History of NASA and the Environment Symposium: Unabridged Notes

Compiled by ***Alan B. Ward*** *and* ***Douglas Bennett*** *[NASA's Goddard Space Center/Global Science & Technology, Inc.]*

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History of NASA and the Environment Symposium

"NASA is called the space agency, but in a broader sense, we could be called an environmental agency . . . Virtually everything we do, manned or unmanned, science or applications, helps in some practical way to improve the environment of our planet and helps us understand the forces that affect it"—**NASA Administrator James Fletcher** [Remarks to Congress, March 1973].

Dates: September 29–30, 2022

Location: Georgetown University, Washington, D.C.

Intercultural Center (ICC) and Virtual

Planning Committee Members:

- **Brian Odom** [NASA's Marshall Space Flight Center (MSFC)—*Acting Director of NASA's History Office*]
- **Neil Maher** [New Jersey Institute of Technology (NJIT)/Rutgers University (RU), Newark]
- **Dagomar Degroot** [Georgetown University (GU)—Professor of History]
- **Teasel Muir–Harmony** [Smithsonian's National Air and Space Museum (NASM)]
- **Chris Heely** [GU] helped with IT and other infrastructure matters.

Motivation for and Purpose of the Symposium

To more critically analyze the historical connection between NASA and the environment, the NASA History Office and Georgetown University invite proposals for papers to be presented at a two-day symposium, from September 29-30, at Georgetown University, Washington, DC. The purpose of the symposium is to analyze the long history of NASA's interest in, responses to, exploration of, and impact upon, environments as broadly construed.

NOTE: Shaded sections were the sessions NOT covered in *The Earth Observer* article. The Discussions from those sections were not recorded in the notes. They can however be viewed on the YouTube recordings.

DAY ONE (September 29, 2022)

Session 1A – ***Pollution: Global and Local***

Moderator: Neil Maher [NJIT/RU Newark]

Stephen Buono [Harvard University]
The Devil's Glow: Starfish Prime and the Invention of Outer Space

He started with a story. **July 9. 1962**. Hawaiians watch for a spectacular light show. College students bought dates to beach. Kids woke up to watch. Detonate H-bomb 250 miles above the Earth. Thor rocket lifts off from Johnston Island and fifteen minutes later… the lightshow (which he showed images from.)

Lightshow visible all over the Pacific Rim

- Transition of colors in quick succession. Initial bright white light. Then blue black to lime green (viridescent) to lemonade pink to deep blood red.
- Accompanying transition of spectators from sense of wonder to sense of fear.
- The glow bubbled aloft. A bucket of blood.
- Watercolor sunset

"For six minutes the night had become watercolor day."

Starfish Prime. Date: July 9, 1962; Yield: 1.44 megatons; Altitude: 248 mi; Test Series: DOMINIC; Location: Johnson Island. Largest space-based weapons test of cold war.

[Livestream interrupted]

In DISCUSSION, he commented that Test Ban Theory of 1963 was as much an environmental treaty as a nuclear arms treaty.

People saw Starfish Prime unfold all over the Pacific. They were in awe of the lights at first—but then they started getting a bit scared by it.

Alyssa Kreikemeier [Boston University]
An "Accident of Geography": Military Overflights and the Tohono O'odham Nation

Acronyms. Federal Aviation Administration (FAA), Papago = Tohono O'odham; Supersonic Transport (SST); National Environmental Protection Act (NEPA); Military Operating Airspace (MOA); Environmental Impact (EIS).

Impact of possible SST flights in 1959. (Compete with U.K. *Concorde*.)

Anti-SST movement combined with environmental groups.

U.S. SST program ended in 1971; flights banned in 1973.

1975 SST Flights over land banned.

1964 Supersonic Flights over St. Louis. Ended early due to backlash against it.

Tohon O'odham Nation in southern Arizona.

NEPA forced AF to assess impacts of this test. Environmental Impact Statement.

[Livestream interrupted again.]

Thomas Turnbull and **Cyrus Mody** [both at Maastricht University]
(both participating virtually)
Earth's Nearest Star: NASA's Demonstrative Solar Energy Projects

Relationship between NASA and development of alternative energy projects in the 1970s.

Solar electrification (photovoltaic project) of the Schuchuli community in Tohono O'odham nation (discussed in last presentation) located in southern Arizona.
- Sun had long been part of their indigenous cosmology.
- Initiative led by NASA.

1970s: NASA Experiencing "Existential Success"; it was at a Turning Point
- Post Apollo. Where do they go from here?
- Budgetary constraints.
- "Whitey on the Moon" [All they bought back was a pile of rocks.]
- A new era of applied sciences.
- Alternative energy research—New NASA mission and links to indigenous cultures.
- Skylab power cost $300/W; the Tohono O'odham village cost $2/W
- Lewis Rosenbloom [NASA Lewis Director] was early advocate for solar power.

Arizona. What better location for solar energy research?
- Ford Administration wanted to set up solar research facility.
- 1975. Visionary paintings of a solar future in the desert.

The myth of electrification. "Completely solar powered." Well, maybe not…
- Communal washers weren't used. This had been a community activity. They hadn't considered this part.
- The more power provided, the more people wanted—and they turned to traditional fuel sources (e.g., diesel powered generators) for it.

Bahr's Two Conceptions of Energy

- Among the tribe. Diesel energy = "STRONG" Solar energy = "WEAK"
- The story shows both the promise and the perils of alternative energy.
- **Brings up question: *What counts as pollution?***

Thomas Rowson [University of Bristol]
From Jamaica to the Moon: Considering the Environmental Impact of Aluminum in Constructing the Saturn V

Mentioned Netflix show *Good Place*.

- Contestants scored based on measure of good deeds versus bad deeds. Infuses comedy with moral teaching.
- Two people purchasing a tomato could have different outcomes.

Analogy fits the environmental impact of Saturn V rocket. Much good enabled but there were bad impacts.

Consider not just the Earthrise photo, but the whole craft—i.e., the overall impact of creating a huge rocket.

Chains and their impacts can impact the whole globe.

Saturn V is 90% Aluminum (or "Aluminium" if you're British)

- No real alternative. Corrosion resistant. Strong—yet relatively light weight.
- Focus on Stage IVB (McDonnell Douglas, subcontractor Keiser→leads us to Jamaica).
- They had worked on Thor rockets previously, so NASA used same alloy on Apollo.
- Douglas used Keiser Aluminum and Chemical Sales, Inc.

Bork site. [I'm not sure what's correct. Precursor of aluminum.]

Jamaica contributed Aluminum. Open-pit mines to extract. Strip mining.

Changes more of local environment than other techniques.

Operations take place in open air. Danger of air and water contamination.

Keiser Aluminum and Chemical Sales, Inc. obtained land in Essex Valley. Bought out farmers—but some stayed.

Wooden hut and banana tree in the middle of mines.

Unintended consequences of roads built—locals could readily engage in illegal deforestation.

Reviewed the process of creating Aluminum in detail—and described all the environmental pollution that comes with each step.

- Aluminum Oxide (or Alumina) [Red Mud is waste product—dumped in large lakes.]
- Spent Pot Lining typically dumped in Landfill.

Hard to discuss the Saturn V without considerable the material impacts it had.

- This big beautiful rocket had quite an environmental impact.

Runs counter to the environmentalist narrative inspired by Earthrise.

Does Saturn V truly belong in the Good Place?

Rachel Hill [University College London]
"Louder than the Loudest Thunders": The Acoustic Ecologies of Launch

Excitement of Artemis 1 shows how much energy gathers around launches—pun intended.

While ignition and liftoff are awesome to behold, they also produce huge amounts of acoustic energy.

Cacophony of launch has enivironmental impacts.

Apollo-IV. Largest sound ever recorded from Saturn V launch.

Figure showing predicted max sound pressure levels for the Merritt Island Launch area.

- **Neat Tidbit:** Her old report shows Launchpad 39-C at Kennedy Space Center which was never constructed.
- Merritt Island itself serves as a sound barrier.
- Threshold for pain is **114 dB**

Walter Cronkite, upon witnessing Apollo IV (??) Saturn V launch said: *"The roar is terrific."*

- Captures the quintessential experience of launch.

Images of Thunder.

- Ancient people associated thunder with *voice of God*.
- Now… Thunder no longer implies divine judgment, rather the thunder of the rocket represents technical achievement.
- "*Man had now something with which to speak to God*"
- *"A whole Niagara of molten metal."* Jules Verne

"In Huntsville, or rather Rocket City, you live in perpetual bombardment, a nightmare of noise and shouting. The most terrible noise comes from that Saturn […] ***The voice of a giant that rumbles and roars like Niagara Falls in autumn****. When it whispers, the Earth trembles up hil and down dale, walls quiver, windows shatter, your eardrums hurt beyond endurance. There are more deaf people in Huntsville than anywhere else in the world"*—**Orianna Fallaei**, *If the Sun Dies* (217–8) Novel

For STS (a.k.a., Space Shuttle, first launch in 1981) a new Sound Suppression System was created

- Thousands of gallons of water poured onto pad at launch.
- Sound energy turned to heat.
- System still used (has been updated for SLS).

Nathaniel Hawthorne. Train whistle interrupts his contemplation of pastoral landscape.

Pictures Don't Always Tell the Whole Story

- Showed 19th century landscape paintings. Note location of clouds (bottom) and sun/light (top).
- Similar positioning used for launch photos—e.g., Shuttle pushes clouds to the ground as it ascends toward blue sky.
- We use such iconic photographs—but those images don't convey the sound!
- Ground clouds (Sonic clouds), or shockwaves.
- Often only evidence in photos is a flock of birds flying—to escape shockwave.

Showed Some Documents discussing Sound Impacts:

- Environmental Impact Statement for the Shuttle (1978)
- Document (2008) for Constellation system. [Now defunct.]
- "The Environmental Impact of Emissions from Space Launches: A Comprehensive Review" J.A. Dallas et al.

"The near-field effects of this ground cloud can be severe due to the fallout of acidic droplets and alumina as it sweeps across the ground. As the cloud rises, and is transported by the prevailing wind., it can also have effects further afield (deposition at a distance of up to 22 km from the launch site has been observed)."—From *Journal of Clearner Production*

Session 1B - *Climate Change, Weather, and Atmospheres I*

Moderator: Dagomar Degroot [GU]

Anna Amramina [NASM]
Their Last Bow: NASA's Involvement in the U.S.–Soviet Environmental Research

The U.S. and USSR. were adversaries in the Cold War—yet they collaborated and entered into science–technical agreements at the same time.

- Her first example was Apollo–Soyuz Test Project 1975. Handshake in space.
- Emerged from same framework as other Cold Ward cooperation.
- Series of bilateral agreements.
- She mentioned an agreement emerging from the Moscow Summit in May 1972.
- Agreement on Cooperation in the Field of Environmental Protection

Ozone hole (known since 1970s.)

NASA's contribution to ozone observations data collection project. Total Ozone Mapping Spectrometer (TOMS). was on Nimbus-7. By late 1980s, Nimbus-7 was on borrowed time, a replacement was needed. Plan emerged to work with Soviets. Launch from Russian North would be beneficial. U.S.– Soviet cooperation led to placing American made instrument on Soviet designed Gidromet weather satellite on a Ukranian-manufactured rocket (formerly ICBM). Launched at Plesetsk (in Russian North) 3 days before the August coup d'etat in Moscow, and 4 months before collapse of the Soviet Union.

Names she mentioned here.

- **Jay Herman** and **Arlin Krueger**. [Both were in the Atmos Chem and Dynamics Branch when I worked there; Jay was my ATR for the Task I worked on.]
- She shared a 2017 Maniac Talk quote from Krueger.
- **Vyacheslav Khattatov**. Ran the Soviet team.

From Sputnik all the way to cooperation on Meteor–TOMS. Plenty of challenges to overcome.

Ode to Project. She showed the verses to the song. 16 TOMS

Mentioned the role of the Central Aerological Observatory

Andrew Ross [GU]
An American Atmosphere: Missile Testing, Military Expansionism, and the Origins of the U.S. Standard Upper Atmosphere, 1946-1952

Overview

- Infrastructure and militarism;
- Models as Maps; and
- Verticality of US State Power after WWII.

How was the Standard Atmosphere used to extend U.S. reach across the planet?

1946–1952. V2 Launches at White Sands Proving Grounds

- U.S. and Allies captured many V2 rockets from the Germans after WWII.
- Experiments with V2 rockets in the U.S. after WWII to incorporate ballistic missiles into U.S. military → Army Oridnance Core organized *ad hoc* Rocket Research Panel.
    - Refine and incorporate ballistic missiles.
    - Better understand the atmosphere in which these missiles would operate.
    - Both these had overarching objective to create a Standard U.S. Atmosphere
- NACA (predecessor to NASA) Standard Atmosphere released in 1947—based on pre-V2 data. From balloon soundings that went to 32 km, plus other scattered sources higher up to 100 km . Scientists hoped V2 launches would offer more data.
- He showed graph showing Altitudes of Various Observation Techniques available at that time. Rockets the most versatile.
- V2 launches would be used to verify/correct the Standard Atmosphere.
- Research Analysis → Missile Design → Instrument Calibration
- "Pressures, Densities, and Temperatures in the Upper Atmosphere" released in 1952.
- 1952 Rocket Research Panel Update.
- Both 1947 and 1952 Standard Atmospheres assumed atmosphere spatially uniform and temporally static.

The investigators agree that the mean conditions in the atmosphere above about 40 km very poorly represent the conditions at any given moment. [Changes between daytime and nighttime conditions] in temperature, pressure, or density in the upper atmosphere have not yet been firmly established, nor have correlations with solar phenomena, aurorae, terrestrial magnetism, or ionospheric activity. Seasonal effects are [also] not evident in the rocket material."—**Rocket Panel**.

However, "limited" doesn't mean Standard Atmosphere had no purpose.

- Standard Atmospheres—more a cartographic than a meteorological tool.
- Infrastructure building was crucial.
- Militarized aerospatial infrastructure.
- Created a vertical map to help military vehicles transit the atmosphere.

Funding comes from Army, Navy, Air Force.

- In an era when Military branches competed, there was considerable cooperation in creating this Standard Atmosphere.
- Insightful window into U.S. Military's vertical expansion. Sprawling outward—and upward into high aerospace.

Edward Goldstein [Independent Scholar (Former NASA Speech Writer)]
The Development of NASA's Earth Science Program and its Role in Climate Change

[Note: Ed spoke with no accompanying Power Point.]

Based on PhD at GW.

- Had an opportunity as NASA Speechwriter to be close to the Earth Science Program.
- Ed acknowledged Dixon Butler's contribution to his presentation. "He likely has forgotten more than I will ever know about the program."
- EOS was an impressive achievement.
- Had a major impact on how Universities taught Earth Science.

IGY (1958).

- James Van Allen was an organizer.
- Sputnik happens the same year. Start of space age.
- It was initially difficult for Earth Science to "get on the agenda"
- And yet it was there from early on…

JFK gave a speech to Congress in 1961, which included the challenge of *"going to the Moon in this decade,"* he also proposed an additional 75M, with 55M for Weather Bureau—including mentioning a satellite system for weather observations.

- *Quote from Piers Sellers at Smithsonian event:* "Our technical ability to view our Earth from space is coincident with our ability to change our planetary environment…" Satellite obs provide the sole means to observe the whole planet every day.
- *Conversation with Mike Freilich*. [Hurricane Ian was impacting Florida when this event happened.] Prior to satellites the human race never had a complete image of a hurricane's complete cloud pattern.

The Moon Landing came to dominate the public perception of what NASA does in the 1960s. However…

- Recently released tapes of Kennedy talking to James Webb (who wanted NASA to have broader focus than just going to the Moon).
- There has been a longstanding symbiosis between human space flight and planetary programs—beginning with ozone studies.
- The ozone program started in 1970s, when NASA proposed Space Shuttle aerosol emissions might harm the ozone layer.
- James Fletcher created Program of research into ozone.
- NASA's research into ozone (initially to assess the impact of Space Shuttle engines on environment) was instrumental in NASA's shift to focusing toward studying environmental impacts and eventually, climate change.

Jim Hansen (before he was famous). Hypothesis that humans might impact ozone layer. "*If you change ozone, you change the climate. I converted weather model to climate model.*"

- He became director of GISS in 1981 and made their focus climate change.
- Developed first Global Circulation Model using satellite, airborne, and ground data.
- Model made connection between human CO_2 and rising temperatures of the Earth.

Hansen went on later to testify to Congress in 1988.

- Based on climate models that NASA pioneered I am 99% certain that climate is warming as result of human activity.
- Told the press, we've got to stop waffling on this.
- This was a *moment of inflection* that changed whole public debate on climate.

When NASA got involved, leaders like Shelby Tilford knew we needed to get the community together—and were quie innovative in doing so. (Or we will lose our lunch to other programs!) Francis Bretherton created comprehensive plan Earth System Science, which served as a mechanism to do this. NASA's program suffered from gigantism. They started with concepts of huge platforms ("Battlestar Galactica") serviced by the Space Shuttle but quickly shifted to smaller, more flexible missions (which became the Earth Observing System we still have today.) EOS was different in that NASA took direct charge of the program. They operate these satellites.

Tanya Harrison [Planet Labs, PBC] [via Recording]
NASA's Legacy and the Birth of the Commercial Earth Observation Sector: Inspiration and Partnerships for a Better Understanding of the Earth System

NASA has long standing history of delivering global remote sensing data.
- Spawned a diverse commercial sector.

Planet was born at NASA Ames.
- Will Marshall and Chris Boshuizen started at the Small Spacecraft Office at Ames.
- Collaborated on PhoneSat as test of using Commerical Off the Shelf (COTS) parts in space, demonstrating that tech that wasn't specifically designed for a space environment could function in LEO.
- The became an inspiration for founding Planet with fellow Ames researcher, Robbie Schingler.

NASA data is critical to Planet's imaging pipeline.
- Atmospheric Correction. To generate our PlanetScope surface reflectance data, we use MODIS data to estimate aerosol optical depth/thickness, water vapor content, and ozone content.
- SkySat (and previously Dove Classic) surface reflectance. Planet uses EO-1 Hyperion spectra (NASA) and Sentinel-2 (ESA, Copernicus) data.
- Previous radiometric calibration process for Dove Classic and RapidEye used simultaneous crossovers with Landsat 8.
- *Data Fusion*. PlanetScope data combined with NASA data.
- *Synergy*. Sum greater than all the component parts.
- This leverages the best of both Earth Observing worlds. NASA's extensive time series of data combined with agility of commercial sector to create applications developed by commercial sector.

Earth is in the midst of a climate crisis caused by widespread habitat destruction and a global economy still reeling from the worst pandemic in a century.

NASA Commercial SmallSat Data Acquisition (CSDA)
- Program was established to identify, evaluate, and acquire data from commercial providers that support NASA's Earth science research and application goals.
- Initiated in 2017 with the Private Sector Small Constellation Satellite Data Product Pilot Project—of which Planet was a part
- Helps to strengthen public–private partnerships and is an excellent pathway for thousands of scientists to gain access to new, state-of-the-art data alongside NASA's exquisitely designed and calibrated missions.
- To date NASA CSDA Program has spawned over 100 publications and conference presentations using Planet data.

Gave two examples where Planet data are being used…

Impacts of climate change on the Arctic.
- Tracking Greenland's ice loss over course of summer 2019. Intense melt season.
- Combine high-frequency (but less calibrated) Planet data with lower-frequency (but "exquisitely calibrated") NASA data—from ICESat–2—allowed them to track the ice loss.

Flooding Triggered by landslide.
- Deadly flash flood in India triggered by landslide.
- Initial report: glacial lake outburst caused it.
- Dove images 27-min apart allowed them to figure out what causes the flood.
- A glacier detached fell 2 km to valley floor, water melted and mixed with debris from valley floor, and created the flood.
- Paper was created and published quite fast.

Observation Legacy
- NASA's technological and scientific developments inspire the commercial sector to imagine what else is possible.
- Providing consistent, exquisitely calibrated data gives a critical baseline for commercial datasets.
- Programs like CSDA enable broad access to commercial datasets for research community.

DISCUSSION

All these different entities are doing Earth monitoring. What are the differences in how they do it?

Edward: It was a challenge at the beginning. NASA could be a world leader in Earth observations—but it would require cooperation with both domestic and international partners and (a bit later) with the commercial sector.

Anna: Soviet Space Program used pretty much the same techniques. Of course, the data isn't as widely shared as NASA data are—but that doesn't mean that you can't get access to Soviet data. One just needs to know where to look.

Andrew: The stark *binary* that now exists between military and civilian roles didn't seem as prevalent in the early days. NACA and Rocket Research Panel had flow between military and civilians. He mentioned a meteorologist named Harry Wexler who went back and forth between agencies.

As the operation viability of these systems became more evident—and especially after Sputnik—the need to have a civilian answer to a military function increased. Why? Perhaps to justify further military development. Then again, you need it to be more than a military tool, so civilian versions are needed.

Edward: NASA has always been constrained by budget. EOS budget was cut/downsized numerous times (leading to re-visioning, -scoping, -baselining). NASA had to look for partners. They entered into partnerships with NOAA and DoD on NPOESS—which was an unwieldy and poorly managed. (They also partnered with other nations.)

Bob: NASA and NOAA have worked out a pretty good relationship—at least NASA views it that way, not sure what NOAA does. DoD runs things differently. Institutionally driven requirements that go through highly formalized process. They have more money (not as much budget constraint as NASA and NOAA), they build more often, they get things done. NASA has more of an interactive design program. Requirements come from community and remains an interactive process. **Chris Scolese** managed a program. Give-and-take between managers, scientists, and engineers—and, especially more recently, with potential users of the data that will be produced. (DOD is much more compartmentalized.) He also mentioned USDA, which he called a "passive customer" to NASA technology. (He said NASA tried the same model we had with NOAA but it failed.) Very different models… The most successful partnership seems to be NASA–NOAA. NPOESS worked. It became JPSS, which became a NASA–NOAA endeavor with DOD opting to pursue its own system.

Dixon: NASA Earth Science started out with whomever wanted to participate, but we wanted worldwide cooperation, and DoD didn't want to do that. So, DoD was increasingly kept out of the loop so that NASA could collaborate globally. Although there was still huge amount of DoD investment.

Dagomar: Not as much a requirement in the early days of the Space Program.

Someone in Audience: Mentioned that DoD and NASA Space Test Program. NASA provides instruments to go on DoD payloads. [I think TCTE was part of this.]

Question About How Political Events Impacted Science Collaboration

Anna: Challenges come from up top. For example, State Department wants collaboration with USSR to stop after invasion of Afghanistan. But then there's a bottom up. Collaborations continue…but they are"kept quiet" or unofficial.

Dixon: Even in worst days of Cold War, there was still data exchange.

Anna: Once again today, there seems to be a rift between Russian and Western science communications.

Bob: After the Cold Ward, we found out Russian Science wasn't very "deep." Good people, but not always rigorous science. As the Soviet Union collapsed, young people left, and in Bob's words, "Good science is done by young people." For example, Piers Sellers was 30 years old when he "shook the world" with new science results.

Dixon: Russia needed help to protect its nuclear assets from terrorists.

Edward: We (the U.S.) had Nuclear Cities program.

Dixon: The idea there was to put the young people to work.

Anna: The exodus of young people is called the Late Soviet Brain Drain.

Tanya: [Joined the conversation remotely.] Expanding out to the commercial partnerships, Tanya said that through CSDA, people have better appreciation for value of commercial data. Early on there was aversion to NASA purchasing data, but over time there has been more openness. Planet has had an academic program for years—where data are made freely available to students. Great to see NASA and commercial data sources coming together.

Dagamor: Do Russians make use of Planet data? What about Global South?

Tanya: Not sure on Russian access currently. Certainly, before the war, they were making use of Planet data. She said that Planet is trying to make their data easier to access in general.

Question for Andrew on Further Development of the Standard Atmosphere

Andrew: Up until about 30 km, there was an internationally recognized Standard Atmosphere. Above that was where the U.S. was doing work. 1956–1958 AF Wx Bureau and NASA work on Standard Atmosphere. Revised in 1962 and 1976. Modified version of 1976 is still used.

Bob: Shared an anecdote related to Andrew's topic. The person he replaced at NASA HQ had 300 copies of 1976 Standard Atmosphere in his office.

Session 2A – Extreme Environments and Cabin Ecologies

Moderator: Melinda Baldwin [University of Maryland, College Park]

Jordan Bimm [Institute on the Formation of Knowledge (IFK), University of Chicago]
Simulating Life in Alien Environments: NASA and the politics of 'Mars Jars'

Mars Jars. Mars Environmental Simulators.

- Carl Sagan introduced them to people on Cosmos.
- They date back to WWII. Hubertus Strughold [German "refugee"] invented Mars Jars. He also organized first Astrobiology conference.
- "Survival of Microorganisms in a Simulated Martian Environment" [Could a microorganism survive on Mars and thus contaminate search for life on Mars.]
- *Frontiers of Science* comic strip mentioned Mars Jars.
- Each tiny simulation (or Mars Jar) imagined the real thing.
- Always more in a Mars Jar than meets the eye.
- Not designs of Mars, but designs on Mars.
- **What if aliens visited Earth and bought with them Earth Jars?**

Vyta Pivo [University of Michigan]
Concrete Space Oddities: NASA and Built Environments in Outer Space

Indirect entry into studies environments in outer space.

- She encountered "New Ways with Concrete."
- Tung Dju Lin [NASA JPL] published in *Civil Engineering* in 1985. Concrete was best material for building in outer space.
- The idea of a "concrete Space Station" didn't seem to make sense.
- Concrete is not so much a material but a recipe: 60-75% aggregates, 14-21% water; 7-15% cement, Up to 8% air.
- Concrete compared to Fruit Cake.
- Linn received 40 g of Moon dust in 1986—from Apollo 16 in 1972.

Lunar soil would have characteristics of the Moon.

- This meant that the concrete recipe could theoretically be altered.
- Concrete space construction project. New phase of space colonization.
- "Pave the foundation for future space colonization."

Influences on Lin

- Reagan's call for reducing expenses.
- The Challenger disaster → Material failures were on his mind.

Lin proposed Concrete Lunar Base. [Looks like a "wheel of cheese."]

More recent photo from the 3D-Printed Extraterrestrial Habitats Challenge (2019).

- Seeking innovative ideas for construction materials.
- **Reinforces the idea that: Place does not exist on its own**. We design place.

Daniella McCahey [Texas Tech University] (participating virtually)
A Model for extraterrestrial Settlements: Antarctic Environments as an Analogue for Space

Antarctica Analog Studies. Harsh environment that most closely parallels conditons humans would encounter in outer space. Test: Undersea rovers; habitats; space suits.

Antarctica seen as "gateway to another world."

- She shared list of ways Antarctica and Space would be comparable.
- But they aren't exact analogs. Antarctic is on Earth; 1000 people at McMurdo; some places have relatively mild climate.
- Origins of U.S. Antarctic Program [Has parallels to NASA.]
- Four early American expeditions. [Admiral Byrd]
- But IGY was impetus for major colonization. 1955
- During IGY, comparisons between Antarctic and Moon/space. "*We know more about Moon than we do about Antarctica*."
- **There are ways the Antarctica is "like another world" but it's also part of our world.**

Issues there (e.g., ozone hole) have important impacts on climate.

David Munns [John Jay College]
An Excremental History of the Space Age (Riding the Algatron to Mars)

- Travel to the stars has always hinged on waste management.
- Story of how bodily "wastes"—urine, feces, and sweat—become nutrients.

Close the loop. Return waste as nutrients.

- Algae were ready-made solutions to waste management in space.
- There is no waste in a closed system.
- There is no such thing as pollution in a closed system.

Even more than Americans, Soviets understood how a closed system worked.

1965. *The Algatron*. William Oswald and Clarence Golueke [Sanitary Engineering, University of California, Berkeley]

Why did NASA adopt "such startling 'do it yourself processes as… the handling of feces with a specially designed glove"?

Showed *Whirlpool Corp* "Apollo Fecal Collection Bag." Some unidentified dude in plaid pants holding the bag up to his butt.

Brings it down to Earth when you have to shit in space.

- Astronauts took an hour to poop! [Whole procedure had to be followed.] There are blank sections in the logs when Astronauts were relieving themselves.
- Kids first question is often: How do you go to the bathroom in space?
- Oswald and Golueke proposed the Algatron to be part of the Saturn V.

Showed Boeing's Algae Tanks. Turned them into Algae Cupcakes. [Eating his feces!]

Session 2B – *Monitoring the Earth Environment*

Moderator: Jennifer Levasseur [NASM]

Christopher Neigh [NASA's Goddard Space Flight Center (GSFC)]
The History of Landsat and the Earth Environment

[Chris noted that Jim Irons had been scheduled but could not attend owing to things going on at GSFC today, so Chris is here in his place.]

Overview

- Vision
- Societal Needs
- Technology Advancement

Vision

Images of Earth from Moon was impetus for environmental movement.

"*The vast loneliness is awe-inspiring and it makes you realize just what you have back there on Earth*"—**Jim Lovell**.

Bill Pecora and Stuart Udall. Plotting a mission. Earth Resources Technology Mission, which later became known as Landsat 1

- Dept of Interior "threatened" to launch a mission on their own—which got NASA and DoD's attention.
- ERTS/Landsat 1.RBV [analog] and MSS [digital]
- RBV only lasted a short time.
- Virginia Norwood. Developed MSS. "Mother of Landsat"

Book Landsat's Enduring Legacy [Open access version via QR code he had on slide.]

Why is Landsat Program Important?

- Provided major advances toward understanding our world beyond what was available for 50 years of prior air photo surveys.
- Provided the optimal ground resolution and spectral bands to efficiently track land use and document land change due to climate change, urbanization, drought, and wildfire.
- The continuous archive [1972–Present] provides essential land change data and trending information not otherwise available. Landsat represents the world's longest continuously acquired collection of space-based moderate-resolution land remote sensing data.

Landsat is a 50-year partnership between USGS and NASA. NASA builds and launches the missions; USGS manages and distributes data.

Building on the Landsat Legacy [Showed timeline of when each mission launched and how long they operated]

- Landsat 1 and 2. Well funded.
- Landsat 3. NASA didn't want to commit to operational.
- Landsat 4 and 5. Gap between missions increases.
- Landsat 5. Launched in 1984 and operated for over 20 years.
- Landsat 6. Launch Failure [ill-fated commercialization effort; "dark time"]
- Landsat 7, 8, 9.
- Landsat Next. The tenth mission.

Landsat Applications.

- Landsat provides multispectral imagery supporting key science and societal benefit areas [Mapping Land Use & Change, Forest Dynamics, Agriculture & Evapotranspiration, Ecosystem Science, Surface Water Quality, Glacier & Ice Sheet dynamics, Geology and Natural Resources].
- Landsat has provided $2.06B of economic benefits to the U.S. in 2017.

Societal Needs

Landsat 1 transferred from analog era to digital era.

Cropland Mapping in the 1970s

- Large area projects couldn't process large amounts of MSS data due to computational limitations.
- Photographic prints compiled into mosaics were often used to map large areas.
- LACIE was first Landsat experiment to test large area crop mapping.
- The example shows EROS data and how Valerie Thomas managed digital image processing to help us move into digital era. She was a Fortran programmer who automated subsets from MSS to train model to detect crop types.
- In the photo he showed, Valerie is holding digital media tapes.

Soviet wheat blight.

- At that time, the U.S. could not detect the blight via satellite.
- Soviets bought up majority of U.S.'s wheat stores at discounted rate.
- Wheat prices then went up 200–300% in mid-1970s.
- Idea was Landsat could be used to map vegetation.

Landsat Commercialization Experiments. [EOSAT (1994–2000)—Expensive imagery—cost was $200 in L1/L2 time period, but shot up to $4400 at this time. Very difficult for scientists to acquire data. A "dark time" for Landsat].

LACIE transformed to Cropland Database. [From just North Dakota in 1997 to national in 2008—which is when Landsat data were made freely and openly available.] This really transformed ability to collect info on crop type and predict yields.

Brazilian Amazon [1985 Landcover Biomass Project] He showed a visualization that begins with a wide view of Northern Brazil. While zooming in a little closer an image of the U.S. fades in to get the relative size of the region. Next we cycle starting in 1985, and then progressing over three decades of transformation in the region showing land use change over time. The visualization ends in 2019 and fades in fire data from that active season.

Recent Breakthroughs: A Global Deforestation Sentry [Matt Hansen (2013]

- Cited on web of science 5000 times since publication.
- Used in Global Forest Watch where we've identified hotspots of change.
- Cloud computing coupled with free and open access to Landsat has enabled global forest monitoring to spot deforestation as it's occurring in real-time.
- Forests are essentially commodities, and the biggest driver of deforestation worldwide is the economic value of trees and the land they occupy.
- Our high demand for food products and agriculture land has resulted in an intractable problem.

What has been the impact of Landsat on Science? Most number of documents for Earth observing instruments. Show comparison to other instruments (MODIS second).

A vision realized. Free and open access with commercial cloud computing.

Google Earth Engine

Landsat data is top dataset in Google Earth Engine.

Take Aways…

- After 50+ years Landsat continues to be backbone mission for land RS.
- Transformational scientific data use with open free resources.
    - Open data policy
    - Cloud computing

Chris's assessment: We've done a god job meeting Bill Pecora's original vision.

Closed with:

- Landsat 9 image. Pearls of Bahrain.
- Quote about Landsat from NASA Administrator Sen. Bill Nelson

Laurence Rothman [Smithsonian Research Associate Center for Astrophysics – Harvard and Smithsonian] (participating virtually)
The HITRAN Project: Molecular Spectroscopic Database Archive for Environmental Monitoring

HITRAN Molecular spectroscopic database.

Originated in1960s with U.S. Air Force (USAF) Cambridge efforts to detect enemy aircraft exhaust.

- U.S. Air Force wanted to be able to detect enemy aircraft.
- Needed to "filter out" the atmosphere.

Origins: 1960s.

- Three breakthroughs: IR detectors, Computer power, high resolution spectrometers.
- Parameterization of molecular transitions.
- Converting a spectral line to a parameterized line list.
- Lambert–Beer law of radiative transfer.

Proto HITRANS

- National Bureau of Standards (now NIST) monographs.
- First made public: March 15, 1966.

Showed Kitt Peak National Solar observatory. [Supplies data to the HITRAN database.]

Last quarter of 20th c saw rapid growth
- *Enhancements*. Spectral coverage (longer and shorter wavelengths, more molecular species, accuracy and precision improved, dynamic range expanded).
- *Programs*. Dept of Transportation (SuperSonic transport effects), Dept of Energy (ARM program), and NASA (EOS) was the main driver. Later Planetary Atmospheres Program also contributed.
- *Collaborative initiatives*. Development of International Assimilation of Data, HITRAN Bienniel Conferences, Atmos Spectroscopy Applications conference, Special Journal Issues.

21st Century
- *Establishment at the Harvard Smithsonian Center for Astrophysics* NASA Environmental Satellite missions, NASA Planetary Atmos program.
- *Media and Access*. New relational database structure, expanded validation, access via website, YouTube tutorials, HAPI, a flexible application program.

He showed the HITRAN homepage.
- Demonstrated Line-by-line.
- New HITRAN version every four years, but updates posted on website.
- HITEMP. High-temperature analog of HITRAN. [Showed data from JWST]

Robert E. Murphy [NASA Headquarters and NASA Goddard Space Flight Center (ret.)]
Land Biosphere Interactions with the Climate System – The Addition of Biology to NASA's Earth Science Program 1983-1996

How biology got involved in NASA. "Rocket Science" meets Biology in the 1970s.

How did the "Hard Science" World NASA Engage with and Fund the Bio Sciences?

Like many history stories. This one involves the interactions of many factors.
- National priorities and politics.
- Scientific consensus and national and international levels.
- Developments in technology.
- Evolvinig organizational structure and power relationships.
- Availability of funds.
- **The ideas and actions of individuals.**

All are relevant—in this case, the last one is most important.

How Did NASA Do Science?
- Historically, NASA is a technology agency. (NASA put things in space that revolutionized "pure" sciences. NASA supported the communities that used its tech. (Comfy boundaries with NSF, DoD.)
- In other areas the programs had to be in support of other agencies. (NOAA for weather; USGS for geologic studies, EPA for pollution; in the 1970s NASA formalized an "Applications" Program for this tech-driven program.)
- NASA was responsive to astronomy and planetary communities it supported. (Integrated activity)
- In other areas it was a supplier of techno-goodies for which it was funded. (The other agencies were the buyers—but not with their own money!)
- Ozone—and then climate—changed this starting in the 1970s. (NASA had a charter to do Ozone.)

State of NASA Sciences in Early '80s
- NASA ES were about physical sciences. (Weather, climate, atmos chem, oceanography, solid Earth, geophysics)
- Bio Science was part of NASA's program in three places—that's it! (Planetary Science, Earth Sciences (Oceanography)—CZCS [1978–86]; and Space Applications (Agricultural Assessment)—AgrSTARS).
- Lack of integration of Biology with the Physical Sciences not limited to NASA.
- This began to drive NASA's focus on the environment.

NASA Climate Priorities
- In the early '80s, climate was a rapidly growing National priority.
- Climate models dictated measurement needs.
- NASA was hardware-driven agency.
- NASA tech could measure key physical variables (e.g., temp profiles, SST, cloud properties).

- NASA built a community that modeled climate, defined need, built sensors, analyzed data. (In house, mostly at GSFC and JPL and in the university community.)
- This was breaking the classic model of interagency roles. HOLD THIS THOUGHT!

A Problem: :Biological process are key to climate.

- *Evapotranspiration*—a biological process—controls 1/3 of the energy budget at Earth's land surface.
- All weather and climate models treated evapotranspiration as a purely physical process; i.e., they modeled evaporation not evapotranspiration until ~1990.
- Evapotranspiration is controlled by biological needs of vegetation—not just the physics of the land–atmosphere interface.
- Classic climate modelers were slow to recognize this.

The First Steps—NASA Climate Plan for 1977

[He showed a hard copy of the 1977 plan!]

Leadership

- *Programmatic*: Dr. Leslie Meredith [GSFC].
- Engineering: Harry Press [GSFC].
- *Science*: Dr. Andrew Ingersoll [Cal Tech].
- *NASA HQ Reps*: Leonard Jaffe, Dr. Morris Tepper, Dr. S. Ichtiaque Rasool.
- *Science Particpants*:
    - 15 gov't and university scientists (included a young James Hansen).
    - Study task force of 25 scientists from GSFC, JPL, ARC, and LaRC (included Dr. Vincent Salomonson).
- Evapotranspiration mentioned 3 times in the 1977 Plan. [That's it!]
- "Vegetation" mentioned 6 times—yet this was considered a breakthrough. [Biology arrives!]
- Who wrote those words? Nobody I know knows for sure.

While evapotranspiration is mentioned in the original NASA Climate Plan (1977), in essence, they say, "We don't know how to do it."

1980s—Increased Environmental Awareness and Institutional Adaptation

- Growing awareness of global scale environmental problems. (Building since the 1970s: global warming, the ozone hole.)
- Awareness was at both the scientific and political level.
- NASA chooses to emphasize its role as science agency. (Popular support for astronomy and planetary exploration, success in addressing the ozone hole with the Upper Atmosphere Research Satellite, or UARS.)
- Dr. Shelby Telford [UARS Science Lead] tapped to lead integrated ES program at NASA HQ. (Consolidated leadership over programs in weather, climate, upper atmosphere, tropospheric chem, solid earth geophysics, oceanography, geology, agriculture.)

About the Biology Issue…. The Development of ISLSCP

- Dr. Ichtiaque Rassool organized three international workshops in 1983.
- ISLCP was initiated under UN Environment Program (Goal: Define research to meet climate modeling needs of biospheric processes.
- Primary need: Measurements of evapotranspiration at a daily interval; Major field experiments needed to develop and validate algorithms.
- ISLCP developed a unifying intellectual framework that guided national level programs and facilitated international cooperation. (Basis for NASA's Land Processes program beginning in 1985—which Murphy led.)
- Intellectual Leadership by: Dr. Piers J. Sellers, later of NASA; Dr. Francois Becker of U of Strasbourg, France, and Dr. Jean Claude André of CNRM.)

About the money: The Collapse of AGRISTARS

- AGRISTARS collapsed. (It had been funded in the old mode.)
- Landsat was manifestly not the right sensor for the job. (Too much data for that era, to many cloudy pixels, insufficient revisit time; major goals required another decade of science.) Murphy commented that Landsat was NASA's and USGS's "brand new hammer" and AGRISTARS was "the nail" to test it on.

1985. The Land Biosphere Joins NASA HQ

- Shelby Tilford established program in terrestrial ecosystems, hydrology, geology and RS physics. (Reprogrammed remaining Applications Program budget.)
- Murphy was appointed head of the Land Processes Branch at NASA HQ. (He hired first ecologist at NASA HQ, Dr. Diane Wickland to define/manage ecology program; Hired hydrologist/ag engineer Dr. Ghassem Asrar to define/manage hydrology program.)
- Program changes. (Introduced rigorous peer review, implemented series of major filed campaigns following ISLCP framework, and broadened field campaigns to support global carbon cycle and ecological issues.)
- Ecologists entrained into the NASA community over the next decade. (GSFC, University professors, Senior ecologists came to HQ to spend sabbatical years developing and managing programs.)

Integration achieved.

- *Major field campaigns*. HAPEX–MOBILHY (1986—France, U.S.), FIFE (1987, 1989—U.S., Canada), HAPEX-Sahel (1991—France, Niger, U.K., U.S.), and BOREAS (1994, 1998—U.S., Canada.)
- Six of the original Interdisciplinary Science (IDS) investigators of the EOS [which Jack Kaye discusses in Session 3B] involved biospheric processes and land-atmosphere interactions (He listed them.)

J. Compton Tucker [GSFC]
Realistic Exchanges of Water, Energy, & Carbon Between Land and Atmosphere: The legacy of Piers Sellers: Meteorologist, Astronaut, Advocate for Earth Science, and Humorist

[Also credited Inez Fung [UC Berkeley], Dave Randall [CSU]; Joe Berry [Carnegie Inst]; Jagadish Shukla [GMU]; Forrest Hall]

Compton talked about the legacy of Piers Sellers.

He took us back to the "dawn of climate modeling".

- Bob Murphy just explained how it began mostly as physics.
- Climate modelers were, "Dragged, somewhat against its will, into including biology."

Piers Sellers revolutionized land surface modeling by including the biosphere on land.

Origins of the ideas leading to the recognition of the importance of land surface processes: Jagadish Shukla [UMD, COLA], Dave Randall [CSU], and Piers Sellers [GSFC] 1982–1986

Piers had Impressive academic lineage. Jule Charney → Yale Mintz → Piers Sellers

Future role of land and biosphere in bridging predictability gap between weather and climate.

Atmosphere is well-mixed and changes on shorter timescales than land (longer) or oceans (longest).

- This means measuring geophysical parameters are key.
- Ichtiaque Rassool [ISLCCP) realized intermediate source of data between satellites and ground was needed → Enter aircraft data.

Piers realized integrated field programs were key: e.g., FIFE and BOREAS.

- Both FIFE and BOREAS used aircraft to bridge the gap between ground studies and satellite data.

Piers always loved flying.

- He went to boarding school from third grade on. Got his pilot's license before driver's license. First thing he did was "buzz the boarding school."
- Took his professor on flight to white cliffs of Dover. Inverted aircraft to give professor a better view.
- Piers flew on three Shuttle flights (STS-112, -121, and -132). [He loved to fly!].
- Compiled 42 Spacewalking hours (25 orbits). Earned the nickname: "Human satellite".

Back to NASA administration [2011–2016] (when he passed away)

- Loved to give interviews—including children.
- When he came back to GSFC, he moved into Tucker's basement.

Piers said: *"We have nowhere else to go. We have a very special planet with one climate and we're in this together. Let's solve our climate problem with human ingenuity and focused hard work."*

Summary of Characteristics: Kindness, wit, intelligence—and monkey business!

- Piers' sense of humor persisted to the end. [Tucker showed "Tumbling Mice" and "The Grim Squeaker".]
- He knew the odds were against him but he continued to work toward the "salvation" of the planet until he passed away.
- Showed a collage of events from Piers' life.
- Piers is elsewhere in the galaxy with new friends. [Showed him with Millennium Falcon crew.]
- Piers "led from the front". [This is in contrast with Italian Generals in WWII who "led from behind."]
- He had his share of "clashes" with NASA HQ over his ideas.
- Didn't shy away from them—nevertheless he always kept his sense of humor.

DISCUSSION

Jennifer (Moderator) commented that she always felt privileged when Piers came to the museum.

Jennifer asked about the importance of public messaging about science. These are not always easy concepts to digest.

How important is it to have a figure (strong public identity) to relate to.

- Tucker remembered Piers would have early morning meetings with Mike Freilich.
- While Mike and Piers were friends, Mike could be quite "frank" at times when he didn't agree with someone. One time when he responded in this way to something Piers said, Piers said something to the effect of: *Mike, I've studied it, I've observed it from space. I think I know.*

The discussion of "spokesperson for the public" triggered a long-ago memory for Dixon.

Remembered a Walter Cronkite interview where Mike Macelroy explained timescales to American public comprehensively in a 45-sec soundbite on the evening news.

Dixon also mentioned the example of Carl Sagan. So, yes, having someone who is both well-educated and engaging is a real asset.

Bob: Having a public face is important—even essential.

Carl Sagan is a well-known example, as was Piers. He came across to the public as easy going—although in person he wasn't necessarily as nice. By contrast, Piers Sellers was genuinely nice. The Community needs to feel that the person is a true spokesperson for them. People certainly felt that with Piers.

Someone asked Lawrence when HITRAN shifted from Air Force to civilian. There was overlap during the 1990s (AF Office of Scientific Research), but then control shifted to Harvard Smithsonian Center for Astrophysics. DOD no longer supports.

Question for Chris Neigh about international diplomacy issues. Countries from Global South concerned about commodity markets or how satellite observations might be used against them. Ground receiving stations all around the world. Other nations could download data and keep it in their own archives.

Chris recalled a time when some MSS data over the Amzaon was lost (the room in Brazilian ground-receiving station apparently wasn't climate controlled). Chris was working for Jim Irons at the time, collecting data to produce a geocover mosaic. Searching through a cabinet while cleaning out Jim Tucker's office, he found a tape labeled "MSS Amazon." Lo and behold, it contained the missing data!

Dixon's sense is that the experience International Affairs gained working on setting up Landsat stations was helpful in networking and creating connections that could be used with EOS.

Someone in the audience pointed out that some relationships go even later to the creation of the Deep Space Network in the 1960s.

Another Piers anecdote from Bob Murphy. Piers once wrote Bob (Director of Land Processes at the time) asking him for a job. Bob had Brian Markham wrote the "rejection letter." Brian had a copy of "Piers' first rejection letter." "My first rejection. I shall always treasure it."

Dixon said Piers Sellers was such an asset as an IDS investigator in 1989.

They all felt a sense of loss when Piers chose to become an astronaut. They were happy for him—and he made a great Astronaut!—but sad to lose his Earth science expertise. The sense was, sure, you *could* be an astronaut, but what you bring to NASA Earth science is unique.

Tucker said that Piers wanted to be an RAF pilot. He entered a judo contest and got hurt and failed his RAF physical, so he went to grad school. Sort of a serendipity. Piers may have been disappointed at not getting into the RAP, but their loss was NASA's gain.

Someone is audience asked Bob: Did NASA study Nuclear Winter? No, not to his knowledge. *[This discussion went nowhere. Kind of an outlier to the rest.]*

Dixon's hesitation about writing a "History of EOS," is the critical things he might have to say.

Question about Landsat progression and what factors most impacted the schedule. OMB decisions impacted the schedule. NASA is an R&D organization. Landsat has an operational legacy—through USGS. Push and pull between commercial takeover i.e., EOSAT and the Landsat 6 debacle) and NASA.

Tucker added that the Europeans (with the Copernicus Sentinel program) have taken over land observations. They built four imagers. These now provide three or four-day revisit (even lower if you include Landsat 8 and 9 available through Harmonized Landsat Sentinel database.)

Dixon disputes that NASA is truly an "R&D agency." This is our "official" position, but face it, NASA operates satellites. But OMB likes to deny this to justify not funding Earth Science investigations.

Tucker (at a party) learned that Landsat 3 was put in the budget without knowledge of NASA.

As Bob said in his presentation, the "breakthrough" was ozone (and then climate). Since then, we've done more long-term mission planning.

Session 3A – *Space Contamination and Astrobiology*

Moderator: Lisa Ruth Rand [California Institute of Technology]

Dana Burton [George Washington University]
Vital Dynamics: Tracing the Intersection of the Office of Planetary Protection and the Lunar Environment

What lies in the crater on the dark side of the Moon?

Future uses of Moon being decided based on past understanding.

Convergence of Three Stories [She later added a fourth—see below.]

- Scientists.
- Mining corps. [Newspace]
- Office of Planetary Protection.

Relationship between vital and non-vital.

Mentioned "National Academies of Science, Engineering, and Medicine Planetary Science and Astrobiology Decadal Survey: 2022–2032."

Vital. Living… Essential…(essence of)

Converging Stories

- *Story 1*. **Office of Planetary Protection**. Contaminants travelling from Earth to Moon (or elsewhere) or vice versa. Leads to NASA Sterilization Policy. First Planetary Protection Officer was part of Navy.
- *Story 2*. **Industrial companies—Newspace**. Engineering the Future of Space. Looking at ways to lower cost of operating in space. Moon as "gateway to Mars." What is alive and what is expendable?
- *Story 3*. **Shift in categorization of Moon**. Cat 1. Unrestricted access. Cat 2. Limited access—inventories of organics in engine and propellants required. *Biological* versus *Organic* classification. *Biological*. Is it alive? Organic. Are organic compounds present?

- *Story 4*. **The public reaction**. *[This is yet to be told.]* What part do we play in shaping this history? This complex story is just beginning to be told.

Aeryn Avilla [Embry-Riddle Aeronautical University] (pre-recorded)
The History of Martian Astrobiology and its Impact on Crewed Martian Exploration
[Aeryn is an undergrad student—and a former GSFC intern.]

Christiaan Huygen's Cosmotheoros. First speculated what life on other worlds might be like.

Canals on Mars? Gionvanni Schiaparelli. *Canali*. Channels, not "canals." Canals implied canal builders→ life on Mars??

The Dawn of Astrobiology (formerly Exobiology). New dsicoveries in life sciences.

- Mariner (1962–1973). Mariner 4, Mariner 6 and 7, Mariner 9
- Viking (1975–1982). Viking 1 and Viking 2. [She listed Viking Discoveries.]
- Mars Science Laboratory (2012–??) [She listed discoveries.]
- Mars 2020–Perseverance (2020–??)

Impact on Future Crewed Missions

- Location of Landing Site (Ancient lakebeds; Near polar ice caps)
- Crew Training (Emphasis on chemistry, geology, microbiology; If traces of life are found → paleontology)
- Astronaut Selection Criteria. Expand applications to allow humanities with increased human presence.

Planetary Protection

- The prevention of celestial bodies from contamination by Earth-originating life and vice-versa.
- Committee on Contamination by Extraterrestrial Exploration → Committee on Space Research (COSPAR)
- First implemented by NASA in 1962 with the lunar Ranger program.
- UN Outer Space Treaty Article IX establishes legal basis.
- Having such a legal basis is crucial for prevention of sample contamination—e.g., false positive from Apollo 12 Surveyor 3 bacteria.
- Example: Sterilizing spacecraft, prevent unintentional impact of hardware.

No Bucks, No Buck Rogers

- Mars has been major component of Sci Fi for more than a century
- Public fascination has grown with tech advancements.
- Public interest → More Funding
- Perception of NASA's mission is sometimes warped by "popular news."

Erik Conway [NASA/Jet Propulsion Laboratory]
Near-Earth Objects as Environmental History, Revisited

NEOs and Environmental History. He's not the first to write about this topic.

He listed others including Dagomar Degroot, one of the symposium organizers.

Many Scientists still don't see NEOs as legit targets for sciences.

Story in Brief

- NEOs weren't of interest before 1970—they are obstacles to seeing what is interesting, they contaminate.
- Referred to as,"Vermin in the skies."
- Asteroids obscure more desirable targets.

And yet… some scientists took interest. [He showed photos.] Tom Garrells [U of AZ—1960s]; Eugene and Carolyn Shoemaker; Eleanor Helene.

- Gene Shoemaker's early work married weapons to large-scale cratering.
- Fatally undermined the idea that cratering was a purely volcanic process. In other words, an object from space could cause them.
- Undermined gradualism inherent in Gould's substantive uniformitarianism.
- 1979—Giant impact led to mass extinction.
- Controversial because it linked cosmic events to history of life on Earth.
- Chicxulub remote in time ~66 Ma

- SL9 impact (on Jupiter) wasn't remote in time.
- Impactor totaled about one-tenth the Chicxlub Mass.
- Drew policy interest.

Grinding Progress Towards Policy
- Took until 1998 for NASA to accept Congress' request to begin a program of NEO discovery.
- Goal would be discovery of 90% of 1 km or larger diameter NEOs.

Sources of Resistance

Included quotes from:

USAF advocate Lindley N. Johnson [now Program Manager at NASA HQ]
- We've got enough missions as it is.
- Didn't get the similarities between was USAF already does and this task.

NASA Program Executive Carl Pilcher
- This isn't good enough science for us.
- We shouldn't be defying Congress.

Erik noted that this attitude still persists: e.g., 2019 National Research Council

Quote Summarizing Attitude within AIAA: "There was an enormous giggle factor about rocks falling from the sky. Chicken Little. This is nonsense. No one's ever been killed by an asteroid."

Conclusions
- Environment and env history are contested grounds.
- Institutional resistance to NEO policies stemmed from different sources.
- It was a roles and missions issue for USAF.
- For NASA's SMD… it was/is an issue of what is/is not "good science."

Session 3B – *Building the Earth Observing System Infrastructure*

Moderator: Roger Launius [Launius Historical Services]

Jack Kaye [NASA Headquarters—*Assistant Administrator for the Research and Analysis Program*] (recorded)
Impact of Earth Observing System Interdisciplinary Science (IDS) Program on the Development of Earth System Science and the Associated NASA Investigator Community

Overview of Presentation
- Earth System Science
- EOS IDS Program and Content
- Questions and Answers about the Program and its accomplishments.
- Potential next steps.

He thanked all those who responded to his requests.

Jack showed the Bretherton Diagram for Earth System Science. Intended to convey the idea that different systems of Earth interact with each other (Earth System Science).

EOS Interdisciplinary Science (IDS) Program
- Created to provide support to "interdisciplinary" teams to work on broad topics of Earth System Science and to "prepare" for the future Earth Observing System (EOS) Through use of existing data and development/utilization of models—proposals were open to Earth System Science community broadly (e.g., academia, NASA centers, other govt agencies' laboratories).
- Allowed for establishment of multidisciplinary multi-institutional, and in some cases as multinational teams. Also "international only" or "international-led" teams were selected to engage international community more broadly. The program began in late 1980s.
- Funding levels were typically large by historical NASA standards and funding was provided for extended period (with intervening progress review).
- The programs in its initial form was eventually terminated following transition to era of having EOS satellite info available and converted to a more traditional program (i.e., three-year funding, with relatively large award

amounts still allowing multidisciplinary/multi-institutional funding—but smaller than historical IDS levels, with topics typically changing with each solicitation.
- Note investigators sometimes had other EOS ties (e.g., instruments) and also students involved through the global change fellowship program.

*Jack noted that the allowable definition of interdisciplinary was more expansive than we would use today.

He showed a *1994 list of IDS investigators*—U.S. and International. Titles were often quite descriptive of the work being done—and you can see the breadth of disciplines represented on the list.

Jack reached out to a sampling of IDS investigators. He had a series of questions and then showed anecdotal answers—which are combined below.
- *What were the interdisciplinary science questions that you were most interested in addressing in your EOS IDS activity?* A variety of interdisciplinary topics were chosen—typically crossing across traditional Earth system components and disciplines. The breadth of topics is significant.
- *How did the IDS opportunity to pull together and interdisciplinary and mulit-institutional team help you address the interdisciplinary science?* (Note this differed for those with international or those that were not multi-institutional.) The ability to bring together multidisciplinary, multi-institutional, and in many cases, multinational teams allowed the Principal Investigators (PIs) to pull together a team that they would almost never have been able to do without such a program. Those integrated teams were essential to the success of investigations.
- *To what extent did the long and stable funding period allow you to tackle science questions and/or make advances that you wouldn't have been able to do if you had to continually propose on shorter cycles?* The long and stable funding period was important, as the challenges tackled needed more time than the typical three-year grant cycle and allowed the PIs to invest the time and energy needed for this kind of effort—and also to help grow the talent through funding of students, post-docs, and early career investigators.
- *Looking back, what do you think were the most important contributions of your EOS IDS effort to advancing the science (especially the interdisciplinary aspects), enhancing NASA's role in it, training future Earth System Scientists, and preparing for the EOS era?* The answers varied from PI to PI, but most felt that their team made important contributions in advancing the science and making the kind of interdisciplinary connections reflected in the Bretherton Diagram and were a central focus of the EOS program; in doing this, they helped set the stage for Earth System Science as looked at by the National Academies in their Decadal Surveys.
- *[For international teams only.] How did you see your participation as an international investigator in the EOS IDS program as helping you be more closely engaged with what NASA was doing (especially in the run-up to the post-launch period, and id that work out as you expected? [I don't think he really answered this question.]*
- *[Bonus question.] It seems like so many of the EOS IDS investigators ended up as real leaders (scientifically and institutionally). Was there a "cause and effect" relationship between the EOS IDS experience and that leadership, or were those selected likely to have ended up as leaders regardless of whether they served as EOS IDS investigators?* The fact that the EOS IDS PIs got to lead large teams and work across traditional disciplines may have helped position them better for the leadership positions which ended up taking more than just "choosing well" (which was certainly also part of it); note that the community-building aspect of the EOS program (e.g., IDS, Payload Panel) gave even greater visibility and award to the IDS PIs.

Potential Next Steps.
- Thorough investigation of this topic would require significantly more effort and analysis of historical record (especially analysis of publication acknowledgements and citations, and also assessment of the extent to which IDS Support career development—particularly for students and post-docs).
- The evolution of the broader community needs to be understood in this context—e.g., how academia evolved from being organized into traditional departments (e.g., Meteorology, Oceanography) to having far more integrated departments (e.g., Earth System Science).
- There is a need to count for co-evolution of instrument teams and IDS teams and the related science, and also how the availability of new data during the IDS time period influenced the teams' ability to address their science.
- Cooperation of Earth System Scientists and historians (especially historians of science), and possibly Public Administration professionals, may be needed for such efforts.

Ron Doel [Florida State University]
Whose Expertise, Whose Skills? Creating Cross-Disciplinary Approaches to Studying Planetary Environments in the Early Space Age

After WWII geologists began to think about the Moon as an area of exploration.

Neil H. McElroy [U.S. Secretary of Defense—1957–1959] said that the Pentagon needed *"to determine our capability of exploring space in the vicinity of the Moon, to obtain useful data concerning the Moon, and provide a close look at the Moon"*—March 27, 1958

What would be professional home for planetary geologists?

Broader context: Shifts In geological practice. The word "planetary" added to geology department names at many universities including: MIT, Columbia, U Miami, Scripps Institute of Oceanography (SIO), UCSD, UCLA, CalTech.

- Timing connects to IGY [1957–58].
- He showed a stamp made for IGY.

Which approaches, which forms of instrumentation, and which institutions would be part of this investigation?

Three Institutions Involved in this story…Columbia U, CalTech, and later MIT.

What was the Moon's general structure?

Were there clear analogies to Earth investigations?

Seismology—a promising geophysical approach. [Applications: Earthquake studies, Nuclear Test Ban Treaty enforcement.]

Two almost simultaneous Lunar seismology proposals submitted to NASA [March 1959]

- Columbia (Lamont Geological Observatory); and
- CalTech (Division of Geology).

Both institutions wanted to put a modified seismometer on the Moon to answer questions about lunar structure.

Did CalTech have an advantage? Quite close to Jet Propulsion Laboratory. Even with today's traffic, they are about half-an-hour apart.

Robert Sharp [1911–2004] Traditionally trained but wide-thinking geologist who advocated for renaming CalTech's geology department to "planetary geology".

- CalTech had initial advantage.
- Ranger and Surveyor missions had CalTech instruments onboard.
- However, by the time of Apollo it was a Lamont Geological Observatory Seismometer.

Was it proximity to NASA facilities? Not initially. Columbia was trying to establish relationship with GISS. Those connections didn't help work in seismology. Lamont facility is just 30 km from the main Columbia

Was it leadership at the Universities? Grayson Kirk [Columbia U] Lee Dubridge [CalTech]. Both University presidents advocated.

The big factor: The Importance of an individual…namely Frank Press [1924–2020]

- He went to grad school at Columbia and was PhD studen of W.Maurice Ewing [Director of Lamont]
- They developed the Ewing–Press Seismograph.
- Press was recruited to CalTech to become Director of Seismology Group.
- Press was impressed with how Lamont was doing cross-disciplinary reaearch and bought all that knowledge with him to CalTech.

What came to limit CalTech's role in planetary geophysics?

Press communicates with W.A. "Bill" Nierenberg [Secretary General for NATO, 1960–1962] seeking NATO backing to create a First Class Division of Earth Science in a university." "It is recognized almost everywhere now that interdisciplinary teams will make major contributions to in the Earth sciences in the next few years."

Press leaves CalTech. Becomes head of Department of Geology and Geophysics at MIT. Chance to develop a new department—funding from Cecil Green.

Press was feeling he could not do what he wanted to do at CalTech. CalTech leadership is reluctant to take military funding.

Also, there are 50 staff members at Lamont—non-tenured employees.

- This plays into the decision which Lab NASA ended up choosing.
- They had experience with building and sending instruments to the most remote, rugged locations on Earth.
- They can easily move from one project to another.
- Work on ocean bottom was quite analogous to what was needed for the Moon.
- George Sutton was the only tenured person working on the project.
- Gary Latham [1965] received contract funding.

Suggested parallels to today: Research schools. These are not unlike what NASA did in its early days…

Dixon Butler [NASA Headquarters (ret.)]
NASA, EOS, and the Environment

Ten minutes on how EOS came to be.

What can we do from low Earth orbit to learn more about the condition of the Earth?

Pitt Thome Committee [10 NASA managers (HQ, GSFC, JPL, Bay St. Louis, MI (Stennis I think)] were to conceive an Earth observation mission requiring a large space platform. The idea is 19 instruments in 3 payloads; with the data system viewed as critical—point of emphasis for Pitt Thome. Concept briefed to NASA Administrator James Beggs—permission given to continue mission study so long as you don't "undermine my Space Station." (Dixon thought maybe Beggs was a "closet environmentalist.)

After a day of frustrating meetings, he had an epiphany: Water was what joined all the missions. The "System Z" concept, which we reported on in the "Perspectives on EOS" series in *The Earth Observer*.

Science and Mission requirements. Planning restarted with outside ES community. Collegial representatives of every Earth science discipline. Earth Observing imperative: *Take today's data today*. Again, there is agreement that the data system is crucial. Reports on data system and multiple instruments. Paralleled the Bretherton Committee. Provided basis for AO and international discussions.

International Coordination. Space station to provide large platform for most instruments. Earth observing offices of Space Station partners. Joined by Meto agencies: NOAA, Eumetsat, JMA, AES Canada. Coordinated facility instruments and selection of PI instruments. Failed to agree on data policy (ESA really wanted a commercial data policy). ESA pointed out that West Coast Shuttle launch and on-orbit servicing were myths. Coordinated polar metsats. NASA to fly afternoon crossing time; ESA to fly morning orbit. (Of course, that's not how it worked out.)

Announcement of Opportunity.

- One of the most complicated AOs ever. 8-week review panel. [He noted good contractor support for the meeting out in the suburbs.]
- Selected: Interdisciplinary investigators (IDS), Instrument investigations, Facility instrument team members and leader.
- 1991: EOS gets "New Start" from Congress.
- Data processing to be done at EOSDIS Distributed Active Archive Centers (DAACs).
- U.S., international, and foreign investigations.

Descoping and Rescoping.

- JPL dropped from mission management.
- Operational mission dropped from spacecraft (platform).
- Platform budget switched from Space Station to EOS.
- Barbara Mikulski reduces 10-yr budget from $17B to $11B.
- Major Review Committee at Scripps. [Chaired by Plasma Physicist.]
    - Hears competing mission concepts from defense community [Space Council at White House].
    - Alternatives are judged inferior to EOS Plan (i.e., Dan Goldni's plan).
    - The EOS approach had to be radically altered—almost overnight.

  - Polar platforms dropped in favor of three moderately large satellites: AM (Terra), PM (Aqua), and Chem (Aura). [Butler, Chris Scolese, and Marty Donahoe]
  - Having both AM and PM orbits would strengthen the science that could be done—especially with MODIS.

Conclusion
- EOSDIS gives Earth science an effective data system.
- EOS budget bailed out Landsat.
- Jason Altimeter is essentially the proposed EOS Altimeter.
- Terra, Aqua, and Aura launched. (Select instruments fly in other orbits.)
- ESA, Japan, and Canada carry out partner missions—data are freely shared among the international community.
- Dan Goldin and Jim Baker cancel second and third series of EOS flight hardware—but they "luck out" as almost everything still works today.
- EOS has provided us an eyewitness to environmental change.

Susan Schoenung [NASA's Ames Research Center]
NASA's Airborne Science Program contributions to Environmental Science

[Her slides didn't advance on the YouTube version.]

Aircraft flow in the "space between" ground and satellites.

She reviewed the Historical context.
- Earliest impact Airborne Science had was on imaging support [Thematic Mapper Simulator, AVIRIS] and ozone hole science [Airborne Antarctic Stratospheric Experiment].
- Aircraft obs provide unique vantage point for atmospheric studies.
- Upper troposphere/lower stratosphere (UTLS) chemistry. Lots of interest in studying the tropopause. (The Standard Atmosphere that Andrew showed in Session 1B reflected this.)
- Atmospheric Effects of Aviation (AEA) program [1992–1994].
- Environmental Research and Sensor Tech (ERAST) program [1994–2003]—a joint effort of ARMD and SMD. Launched NASA into use of UAV.
- Western States Fire Mission [2006–2010].
- Lots of flight hours Atmos Chem and Dynamics. [Slide listed some of the missions.]
- ATTREX. Flights out of Guam and Hawaii. Studying the tropopause region.
- ATom. DC-8 flights.
- ASMCCM. Asian Summer Monsoon Climate Change Mission.

Also work in…
- Cryosphere—Airborne support during periods of rapid change;
- Land Change—flying advanced sensors; and
- Recent and Next Generation Earth Observations.

DISCUSSION

Bob Murphy. Frank Press story in Ron Doel's presentation was quite interesting.

Ron said he's always interested in the biographies or stories of people involved.

Chris Neigh. Nowadays, to fly anything in space, you need an airborne version. Was that the case with EOS instruments?

Dixon mentioned that HIRIS (originally planned for EOS) was to be tested using aircraft.

HIRIS was originally planned. [Dixon said JPL mismanaged.] ASTER took its place.

MODIS-Tilt got dropped in that same process.

He said, in short, they really wanted to move from radiometers to spectrometers.

But then the two spectrometers ended up getting dropped…

Audience Question: Why does NASA have three G3 aircraft?

Each does different things.

The Armstrong Gulfstream is UAV SAR pod.

The Johnson G3 used for ISS crew movement. Now Armstrong Gulfstream backup.

The newer Langley G3 has two nadir ports. Dropsonde capabilities, plus replacing capabilities of other Langley aircraft that are being sold.

Bob Murphy: NASA went to mostly facility (NASA directs the development) instruments for EOS, versus PI (PI's institution builds and maintains) instruments. Was that an intentional choice?

Dixon said he's not given it enough thought to give a good answer.

Discussion about international partnerships.

Susan said they are important, especially when campaigns are conducted in foreign countries.

Dixon said that NASA worked closely with Brazilian Space Agency to get permission to do flights over the Amazon. ESA had earlier tried to negotiate such an agreement, but things didn't work out and they weren't allowed to enter Brazilian airspace.

Jack mentioned LBA. Requirement from Brazil was that each investigating team had to have a Brazilian on the team. Whole generation of Brazilian researchers got their start in LBA.

KEYNOTE PANEL DISCUSSION (September 29, 2022—6–8 PM)

Heely Family Student Center

Idol Family Social Center

Pete Mara [Georgetown Univesity—History Professor, Earth Commons] gave a brief tease for the Environment Sustainability programs at G'town. He's a bird ecologist by training, which made him acutely aware of the degradation to the planet. He jumped at the opportunity to train hundreds of students around issues of environmental degradation. GU is now offering an Environment and Sustainability Management Masters Program. More Masters Programs to come… Also working on an Undergrad program. They are cluster hiring faculty to fill out the program. He rattled off a list of recent hires and described their backgrounds in climate/environmental issues.

Moderator: John McNeill [GU—*Environmental Historian*]

Panelists: [Alphabetical]

- **Dagomar Degroot** [GU—*Assoc Professor of Environmental History*];
- **Kelsey Herndon** [NASA's Marshall Space Flight Center—*NASA SERVIR*];
- **Joshua Howe** [Reed College—Assoc Prof of History and Env Studies] Book: *Documents from Global Warming's Past;*
- **Neil Maher** [New Jersey Institute of Technology/Rutgers University, Newark—*History Professor*]; Book: *Apollo in the Age of Aquarius*; and
- **Nancy Searby** [NASA Headquarters—*Program Manager for Earth Science Applied Science Capacity Building*].

FORMAT: The moderator would ask a question, allow the panelists to give answers, and then open up to the audience and other panel members for discussion and **follow-up questions**.

MODERATOR (John): NASA driving force creating, collecting, analyzing data about climate change. How successful has NASA been at publicizing this looming crisis?

Nancy: She helps people use ES info. NASA is certainly "a player" in ESS, but other agencies and international space agencies are involved. They make info readily available. They look wholistically at the Earth System. (As opposed to NOAA and USGS whose mandates focus them on certain aspects of the system.) However, it's not always easy to use the data.

Nancy mentioned the new *Earth Information Center* that has been proposed. The idea is to take our wholistic understanding of Earth System and try to make it readily available and easier to use and understand. She said it's a work in progress.

Josh: NASA was integral in creating concept of studying Earth as an integrated system of systems. Study of Earth has been part of the NASA mission from its inception, but the concept of Earth system science really emerged in mid-1980s. However, NASA tends to think of climate change globally—so they might not emphasize important regional issues as much.

Kelsey: NASA uses its capital to communicate about climate science. Social media, workshops, training (ARSET). Educational resources. The Earth Observatory, The Earth Observer. Capacity building component, including SERVIR. Help people in low- and middle-income countries to learn to make use of data. So, NASA does look globally but are taking active steps to be place oriented.

Dagomar asked Josh. Would you argue that NASA's global view can discourage regional focus (or grassroots climate action)?

Josh: Institutions focus on global view leads to placing faith in institutions (e.g., NASA, NCAR) to provide policy input. Scientific internationalism (started in the Cold War) still prevails. He noted that the IGPCC is a global agency. Global focus can leave behind marginalized communities.

Nancy: Recalled a conversation with a hydrology modeler. Made a comment that, in essence, said the people living in the area he was studying were ruining his efforts to model. On the other hand, for 17 years SERVIR has been working with people in local communities around the world. They work at the nation/sub-nation level—along with USAID. She mentions NASA has established an Equity and Environmental Justice program. SERVIR works with community to figure out what's useful—and what isn't.

Josh (to the Other Panelists): Should NASA be tasked with publicizing climate change?

Neil: NASA does communicate—and they do it well. In 1988, after the Ozone debate, they created a Science Visualization Office. The ozone graph (boring) was transformed into the colorful ozone hole images we have today—and this grabbed the public's attention. NASA create narratives around the science. However local people don't always feel included. "*We're being erased*." For example, people in Newark, NJ, care most about the possible toxins in their neighborhood. They turn to their own *ad hoc* version of citizen science efforts to collect data. So, NASA does a good job promoting—but the issue is who has access to the information?

Dagomar: Could we argue that NASA could've been more proactive then they've been? And might this have allowed us to make more progress on combatting climate change before now?

Nancy: Reminder: NASA can't recommend policy. Also, scientists are reluctant to go public with their research if they are the least bit uncertain of their findings.

Audience Question: Is this an issue of scale?

Dagomar: Yes… scale. Local and global go together Climate change is inherently a local problem. His observation was: NOAA is good at local; NASA is good at global. He also said NASA has done a good job making model outputs more accessible and intelligible to users.

Neil: In Newark where he works—climate change is not their biggest concern. They turn to EPA. which is very good at localized data. **His students can look up conditions at their zip code**.

Nancy: The newly proposed Earth Information Center is thinking locally as well as global. She mentioned a recent Equity Stakeholders Town Hall. Question that came up: **Do we have climate data at the zip code level (the way EPA does with pollution data)? Not really as of yet but this what we're striving towards**.

Josh: **The discussion we're having boils down to**: **What counts as knowledge?** This gets into politics of *Knowing* versus the *politics of Being*, the latter of which gets left out when you start at global scale. Ideally, the data collected globally should be available locally. If the politics of climate change are all about *knowing*, then you lose the being, which is a problem because being is where people live.

Kelsey: SERVIR is not so much focused on climate models output They work personally with partners to get on the ground info. Translation between global and local is ongoing.

Dagomar: Climate has always been local. It became global well before NASA (e.g., weather stations in nineteenth century). **Is this lack of public knowledge about climate an American problem or a global issue?** Global—although it seems worse in the U.S. Corporate disinformation is especially powerful in the U.S.

Audience Question: Returning to Nancy's earlier comment—Is NASA not allowed to create policy?

Nancy: NASA research is: *Policy-relevant but policy-neutral.* In other words, NASA can talk about scenarios, but can't advocate a particular policy.

Josh: This all sort of came to a head with Jim Hansen [a NASA employee] spoke out on climate change with a Senator Tim Wirth on the Capitol steps in 1988 on the issue of global warming. Since then, there's a reluctance to talk about policy at NASA.

Neil: It actually dates even further back than 1988. NASA teamed up with military to help in war in Vietnam, which was unpopular with the public, so they canceled the program. Since then the agency has taken the stance of staying neutral in terms of policy advocacy.

Josh: Also, most scientists are still uncomfortable entering political realm.

Audience Comment (Bob Murphy): Noted that he lived through some of this debate when he worked at NASA. His view was that NASA should speak about science—but not make policy recommendations. Congress and the President set policy.

MODERATOR (John): Now turning to the Earth Science Applications Program. How have efforts been in broadening benefits of Earth applications to include lower- and medium-income nations?

Kelsey: Motivation for SERVIR was to work with low- and middle-income nations to educate them about NASA Earth Science resources to equip them to improve decision making related to climate. In past 17 years, NASA has done better job engaging the entire Earth.

Nancy: ARSET program keeps metrics on who they reach with training. They are finding that they reach all over the world. Even places "we don't *officially go*"—e.g., Mongolia. Not as much data on whether we reach underserved communities however. Nations definitely work together (e.g., GEO working together at level of Ministry of the Environment) but not at the highest level (UN). She mentioned a CEOS meeting in October in Ghana. There is wide participation in CEOS, but realistically not everyone will travel to Africa. The good news is that this will be a hybrid meeting. So, in summary, the Global South is represented—but there are still barriers to participation.

Neil: History of this discussion dates back to 1970s when Landsat was developed. NASA and USGS had to show developing countries the benefits Landsat data could offer them. Sounds similar to today, but it was a different time—the Cold War—and had an almost colonial context. Now, it's evolved into a more authentic effort to aid fellow humans.

MODERATOR (John): To what extent is cooperation with Russia and China happening.

Nancy: Law says NASA is not allowed to collaborate with China. (Other agencies don't have the same Law in place.) That said, NASA still works with Russia—but of course it's more challenging with current world events. Collaboration happens at grassroots level even if governments are formally talking—e.g., see Anna Amramina's presentation in Session 1B.

Josh asked the NASA reps on panel [i.e., Nancy and Kelsey]: How do you deal with "legacy trust issues" when interacting with countries with which the U.S. does not have a good relationship?

Kelsey: Yes, there's "baggage" when working with some countries. The key is to develop long-term, positive, inter-personal relationships with individuals in these countries—which take a long time to create. She said that SERVIR has spent over a decade working on relationships. They try to keep the promises they make to these other countries and listen and respond to the perspectives shared by the people they work with.

Nancy: Agreed with Kelsey, but added that the "competition" still exists. The communism versus democracy debate still lingers in some places. *"Why should we work with you all?"*

Dagomar asked Other Panelists: What about the role of corporations/commercial? For example, Tanya Harrison [PLANET] spoke today during Session 1B.

Kelsey: Tanya spoke about interconnectedness of Planet and Landsat. Planet provides capabilities that NASA doesn't have [e.g., really high-temporal and -spatial res imagery]. SERVIR uses Planet data for some of their work. These private companies aren't viewed as competition as much as partners.

Neil: Don't really want to get into *Newspace*. However, we should think about what we lose when corporations run our space flights? In the 1960s, NASA's plans were more publicly known, and people could protest if they disagreed. They could also promote their interests. Now, because private companies are so deeply involved, the public doesn't have as much influence on decisions made.

Audience Question: (Person was from Kenya). Curious about how she would access data and info.

Kelsey: Kenya is one of the oldest SERVIR Hubs. Works through space agencies in the country. Through USAID, RC MARDI gets funding, and through Regional Center for Mapping of Resources for Development (RC MARDI) SERVIR makes contacts on the ground.

Nancy: RC MARDI has gov't mandate for mapping. Small grants have helped them. Kenya's is a newer space agency. There's lots of value in having a space agency—being able to launch a satellite and learning to use data.

Dagomar asked Nancy: Is there technology sharing at international level?

Nancy: UN Office of Outer Space Affairs. Brings Space Agencies together. However, NASA doesn't do as much of this.

Audience Question: Do nations' space agencies coordinate when planning what missions to pursue?

Nancy: Yes… it's not perfect but nations do work together. Just about every space mission ends up being an international partnership. CEOS is an international body that coordinates efforts. As examples, she mentioned the international "A-Train" constellation (orbit coordination and calibration and validation) and Harmonized Landsat Sentinel (HLS).

Kelsey: Yes, there is coordination. However not all nations have same open data policy as NASA.

Nancy: We're now moving toward open-source science. Now, not just data, but all aspects of the scientific endeavor have to be open (data, publications). This represents a significant culture shift for NASA and other agencies.

MODERATOR: Racial and gender discrimination has been issue in the past and NASA has been addressing this. Environmental justice is a related issue. How is NASA doing here?

Nancy: She's been at NASA for over 30 years. Speaking as a person and not a government worker, she's excited to see NASA reckoning with its history of injustice. Words and phrases we use are pejorative, e.g., "brown bag" is now "lunch and learn." Inclusion is now a NASA value. New program in Equity and environmental justice. *Equity* involves how we interact with the rest of the world. To whom do we give our funds? Is the language in the solicitation inclusive? Are teams inclusive? There were 31 projects funded under Equity and Environmental Justice solicitation. (Another solicitation on global Environmental and Climate Justice issues.)

Neil: Told story from early 1970s at Johnson Space Center—when they held a Lunar Landing Festival Beauty Contest. Nominated women and sent out ballots. Women got upset. Snuck in and stole ballots and replaced with fake ballots that listed Johnson leaders. There was uproar. They snuck in again. His point is that there's always been a desire to be equitable, but at that time, women had to take much more extreme actions to pursue equity than they do today.

Dagomar: Environmental justice is the topic here. What would it look like to orient NASA around issues of environmental justice? Two-thirds of NASA property located near coast are in jeopardy due to rising seas. KSC will inevitably be under water. SLS/Orion will consume lots of money ($150 B by 2025.) What if, instead, we pursued orbital solar power stations, as China is doing now? . In other words he asked: **What if climate change became *the* driving issue to ensure that environmental justice is facilitated around the world?**

Josh: This gets back to: **For what areas is NASA responsible?** Incorporate diversity and inclusion into its day-to-day activities seems a clear mandate. However, is addressing systemic inequities in STEM education included? In the past, American exploration to discover resources in other countries leads to American exploitation of said resources, e.g., presentation during Symposium on aluminum extraction for Saturn V construction.

Kelsey: This is a really good conversation. SERVIR has evolved into addressing this issue. At first, U.S. based scientists did much of the work, but they've moved toward co-development. In Kenya, for example, SERVIR helps the Ministry of Agriculture to develop their own exploration capabilities. They try to help middle- and low-income countries have the same capabilities as others.

Nancy: The public loves NASA, but she still thinks people first identify with the Human Space Program. For example: Did you see the *DART mission*? Her family enjoyed watching that unfold. Likewise, JWST images are now capturing public attention. A key role of NASA is inspiring the next generation. Space missions seem to do that.

Dagomar: Yes. But couldn't new climate technologies could also be just as exciting?!

Neil: Not exactly new a new issue, here. During Apollo, there were complaints of why spend billions on space exploration. *What about the ghetto?* The argument (then and now) is that we should redirect these resources toward addressing problems here on Earth. Nancy is correct, however; people love Human Space Exploration. So then: **How does NASA balance public interest and societal needs?** [Kennedy's famous speech at University of Rice was in part in response to these kinds of complaints.]

Dagomar: Perhaps we can both explore "out there" and improve life "down here."

Audience Question: Another dimension added: the private sector. How is *Newspace* (e.g., SpaceX) altering the balance? Does Newspace help or hinder? This person said she attended recent World expo at Dubai. The U.S. had a whole floor dedicated to NASA. But the conversation was all about Elon Musk—because SpaceX had a rocket demo.

Nancy: Newspace is on the agenda for the CEOS meeting. So, people are talking about this and seeking balance between government assets and commercial assets.

Dagomar: Newspace may have pluses and minuses for NASA. Dramatically reduced cost of accessing space—e.g., through reusable rockets. It gets people excited about space trave. OTOH, it makes the expensive NASA SLS system look bad. Newspace is great for quicker access to space. Offshoring energy generation into space. However, we don't really want to export colonialism into space. Creating utopian society by going into space.

Audience: Question: How is NASA thinking about the "race to space"? What about the carbon impact of each launch?

Neil: When NASA first took flack over environmental impact of its launches in the 1960s–70s, NASA paid attention. They were quick to create Merrit Island National Wildlife Refuge and Cape Canaveral National Seashore—two environmental refuges around Cape Canaveral. The tour of KSC shows you both launchpad and wildlife. You can view this cynically or you can assume people actually cared about the planet.

Audience Question: How will/does NASA work with Space Force?

Nancy: Through the National Space Council that includes NASA, Space Force, and other agencies. Other than that, she really wasn't sure.

Dagomar: Any more knowledgeable folks in the audience, please speak up.

[Not much response on Dagomar's invitation, so conversation moved on...]

Audience Question: What defines the *environment*? In other words, what are the limits? Is it just at launchpad or is it broader than this?

Nancy: It goes beyond the launchpad for sure. We have Environmental Justice experts at NASA. Our management does have this mentality. New Program Manager recently hired at NASA HQ is from Wallops and has experience dealing with environmental issues around launch.

Josh: NASA does a good job asessing environmental impact of their activities. But make sure we don't' conflate *environmental impacts* and *environmental justice*. EJ is about disproportionate impact of environmental problems on specific communities—especially communities of color.

MODERATOR (John): Ended with two questions…

- **Scientists and environmental historians have gathered today—but presentations tend to be one or the other. Both are represented at this symposium—but work largely remains separate. How can these two areas work together?**
- **What topics have been missing from this symposium?**

Dagomar: Historians of science challenge dominant narrative (heard that in several presentations today). Scientists reinforce the dominant narrative. Two groups are "talking past each other." Scientists are the subjects of the historian. It's hard to find middle ground at these conferences.

Josh: He said that he rejects the idea of interdisciplinarity for the sake of interdisciplinarity. He teaches a class on Non-Disciplinary Problem Solving. Historians and scientists come to this conference from different communities (siloes). What is our common purpose when we gather? Think of our work as non-disciplinary problem solving.

Neil: He helped write the call for this symposium. Went out of their way to list 20 topics. But… The majority of the submissions were science-focused. Why? Convergence of different groups: NASA folks, space history people, historians of science, environmental historian. What we got was more historians of science and space historians. While he'd hoped for more disciplines represented, he emphasized that he was pleased with the diversity that was achieved. This is a key step forward in interdisciplinary work.

Kelsey: This is a good first step. But she admitted it seemed odd to work with historians. She hasn't really had a history class since high school! A forum like this helps us step out of our comfort zone and begin important conversations that hopefully lead to more interaction in the future.

Nancy: She completely agrees that this conference was a good first step toward collaboration between these areas. But as she prepared for this conference… it felt like an *odd pairing* to her. It's okay to step out of your comfort zone and enter the world of another.

Kelsey: **What do scientists gain from interaction with historians?** Kelsey said she thought she came to hear cool stories of the past and perhaps learn something from them, but it's really turned out to be a chance to reflect on how we think about what we do and what is the larger context of what we achieve. How has the past impacted who we are today—and who we can become in the future. But what is the "end goal" of this endeavor? There's more to do, but specifics are still TBD.

Audience Question (Undergrad Student) for Josh. You sounded critical of interdisciplinary studies earlier. What exactly was your critique?

Josh: Learning how different disciplines approach subject matter is good, but interdisciplinary is not an end in itself; it's a means to an end. The *end* is figuring out to solve problems that our society faces. We take pride in identifying ourselves by the group to which we belong (e.g., our major in college, our job title.) But we need to start thinking in terms of how we can "work together" to solve problems—and the world has no shortage of them to solve! In today's context, we're focusing on climate/environmental issues. He cautioned that a single class in any topic isn't going to show you how to solve problems. We need a synthesis.

Audience Question: Earlier discussion said that NASA doesn't offer input on policy. However, SERVIR works with people in other countries. What defines *policy* when you work with people in other countries?

Kelsey: Again, we don't prescribe policy. We work with the country to empower them to make decisions about environmental issues.

Dagomar (to Kelsey): But it seems boundaries can blur sometimes.

Kelsey: Yes they can. This conference has given her much to think about in this area.

Audience Comment: Doing good science is knowing what questions to ask. History can help scientists with this aspect. What has threatened civilization in the past?

Audience Comment (Bob Murphy): He thinks this gathering was a good first step. Two communities have gathered, and modeled to one another how they talk about these issue. Bob comes from the science background, but in his own presentation, he tried to frame things in terms of history. Hearing the specific story of Frank Press helped fill in details of why things unfolded as they did.

Audience Question (Andrew Ross): Why did the NASA History Office do this symposium? Why should GU students (who made up a significant percentage of tonight's audience) care about the NASA History Office?

Brian Odom [MSFC—*Acting NASA Historian*] was the head of the planning committee for this symposium. He answered this question as a representative of the History Office. He commented that chronicling the work of the agency is what the History Office does.

The History Office has done this with a lot of different topics in the past (e.g., civil rights). We seek to chronicle the work of the ages. But we also have to think about the questions we ask. What does the agency need to know? What will help NASA do it's work better? It's a leadership question, yes, but it also impacts the workforce.

The History Office wants to engage history at every level. They wants to engage precisely the crowd gathered here tonight (college students). They want students to be part of this conversation.

Concluding Thanks from Brian Odom:
- Thanks to those who helped! Kudos to **Chris Sealy**, who helped with tech issues today.
- Thank the Undergaduate students that came out for their great questions!

DAY TWO (September 30, 2022)

Session 4A – *Cultural Meanings and Changing Perceptions*

Moderator: Teasel Muir–Harmony [Smitshonian's National Air and Space Museum]

Karen Holmberg [New York University]
The Biographical Arc of One NASA Aerospace Engineer as a Mirror of the Transforming US Perception of the Earth in the 20th Century

The Engineer was Neil Holmberg—the presenter's father.

She did Oral History interviews with him

She said her dad couldn't understand why anyone would want to interview him.

He worked on Nuclear Emulsion Recovery Vehicle (NERV). They bombed the Van Allen Radiation Belts and he helped retrieve samples that were returned. The idea was to test radiation levels Astronauts would be exposed to.

Suggests Earth is impervious to environmental impact.

This was in association with *Starfish Prime*. [Discussed by Stephen Buono in Session 1A.]

Post cards celebrated bombing of Van Allen belts.

He later worked on HALOE, which studied air pollution… Ozone chemistry… CFCs.

Last project before his retirement: Efforts to improve energy efficiency of Langley Research Center.

She came into possession of many of his old books.

Including one about "Middle Age Crisis." Apparently, it was an issue among the early Langley workforce.

Kept hearing tapping in the floor during her interviews with her dad. Turned out to be bat colony in their drop-ceiling. Bats shouldn't have been clustered together at the time they were doing these interviews.

There would've been more items in her archive. But some were destroyed by flooding in Tidewater Virginia—which is happening more frequently in recent years.

She mentioned the pictures of Earth from the Moon that shaped how we think about the environment—e.g., Earthrise.

There has been a pretty big change in our perceptions of the environment in 40 years!
- Neil's career bookended by two radically different missions.
- From bombing the Van Allen belts to "worry we used too much hairspray."

Conceptual rift (cartesian). Separated humans from our impact on the environment.

- Was the late 20th century the battleground?
- Will we adopt the epic of the Anthropocene?

Time will tell…

Jeffrey Nesbit [Temple University]
Architecture of Assembly: A Brief History of Building NASA's Enclosed Garden

Infrastructure of assembly became part of NASA's image-building.

Traditional European gardens demonstrated wealth, intelligence, and power.

But in the 20th century the "garden" was transformed…became enclosed…synthetic environment.

Spaceport landscape became the "enclosed garden."

Showed 1962 plan for the Operations and Checkout Building at KSC.

- Included Admin offices and High Bay or Assembly Building.
- Open space in between (originally two story building was conceived as being built in that space).
- Instead, it became a transitional space from one enclosed space to another.

Neil Armstrong. Astronauts enter the "unknown wilderness" of outside.

- Twentieth century gateway for entering space.
- Building is renamed Neil Armstrong Operations and Checking.
- Humans have reached the Moon and nature is transformed.

KSC High Bay Area.

- Meant to appear synthetic.
- A place set up to exhibit a 20th century modern machine.

Exhibiting modernity…

- Assembly Building(s) compared to the Crystal Palace in Hyde Park in London, U.K. Joseph Paxton
- It was built for1851 World Expo.
- Putting the technical prowess of a nation on display.

Crystal Palace—Iron ←→ NASA Assembly Building—modern machine

Switched to Johnson Space Center Space Vehicle Building.

- Elevated platform where visitors could look down (similar to Crystal Palace).
- Visitors sit in stadium seating and that looks into the Mission Control room—which matches how it looked in 1968 down to the most minute details.

Modern garden and machine theme is most evident at Rocket Park.

- Saturn V is stored in a shed on artificial grass—same as used in the Houston Astrodome in 1964.
- But Rocket Park is right next to Texas farmland, where there are Texas Longhorn cattle grazing.
- Machine is closed in the shed.
- The Saturn V is the focal point of of the nation's technological garden.

Luca Thanei [ETH Zurich]
Stabilizing "Near-Earth Space" NASA's Early Calculation Methods for Collision Probabilities, 1970 – 1975

1970–1975. Focus turned to near Earth orbit.

- Use U.S. Skylab and USSR Salyut space stations.
- Surveillence (Networks and TLE).
- Regulation (Liability and registration).
- What did outer space mean "near" Earth?
- What might "near" mean in this context?
- Delimitations? Quantifications? Separating features?
- Initial—Making? Production? Stabilization?

He searched Technical Reports from this time period.

- Notion of "near Earth" began to be defined as soon as mathematical calculations of collision probabilities.
- "Predicting the Probability that Earth-Orbiting Spacecraft Will Collide…" [1974]

Implicit Translations in *Brooks, Bess, Gibson* [1974]

- Distribution of artificial objects around Earth → Delimitation of "near-Earth space."
- Collision probabilities of artificial objects around Earth → Densities of near-Earth-space.
- Growth rate of object population around Earth → Future of near-Earth-space.

The notion of *near-Earth* space emerges over time.

Matthias Wong [University of Hull, Treatied Spaces Research Group,]
Lunar Ambassadors: British Perceptions of Moon Samples from NASA and the USSR

Context

- U.K. scientists received samples from American Apollo ('69–'72) and Soviet Luna ('70–'76) Moon missions.
- Apollo samples were loaned to individual PIs, via the Science Research Council.
- Luna samples were given to the Royal Society, which allocated portions.

Apollo samples—Generously on loan, Unique character; valuable for science. Strict control—don't display them to public. Take care of these… or you will never, ever get samples again! Language is all about science.

Luna samples—U.K. outreach to Russia. We're doing "good work" with your lunar samples. Inter-state competition to get the samples.

Story of Monster Pumpkin. Person (C. Roberts) interested in Moon dust for growing pumpkins! Could Moon dust help him grow a pumpkin? Did he get his dust?

Conclusions

- Meanings and symbolism were taken onboard from NASA and USSR.
- *Relative lack of power*. Need to speak and behave on their terms (e.g., security, scientific productivity).
- *Playing the long game*. Ensuring long-term access to samples, showing resilience and resourcefulness.

Session 4B – *Deep Space and Deep History*

Moderator: Josh Howe [Reed College]

Andy Bruno [Northern Illinois University]
Viewing the Landscape of an Asteroid Disaster from Afar: A History of NASA's Investigations of the Tunguska Event of 1908

Tunguska event happened in Siberia. The largest known meteorite explosion in modern history. It makes a splash locally, but then is largely forgotten—until the 1920s.

His book, *Tunguska*, emphasizes role of mystery when conveying environmental history: landscape practices, alternative knowledge, and approaches to disaster. Today, he focused on the international story of Tunguska research—especially NASA's role in it. They got involved late (only formed in 1958) and shifted the conversation. Two divergent versions of the Tunguska event emerged among Soviet and foreign researchers. Soviets viewed Tunguska as possessing a special aura. NASA just viewed it as a "case study" to learn about these kinds of events in general.

The book highlights that the Russian (Soviet) views of Tunguska develop because of the struggle to investigate Tunguska. The terrain is difficult to access, but fieldwork is needed to solve the mystery. It's also a fun place to go—and becomes a site for conservation. Nature reserve specifically created to preserve evidence of the 1908 event.

In the international community, Tunguska becomes a site of speculation, analogy, and curiosity. There are some wild theories (e.g., was it anti-matter or an miniature black hole.) There are not that many international field investigations of Tunguska.

NASA offered a new/old solution. Tunguska is an analog. What can we learn from this specific case and use in other locations?

Dominant view of 1950s and 60s was that this was a comet. Now, its viewed as the disruption of a stony asteroid that had an airburst explosion. There was a symposium as recently as 2018: *Tunguska Workshop: Applying Modern Tools to Understand the 1908 Tunguska Event*.

Kelsey Herndon [MSFC]
Seventeen Years of SERVIR: Applications of Earth Observations to Improve Environmental Decision Making Around the Globe

Daniel Irwin [MSFC—SERVIR Global Program Manager (and Founder)] credited.

SERVIR is a joint initiative of NASA, USAID, and leading geospatial organizations in Asia, Africa, and Latin America that partners with countries and organizations in these regions to address critical challenges in climate change, food security, water and related disasters, land use, and air quality.

SERVIR has five hubs around the world. Supports projects in more than 50 countries though five regional hubs in the Amazon: West Africa, Eastern and Southern Africa, the Himalayas, and Mekong region.

She gave background on SERVIR. SERVIR offers dozens of applications. Today, she focused on two of them: crop mapping in Kenya and improved severe weather forecasting in Bangladesh. High Impact Weather Assessment.

For farmers in East Africa, microinsurance is an adaptive strategy to cope with drought. SERVIR Eastern and Southern Africa is partnering with gov't of Kenya on an insurance program. SERVIR developed a satellite approach to map and assess crop area and crop conditions at scale. SERVIR helped the government of Kenya reduce data costs by 70%.

As a result of this partnership with SERVIR, the government of Kenya now offers agriculture microinsurance nationwide; five years ago, there were 900 farmers insured against crop lost—today there are over 1.4 milion insured farmers. They also actively target women farmers to participate in index-based insurance.

High Impact Weather Assessment Tool (HIWAT) is currently used by the Bangladesh government departments to produce actionable warnings ahead of hail, lightning, extreme rainfall, and other hazards. The tool was co-developed with forecasters in the region. Several trainings have helped partners in the region use HIWAT data more effectively. HIWAT forecasts are helping Bangladesh Meteorological Department and Department of Agricultural Extension put out timely alerts to save lives and property. Alerts based on SERVIR HIWAT forecasts will be sent to over 30 million farmers in Bangladesh within the next two months.

She reflected on the **origin story of SERVIR**. In the late 1990s, Dan Irwin lived in Guatemala, and had a chance meeting with a NASA space archaeologist (Tom Seaver). Irwin realized that he'd spent years in the field trying to map out what this single satellite image was showing him. The idea emerged that RS could be used not only for learning about the past but also learning about present. SERVIR originally conceived as "one-stop-shop" for data—she showed the original mock-up on her slide. NASA REASON proposal in 2003; bought in USAID as partner.

SERVIR has expanded to seven hubs.

SERVIR Then and Now in Three Key Areas

- *Open Science*. SERVIR was originally proposed as a "One stop shop for geospatial data" but now open data abounds and SERVIR focuses on co-developing and implementing sustained solutions.
- *Compute Resources*. SERVIR was limited to one-off analysis over small areas but now the SERVIR network is able to take full advantage of EO big data to develop solutions to solve major environmental challenges.
- *Capacity Building*. SERVIR originally developed solutions and then passed off the results to local partners, hoping in made an impact, but now SERVIR co-develops demand-driven solutions with regional partners through a long-term commitment to institutional capacity building.

Timothy Murtha [University of Florida, Center for Latin American Studies]
NASA, Archaeology, and Environmental History (recorded)

[Speaker was unable to attend in person due to Hurricane Ian.]

Power and promise of RS not just used to discover sites—but to examine them.

Summary of Content

- Introduction and brief overview to space archaeology and NASA.
- Describe why the approach was so innovative. (Not discoveries but systems)
- The Ancient Maya Landscape: A View from Tikai
- Urbanization, Settlement, and Land Systems architecture across the Maya Lowlands
- Next Steps?
- Our Past–Our Future

While NASA has contributed to archeological discoveries (particularly with the more recent use of lidar observations) NASA data have been used to study archaeology for over 50 years. The early work focused not on discovering sites but understanding systems. It also focused on discovering coupled and natural human systems—expanding our understanding of past beyond mere site discoveries. Remote sensing opened up new possibilities and anthropological questions we can ask.

Power and promise of RS not just focused on discovering sites but on critical anthropological questions about human environmental dynamics that can only be answered by large-scale analysis.

Presented Brief historical overview.

Systems-based research offers new window into the past. Emphasis of this research is on how cities shape—and were shaped—by their environment. Past landscapes offfer critical global and comparative narratives about our shared past. Past landscapes provide artifacts of our past decisions.

Our human landscape is our unwitting autobiography reflecting our tastes, our aspirations, and even our fears, in tangible visible form. We rarely think of landscape that way, and so the cultural record we have "written" in the landscape is liable to be more truthful than most autobiographies because we are less self-conscious about how we describe ourselves —**Piers Lewis** (1979)

He said that Tom Seaver opened door to using RS for archaeology. He did work all over the world, but for the author work in Mayan Lowlands was most influential. Mentored and advises many friends and colleagues, including Dr. Rob Griffin, who is partner in this effort.

Timothy's focus is on the Ancient Maya Lowlands. Aerial perspective revolutionized how we viewed the Mayan society and history. Early images identified raised fields and new regional scales. The discovery of terraces in the Rio Bec region challenged prevailing assumptions about the carrying capacity of lowlands. Mistakenly though that the forest couldn't sustain the culture.

Tom Seaver and Dan Irwin (founder of SERVIR) published first images from ancient Mayan city Tikal (Guatamaela). Shifted focus from the massive building in the city center when they showed clear signs of human activity in swampy areas east of the city—previously though unsuitable for cultivation. He and colleagues at PSU followed up on this work. They studied land and water at Tikal. Evidence for agriculture was also over the city of Tikal. Tikal was truly a "garden city"—despite having a denser core of architecture in the city center. Early residents of Tikal impacted their environment most by erosion. After soil tests, RS analysis revealed them full regional pattern of landscapes. Tikal city form influenced by distribution of land and water, reflected early form of ecological landscaping.

Ecological urbanism. Productive agrarian space interspersed with households and neighborhoods.

Next question: Were all Mayan cities similar?

Multiyear spatially distributed study supported by NSF then NASA Archaeology. They did G-LiHT transects. Longterm patters of agricultural resilience in the lowlands. [He showed a cool image of a drone being used to take data.] Repurposed massive amounts of big data (NASA env surveys to study above ground carbon storage) to study the lowland. Today tropical forests cover the region, but RS allows them to strip away the vegetation to reveal land patterns. They discovered evidence of a resilient mosaic of land use. The focus previously had been on big architecture and warfare—but Timothy and his colleagues investigate a different story—focusing on households, communities, and landscape use. People in this culture adapted to land changes.

Processed 458 samples and thousands of features. Identified critical—and complex— systems. Preliminary results: Open Space defines the Mayan landscape in complex ways—contrary to conventional city models. Future work will involve data integration.

Modern land use shifts might be influenced by ancient land patterns.

"*Surely the brilliance and magnitude of ancient Maya achievements are a reflection of an entire network of stable and harmonious adjustments to the special conditions found in the tropical forest environment.*"—**Puleston**

"*So as not to become trapped in the cul-de-sac of environmental determinism, it may be better to speak of 'environmental possibilism.*"—**Puleston**

There is a critical "landscape narratve" embedded in Mayan Lowlands that we need to preserve, document, and share. NASA helps us begin to unearth this narrative.

Thomas Wozniak [Eberhard Karls Universität Tübingen]
Medieval Approaches to the Interpretation of Celestial Signs

Overview
- Types of natural and celestial events recorded in Medieval sources.
- How and for what purpose?
- How are solar activities reflected in these sources?

Written sources from this period (500–1100) are limited.

He described his "Historical Measuring Grid.' He studied 150 sources from the sixth to eleventh century. Found references to various natural events. They read like short "Tweets" of info. (It would be like trying to reconstruct COVID-19 pandemic based on a few Tweets that described it.) Monks didn't write down everything—and sometimes chose to leave out something when they went from an old version to a new one.

Medieval sources list only the most extreme events. Some events are only seen locally (e.g., landslide) while others are worldwide (e.g., comets). Writers also tailored their message to their audience.

Annales Fuldenses vs. Book of Revelation. Monastic life would've influenced how they interpreted what they experienced. So, a monk sees a swarm of locusts as fulfillment of Book of Revelation—apocalypse. There's mention of a terrible plague, but no other sources record it. Other events seem to have been manufactured to match the apocalyptic narrative. No other sources from the time report them happening.

Celestial events served as omens of birth or death of rulers—e.g., wise men follow a star to find Jesus. Appearance of comets, solar eclipses, and lunar eclipses. In a typical century, there are 300 solar eclipses. A small number of these (about 10%) are visible in Europe or China. An even smaller number (about 1%) can be seen in **both Europe and China**. These latter rare events are very helpful. He showed a list of these from 900–1600.

Example: June 7, 1415. Total eclipse. Bohemian chronicler noted Holy Mass couldn't be celebrated. Same eclipse seen in China, and rulers saw it as an omen.

DISCUSSION

[This conversation was harder to track as it's a bit outside my areas of familiarity.]

Moderator (Josh) mentioned the *Paradox of Presentism* which refers to the tendency to focus on the era you are analyzing. The past is treated like a foreign country. All this to say: You don't come to history without some reason for coming.

He then asked about the relationship between speculation and observation?

Thomas: Said in his research, he is leery of speculation. Someone's speculation may lead to dubious recording of history—e.g., interpreting events to go along with the apocalyptic narrative in Revelation.

Tim: The work he does begins with speculation (hypothesis). Then the science is designed around investigating the questions (observations). Then, you learn new things in the field, which leads to new questions and more speculations about the answers. He quipped that this is why many archeologists never retire. That is to say, the cycle keeps repeating itself so there's always something new to invesitgate. The hope is that the past becomes a dataset that we can leverage to make decisions today.

Kelsey: At SERVIR, speculation and observation go together. We have satellite observations that show us something. We speculate but we don't know until we investigate the situation on the ground.

Question (from Dagomar) for Tim about use of lidar data in paleo investigations.

Tim: Lidar data allow us to connect multiple locations. However, right now, we only use ~2% of the data. Lidar improves fidelity and precision of info we have about certain locations. Traditional archaeology creates detailed history at specific location. Lidar data helps us expand beyond site boundaries. Really need to start using the lidar data more creatively. As we do, we'll discover more. Absence of info in archaeology is hard to deal with.

Question for Thomas about proxy sources.

Thomas: In his research, it's important to figure out something about the person recording the information. Does this person have any "interest in nature"? There are religious and political beliefs that mix in.

Question to Andy about Soviet versus American relations with the Tunguska event.

Andy: Soviets thought idea of "black hole" was ridiculous.

Comment from Bob Murphy: ***How things get done… Individuals matter***. Tom Seaver discussion [mentioned in two of the presentations in this session] was fascinating. He saw a technology and figured out something that could be done with it. Shelby Tilford is another example of someone who did this. In Tilford's case, he used discretionary funds to create a Land Processes Program (which Bob headed up.)

Are there ethical concerns that arise in this kind of research?

Tim: Lidar data needs to change the way we practice archaeology. Open source data changes the traditional way archaeological research is done—traditionally viewed as private datasets. Also changing issues around conservation. There are numerous complex ethical questions that've come up.

Kelsey: SERVIR always works under the direction of the country where they are working.

Tim: The technology used even allows monitoring for looting.

Session 5A – *Photography, Gender, and Science*

Moderator: Neil Maher—who covered for **Margaret Weitekamp** [NASM]

Allison Fulton [University of California Davis] (participating virtually)
"The Sun Tells Its Own Story:" Seeing and Unseeing the Environment Through Maria Mitchell's Solar Photographs

Maria Mitchell described experience of total solar eclipse in 1869.
- She took solar photographs on regular basis.
- "The Sun tells its own story."

Space photography as a tool for Astronomical study—and as a storytelling device. Weaving cosmic narrative into daily life.

What does it mean to see and unsee our environment? Fine air, good observations, and competent observer.

See what is… do not see what is *not*.

Observations of sunspots well suited to everyday life.

Jim Fleming [Colby College] (participating virtually)
Joanne Simpson and the Tropical Atmosphere

Hot Tower hypothesis

- Experiments on cloud and hurricane modification.
- New understanding of Tropics.
- TRMM.

University of Chicago

No woman has ever earned a PhD in METO. No woman ever will. Even if you did, on one would give you a job.

Advisor: C.G. Rossby told Joanne: Studying clouds is good area for a "little girl."

Tropical Meteorology

- Motivated by Wx Forecasting needs in the Pacific.

Climatological approach.

- Norwegian air-mass analysis. Mythical "Equatorial front" [More male meteorologists.]
- Observations.

Trade Wind Cumuli. Most clouds can't break through barrier—but "hot towers" can break through.

NASA [1979–2004] TRMM Project Scientist. Joanne received the following awards:

- Rossby Research Medal [1983];
- Nat Academy of Engineering [1988];
- President of AMS [1989]; and
- AMS Award [2002 – only given every 10 years].

Joanne was not the first woman meteorologist, but she was the first to achieve legendary status in her field. She is credited with many accomplishments during her 60 year career—all directly involving tropical METO. These include developing computerized cloud models, the hot tower hypothesis, hurricane study and their attempted modification, large field projects involving aviation, and Tropical Rainfall Messuring Mission (TRMM).

She was not merely the best female meteorologist of her age, but the best meteorologist—period. Her stature, influence, and mentorship resulted in marked increase in the number of female meteorologists over the course of her life.

Joanne overcame daunting challenges, including stereotypes and persecution. She worked at the cutting edge of a new field, and successfully confronted her personal insecurities, while reaching the top, breaking through the clouds, and opening doors for the future.

[The speaker wrote a book called First Woman, which has much more on Joanne Simpson.]

Billy Marino [University of California, Santa Barbara]
Seeing Mars: How the First Close-Up Images of Mars Reshaped Understanding of the Red Planet's Environment in the 1960s

I argue that the first close-up images of Mars mediated human understanding of the Martian environment by revealing an unexpected surface environment—one more akin to the cratered "wastelands" encountered on the Moon—while helping substantiate the possibility that we can know not just our terrestrial environment but also other planetary environments through photography captured from outer space.

Building to Mariner IV. Late nineteenth century—notion of canals on Mars. 1950s and 1960s, Ranger (Moon) and Mariner-1 and -2 (Venus) and Mariner-3 and -4 (Mars).

Making the Television Experiment. Gerry Neugenberger and Robert Sharp bring in Leighton's proposal. Design based on vidicon tube—as common TV-based technology. As Mariner IV passed Mars it took 21 photos.

Receiving Images on Earth. Newly established Deep Space Netowrk in 1965.

They make an image from numbers. Coloring code on Paper Tape.

Dissemination and Reception of Images.

Tyler Peterson [Colorado State University-Pueblo]
The Role of the Astronaut in Environmental Observations

Mercury
- The seven Mercury astronauts underwent a training regimen that ensure they would voyage into space with eyes and minds open.
- Astronaut Training Officer Bob Voas wrote the specifications concerning the duties that John Glenn would undertake during the first American orbital flight.
- These duties included observing and photographing Earth, which John Glenn first did successfully on February 20, 1962 (first hand-held photo taken from space), followed by three more Mercury astronauts.

Gemini
- The Gemini astronauts carried out experiments in Earth observations that called for them to work with Principal Investigators and train to develop their knowledge of the Earth before flight.
- The Gemini IV crew, Jim McDevitt and Ed White, took more than 100 photos of Earth in becoming the first crew to carry out the Synoptic Terrain Photography Experiment in June 1965.
- The ten Gemini crews succeeded in returning high quality color photos that advanced scientific knowledge of Earth features.

Apollo/Skylab
- The Apollo and Skylab crews received the most intensive briefing on Earth observations from PIs to date.
- The Skylab workshop simulator familiarized the three Skylab crews with the hardware they would need to take high quality photos.
- By the last Skylab mission, the crew smashed previous records by amassing about 200 photos of Earth and 850 verbal descriptions to complement their photos in real time. (They observed an erupting volcano in Japan.)

Space Shuttle
- Astronauts took more than 400,000 photos of Earth using handheld cameras during the 135 Space Shuttle flights from 1981–2011.
- Scientists from the Space Shuttle Earth Observations Project worked with each crew before flight to develop the astronauts' knowledge in geology, geography, meteorology, oceanography, and environmental change.
- Shuttle crews primarily used Hasselblad film cameras, but beginning in the 1990s also used digital cameras that allowed for direct transmission to Earth and distribution on the World Wide Web.

International Space Station
- Photos taken by ISS crews have shown the Earth in higher resolutions than possible aboard the Space Shuttle and their longer missions have allowed for study of longer-term climatic effects.
- Trained humans aboard the ISS have the flexibility to observe Earth from oblique viewing angles (e.g., the limb), react rapidly to unexpected events they see happening, and make rapid determinations as to the quality of the observations they can make.
- **Astronauts continue to remind us of the value of human beings in contributing to space science, a lesson likely to be reinforced as the twenty-first century continues (e.g., Artemis astronauts.)**

Session 5B – *Climate Change, Weather, and Atmospheres II*

Moderator: Mike Hankins [Smithsonian National Air and Space Museum]

Christopher Hain [MSFC] (virtual)
NASA's Short-term Prediction Research and Transition Center: A Historical Perspective on Transitioning NASA Research into Operations

Rapidly transitioning user-driven science needs into applications.

NASA SpoRT Overview

SPoRT was established in 2002 with a focus on transitioning unique NASA satellite observations and research capabilities to end users to improve short-term operational weather forecasting and decision support.

The SPoRT paradigm [he showed flowchart on slide] has been used (over the past 20 years) to successfully transition 50 satellite datasets and research capabilities to operational users. Notable accomplishments include:

- SpoRT has built and maintained a strong relationship between NASA and NOAA/NWS. The project actively collaborates and provides support to 30 NWS offices in all 6 NWS regions and multiple NWS National Centers (e.g., WPC, SPC, AWC, OPC, NHC).
- SpoRT's user-focused "research-to-operations" and "operations-to-research" paradigm and applications-based training concepts have been adopted by other groups nationally and internationally.
- SpoRT was a leader in the GOES-R/JPSS Proving Grounds, using NASA missions (Terra, Aqua, Suomi NPP) to help prepare users for GOES/JPSS capabilities (Geostationary Lightning Mapper, multispectral composite imagery, hyperspectral infrared soundings) and demonstrate further integration with NASA observations and capabilities.
- SPoRT team members have authored 46 peer-reviewed journal articles since 2014.

SPoRT Flowchart: Consultation with End User → Identify Forecast Problem → Match to Research Product → Develop Solution → Provide Training/Integrate Date → Assess Impact → Problem Addressed?? Loop back as needed.

What's unique about the SpoRT paradigm: Co-development with stakeholders. Everything SPoRT develop starts with a conversation to understand what the user needs. They develop a solution together—SPoRT stays with stakeholder through the process.

[Discussed and showed NASA SpoRT Structure.]

Over the past several years, SPoRT has been broadening its reach and has begun to apply it's known "research-to-operations" paradigm to a number of new partners thatn can benefit from the integration of unique NASA satellite observations and research capabilities.

Current SPoRT "Research-to-Operations" Thematic Areas. Tropical METO, Atmos Remote Sensing, Lightning/Convection, AQ/Human Health, Land Surface RS, Machine Learning.

Transition Activities. End-User Training, Product Assessments, Data Production [Social Science aspect of the program.]

Current Partners. NOAA, NWS, USDA, SERVIR, USFS, USGS, NDMC, Smithsonian, FEMA National Guard, etc.

SPoRT remains focused on applying and utilizing its "research-to-operations" paradigm to support the current suite of NASA satellites and those upcoming in future missions, with a focus on future missions related to the Earth System Observatory.

SPoRT has broadened its reach to apply "research-to-operations."

Then he went through some examples…

- *Multispectral Imagery*. Pioneering use of RGB imagergy to support wx forecasting applications and demonstrate utility with proof of concept applied research. Focus on use of NASA data to prepare forecasters for GOES-R and development of innovative display capabilities.
- *Tropical Meteorology*. Leverage new instrument platforms (e.g., GLM, CYGNSS, and TROPICS) together with existing technology, to improve tropical cyclone forecasts. Track forecasts are have improved significantly but intensity is still a growing edge. Lightning activity in the inner core of a storm may be an indicator of rapid intensification.
- *Land Info System*. Development of high spatial resolution land-surface fields for improved situational awareness. Used routiney by U.S. Drounght Monitor.
- *Damage Assessment Toolkit*. Development of tool to use high-res satellite info to better inform ground-based damage surveys by the NWS.
- *Lightning Safety*. Improve and refine lightning safety metrics to take advantage of new techniques. SPoRT Stoplight Product (Green, Yellow, Red to indicate most recent lightning strike), Machine Language for Short Term Prediction of Lightning.

James "Jim" Garvin [GSFC—*Chief Scientist* (recorded)
Topographic Monitoring and Modelling of the Earth's Environment from the 1980s to Present

Garvin gave a brief pre-recorded presentation that summarized the history of laser altimetry.

- A story of engineering and science coming together to measure the shape of the Earth at "human scale."
- Started back in the 1980s at GSFC.
- He intended the video to encapsulate a longer story.
- History of NASA and climate research is one of establishing boundary conditions.
- Shape of the land is one of those boundaries—at scales that aren't always accessible. Technologies that are now "standard" had to be invented 40 years ago. Techniques are evolving rapidly.
- What GEDI and ICESat-2 can do is impressive—and there is more to come.
- New missions will bring new chapters to the story: e.g., NISAR.

Garvin is Project Scientist for the DaVinci mission to Venus with planned launch 2029. Goal is to understand Venus—runaway GH effect, and how what's going on there might be predictive of Earth's future.

Gemma Cirac Claveras [University of Barcelona] (virtual)
Introduction to the Project CLIMASAT: Using the History of Satellite Data to Write a History of Climate

[Opened with a Hurricane image and commented how it has become so common to see these.]

Questions She Wanted to Answer

- What are the origins of the relationship between (satellite) data and the environment?
- How did this relationship come about?
- On what infrastructures did it happen?
- What are its political, epistemic, and social consequences?
- What kind of environment speaks through these data?

Conceptual frame: Digital environment, digital climate. Digital environment—data about the environment—can be confused with the environment.

- Theoretical and empirical context.
- Research Project: CLIMASAT.

Digital Environment, Digital Climate

- The production, circulation, and use of data underpins the Digital Environment. The DIigital Environment implies the continued production, reproduction, storage, maintenance, dissemination, and use of data.
- In the DE, data about the environment can be confused with the envirionment. (Especially for policy decisions.)
- The DE is oriented toward governability of present and future environment.
    - The DE assumes the connections between monitoring and managing the environment.
    - Satellite data are taken for granted as tools for monitoring and managing the environment.

Theoretical and Empirical Context

- Our perceptions of climate, including its changes and its political implications, change throughout time.
- All spheres of life "colonized" by climate influence.

Climate history tells us that climate change became mainstream in the 1980s/1990s.

We went from a few experts to a worldwide conversation.

- Technology influences our perceptions of climate.
- What counts as data changes over time—e.g., Consider climate models
- Satellite data are cultural artifacts, historically stuated and profoundly marked by the highly localized scientific practices, institutional settings and sociotechnical arrangements from which they emerge. *Becoming data*.

Is data a public good or a commodity which has to be purchased?

- *Factory of data*. Separation between those who produced data and those who used it. Inequality of access to data.
- Satellite data form the nexus of various scientific, technical, economic, diplomatic, regulatory, and communication interests.
- We should not take satellite data for granted.

Gemma discussed her research project: CLIMASAT, which seeks to understand to coproduction, historically contingent, of satellite data.

Contact: **Gemma.cirac@uab.ct**

Timothy Lang [MSFC—LIS on ISS Project Scientist]
History of NASA Global Lightning Observations

Acknowledged up front that other countries are making lightning obs from space.

Why does NASA study lightning from space?

- Lightning is a natural hazard—threatening lives, damaging infrastructure, causing wildfires, and posing a risk to NASA launches (e.g., Apollo 12).
- Lightning is related to processes within deep convection, and by studying lightning we learn more about how storms impact Earth's weather and climate.
- Lightning produces trace gases—nitrogen oxides—which modulate ozone levels in the atmosphere, These gases are important for biogeochemical cycles and Earth's climate.
- Lightning can go beyond troposphere (e.g., sprites and halos) and occurs on other planets.

Nighttime/Daytime Optical Survey of Lightning (NOSL) and the Mesoscale Lightning Experiment (MLE).

- Space shuttle campaigns starting in 1980s using video cameras to observe lightning from space.
- Enabled photogrammetry and other quantitative analysis of lightning.
- Also detected "vertical discharges" above the cloud tops (e.g., transient luminous events like sprites.)

Optical Transient Detector (OTD) [1995–2000]

- First NASA spaceborne global lightning mapper, which demonstrated lightning's preference for tropical land masses…
- Used 777-m oxygen emission line to detect lightning during both day and night.
- Demonstrated lightnings preference for tropical land masses, and provided accurate estimate of global flash rate.

LIS on TRMM. [1997–2015]

- LIS would originally have been on EOS. Ended up on TRMM
- Same obs approach as OTD.
- First combined spaceborne observations of lighting with other sensors, including microwave radars and radiometers. [The lightning obs and microwave obs are complementary.]
- Long life enabled ultra-high-resolution climatology of tropical lightning.
- Allowed us to figure out the hotspots?

LIS on ISS [2017–Present]

- Modified flight spare of TRMM LIS instrument.
- Extends and expands TRMM time series and provides NRT data for applications.

Geostationary Lightning Mapper (GLM) [2017–Present].

- GLM updated the LIS/OTD measurement approach for geostationary orbit. Continuous monitoring lightning over the hemisphere. [He said that geostationary lightning obs was "always the dream." But LEO options allowed for global observations.]
- NASA plays major role in validation of GLM obs.

FUTURE—CubeSpark. Mission concept being developed at MSFC and Los Alamos National Laboratory to improve the detection of optically dim flashes—and three-dimensional profiles.

Suborbital Observations of Lightning. Major role since 1970s. Key role in figuring out the 777 nm observation was ideal for lightning detection.

NASA has produced a Multidecadal record of lightning from space and looks forward to continuing it into the future. Challenge today is to merge data from different instruments to create continuous time series to allow investigations of climatological trends.

DISCUSSION

Lots of institutional interplay seems involved. Talk about how this plays out?

Timothy: Lightning is "red-headed stepchild." It's almost too small to get recognized. But there are quite a few groups that are interested in lightning studies, so if you build collaboration among all the institutions researching lightning, it builds strength. No one institution could do this on its own.

Jim: Topography (shape of ground) is a community-based commodity. We live on it, we sail on it, it's inherently trans-institutional. Scientists study it at many different scales. The data are important because real lives are impacted by changes in topography. Partnerships benefit science and economics. *Digital artefactual world*.

Gemma: Have to consider foreign relations (not just science and technical institutions). Negotiating data sharing involves a wide variety of institutions.

Chris: SPoRT has had nothing but positive interactions with other groups. Make sure data they collect has societal impact. Don't want to do "science in a vacuum." Develop applications to address a specific problem that has been identified.

Always a balance between science and applications. Do science questions or applications drive plans for missions?

Tim: Science questions drive these practices—e.g., he mentioned Decadal Survey process (White Papers written, then committee evaluates). However, applications have become increasingly important from the beginning of planning for more recent missions.

Jim: Mentioned that there are cycles of NASA development… Mentioned ES Application Program at NASA HQ in 1970s—a response to this issue coming up in the 1960s/70s with Apollo. Led to development of Applications Program in the 1970s/80s. Attempt to bridge gap before Decadal Surveys. MTPE infrastructure (EOS) was implemented in the 1990s. As we understand more about climate, we realize what fundamental measurements are missing—but we also see feedback loops into societal benefits. (Same is true as we look at environments beyond Earth—e.g., Moon and Mars.)

Chris: Welcome change to see applications considered from the formulation phase of a mission. Much of our science is done with applications they will benefit in mind from the beginning. Balance between science and downstream applications is definitely a point of emphasis for NASA. People need to be able to use data from the beginning.

Question for Gemma. What do you define as Europe?

Gemma: She focused on "Western Europe." Germany, France, European Space Agency. This is the area she has access to, but also, these countries were quite active in the 1980s.

There was a question about MOLA—directed to Jim Garvin.

MOLA mapped Mars [1997–2001] and was a pathfinder for altimetry. Produced geodetic format for all measurements, which allows measurements to be repeated over time. Mapped Mars geodetically more precisely than Earth—nearly one billion Mars topography measurements. Intersection of data, measurements, and application. Gave geodetic map—which is framework for change detection. MOLA was driven by science—and by applications. How do you land rovers without knowing precise position of the ground? Topography is a "definitive dataset", allowing it to be used as reference frame. Reference frames have triggered software applications moving beyond MOLA and were integrated into Earth altimeters for tracking a wide variety of properties.

For Davinci (Venus mission for 2029) they will use new technology borrowed from machine vision. High-end processing allows move toward software processing in space. Could eliminate need for active sensing.

We also map Earth using high-resolution imaging from private companies.

Question about interplay between projects. Do you see places where the data you are producing is needed? For example, is your data used in SERVIR?

Timothy: Data from LIS played a role in developing risk Maps Kelsey showed (Bangladesh severe weather.) LIS Scientist was on the Bangladesh project team.

Chris: SPoRT focuses mostly on domestic partners—but they do work with SERVIR. Provide subject matter expertise on the issues the SERVIR hubs are working on. Being in the same building, collaboration is made easier. Again, the cutting edge for lightning is to be able to predict when it's going to occur (i.e., when will the "first strike" happen). Pushing the envelope on science in turn opens up new applications.

Nancy Searby (I think) asked about taking into consideration demands (needs) of others. Are there needs that are known, but for whatever reason, we cannot meet.

Chris: All that is done at SPoRT is in response to user needs. They don't start a project unless they know that there is a need to address—e.g., connect an apps-focused meteorologist with local met office. Applied science should be driven by user needs. Codvelopment is the whole philosophy of SPoRT. We proactively ask users what they need. NASA isn't an operational agency—but supports operational agencies.

Tim: The relationship that the U.S. has with a particular country where something is happening where NASA data could help, can impact whether anything is done. For example, Lake Maricopa in Venezuela is lightning hotspot, but no observations there due to the bad relationship the U.S. currently has with Venezuela.

Jim: We know what measurements we'd like to make. The problem is that many of them are unmeasurable with current tech. For example, local-scale wind measurements via RS would be highly desirable—but it's hard to do. Mars could be a learning lab for how to do this on Earth—since there are less variables to control.

Session 6A – *Publicity, Promotion, and Education*

Moderator: Martin Collins [NASM]

Emily Watkins [American University, Grad Student and recent NASA GSFC intern]
Experiments in Efficacy: NASA Earth Science Video Production Team's Evolving Strategies for Climate and Environmental Communication

Why do we need science communicators? There's a whole lot of info out there—and not all is accurate. There's a need for accurate info to be conveyed in unbiased manner. Personal opinions and politics can bias our communication.

JFK. 1961. Commitment to Worldwide weather communications commitment.

How to communicate Science?

- *The science*. Three pillars: Current events. Scientific visualization pipeline. Input from Scientists.
- *The story*. Story is best way to convey information. NASA comes up with innovative ways to tell stories. Requires quality communicators…
- *The audience*. Have to know your audience—and the requirements of the medium you are using to communicate.
- *The visualization*. NASA has a whole archive of videos that can be drawn upon. Data visualizations, animations, archival footage, and interview footage.
- *The assessment*. How successful was the communication? Collect metrics on engagement.
- *Examining the evolution*. NASA sticks to science—and science only. We adapt to new environments and situations (e.g., COVID).

Emily showed part of the video she produced when she was an intern as GSFC, which discussed the Honga–Tunga eruption and its impact. [The video included clips from Jim Garvin.]

Elizabeth (Scout) Blum [Troy University]
"The Early Space Program: Impacts on Views of Space by American Pre-Teens, 1960-1980"

Part of a larger paper on children's views of nature.

- 1960–1980. Focused on the two decades surrounding the first Earth Day.
- Assessment of children's interest.
- Children wrote less about space than other topics.
- Looked at examples from two magazines: *Highlights* and *Jack & Jill*.
- There is a lack of Children's entries in/about space. [She showed a list that included the topics the magazine subscribers wrote about—and how frequently they did it; space ranked last.]

Questions She Considered

- What did pre-teens (8–12) say about space?
- What messages did *Highlights* choose to focus on?
- What does this tell us about NASA and space program?

Highlights style seemed to shift after Sputnik launch.

- Before Sputnik, entries were more fantasy-related when it comes to space; after Sputnik, more science focus.
- She showed a very detailed account of Apollo missions from 1966. Descriptions emphasized danger.
- Conveyed more of a sense of fear than one of wonder. *Highlights* was "all business" in their coverage of space.

Kids, however, continue to use fantasy in their discussion of space.

- Space lacked rules and thus was a place where imagination could run wild.
- Kids wrote poetry about the beauty of the Moon.
- Kids used space to discuss Earth-based problems. (Whereas *Highlights* tended to downplay these issues.)

Discussed gender imbalance in responses.

Submissions to *Highlights* and *Jack & Jill* were female dominated.

- But 80% of space-based entries published are from boys.
- In short, girls weren't writing about space. Boy were only ones to draw pictures of space.
- Woman's movement had an impact. More biographies of women published.
- Some girls did step beyond the gendered stereotypes.

Her conclusion. *Highlights* didn't "read the room" well. They didn't connect with their audience. They went rational, intellectual, and technical with their coverage, when clearly kids were relating to it through fantasy.

Shobhana Gupta [NASA HQ] and **Diana Garcia Silva** [Queens College, Graduate Student], NASA HQ Intern], (Diana was virtual)
Crowdsourcing To Support Earth and Environmental Science

Croudsourcing. Soliciting solutions from "the crowd."

Opening up our workflows beyond the "usual crowd" with which we interact.

Engage non-traditional audiences to help advance our scientific knowledge and impacts.

- Focus on basic, critical problems to solve to help achieve desired outcomes—new discoveries, increased capacity, beneficial applications.
- Openly and broadly share challenges and resources to equitably invite out-of-discipline expertise.
- Design projects with users to codevelop and test/refine solutions together.

Examples: Prize competitions, hackathons, citizen science, open talent.

You don't just pick a random person to participate; it is more targeted than that, but…

One can draw upon expertise of others outside your field to give input to you.

NASA has a rich history in Crowdsourcing, Goes back to 2005. [She showed timeline slide.]

- 2005. Centennial Challenges
- 2011. OSTP directed NASA to create Center of Excellence for Collaborative Innovation. Allows NASA to help other agencies do crowdsourcing.
- Curated crowds can help with crowdsourcing.

Shobhana then showed video from Diana.

Crowdsourcing projects in Earth and environmental science.

Analysis of History in Crowdsourcing Project.

Aimed at analyzing impacts from prizes and challenges that support Earth Science endeavors.

Goals: Review past projects and understand common impacts we see; and develop a metric to do future impact assessments for Prizes and Challenges Projects.

Why is this important? Want to see what types of value was generated and how to we measure those values in the future.

Impact Assessments. A structured decision process that describes the impacts from a project and identify pathways to reduce/mitigate their implications on enhance positive outcomes.

Different types of Impacts reported, depending on project scope: Environmental, Technology, Social, Risk, Policy, Academic, Culture, Economic, Wellbeing, Scientific Advancement.

Procedures

- Lit review completed on Impact Assessment, Protocols, and Metrics.
- Catalog NASA Prizes and Challenges in Earth and Environmental Sciences.
- Designing tailored assessment program requirements for Prizes and Challenges projects with goal to standardize Impact Assessments for Prizes and Challenges:
    - How to identify all relevant stakeholders including competition runners, contest participants, and solution users.
    - Collecting data including competition metrics, process-related feedback, impacts of solutions.
- Qualitative and quantitative impact assessments for selected projects taking place.

Future Steps.

- Revise Impact Assessment Plan with expert input after each Assessment iteration.

Sample Competitions:

NASA AIR-ATHON: Air Quality Challenge. Developing algorithms for estimating daily levels of surface air pollutants with high spatial resolution, through the use of NASA satellite data, model outputs, and ground measurements. Lead to more accurate AQ measurements (e.g., MAIA and TEMPO).

CO_2 Conversion Challenge. Convert carbon dioxide into simple sugar molecules known as D-sugars to make useful products—e.g., plastics, adhesives, and fuels to food and medicine in space. New process similar to photosynthesis that might be used for space travel.

Next Steps

- Quantitative and qualitative assessments of impacts of ES crowdsourcing projects.
- Apply insights from these towards development of new products.

Lin Chambers [NASA's Langley Research Center]
How NASA Engaged Students and the Public Around the World in Observing the Environment to Support NASA Science

Historical context. We started in the early days of the Internet—1994.

- 1989 Tim Berners–Lee concept of WWW
- 1990 Hypertext Markup Language (HTML) invented.
- 1993 Mosaic Browser introduced.
- 1994 Earth Day—GLOBE Program Announced
- 1995 Earth Day—GLOBE Program Launched

- 1996 Fall—S'COOL Project concept
- 1997 January–S'COOL Project launched

Global Learning Observations to Benefit the Environment (GLOBE) was in NOAA Authorization Act of 1994—White House initiative (Al Gore). Students participate in real science. When it started in 1995, 8 US Agencies and departments, plus the White House participate; 11 countries other than the U.S. were involved (UN Resolution). From its inception it was a science and education program with international involvement.

[Showed data from Year 6 Evaluation to demonstrate early impacts of GLOBE.]

She discussed Learning Expeditions, which take place every four years.

2003 NASA took over.

Students Cloud Observations Online (S'COOL). A grassroots effort that began in 1996. Developed iteratively.

Started with students sending in post cards, then email, then web.

Looking at: What is the effect of clouds on Earth's climate?

- She showed some archival photos.
- She showed the first S'COOL data. Taken on a clear day→no clouds to observe. Lesson: Zero is data.

2016 S'COOL and GLOBE Combined. S'COOL became cloud protocol for GLOBE Observer Ap

She discussed the GLOBE Observer App. Citizen sciences and students can take data using their phone and upload it.

Showed data from 2017 Total Solar Eclipse.

Just this month. Millionth Match between ground observations and satellites.

DISCUSSION

Question on science diplomacy.

Lin: GLOBE has component of science diplomacy. State Department is a partner helps negotiate bilateral agreement with each country involved—127 and counting. Mosquito App was added to Globe Observer courtesy of State department. They wanted something during the Zeka virus outbreak in South America. They've trained hundreds of people across the Tropics to use this protocol on the App.

Emily: *Highlights* had connections with NASA.

Were kids impacted by failed missions like Apollo 1 or 13, or Vanguard?

Emily: Magazine doesn't talk about any failures. Barely mention the Soviets. They don't want to scare kids. They really avoided failures completely.

Assessment of programs and future plans. What were foundational challenges for bilateral agreements?

Lin: Multilateral agreement for original participants. Subsequent agreements (which are largely the same for every nations that join) involve a long process. Some countries have dropped out because they don't want data from their nation available on a NASA website. Again, State Department plays a key role in negotiating these agreements.

What is it like to be a student and NASA intern?

Emily: Intimidating. But she's learned a great deal. Great opportunity to network, prove yourself, gain experience. Different process in a government agency compared to production for other outlets. For example, she produced one video the entire summer!

Diana: Intimidating when she started, but like Emily, a rewarding experience. Shobhana helped to open a path for her.

Nancy: Diana was a great intern. She added that they learn from the interns as much as the interns learn from them.

Discussion about Science Visualization Studio.

Emily: We don't take as much advantage of conceptual animators as we do visualizers. They get the concept that it's more effective to *show* than tell.

Session 6B – *Colonization, Geoengineering, and Astrofuturisms*

Moderator: Matt Shindel [NASM]

Caitlin Kossmann [Yale University]
Microbes, Cyborgs, and Gaia 2.0: Agency and Geoengineering in the History of Earth and Climate Science

- One way of contributing to knowledge of environment: Earth System Science, which has been discussed.
- Midwife to Gaia Theory. James Lovelock. Mariner-B to Mars.
- Led to Gaia hypothesis. Planetary environments betray presence of life because they were in part the products of life. Theory of living Earth and evolution.
- Most consequential actors in Gaia are bacteria. Oxygen began as a pollutant (from the perspective of microbes at the time) but now our atmosphere is 21% Oxygen.
- Ultimate harm to protect against is harm of Gaia.
- Machines are seen as part of Gaia—e.g., Earth observing satellites.
- Cyborgs. Artificial Intelligence. Evolved sentient machines who realize they are members of Gaia.

Gaia 2.0. The Anthropocene is Gaia's conscious awakening.
- They ignore the danger of pushing Gaia beyond its limits.
- Gaia is a cyborg now.
- Gaia has embraced other kinds of sensing.
- Remote sensing and Gaia converging. [NASA searches for techno-signatures—since 2018.]

Stuart Simms [Auburn University]
"Snakes, Mosquitoes, and the Mississippi Mud": NASA, Environmental Management, and the Tropes of Dispossession at John C. Stennis Space Center

Started with a quote. Alton Keller described the loss of his hogs.

People displaced when Stennis Space Center was created in 1961 when NASA searched for a site to build a new rocket test facility.
- Huntsville was too urbanized to be used.
- There were towns that had to be "relocated".
- There were 1500 people present for a Senator John Stennis speech (November 1). [Report said only 300–500 lived there.] "Thorn (of dispossession) before the rose."
- Real Estate agents purchased the land.

Stories from Locals Paint a Different Picture
- Mack Herring told story of Cora "Aunt Blue" Davis, who supposedly sat on her porch as her house was demolished.
- Heartbroken elderly residents die of sudden cardiac arrest upon hearing the news.
- "Moon Race Blots Out a Town" [1964] Features 92-y-o who didn't want to leave.
- Residents wanted site access.
- Why didn't NASA choose a truly uninhabited place to build its new facility?
- Why could NASA employees fish on the property if the owners couldn't?
- Not allowed to visit gravesites of loved ones. [At this time I-10 and I-59 didn't exist.]
- Local people weren't silently accepting the decision.
- **Residents clearly attached their own meaning to the site.**

Mack Herring: Way Station to Space
- Interviewed Roy Baxter
- Roy reinforced narrative of uninhabited space.

Triumphalist history told by NASA versus stories told by locals.

- *The official history*: In 1961, NASA decided to brave poisonous snakes, mosquitoes, and the Mississippi mud to build a huge new testing facility—covering 13,500 acres.
- *Official history* harms people who lived there to the point of dehumanization.
- It's our job to give voice to the snakes, mosquitoes, and mud.

Nikoleta Zampaki [National and Kapodistrian University of Athens] (virtual)
Thinking Beyond the Future of Aesthetics: Space Art or the Art of Space

Anthropocentrism versus *vitalism*. Will "colonization" of other worlds (e.g., Mars) be human-based or non-human?

Showed paintings. Representations of life in outer space, e.g., Mars.

Mars Artist Community.

- Creating art of outer space while based on Earth.
- Use art to imagine the future.
- Move beyond the binaries.

Posthuman aesthetics.

Symbiotic citizenship. *Citizen humanitus* (citizen science in the humanities).

IN DISCUSSION: Nikolera emphasized that she believed whatever exploration we end up doing, humans are likely to be involved—i.e., it won't be completely automated. Thus, the speculative art is applicable. It envisions things similar to what we currently do on Earth.