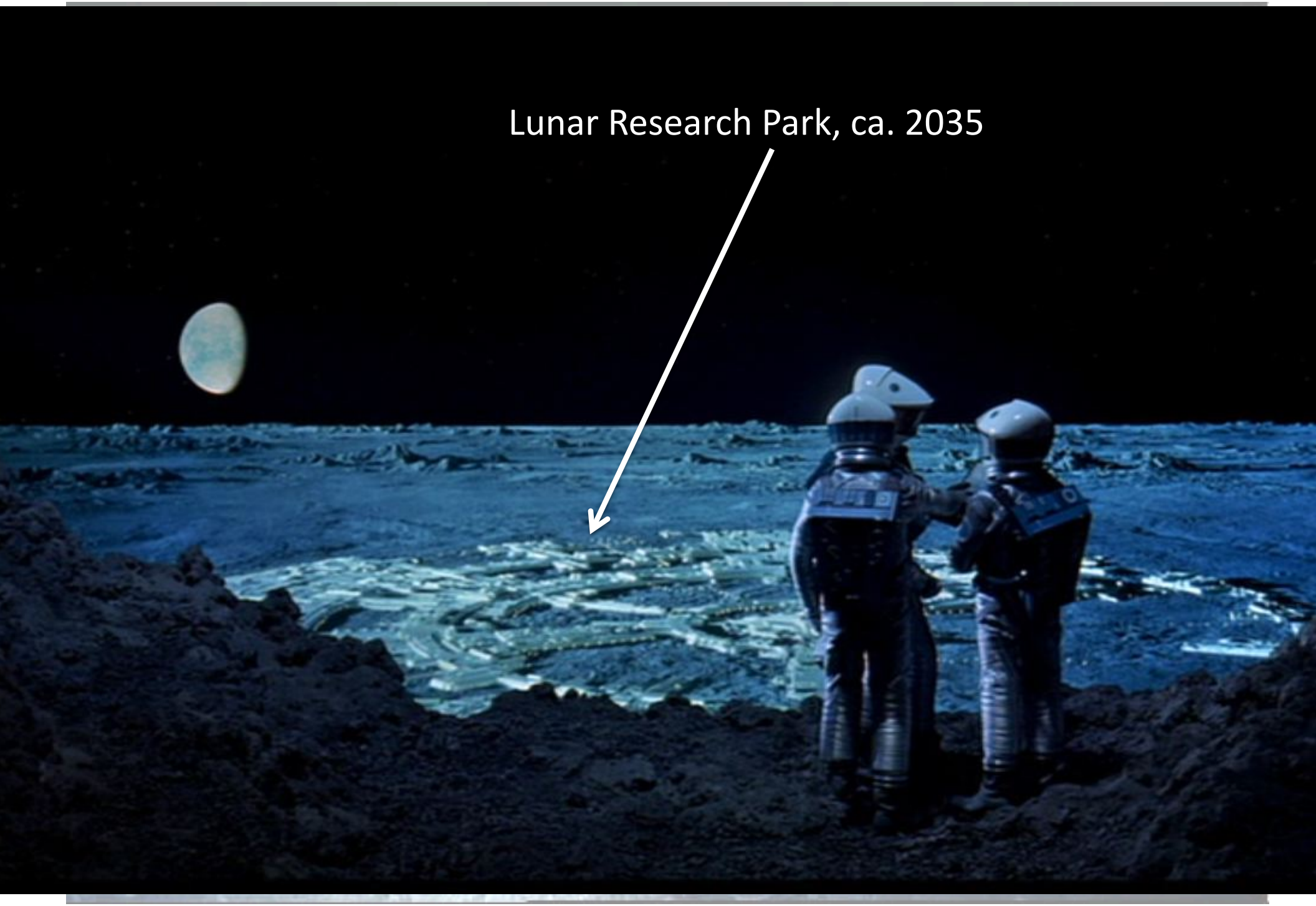
Averaging 5,000+ users per day, >14,000 participants so far!

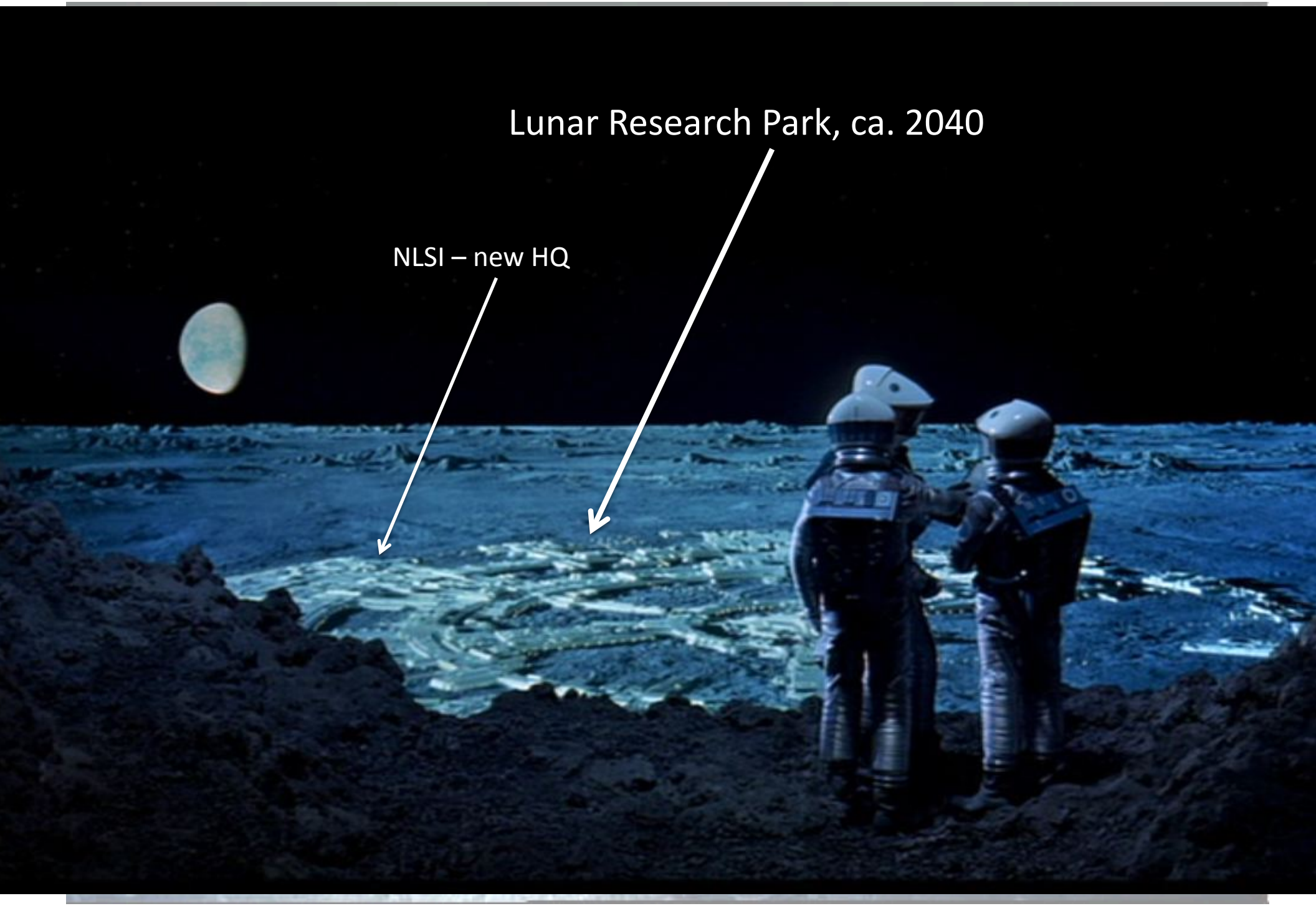
***Joining is easy! Become a lunar scientist today at www.moonzoo.org***

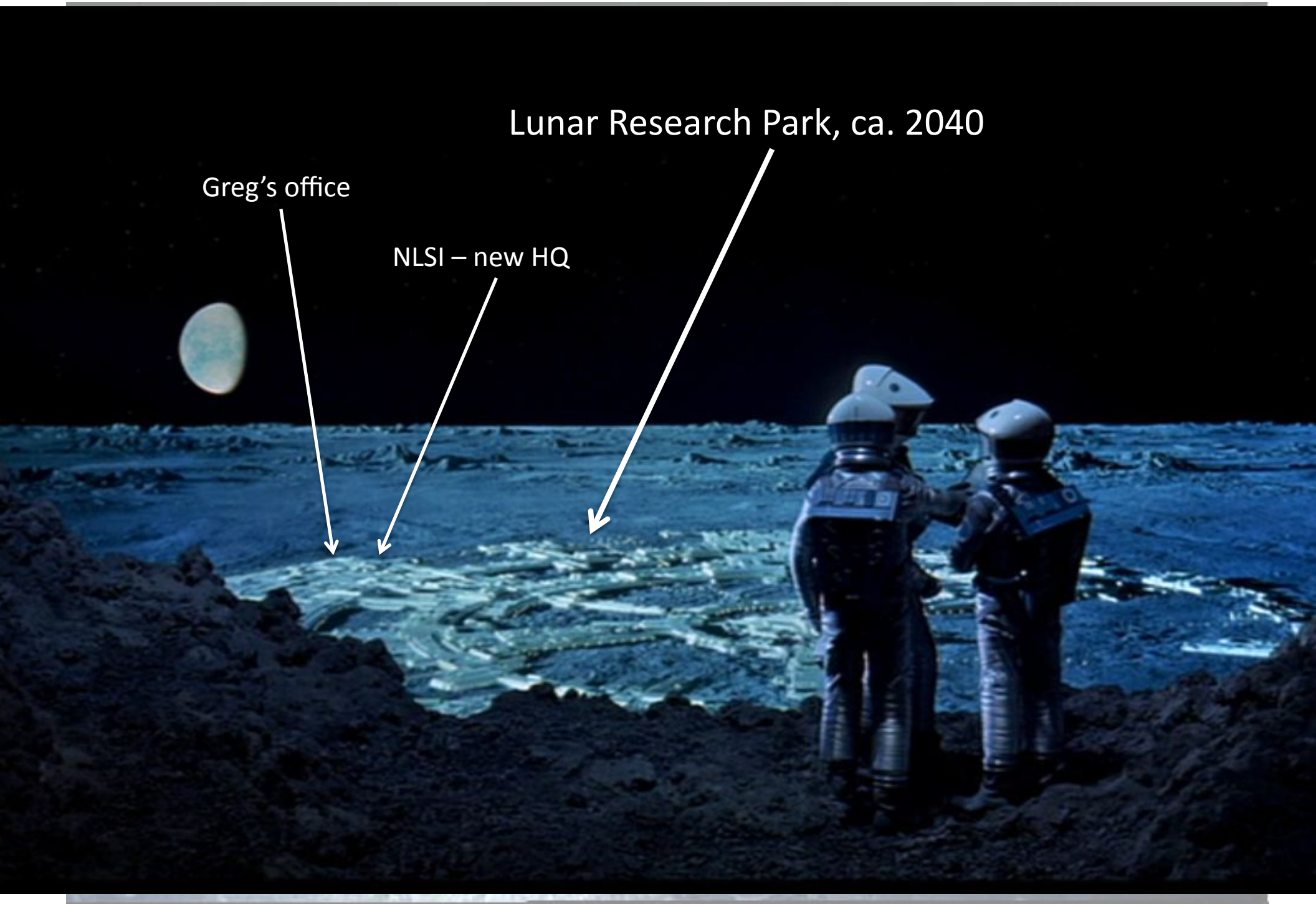
# Summary

- The right ingredients exist to make first steps toward creating a lunar research park – right now!
  - International interest in the Moon
  - Virtual science as modeled by the NLSI
  - Commercial interest and opportunities
  - A rapidly maturing capability in robotics
  - Engagement with the public in a wide variety of ways
  - New models for research parks as evidenced by the NASA Research Park
- Hawaii and JUSTSAP are an ideal place to move these ideas forward
- What's needed? A plan! (and then, resources)

# A vision


Lunar Research Park, ca. 2035


Lunar Research Park, ca. 2040
NLSI – new HQ


Lunar Research Park, ca. 2040
Greg's office
NLSI – new HQ