RTI Innovation Advisors

Supporting the United States Office of Science and Technology Policy in Developing a National Plan for Civil Earth Observations

Response to Request for Information (RFI) 2023-25798

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Executive Summary

Through the National Plan for Civil Earth Observations ("the Plan"), the U.S. Office of Science and Technology Policy (OSTP) U.S. Group on Earth Observations (USGEO) team aims to define and realize its vision for the United States' continued global leadership in enabling increased access to and use of earth observation (EO) data to address global challenges. The challenges the Plan is addressing are not new. As such, a clear understanding of the nature of historical challenges in working, along with a plan to refine this understanding based on input from diverse stakeholders throughout the Plan's pursuit, will be critical to achieving OSTP's thematic goals, objectives, and cross-cutting Enterprise Initiatives.

RTI International (RTI), a not-for-profit research and technical services institute, has a long history and extensive experience using EO data in its own research, developing analyses around the utility and value of EO data, and advising numerous U.S. federal agencies involving EO data and applications. RTI's broad set of multidisciplinary research teams occupy positions along the EO data value chain: from data collection to processing low-level data products into higher-level products, integrating various internally and externally produced data products into applications (evapotranspiration, snowpack estimate, water supply monitoring, drought monitoring, irrigation scheduling, etc.), and ensuring end users and diverse non-research private-sector stakeholders are able to use these products to enhance their decision-making. Through our work in partnership with the National Aeronautics and Space Administration (NASA), philanthropic foundations, and other organizations, RTI has developed deep expertise in engaging diverse sets of end users across the EO value chain to understand key barriers to increased integration of EO data into commercial uses and decision-making. As such, this Request for Information response focuses on topics related to RTI's expertise areas: (1) challenges in integrating EO data from across the EO data value chain, (2) diverse stakeholder engagement, and (3) strong public-private partnerships that transfer data and technology to create new sources of value.

After reviewing the Plan, RTI developed a series of potential roadblocks and additional opportunities for USGEO to consider when finalizing and executing the Plan. RTI offers these comments—a synthesis of how our experience and expertise might inform the Plan's finalization and execution—with the hope of supporting the continued strengthening of the EO Enterprise (EOE) by the USGEO team. We welcome the opportunity to provide clarification or further comments as is helpful to USGEO, its members, and its partners.

Potential Roadblocks

- Finding and contextualizing feedback will be hardest in communities of potential (wherein most users do not use EO products but could gain significant value from said products).
- There is tension between open-source climate/environmental data and protected, anonymized human health data. Health data sources must be modernized and harmonized to be maximally valuable for informing EO-enhanced public health decisions.
- It will be important to consider unintended consequences related to reliability (e.g., disruption of data access for communities of practice) and equity before data are decoupled from their current agency homes.
- Existing challenges hindering democratization of data access and use must be addressed directly to expand equitable access to EO data benefits.
- If user-centered design methods do not drive stakeholder engagement, the impact of EO data in communities of potential will persist. This will be due to unidentified or unaddressed gaps in suitability, usability, and awareness of EO products.

- To ensure that the most critical observing system gaps are identified, user-centered design should be used to drive community engagement during assessments.

Additional Opportunities

- USGEO could introduce key frameworks to make collection and cross-comparison of feedback from stakeholders more effective.
- With respect to establishing data use metrics, USGEO can provide leadership through facilitating stocktaking and analysis of current practices, gaps, and solutions to address pain points that might hamper scalability of data use metrics. USGEO can then help establish a centralized portal for reporting data use metrics.
- USGEO could serve as a home for various economic analyses related to EO data to facilitate economic policy development.
- For Benchmark Sites, include features that maximize value for different users. In addition to demonstrating key data products, include a clear access point to all EO data products available from the government (for communities of practice) and 101-level learning opportunities and next steps (for communities of potential).
- For Benchmark Sites, include non-satellite observations into (from national and other U.S. government entities) and satellite observations from foreign governments and the private sector (as well as U.S. government satellite data).
- Engage private-sector companies developing risk models for insurance purposes; insurance is a key mechanism of “risk transfer” that can help enable adaptation in areas facing increasing climate risk.
- While working to increase spatial density of ground-based measurements and networks, leverage lessons learned from previous citizen science campaigns working toward this aim.
- USGEO could facilitate agency-level scouting for ground-truth data collection assets (e.g., new sensor architectures) within agency Technology Transfer Offices. These assets could represent opportunities to advance ground-truth data collection.
- While working on aims at the intersection of EO data and health, consider how USGEO might engage or partner with companies working in this domain today.
- To support agency-level best practices for driving more equitable use of EO data, USGEO might conduct a stocktaking of agency-level lessons learned and mainstream them across other agencies.
- Create and apply a repeatable structure to the annual assessments to better characterize (quantitatively and qualitatively) the benefits in target thematic areas and to enable consistent cross-comparisons among these thematic areas.

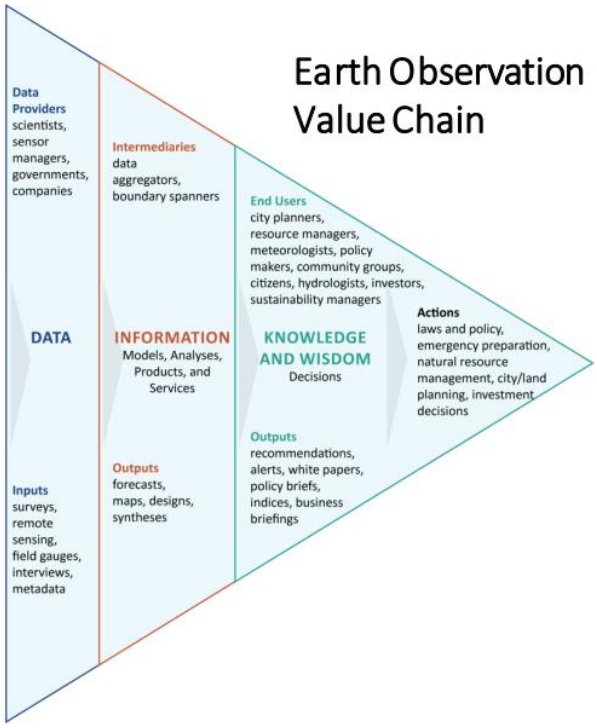
Potential Roadblocks and Additional Opportunities

Goal 1: Advancing Science-Informed Climate Mitigation Activities

The Plan rightly notes the importance of USGEO- and agency-level outreach and engagement of external stakeholders, as well as improved data use metrics, to collectively inform activities that promote the use of EO data in response to climate mitigation and adaptation activities. In pursuit of this goal, consider the following:

- **Potential roadblock in Objective 1.1—Finding and contextualizing feedback will be hardest in communities of potential (wherein most users do not use EO products but could gain significant value from said products).**
  It will take substantial time and concerted effort for USGEO and agencies to engage "communities of potential" (i.e., communities of users that largely do not use EO data products) in an effective and equitable way compared with "communities of practice" (i.e., mature users of EO data products). This is because stakeholders from communities of practice are better known (e.g., agencies may have their contact information from past engagements) and because they are more familiar with the subject matter. For example, members of communities of practice will be able to easily describe their EO data and application needs (e.g., temporal, spatial, and spectral resolution requirements for different clearly defined and understood use cases). Although, on the other hand, members of communities of potential deeply understand the decision they need to make, they will be less familiar with how EO data and products can assist in that decision-making, and they will not have an expert's familiarity with explaining their needs in terms used for collection mission planning or data product creation. This user needs articulation; technology translation is a common challenge in all government agency technology transfer efforts, and USGEO will also face this challenge as part of successfully translating and transferring EO technology data and products to communities of potential. USGEO has an opportunity to spearhead efforts to adequately engage communities of potential, learn their needs, and translate the value of EO data and products for their needs, which can result in large gains in the use of and value derived from EO data produced or otherwise made available by the United States. But without intentionally developing USGEO's and agencies' capacity to discover user needs and translate the utility of EO data, and spending more time and effort in engaging these communities of potential, the full value that can be derived from EO data will not occur.

- **Additional opportunity in Objective 1.1—USGEO could introduce key frameworks to make collection and cross-comparison of feedback from stakeholders more effective.** USGEO can function as a leader of agency-level partners by establishing key criteria across which to collect user needs and their associated technical requirements. This will make consideration of the net needs of diverse communities easier to understand over time, allowing USGEO and agency partners to better collaborate in planning for future collections and data buys, as well as future measurement, monitoring, and reporting efforts. For example, USGEO could develop a framework that places the source of feedback at a discrete position on the EO data value chain (figure on right)[1]; this could enable consideration of the needs of data providers separately from those of intermediaries and end users.



- **Additional opportunity in Objective 1.2—With respect to establishing data use metrics, USGEO can provide leadership through facilitating stocktaking and analysis of current practices, gaps, and solutions to address pain points that might hamper scalability of data use metrics. USGEO can then help establish a centralized portal for reporting data use metrics.** Understanding the broad range of public and private-sector use of EO data products will help evaluate the impact of key data products over time, enabling better understanding of impacts on climate policy and helping to inform future collections and processing priorities. Various U.S. government agencies, foreign governments, and commercial organizations approach this in different ways today, and it will be challenging for all organizations to adopt a unified approach in the future. To maximize the acceptance of more unified, regular, and reliable collection and sharing of use metrics, USGEO can first conduct a stocktaking of how these practices are performed now across its agency partners, international partners, commercial producers of data products, and commercial providers of software for access to or processing of data products (e.g., U.S. Geological Survey landing page for Landsat use metrics, Copernicus Sentinel data use metrics over time—2022 Annual Report)[2,3]; the stocktaking will include interviews of stakeholders to understand their pain points related tracking EO data user metrics. USGEO could also scout for potential improvements to tracking data product use from outside the realm of EO data (e.g., in other sectors tracking data product utilization). Informed by stocktaking of current practices and potential additive solutions, USGEO can lead efforts in establishing standardized best practices for collecting and reporting data use metrics. Aligning on adoption of data use metrics with agency and other partners is recommended. Once a reporting template is developed, USGEO can create a home for partners to report these data live (and make the home accessible to any type of organization willing to meet reporting requirements).

- **Additional opportunity in Objective 1.3—USGEO could serve as a home for various economic analyses related to EO data to facilitate economic policy development.** USGEO could collect these analyses where they have been performed for U.S. government assets (e.g., Economic Benefits of

the Global Positioning System[4]) from the public domain and associate them with specific data products in order to help developers of economic policy more easily understand what is already learned about the economic impacts of EO data. USGEO is well positioned to aggregate these studies where they exist today, and their aggregation could help develop understanding of key gaps in economic analyses. USGEO could also consider gathering non-U.S. analogs, like Copernicus economic analyses, depending on the needs of policymakers.

Goal 2: Strengthening Environmental Monitoring and Management

To ensure sustained existing and improved capabilities for monitoring, modeling, and forecasting changes across various ecosystems, consider the following additions to planned activities:

- **Additional opportunity in Objective 2.1—For Benchmark Sites, include features that maximize value for different users. In addition to demonstrating key data products, include a clear access point to all EO data products available from the government (for communities of practice) and 101-level learning opportunities and next steps (for communities of potential).** Selection and promotion of Benchmark Sites will help stakeholders across the EO value chain to better understand the utility of EO data in addressing challenges they face. The private-sector companies within the EO community of practice resonate with the concept of Benchmark Sites per feedback RTI gathered previously in support of NASA. As summarized in a 2021 report to NASA[1], RTI noted that service developers in the community of practice face challenges communicating the value of EO-enabled solutions to their customers, who typically have limited to no familiarity with the concept that NASA and other organizations capture EO—much less the potential benefits EO data could bring to their decision-making. To meet the needs of these users, Benchmark Site landing pages must use simple, easy-to-understand language (i.e., no technical terms or jargon) and graphics in order to ensure that visitors with no understanding of EO data and their uses can begin to learn. In the words of EO service developers in 2019,[1] the benefit of these Benchmark Sites could be large:
    - "Making the hard-core science more approachable for public consumption and use in improving public's quality of life is key to future success of programs."
      Commodity and Risk Management Executive, Ingredient Company
    - "If I was to ask 1,000 farmers what NASA was doing for them, I'd get 1,000 befuddled looks and head shakes."
      Former EO Technology Lead, Agricultural Platform Company
    - "Even just an increase in the level of awareness about the potential of SAR [synthetic aperture radar] data would be beneficial for the market and the applications."
      Executive, SAR-Based Service Provider
    - "If innovative farmers hear about satellites before we arrive [to sell services], that's really helpful … ESA is doing really well evangelizing satellite data. People know about Copernicus [in the EU]. But radar data is still a high unknown."
      Executive, SAR-Based Service Provider
    - "It would be great to have a live map of somewhere, like Yellowstone, where we could show clients live monitoring with SAR data and other data. To make it real for them. The NISAR [NASA-ISRO SAR] page shows a picture of a volcano that's not actually NISAR data; when it launches, we need collateral showing real, live data."
      Technical Lead, Mining Industry–Focused EO Value-Added Service Provider

This feedback indicates that there will be at least two types of archetypical visitors to Benchmark Sites in the future: (1) community of practice members with high understanding of EO data products (e.g., a company's business development lead will open the site while on a call with a prospective client to show them the vast array of EO data products they have been under-utilizing), and (2) community of potential members with low understanding of EO data products. Benchmark Sites can serve the important, distinct needs of both archetypical visitors by the following:

- **Community of practice members:** As USGEO succeeds in decoupling data ownership per Initiative D of the Plan, include decoupled data on the back end of Benchmark Site pages. This will make it easier to find and review exhaustively. Private-sector organizations have long sought a single site through which they can explore all data products available from the U.S. government. Even these expert users of EO data believe there could be data opportunities they are missing. In the words of an operations lead at a hydroelectric power company RTI engaged in 2019, "[s]ometimes there may be data available that we are not aware of, or we don't know where to get it."[1]

- **Community of potential members:** To meet the needs of the latter group, Benchmark Sites must contain approachable language, graphics, demonstrations, and next steps. A question-and-answer feature to enable interactive learning through an artificial intelligence agent or expert staff member can also help this user group (or potentially both user groups) learn about and determine what to do next with regard to EO data.

- **Additional opportunity in 2.1— For Benchmark Sites, include non-satellite observations (from national and other U.S. government entities) and satellite observations from foreign governments and the private sector (as well as U.S. government satellite data).** There are many types and sources of observations that are critical to enabling applications of EO data, for example:
  - Observations from European Space Agency (ESA) Sentinel-1, Japan Aerospace Exploration Agency (JAXA) Advanced Land Observing Satellite-2 (ALOS-2) and commercial SAR data providers can complement future NISAR observations to achieve higher temporal frequency SAR data monitoring.
  - USGS streamgage data and National Oceanic and Atmospheric Administration airborne snow water equivalent can help constrain hydrologic modeling.
  - Aerosol sensor captures from commercial airlines can increase the accuracy of weather forecasts.
  - Ground-truth data related to soil composition and historical maize yield can be used by state-level extension services to help enable agronomic applications for local farmers.

  Showcasing the role of diverse data products as part of Benchmark Sites can help increase future site visitors' use of these data.

- **Additional opportunity in Objectives 2.1 and 2.3—Engage private-sector companies developing risk models for insurance purposes; insurance is a key mechanism of "risk transfer" that can help enable adaptation in areas facing increasing climate risk.** The Plan as drafted names important initiatives of the U.S. government that will benefit from sustained and improved observations to better establish baselines and monitor changes in landscapes, and it already includes a plan to engage firefighting community stakeholders. In line with the Plan's overall aim to partner with the private sector, USGEO could consider including private-sector engagement in the hazard risk analysis community (e.g., value-added service providers focused on the insurance industry, insurance

companies themselves), so activities like the Benchmark Sites partnership and provision of modern tools for informed decision support for fire management can be made with their capabilities and needs in mind. In a 2021 study, RTI outlined current needs and priorities of this community of practice (with a focus on SAR data but also covering other data sources), including with respect to fire management (see pages 15–24 of the cited report).[1] At that time, the community's priorities included addressing two pain points: (1) lack of an accessible digital elevation model with spatial resolution finer than 30 meters is reducing the utility of high-resolution data products, and (2) the temporal resolution of national land cover products (i.e., 5-year updates) makes fire and flood risk assessment and thus insurance provision challenging, and a 1-year update cycle could solve this challenge. Re-engaging the community could give insight to USGEO and ensure the climate risk transfer mechanism of insurance is well enabled by EO data.

Goal 3: Improving Human Health and Safety

The connections among EO data, human health, and environmental health will continue to grow. To improve health outcomes through expanded and new uses of EO data, USGEO plans to reduce disparities in access to public health information, reduce exposure to environmental risks and hazards, and better characterize impacts on human health. In pursuit of these objectives, consider the following:

- **Potential barrier in Objective 3.2—There is tension between open-source climate/environmental data and protected, anonymized human health data. Health data sources must be modernized and harmonized to be maximally valuable for informing EO-enhanced public health decisions.** Although EO data products related to climate and the environment tend to be open source and readily accessible, health data (for valid historical reasons such as patient privacy) are protected and anonymized. It is crucial to recognize the historical importance of safeguarding patient privacy and uphold the principles that led to the protection of health data. However, the value of EO data will be limited by aggregated, spatially coarse health information—constraining EO data's impact on public health outcomes. To overcome this challenge, USGEO must address this tension and find ways to increase the utility of health data for use alongside EO data—while still respecting patient privacy.

- **Additional opportunity in Objectives 3.1 and 3.2—While working to increase spatial density of ground-based measurements and networks, leverage lessons learned from previous citizen science campaigns working toward this aim.** Many federal agencies and local governments have undertaken versions of citizen science campaigns as part of enabling more reliable satellite EO-inclusive data products and services; many private-sector non-governmental organizations and charitable/philanthropic entities also engage citizen scientists alongside their own researchers to track environmental and climate-related data. For example, RTI worked with NASA and various other partners to deploy low-cost air quality monitors at a ground level. The data from these monitors could be used to provide additional information to improve satellite-driven data products.[5] Many other examples exist—including measuring snow cover in the Pacific Northwest, recording birdsongs on smartphones to track species diversity, mapping floating kelp forests, and measuring ground temperatures at different locations across larger cities during heat waves. Lessons learned from agencies and many different private-sector organizations and partners driving these efforts will provide valuable insights about how such ground-based measurement collections might best be leveraged.

- **Additional opportunity in Objective 3.1—USGEO could facilitate agency-level scouting for ground-truth data collection assets (e.g., new sensor architectures) within agency Technology Transfer**

Offices. These assets could represent opportunities to advance ground-truth data collection. Many federal agencies, through intramural research, may have intellectual property that is not yet fully developed but could help solve challenges related to the density of repeatable and accessible *in situ* observations. For example, NASA researchers have developed lightweight kite-borne instrument packages that could aid in ground-truth data collection during tropical storms. In some cases, these technologies may not have had enough agency-level funding to be fully developed. Identifying opportunities to further fund or partner around scaling new ground-truth data collection assets could result in increased density of future observations.

- **Additional opportunity in Objectives 3.2, 3.3, and 3.4—While working on aims at the intersection of EO data and health, consider how USGEO might engage or partner with companies working in this domain today.** USGEO rightly notes in the Plan that the U.S. government will work with the broader EOE in improving integration of EO and public health data, as well as enhance ground-based networks. In working with organizations from across the EOE, USGEO and its partners can ensure feedback is gathered from across the EO value chain in order to paint a full picture of community needs and priorities related to health. RTI and NASA have previously collaborated to examine the EO needs and priorities of researchers, health care providers, patients, and various private-sector actors with respect to health and short-term air quality monitoring. With respect to air quality focus areas within Objectives 3.2, 3.3, and 3.4, RTI recommends that USGEO and relevant partners review these findings; a summary of the findings can be reviewed here on pages 79–91 of the cited report.[6] For other focus areas beyond air quality, similar engagement across the EO value chain will provide a full picture of community priorities.

Enterprise Initiatives A (Sustained Observing and Monitoring System Capacity) and B (Equitable Access and Ethical Use of Earth Observation Data)

These initiatives seek to review existing data asset processing, storage, and dissemination practices to equitably increase societal benefits from EO data. In pursuing these initiatives, USGEO will have to address the tensions among increasing costs of data management, data streamlining opportunities, and equity. Cost reduction efforts and "doing nothing" to change the status quo could negatively impact different stakeholders. This tension must be addressed directly through engagement across the EO value chain. In pursuit of these initiatives, consider the following:

- **Potential roadblock in Initiatives A and B—It will be important to consider unintended consequences related to reliability (e.g., disruption of data access for communities of practice) and equity before data are decoupled from their current agency homes.** Although the Data Asset Review activity makes note of a plan to seek external input (i.e., input beyond the U.S. government), the importance of this step cannot be overstated. It is good to understand how departments and agencies might harmonize processing, storage, and dissemination of data products. However, commercial organizations that download and further process government data products are key to reaching the maximum number of end users and impacts for EO data. Their point of view must be integrated deeply into any decisions made, especially with regard to reliability and their desired data products:

    - Reliability of data access is a key priority and has historically limited the scale of EO data use in the private sector. Before making any decisions to streamline EO data within the U.S. government, fully explore unintended consequences related to disruptions in data access. For example, commercial providers of deforestation monitoring services (e.g., startups providing this service to

sustainable sourcing leads in large consumer packaged goods companies) have previously experienced monitoring service failures when a file naming convention was changed in a NASA data catalog.[1] As they explained in 2019, this caused all downstream processors of that NASA data set (i.e., all service providers in the industry) to be negatively impacted—degrading the trust they had worked to build with their customer base. Loss of trust from the end users is hard to recover, so it is important to ensure that similar impacts are avoided in the future.

- Desired data products can be non-intuitive. Commercial organizations (e.g., startups, agricultural input companies) running businesses powered by EO data often work globally, and they source observations from a variety of sources. They source from the U.S. government, but they also source from ESA and JAXA and from commercial constellations. As a result, to streamline their internal operations, they aim to source data products in the format available from all providers. Doing so streamlines their internal processing. For example, with respect to SAR data, most commercial organizations work from Single Look Complex (SLC) files today.[1] They spend significant time and internal resources correcting (radiometrically and for elevation) Sentinel-1 SLC files to enable their global use cases, and they do want to work together with the U.S. government to achieve more modern data formats and access methods. However, the U.S. government alone cannot solve this problem. If NISAR data products are available in higher-level products, but data products from ESA, JAXA, and commercial providers are not, the NISAR products may not be used (or companies will opt to download NISAR SLC products). The large scope of the EOE globally is important here. USGEO should aim to work to further global leadership and push toward harmonized approaches to providing higher-level products (solving challenges related to parallel processing, data storage and download costs, and more), but avoid focusing on only U.S. government actors' needs. Also, USGEO should aim to avoid a situation wherein low-level data products are not offered for download in the meantime.

- **Potential roadblock in Initiatives A and B—Existing challenges hindering democratization of data access and use must be addressed directly to expand equitable access to EO data benefits.** Methods to access EO data have expanded in recent years to include private firms that have closed the gap between data and processing. These platforms include Google Earth Engine and Microsoft Planetary Computer. With these solutions, the user can access and analyze data on a single platform without having to download large volumes of data to a local computer. However, these two platforms have taken different approaches to data access and processing, including application programming interfaces (APIs) that are not compatible. Additionally, the end users are typically limited in the amount of data they can access and process at a time, reducing the ability to scale analysis.

  Although we recognize that data processing on remote servers and cloud platforms is not free, these existing systems are somewhat limited in their offerings to access and process spatiotemporal data without paying. Users interested in data search, discovery, and access have limited tools outside the traditional means of downloading data from websites (e.g., https://earthexplorer.usgs.gov/) that are not easy to integrate into data processing workflows and pipelines. Through these existing data access methods, a user is required to download entire scenes of data even if their study area is a relatively small geographic portion of the scene. Solutions like SpatioTemporal Asset Catalogs (STAC) (https://stacspec.org/en/) are a step in the right direction to democratize data access. These types of tools can be used to search, discover, and access data directly, without having to go through graphical user interfaces and websites. They also leverage modern file formats, such as cloud-optimized TIFFs, allowing a user to download only the parts of a scene they need, significantly reducing the volume of data that must be downloaded or transferred. However, the end points for

data access are currently paywalled. These end points are typically mirrored collections of government data that a private company has hosted on commercial cloud platforms.

If open-source tools like STAC can be linked directly to government resources and not to third parties that provide paid access to the same assets, this could significantly improve access to data for all end users. The government could, therefore, look to adopt these modern technologies by hosting data access themselves and by providing front-facing APIs for data search, discovery, and download, leveraging open-source technologies like cloud-optimized TIFFs and standard APIs. Open-source solutions for data processing and analysis are essential to democratize data access. However, many open-source solutions are developed and maintained by volunteers, academics, and industry partners with the means and time to develop these tools. Several organizations that try to support and integrate ecosystems of software (such as Pangeo—https://pangeo.io/index.html) are partly funded by the government. Expansion of funding for these open-source solutions would further increase the democratization of data access, processing, and analysis for all end users—particularly those groups and organizations that lack funding to afford large commercial software suites to perform advanced data analysis.

RTI engagement with agricultural field analysis and water utility–focused EO data processors in 2019 surfaced broad private-sector feedback about these challenges:

- Agricultural field analysis community feedback was synthesized as follows: "[r]egarding data access and preprocessing, multiple agrochemical firms noted that significant internal time and resources are spent downloading unneeded data (e.g., 100- x 100-km scenes when only 10 x10 km are of interest) and correcting Sentinel-1 for elevation. They would be interested in NASA providing (1) cloud-based cropping tools, (2) geometrically corrected data products, and (3) simple cloud-to-cloud transfers (e.g., for thousands of files). These tools and improved data products would simplify their workflows. They explained that they would highlight value-cleaned, SpatioTemporal Asset Catalog (STAC)-compliant SAR analogs to those optical products available in a cloud environment. They also noted that SAR data are not easily combined with established optical imaging archives and that this technical challenge could be a barrier to SAR adoption."[1]

- When asked how they would like change to unfold, two companies in the agricultural field analysis community noted the need for collaboration across the EOE in addressing this issue. One said, "[t]o achieve more modern data formats and easier access to ready-to-use products for ag-specific applications—that requires partnership with industry and NASA … we need to go beyond the 'logo sharing' of past engagement programs to something more meaningful, with specific targets to make real progress."[1] Another company added this topic: "[w]orking groups on data standards/ documentation are also good; they can help connecting private company needs [with] public."[1]

- In the water utility management community, interferometric synthetic aperture radar (InSAR) analysis can be used to monitor groundwater withdrawals, a use case the company actively works to address with various *in situ* and satellite data products today.[1] However, InSAR is not widespread in this community. Surprisingly, it is not due to a lack of expertise; it is due to the cost of InSAR software. In the words of one hydrogeologist who works in support of local water utilities as a consultant, "[w]e see an open-source software gap in the use of SAR data. If we want to do InSAR processing in-house, the available commercial software is super expensive."[1] Higher-level data products from government suppliers or solutions that reduce cost barriers for InSAR processing software could meet these users' needs.

Enterprise Initiative C: Increased Diversity and Expanded Stakeholder Engagement

In efforts to strengthen engagement with local and tribal communities, USGEO can borrow from practices and lessons demonstrated by USGEO stakeholders to date and mainstream them across other agency and USGEO direct activities. For example, consider the following:

- **Potential roadblock in Initiative C—If user-centered design methods do not drive stakeholder engagement, the impact of EO data in communities of potential will persist. This will be due to unidentified or unaddressed gaps in suitability, usability, and awareness of EO products.** User-centered design methods are a critical component of any effective program designed to increase EO user diversity and enhanced engagement. It is critical that user-centered design is properly used to drive engagement and evaluation processes.

  Communities of potential for EO data have historically received fewer benefits from existing EO knowledge products. This is driven by three realities: (1) there is low awareness of the data products, (2) the data products (due to the attributes of the underlying data or the level of analysis) are not suitable for informing decisions, or (3) although the user is aware of the products and they are suitable for decision-making, the user is not able to use them (e.g., due to lack of technical knowledge or time or budget constraints).

  These realities combine to prevent these communities from having equitable and inclusive access and utilization of EO products. To work toward closing these gaps, the EOE must first understand them through user-centered research. Past approaches to equity and inclusivity can help guide this work:

  - NASA, in collaboration with RTI, worked to better understand the barriers Black farmers in North Carolina face. RTI worked with various community organizations to understand the nature of the unique challenges, including centuries of institutionalized racial and environmental injustices, facing this community.[7] Partners then worked to identify barriers preventing Black farmers from accessing and understanding the earth science information NASA has created for the agriculture industry. The final project findings are accessible here.[8]
  - To inform a future design of gravimetric water observations, NASA partnered with RTI to leverage user-centered design principles to understand hydrologists' needs. As part of engaging the hydrology community, RTI engaged Tribal hydrologists to understand the nature of their needs. As one hydrologist explained in 2019, they have many needs similar to those of other water resource managers, but they have an additional layer of need because they do not have access to the same historical data as local governments do and have generally been widely underserved in terms of hydrology, snow cover, and surface water studies.[9] Historically, data on the order of 30 years are required in many hydrology applications to reliably understand drought patterns, but there have been many data discrepancies in relevant collections over decades; as a result, proper drought monitoring remains a work in progress.

  Note that it will be important for research teams undertaking this work to be skilled in user-centered design methods or have access to partners who are for the research teams to be diverse themselves and for the teams to center equity in their approach to understanding user needs.[10]

- **Additional opportunity in Initiative C—To support agency-level best practices for driving more equitable use of EO data, USGEO might conduct a stocktaking of agency-level lessons learned and mainstream them across other agencies.** To drive equitable access to EO data, there must be capacity building in targeted, non-research, and underserved communities. USGEO's partnering agencies have been learning how to do this well already, and USGEO could collect and mainstream lessons learned across agencies. For example, NASA has established specific capacity-building programs to address diverse and global communities that can serve as best practice programs to learn from. In partnership with USAID, the SERVIR program "is a joint development initiative between NASA and the U.S. Agency for International Development (USAID) (which) provides local decision-makers with the tools, training and services they need to act on climate-sensitive issues like disasters, agricultural security, water management and land use."[11] The Applied Remote Sensing Training (ARSET) program seeks to train global and local groups and non-traditional/non-research users of EO data to ensure they have the skills necessary to access and adopt EO data use and products. NASA also has specific Indigenous Peoples Initiatives.[12] All of these efforts could serve as the basis for proven models other USGEO agencies can use or to expand interagency EO use capacity-building efforts.

Enterprise Initiative D: Domestic and International Partner Collaboration

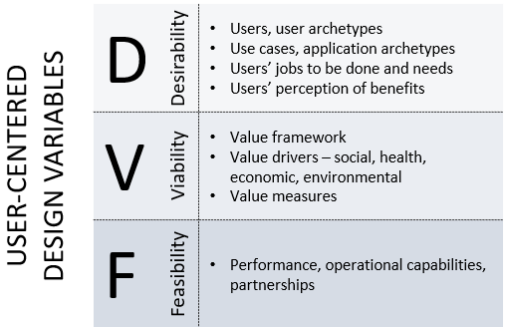
As part of work to decouple data ownership, the aforementioned notes related to Initiatives A and B also apply.

Enterprise Initiative F: Continuous Assessment of Earth Observation Systems

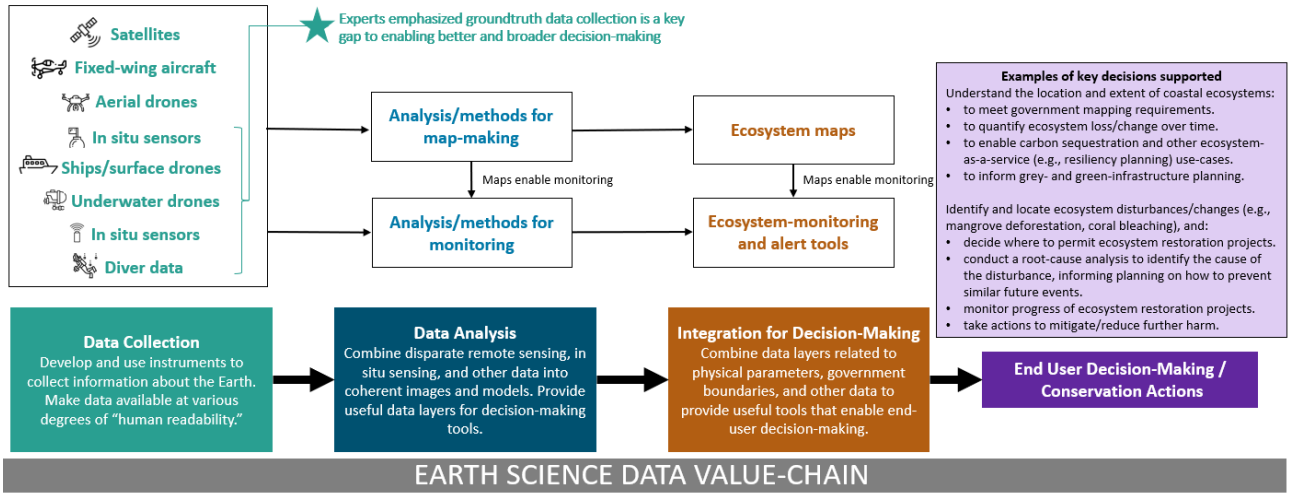
The continuous work of assessing and developing integrated accounts of users across these thematic benefit areas is necessary to drive future increases in societal value generated by the EOE. Many resources can inform and shape the design, execution, and continuous improvement of the assessment process. Some of these resources include the following:

- **Potential roadblock in Initiative F—To ensure that the most critical observing system gaps are identified, use user-centered design to drive community engagement during assessments.** Leverage the EO value chain referenced previously in this report—along with user-centered design—to drive engagement with communities as part of these assessments. A key variable in applying user-centered design is a use case. Framing benefits of EO data around use cases (i.e., decisions that a specific user makes based on specific information) is an important best practice for building up to EO data value estimates and for identifying the most critical unaddressed needs in a thematic area.

User-Centered Design Framework



An example of use case–level analysis of EO data is shown as follows. As in this example, use case–level analysis in assessments conducted per Initiative F must be very specific to subsets of the thematic areas. The following figure is from a study RTI conducted in support of a philanthropic partner's effort to improve decision-making enabled by coastal ecosystem mapping and monitoring products. Being clear about how specific data sources combine, the higher-level products they support, and how those products are used to inform decisions made by people was important to guide interviews with users and help them articulate their challenges and opportunities. In this example, feedback gathered across a variety of use cases pointed back to a common problem: low trust from conservation decision-makers in the map products produced due to the lack of good, recent, ground-truth data in the region where the decision-maker is located. This finding helped prioritize an increased focus on *in situ* data collections to improve user confidence (and thus improve the value of the satellite-based observations of seagrass ecosystems).



- **Additional opportunity in Initiative F—Create and apply a repeatable structure to the annual assessments to better characterize (quantitatively and qualitatively) the benefits in target thematic areas and to enable consistent cross-comparisons among these thematic areas.** For example, when RTI developed detailed analyses of user needs for non-traditional user communities in support of NASA, multiple parallel studies leveraged shared frameworks. These comparative frameworks allowed for different levels of synthesis and were used to consistently inform different types of analyses. For example, a common framework was used to capture EO data technical needs and current practices in a given community (e.g., the agricultural field analysis community). The communities' needs and priorities related to spatial resolution, temporal resolution, spectral bands, polarizations, latency, coverage area, data formats, and other priorities—informed by many interviews and virtual working groups—were all captured in a three-page synthesis (see pages 38–40 of this report).[1] These data could be further synthesized into frameworks that compared SAR needs across communities, like the one shown as follows (note that the following table was made specifically to inform a NASA planning activity).

Table Legend

Valued Data Attributes	**Valued in Most Community Use Cases** Ranges are (best-case attributed; preferred)—(worst-case attribute where data still valued)
Data Attribute Priorities	Highest Priority Expressed by Community Engaged in RTI Study
	High Priority Expressed by Community Engaged in RTI Study
	Valued But Not a High Priority Expressed by Community Engaged in RTI Study

User Community	**Valued Data Attributes and Priorities**							
	Spatial res.	Temporal res.	Spectral band	Polarization	Latency	Coverage area	Continuity	Other
Property Geohazard Risk Analysis	**10 m** <3–30 m	**7-day** Daily-monthly	**L-band** but others valued	**Dual-pol** single-quad	**Daily to weekly** Low priority	**Global** especially valued outside U.S.	**Long (15–30) year time series desired** though data useful before this point	Higher temporal res. land cover maps
Sustainable Forestry	**10 m** 10–30 m	**7-day** 2–10 days	**L-band** but C-band similar in value	**Dual-pol** dual-quad	**Daily** 1–3 days	**Global**	**PoR-like** in collection and swath	**Better user experience**; SAR-optical fusion tools or products
Agricultural Field Analysis	**10 m** 3–20 m	**7-day** 2–10 days	**Multiband**	**Dual-pol** dual-quad	**Daily** <24 hr–3 days	**Global**	**PoR-like** in collection and swath	**Better user experience**
Oil & Gas Infrastructure Management	**5–10 m** 3–10 m	**7-day** Hourly-weekly	**Multiband** But L-band unique value	**Single pol** Single-quad	**Daily** 2–3 to 36 hr	**Global**	**Long (5–10+) time series desired** for historical analyses	Dual-look geometries and **better user experience**
Mineral Exploration and Extraction	**10 m** 1–30 m	**7-day** Daily-monthly	**Multi-band** but L-band unique value	**Single/multi** Single-quad	**Daily** for safety critical use cases	**Global** to support exploration workflows	**Long time series helpful** for historical analyses	**Better user experience**, dual-look geometries, higher temporal res. DEMs
Water Utility Management	**Variable** 10–100 m	**Daily-Monthly** Daily-annual	**Multi-band** but L-band unique value	**Quad pol** Dual-quad	**Daily** <24 hr–3 day	**Watershed-Regional**	**Long time series helpful** for historical analyses	Lower cost InSAR processing
Power Generation and Distribution	**Variable** 10–100 m	**Daily-Monthly** Daily-annual	Nonspecific	**Dual pol**	**Daily** <24 hr–3 day	**Regional-National**	**Long time series helpful** for historical analyses	Easier path to understand available NASA products

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