United States Department of the Interior

OFFICE OF THE SECRETARY
Washington, DC 20240

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The Honorable Kyrsten Sinema
Chair, Commerce, Science, & Transportation
Subcommittee on Space and Science
United States Senate
Washington, DC 20510

Dear Chair Sinema:

Enclosed are responses prepared by the Department of the Interior to the questions for the record submitted to the Department's witness, Kevin Gallagher, Associate Director of Core Science Systems, U.S. Geological Survey, following his appearance before your subcommittee at the December 1, 2022, hearing titled: "Landsat at 50 & the Future of U.S. Satellite-based Earth Observation."

Thank you for the opportunity to provide this information.

Sincerely,

Christopher P. Salotti
Legislative Counsel
Office of Congressional and
Legislative Affairs

Enclosure
cc: The Honorable Eric Schmitt
Ranking Member

Questions for the Record
Subcommittee on Space and Science
Senate Committee on Commerce, Science, and Transportation
Oversight Hearing: Landsat at 50 and the Future of U.S. Satellite-Based Earth Observations
December 1, 2022

Question from Senator Maria Cantwell

Landsat Data: Landsat has provided a virtually unbroken record of Earth Observation data for the last 50 years. As you said in your testimony, the U.S. Geological Survey has been intimately involved since the beginning of the program and has since 2008 provided free and open access to Landsat data. These data have become an invaluable resource for our nation's infrastructure, informing urban planning, precision agriculture, and disaster response.

Question: Could you describe the importance of Landsat's historical dataset? What new data will the Landsat Next satellite bring, and how do you see the program evolving from there?

Response: Both today's Landsat observations and the long-term data record to which they contribute provide unique value and impact. Scientific and technology advancements in data storage, data processing, and algorithms have enabled Landsat's data record to give us new insights into changes occurring on our Nation's land surfaces, surface waters, and coastal regions.

Following the first Landsat mission, launched in July of 1972, we have had at least one satellite in the series collecting data and often two satellites, which is our current operational baseline. This baseline allows us to image the entire Earth's land surfaces every eight days. Landsat's multi-decadal, global data record is unique – no other Earth-observing satellite mission comes close to its timespan, its consistency, and its scientific accuracy. Two U.S. Group on Earth Observations-led interagency Earth Observation Assessment reports ranked Landsat as the most impactful Earth-observing satellite system used by Federal agencies. In short, Landsat is a unique "witness" to changes that have occurred across the globe over the last 50 years.

While Landsat senses phenomena visible to the human eye, it also can "see" in the near infrared (NIR), shortwave IR (SWIR), and thermal IR (TIR) regions of the electromagnetic spectrum. Landsat's capabilities enable users to perform land use and urban development planning, observe soil moisture, accurately estimate agricultural water use, assess crop health, understand wildfire risk and forest recovery processes, and respond to natural disasters, including flooding, drought, and wildfire, while also supporting many other societal applications.

The Landsat archive is open and accessible to all users. Utilizing cloud processing and storage, the U.S. Geological Survey (USGS) has reprocessed and re-released the entire dataset as Landsat "Collection 2". The dataset provides every Landsat measurement taken over the life of the Landsat program as a time-series of observations, thus enabling in-depth analysis of land cover changes over the past 50 years. In a little less than two years, the USGS has recorded over 4 billion user accesses to this data.

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Throughout Landsat's history, the National Aeronautics and Space Administration (NASA) and the USGS have continually advanced its technology to better address users' growing needs for high-quality data. The earliest Landsat missions sensed the Earth in four spectral bands, and in the 1980s, Landsat utilized eight bands, including a thermal band. Today, Landsat 8 and 9 operate in 11 bands. The USGS has also advanced the mission's spatial resolution – the ability to resolve small or adjacent details in an image. The earliest Landsat satellites imaged at about 75-meter resolution, whereas Landsat 8 and 9 operate at 30-meter resolution – about the size of a baseball infield. Landsat Next will image in 26 spectral bands at resolutions as fine as 10 meters, more than doubling Landsat spectral and spatial resolution capabilities. Landsat Next will also improve revisit rates so that every location on Earth will be imaged every six days.

Landsat Next's spectral, spatial, and timeliness requirements are driven by the most detailed land imaging user needs ever available for Landsat formulation. We conduct our peer-reviewed user needs process across the USGS, the Department of the Interior (DOI), and other Federal agencies. This process connects our users' continually growing science and public service needs to specific Landsat Next spectral bands while maintaining Landsat Next's continuity with the historical data record.

Under the NASA-USGS Sustainable Land Imaging partnership, Landsat Next will provide the core, operational U.S. Government land-imaging capability for the Nation. The USGS will augment this core capability through partnerships with commercial and international satellite data providers, to serve an even broader array of user needs than can be served by a single system.

The Landsat Program is evolving on the ground as well as in space. We are improving the interoperability among Federal, commercial, and international land-imaging datasets. While Landsat already provides essential calibration utilized by the commercial satellite providers, which enhances interoperability, we intend to optimize user tools for discovering and accessing data across disparate archives – enabling a multi-source "data ecosystem" – so that users may apply multiple datasets (commercial and government) for improved land cover/land use analysis, monitoring, and forecasting. These capabilities and tools will help U.S. scientists answer some of the Nation's most pressing questions about resource management, disaster preparation, response, and mitigation, ecosystem health, and climate change resiliency.

Prior to launching Landsat Next, NASA and the USGS expect to determine Landsat Next's successor mission and analyze future commercial and international remote sensing capabilities to determine the best approach to address our users' future needs. We plan to work closely and collaboratively with NASA and other organizations as we chart our future course.

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Questions from Senator Kyrsten Sinema

Drought and Fire Monitoring: Fire season begins in late April in Arizona, as the Southwest experiences the most severe drought in twelve hundred years. This is one month earlier than the average start of peak fire season between May and June. Earlier this year, the Tunnel Fire north of Flagstaff burned over twenty thousand acres while the Crooks Fire consumed over six thousand acres south of Prescott. After the fires were extinguished, burn scars have led to significant flooding issues in Flagstaff and other areas in northern Arizona.

Question 1: How can researchers utilize Landsat data to examine the effects of drought and wildfire and help predict where future fire and flooding events may occur?

Response: Arizona is in a region where forest fires and drought are occurring more often and with increasing intensity. Landsat plays a critical role in wildfire science and in helping to prevent damage to life, property, and natural resources. Land managers and scientists use Landsat to predict wildfire, assess wildfire risks, and to understand their immediate and long-term impacts. They also use Landsat to map the rapidly growing wildland-urban interface, which is highly susceptible to wildfire damage.

Scientists use Landsat to characterize vegetation and fire fuel load. This characterization enables them to model different fire regimes and to support proactive vegetation and fire management to reduce fire risks and mitigate fire impacts, such as erosion and flooding. Land managers and scientists also use Landsat to assess the severity and extent of large fires as they plan recovery efforts, to estimate how much pollution burning releases into the air, and to monitor the post-fire recovery of burned areas.

Landsat can capture active fires and smoke plumes as they occur, showing images of large, rapidly developing fires in the West. Because Landsat instruments can detect surface temperature differences over broad areas, they can also help detect wildfires burning in remote regions.

Question 2: How does your agency share this information with federal and local emergency officials, federal land management agencies, and water managers to inform their response to drought, wildfire, and flood risks?

Response: The USGS shares Landsat data and information products with partner agencies working to address these risks. Landsat enables natural resource managers to assess the severity and extent of large fires for planning recovery efforts. For example, the U.S. Department of Agriculture (USDA) U.S. Forest Service (USFS) Burned Area Emergency Response (BAER) team uses Landsat data to map vegetation, water, and soil changes immediately after a fire. With these maps, the USFS can identify the most severely burned areas and treat them to mitigate increased water runoff and erosion. BAER has been estimated to yield cost savings of up to $35 million over a five-year period. By using Landsat data to map vegetation, water, and soil changes after a fire, response staff can identify the patchwork of burned areas left in the wake of the flames.

Landsat also enables fire fuel mapping through the joint USFS - DOI LANDFIRE program. This program supports a range of land management analysis and modeling for fire behaviors and informs strategic land management.

Worldwide, droughts can have disastrous impacts on lives and livelihoods. Landsat data show the impact of drought on vegetation at a scale that enables water managers to better allocate limited water resources. Landsat's unique thermal infrared data can map evapotranspiration (ET) – water evaporating from the ground or transpiring from the plants – to estimate water use, soil moisture, and drought impacts on vegetation and ecosystems. As climate change exacerbates drought conditions, Landsat can help improve water allocation to support more effective adaptation.

Landsat captures before and after images of flooding across the Nation and around the world, illustrating flood extent, vegetation loss, and structural damage. Landsat can also help monitor post-flooding impacts on water quality and long-term vegetation recovery. By using Landsat to map historic flooding patterns, USGS hydrologists can better predict future flood hazards.

Question 3: In particular, can you describe how the U.S. Geological Survey's Arizona Water Science Center in Flagstaff employs Landsat data when making forecasts regarding the Colorado River and Arizona watersheds?

Response: While the Arizona Water Science Center's activities focus primarily on field work and in-situ observation, Landsat has complemented this work in the Colorado River Basin and Arizona watersheds. Irrigation accounts for over 40 percent of freshwater withdrawals in the United States. Increased demand for scarce water supplies has shifted water management strategies from increasing water supply to innovatively managing water use at sustainable levels. Landsat's unique thermal infrared data enables field-scale measurements of ET to accurately estimate consumptive water use. With the warming climate and increasing drought conditions, Landsat-based analyses provide a reliable, consistent, impartial, and non-proprietary data source to inform water rights negotiations and resolve water rights disputes. Landsat-based water use information is also combined with climate models to forecast future water use across the Colorado River Basin.

Prolonged drought has changed Arizona's watersheds, water quality and availability, riparian vegetation, and ecosystems. Scientists and land managers use Landsat to monitor vegetation type conversions, native and invasive species along the watersheds, inform watershed restoration efforts, and monitor restoration progress over time. One example involves their use of Landsat to monitor vegetation establishment and growth after installing rock detention structures – low-cost, low-tech, natural systems in dryland streams. Landsat data recorded 30 years of sustained or increased vegetation cover where these natural structures were installed, despite prevailing long-term drought conditions. Landsat observations demonstrated that these nature-based solutions can help improve watershed condition and boost local climate change resilience.

Additionally, Flagstaff Science Center scientists have used Landsat data collaboratively with the San Carlos Apache Nation in Arizona, to support the Tribe's management of its natural resources. They have used Landsat to assist the National Park Service with understanding potential effects of climate change on wildlife habitat in park lands. The Center's staff has used Landsat data to derive global cropland extent maps to support food security and sustainable agricultural practices.

Heat Health: Large portions of central and southern Arizona experience extreme heat events, particularly during the summer months. Extreme heat can contribute to negative outcomes for individuals who lack access to air-conditioned residences or suffer from ailments that affect the ability of their bodies to regulate heat. 552 people died in Arizona from heat-related causes in 2021, and nearly 2,800 passed away over the past 10 years from heat-related causes.

Question 4: Can your agency utilize Landsat data to predict or track urban areas that will experience the worst heat on a summer day, as well as the features of certain urbanized areas that contribute to or mitigate extreme heat areas? If so, can you describe the process for making those predictions?

Response: Yes, Landsat has informed municipal authorities' urban heat-island and green-infrastructure efforts in various U.S. cities, including metropolitan New York City, Chicago, Illinois, and Boston, Massachusetts. Landsat collects surface temperature and vegetative change information that pinpoints urban heat islands. This information supports urban authorities' actions to mitigate heat stresses for residents. This work is growing in scope and urgency as urban and exurban landscapes throughout the world are growing at a rapid pace, with the total area of urban land cover estimated to triple between 2000 and 2030 and as global average temperatures continue to rise.

Continuing urbanization has numerous impacts on social and ecological systems. These impacts include expansion into critical protected areas, loss of croplands, changes in local hydrology, and changes to local climate. All these factors can contribute to residents' increased heat-borne mortality rates. Monitoring these landscape changes is critical for urban planners, resource managers, and decision makers seeking sustainable and equitable growth. Landsat is well-suited to this task, due to its multi-decade imagery archive, landscape-scale spatial resolution, and range of spectral imaging capabilities.

Descartes Labs, a New Mexico-based startup, has mapped urban growth and heating by using Landsat data combined with machine learning algorithms and Geographic Information Systems. The company produced a map of urban heat islands in the greater Boston area by generating a mosaic of Landsat's thermal bands over several months. Its results show the stark difference between urban green spaces, major transportation corridors, and built-up areas. The team was also able to detect local patterns on the landscape resulting from large climate-controlled warehouses or brick buildings. Through Descartes Labs' platform, it is possible to model seasonal changes in urban land-surface temperature over the course of more than thirty years, with significant implications for the study of climate and its effects on cities.

A September 2019 report featured on National Public Radio also used Landsat thermal-imaging capabilities to determine whether urban areas of lower income are correlated with higher daytime temperatures. The report found a strong, negative correlation between heat and income in many cities, indicating that the urban poor are often more susceptible to heat-related illnesses than their wealthier counterparts.

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Question from Senator John Hickenlooper

Earth Observation Mission Architectures: The USGS and NASA collaborated on the Sustainable Land Imaging Architecture Study to examine novel concepts for next-generation Earth observing missions, including the use of satellite constellations. They also gathered user feedback to establish data requirements and maximize scientific impact of future Landsat missions.

Question: Can you discuss how the findings of this study will impact the Landsat Next mission?

Response: The USGS participated in two separate efforts to quantify the requirements and determine the architecture of the Landsat Next mission. First, the USGS National Land Imaging Program sought to understand and document user needs associated with Earth observation in general, and moderate-resolution space-based Earth observation in particular. The Program utilized a peer-reviewed process consisting of hundreds of expert interviews to understand user applications and observation needs. These findings were compared to existing and future observing systems to identify gaps in planned Earth observation capabilities.

These findings were a direct input into our second effort, a mission architecture study. Along with NASA, our Sustainable Land Imaging partner, the USGS commissioned an Architecture Study Team to examine candidate architectures which would maintain the Congressionally mandated Landsat data continuity record while also addressing the gaps identified by our user needs analysis. The Team developed scores of architecture options and evaluated them against mission capabilities, required technologies, and relative costs. It presented its methodology, driving requirements, leading candidate architectures, and its recommended architecture to NASA and DOI/USGS leadership. Recommendations were guided by the need to execute a cost-effective solution that would meet the user needs within the schedule and risk constraints of an operational Landsat mission. The architecture proposed by the study team, and eventually accepted by the agency partners and administration, is known as "hybrid triplets". The triplets are a simultaneously operating constellation of three observatories in a repeating ground track Sun-synchronous orbit. The selected architecture achieves an aggregate six-day revisit over the Earth's land surface and more than doubles Landsat's spectral and spatial resolution.

For Landsat Next, NASA and the USGS determined that this hybrid triplets architecture will be the most cost-effective option to meet user needs for emerging science and applications while assuring continuity – an enduring connection – to the historical land record started by Landsat back in 1972.

The new architecture will enhance users' ability to perform land use and urban development planning, observe soil moisture, accurately estimate agricultural water use, assess crop health, understand wildfire risk and forest recovery processes, and respond to natural disasters including flooding, drought, and wildfire, while also supporting many other societal applications.

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Questions from Senator Raphael Warnock

Coastal Erosion: Georgia's coast is home to numerous barrier islands that support thousands of residents and significant biodiversity. These islands play a crucial role in not only tourism and shipping, but also protecting the mainland from powerful winds, tides, currents, storms and hurricanes.

Question 1: Your testimony references Landsat images showing the effects of Hurricane Ian on the coastlines of Georgia and Florida. How does the United States Geological Survey (USGS) use Landsat data such as this to work with local governments to address coastal erosion?

Response: Landsat's consistent, reliable, repeated observations of Earth's landscapes keep an objective record of their conditions before and after disasters. This information serves as an essential tool for inventorying land resources, assessing the risks of hurricanes, mapping the extent of hurricane damage, and planning post-disaster recovery in states such as Georgia. Landsat images are among the remote sensing images that feed into the USGS's Hazards Data Distribution System. This system is used by local responders across the nation to support citizens affected by hurricanes, typhoons, volcanoes, earthquakes, widespread flooding, and other hazards.

During the recent Hurricane Ian, Landsat 8 passed directly over the storm's eye on Sept 28 as the hurricane approached southwest Florida, enabling scientists to scrutinize the images and analyze the forces that made it so catastrophic. In the hours after the storm passed, millions lost power. Landsat helped capture the extent of the power outage, as well as post-storm sediment runoff from rivers and streams on Florida's southwest coast. Authorities used Landsat to generate the first high-resolution, broad scale land disturbance map detailing damage wrought by the hurricane's wind and storm surge. This map was released just days after the storm to aid teams on the ground in their search and recovery work.

Landsat measures coastal change not only after storms but continuously through time. This capability enables scientists and coastal managers to calculate erosion trends, evaluate processes that shape coastal landscapes, and predict how coastlines will respond to future storms.

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Agriculture: As you may know, Georgia is a proud agricultural state. However, changes in weather patterns and climate can threaten the success of Georgia's agricultural sector.

Question 2: Your testimony discusses the importance of Landsat in agriculture. Please elaborate on how USGS partners with the agricultural sector to identify challenges and implement solutions based on Landsat data. How can an agricultural state such as Georgia strengthen its partnership with the USGS to better support farmers?

Response: Freely and easily accessible Landsat data has long benefited the agricultural sector. The USGS would be glad to work with the USDA and your staff to discuss how Landsat can further benefit Georgia's farmers.

Millions of farmers and consumers already benefit from Landsat data that improve crop and water management decisions. Food and farming organizations rely on Landsat's unbiased, accurate, and timely information. It enables Federal and state agencies, local authorities, businesses, and farmers to analyze the health and vigor of crops as they mature over the growing season; to understand needs of specific fields for fertilizer, irrigation, and rotation; to monitor planted acreage to forecast crop production and fight crop insurance fraud; to decide how much water is used in irrigation; and to forecast the impacts of drought on particular crops.

Farmers once had to walk their entire farm, which could be hundreds of acres, on a regular basis to witness the same crop conditions that can now be readily detected by Landsat. The USDA uses Landsat data as a key input into several reports during the growing season that forecast crop production. In turn, the multimillion-dollar U.S. agricultural commodities market relies on these forecasts when conducting futures trading.

Nearly two-thirds of U.S. surface-freshwater withdrawals are for crop irrigation. Keeping track of just how much water gets used – and making sure it gets used efficiently and legally, where and when it's needed across millions of acres of crop land – is no easy task. Landsat images can map evapotranspiration – water evaporating from the ground or transpiring from the plants – to estimate how much water crops are using.

As rising temperatures, more widespread droughts, and intensifying weather events threaten food security and farmers livelihoods, farmers can use Landsat as a tool for effective action before, during, and after the growing season.