ASSESSMENT OF THE EARLY ADOPTERS PROGRAMS

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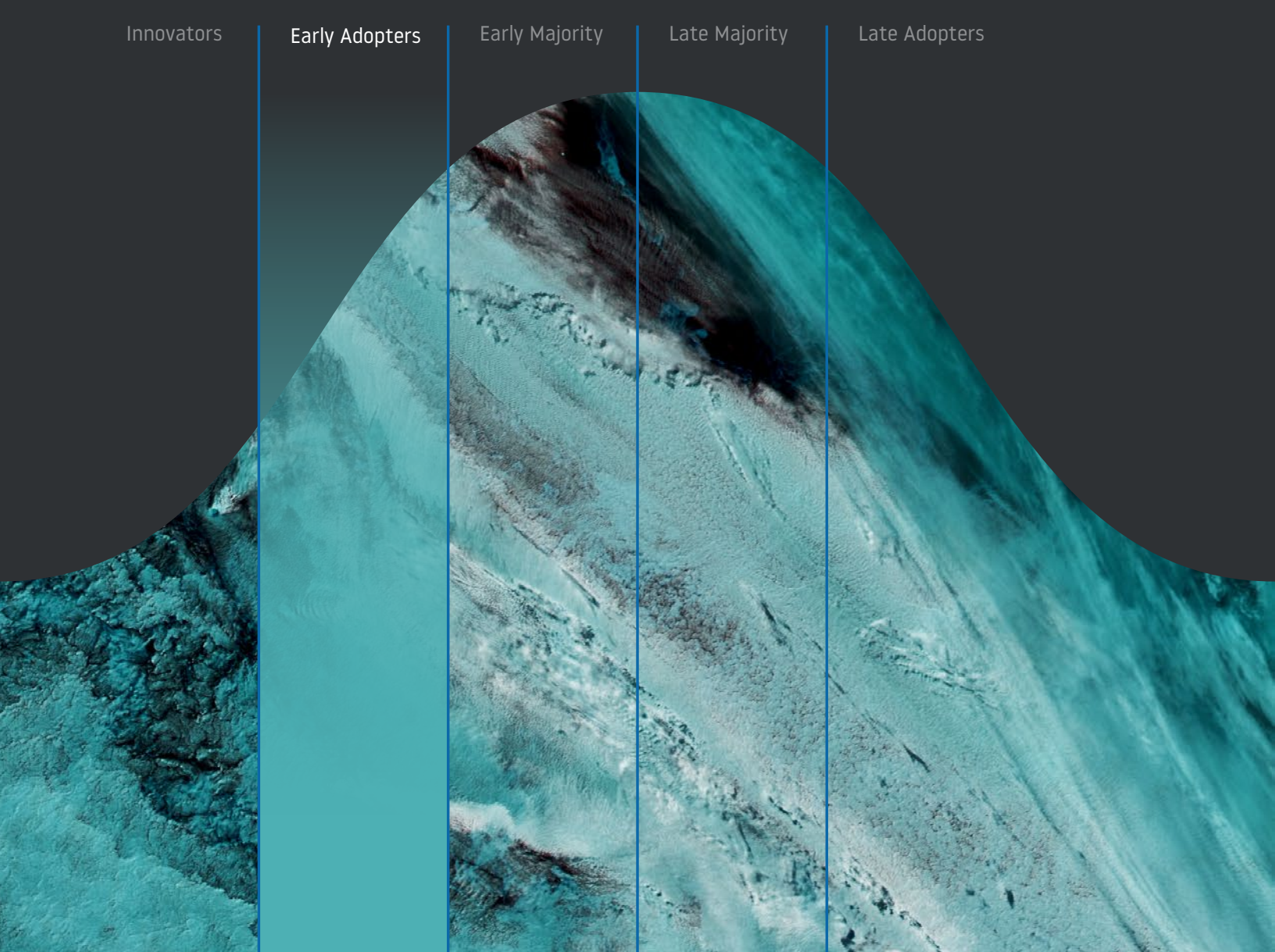
EARTH SCIENCE
APPLIED SCIENCES



EXECUTIVE SUMMARY

- Officials at the city of Los Angeles use land surface temperature and urban heat analysis information from ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) to determine mitigation strategies for urban heat and heat stress[1]
- Analysts using the Crop Explorer from the U.S. Department of Agriculture' Foreign Agricultural Service access products that have been improved by the incorporation of data from the Soil Moisture Active Passive (SMAP) mission[2]
- Researchers at the Naval Research Center get ready to use Ice, Cloud and land Elevation Satellite-2 (ICESAT-2) data to validate the U.S. Navy's operational ice forecasts[3]

These are just a few examples of actions that are routinely made using Earth observations from data collected from satellites, airborne sensors, or in situ measurements. The NASA Earth Science Division's Early Adopters Programs seek to accelerate the ingestion and use of NASA data by decision makers. Early Adopters Programs provide potential users with proxy[4] data products before a launch, train them to use these products, and foster interactions between the Early Adopters and Science Team members to enhance algorithms and data products for wider utility.

In our assessment of the 11 Early Adopters Programs implemented over the past decade, we identify a number of successes and challenges.

SUCCESSES

- Early Adopters Programs have successfully taught users how to use NASA data products for their applications.
- Some NASA Flight and Science Teams have learned how their data are used in applications.
- Feedback from Early Adopters has informed and led to NASA actions which then enabled new applications.
- Early Adopters Programs have engaged new stakeholders and developed novel applications with the NASA data.

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1 "ECOSTRESS used in urban heat mitigation decision support." https://ecostress.jpl.nasa.gov/news/ecostress-used-in-urban-heat-mitigation-decision-support (accessed 15 January 2021).

2 "NASA Soil Moisture Data Improve Global Crop Forecasts." https://smap.jpl.nasa.gov/news/1266/nasa-soil-moisture-data-advance-global-crop-forecasts/ (accessed 15 January 2021).

3 "Early Adopters." https://icesat-2.gsfc.nasa.gov/early_adopters/early-adopters-12 (accessed 15 January 2021).

4 Proxy data are data that have similar characteristics to the data anticipated from a new satellite or instrument. The data may be simulated, come from a similar instrument such as one mounted on an uncrewed aerial vehicle, or may be early or "beta" data that have not yet been finalized.

CHALLENGES

- Early Adopters Programs have struggled to sustain engagement between the Early Adopters and the NASA Science Team members, indicating lack of clarity in the value proposition of the engagement for each side.
- An absence of direct funding for Early Adopters Programs has limited the participation of some Early Adopters
- Insufficient resources for the management of the Early Adopters Programs has limited NASA's matchmaking capability to connect decision makers and scientists.
- Originally, the intent of Early Adopters Programs was to accelerate the use of NASA data by decision makers; however, a majority of the Early Adopters are academic researchers, many of whom are not supporting a specific non-academic end user or decision maker.

Based on these findings, we make the following five key recommendations to the Applied Science Division and the Earth Science Division for future Early Adopters Programs. Implementing these recommendations will improve the efficiency, return on investment, and consistency of Early Adopters Programs and align them better with the goals of the Earth Science Division.

A. Focus and Standardize Early Adopters Programs.

A1. Focus Early Adopter Programs on accelerating the use of Earth observations in decision-making contexts.

A2. Require Early Adopters Programs follow the criteria described in the Directive on Project Applications Program.[5]

A3. Develop a guidebook for how to set up and implement an Early Adopters Program.

A4. Provide opportunities to obtain feedback and to review the individual Early Adopter Programs and the set of programs as a whole.

B. Enhance Support for Early Adopters Programs.

B1. Assign a Missions and Applications Program Manager to coordinate the implementation of Project Applications Plans and Early Adopters Programs.

B2. Increase support for Early Adopter Coordinators to at least 0.5 work-year equivalent (WYE) for the duration of the Early Adopters Program.

B3. Dedicate appropriate funding to Early Adopters Programs.

C. Articulate the Value Proposition of Early Adopters Programs

C1. Conduct research to identify potential Early Adopters with high-value applications prior to the start of an Early Adopters Program.

C2. Conduct market research to determine whether the term "Early Adopters" is understandable and appealing to communities of practice and communities of potential.

D. Better Integrate Early Adopters Programs into Missions

D1. Allow Early Adopters Programs to begin in Phases B, C, or D of the life cycle for flight projects, as defined in NASA Procedural Requirement (NPR) 7120.5.

D2. Identify and select dedicated multiple Science Team members who will champion and partner with the Early Adopters Program for a mission.

D3. Create a multi-mission alumni program to enable Early Adopters to continue engaging with NASA and other former Early Adopters following mission launch.

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5 Directive on Project Applications Program." https://smd-prod.s3.amazonaws.com/science-red/s3fs-public/atoms/files/ESD%20Missions-Applications%20directive.pdf. (accessed 4 March 2021).

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PREFACE

NASA's Earth Science Division (ESD) delivers the technology, expertise, and global Earth observations to map the myriad connections between our planet's vital processes and the effects of ongoing natural and human-caused changes. ESD provides Earth science data products freely and openly for anyone to use. While academic users are usually familiar with these data, non-academic users who could use the data for making decisions are not always aware of the potential of these data products or are not prepared to ingest data products from new missions and instruments. To address this issue, the Applied Sciences Program in ESD works to lower technical and institutional barriers for using Earth science datasets for decision making.

One such effort within Applied Sciences is the set of "Early Adopters Programs". Over the last decade, there have been 11 Early Adopter Programs that have sought to accelerate the ingestion and use of NASA data by decision makers by a) providing potential users with proxy data products before launch, b) training them to use the proxy data products, and c) facilitating interactions between the data users and science team members to enhance algorithms and data products for wider utility. This study is a retrospective examination of these programs. The goals of this study are to:

1. understand the different forms of Early Adopters Programs to learn what should be standardized across different flight projects, and
2. develop recommendations for more consistent, efficient, and improved Early Adopters Programs that meet the goals of NASA's ESD.

To accomplish the goals listed above, it is necessary to understand both the organizational context of the application activities for flight projects within NASA's ESD, as well as the history of the Early Adopters Programs, since both of these factors influence the trajectory that these programs have taken and the state of the programs today.

We describe the successes and failures of these programs, and based on our findings, make five key recommendations to help ensure the future success of these programs.

BACKGROUND

Origin of Early Adopters Programs

This section aims to provide a concise history of Early Adopters Programs. A more detailed description of this history is contained in Appendix A. In 2010, the Applications Working Group of the Soil Moisture Active Passive (SMAP) mission started an activity that they referred to as an Early Adopters Program "to help demonstrate the value and impact of SMAP data."[6] Early Adopters were defined as "a diverse subset from within the SMAP user community who have volunteered their own time and resources to conduct research on behalf of the mission and provide feedback on the impact of the mission data in areas of weather, drought, agriculture, health and national security."[7] The Applications Working Group provided Early Adopters with simulated SMAP data prior to launch, and held educational workshops and tutorials. This set of activities provided a forum for Early Adopters to give feedback to the SMAP Science Team that created the data products, enabling them to make those products more useful, and helped Early Adopters prepare for the actual SMAP mission data so that once it became available, they could put it to immediate use.

The SMAP Early Adopters Program demonstrated that engaging users prior to a satellite's launch, helping them work with simulated or proxy data, and pairing these users with Science Team members increased the value and impact of mission data in a wide variety of applications.

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6 Escobar, Vanessa M., et al. "Overview of the SMAP Applications and the SMAP Early Adopters program-NASA's first mission-directed outreach effort." 2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS). IEEE, 2016.

7 Ibid.

Due to the success of the SMAP Early Adopters Program, the Applied Sciences Program encouraged the application of this model to additional NASA Earth Science flight projects involving satellite missions or individual instruments.

In the mid-2010s, the Applied Sciences Program sought a way to institutionalize the role of applications in flight projects. In 2017, NASA's Earth Science Division issued the Directive on Project Applications Program, which established guidelines for implementing a Project Applications Plan for ESD flight projects.[8][9] This document recommends that flight projects consider including Early Adopter Program activities as part of the Project Applications Plan, and provides the following (paraphrased) guidelines:

1. Each Early Adopter should provide a research project title with the end user clearly identified and a short abstract describing the societal benefit of the project
2. Each Early Adopter should be partnered with a Science Team member who can provide guidance and information on project data product development
3. Each Early Adopter should receive access to developmental products and interact with the product developer, enabling them to understand and integrate the new products into their systems
4. Each Early Adopter should provide feedback to the Science Team member regarding data product functionality as well as potential calibration and validation information
5. Each Early Adopter should provide metrics and testimonials that explain how the use of a product will improve a policy or decision relevant to their organizational goals and objectives.

Coordination of Early Adopters Programs

Within NASA Headquarters, there are designated individuals who contribute to the programmatic oversight and/or management of a flight project: a Flight Program Executive (PE), a Program Scientist (PS), a Program Application Lead (PAL) and an Earth Science Data Systems PE. Each of these individuals is located at NASA Headquarters and communicates with the Flight Project Team, which has members located at the NASA Centers (or at a university in the cases of some Earth Venture projects).

Application activities for a given flight project are managed by the PAL, who is a civil servant within Applied Sciences. Application activities are implemented by one or more Deputy Program Application Leads (DPA) and/or Project Application Scientists (PAS), who may be civil servants or contractors at a NASA Center.[10] In addition to coordinating Early Adopters Programs, the DPA or PAS has many other applications-related responsibilities, including supporting the applications website, reporting on uses of the flight project data, engaging with the Science Team as they develop algorithms for data products, and creating and growing the user communities. In this document, both DPAs and PASs are referred to as "Early Adopter Coordinators" because the functionality of both roles is the same with respect to the Early Adopters Program.

8 "Directive on Project Applications Program." https://smd-prod.s3.amazonaws.com/science-red/s3fs-public/atoms/files/ESD%20Missions-Applications%20directive.pdf. (accessed 4 March 2021).

9 The Directive on Project Applications Program was intended to apply to directed or strategic missions, though the guidance could be tailored to apply to Principal Investigator (PI)-led missions.

10 Whether an Early Adopter Program has a Deputy Program Application Lead (DPA) or Project Applications Scientist (PAS) depends on when the flight project was initiated. Prior to the release of the Directive on Project Applications Program, a NASA policy document, the Applied Sciences Program funded DPAs to help coordinate Early Adopters Programs. The Directive on Project Applications Program established a new member of the leadership of a flight project, that of the PAS. The PAS is funded by the Flight Program.

Study Methods

The study team gathered information using: (1) guided discussions, (2) questionnaires, and (3) publicly available documents.

The study team conducted guided discussions with the following groups (a list of individuals is provided in Appendix B:

- ESD leadership: This group consisted of the Acting Director and the Acting Deputy Director of ESD, as well as the Associate Directors and other leadership members of the four elements of ESD: Applied Science, Flight, Research, and Technology.[11] Discussions with ESD leaders were focused on understanding their perceptions of the contribution of Early Adopters Programs to ESD's goals.
- PALs: This group consisted of four Applied Science Program Managers who lead application efforts for various flight projects. Discussions with PALs focused on the challenges and successes of the Early Adopters Program, and recommendations for the future.
- Early Adopters: This group consisted of three Early Adopters total for two different missions. Discussions with the Early Adopters were focused on the benefits and challenges associated with participating in the Early Adopters Program.
- Those with a lengthy history of involvement: This group consisted of two of the individuals who started the Early Adopters Program. The discussions focused on the original vision and intent of the program, and recommendations for the future.
- Early Adopter Coordinators: This group consisted of DPAs and PASs who lead Early Adopters Programs or similar application-related efforts for three different missions. These discussions focused on determining which activities were most successful, and what was needed to develop an applications community for their respective flight projects.

The majority of input from Early Adopter Coordinators is derived from questionnaire responses, though a small subset of Early Adopter Coordinators (DPAs or PASs) participated in guided discussions either in addition to or instead of responding to a questionnaire. The study team developed questionnaires using Google Forms and sent out one questionnaire to each flight project's Early Adopter Coordinators.[12] Questions focused on the specific activities conducted as part of the Early Adopters Program, as well the program's outcomes, what has been successful or challenging, and recommendations for the future. For flight projects that have launched, the questionnaires also included a question about whether or not the progress of Early Adopters is being followed or will be followed.

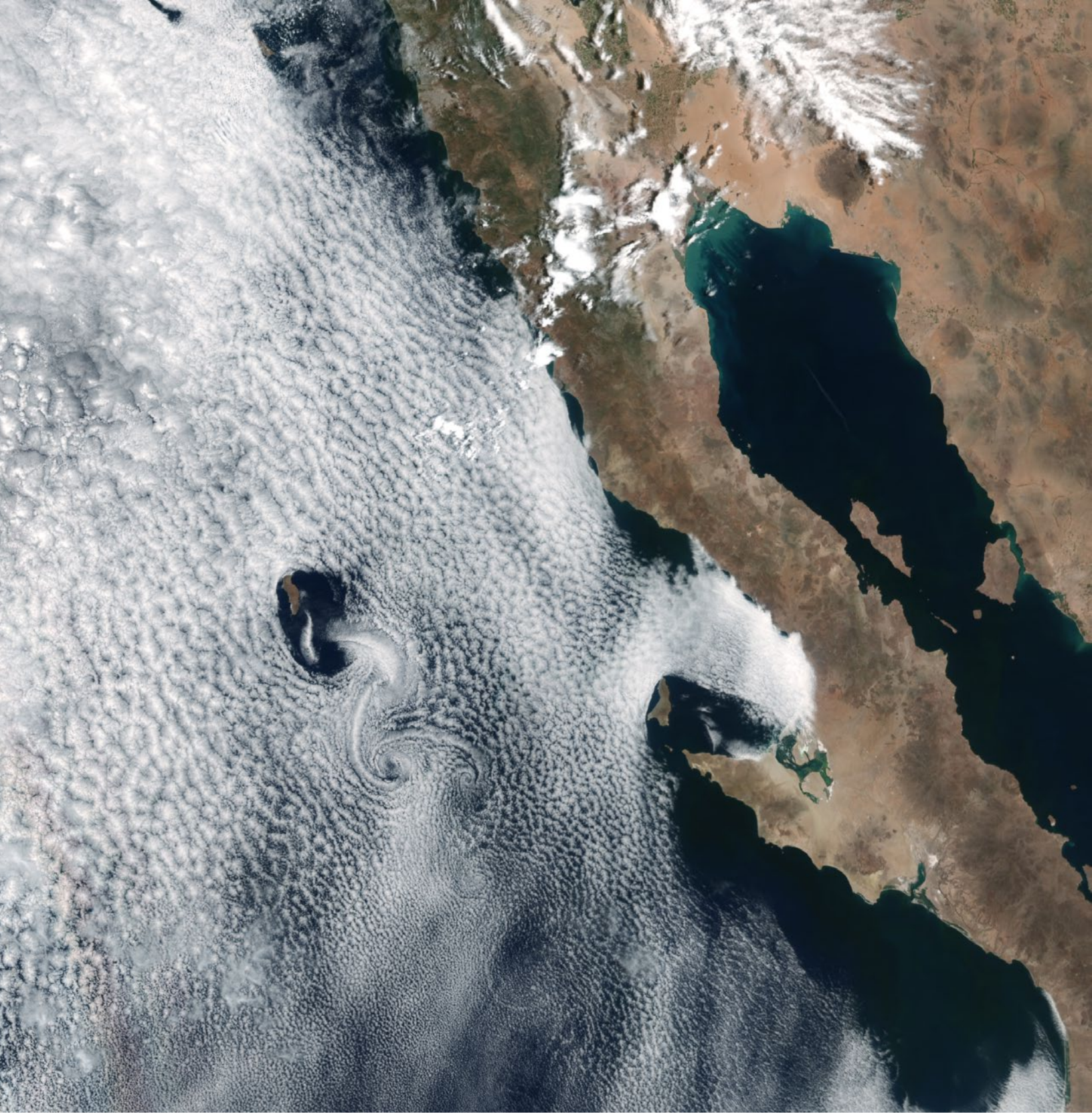
The study team received responses to the questionnaire from most Early Adopters Programs. The exceptions were: ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS), whose coordinator opted to discuss the program verbally instead, and SMAP (the study team filled out the SMAP questionnaire using information from publications and other publicly available documents).

The study team also examined other published materials about the Early Adopters Program, including Early Adopter websites, NASA's Directive on Project Applications Program, and white papers from different flight projects' applications efforts.

The information in this study is derived from analysis of the discussions, questionnaires, and publicly available documents.

11 The study team was unable to interview the Associate Director of Flight. However, the study team did interview the Program Executive for Earth Science Data Systems, which is within the ESD Flight element.

12 In the case of SMAP, the study team filled out a questionnaire using publicly available information about SMAP: Moran, M. Susan, et al. "Connecting NASA science and engineering with earth science applications." Journal of Hydrometeorology 16.1 (2015): 473-483.



EARLY ADOPTERS PROGRAMS TODAY

EARLY ADOPTERS PROGRAMS TODAY

To date, there have been 11 flight projects with Early Adopter-like programs (see Figure 1): six directed missions (SMAP, Gravity Recovery and Climate Experiment - Follow On [GRACE-FO], ICESat-2, Surface Water and Ocean Topography [SWOT], NASA-Indian Space Research Organization [ISRO] Synthetic Aperture Radar [NISAR], Plankton, Aerosol, Cloud, ocean Ecosystem [PACE]) and five Earth Venture missions and instruments (ECOSTRESS, Orbiting Carbon Observatory-3 [OCO-3], Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of SmallSats (TROPICS), Tropospheric Emissions: Monitoring of Pollution (TEMPO), and Multi-Angle Imager for Aerosols [MAIA]). The NISAR Early Adopters Program is considered part of a larger effort—an Early Engager program.[13] There was not a GRACE-FO Early Adopters Program, but there was an applications program that included working with potential users in modeling efforts that would ultimately support decision makers.

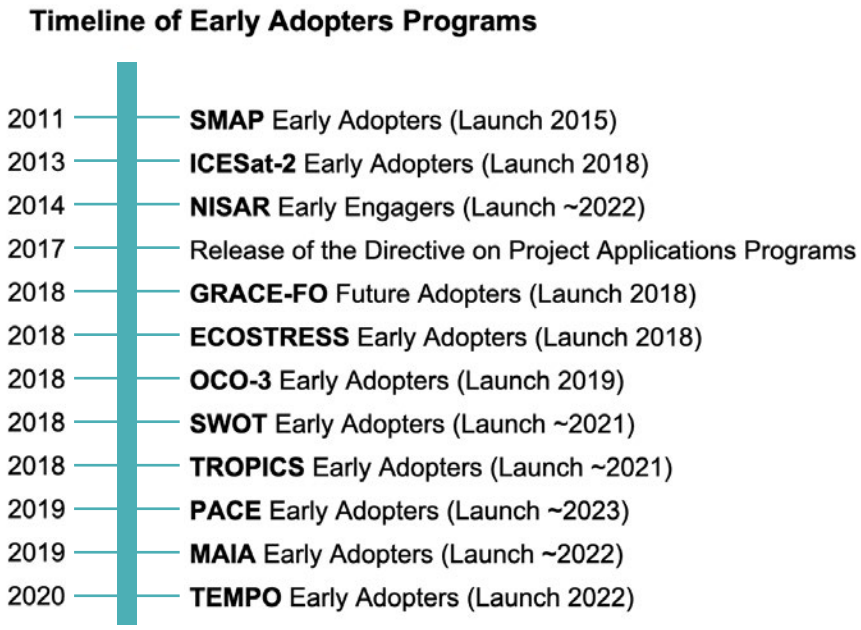


FIGURE 1
Timeline of Early Adopters Programs to date. The dates on the left show when planning for the respective Early Adopters Programs started.

Recruitment and Selection

As shown in Figure 2, NASA seeks Early Adopters both from existing communities of practice[14] [15] (those who currently use satellite data), and communities of "potential" (those who have not used satellite data but could benefit by doing so). The goal of reaching out to current and potential users is to increase the societal benefits that can accrue through the use of the data to make decisions.[16] [17]

13 The NISAR application team focused engagement primarily on the user community already engaged with the type of data NISAR will provide (synthetic aperture radar or SAR data).

14 Wenger, Etienne. "Communities of practice: A brief introduction." (2011).

15 Brown, Molly E., and Vanessa M. Escobar. "Assessment of soil moisture data requirements by the potential SMAP data user community: Review of SMAP mission user community." IEEE Journal of selected topics in applied earth observations and remote sensing 7.1 (2013): 277-283. DOI: https://doi.org/10.1109/JSTARS.2013.2261473

16 Macauley, Molly K. "The value of information: Measuring the contribution of space-derived earth science data to resource management." Space Policy 22.4 (2006): 274-282

17 Zhu, Zhe, et al. "Benefits of the free and open Landsat data policy." Remote Sensing of Environment 224 (2019): 382-385.

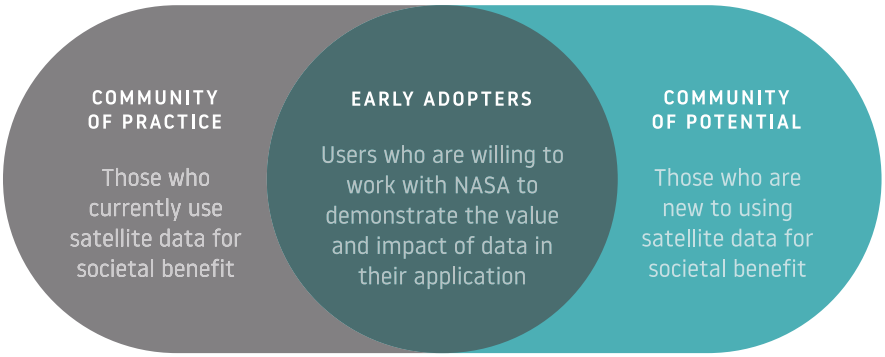


FIGURE 2
Types of communities that could be involved in Early Adopters Programs.

The recruitment process for participants in the Early Adopters Programs has been relatively consistent following the example of SMAP. Every flight project after SMAP has advertised for participants at conferences, workshops, and other community events, as well as via the mission website. Many others advertised via newsletters or other periodic emails to relevant communities. Early Adopter Coordinators also reached out to individuals with known interest and received recommendations from Science Team members.

No Early Adopters Programs have used a Federal Register Notice to advertise the program. Promotion is mostly through word of mouth, outreach to existing networks, and advertising at conferences. The recruitment activities each flight project has employed are shown in Table 1.

Flight Project	Early Adopter Coordinators advertised at conferences, workshops and other community events	Early Adopter Coordinators advertised via mission website	Early Adopter Coordinators advertised via newsletters or other periodic emails to relevant communities	Early Adopter Coordinators reached out to individuals with known interest	Early Adopter Coordinator received recommendations from Science Team members	Other ways Early Adopter Coordinators recruited participants
ECOSTRESS*	X	X	X	X	X	Issued media/press releases about the data utility and the Land Processes Distributed Active Archive Center (DAAC) released articles.
ICESat-2	X	X	X	X	X	
MAIA	X (currently)	X (will in the future)		X	X	
NISAR	X	X	X		X	Received recommendations from relevant Program Scientist and DAAC
OCO-3	X	X	X	X	X	
PACE	X	X	X	X	X	
SMAP*				X		Initial names were generated at a workshop, and subsequent rounds of names were generated through various nomination processes.
SWOT	X	X	X	X	X	Sent emails on open solicitation for Early Adopters
TEMPO	X	X	X	X		
TROPICS	X	X			X	

TABLE 1
Recruitment activities for different flight projects. Data was collected via survey except as noted below.

*Note: ECOSTRESS data was collected via discussion and SMAP data was collected via published articles. As a result, data for these two flight projects may be incomplete.

The process flight projects use to select Early Adopters range from a completely open process (anyone can become an Early Adopter), to one in which potential Early Adopters propose a project, which the flight project extensively vets to determine the extent of alignment, chance of success, diversity of application, and other criteria. The process each flight project used to select its Early Adopters is shown in Table 2.

Flight Project	Permission granted to anyone who wanted to participate	Permission granted to anyone who signed an agreement	Permission granted to anyone that met certain criteria	Additional details
ECOSTRESS*		X		Interested parties/individuals were required to complete a form on the Land Processes DAAC website, which included a project description and concurrence with a charter.
ICESat-2		X	X	Interested parties/individuals self-nominated or sent nominations to join the Early Adopters Program. Then, Early Adopter Coordinator sent them an application (developed by the team). Then, after initial review by the Early Adopter Coordinator, the team met to conduct a formal review to accept or reject the nomination.
MAIA	X (currently)	X (will in the future)		Permission is open for all now, but there will be an agreement for receiving simulated data
NISAR	X			There will be tiers of early adopters; there is an open tier and a permissive tier (that will likely include an agreement)
OCO-3	X			
PACE			X	
SMAP*		X	X	Selection criteria included: Early Adopter has a good end user connection, high chance of success, reasonable metrics, basic understanding of SMAP products; the project has maximum return on SMAP project investment, a high-impact application; collectively, the projects cover one of a diverse range topics, societal needs, product uses, and geographies. Early Adopters agreed to engage in pre-launch research to enable integration of SMAP data after launch in their application, and, depending on when they joined, to either complete the project with quantitative metrics prior to launch or provide feedback to the SMAP project upon request concerning their experience with using the data.
SWOT		X	X	The Early Adopter project had to have an overlapping goal with SWOT mission to focus on water or allied issues.
TEMPO	X			
TROPICS	X		X	Users submitted a project description that was then reviewed by the Science Team. No applications were rejected.

TABLE 2
Early Adopter selection process employed by various flight projects. Data was collected via survey except as noted below.

*Note: ECOSTRESS data was collected via discussion and SMAP data was collected via published articles. As a result, data for these two flight projects may be incomplete.

The most extensive vetting process was conducted by ICESat-2, which required that Early Adopters submit an application with a research proposal that included (1) a description of research (including data currently used and ancillary data needs), how the research results would be used by the end user, and how it would impact their decision-making process; (2) an approach to solve basic challenges in applying ICESat-2 products and/or including ICESat-2 products into routine operations; (3) foreseeable requirements for pre-launch simulated data products and plans for field experiment demonstration; and (4) a post-launch implementation strategy. The application also included responsibilities agreed upon by both the Early Adopter and the mission. The ICESat-2 Early Adopter application is shown in Appendix C.

Number and Affiliation of Early Adopters

The number of Early Adopters in a given program ranges from four (for a newly established Early Adopters Program that is currently recruiting) to over 300 (in the case of ECOSTRESS's Early Adopters Program). Three flight projects (ECOSTRESS, MAIA, and SMAP) have had more than 50 Early Adopters each. The number of Early Adopter Principal Investigators (PIs) for each flight project is shown in Table 3. It should be noted that because different Early Adopter Programs were in different phases of development (from just beginning to having ended) at the time of this study, the data below represents a snapshot in time, rather than a final count of Early Adopters per flight project.

Early Adopters usually are and have been academic researchers. When an Early Adopter project involves an academic researcher and a specific, non-academic end user, the academic researcher can be considered a boundary organization,[18] in that they function as an intermediary between two different social contexts such as Earth science and policy.

There were seven flight projects for which it is possible to analyze the approximate fraction of Early Adopters with a specific, non-academic end user involved in their projects. Three flight projects (ICESat-2, PACE, and SMAP) indicated more than 75% of their Early Adopter projects have a specific, non-academic end user involved; notably, PACE was just beginning recruitment and at the time of the study had four Early Adopter projects in total. One flight project (SWOT) indicated that 51% to 75% of its Early Adopters have a specific, non-academic end user involved in their projects. Three flight projects (OCO-3, TEMPO, TROPICS) indicated that 26% to 50% of Early Adopters have a specific, non-academic end user involved in their projects. This data is shown in Table 4.

Flight Project	Total count of Early Adopter Principal Investigators
ECOSTRESS	>300
ICESat-2	24
MAIA	130
PACE*	4
SMAP	55
SWOT	15
TEMPO	20
TROPICS	18

TABLE 3 Number of Early Adopter Principal Investigators for flight projects at the time of data collection.

*PACE was recruiting Early Adopters at the time of data collection.

18 Guston, David H. "Boundary organizations in environmental policy and science: an introduction." (2001): 399-408.

	Affiliation						
Flight Project	Federal Government	State, local, tribal, or territorial governments	International governments	Academic institutions	Non-profit, non-governmental, or intergovernmental organizations	Private sector	Fraction of Early Adopter Projects with a specific, non-academic end-user-involved partnership, or a project having ties to a specific end user outside of academia.
ICESat-2	>5	0	4	>5	0	4	Most (>75%)
MAIA	>5	>5	>5	>5	>5	>5	Not Applicable
OCO-3				>5	>5		Some (26-50%)
PACE	2	1	0	1	0	0	Most (>75%)
SMAP	>5	1	>5	>5	2	>5	Most (>75%)
SWOT	2	3	3	3	1	3	Many (51-75%)
TEMPO	>5	0	1	>5	0	1	Some (26-50%)
TROPICS	>5		4	>5		1	Some (26-50%)

TABLE 4
Affiliation of Early Adopter Principal Investigators for different flight projects, as well as the fraction of projects with a specific, non-academic end-user-involved partnership, or a project having ties to a specific end user outside of academia. Blank cells indicate lack of response rather than a value of zero.

Activities

Early Adopters Programs provide simulated or proxy data products, or in some cases early "beta" data products, to the Early Adopters.[19] NASA's Earth Science Data and Information Policy ensures that all NASA Earth science data becomes available to all users, which includes simulated or proxy data products.[20] This means that the data access that these programs provide does not specifically privilege the Early Adopters. One of the benefits of the Early Adopters Program is that Early Adopters are able to participate in activities to help them use these simulated or proxy data products so that they are prepared to ingest the "real" data products when they become available.

The three most common activities coordinated by Early Adopter programs are Applied Remote Sensing Training (ARSET) training programs, workshops focused on identifying and scoping data products and their applications, and mission-led training sessions to help Early Adopters work with data products.

Early Adopters Programs have included a diverse range of activities including sponsoring hackathons; hosting a Slack channel; publishing papers in scientific journals; publicizing the mission at both traditional scientific conference venues (such as the American Geophysical Union) and non-traditional, practitioner-focused conference venues (such as the American Water Resources Association); conducting site visits with the Early Adopters; sponsoring relevant DEVELOP projects; and holding periodic teleconferences.

19 In the case of ECOSTRESS, Early Adopters were provided with early release data products that were considered "beta products" and were not intended for science analysis. (https://ecostress.jpl.nasa.gov/downloads/ECOSTRESS_Early_Adopters_Charter_180913c.pdf)

20 "Data and Information Policy." NASA Earth Data. https://earthdata.nasa.gov/collaborate/open-data-services-and-software/data-information-policy. (accessed February 3, 2021)

In particular, ICESat-2 has undertaken some unique activities including Early Adopter round table events, an Early Adopter showcase at the mission launch, a town hall with Early Adopters, a post-launch Early Adopter program (called the Applied Users program), and Early Adopter-led tutorials.

The specific activities viewed by Early Adopter Coordinators as most successful in accomplishing the goals of the program varied. Some of the activities mentioned were: (1) workshops that include Early Adopters and Science Team members (it was noted that workshops involving formal presentations are not as useful as interactive panels or discussion-based workshops), (2) quarterly calls with the Early Adopter Coordinator and Early Adopters, and (3) assessments of Early Adopters' needs. In addition, some Early Adopter Coordinators noted that the most successful program activities were those that provided one-on-one, sustained, hands-on engagement between NASA and the Early Adopters.

Outcomes

One of the goals of Early Adopters Programs is to increase the societal value of Agency investments by accelerating the uptake and use of NASA data products.[21] The Early Adopter Programs are accomplishing this goal by helping Early Adopters to use early flight project data or proxy (i.e., simulated) data to determine whether these data would have value in their systems, applications, or the applications they are developing for a partner, and, if so, prepare to be able to ingest the "real" data when it becomes available. In addition, the Early Adopter Programs gather feedback from Early Adopters to ensure that the data products are usable in their applications.

Early Adopter Coordinators indicate that the aim of accelerating the update and use of new data products is being achieved. One Coordinator, in a questionnaire, responded that Early Adopters have indeed made significant progress in preparing for data ingest, and have identified key data integration needs. The Coordinators reported that Early Adopters also engage in discussions about data assimilation tools and techniques.

Early Adopter Coordinators reported that the Early Adopters provide useful feedback regarding the data products that would be most useful, desired data formats, compatibility requirements (for example, the data must be able to work within geospatial information system [GIS] tools), visualization needs, and download needs. NASA is using this feedback to help design tutorials and sample scripts, and to identify opportunities for collaboration with the relevant Distributed Active Archive Center (DAAC). Examples of changes that were made to data products in response to Early Adopter feedback from ICESat-2 include: ensuring a consistent step size for a land vegetation height data product; incorporating relative canopy height metrics rather than only the top canopy height in a data product; and exploring the generation and production of low-latency, along-track data products. In the case of SMAP, Early Adopter feedback resulted in a reduction in data latency from 45 days to three days. In the case of MAIA, Early Adopter feedback resulted in choosing specific target areas for data collection. In the case of NISAR, Early Engager feedback resulted in reduced product latency from 30 days to 2 days and informed map projection discussions.

In addition to meeting the original goals of the program, Early Adopter Coordinators noted other positive outcomes. The three most notable were (1) that Early Adopters who had not previously used satellite data became engaged in doing so, (2) that there has been wider recognition and use of particular data products, and (3) that the Early Adopters demonstrated potential applications to the general user community, prompting further interest in the flight project. In addition, Early Adopters often seek to become Early Adopters for other flight projects.

FACTORS THAT LEAD TO SUCCESS

A. Early Adopter Coordinator Skills

The job of an Early Adopter Coordinator requires very strong relationship-building and relationship-maintenance skills, because many of the activities rely on the ability to convince Early Adopters, Science Team members, and DAACs to perform work that they are not explicitly funded to do. A dedicated Coordinator (or a primary and a backup Coordinator, if one person does not have enough time) is necessary to establish the relationships necessary for high engagement of all relevant parties.

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21 Macauley, Molly K. "The value of information: Measuring the contribution of space-derived earth science data to resource management." Space Policy 22.4 (2006): 274-282.

B. "Grassroots" Support for Applications

"Grassroots" support for applications from international partners, the Flight Project Team and its leadership, and others is important so that it is not just the PAL and Early Adopter Coordinator advocating for and pushing applications into a mission. PALs view buy-in to the value of applications from Science Team members and others outside the Applied Science Program, such as international partners, as incredibly important to the success of the Early Adopter Programs. Early Adopter Coordinators also view buy-in from the flight project leadership as crucial to the success of Early Adopter Programs. Without this external and internal buy-in, the PAL and Early Adopter Coordinator are left to try to compel the Science Team to spend time on applications when they are not otherwise motivated to do so. It sometimes takes a significant amount of time and effort to get the Science Team, as well as the Flight Project Team, to understand why they should engage with Early Adopters.

C. Student and Post-Doctoral Researcher Participation

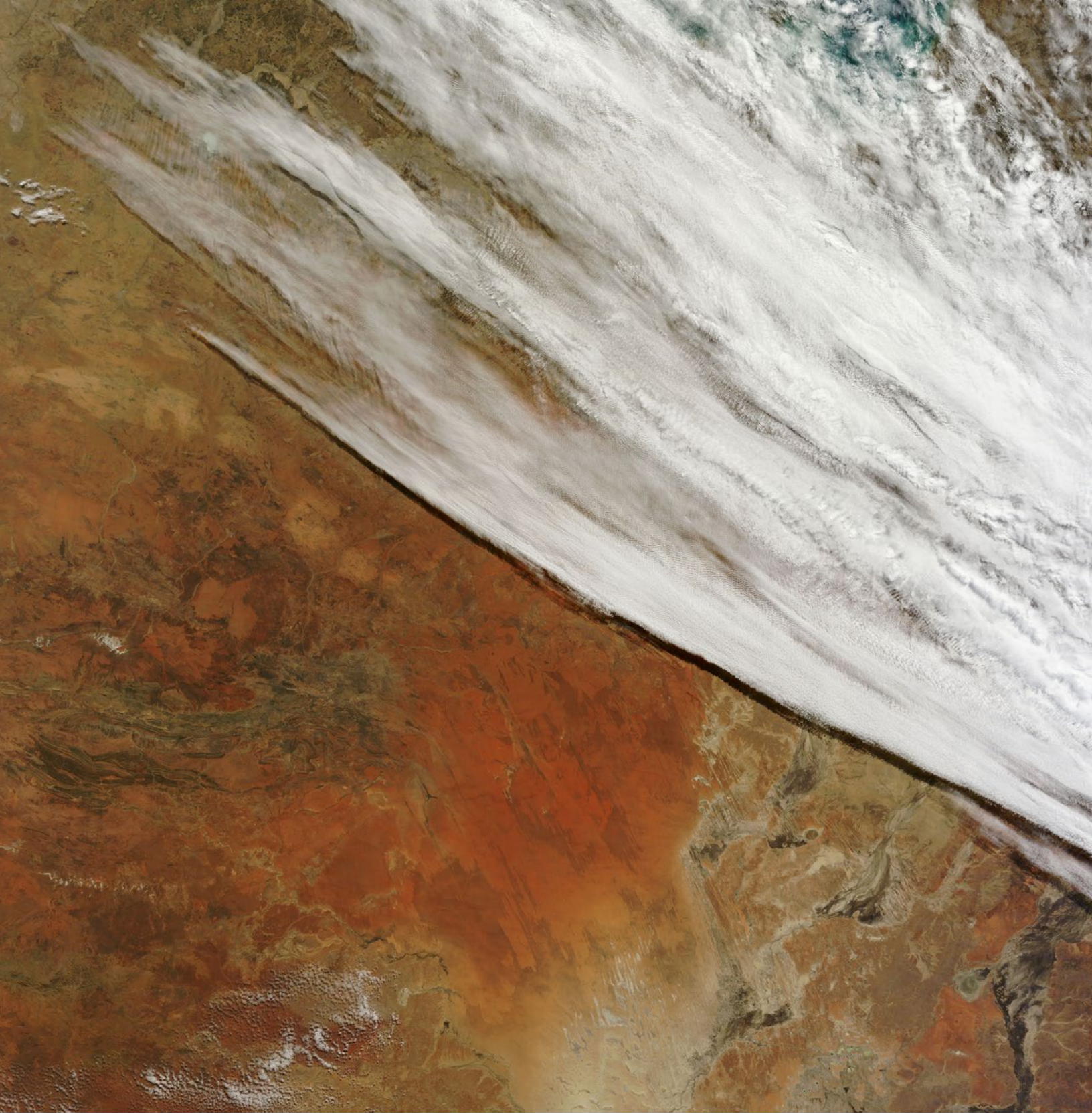
When Early Adopters and Science Team members involve their students and post-doctoral researchers in Early Adopter Program activities, both the Science Team's understanding of Early Adopter needs and Early Adopter's understanding of the data products can be increased. One Early Adopter Program found that conducting hands-on tutorials in conjunction with Science and Applications Team meetings encouraged Science Team members to bring their students and post-doctoral researchers along with them to participate in Early Adopter activities.

D. Early and Frequent Engagement with the DAACs

The DAACs are ultimately the providers of the proxy and final data products, as well as providers of user support. Ensuring the DAACs are engaged throughout an Early Adopters Program means that DAAC teams obtain insight into a diverse user community prior to launch, which enables them to understand the needs of the user community and how to meet those needs.

E. Accurate Proxy Data

Early Adopters rely on accurate proxy data to engage with their partners and to test the ability of the data to work within their research contexts. Having proxy data that are as "true" to the final data products as possible is key to ensuring that researchers can transition seamlessly once final data products become available.



OVERARCHING FINDINGS

OVERARCHING FINDINGS

A. Early Adopters Are Not Those One Might Expect

The original vision was for Early Adopters to be those who (1) were already planning to use satellite data for their application and (2) would provide valuable feedback to NASA. As the program expanded, Early Adopters included both those who had never before used satellite data, and those who were extremely experienced users of satellite data. Some Flight Project Teams decided that any and all feedback from users would be helpful to NASA and did not focus on restricting the set of potential Early Adopters.

There is a diverse range of views regarding who could and should be an Early Adopter. The ESD leadership team is generally less interested in the Early Adopters Programs as a way to connect with decision makers and is more focused on ensuring that users understand data before mission launch. Several ESD leaders indicated that it adds value to have any potential user of flight project data ready to use those data as soon as they become available. While ESD leadership and others see value in letting potential data users (regardless of whether they will be working with decision makers) become familiar with proxy data products before a mission or instrument launches, inclusion of all potential data users in an Early Adopters Program could cause the needs of decision makers to be overshadowed by the needs of academic researchers, especially given the limited amount of time allocated to the role of coordinating Early Adopter Programs.

The majority of Early Adopters appear to be academic researchers—possibly because academic researchers see a stronger benefit from associating with NASA than other types of Early Adopters. It is sometimes difficult to distinguish between Early Adopters and Science Team members in terms of expertise and research focus. Some Early Adopters were previously Science Team members and view their ability to interface with Science Team members as peers as part of what makes their work successful.

There are several Early Adopter Programs in which most Early Adopters lack a specific, non-academic end user. This fact is concerning, given that one of the goals of an Early Adopters Program is to increase the impact of flight project data through its use in decision making. A lack of connection to decision makers limits the potential value of the information from a flight project.[22]

B. Challenges in Engaging and Sustaining Interest among Early Adopters

Conversations with Early Adopter Coordinators and Early Adopters suggest that the incentives for participating in Early Adopters Programs are too low to obtain the level of participation that the Applied Sciences Program would like. Early Adopters do not receive funding or other credit for participating in Early Adopters Programs, and as a result, do not always see the value in participating at all, or participating to the extent that the Early Adopter Coordinators think would be required for meaningful engagement. One Early Adopter Coordinator estimated that due to lack of funding, only 50% of the Early Adopters are fully engaged. Another Early Adopter Coordinator stated that the "Early Adopter program, being unfunded, is founded on the premise that 'if we build it, they will come' or 'if we just engage… things will snowball.' This is a false and naive premise…. [The Early Adopters Programs lack] any incentivizing mechanism to attract (recruit and retain) Early Adopters…."

In discussions, academic, "soft-funded" Early Adopters corroborated this idea that lack of funding is a barrier to further engagement. Funding is likely a key issue because Early Adopters are mostly academic researchers rather than researchers or organizations that are fully funded, would be pursuing incorporating mission data without NASA's support, or would not be competitive in a NASA funding solicitation. However, adding a funding element to Early Adopters Programs would require additional work to ensure a fair and open process that is consistent with NASA's other competitive funding opportunities.

While the Early Adopters Programs provide Early Adopters the ability to work with Science Team members and provide feedback, the data access that these programs provide does not specifically privilege the Early Adopters. Any

22 Macauley, Molly K. "The value of information: Measuring the contribution of space-derived earth science data to resource management." Space Policy 22.4 (2006): 274-282

proxy, simulated, and beta data products developed for a mission are freely and openly available, per NASA's data policy, and so can be accessed both by Early Adopters and the general public.[23] This means that those who might want to test these data products in their systems do not need to participate in an Early Adopters Program to do so.

One Early Adopter Coordinator and one PAL noted that it can be difficult to generate excitement among some end users when data is not yet available, and when a mission is far in the future and does not yet have a launch date. The Directive on Project Applications Program recommends that Early Adopters Programs begin in Phase B of the project life cycle, as defined in NASA Procedural Requirements (NPR) 7120.5.[24] Phase B is described in the NASA Headquarters Science Mission Directorate (SMD) Management Guidebook as preliminary design and technology development.[25] Additional feedback suggested that having Early Adopter Programs begin in Phase B is too early, as potential Early Adopters have difficulty seeing the value of engaging so far before a flight project is launched. One individual suggested starting Early Adopter Programs in Phase C (final design and fabrication) or Phase D (during which integration, testing, and launch occur).[26]

Additional feedback suggested that engaging Early Adopters for each mission as a separate effort may contribute to fatigue for those that could be Early Adopters for multiple missions, and that having a need-based set of Early Adopter Programs rather than a flight project-based set of Early Adopter Programs could help address this issue.

The concern that Early Adopters are not appropriately incentivized to participate likely underlies a reluctance by PALs and Early Adopter Coordinators to turn away any potential Early Adopters. Interviewees also expressed concern that an overly-structured Early Adopters Program with too many requirements would discourage Early Adopters from joining.

C. Challenges in Engaging Science Team Members

Early Adopter Coordinators have also encountered difficulties in getting Science Team members to engage with the Early Adopters Program. Because working with Early Adopters is not a formal responsibility of the Science Teams, Early Adopter Programs rely on Science Team members seeing the value in obtaining feedback from the applications community. Science Team engagement with the Early Adopter Program is not consistent, and when Science Team members do not engage, it disadvantages the entire program.

D. Variable Implementation of Early Adopters Programs

There are no requirements for Early Adopters Programs and Early Adopters Programs do not generally follow the five criteria in NASA's Directive on Project Applications Program. In particular, five flight projects allow anyone to become an Early Adopter—meaning that there is no requirement for Early Adopters to provide a research project title with the end user clearly identified or a short abstract describing the societal benefit of the project, nor do Early Adopters need to provide metrics and testimonials that explain how the use of a product will improve a policy or decision relevant to their organizational goals and objectives.

There are advantages and disadvantages to selectively choosing Early Adopters. Selectivity ensures that Early Adopters are well suited to the goals of the program, limits the number of Early Adopters to a manageable number, and sets clear expectations for Early Adopters. However, if the goal of an Early Adopters Program is to provide the most feedback about the data, selectivity limits the amount of feedback provided. A selection process that involves an application can also incur time delays for the Early Adopters. The SMAP Early Adopters Program found that it could take an Early Adopter at a federal agency six months (or longer) to obtain approval from the agency to submit the Early Adopter application.[27]

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23 "NASA Earth Science Data: Yours to Use, Fully and Without Restrictions." https://earthdata.nasa.gov/learn/articles/tools-and-technology-articles/nasa-data-policy#:~:text=EOSDIS%20Update-,NASA%20Earth%20Science%20Data%3A%20Yours%20to%20Use%2C%20Fully%20and%20Without,%2C%20openly%2C%20and%20without%20restrictions.&text=More%20than%201.61%20billion%20EOSDIS,EOSDIS%20data%20and%20services%20worldwide. (accessed 15 January 2021).

24 NASA Procedural Requirements (NPR) 71250.E https://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=7120&s=5E (accessed 3 March 2021).

25 NASA Headquarters Science Mission Directorate (SMD) Management Guidebook, Updated as of 20 May 2019.

26 Ibid.

27 Moran, Susan. "SMAP Early Adopters Program" 11 April 2012. Received via personal communication.

E. Need for Flexibility in Implementation

All four of the PALs interviewed identified the need for flexibility in designing Early Adopters Programs to be responsive to the specific needs of a flight project and the respective user communities. For example, a flight project that is a follow-on mission may have well developed user communities and established applications compared to a flight project that will be collecting new types of data. Such divergent situations lead to variability in the preparedness of Early Adopters to ingest new data. Data from flight projects may also exhibit varying degrees of application readiness, with some flight projects producing higher-level data products that can be readily ingested by users, and other flight projects producing data that requires multiple modeling-intensive transformations to become usable for decision making. There is also diversity in terms of the budget for a given flight project; Earth Venture instruments and missions have much lower budgets than strategic or directed missions. Finally, the number of distinct application communities that may be served by the data from a given flight project can also vary.

F. Need for Greater Support

In some cases, the need for flexibility in the implementation of Early Adopters Programs seemed to stem from a lack of resources, either from budget limitations (i.e., a flight project chose not to invest funding in an Early Adopters Program), or from time limitations (one Early Adopter Coordinator could only dedicate a small amount of time to the effort). PALs reported that resource limitations necessitated different structures and scope for different Early Adopter Programs. The most successful Early Adopter Programs were programs like SMAP and ICESat-2, which benefited from significant budgetary and staffing resources. For reference, the Applied Sciences Program has generally provided support to DPAs for approximately 20 percent of their time, and this 20 percent is to cover all relevant applications activities, including an Early Adopters Program.

PALs generally view Early Adopters Programs as a useful and cost-effective way to engage with potential users of the flight project data. However, they felt that they do not have as much time as they would like to engage with Early Adopters Programs and feel less connected to the missions following the recent loss of a dedicated program manager tasked with coordinating the Applied Sciences Program and the flight projects. Interviewees expressed a desire to have a member of the staff fill this coordination role, but also recognize that this role is challenging because of the need to coordinate across programs, flight projects, and personnel.

Early Adopter Coordinators who are DPAs as opposed to PASs are only supported for a small amount of time compared to the number of responsibilities that they take on to run a robust Early Adopters Program as well as to lead other application activities for a given flight project.

G. Views of Early Adopters Programs by ESD Leadership

Members of the ESD leadership team have a generally positive view of Early Adopters Programs. Those who are familiar with these programs are supportive and view the programs as having been successful and in alignment with the goals of ESD. However, not all members of ESD leadership fully understand what the Early Adopters Programs are or specifically what they are trying to accomplish. In addition to lack of clarity on the specifics of the programs and their goals, no members of ESD leadership outside the Applied Sciences Program can point to specific examples of Early Adopters Programs' success.

H. Views on the Name of the Early Adopters Program

Early Adopter Coordinators for six missions said that they liked the name "Early Adopters" for the program. Early Adopters Coordinators for two flight projects do not identify with the Early Adopters name; both are affiliated with missions in which there are existing user communities that are experienced with the data, and believe that "Early Adopters" does not properly reflect the level of expertise their users have. Early Adopter Coordinators for three flight projects said that they would not mind whether the name stays the same or changes. PALs that brought up the issue of the name of the program recognized the need to be accommodating with regard to the identities of the communities involved in each flight project.

I. Tracking Early Adopters

Tracking Early Adopter success stories could be a way to bring visibility to Early Adopters Programs and the Applied Sciences Program. In most cases, however, Early Adopter Coordinators are not planning to track how Early Adopters use flight project data following the conclusion of an Early Adopters Program. Even while an Early Adopters Program is ongoing, it can be challenging to keep track of Early Adopter success stories for a variety of reasons, including the workload required by Early Adopter Coordinators, open access to data, anonymity in accessing data from DAACs, and lack of incentives for Early Adopters to report back to NASA.

RECOMMENDATIONS

RECOMMENDATIONS

Over the past decade, approximately 11 flight projects have implemented Early Adopters Programs that included many variations of the original program design. While some of these changes are positive innovations, this variation has also allowed the programs to expand beyond the original target audience of users who are fully funded and connected to decision making. The variation has also led to deviation from the original format, which was structured around helping Early Adopters with specific research projects focused on application development.

While it may not make sense for every flight project to have an Early Adopters Program, there are many different forms of user engagement that can help ensure that data from a flight project is used widely. For some flight projects, the data requires many transformations before it becomes useful to end users (e.g., spherical harmonics from gravity data); in such cases, an Early Adopters Program may not make sense, and instead, the PAS may choose to dedicate time to working with the relevant modeling communities. Even for those flight projects that decide to pursue an Early Adopters Program, a small-scale Early Adopters Program might be a better choice. A flight project with few near-term applications could engage a small number of Early Adopters and sponsor correspondingly fewer events and activities.

The following recommendations assume that Early Adopters Programs continue to focus on specific flight projects. This flight project-driven approach makes sense given how the majority of ESD's budget is linked to the support of a specific flight project. However, because many applications are enabled by several different observations and data types, it would benefit ESD to consider an approach to engage potential data users based on topical areas, industries, or applications. Such an approach would require ESD-wide support to incorporate feedback from users into the data products for multiple flight projects.

A.Focus and Standardize Early Adopters Programs

Recommendation A1. Focus Early Adopters Programs on accelerating the use of Earth observations in decision-making contexts.

To increase the likelihood of developing successful applications, Early Adopters should demonstrate a direct and clearly defined need for the flight project data to support an existing decision-making activity. While the Early Adopters do not themselves need to be the decision makers for a particular application, they should be working in close coordination with (or on the behalf of) decision makers.

An Early Adopters Program should strive to include participants with diverse ideas and backgrounds. The recruitment process for Early Adopters must be broad, inclusive, and equitable. This broad recruitment should be paired with an equitable selection process that emphasizes the selection of a diverse range of Early Adopters with significant potential to increase the value of flight project data through its use in decision making.

In addition, directly and clearly defining the need for data to support a decision-making activity, Early Adopters should demonstrate the institutional support (e.g., leadership support, access to resources and/or a plan to acquire needed resources) required to test the utility of simulated, proxy, or early flight project data in their application.

Engaging with academic users who do not have a clear connection to decision making should not be the purview of Early Adopter Programs. While ESD leadership sees value in enabling all types of potential data users to engage with flight projects and use proxy data prior to actual data release, the determination of how to engage with the broader academic community prior to launch should be made by Flight Project Teams.

Recommendation A2: Require Early Adopters Programs follow the criteria described in the Directive on Project Applications Program.

The Directive on Project Applications Program defines five criteria for Early Adopters Programs. Ensuring that the programs adhere to these criteria will help guarantee they are structured consistently and in a way that allows meaningful feedback regarding the use of data in applications. The criteria are paraphrased below:

6 Each Early Adopter should provide a research project title with the end user clearly identified and a short abstract describing the societal benefit of the project

7 Each Early Adopter should be partnered with a Science Team member who can provide guidance and information on project data product development

8 Each Early Adopter should receive access to developmental products and interact with the product developer, enabling them to understand and integrate the new products into their systems

9 Each Early Adopter should provide feedback to the Science Team member regarding data product functionality as well as potential calibration and validation information

10 Each Early Adopter should provide metrics and testimonials that explain how the use of a product will improve a policy or decision relevant to their organizational goals and objectives.[28]

Since an Early Adopters Program that follows the five criteria requires significant investment in time and resources by the mission, the number of Early Adopters should be limited to match the resources available. A smaller number of Early Adopters that meet the criteria described above is preferable to a larger number of Early Adopters who do not meet all of those criteria. Limiting the pool of Early Adopters will help the Early Adopters, Early Adopter Coordinators, Science Team members, and Flight Project Team members have enough time to engage productively.

Recommendation A3: Develop a guidebook for how to set up and implement an Early Adopters Program.

A guidebook that describes how to implement an effective Early Adopters Program would be helpful for new Early Adopter Coordinators or for PALs, DPAs, and PASs to decide whether to pursue an Early Adopters Program, and if so, how to implement it. This guidebook should include the lessons learned over the past decade and should be updated periodically. Essential features that a guidebook should contain are:

1 Guidance for Early Adopter Coordinators, Science Team members, and Early Adopters about roles and responsibilities

2 An inclusive and equitable process for broad recruitment of Early Adopters, particularly from historically under-represented groups

3 A selective acceptance process to ensure a manageable number of Early Adopters

4 Best practices and lessons learned from past Early Adopter successes and failures

5 Guidelines for maintaining flexibility to tailor an Early Adopters Program for a directed mission or Earth Venture mission or instrument;

6 Metrics of success that can be used for evaluations or self-evaluations;

7 Guidelines for periodic reviews and an exit review of the Early Adopters Program.

Recommendation A4: Provide opportunities to obtain feedback and to review the individual Early Adopter Programs and the set of programs as a whole.

Increasing the oversight of and communication about Early Adopters Programs will help ensure that each Early Adopters Program meets the overall goals and is aligned with the programs' principles. Status of the Early Adopters Programs should be reported to ESD leadership and preferably to the entire ESD for visibility and feedback. Potential venues for reporting include Flight Program review meetings, Mission Applications review meetings, and Science Mission Directorate's monthly status reviews.

Ongoing Early Adopters Programs should undergo periodic external reviews throughout the lifetime of the program, with a closeout review held at the conclusion of the program. These periodic reviews should aim at providing course-corrections and should consider possible termination of an Early Adopters Program, if appropriate. The closeout

28 Early Adopters should be given specific opportunities to provide feedback to NASA post-launch; however, it is not feasible to enforce this criterion.

review should summarize successes and lessons learned, which should be documented and broadly distributed. The entire set of Early Adopters Programs should be reviewed externally at least once every five years—possibly as part of a review of the entire Project Applications effort across ESD—to gauge the program's effectiveness and identify improvements.

B. Enhance Support for the Early Adopters Programs

Recommendation B1: Assign a Missions and Applications Program Manager to coordinate the implementation of Project Applications Plans and Early Adopters Programs.

The dedication of appropriate personnel and funding will allow for effective management of Early Adopters Programs. A civil servant "Missions and Applications" program manager (required effort at least 1.0 full-time equivalent [FTE]) who can work across the Earth Science Division to coordinate the implementation of Project Applications Plans, including the Early Adopters Programs, will help ensure consistency, provide guidance, and increase overall efficiency. We recommend that this position be filled by a dedicated civil servant, given the scope and requirements of the position.

Recommendation B2: Increase support for Early Adopter Coordinators to at least 0.5 Work-year Equivalent (WYE) for the duration of the Early Adopters Program.

The PAL, DPA, and PAS should determine the level of effort needed for a project to implement an Early Adopters Program, and whether the role of Early Adopter Coordinator should be filled by the Project Application Scientist and/or another person.

Specific funding dedicated to an Early Adopters Program and the role of the Early Adopters Coordinator would help alleviate many potential resource constraints. For example, a dedicated Early Adopter Coordinator, distinct from the Project Application Scientist, could spend more time recruiting Early Adopters from relevant communities, working with potential Early Adopter applicants to ensure that they have relevant research proposals, organizing high-value workshops and training sessions, and working with the Science Team and DAACs.

To help potential Early Adopters determine which new data products are best suited for their application, an Early Adopter Coordinator could work across multiple flight projects rather than be assigned to a single flight project.

The study team recommends allocating at least 0.5 WYE for an Early Adopter Coordinator for a single Early Adopters Program (though there may be periods when 0.75 WYE is required, and it is possible that there could be efficiencies gained if an Early Adopter Coordinator is working on multiple Early Adopter Programs).

Recommendation B3: Dedicate appropriate funding to Early Adopters Programs.

The dedication of appropriate funding will help ensure that workshops, hackathons, and other events are conducted in a manner that best benefits the flight project and the development of applications. This funding should be determined as part of the Project Application Plan in a manner consistent with NASA funding policies. Particular attention should be given to ensuring that the DAACs also have enough resources to support Early Adopters Program efforts. NASA should explore possible methods to fund Early Adopters.

C. Articulate the value proposition for participating in Early Adopters Programs

Recommendation C1: Conduct research to identify potential Early Adopters with high-value applications prior to the start of an Early Adopters Program

Market research, community assessment reports, and forward-looking value of information studies could be used to research potential high-value applications prior to the start of an Early Adopters Program. This research will help identify a pool of Early Adopters that could benefit from participation.[29]

29 Following the application of flight project data in an Early Adopter's work, impact assessments could be used to determine the socio-economic benefits of the flight project data.

Recommendation C2: Conduct market research to determine whether the term "Early Adopters" is understandable and appealing to communities of practice and communities of potential.

The Applied Sciences Program should conduct market research to determine whether the "Early Adopters" name makes sense and is appealing to those with a connection to decision making. If the name does not resonate with members of the relevant communities, consider rebranding the program with a name that will have immediate recognition and yield buy-in.

D. Better Integrate Early Adopter Programs into Missions

Recommendation D1: Allow Early Adopters Programs to begin in Phases B, C, or D of the life cycle for flight projects, as defined in NASA Procedural Requirement (NPR) 7120.5.

Sustaining engagement among Early Adopters for many years between the start of Phase B (preliminary design and technology development) and the completion of Phase E (when science operations occur) is a challenge for the Early Adopter Coordinators. Given the focus on data use, it may be more efficient to target some Early Adopter Programs to begin in Phase C (final design and fabrication) or Phase D (during which integration, testing, and launch occur).

Recommendation D2: Identify and select multiple dedicated Science Team members who will champion and partner with the Early Adopters Program for a mission.

To help set realistic expectations for Science Team members, NASA should clarify Science Team responsibilities and clearly convey the value of Early Adopters Programs. There are points in the Science Team selection process where NASA can help increase the likelihood that Science Team members will be supportive of the Early Adopters Program. For example, NASA could include text in the solicitations for Science Team members that references the potential role in an Early Adopters Program to help clarify this responsibility from the start. Additionally, the selection of Science Team members should involve the PAL to ensure that the Science Team appreciates the learning opportunities posed by engagement with Early Adopter projects and is interested in the development of applications.

Recommendation D3: Create a multi-mission alumni program to enable Early Adopters to continue engaging with NASA and other former Early Adopters following mission launch.

We recommend that the Applied Sciences Program create an alumni program for those Early Adopters who would like to continue engaging with NASA and other former Early Adopters following launch. Program alumni could be grouped according to application rather than flight project. A comprehensive database of all Early Adopters with appropriate metadata describing their applications, relevance of their applications to decisions, and end user connectivity can help determine who to invite to become part of an alumni program, track progress, and identify potential Early Adopters for new flight projects.

APPENDIX A.
HISTORY OF THE EARLY ADOPTERS PROGRAM

Prior to the Early Adopters Programs' existence, many potential flight project data users were not aware of the expected data products prior to launch. Lack of outreach and communication, combined with difficulty in incorporating new data into existing workflows, meant that it sometimes took three to four years for users to apply data in their work. This delay meant that if a potential user found out about a five-year-long mission when it launched and required low latency data products, he or she would only be able to work with the data for the last year or two of that mission. The significant amount of time and effort required to use a flight project's data compared to the short duration of its availability was a disincentive for many potential users to invest the resources required to adapt their workflows to use the data.

The concept of the Early Adopters Program stemmed from a SMAP Applications Working Group workshop. The idea for the program was to have potential users (the Early Adopters) inform the Science Team about possible applications in the hope that the design of the sensor and data products would be able to support those applications. The SMAP Early Adopters Program aimed to benefit NASA by increasing the use—and therefore the value—of SMAP data, both through direct application by the Early Adopters, and by the Early Adopters articulating the value of the data in their work and inspiring additional applications. The Early Adopters would benefit by interacting with members of the Science Team who could address their questions and concerns, and receiving proxy SMAP data to incorporate into their systems or models before the final data products were available.

Once final SMAP data products were produced, the Early Adopters were able to seamlessly transition from using the proxy data products to using the real data products. As a result of this successful SMAP program, Program Managers, in their capacity as PALs, began to implement Early Adopters Programs for other flight projects.

The Directive on Project Applications Program, which establishes guidelines for implementing a Project Applications Plan for ESD flight projects, recommends that flight projects consider including Early Adopters Program activities as part of the Project Applications Plan, and describes the elements of a Early Adopters Program.

According to PALs, the impact of the Directive on Project Applications Program was that it gave the Applied Sciences Program and applications activities "a seat at the table" in flight project planning activities. At the time of this study, the first flight projects required to follow the Directive on Project Applications Program, the Designated Observable missions, were pre-Key Decision Point (KDP) A, and had not initiated Early Adopters Programs.

APPENDIX B. INTERVIEWEES AND STUDY QUESTIONNAIRE RESPONDENTS

INTERVIEWEES

Earth Science Division (ESD) Leadership

- Sandra Cauffman, Acting Director of ESD
- Paula Bontempi, Acting Deputy Director of ESD
- Lawrence Friedl, Associate Director, Applied Sciences Program
- Jack Kaye, Associate Director, Research and Analysis
- Pam Millar, Associate Director, Earth Science Technology Office
- Kevin Murphy, Program Executive, Earth Science Data Systems and Sara Lubkin, Support Scientist, Earth Science Data Systems

Program Application Leads

- Brad Doorn
- David Green
- John Haynes
- Woody Turner

Deputy Program Application Leads and Project Application Scientists

- Sabrina Delgado Arias, regarding ICESat-2
- Margaret Srinivasan and Mike Jasinski, regarding GRACE-FO
- Christine Lee, regarding ECOSTRESS

Early Adopters

- Nancy Glenn, Early Adopter for ICESAT-2
- Yang Liu, Early Adopter for MAIA
- Meredith Franklin, Early Adopter for MAIA

Those with a lengthy history of involvement in the Early Adopters Program

- Molly Brown, SMAP Applications Coordinator
- Susan Moran, Chair of SMAP Applications Working Group and member of SMAP Science Definition Team

QUESTIONNAIRE RESPONDENTS

Note: only one questionnaire was requested per mission

- GRACE-FO: Michael Jasinski, John T. Reager, Margaret Srinivasan
- ICESat-2: Sabrina Delgado Arias
- MAIA: Abigail Nastan
- NISAR: Natasha Stavros, Batuhan Osmanoglu, Cathleen Jones
- OCO-3: Karen Yuen
- PACE: Erin Urquhart Jephson, Ali Omar, Joel Scott, Maria Tzortziou
- SWOT: Margaret Srinivasan, Ed Beighley, Faisal Hossain
- TEMPO: Aaron Naeger
- TROPICS: Emily Berndt

APPENDIX C.
ICESAT-2 EARLY ADOPTER APPLICATION

ICE, CLOUD AND LAND ELEVATION SATELLITE-2 MISSION EARLY ADOPTER PROGRAM

Early Adopters are defined as those groups and individuals who have a direct or clearly defined need for ICESat-2 data products, have an existing application or decision making activity, and who are planning to apply their own resources (funding, personnel, facilities, etc.) to demonstrate the utility of ICESat-2 data for their particular application. Application is defined here as an innovative use of mission data products in decision making activities for societal benefit.

The goal of the EA designation is to accelerate the use of ICESat-2 data products after launch of the satellite by providing specific support to Early Adopters who commit to engage in pre-launch research. It is expected that this pre-launch research will result in a fundamental understanding of how ICESat-2 data products can be scaled and integrated into organizations' policy, business and management activities to improve decision-making efforts. The EA may be either an end-user or conduct the pre-launch research for an end-user. End-user is defined here an individual or group from a national or international public or private sector organization, industry association, university, or government agency who can effectively use the data to make actionable decisions that influence the well-being of their target communities.

Below is the evaluation process your application will go through. Please make sure to fill in all the highlighted areas of the application and send a signed copy (Word and/or PDF format) to the ICESat-2 Applications POC (Sabrina Delgado Arias; sabrina.delgadoarias@nasa.gov) to initiate the evaluation process. You will be notified when/if you have been selected as an Early Adopter for the ICESat-2 Mission.

Thank you in advance for your interest and we look forward to reading about your research efforts!

Sabrina Delgado Arias
ICESat-2 Mission Applications Coordinator & POC

Vanessa Escobar
ICESat-2 Mission Deputy Program Applications Lead

Molly Brown
ICESat-2 Mission Program Applications Lead

EA application Process:

1. Contacting/nomination of potential Early Adopter must be done with the application form herein. Please contact Sabrina Delgado Arias for a copy.
2. ICESat-2 Application review and evaluation of completed application (conducted by Applications Leads and Deputy Project Scientist).
3. Project approval of reviewed EA application.
4. Welcome letter and acceptance announcement sent to the EA. EA name and institution posted on the mission website.

We will be accepting EA proposals for this biannual approval process up to the last day of the month preceding the month of review, as follows:[30]

- For Mar review, submission deadline 28 February 2017
- For Sept review, submission deadline 31 August 2017
- For Mar review, submission deadline 28 February 2018

Application for the Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) Early Adopter Program

<Title of Early Adopter's Pre-launch Research>

<Name and Organization of PI(s)>

<End-User (& POC)>

<Requested SDT Partner, if known>

ABSTRACT

[Use this space to add abstract]

30 As of January 2016, we are also accepting proposal submissions and reviewing proposals on a rolling basis.

Application for the Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) Early Adopter Program

This application is an informal understanding between all parties that outlines prospective roles and responsibilities. It also provides a designation of "Early Adopter" (EA) for the ICESat-2 mission and outlines the proposed roles and responsibilities of the respective parties. The ICESat-2 mission is currently scheduled for launch in September 2018. This agreement is targeted for the ICESat-2 pre-launch phase of the mission development during which simulated ICESat-2 data products (but no actual ICESat-2 observational data) will be available.

I. Description of research (including data currently used and ancillary data needs), how it will be used by end-user, and how it will impact their decision-making process.

< Please make sure to identify end-user/stakeholder, if other than Early Adopter, including Points of Contact (POC), and describe how end- user/stakeholder plans to incorporate your research into their decision-making process. >

II. Approach to solve basic challenges in applying ICESat-2 products and/or including ICESat2 products into routine operations.

< Please provide a detailed description of how you plan to address, in terms of methods, the limitations or challenges of using ICESat-2 data for your application, as well as the approaches you plan to use to improve the effectiveness/utility of ICESat-2 data in your system/model/tool. >

III. Foreseeable requirements for pre-launch simulated data products and plans for field experiment demonstration.

< Please list all of the products that you will use (for direct assimilation, validation, or potentially) from the ICESat-2 Science Data Products Table (Exhibit I). You may list any MABEL campaigns, airborne surveys, or other data that you will use for collecting observations to use as proxy data sets for your ICESat-2 EA study. You may also list any field work that you plan to carry out for obtaining coincidental measurements. >

IV. Post-launch implementation strategy.

< Please identify any methods or approach for your implementation strategy after launch >

V. Process

Timeline and Responsibilities

The ICESat-2 mission is currently in Phase D of design and development. This application is targeted for the ICESat-2 pre-launch phase during which data from the ICESat-2 airborne simulator, the Multiple Altimeter Beam Experimental LiDAR (MABEL) instrument, and simulated ICESat-2 data products (but no actual ICESat-2 observational data) will be available. Work will be initiated immediately upon acceptance of this application and will be completed before the launch of ICESat-2. Feedback and communication between the EA and the mission are a measure of success and applications effort that projects are completed with quantitative metrics prior to launch.

The EA agrees to the following:

< Please provide EA Team Member names and a brief description of expected roles >

- To use the data provided by engaging in pre-launch research as described below that will enable integration of ICESat-2 data after launch in their application;
- To provide feedback to the ICESat-2 project upon request concerning the EA experience in using the data;
- Provide quantitative metrics prior to launch that enable evaluation of the value of the ICESat-2 data to the EA activity after launch; and
- Provide the mission access to cal/val data or simulated data generated under the EA research effort.

The ICESat-2 Mission agrees to the following:

< Please identify a Science Definition Team (SDT) member that the Early Adopter would like to incorporate into their application. For a list of current ICESat-2 SDT members please visit: http://icesat-2.gsfc.nasa.gov/science_definition_team **>**

- Incorporate Early Adopter contributions into the ICESat-2 Mission Applications plan
- Provide Early Adopters with simulated ICESat-2 data products via the ICESat-2 website (or other electronic data transfer process) when they become available and/or
- Provide Early Adopters with planned pre-launch calibration and validation (cal/val) data from ICESat-2 field campaigns, modeling and synergistic studies as described in Exhibit 2.

EXHIBIT 1

Description of ICESAT-2 Data Products

The planned ICESat-2 science data products are shown in Table 1. The products will conform to the HDF5 standard.

ICESat-2 Science Data Products (revised February 2015)

Product Number	Name	Short Description	Latency*
ATL00	Telemetry Data	Raw ATLAS telemetry in packets with any duplicates removed by EDOS.	Downlinked 8 times per day
ATL01	Reformatted Telemetry	Parsed, partially reformatted, HDF5 time-ordered telemetry.	2 days
ATL02	Science Unit Converted Telemetry	Science unit converted time ordered telemetry calibrated for instrument effects. All photon events per channel per shot. Includes atmosphere raw profiles. Includes housekeeping data, engineering data, s/c position, and pointing data.	2 days
ATL03	Global Geolocated Photon Data	Precise lat, long and height above ellipsoid for all received photons determined using POD and PPD. Along-track data, per shot per beam. Geophysical corrections applied. Classification of each photon (signal vs. background) and into surface types (land ice, sea ice, ocean, etc…).	21 days
ATL04	Normalized Relative Backscatter	Along-track normalized relative backscatter profiles at full instrument resolution (25 times per second for ~30m vertical bins). Includes calibration coefficient values calculated in the polar region.	21 days
ATL06	Land Ice Height	Surface height for each beam, along and across-track slopes calculated for beam pairs. All parameters are calculated at fixed along-track increments for each beam and repeat.	45 days
ATL07	Sea Ice Height	Height of sea ice and open water leads (at varying length scale). Includes height statistics and apparent reflectance.	45 days
ATL08	Land-Vegetation Height	Height of ground and canopy surface at varying length scale. Where data permits, include estimates of canopy height, relative canopy cover, canopy height distributions, surface roughness, surface slope, and apparent reflectance.	45 days
ATL09	ATLAS Atmosphere Cloud Layer Characteristics	Along-track cloud and other significant atmosphere layer heights, blowing snow, integrated backscatter, optical depth.	45 days
ATL10	Sea Ice Freeboard	Estimates of freeboard using sea ice heights and available sea surface heights within km length scale; contains statistics of sea surface samples used in the estimates.	45 days
ATL11	Land Ice H(t)	Time series of height at points on the ice sheet, calculated based on repeat tracks and/or crossovers.	45 days from receipt of last data in product
ATL12	Ocean Surface Height	Surface height at varying length scales. Where data permits, include estimates of height distributions, surface roughness and apparent reflectance.	45 days from receipt of last data in product
ATL13	Inland Water Body Height	Along-track inland water height. Where data permits, includes roughness, slope and aspect.	45 days from receipt of last data in product
ATL14	Antarctic and Greenland Gridded Height	Height maps of each ice sheet for each year of the mission, based on all available ICESat-2 elevation data.	45 days from receipt of last data in product
ATL15	Antarctic and Greenland Height change	Height-change maps of each ice sheet, with error maps, for each mission year and for the whole mission.	45 days from receipt of last data in product
ALT16	ATLAS Atmosphere Weekly	Polar cloud fraction, blowing snow frequency, ground detection frequency.	45 days from receipt of last data in product
ATL17	ATLAS Atmosphere Monthly	Global cloud fraction, blowing snow and ground detection frequency.	45 days from receipt of last data in product
ATL18	Land-Vegetation Gridded Height	Gridded ground surface height, canopy height and canopy cover estimates.	45 days from receipt of last data in product
ATL19	Gridded Sea Surface Height – Open Ocean	Gridded ocean height product including coastal areas. TBD grid size. TBD merge with Sea Ice SSH.	45 days from receipt of last data in product
ATL20	Gridded Sea Ice freeboard	Gridded sea ice freeboard. (TBD length scale)	45 days from receipt of last data in product

* Latency is defined as the approximate time it takes from the data acquisition on a satellite until it reaches an individual in a usable format.

EXHIBIT 2

Datasets that are available now:

- Predicted orbit tracks (can be used to identify locations where data will be available) o MATLAB file format
- Some ancillary data for product generation o DEM, preliminary surface classification mask, etc.
- MABEL airborne data o L2A data: geolocated photon ellipsoidal height
- Preliminary cal/val site locations o Point files (ASCII)

Datasets that will be generated during pre-launch phase:

- Test data products from algorithm development o M-ATLAS: derived from MABEL data simulated to ICESat-2 performance o Provisional M-ATLAS data available: http://icesat-2.gsfc.nasa.gov/icesat2/data/matlas/matlas_docs.php
- Synthetic data o Developed for ground system testing o Available mid-2015 (or 1 year before launch)

All simulated products will be in HDF-5 file format (to match the mission data format). Early Adopters will be granted access to these data sets for testing purposes via electronic file transfer (either through the ICESat-2 website or through the ICESat-2 DAAC (the National Snow and Ice Data Center).

APPENDIX D.
ACRONYMS AND ABBREVIATIONS

ARSET	Applied Remote Sensing Training
DAAC	Distributed Active Archive Center
DPA	Deputy Program Applications Lead
ECOSTRESS	ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station
ESD	Earth Science Division
FTE	Full-time Equivalent
GIS	Geospatial Information System
GRACE-FO	Gravity Recovery and Climate Experiment - Follow On
ICESAT-2	Ice, Cloud and land Elevation Satellite-2
ISRO	Indian Space Research Organisation
KDP	Key Decision Point
MAIA	Multi-Angle Imager for Aerosols
NISAR	NASA-ISRO Synthetic Aperture Radar
OCO-3	Orbiting Carbon Observatory-3
NPR	NASA Procedural Requirements
PACE	Plankton, Aerosol, Cloud, ocean Ecosystem
PAL	Program Applications Lead
PAS	Program Applications Scientist
PE	Program Executive
PI	Principal Investigator
PS	Program Scientist
SMAP	Soil Moisture Active Passive
SMD	Science Mission Directorate
SWOT	Surface Water and Ocean Topography
TEMPO	Tropospheric Emissions: Monitoring of Pollution
TROPICS	Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats
VOI	Value of Information
WYE	Work-year Equivalent