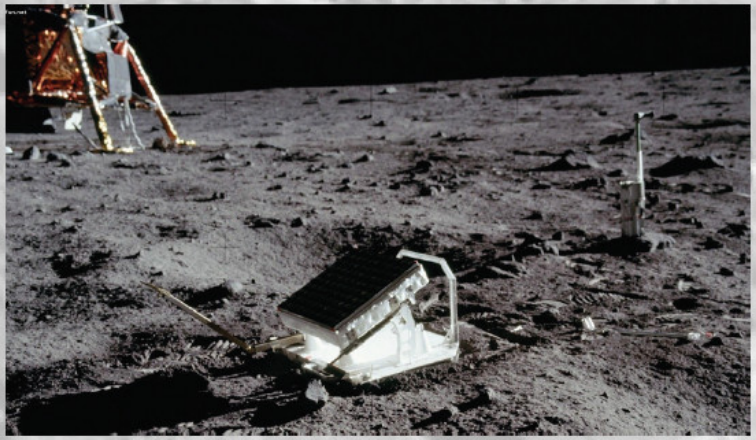
An IEEE Milestone Dedication:
The Apollo 11 Lunar Laser Ranging Experiment (LURE)



1 August 1969 / 1 August 2019: *50 Years Later*

IEEE

Footprints

Laetoli (East Africa)
~3.7 MYA

Tranquility Base (Luna)
0.00005 MYA

image credits: John Reader/PhotoResearchers.com (Left)/NASA (Right)

see also: Jurmain, Kilgore, Trevathan, eds. *Essentials of Physical Anthropology*, 8th ed. (2010)
"One Small Step for Man..." by Robert Krulwich, npr.org, 09 Sep 2010

IEEE Advancing Technology for Humanity

Apollo 11 Newspaper Coverage

EXTRA EXTRA EXTRA EXTRA

San Francisco Chronicle

FINAL

105th Year No. 201 — MONDAY, JULY 21, 1969 — 10 CENTS — GArfield 1-1111

MEN ON MOON

Man Makes a Lunar Landing --Astronauts Walk on Surface

The first men on the moon, Neil Armstrong and Edwin Aldrin, planted a plastic American flag in the lunar soil

Historic Moment

Spacemen Scout The Landscape

Eagle Lands Close to Target Area

More Apollo news Pages 1A through 7

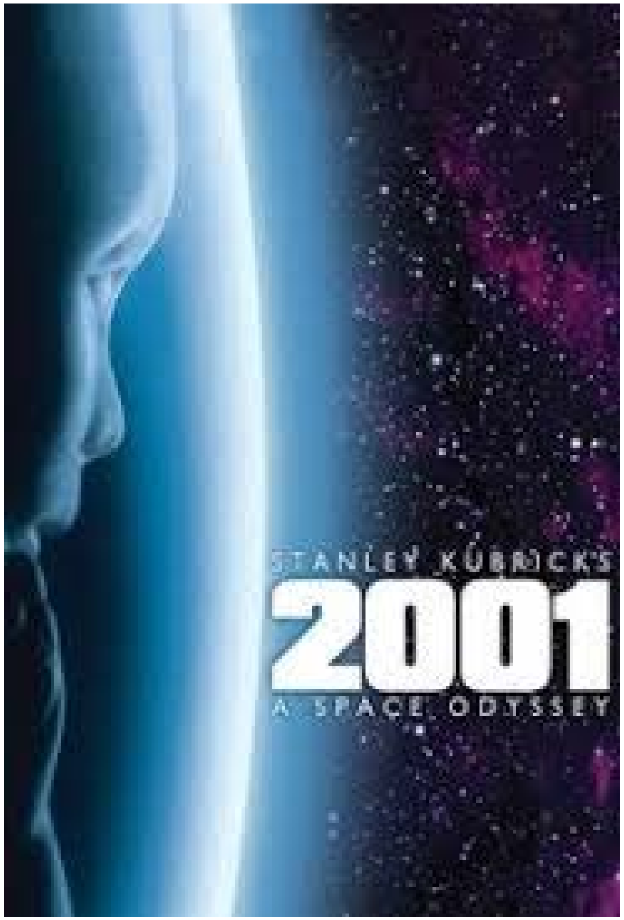
Air War Erupts In the Mideast

Chief Says Kennedy to Be Charged

What Spacemen Found--Moon's Unusual Rocks

Index

1968: *2001: A Space Odyssey*



IEEE Advancing Technology for Humanity

Thank you to those who helped me!

Texas Instruments

sce
Shadow Cliffs Engineering

IEEE
Santa Clara Valley Section

IEEE Foundation

The Bridge Between the Heartland and Silicon Valley

DeVry University

MOSTAFA MORTEZAIE, PH.D.

Elinor Gates

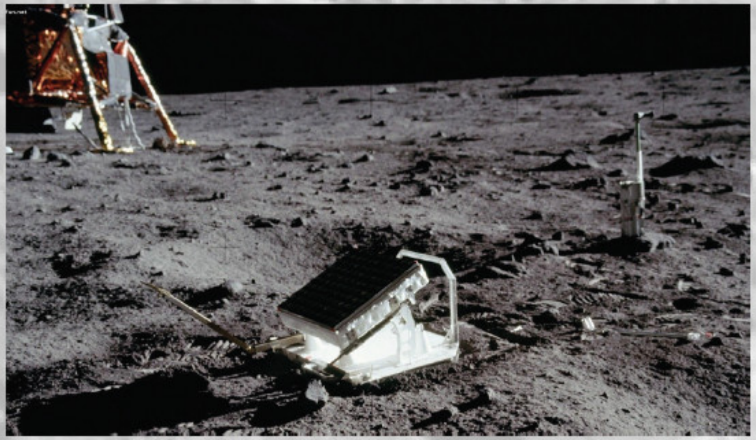
Staff Astronomer

LICK OBSERVATORY
Mt. Hamilton, California

Some Questions, and …

An IEEE Milestone Dedication:

The Apollo 11 Lunar Laser Ranging Experiment (LURE)



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REALIZE
THE FULL POTENTIAL OF IEEE
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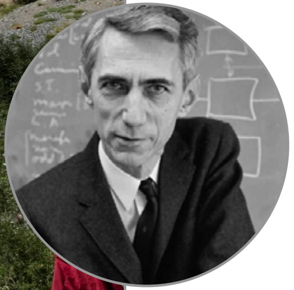
Enabling donor investment in IEEE programs that deploy human and intellectual resources worldwide.

Programmatic Focus Areas

Illuminate the possibilities of technology

Educate the next generation



Engage a wider audience

Energize innovation

A Historic Campaign

Raise Awareness
Forge Partnerships
Expand Resources

GOAL: $30 million
by IEEE Day 2020

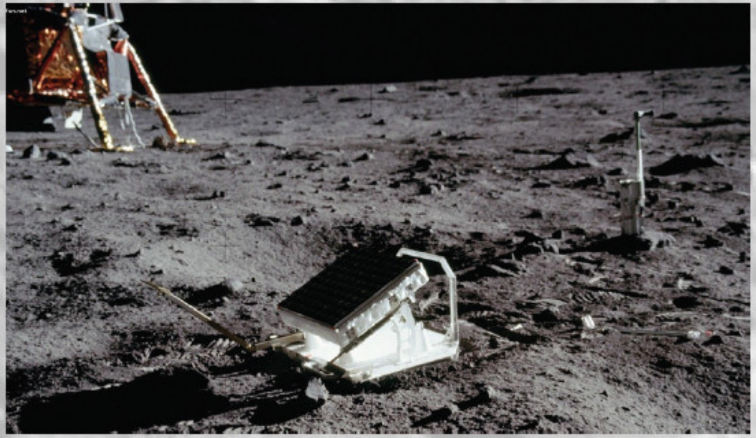
$30 Million

68.00%
Funded

$20,399,798
Raised

433
Days to Go

An IEEE Milestone Dedication:
The Apollo 11 Lunar Laser Ranging Experiment (LURE)



1 August 1969 /
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50 Years Later

IEEE

Lick Observatory's Place in the World

Michael Bolte

University of California, Santa Cruz

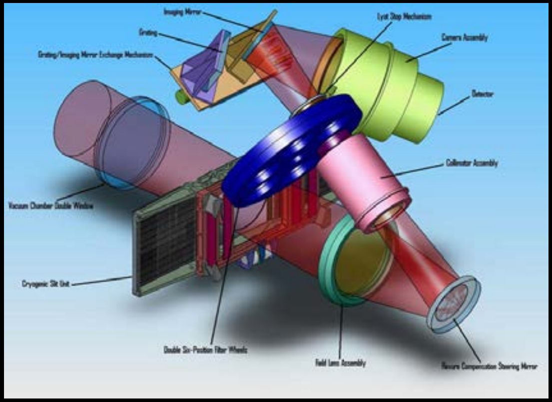
UC Observatories

University of California Observatories (UCO)

- Multi-Campus UC Research Organization
- HQ in Santa Cruz
- Primary purpose:
  - to efficiently develop and manage the astronomical optical/IR facilities for UC astronomers
  - Operate as a major research center

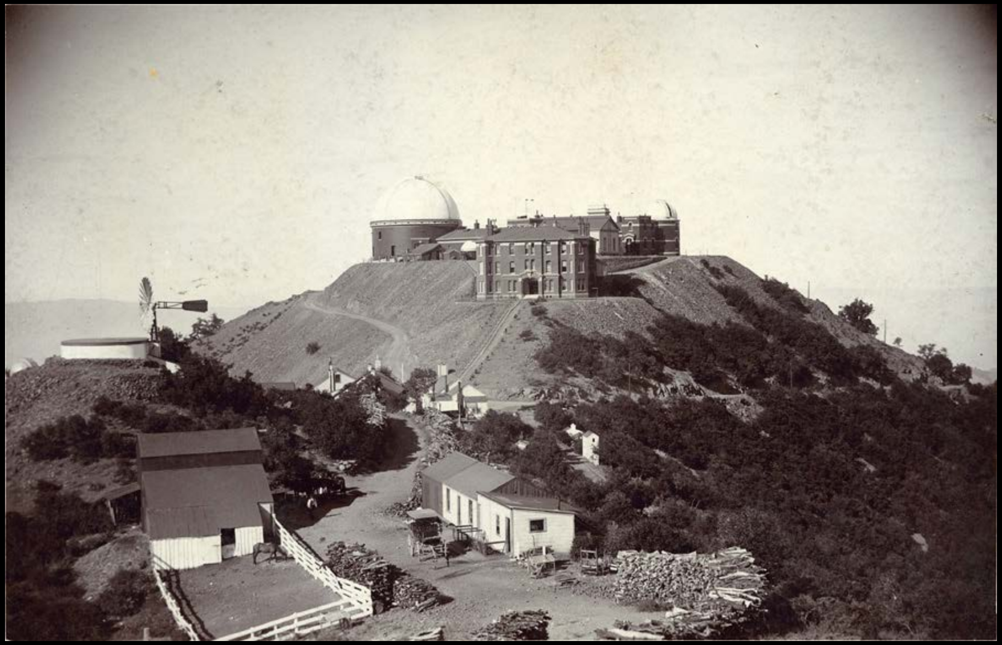
Lick Observatory

Keck Observatory, Hawaii



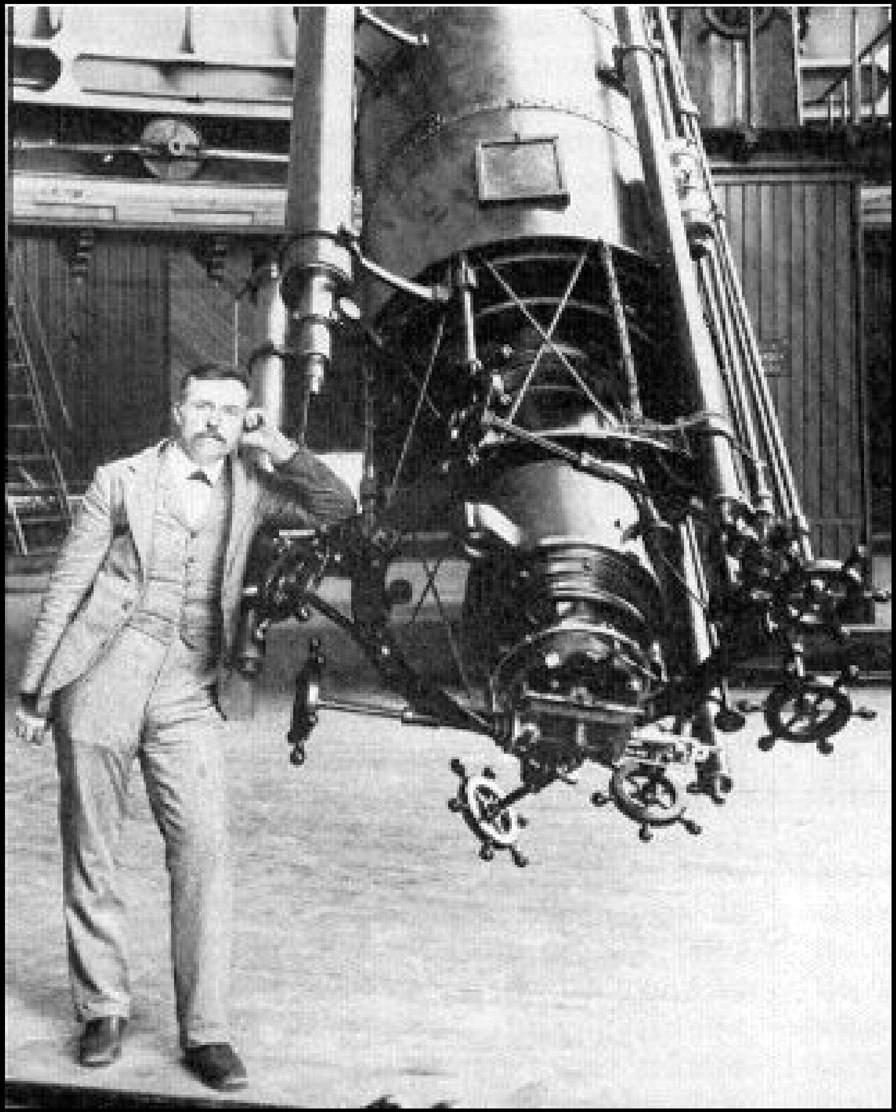
UCO instrument shops

Lick Observatory: The Start



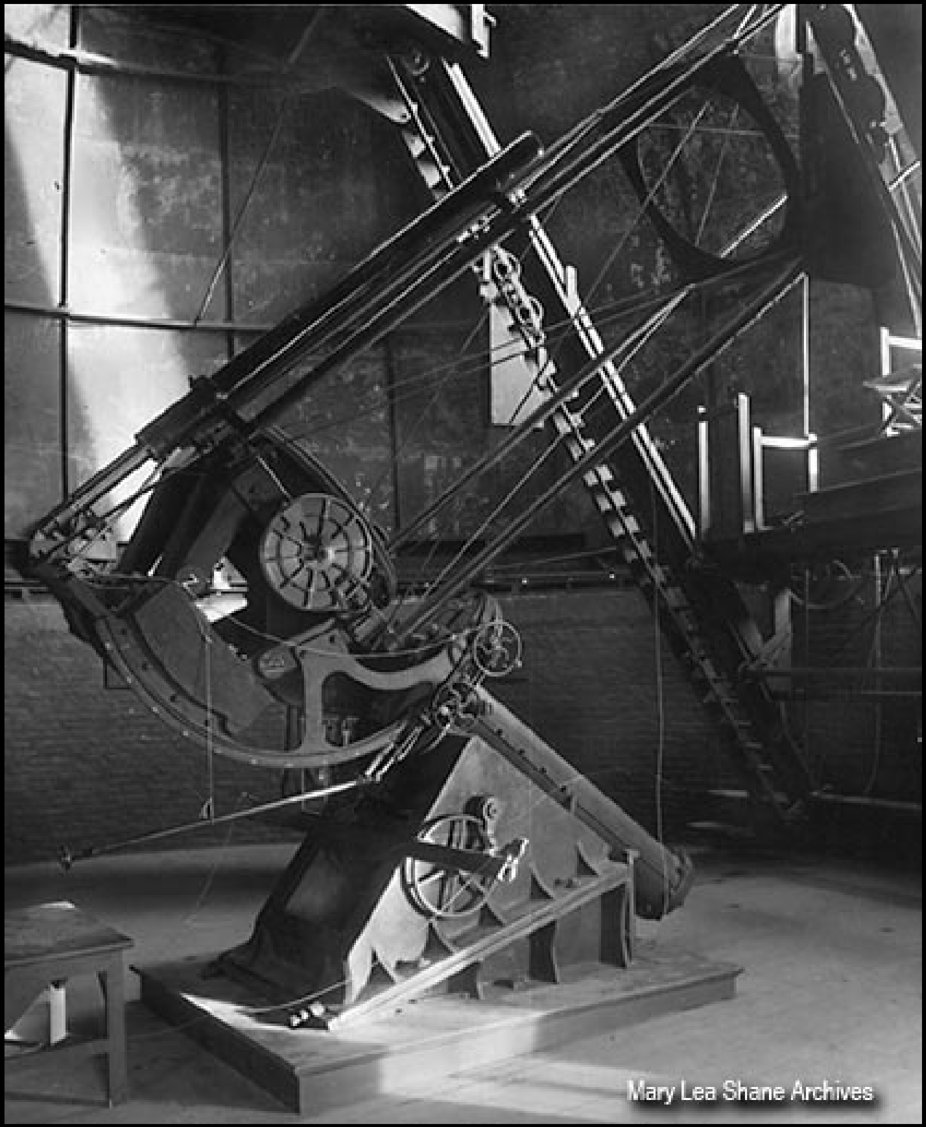
- James Lick made a $700,000 gift:
  - build the “finest observatory in the history of mankind”
- 1888: world’s first permanently occupied mountaintop observatory
- Immediately became the world’s Premier Observatory

Early Work at Lick Observatory



- Firsts at Lick:
  - photographic mapping of the Milky Way
  - the source of much debate about the nature of the dark regions
- Numerous comets were discovered
- Motions of stars in our Galaxy were measured
- Binary star orbits and masses of stars were measured

The Rise of the Reflectors



- 1895: 36″ Crossley Reflecting Telescope arrived at Lick
- World's first reflecting telescope
  - Reflecting telescopes became important worldwide
  - These led to the discovery of the extra-galactic universe

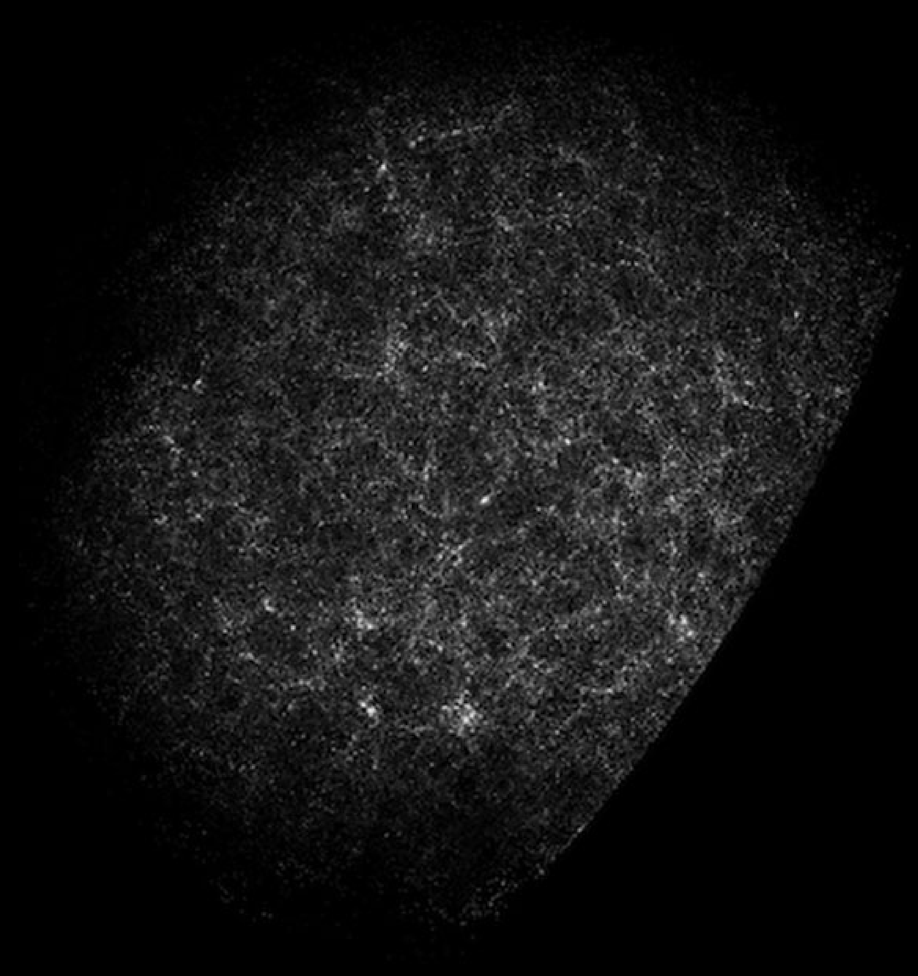
Lick Observatory and Einstein

- W. W. Campbell:
  - Lick Director (1901-30)
  - UC President (1923-30)
- Campbell carried out a decade long program to observationally verify Einstein’s Theory of General Relativity
- 1922: final success during an eclipse in Australia

Lick Observatory: The Modern Era

- 1959: Shane 3-meter reflector telescope was completed
  - 2nd largest telescope in the world
- 1969: One of 3 observatories to attempt the LURE
- 1996: First adaptive optics system for astronomy
  - use of a laser to compensate for the atmosphere
- Robotic telescopes are in regular use
  - Allows for remote access from 8 UC campuses

Discovery of Large-scale Structure



- A huge survey of the entire Northern Sky was carried out twice to map the motions of stars in the Galaxy
- A by-product, the position of 1 million galaxies, first showed the large-scale structure of the Universe

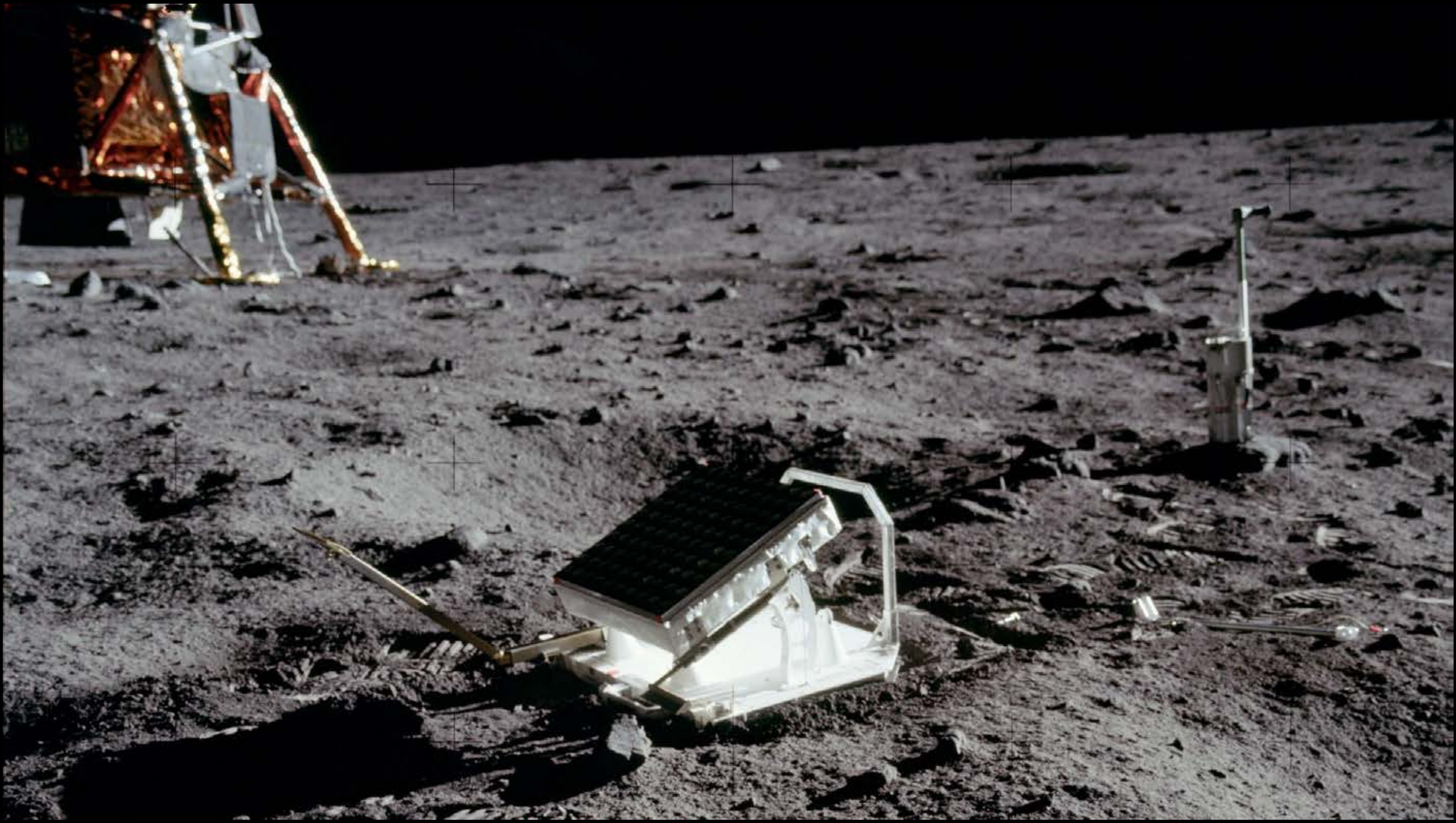
Lick Observatory 2019

- At the forefront of science
  - Exoplants
  - Supernovae and the expanding Universe
  - Support of Keck programs
- Technology development
- Undergrad/grad education in A&A
- Public outreach and education

Lick Observatory Public Outreach

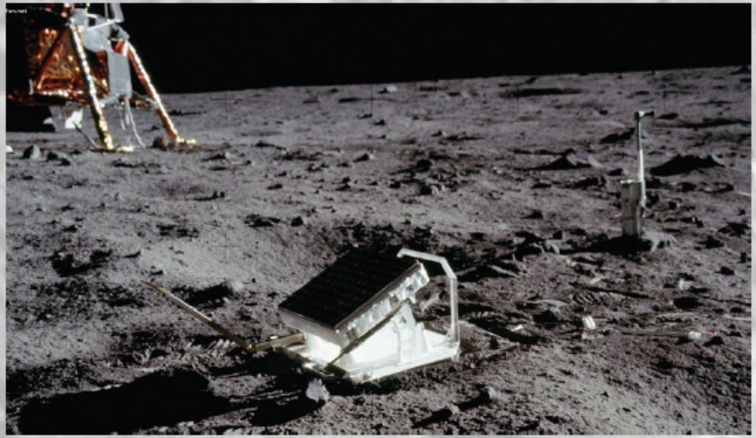
- Open all year: ~25,000 visitors come per year
- Summer concert series with live music, lectures and viewing
- Summer Open House nights with lectures and viewing
- Tours for school groups and others

130 years of ground breaking scientific discovery, technology development, training of new generations and bringing the wonder of astronomy to the public



With all that amazing history, my favorite story:
The time we shot the laser at the moon…

An IEEE Milestone Dedication: The Apollo 11 Lunar Laser Ranging Experiment (LURE)



1 August 1969 / 1 August 2019: *50 Years Later*

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Skycorp Incorporated Lunar Studies, 3D Manufacturing and ISRU

Dennis Wingo

CEO

The Time is Now

- With the advent of recent scientific missions from Chandrayaan and the Lunar Reconnaissance Orbiter, coupled with legacy data from Lunar Prospector, Clementine, and Lunar Orbiter we now have sufficient remote sensing data to plan a commercial lunar development. The next step is ground truth with a high capability commercially focused lander and rover.

The Goal, Industrial Development

- The goal of lunar industrial development, once the realm of science fiction, is now attainable.
- Recent remote sensing missions have dramatically improved our terrain knowledge and Apollo samples continue to inform.
- The key is a systems engineering approach, selecting a site, importing enough infrastructure, then implementing additive manufacturing for growth.

Peary/Whipple Ground Truth (LOLA Data)

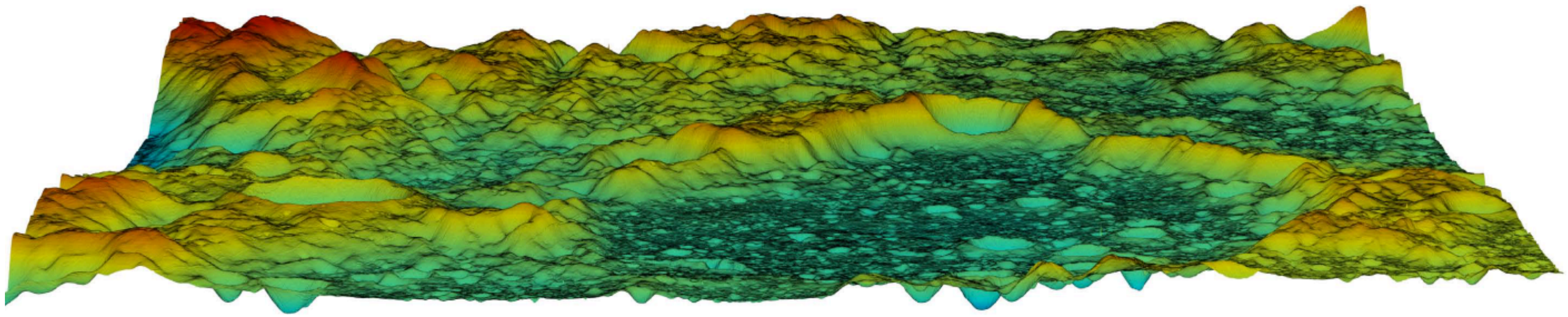


Figure 1a: LOLA 10 Meter Gridded Data Record Terrain from 87.5° North to the North Pole (3x vertical exaggeration)

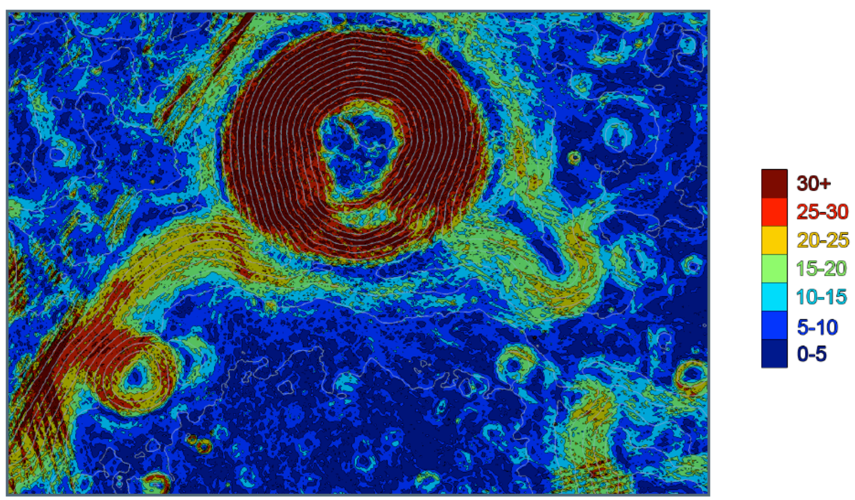


Figure 4: Slopes in the area of Peary/Whipple craters with overlaid elevation contours at 200 meter vertical spacing. Slopes are derived from LOLA GDR.

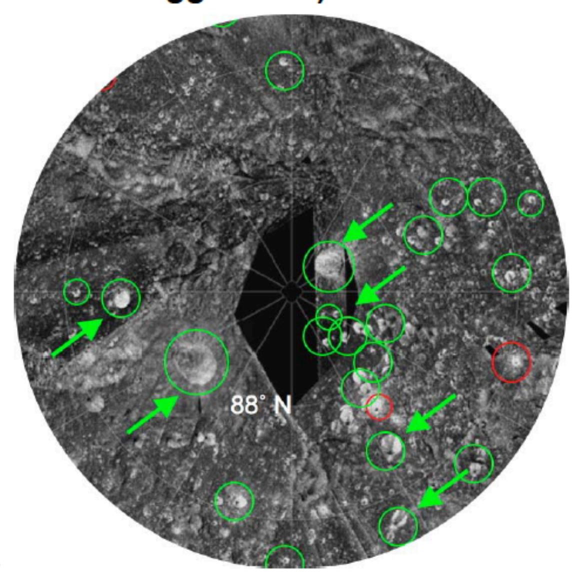
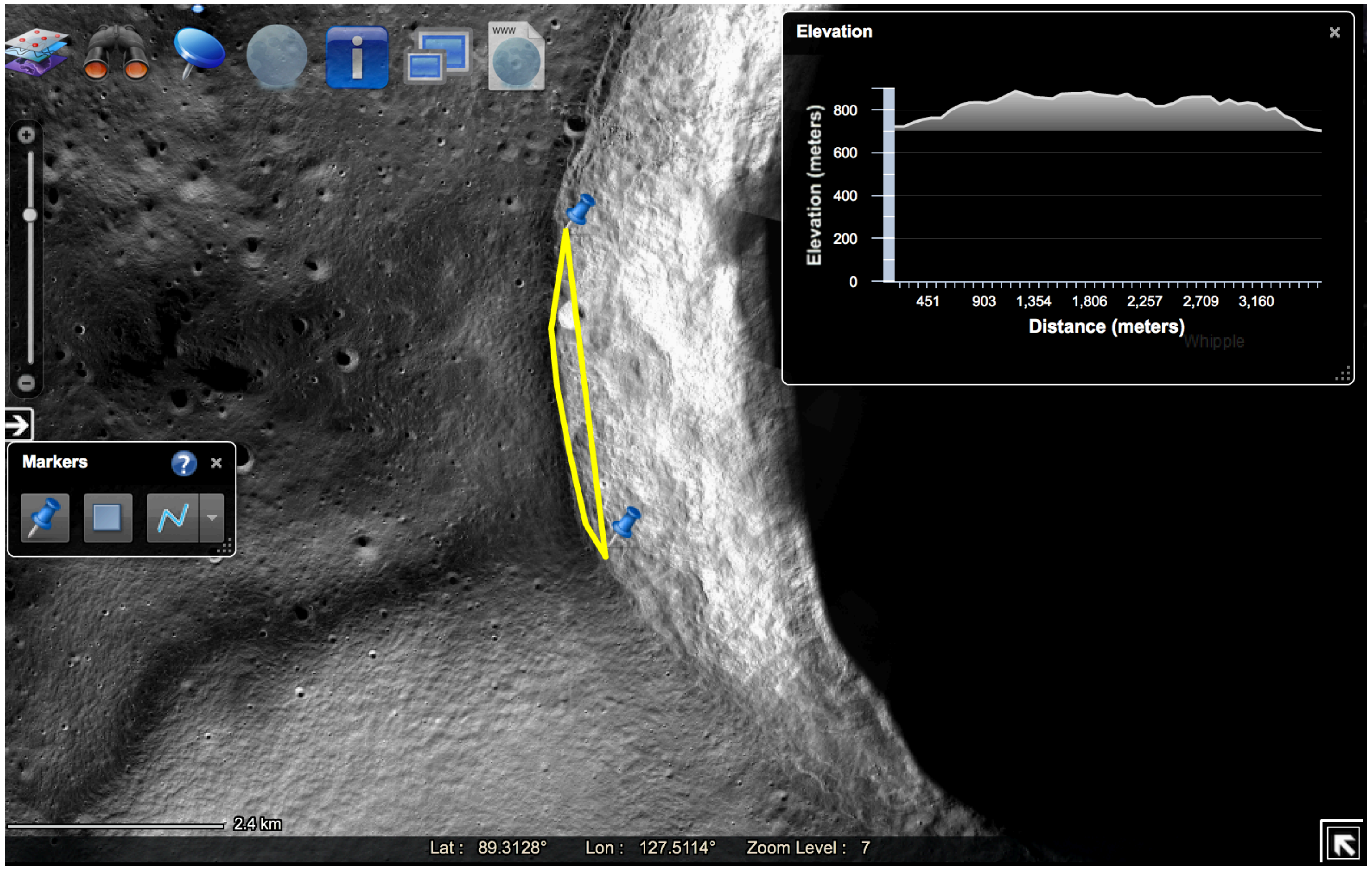


Figure 5: Circular Polarization Ratio map from the Mini-SAR instrument on Chandrayaan-1 cropped to show the area from approximately 85°N to the pole. Anomalous craters suspected of containing volatiles, including several craters on the floor of Peary, are circled in green [see reference 1].

For the purpose of economic development the north lunar pole is far superior to other locations

Whipple Site Details

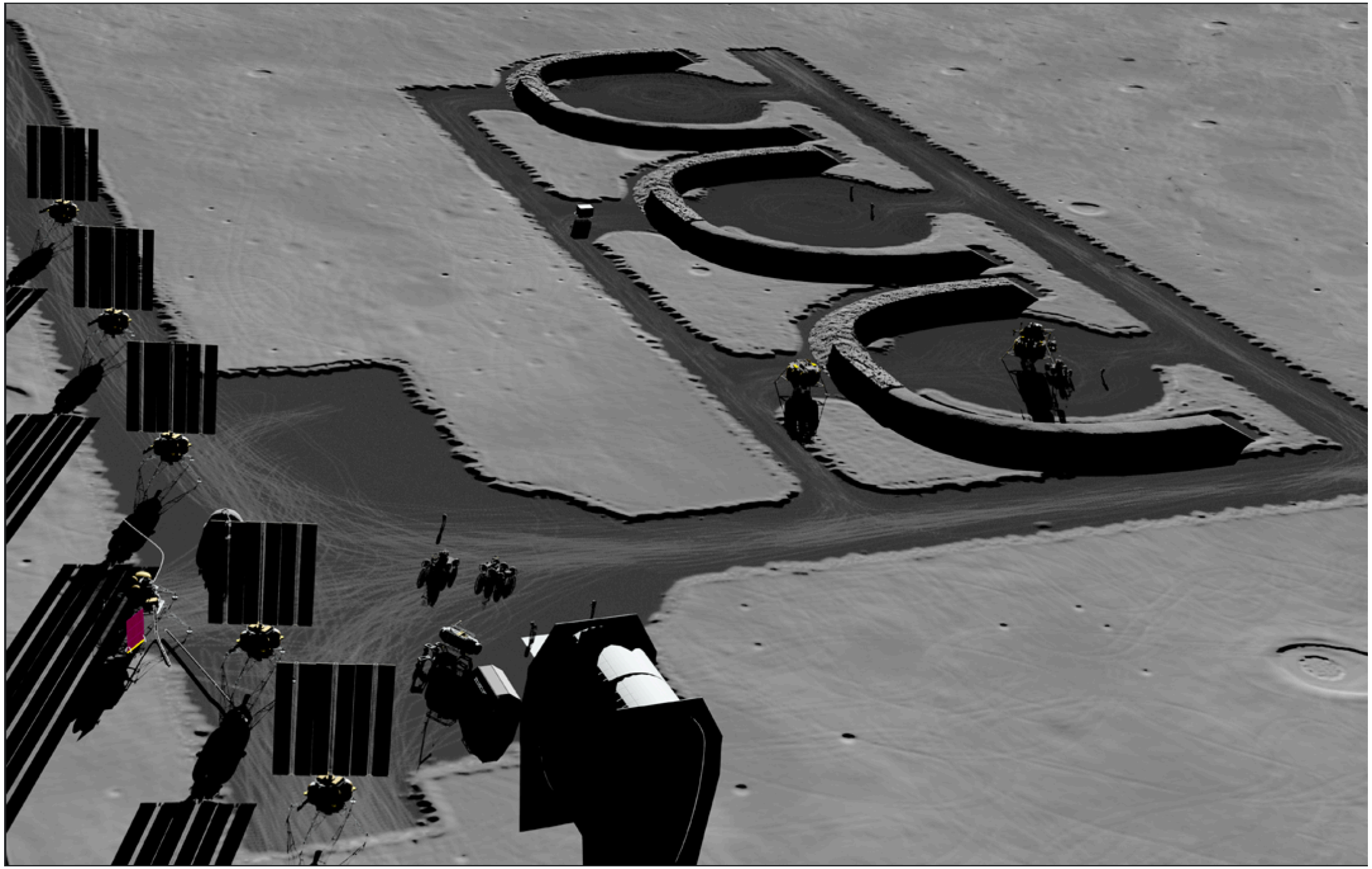


Using images from the LRO NAC high resolution imager, coupled with LOLA terrain data we now have the ability to plan not only the general outline of a site but to do a first order determination of locomotion and energy needs for mobility and day/night Cycles.

Steps to a Lunar Development

- There is a fundamental difference between a science outpost on the Moon (think Antarctica) and any other use case.
- As on the Earth, a sustainable industrial infrastructure on the Moon must begin with, and is limited by, available power and local resources.
- The Moon is RICH with resources, we must start (after the recon period) with power.

Lunar Industrialization

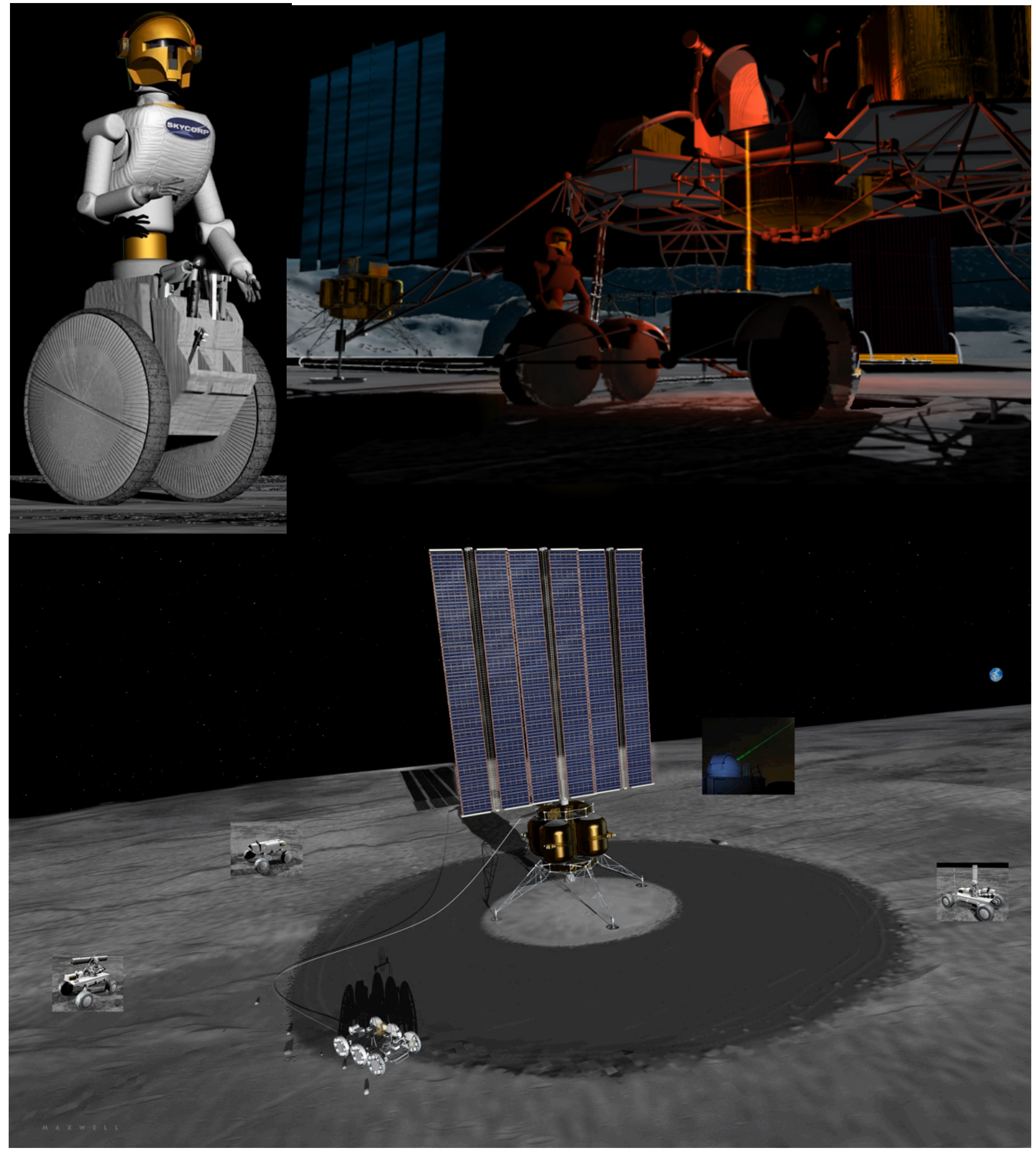


The First Requirement, Power

- Skycorp Power Lander™
  - 100 Kilowatts power output
  - 3500-4000 kg
  - One Delta IVH or Falcon Heavy launch
  - Based on Modular Lunar Lander Heavy
  - Extended lander legs to get solar array into more sunlight
  - Provides standard 110//220/440 V AC Power
  - Closed loop 80 kW PEM Fuel Cell scavenging residual H2 and O2 propellants
  - Average power supplied over 708 hours is ~67 kW/hr/hr
  - Unit one supports outpost buildup
  - 5-7 units required for industrial self sufficiency.

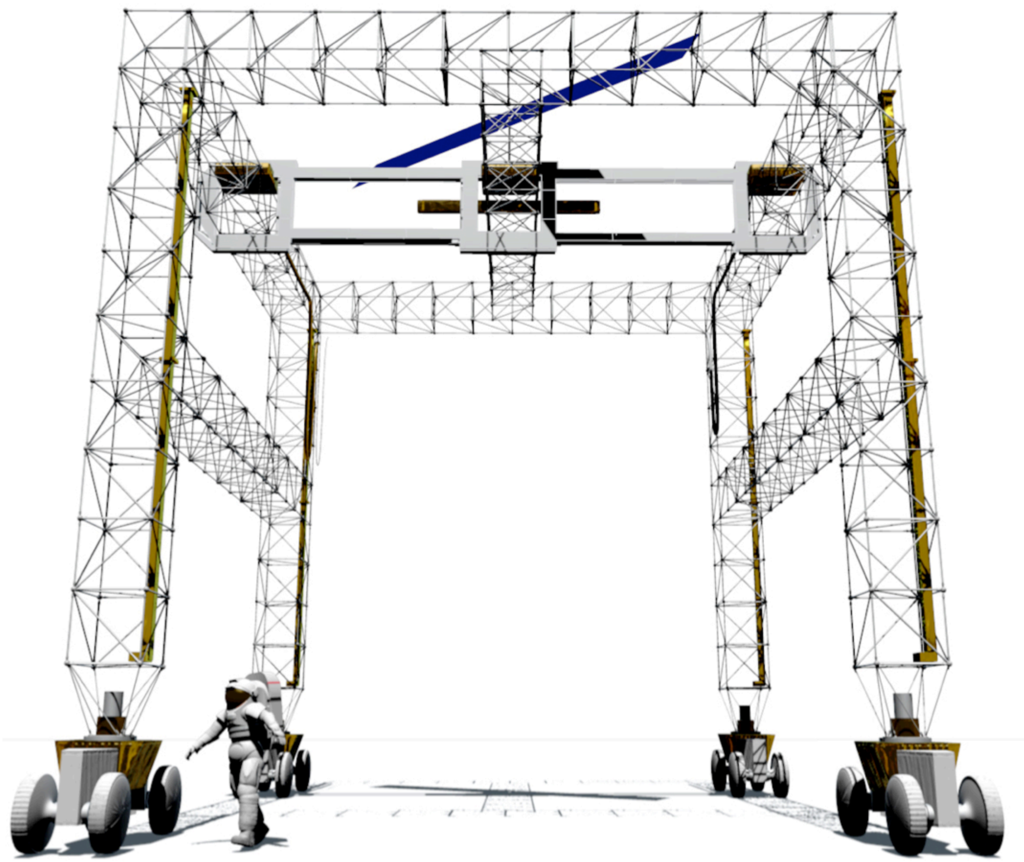
Adding Capability

- Leveraging telepresence and advances in terrestrial robotics
- Terrestrial robotics have exploded in capability in recent years. This, along with metals In-Situ Resource Utilization (ISRU) rewrites the book on lunar (and mars) development



Versatile Robotics

Advanced robotics coupled with traditional cranes will provide high productivity for site development. This gantry crane could be used for large scale 3D printing



Landers designed with modular parts could be disassembled and the parts used to build cranes, propellant storage, or even raw materials for ISRU systems. This leverages delivered mass fraction by 30-50%

Scouting with the High Mobility Lunar Rover (HMLR)

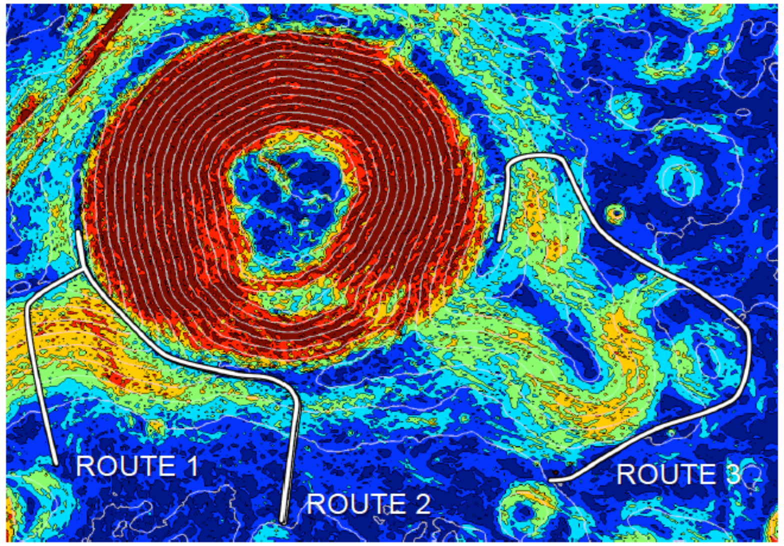
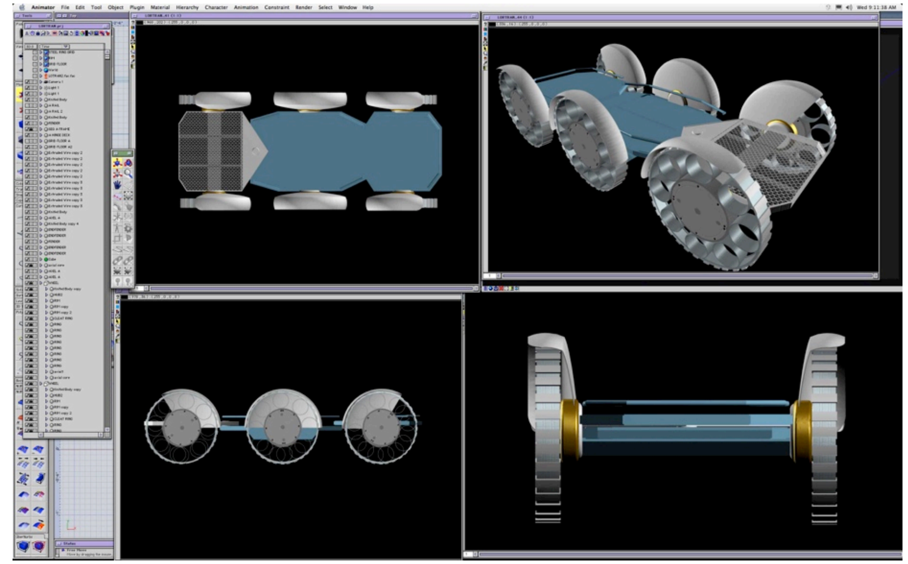


Figure 6a: Slopes with overlaid elevation contours and examples of candidate rover driving routes from high-illumination regions on the rim of Whipple crater to the floor of Peary.



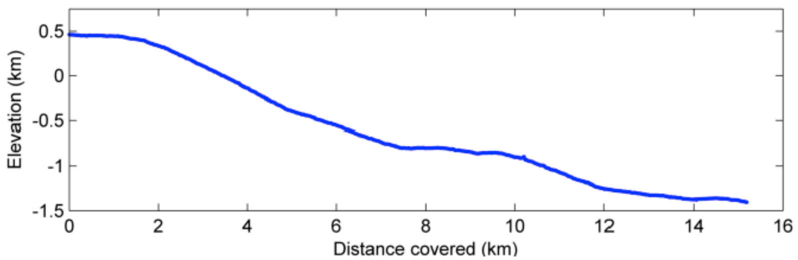


Figure 6b: Plot of elevation vs. traverse distance for route 2 shown in figure 5a.

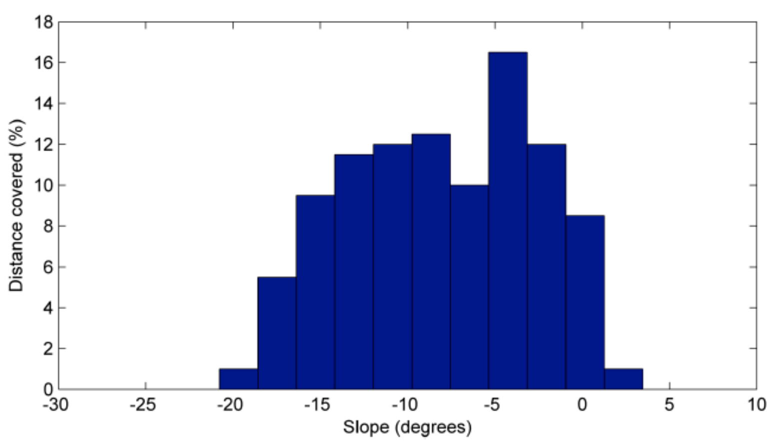


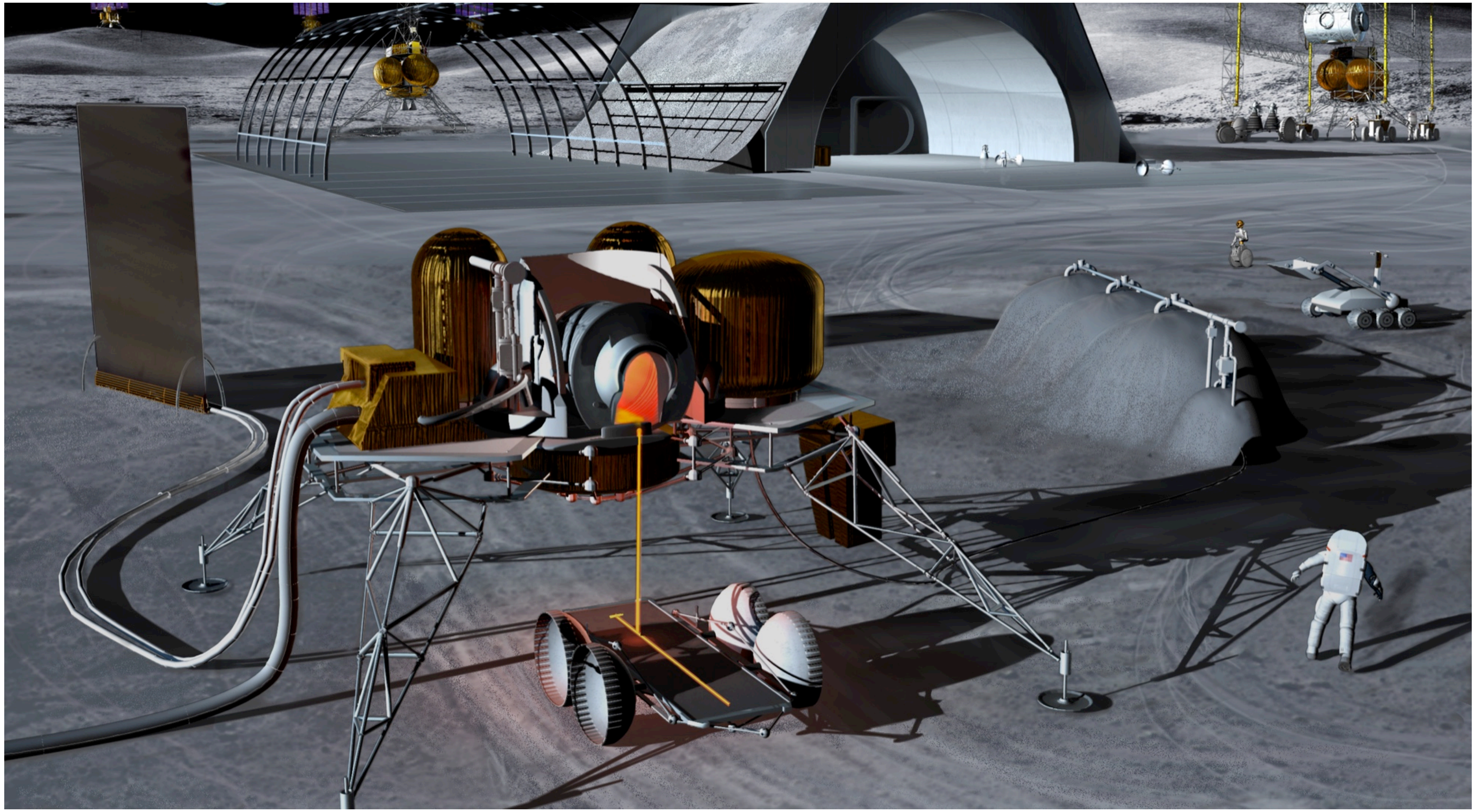
Figure 6c: Slope histogram for route 2 shown in figure 5a.

- A rover based on the 1970’s Eagle Engineering LOTRAN modular design would give high mobility (20 km/hr), all wheel drive, and allow for heavy loads.
- Slope angles on identified routes to floor of Peary have moderate slope and short distance.

3D Printing/Additive Manufacturing

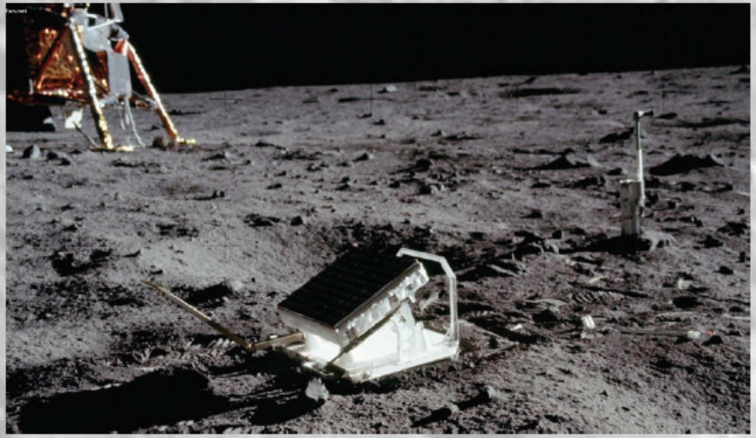
- A truly transformative technology, allowing the rapid utilization of lunar resources.
- Lunar materials, from raw regolith to metal meteoric fragments can be immediately processed with with little preprocessing.
- Laser Sintering is a key technology, ready for almost immediate deployment on the Moon.

Advanced Base Is Just the Beginning



This is not your grandfather's lunar base. It is time to throw off the old conceptions and to use the benefits of 2st century technology development to build a lunar base that will then enable a solar system wide industrial and transportation infrastructure.

An IEEE Milestone Dedication: The Apollo 11 Lunar Laser Ranging Experiment (LURE)



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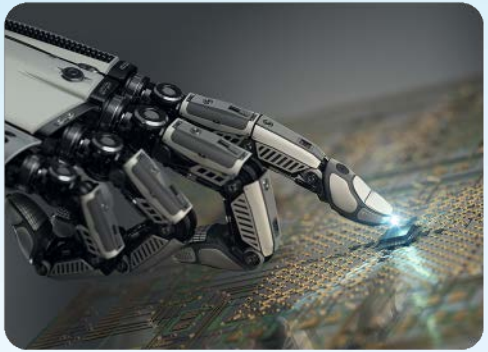
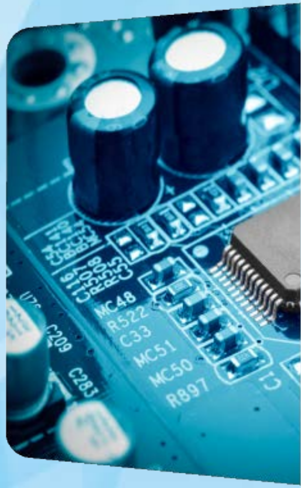
IEEE: Celebrating our Historical Legacy







Jim Jefferies, 2019 IEEE Past President

Apollo 11 Lunar Laser Ranging Experiment (LURE), 1969

1 August 2019

IEEE
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for Humanity

The Fuel of IEEE

Who we are

- Forward-thinking technology professionals coming together …

… to discover the next technological innovation,

to develop international standards,

to form communities,

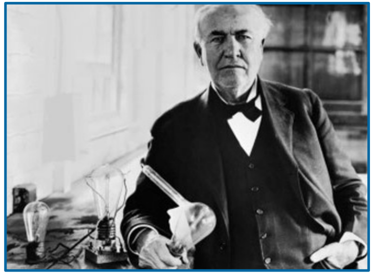
to share research and educate,

in the spirit of collaboration.

IEEE Legacy

IEEE's story of innovation begins with a spark of collaborative spirit

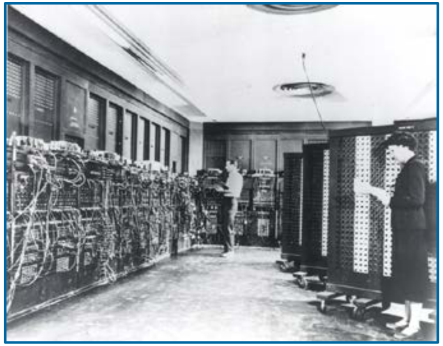
- The public's need for increased technological innovation brought our founders together in the spirit of collaboration
- Since 1884, IEEE has been fostering technical advancement for the benefit of humanity
- As the largest technological association in the world, it is our responsibility to preserve this history

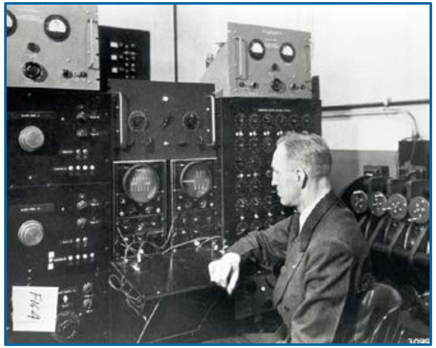


Benefits of Preservation

Importance of engineering history

- Increase public understanding of the achievements of electrical, electronics, and computer engineers
- Enhances the image of engineers and elevates the prestige of the profession
- Pride in local accomplishments and global contributions
- Preservation of landmark structures

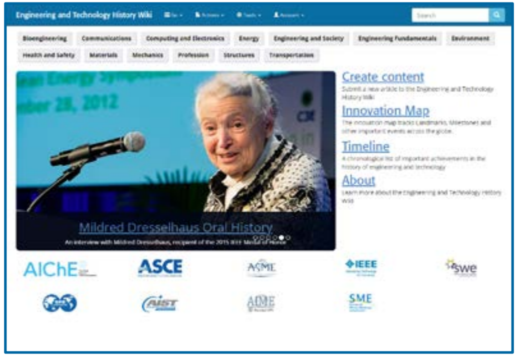




IEEE History Center

The center for the public history of technology

- Preserve, research, and promote the history of IEEE, its members, their professions and industries, and the related sciences and technologies
- Manage the [Engineering & Technology History Wiki] on behalf of a consortium of engineering societies
  - Oral and first-hand histories
  - Articles/ educational material
  - IEEE Archives/Institutional history
  - IEEE Milestones



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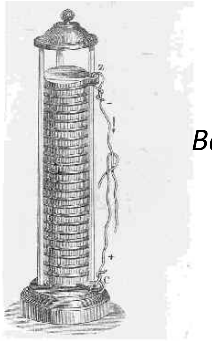
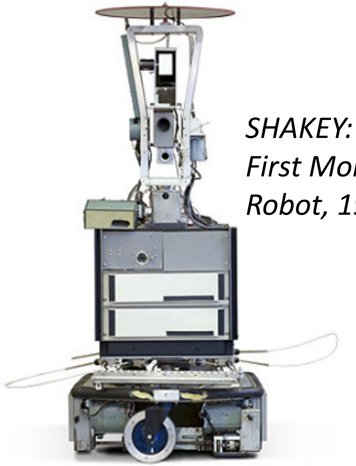
- Honors significant technical achievements in electrical, electronic, and computer engineering and the associated sciences
- Started in 1983 as part of IEEE Centennial Celebration
- Today's milestone is our 198th worldwide



Volta's Electrical Battery Invention, 1799



SHAKEY: The World's First Mobile Intelligent Robot, 1972

The Pearl Street Generating Station, 1882

Footsteps: IEEE's Commemoration of Human Space Travel

Raising awareness of the role of IEEE members

- A unique collection of spaceflight-related primary sources
- Outreach to Life Members yielded 50+ space travel first-hand histories
- 2 space-related IEEE Milestones dedicated in 2019
  - Detection of Radar Signals Reflected from the Moon, 1946
  - Apollo 11 Lunar Laser Ranging Experiment (LURE), 1969
- Seminal IEEE journal and conference papers
- Images, video, and sound recordings

IEEE

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Get Involved!

Help preserve our history

- Propose a Milestone
- Do Your Own Milestone Selfie
- Contribute Your Story to ethw.org
- Support the IEEE Foundation

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kia ora
barka
welalin
tack
mahalo
tapadh leat
faafetai lava
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shukriya
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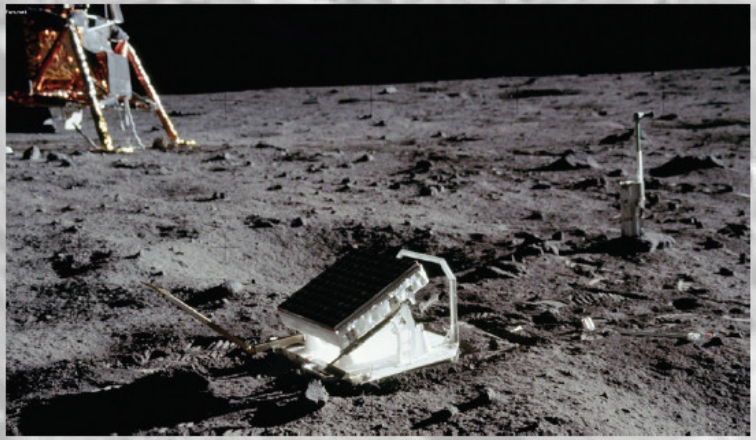
তোমাকে ধন্যবাদ
감사합니다
xièxie
merci

An IEEE Milestone Dedication:

The Apollo 11 Lunar Laser Ranging Experiment (LURE)



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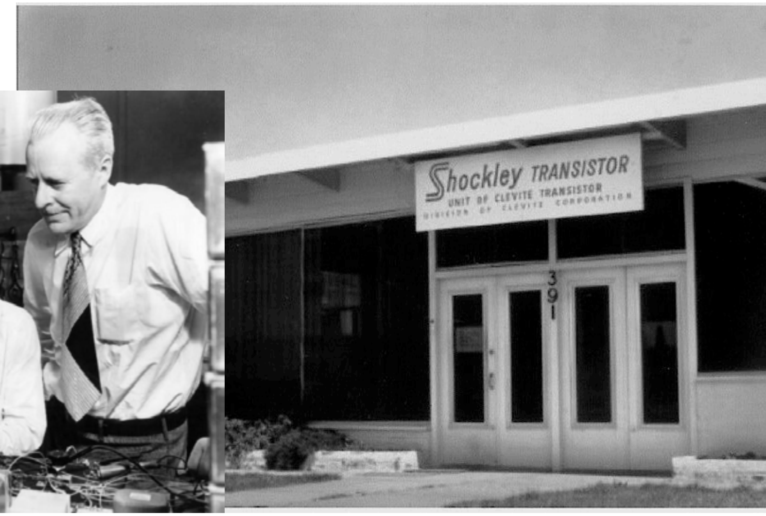
50 Years Later

IEEE

Milestone: Birthplace of Silicon Valley, 1956

- At Shockley Labs site: corner of San Antonio Rd and California Ave, Mountain View



IEEE Milestone: Moore’s Law, 1965

Ampex Videotape Recorder, 1956: Redwood City

- Milestone plaque at Green Library at Stanford Univ.

VR1000 1956

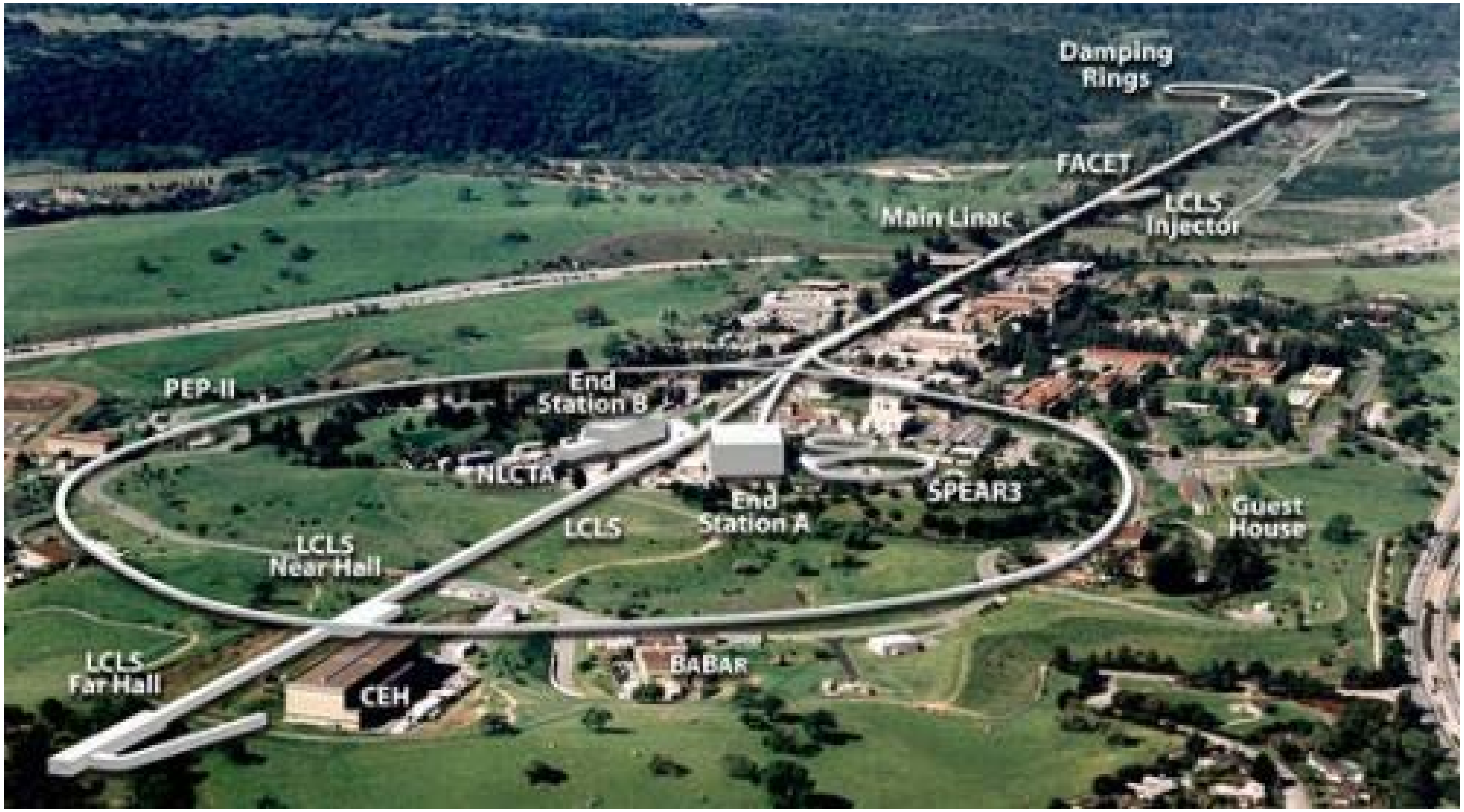
Fig. 12. The video project team, 1957, with Ampex Emmy and an early version of the videotape recorder.

From the left: Charles Anderson, Ray Dolby, Alex Maxey, Shelby Henderson, Charles Ginsburg and Fred Pfost.

RAMAC, 1956:
99 Notre Dame St, San Jose, CA (IBM)

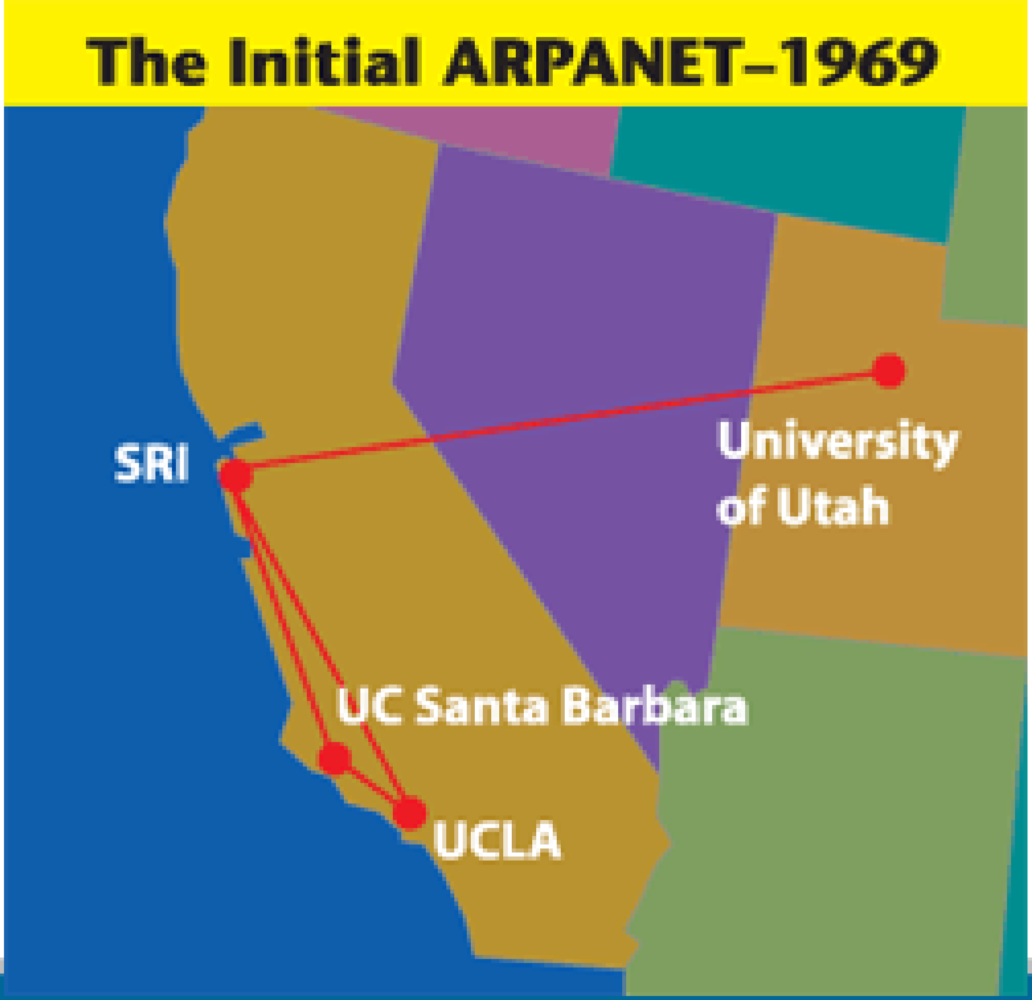
Stanford Linear Accelerator Center, 1962: Sand Hill Rd, Menlo Park

Silicon Valley History

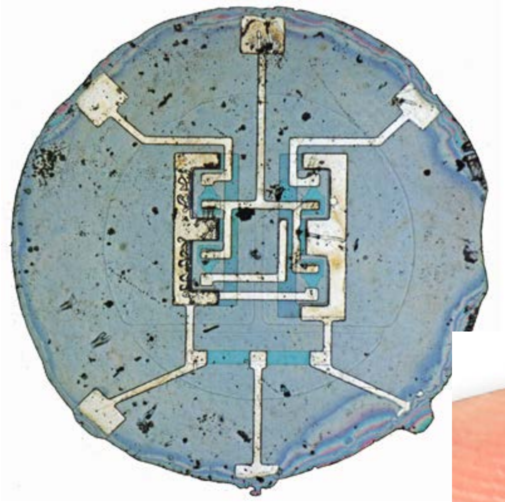


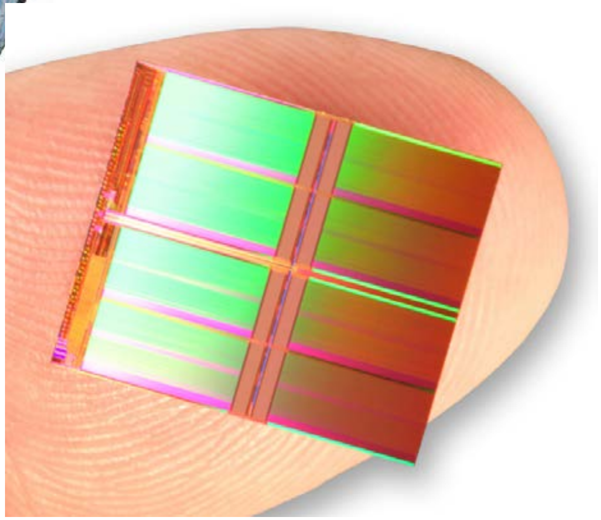
Inception of the ARPANET, 1969: SRI, Menlo Park

IEEE Silicon Valley History

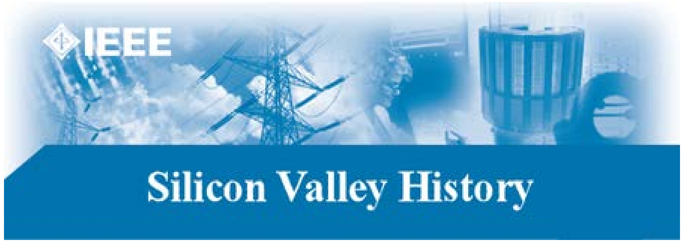


Integrated Circuit, 1959: Charleston Rd, Palo Alto (Fairchild) (near San Antonio Rd / US-101)



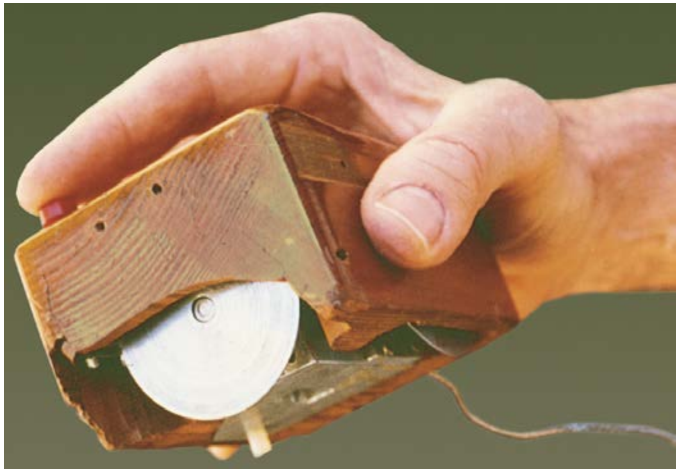


“Mother of All Demos” by Doug Enbelbart, 1968: Menlo Park (SRI)



- First public demo of:
  - the mouse
  - collaborative online editing
  - Hypertext, video conferencing
  - word processing, spell checking

- Demo in San Francisco
- Computer and team members in Menlo Park



CP/M Microcomputer Operating System, 1974: Pacific Grove

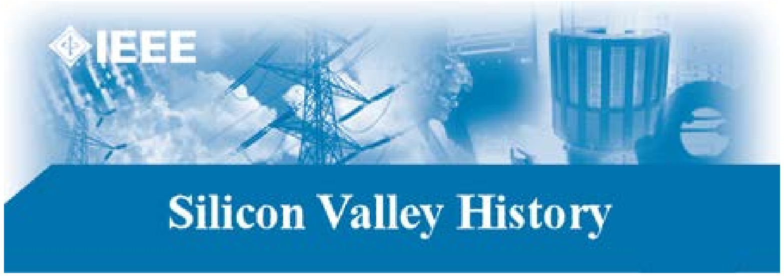
- Developed by Dr. Gary Kildall while at Naval Postgraduate School
- Launched the Personal Computer revolution

DIALOG Online Search System, 1966

- Used initially by NASA and the European Space Agency
- Preceded modern search engines by over 2 decades
- Dedicated in May 2019

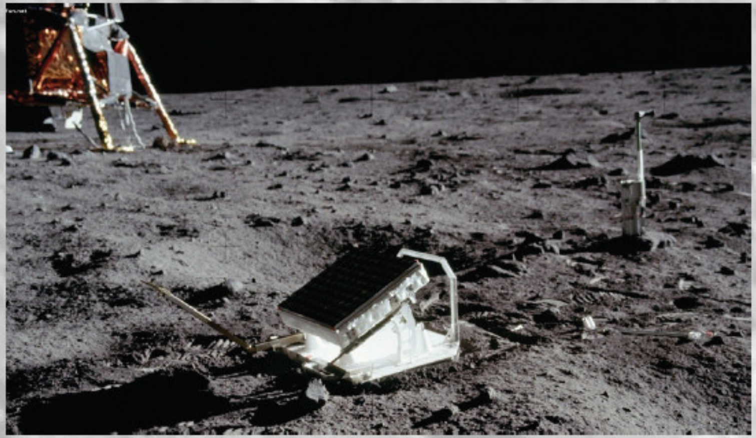
Computer History Museum, 1979 (SPECIAL CITATION): Mountain View

- Dedicated at the CHM in 2015
- 8 plaques are mounted at CHM



Computer History Museum

An IEEE Milestone Dedication:
The Apollo 11 Lunar Laser Ranging Experiment (LURE)



1 August 1969 / 1 August 2019: *50 Years Later*

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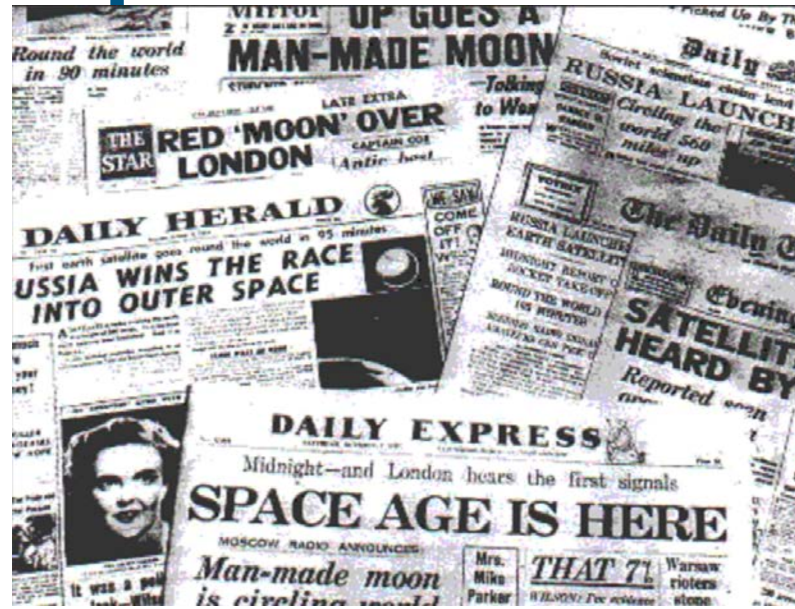
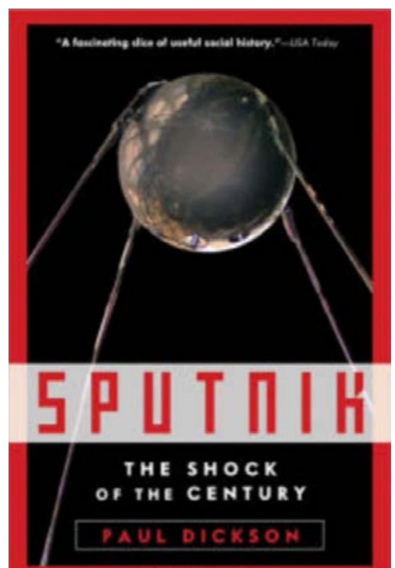
Early Radar Work

- US Navy: onboard USS Rendova Aircraft Carrier
- Douglas Aircraft:
  A3D Skywarrior Strategic Bomber

Oct. 4, 1957: Sputnik!





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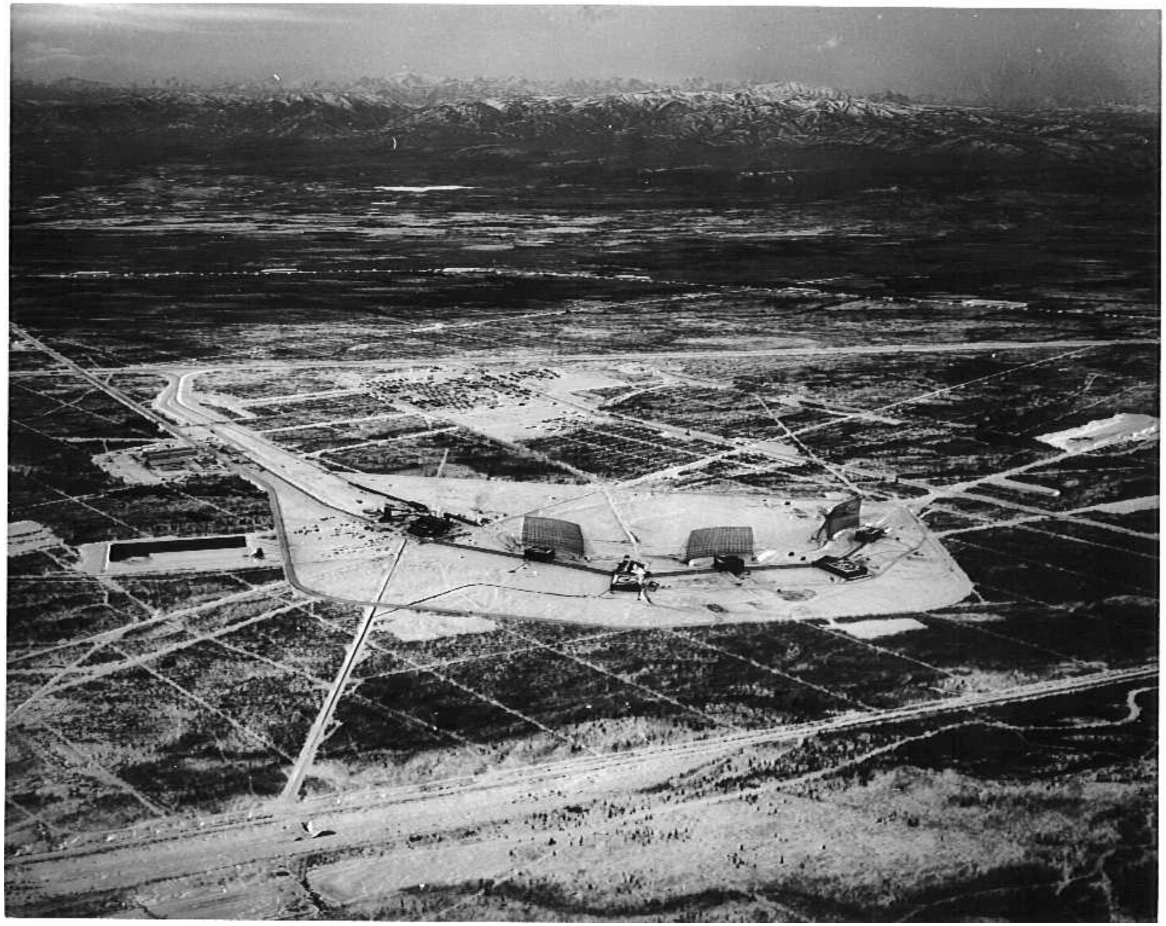
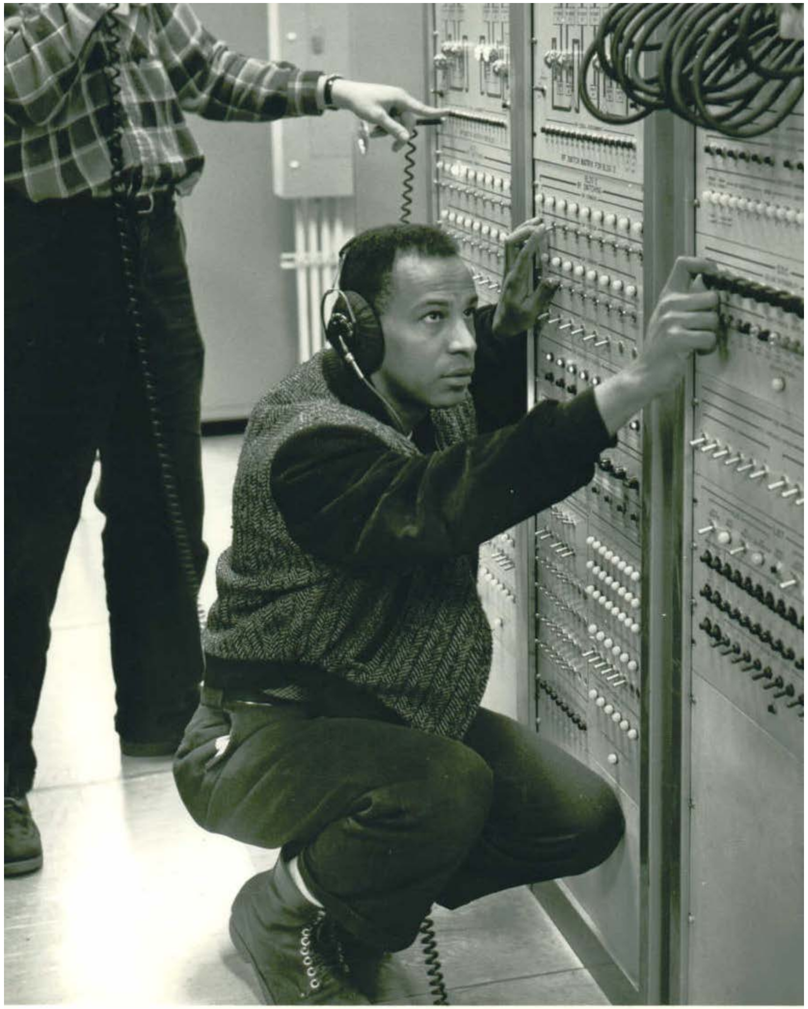
Monitoring the Soviets in Alaska

- RCA Corp.: Ballistic Missile Early Warning System (BMEWS)
  - Clear Air Force Station in central Alaska



IEEE Advancing Technology for Humanity

Monitoring the Soviets in Alaska

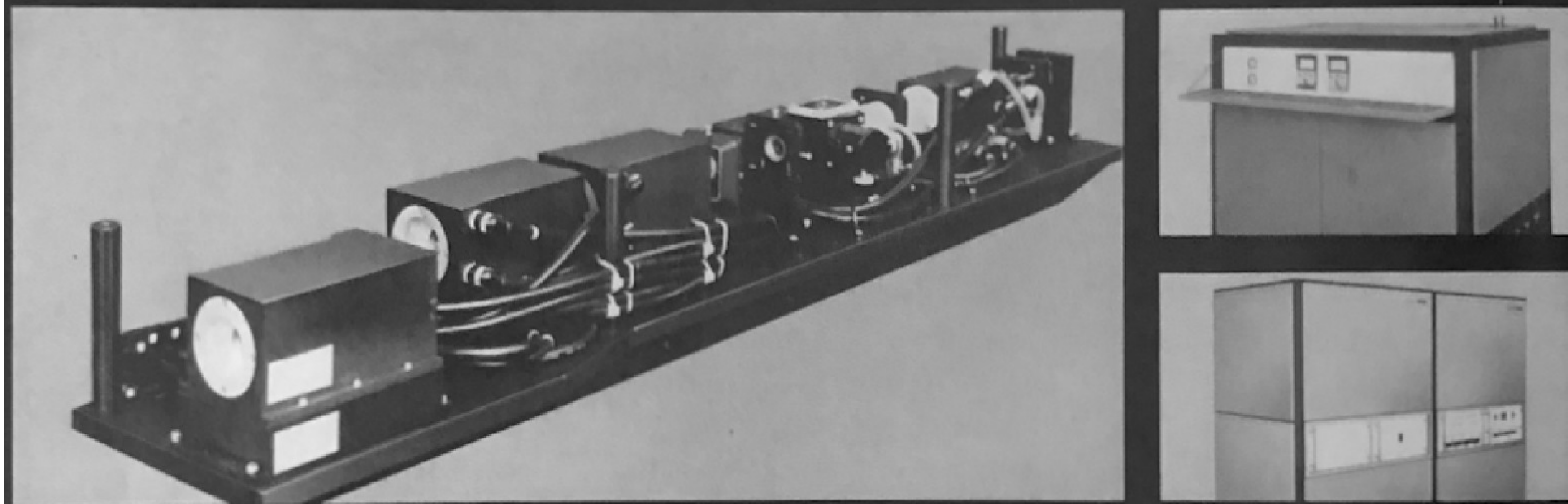


Maiman's Laser Invention

- 1960: Theodore Maiman invented the laser while at Hughes Aircraft
  - *Light Amplification by Stimulated Emission of Radiation*
  - Laser light can be focused onto a tight spot
- 1962: Maiman formed KORAD Corp. to manufacture high-power ruby lasers
- 1968: Union Carbide acquired KORAD

The KORAD Gigawatt Laser

KORAD's new K-2600 high-powered ruby laser system was designed for NASA's Lunar Ranging Experiments.



KORAD built this four-headed system to monitor the moon, so the performance it offers you is little less than spectacular.

2 GW peak power (over 5 joules in 2.5 nano-seconds) ■ repetition rate to 20 ppm ■ full angle beam divergence of 0.7 milliradians (½ power point)

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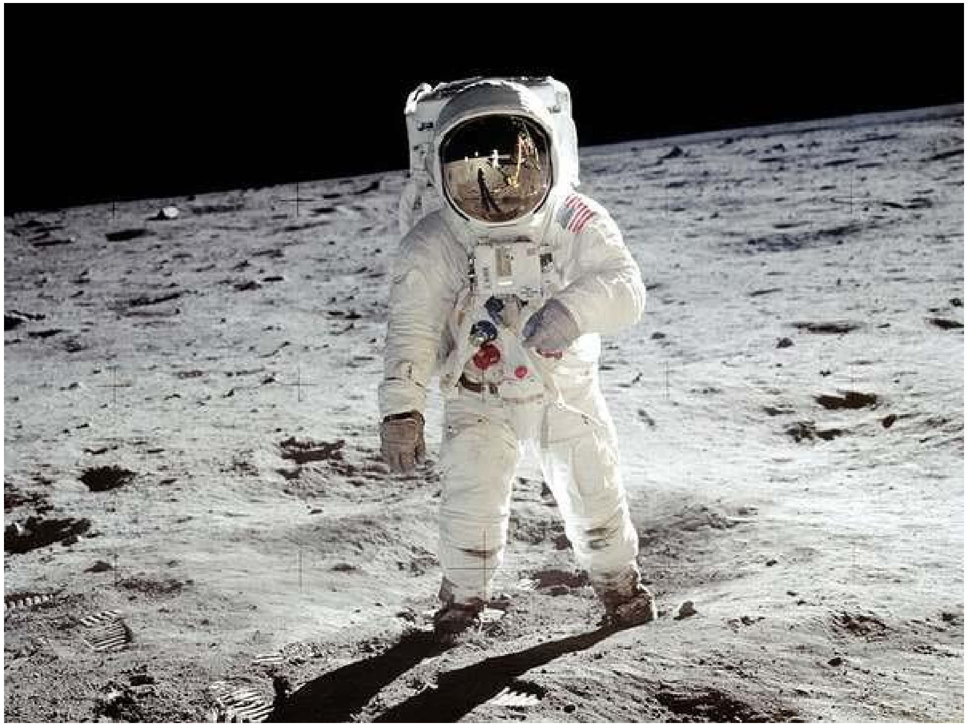
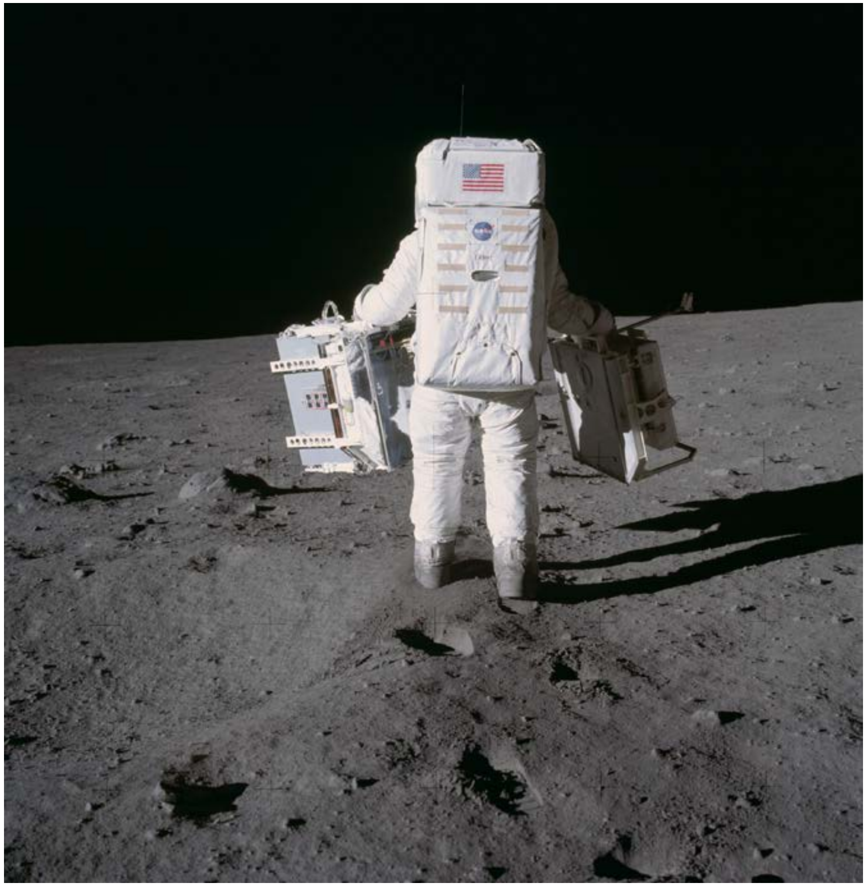
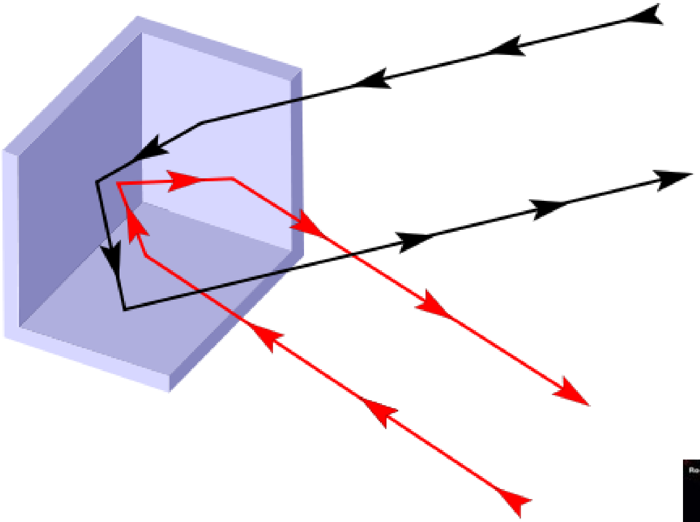
Apollo 11: July 20, 1969

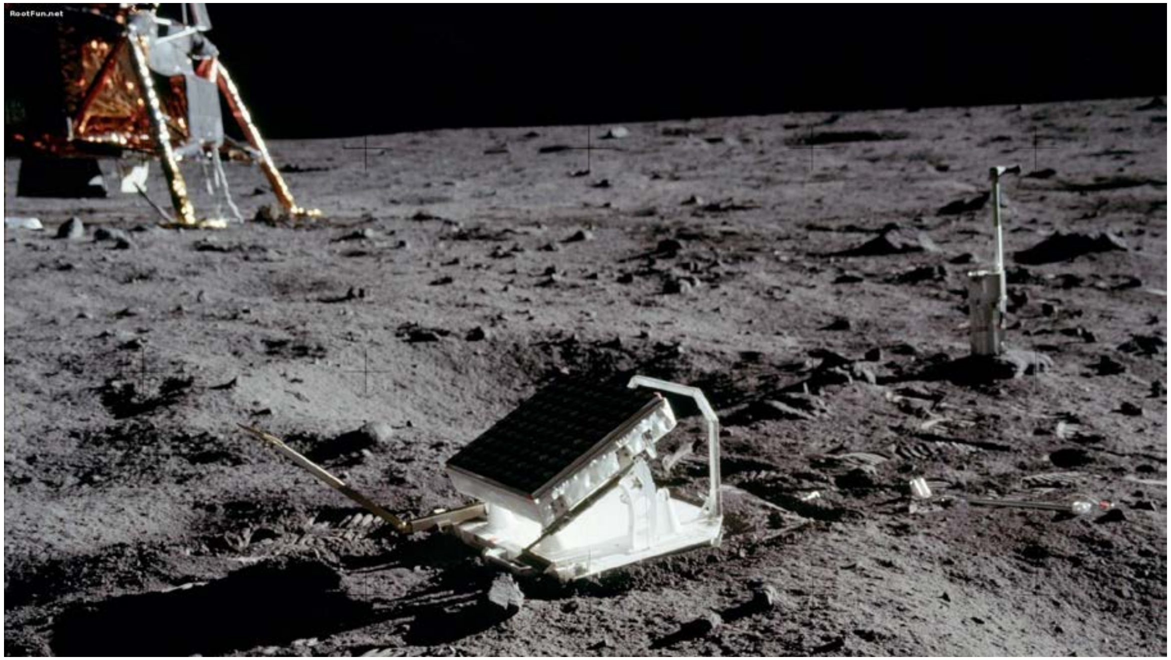
- July 20, 1969:
  - Apollo 11 Landed in Sea of Tranquility on the Moon
  - Retroreflector placed on lunar surface





A Retroreflector





NASA's lunar laser-ranging : How it works

A laser pulse from a telescope on Earth hits the retro-reflector array on the moon. The corner-cube reflectors in the array redirect the laser pulse and send it straight back to the telescope on Earth. Researchers average the round-trip signal to calculate the distance to the moon.

- **The average distance from the Earth to the moon is about 385,000 km.**
- **Dispersion causes the laser beam "footprint" to be about 7 km in diameter when it reaches the moon, and 20 km in diameter when it returns to Earth.**

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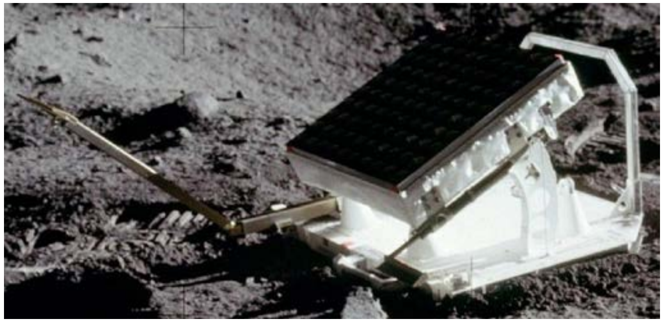
Locating the 18” x 18” Array



Sites Attempting the LURE

Lick Observatory's Shane Telescope

Haleakala Observatory, Maui, Hawaii

McDonald Observatory, Texas

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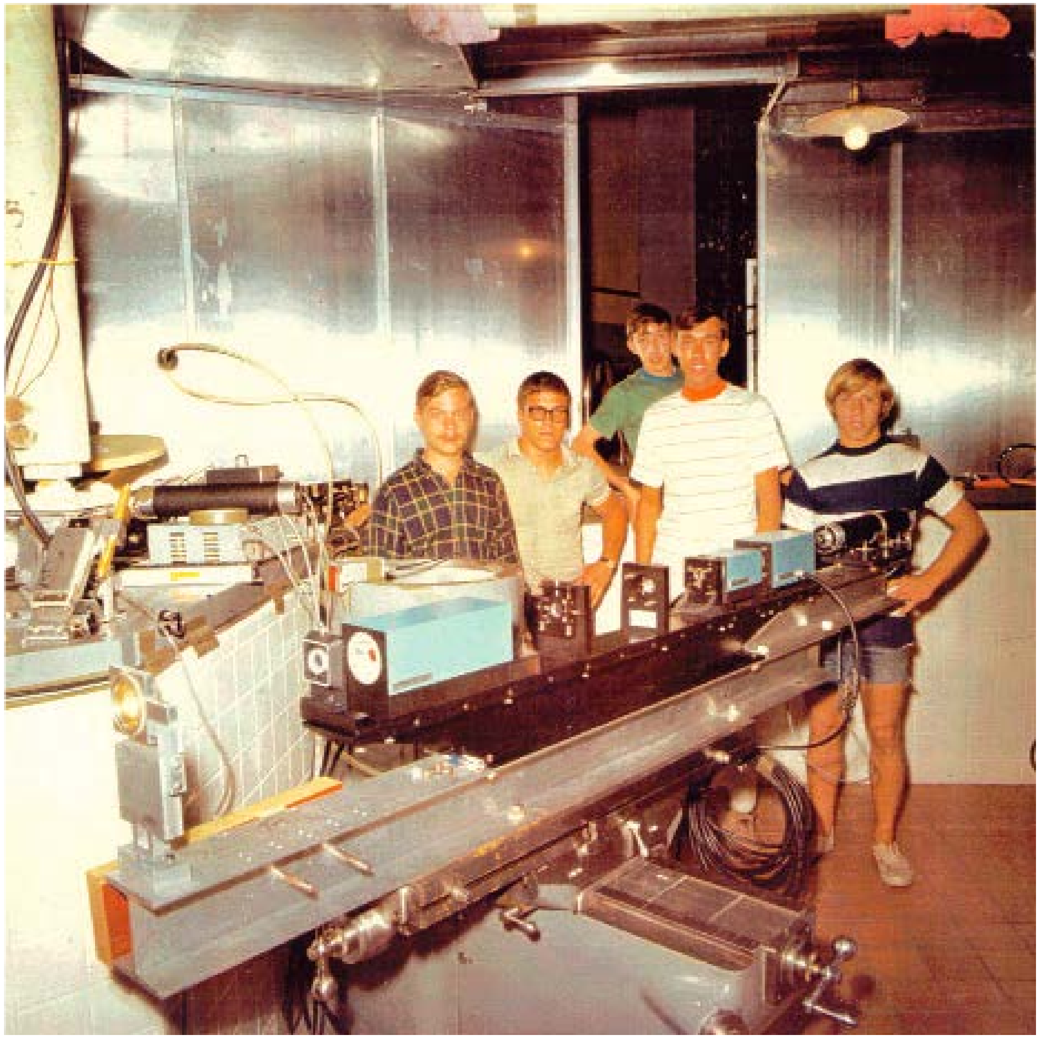
“Upstairs” in the Shane Telescope Dome

The Shane "Basement" with the KORAD Gigawatt Laser



These 5 Wesleyan Univ. (Connecticut) undergraduates helped with the LURE; all 5 went on to get PhDs in physics

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Official Declaration of Success

Circular No. 2160

CENTRAL BUREAU FOR ASTRONOMICAL TELEGRAMS

INTERNATIONAL ASTRONOMICAL UNION

POSTAL ADDRESS: CENTRAL BUREAU FOR ASTRONOMICAL TELEGRAMS.
SMITHSONIAN ASTROPHYSICAL OBSERVATORY. CAMBRIDGE, MASS. 02138. USA
CABLE ADDRESS: SATELLITES, NEWYORK - WESTERN UNION: RAPID SATELLITE CAMBMASS

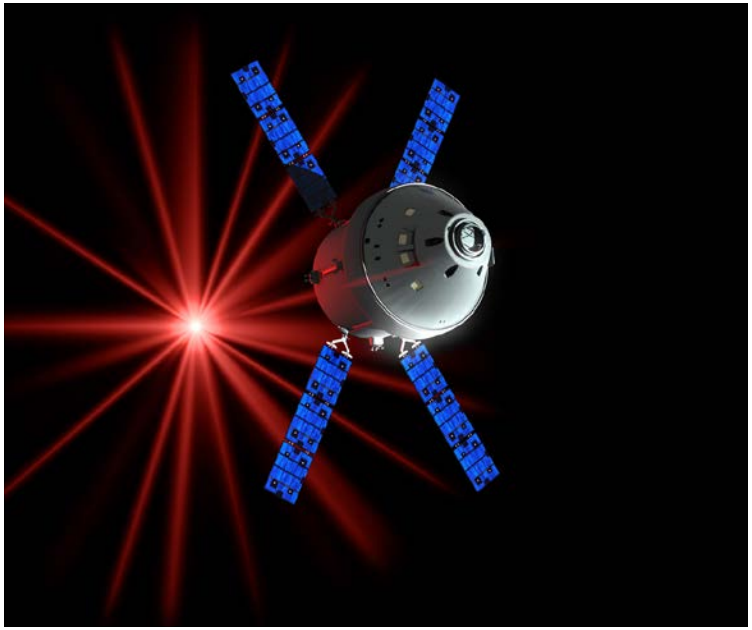
OBSERVATION OF LUNAR RETROREFLECTOR ARRAY

Dr. James Faller and Dr. E. Joseph Wampler, Lick Observatory, communicate: "We should like to report the successful acquisition on August 1 between $10^{h}15^{m}$ and $12^{h}50^{m}$ UT of the retroreflector array placed on the moon by the Apollo 11 astronauts. After the return signal was first detected it continued to appear with the expected time delay for the remainder of the night, a total of six integrations showing a signal level 3 to 10 standard deviations above noise. The coordinates of the laser ranging retroreflector

After the LURE

- Meeting with Buzz Aldrin:

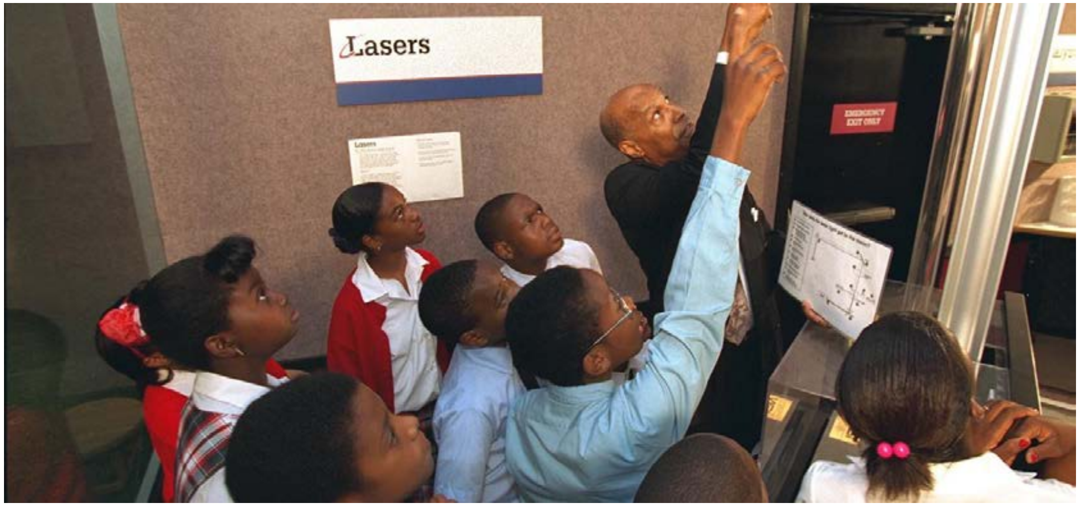
- Work at Hughes Electro-Optical Data Systems:



- Consulting work with lasers

NASA Solar System Ambassador

- JPL outreach program
  - Youth education
  - Outreach STEM programs in the US and in Africa



Hal and Wife Bettye Formed the A-MAN Science and Technology Program

- 1997: Hal and his wife and STEM educator Dr. Bettye Walker met with President Nelson Mandela
- 1998: The Walkers started returning to South Africa to continue this work

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First Chapter of the National Space Society (NSS) on the African Continent

- Cape Town Space Society formed in March 2019
- Hal (left) and his wife and STEM educator Dr. Bettye Walker (right) with chapter members

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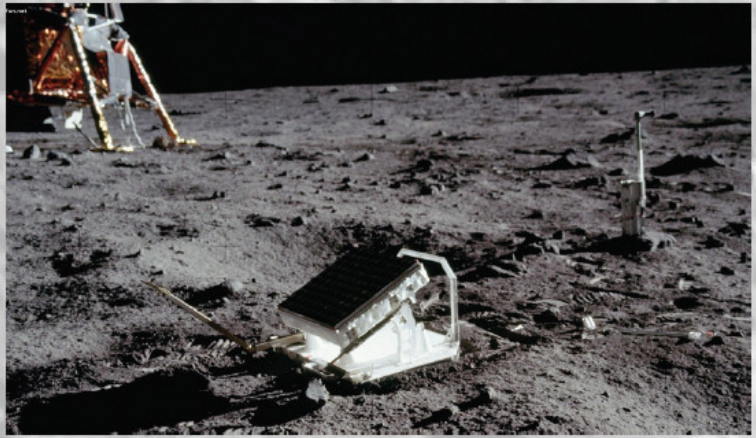

1 August 1969 / 1 August 2019:
50 Years Later

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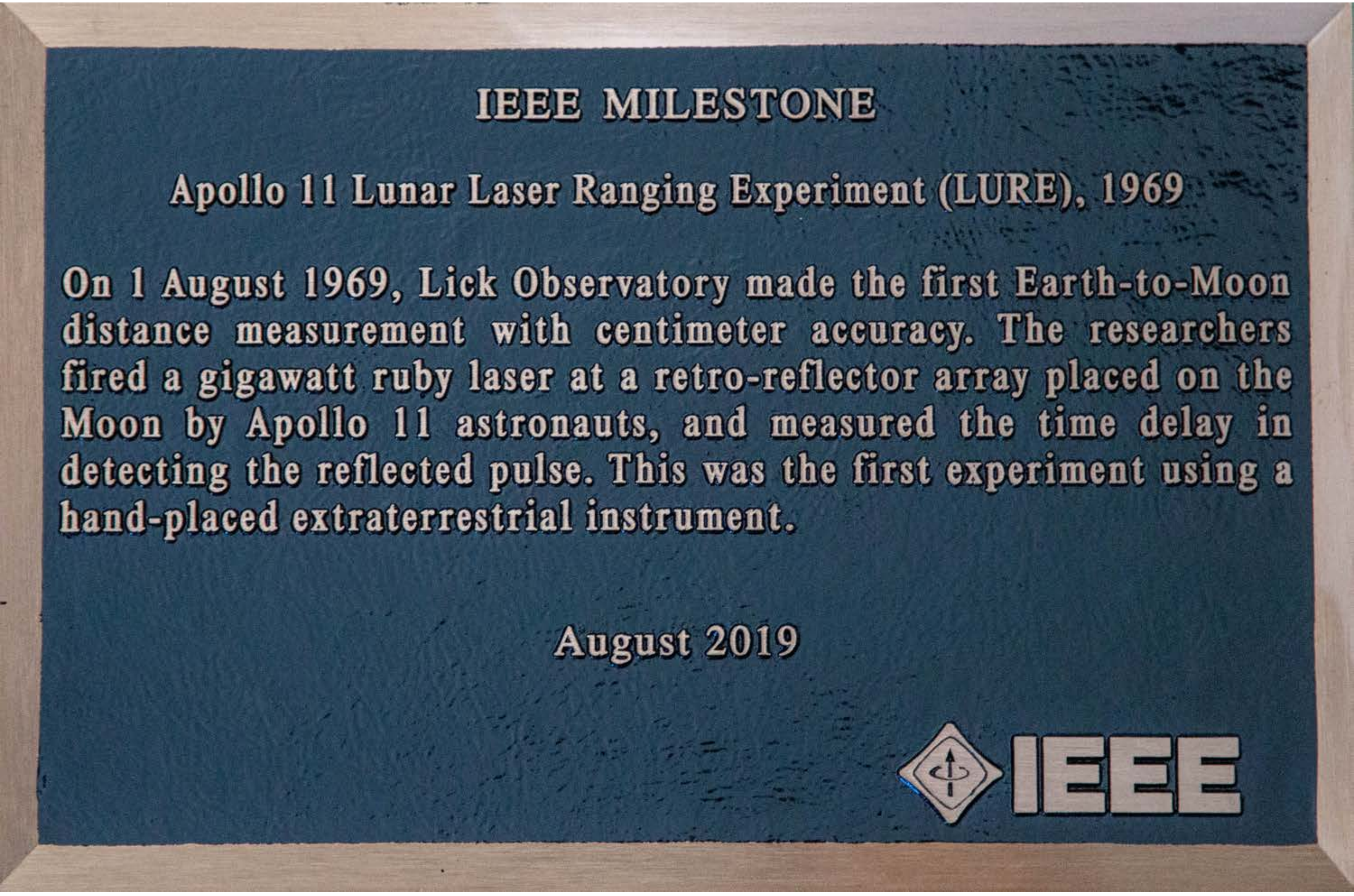
IEEE MILESTONE
Apollo 11 Lunar Laser Ranging Experiment (LURE), 1969
On 1 August 1969, Lick Observatory made the first Earth-to-Moon distance measurement with centimeter accuracy. The researchers fired a gigawatt ruby laser at a retro-reflector array placed on the Moon by Apollo 11 astronauts, and measured the time delay in detecting the reflected pulse. This was the first experiment using a hand-placed extraterrestrial instrument.
August 2019
IEEE