Building Pathways to Societal Applications of the Surface Water Ocean Topography (SWOT) mission though the Early Adopter Program

2019 SWOT Early Adopters Training Workshop

20-21 May 2019

Location: CNES Headquarters, Les Halles, Paris

WORKSHOP REPORT

Prepared by

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With Contributions from:
All workshop participants

Some of this work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

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Summary

SWOT is a research satellite mission, planned for launch in late 2021, and is being jointly developed by NASA and Centre National D'Etudes Spatiales (CNES), with participation from the Canadian and United Kingdom space agencies. The SWOT mission will serve both the hydrology and oceanography communities by providing the first global survey of Earth's surface waters including rivers, reservoirs, lakes, and wetlands, as well as unprecedented detail in the topography of the ocean surface. During May 20-21, 2019, a workshop was organized at CNES headquarters (HQ) in Paris (France) for SWOT Early Adopters (EA). These EAs had earlier proposed a tangible plan to proactively assess the utility of future SWOT data to address the needs of their respective agencies or organizations on surface water or ocean related applications. With two years to launch, it was considered an opportune time to further engage with the EAs to provide new hands-on training, to understand the progress they have made, to document the hurdles and needs they face in integrating data from a mission like SWOT, and to identify clear pathways to accelerate successful use of SWOT data after launch.

This workshop was organized by the SWOT Application Working Group (SAWG) leads comprising Alice Andral (CNES), Margaret Srinivasan (NASA JPL), Ed Beighley (Northeastern University) and Faisal Hossain (University of Washington) with support provided by the NASA Applied Sciences Program, The SWOT Project, and CNES. This is the second such EA workshop designed to explore ways to maximize the user-readiness of the SWOT data after launch. Summaries from the previous EA workshop and a series of SWOT applications workshops are available online (https://swot.jpl.nasa.gov/applications.htm).

More than forty participants attended the workshop. Representatives from eleven EA agencies, spanning three continents, participated as potential user communities of SWOT data and presented updates on their project over the period of two days. These participants represented various stakeholder agencies from the public and private sector that deal with water issues, including; Asian Disaster Preparedness Center (ADPC), Indian Institute of Technology (IIT), Pakistan Council for Research in Water Resources (PCRWR), Collecte Localisation Satellites (CLS), BRL Ingénierie (BRLi), Consortium of Universities to Advance Hydrologic Science Institute (CUAHSI), NASA Short-term Prediction Research and Transition (SPoRT) Center, Compagnie Nationale du Rhône (CNR), Mercator Ocean, University of Bonn, and FM Global. Several participants from the NASA and CNES SWOT Mission HQ and SWOT Science Team (ST) were also present in order to better understand the needs of future SWOT user communities.

A hands-on training session on the use of cloud computing and for simulating SWOT-like data was organized in recognition that SWOT mission data would be hosted on a cloud-computing platform after launch. EAs shared a futuristic vision of where they would like their project to evolve after SWOT launch with anticipated future press release titles. These press release titles summarized the desired newspaper headline each EA aspired to achieve after demonstrating a successful societal application or benefit from future SWOT data and information products. The workshop helped identify clear pathways

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to accelerate user-readiness of SWOT data for real-world societal applications. The key take home messages extracted from this workshop are:

i) Most EAs have identified clear pathways to assessing the use of SWOT data for exploring value to their decision-making or societal application needs within their existing infrastructure and operations.

ii) EAs identified the lack of SWOT simulated data with realistic geophysical, spatial and temporal representation over their study region as a key hurdle to successful completion of their EA project, and look forward to SWOT Project-provided datasets in the near future.

ii) EAs urged for continued support and guidance from the SWOT Application Working Group to address training needs for SWOT data handling in the cloud and use of ancillary tools and satellite data.

iii) Immersive learning and training experiences at research or academic centers relevant to SWOT followed by hackathons for rapid prototyping of solutions were identified as timely for EAs.

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INTRODUCTION

BACKGROUND

The Surface Water and Ocean Topography (SWOT) mission, jointly developed by NASA and CNES, and with contributions from the Canadian and UK space agencies, is designed to provide for the first time spatially distributed and high frequency measurement of water surface extent and elevation data for the hydrology and oceanography communities. The NASA Applied Sciences Program, the SWOT Applications Working Group (SAWG), the CNES SWOT Downstream Program, the SWOT Project, and members of the SWOT Science Team (ST) have been coordinating these efforts and recently launched the SWOT Early Adopter (EA) Program.

The Early Adopter Program (EAP) supports recommendations of the National Research Council's 2017 report "Thriving on Our Changing Planet; A Decadal Strategy for Earth Observation from Space" [also referred to as the Decadal Survey], which states that; "*To sustain prospects for adapting in the future, society need a more comprehensive understanding of how and why our environment is changing and what the associated implications will be."* It further states, "*Improved capacity for transitioning science to applications will make it possible to more quickly and effectively achieve the societal benefits of scientific exploration, and to generate applications more responsive to evolving societal needs*."

In the vision of the EAP, each selected EA proposed an activity for the use of SWOT data. EAs were defined as those groups and individuals who will have a potential or clearly defined need for SWOT surface water or ocean topography data or information, and who are planning to apply their own resources (i.e., funding, personnel, facilities) to demonstrate the utility of SWOT data for their use, system or model. The goal of this EA program is to accelerate the use of SWOT products after launch of the satellite by providing specific support to EAs who commit to engage in pre-launch research that would enable integration of SWOT data in their real-world applications. This research is intended to provide a fundamental understanding of how SWOT data products may be scaled and integrated into their organizations' policy, business and management activities to improve decision-making efforts.

In the initial cohort (beginning in 2018), 11 Early Adopters were selected from various hydrology and oceanography domains. These were: Asian Disaster Preparedness Center (ADPC)/SERVIR-Mekong; NASA Short-term Prediction Research and Transition (SPoRT) Center; Pakistan Council of Research in Water Resources (PCRWR); Indian Institute of Technology (IIT Bombay); University of Bonn; Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI); FM Global; Collecte Localisation Satellites (CLS); Compagnie Nationale du Rhône (CNR); BRL Ingénierie (BRLi); and Mercator Ocean.

Although SWOT is a research mission and not scheduled for launch until late 2021, work by the SWOT Applications Working Group (SAWG) to build strong engagement with the applications community began in 2014. This workshop was planned primarily for the selected EAs to understand the progress

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made on their proposed activity and to identify clear pathways to real-world societal use of SWOT data in their work.

WORKSHOP GOALS AND OBJECTIVES

The key goal for the 2019 workshop was to provide a voice for selected EAs to share their application projects involving SWOT data, their decision-making activity, to share their progress, and to highlight their concerns and future needs. This workshop aimed to bring the EAs to a focal point for collaborative learning and sharing of lessons on what has worked for exploring the utility of SWOT data, and what more can be done in the years remaining before launch.

Over the span of two days, the workshop was designed to achieve the following objectives:

1. To provide selected Early Adopters (class of 2018) an opportunity to share their SWOT-related application projects and their progress with the SWOT Mission and Science Team.
2. To facilitate peer-to-peer collaborative learning for selected Early Adopters through lessons learned in other early adopter projects.
3. To provide hands-on training on cloud computing to train Early Adopters on a freely available cloud-computing platform (such as Google Earth Engine) to process, analyze and make decisions using massive amounts of satellite data in the cloud. [Note: *This objective is designed to acclimatize EAs to NASA's Physical Oceanography Distributed Active Archive Center (PO.DAAC), which will jointly host SWOT data products with the CNES data center, and their plans for hosting SWOT data on a cloud-computing platform*.]
4. Introduce Early Adopters to SWOT-like data on water elevations.
5. To identify concerns and needs of Early adopters for successful completion of their projects.
6. To document the activities and outcomes of the workshop into the broader Earth science-interested community and identify strategies in near future to maximize the societal relevance of SWOT mission and its data.

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Figure 1. Group picture of Early Adopters and other participants at the 2nd SWOT Early Adopter Workshop, CNES HQ, Paris, May 20-21, 2019.

AGENDA

DAY 1: Monday, 20 May 2019

1-1	Intro/Welcome/Objectives	**Alice Andral (CNES), Margaret Srinivasan (JPL), Faisal Hossain (UW), Ed Beighley (NEU)**
Introductory Remarks		
1-2	NASA Applied Sciences Program and CNES SWOT downstream program Status of SWOT mission	**CNES – Alice Andral for Selma Cherchali** **NASA ASP – Brad Doorn** **SWOT Project CNES & NASA – Thierry Lafon/Parag Vaze**
1-3	Applications: Where are we now?	**SAWG Leads – Faisal Hossain, Alice Andral, Ed Beighley, Margaret Srinivasan**
Hearing from our Early Adopters		
1-4	SWOT Early Adopter Project-1	**Susantha Jayasinghe- ADPC**
1-5	SWOT Early Adopter Project-2	**Laurent Tocqueville - BRLi**

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1-6	SWOT Early Adopter Project-3	**Guillaume Valladeau – CLS *(Webex)***
1-7	SWOT Early Adopter Project-4	**Sébastien Legrand - CNR**
1-8	SWOT Early Adopter Project-5	**Indu Jayaluxmi - IIT**
1-9	SWOT Early Adopter Project-6	**Yasir Kaheil - FM Global**
PO.DAAC Activities		
1-10	PO.DAAC Cloud EA Services Roadmap	**Catalina Oaida (JPL)**
1-11	PO.DAAC – Currently Available Services & Data	**Jessica Hausman (JPL)**
Hands On – Introduction to Google Earth Engine		
1-13	Introduction to Google Earth Engine	**Matt Bonnema (UW)**
Discussion		
1-14	• What questions will SWOT answer in your process, workflow or organization? • Will SWOT supplement an information stream or product that exists, or will it replace?	
Closing		
1-15	Recap, Objectives for Day 2	**Margaret Srinivasan (JPL), Alice Andral (CNES), Faisal Hossain (UW), Ed Beighley (NEU)**

DAY 2: Tuesday, 21 May 2019

2-1	Outline plans for the day	**Margaret Srinivasan (JPL), Alice Andral (CNES), Faisal Hossain (UW), Ed Beighley (NEU)**
2-2	Simulation Tools for Ocean	**Nicolas Picot (CNES)**
2-3	Estuary & coastal regions	**Benoit Laignel (M2C Rouen)**
Hearing from our Early Adopters		
2-4	SWOT Early Adopter Project-7	**Luciana Fenoglio-Marc - University of Bonn**
2-5	SWOT Early Adopter Project-8	**Bareerah Fatima – PCRWR *(Webex)***
2-6	SWOT Early Adopter Project-9	**Nicolas Picot (CNES) - Mercator Ocean**

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CNES Training Activity		
2-7	Large-scale simulator for hydrology	**Damien DESROCHES (CNES)**
2-8	Demonstration of the use of the Hydro simulator	**Damien DESROCHES (CNES)**
Hearing from our Early Adopters		
2-9	SWOT Early Adopter Project-10	**Ed Beighley - CUAHSI**
2-10	SWOT Early Adopter Project-11	**Nicholas Elmer - NASA SPoRT *(WebEx)***
Early Adopter Discussion and Feedback		
2-11	• How SWOT data could improve your organization's mission (for decision-making or research) to move in the desired direction? • What are your key risks and challenges to completing the Early Adopter project? • What your needs? What information or support do you need immediately in order to incorporate SWOT into your planning or workflow? • What do you hope to accomplish from this Early adopter project	
2-12	● Near and long term plans ● Recap	**Margaret Srinivasan (JPL), Alice Andral (CNES), Faisal Hossain (UW), Ed Beighley (NEU)**
Closing		

MAKE UP OF WORKSHOP PARTICIPANTS

Table below provides a distribution of in-person attendees according to their parent organization. A similar number of participants attended the workshop remotely via Webex.

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Agency	Name
ADPC*	Susantha Jayasinghe
BRL*	Laurent Tocqueville
CLS*	Fabien Lefèvre
CNES	Thierry Lafon
CNES	Alice Andral
CNES	Nicolas Picot
CNES	Santiago Peña-Luque
CNES	Philippe Maisongrande
CNR*	Sébastien Legrand
CUAHSI*	Jerad Bales (represented by Ed Beighley)
DLR	Sandro Martinis
FMGlobal*	Yasir Kaheil
IIT Bombay*	Indu Jayaluxmi
IRSTEA	Hind Oubanas
Mercator-Ocean*	Pierre-Yves Le Traon (Represented by Nicolas Picot)
Meteo-France	Patrick Le-Moigne
NASA HQ	Bradley Doorn
NASA JPL	Parag Vaze
NASA JPL	Shailen Desai
NASA JPL	Jessica Hausman
NASA-JPL	Margaret Srinivasan
NASA-JPL	Catalina Oaida
NASA SPoRT*	Nicolas Elmer
Northeastern University	Ed Beighley
PCRWR-Pakistan*	Bareerah Fatima
University of Bonn*	Luciana Fenoglio-Marc
University of Rouen	Benoit Lagnel
University of Washington	Faisal Hossain
University of Washington	Matthew Bonnema

* Early Adopter

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WORKSHOP PREPARATION

In order to maximize the effectiveness of the workshop and the chances of fulfilling the workshop objectives, organizers worked closely with many Early Adopters to explain the purpose and specific expectations. Each EA was provided with a presentation template to follow to efficiently summarize their progress and provide relevant details and information. The goal of this template was to help EAs focus on the key issues that organizers and the SAWG require in order to understand individual EA organization needs. EAs were mentored 1-1 by SAWG leads in the process and were encouraged to think carefully about the issues in advance of the workshop. In particular, EAs were requested to prepare thoughtful responses to the following questions so that they could provide ample feedback during the discussion sessions. The templates contained the following points:

- What questions will SWOT answer in your process, workflow or organization?
- Will SWOT supplement an information stream or product that exists, or will it replace?
- Are you able to assess a potential value to your work process if SWOT fulfills its mission requirements (low, medium, high, unknown, or a monetary value?)
- What information or support do you need immediately in order to incorporate SWOT into your planning or workflow?
- In what ways do you think the use of SWOT data products might be able to improve your organization's mission (for decision making or research) to move in the desired direction?
- Are you using SWOT proxy or other datasets? Which one(s)? How are you using this information to advance your understanding of how SWOT will benefit your organization?

EAs were also encouraged to think strategically about their projects and where they would like to take their project as a successful outcome in the end. For sharing strategic plans, EAs were share the following guidance in advance of the workshop:

- What are your key risks and challenges to completing the Early Adopter project?
- What are your needs? (Do not be shy! Please ask what you think will help your agency)
- What do you hope to accomplish from this Early Adopter project?
- How do you plan for your agency to get ready for SWOT data to improve decision making or existing applications after launch in 2021?

An innovative EA engagement strategy was introduced at the workshop. Each EA was requested to imagine desired future press releases or newspaper headlines that their project might bring about. This

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could be an outcome of their use of SWOT data that they would like to aspire to as a success story of their project. For example, an early adopter proposing to assess SWOT data for flood management in the Mekong region may aspire to eventually report success through press coverage of a story titled *"SWOT data helps in early flood preparedness of Myanmar."* These press releases are hypothetical and their realization is dependent on numerous conditions beyond the control of the EA. However, the workshop organizers felt that this was a good way to design a project trajectory for each EA, delineate a tangible goal and then work closely with EAs to realize that press release during the post-launch phase of the SWOT mission.

The exercise provided a rich, interactive experience for the EAs and the SWOT Applications team. It was also an opportunity for SWOT Project participants to understand the scope of potential outcomes that could result from their dedicated technical and engineering work to build and launch SWOT.

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WORKSHOP KICK-OFF

WELCOME SESSION

The workshop kicked off with SAWG leads presenting a welcome presentation titled "*Where are we now?"* SAWG leads emphasized the key objectives and goals of the workshop, highlighting that this workshop was essentially tailored *for* the EAs to give them a platform to share their progress and concerns. The welcome session was then followed by messages from Bradley Doorn (Program Manager of NASA Applied Sciences Water Resources Program), NASA SWOT Project Manager Parag Vaze, and CNES SWOT Project Lead Thierry Lafon.

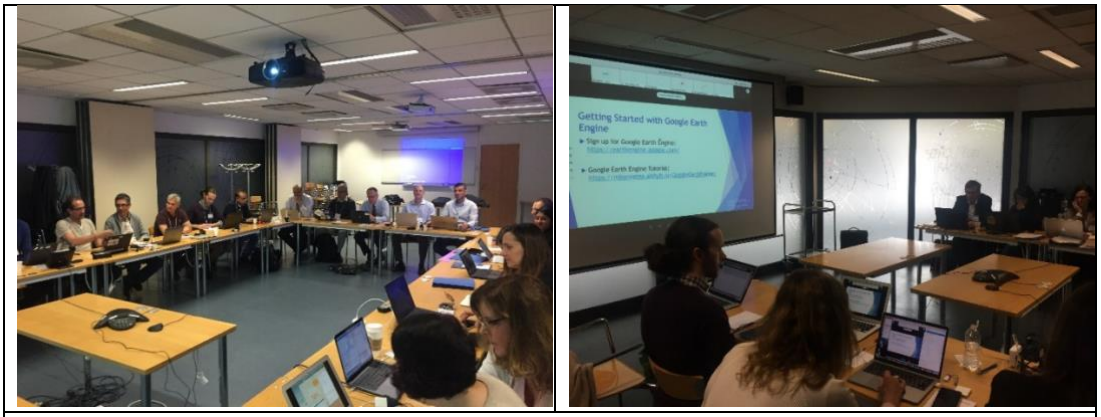

Figure 1. Left panel: Participants of SWOT Early Adopter workshop; Right panel: tutorial on Google Earth Engine being delivered for SWOT Early Adopters.

SWOT PROJECT CONTRIBUTION

To complement background information provided earlier in the workshop on SWOT capabilities and data and measurement systems, members of the SWOT Science Team (ST) provided summary information on some topics relevant to the EA community. A summary of plans and status of a SWOT ocean data simulation tool was provided by Nicolas Picot and Gérald Dibarboure of CNES. This simulator will provide a platform for the Project to test algorithms and to streamline processing and methods of data access. Similarly, a demonstration was shared by CNES on an open-source SWOT hydrology data simulation tool by CNES's Damien Desroches. Estuary and coastal regions are among the most affected by both human impact and by climate change. With over 50 percent of the world population living within 100 kilometers of the shoreline, the value of global, high spatial resolution coverage that SWOT will provide is of high interest and value. Benoit Laignel of the University of Rouen, France, presented several projects he is working on as a SWOT ST member to provide decision-makers with tools for monitoring coastal zones.

PROGRESS UPDATES BY EARLY ADOPTERS

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In the next session, early adopters presented an update on their proposed activity. Below we present the summary of the project update by each EA with a summary of responses to questions the EA was asked to consider beforehand.

ASIAN DISASTER PREPAREDNESS CENTER (ADPC)

Title: Plugin SWOT to Enhance Water Resource Management in Lower Mekong Region
Leads: Susantha Jayasinghe, Technical Specialist-ADPC***;*** Chinaporn Meechaiya, Hydrologist-ADPC

Summary: ADPC has embarked on assessing the value of SWOT for improving water management in Lower Mekong countries. In particular, ADPC aims to address the value added by SWOT in four types of applications: 1) Enhancement of an altimetry-based virtual stream monitoring network with SWOT; 2) Enhancing web-based water accounting at the basin level; 3) Improve regional drought prediction and monitoring through SWOT data assimilation; 4) Improving hydrologic model-aided satellite altimetry flow forecasting with SWOT data.

What questions will SWOT answer in your process, workflow or organization?

Can SWOT Enhance Water Resource Management in Lower Mekong nations

Can SWOT improve water availability/flow forecasting?

Can SWOT data assimilation in RHEAS improve drought management?

What is the improvement with the use of SWOT data in resource (water-agriculture) management in terms of skill, longer lead-time, faster response time in decisions?

Which countries in Lower Mekong might be bigger beneficiaries of SWOT?

Will SWOT supplement an information stream or product that exists, or will it replace?

No

What are your key risks and challenges to completing the Early Adopter project?

Lack of access to SWOT simulated data and lack of access to adequate training on handling data

What are your desired future press releases for project success?

"SWOT Helps Supporting Early Flood Preparedness in Myanmar"

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NASA SHORT-TERM PREDICTION RESEARCH AND TRANSITION (SPORT) CENTER

Title: Assimilation of SWOT WSE to Improve National Water Model Initialization and Streamflow Prediction

Leads: Nicholas Elmer (NASA SPoRT / Univ. Alabama in Huntsville)***;*** Christopher Hain (NASA SPoRT / NASA MSFC)

Summary: NASA SPoRT is exploring the transition of NASA satellite capabilities to operational forecasters and operational models. For the EA project, the SPoRT project will develop a methodology to assimilate SWOT water surface elevation (WSE) into the National Water Model (NWM) to expand the spatial coverage of observations to regions of the world without adequate in situ streamflow information. In order to use SWOT data to initialize the NWM, case studies will be examined within Alaska related to rain-generated flooding events. First synthetic SWOT data will be assimilated into WRF-Hydro followed by simulated SWOT data

What questions will SWOT answer in your process, workflow or organization?

Do SWOT measurements provided value-added impacts in basins where in situ gauge networks exist?

Will the assimilation of SWOT water surface elevations provide measurable improvements to National Water Model performance?

Will SWOT supplement an information stream or product that exists, or will it replace?

SWOT will supplement the current information stream through assimilation

What are your key risks and challenges to completing the Early Adopter project?

Lack of access to SWOT simulated data and lack of access to adequate training on handling data. A hydrology simulator that accounts for error sources beyond random noise (e.g., topographic and vegetation layover) would be beneficial.

More accurate estimates of channel geometry/bathymetry are needed, both from measurement perspective and model perspective

What are your desired future press releases for project success?

"Assimilation of SWOT data improves forecasting skill of NOAA National Water Model"

"SWOT Follow-on Mission in development after successful use of SWOT data in operational forecasting"

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PAKISTAN COUNCIL OF RESEARCH IN WATER RESOURCES (PCRWR)

Title: SWOT applications for determining water surface area change to manage highly regulated transboundary rivers and artificial wetland management

Leads: Bareerah Fatima PCRWR (Pakistan Council of Research in Water Resources), Islamabad, Pakistan;

Summary: This project will use SWOT-relevant data products to enhance the quality of transboundary flow monitoring, river flux at the outflow points of trans-boundary for improving flood management in Jhelum basin This will allow for early preparation by downstream dam operator and inhabitants. For delineating and management artificial wetlands, SWOT-based model simulations will be created for southern Pakistan, Sindh Province. Ground data will be used for calibration/validation of the water inundation simulation. Once a simulation is created, SWOT-like products will be connected whenever available to gain monthly/cross seasonal variations in the wetlands developed on waterlogged soil.

What questions will SWOT answer in your process, workflow or organization?

Can SWOT provide a complete and trustworthy package ranging from trans-boundary river flow monitoring to water use in agriculture and climate impacts in water consuming sectors?

Will SWOT supplement an information stream or product that exists, or will it replace?

SWOT will create a new information stream, a new service (such as proactive management of Mangla reservoir) and in other cases supplement the traditional hydrologic data

What are your key risks and challenges to completing the Early Adopter project?

Lack of understanding SWOT mission skill prior to launch.

Lack of access to SWOT simulated data for hydrologic applications in steep and narrow rivers subject to layover

What are your desired future press releases for project success?

"SWOT data enables popular and blameless management of waterlogging in Sindh Province of Pakistan"

"SWOT Data helps in rationalizing irrigation supplies while preventing loss of land to waterlogging"

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INDIAN INSTITUTE OF TECHNOLOGY – BOMBAY (IITB)

Title: Examining the potential of SWOT mission in Hydrometeorology over India

Lead: Jayaluxmi Indu, Associate Professor, IIT Bombay

Summary: In order to derive weekly/monthly estimates of river discharge, this project will use data assimilation to generate continuous fields of SWOT-relevant observables by merging them with model predictions. This will provide hydrologic information in areas where SWOT data gaps will prevent direct observation. The research objectives of this project are;

1. Evaluate various data assimilation (DA) techniques on synthetic SWOT measurements to generate improved SWOT observables
2. Uncertainty quantification of SWOT orbital data products
3. Using SWOT measurements for the creation of a data inventory towards flood forecasting for different hydro-climatic scenarios

What questions will SWOT answer in your process, workflow or organization?

Can SWOT improve urban flood inundation modeling and forecasting for cities in India?

What is the optimal way to assimilate SWOT data for river flow and reservoir modeling in Mahanadi river system?

Can data size and its processing negatively impact flood forecasting lead-time?

Will SWOT supplement an information stream or product that exists, or will it replace?

SWOT will supplement the current information stream through assimilation of the data in hydrologic and hydraulic models. SWOT will also improve the space-time frequency of the information availability.

What are your key risks and challenges to completing the Early Adopter project?

Lack of access to SWOT simulated data at hydrologically relevant scales that simulates layover due to steep topography and realistic error characteristics in humid basins.

What are your desired future press releases for project success?

"SWOT data improves reservoir outflow forecasting to reduce downstream flood risk in Kerala"

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UNIVERSITY OF BONN

Title: Monitoring estuaries and coastal zone with SWOT

Lead: Dr.-Ing. habil Luciana Fenoglio, University of Bonn, Institute of Geodesy and Geoinformation

Summary:

The proposed activity aims to investigate the new SWOT data to study the ocean processes at different scales from regional (North Sea and Baltic Sea) to coastal/estuarine/tidal inlets and along the German coasts. In the 1-day phase data calibration will be attempted and the high temporal and space variability investigated over ocean and in-land water. The synergy between SWOT observations and in-situ, model simulation and SAR altimeter data will be further used in the following science phase to improve the actual understanding of physical phenomena. The modelling tool will be based on the high spatial and temporal-resolution integrated coupled (ocean, wave, sediment transport and hydrology) model system GCOAST for river-to-ocean continuum scales

What questions will SWOT answer in your process, workflow or organization?

How well can SWOT capture the high spatial and temporal variability of estuarine processes during the SWOT fast sampling phase?

What type of synergies can be built between SAR and SWOT during the SWOT science phase and how can that inform coastal city vulnerability?

Will SWOT supplement an information stream or product that exists, or will it replace?

SWOT will augment the current information stream through assimilation of the data over estuarine regions

What are your key risks and challenges to completing the Early Adopter project?

Lack of access of high-resolution SWOT simulator tailored for coastal and estuarine regions.

Lack of guidance on the use of SWOT data and its data products

What are your desired future press releases for project success?

"SWOT helps in predicting the 100 year event of Elbe water level extremes from Hamburg City to coast

"Small scales dynamics in ocean circulation in Danish Straits"

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CONSORTIUM OF UNIVERSITIES FOR ADVANCEMENT OF HYDROLOGIC SCIENCE (CUAHSI)

Title: Connecting the water science community to SWOT

Leads: Dr. Jerad Bales, Executive Director, CUAHSI

Summary:

Building on CUAHSI's Water Data Services, CUAHSI, in collaboration with the SWOT Science Team (ST), Applications Working Group (SAWG) members and NASA PO.DAAC representatives, will explore optimal methods for: (i) hosting of available synthetic SWOT data products, and (ii) enabling web services for exploring available synthetic SWOT data products and subsetting non-SWOT datasets (e.g., in-situ or simulated water surface elevations, water extents, and river discharges for lakes and rivers) to reflect the space/time sampling characteristics of SWOT. Corresponding SWOT data product uncertainties will also be included based on findings and simulator developments from the SWOT ST. The subsetting web services are primarily intended to help users explore SWOT's space/time sampling within their river basin(s) prior to launch.

What questions will SWOT answer in your process, workflow or organization?

Can SWOT data can fill in gaps to provide a more complete inventory of the state of water bodies (lakes, rivers) as standardized data products for CUAHSI?

Can SWOT data improve granularity of hydrologic data?

Can SWOT data improve visibility of CUAHSI services for hydrologic data for the community?

Will SWOT supplement an information stream or product that exists, or will it replace?

SWOT will add new data streams and improve existing data products for CUAHSI in terms of space-time coverage

What are your key risks and challenges to completing the Early Adopter project?

Depending on size of NASA products and the extent of pre- and post-launch adoption, some cyber-infrastructure challenges may arise, especially if SWOT products are offered as services upon which operational forecasts are dependent.

Depending on size of NASA products and the extent of pre- and post-launch adoption, some cyber-infrastructure challenges may arise, especially if SWOT products are offered as services upon which operational forecasts are dependent.

What are your desired future press releases for project success?

"The National Water Model skill improves with SWOT data"

"National Water Model now assessable at 72,000 km of streams in the U.S. rather than at 8,000 individual points."

"Demand for CUAHSI workshops on use of SWOT streamflow products are in high demand."

Some of this work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

FM GLOBAL

Title: Calibration of hydrologic and hydraulics models used for flood hazard mapping using synthetic SWOT data products

Leads: Dr. Yasir Kaheil, Staff VP, Principal Research Scientist

Summary: FM Global plans to make incremental assessments of synthetic SWOT data products to: (i) ensure they meet suggested accuracy and uncertainty expectations, (ii) fully understand the unique space-time sampling impacts, (iii) quantify how they may add value to local/regional hydrologic and hydraulic understanding, and (iii) integrate relevant data products into the flood mapping workflow if needed. Case studies will be explored in collaboration with SWOT Science Team and Applications Working Group member, Ed Beighley-Northeastern University, to address the above.

What questions will SWOT answer in your process, workflow or organization?

Can SWOT data be effective in flood risk reduction and minimize losses?

How much can SWOT support extreme event forecasting using models?

How can SWOT be helpful in global water management?

Can SWOT improve understanding of trends in vulnerability of cities to coastal inundation and storm surge?

Will SWOT supplement an information stream or product that exists, or will it replace?

SWOT will supplement the current information stream through assimilation

What are your desired future press releases for project success?

"Assimilation SWOT data Improves Flood Forecasting Skill in the Mississippi"

"Near real-time SWOT data helps insurance field engineers prioritize their visits after Hurricane"

Some of this work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

COLLECTIE LOCALISATION SATELLITES (CLS)

Title: SWOT data to be included in a Water Resources

Leads: Fabien Lefèvre, Guillaume Valladeau

Summary: CLS collects analyses and disseminates satellite hydrological parameters to provide databases and services monitoring surface water and natural resources based today on remote sensing observations and in situ data. CLS works also on numerical modelling data. It develops also management tools and databases for hydrological parameters, hydrological monitoring and in the future plans to include forecasting services. CLS will integrate SWOT data in the Hydroweb database and plans to use SWOT data for validation and calibration of numerical models.

What questions will SWOT answer in your process, workflow or organization?

How does catchment size impact the assimilation of SWOT data for water management?

Can SWOT facilitate “fair & transparent” management of water resources in large and transboundary river basins

Will SWOT supplement an information stream or product that exists, or will it replace?

SWOT data will be included in a Water Resources Management System of a River Basin with Satellites in situ and Numerical Modeling technologies

What are your key risks and challenges to completing the Early Adopter project?

Getting at least one year of simulated SWOT to be compared to numerical model and in situ data

Accessing the data at least one year before the launch of SWOT

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COMPAGNIE NATIONALE DU RHÔNE (CNR)

Title: Examining the potential of SWOT in hydropower and navigation

Leads: Sébastien Legrand

Summary: Since 1933, based on the concession received by French Government, CNR has been developing the Rhone River according to three core missions: hydropower generation, inland navigation and irrigation. CNR is particularly interested in ungauged basin/river and long time series of water level that could be made available to end users thanks to SWOT. CNR already uses altimetry data to develop operational applications in the field of water resources management, hydropower potential assessment and navigation forecasting. CNR plans to assess the value of SWOT data in ungauged and transboundary basins for improving navigation and hydropower assessment

What questions will SWOT answer in your process, workflow or organization?

Can SWOT be a complementary data to CNR's hydrometric database?

What is the added value of SWOT data for improving navigation and assessment hydropower potential be determined (such as for Congo)?

Will SWOT provide data at current virtual stations that will be comparable with current data?

Will SWOT supplement an information stream or product that exists, or will it replace?

SWOT will supplement the current information stream through assimilation

What are your key risks and challenges to completing the Early Adopter project?

Lack of access to SWOT simulated data at high resolution for hydrologic studies

What are your desired future press releases for project success?

"Near real-time SWOT data improves navigability prediction and integrated resources water management on the Sangha River"

"SWOT data help mapping potential sites for hydropower projects in the Congo basin"

Some of this work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration

BRL Ingénierie (BRLi)

Title: Toward a better water resources management with altimetry and SWOT mission

Leads*:* Damien Brunel, Laurent Tocqueville, Stéphane Delichère

Summary: BRLi is a consulting firm that specializes in areas related to water, the environment and regional planning, providing design and construction engineering, management services, integrated water resource management, hydraulic, port and navigation infrastructures, protection of the environment and coastal areas and natural risk management. BRLi is part of the French working group on Space Hydrology lead by CNES, AFD – the French development agency and IOWater. This groups aims to promote the use of space data in hydrology and to prepare the use of SWOT data. In this project, BRL will explore the value of SWOT is particularly interested in ungauged basin/river to help basin's holder to have a better water resources management. It also has applications on navigations and flooding maps and forecast.

What questions will SWOT answer in your process, workflow or organization?

How can temporal frequency of SWOT data be managed with model-driven estimation of flow using more frequent satellite observations?

Can SWOT improve navigation (Congo River) and reservoir management (Ethiopia)?

Will SWOT supplement an information stream or product that exists, or will it replace?

SWOT will supplement the current information stream through assimilation

What are your key risks and challenges to completing the Early Adopter project?

Lack of access to SWOT simulated data at high resolution for hydrologic studies

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Mercator Ocean

Title: Assimilation of SWOT in the Mercator Ocean analysis and forecasting systems

Leads: Pierre-Yves Le Traon

Summary: In routine or in real time, on a global or regional scale, both on the surface and beneath it, Mercator Ocean describes, analyses and forecasts the state of the ocean by developing the "Mercator System" for ocean analysis and forecasting and maintaining it in an operational condition. Mercator Ocean is the entrusted entity to implement the Copernicus Marine Environment Monitoring Service. Mercator Ocean prepares the assimilation of SWOT data in the Mercator Ocean analysis and forecasting systems. It plans to combine SWOT, nadir altimeter, other satellite data (SST, Ocean Color) and in-situ data with high-resolution global models to allow a dynamical interpolation of SWOT data and to describe and forecast the ocean state worldwide.

What questions will SWOT answer in your process, workflow or organization?

How will SWOT data improve Copernicus Marine Service and its Applications?

What are the demonstrable impacts of ocean application with the SWOT data integration in Copernicus Marine Service Sea Level assembly center?

Will SWOT supplement an information stream or product that exists, or will it replace?

SWOT will supplement, improve or innovate new information streams

What are your key risks and challenges to completing the Early Adopter project?

Capability for near real time processing of SWOT data (< 2 days).

Ensuring consistency with other altimeter missions (S3, S6/Jason-CS). Including cross calibration methods to be applied in near real time.

Preparing of the assimilation of SWOT data in very high-resolution models.

What are your desired future press releases for project success?

"Hosting of SWOT data in Copernicus Marine Service doubles the number of operational ocean applications involving SWOT and other types of ocean data."

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CLOUD COMPUTING TUTORIAL USINGGOOGLE EARTH ENGINE

SWOT mission will produce massive amount of data every day after launch in the terabyte scale. The lower level data will need further processing to make the data analysis ready for users, particularly the EAs. Because of this, SWOT data is planned for hosting on a cloud-computing platform so that data download time and cost can be minimized. Google Earth Engine (GEE) is one such cloud computing platform that is becoming increasingly popular for geospatial datasets. For the EAs, SAWG member Matthew Bonnema delivered a hands-on introduction to GEE.

The entire session was designed as a 2.5-hour easy-paced tutorial session comprising the following modules:

- Introduction to cloud computing and Google Earth Engine
- Live test of cloud computing capabilities
- Hands on Google Earth Engine tutorial
- Review of SWOT concepts
- Google Earth Engine Demos: SWOT like data in Google Earth Engine
- Google Earth Engine Demos continued
- Wrap up

By the end of the session, each EA was expected to have learned:

1. Basic concepts of geospatial cloud computing for satellite data analysis
2. How to navigate SWOT like data in Google Earth Engine cloud computing environment

Four examples relevant to SWOT hydrologic application were demonstrated, and the EAs were coached to replicate the process to complete each example on GEE. SWOT-like example datasets were made for locations such as the Mekong River basin, Oroville Reservoir in California, flooding in coastal Mozambique and the Barak River on the India-Bangladesh border using SWOT sampling overlaid on SAR water extent imagery. The cloud computing session ended with positive feedback from EAs with the following conclusions:

1. Cloud computing is a powerful tool for big satellite data analysis like SWOT [for SWOT data, cloud computing is almost a necessity]
3. Google Earth Engine is an accessible cloud-computing platform for satellite data analysis
4. SWOT-like observations can be created by combining observations from different sources on Google Earth Engine

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WORKSHOP DISCUSSION

COMMON UNDERLYING NEEDS OF EARLY ADOPTERS

EAs were candid in their response to the question about progress—specifically when asked; "*What are your needs? What information or support do you need immediately in order to incorporate SWOT into your planning or workflow?"* While all EAs did not indicate a need for resources or other financial support per se, they did indicate a range of needs on guidance, data, and engagement. Based on feedback shared by EAs, the following key underlying needs emerged as common to all EAs:

1. EAs need simulated SWOT data for hydrology application that mimics the real-world geophysical, spatial and temporal constraints of SWOT observation due to topography, climate and vegetation.
2. EAs need clear and timely meta data information on SWOT data products now to begin their project if they are to use SWOT simulated (or actual) data properly and get acclimatized to actual SWOT data after launch.
3. Many EAs require engagement support to visit a research center/collaborator relevant to SWOT mission that can allow them to engage in weeklong immersive training to solve the specific application problems.
4. Many EAs require online training programs and tutorials/webinars on how to handle SWOT data. In this case, NASA Applied Remote Sensing Training (ARSET) program, CUAHSI, or the training programs of JPL PO.DAAC and CNES should be tailored for SWOT EAs.
5. EAs would benefit from SWOT-specific "hackathons for Early Adopters" to rapidly prototype solutions for their EA project, particularly for tricky components that require team-based thinking. Such hackathons could cater to specific tools that EAs are planning to build for their project and should use proxy data if necessary as a proof of concept. For example, the PO.DAAC Cloud Early Adopter program with SWOT Application Working Group leads could potentially guide EAs on building a prototype of the SWOT data-based solution.

KEY RISKS OR CHALLENGES OF EARLY ADOPTER PROJECTS

From the discussions, a clear pattern emerged on the critical challenges that EAs face for the successful completion of their project. These can be summarized as follows:

1. Current lack of access to simulated SWOT data for hydrologic application over river basins with steep topography, vegetation and humid climates, that represent realistic limitations of measurement and spatial and temporal sampling;
2. Need for adequate skill or training in handling SWOT data;
3. Continued guidance/engagement from SAWG and ST for troubleshooting problems as they happen.

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FUTURE IMAGINED PRESS RELEASES

When it came to discussing the question, "*What do you hope to accomplish from this Early adopter project?"* the key points could essentially be repackaged as future "press releases" that each EA aspired to after successful completion of their project. In other words, these press releases are future newspaper or magazine headlines that each EA could aim for after successful completion of their project. Below, the press releases offered by EAs are summarized with fictitious newspaper/magazine titles and year.

- **Bangkok Times July 2023** - *SWOT helps supporting early flood preparedness in Myanmar (ADPC)*
- **DAWN Newspaper September 2023** - *SWOT data enables popular and blameless management of waterlogging in Sindh Province of Pakistan (PCRWR)*
- **New York Times January 2023** - *SWOT data helps in rationalizing irrigation supplies while preventing loss of land to waterlogging (PCRWR)*
- **Hindustan Times August 2023** – *SWOT data improves reservoir outflow forecasting to reduce downstream flood risk in Kerala (IIT-Bombay)*
- **EOS- AGU July 2022**- *The NOAA National Water Model forecast accuracy is improved*
- **EOS-AGU December 2025**- *Demand for CUAHSI workshops on use of SWOT streamflow products are in high demand*
- **Le Monde April 2023**- *SWOT data improves navigability prediction and integrated resources water management on the Sangha River (CNR)*
- **Le Figaro December 2022**- *SWOT mission improves mapping of potential sites for hydropower projects in the Congo basin (CNR)*
- **EOS- AGU July 2022**- *Assimilation of SWOT data improves forecasting skill of NOAA National Water Model (NASA-SPoRT)*
- **EOS-AGU -July 2024** - *SWOT follow-on mission in development after successful use of SWOT data in operational forecasting (NASA-SPoRT)*
- **EOS-AGU** - *SWOT helps in predicting the 100-year event of Elbe water level extremes from Hamburg City to coast (UniBonn)*
- **EOS-AGU** - *Small scales dynamics in ocean circulation in Danish Straits (UniBonn)*

POLLING OF FUTURE PRESS RELEASES

Assuming that all future "press releases" were achievable through very close mentorship from the SAWG leads, these press releases were subjected to a vote by workshop participants for prioritization for future action by SAWG leads. It would make most sense to tackle those EA projects that are more likely to result in a post-launch press release success story for SWOT mission and then focus on the rest as time permits. Each workshop participant therefore chose

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their three favorite press releases that they thought were most feasible and important to show the unique value of SWOT. The top three most popular future press releases were:

1st place. EOS-AGU, July 2022- *Assimilation of SWOT data improves forecasting skill of NOAA National Water Model (by NASA SPoRT)*

2nd place. **Bangkok Times July 2023** - *SWOT helps supporting early flood preparedness in Myanmar (by ADPC)*

3rd place (tie). DAWN Newspaper, September 2023 – *SWOT data enables populate and blameless management of waterlogging in Sindh province of Pakistan (by PCRWR)*

3rd place (tie). EOS-AGU, July 2022- *SWOT follow-on mission in development after successful use of SWOT data in operational forecasting (by NASA SPoRT)*

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KEY RECOMMENDATIONS

The 2019 Early Adopter workshop revealed many insightful findings related to EA projects, their needs, their potential hurdles, perceptions and concerns. Through the discussions with SAWG leads and SWOT project participants many issues were discussed further. Based on the proceedings over the two-day period, comprising 11 EA project presentations, tutorials and interactive discussions, the following are the recommendations for the SWOT Science and Applications community:

1. SWOT hydrology simulated datasets that represent accurate performance characteristics due to geophysical constraints (lay-over, vegetation, dark water, spatial and temporal sampling) and follows the SWOT data product definition need to be made available urgently to EA for their projects on an urgent basis.
2. A faster SWOT simulator, such as the one being developed by CNES, is an acceptable start and can help EAs acclimatize to SWOT data product structure. Such a simulator can be useful for large water bodies (lakes and reservoirs) in flat terrains.
3. The SAWG and the EA community would benefit from additional online resources for tutorials on a) cloud computing using platforms such as Google Earth Engine; b) explanation of SWOT mission, how it works and its data type; c) collection of existing tools and datasets that may be relevant to SWOT for the EA projects.
5. SAWG leads should consider organizing hackathons for SWOT EA projects to solve specific hurdles and build tangible solutions. The EA projects are now gradually maturing and will likely need to start using high resolution SWOT simulated data soon for complete the first run of proof of concepts for next year's reporting. This means that hackathons tailored to solve specific problems of EA projects enable rapid prototyping of solutions is now timely.
6. Programs that encourage deeper engagement for EAs at academic or research centers for immersive learning or training in USA/France would benefit EA organizations and future SWOT user communities. Such immersive learning could be a crucial part of the EA project in gaining problem-specific understanding for an EA and co-developing solutions. For example, a week-long training designed for a specific EA to learn about the cloud computing solutions for his/her problem in the USA is an example of immersive learning.
7. Close and more frequent mentoring support for EAs is needed as their projects mature and they begin facing new challenges with data structure and use. EAs will continue to require guidance, pointers on data access, and with queries on data structure/handling. Optimal support of EAs will set a good precedent to maximize the user readiness of SWOT data after launch.
8. Solicit brief (two page) proposals from the top three press releases and their EAs for more details on how an EA would go about making them a reality. These proposals should be reviewed by a SAWG panel and followed up further with the EAs. The proposals that appear most likely feasible should receive prioritization by SAWG leads for more frequent mentorship support and guidance tailored towards maximizing EA project success for a press release.

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9. SAWG leads should identify any major application areas that are not yet represented in the class of 2018 and explore how to fill them in the next cohort. For example, private consulting firms, water utilities, fisheries management, coastal/estuarine management could be areas that could make SWOT application effort more complete. It is understood that the EA program is an unfunded activity and therefore not all agencies or entities can be adequately supported for their needs.
10. SAWG community should explore with EAs how data continuity of other satellite observations (such as altimetry, SAR, Landsat, mass change) can be made available with SWOT data to enable users to explore historical trends.
11. Using studies published in the recent past during the SWOT Science Team (ST) phase, specific products or capabilities of SWOT that are truly groundbreaking should be summarized in a brief document. This information could be useful for the SWOT project to justify mission continuity. For example, there are studies that have documented 'how much will SWOT see for rivers' from a global standpoint that is not possible in the pre-SWOT era.
12. The availability and download functionality of the SWOT data is a key issue for users. PO.DAAC will distribute SWOT products on the Amazon cloud. CNES will have a multi-satellite platform. However, data volume will impose on-line processing constraints. The question on how to link PO.DAAC / CNES solutions with existing cloud computing tools for users (for example Google Earth Engine for instance) is an open issue that needs further exploration.

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FUTURE PLANS

In closing, the 2019 Early Adopter workshop was a successful engagement of our EA community and the SWOT Project and science communities. The proactive mentoring and encouragement to pre-consider key issues yielded clear and extensive feedback for SAWG to plan strategies forward for each EA. The recommendations highlighted in the previous section have provided a clear path forward for building tangible societal applications with SWOT data for the EAs. Thus, in the near-term (within the next year), the following comprises the plan for the SAWG Leads:

1. Continue supporting our EAs as closely and as frequently as possible as honest brokers of science and the mission objectives.
2. Organize one hackathon for EAs to solve a specific problem and build an application. An online version of a hackathon may be considered.
3. Support immersive training or learning experiences for candidate EAs on a case-by-case basis at a research/academic center to accelerate progress on the EA project.
4. Investigate potential coordination with ARSET, PO.DAAC, CUAHSI and THEIA on creating more online/virtual resources for training on SWOT mission, datasets and ancillary missions and tools.
5. Solicit brief proposals (two pages) on “How to achieve the Press Release Title” from the top three voted EA projects. Repeat this exercise in future years for the other EA projects according to available bandwidth for SAWG leads.
6. Publish outreach or public communication articles on SWOT Early Adopter program
7. Initiate quarterly telecons for EAs for more opportunities to open communications (see #1)
8. Organize the 2020 annual workshop for Early Adopters.

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