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PACE Vicarious Calibration Plan

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Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and
Space Administration

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PACE Vicarious Calibration Plan

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Preface

This document is under Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) Mission configuration control. Changes to this document require prior approval of the PACE Configuration Control Board (CCB) Chairperson or designee. Submit proposed changes to the PACE Configuration Management Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

Change History Log

Revision	Effective Date	Description of Changes (Reference the CCR & CCB/ERB Approval Date)

Table of TBDs/TBRs/TBSs [optional]

Action Item No.	Location	Summary	Individual/ Organization Actionee
TBR	Section 2.1	Systematic uncertainty allocations. Listed for information only.	Proj Sci; just needs to be updated as L1/L2 requirements get updated.
TBR	Section 2.3.2.1	SVC instrument system calibration strategies and data processing algorithms.	Proj Sci / SDS / SVC Team; updated when SVC Team selected.
TBR	Section 2.3.2.2	SVC site selection.	Proj Sci / SVC Team; updated when SVC Team selected.
TBR	Section 2.3.2.3 and 2.4	SVC interaction and deployment schedule.	Proj Sci / SDS / SVC Team; updated when SVC Team selected.
TBD	Section 2.4	SVC Team participation in mission reviews.	Proj Sci / Prog Sci / SDS / SVC Team; updated pre-CDR.

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1 INTRODUCTION

1.1 Purpose and Scope

This document describes the technical approach for vicarious calibration of the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission's Ocean Color Instrument (OCI). Its scope encompasses the necessary technical capabilities of a PACE vicarious calibration system, the necessary interactions between the Vicarious Calibration Team and the PACE Project, and the general vicarious calibration method to be applied to OCI. While the PACE Project is not required to vicariously calibrate HARP-2 and SPEXOne, the technical approach described in this Plan can be adopted by these instruments without modification and will be used to study and evaluate their vicarious calibration on a best-of-effort basis.

1.2 PACE Mission Overview

The Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission is a strategic climate continuity mission that was defined in the 2010 document *Responding to the Challenge of Climate and Environmental Change: NASA's Plan for Climate-Centric Architecture for Earth Observations and Applications from Space* (referred to as the "Climate Initiative"). The Climate Initiative complements NASA's implementation of the National Research Council's Decadal Survey of Earth Science at NASA, NOAA, and USGS, entitled *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*.

PACE will extend the high quality ocean ecological, ocean biogeochemical, cloud, and aerosol particle data records begun by NASA in the 1990s, building on the heritage of the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS), the Moderate Resolution Imaging Spectroradiometer (MODIS), the Multi-angle Imaging SpectroRadiometer (MISR), and the Visible Infrared Imaging Radiometer Suite (VIIRS). The mission will be capable of collecting radiometric and polarimetric measurements of the ocean and atmosphere, from which these biological, biogeochemical, and physical properties will be determined. PACE data products will not only add to existing critical climate and Earth system records, but also answer new and emerging advanced science questions related to Earth's changing climate.

PACE is classified as a Category 2 mission, per the criteria in NASA Procedural Requirement (NPR) 7120.5E, NASA Space Flight Program and Project Management Requirements. The mission classification is C according to NPR 8705.4B, Risk Classification for NASA Payloads.

The PACE observatory is comprised of three instruments, an Ocean Color Instrument (OCI) and two polarimeters, the Hyper-Angular Rainbow Polarimeter 2 (HARP-2) and the Spectro-Polarimeter for Exploration (SPEXone). The OCI is the primary instrument on the observatory and is being developed at Goddard Space Flight Center (GSFC). The OCI is a hyper-spectral scanning (HSS) radiometer designed to measure spectral radiances from the ultraviolet to shortwave infrared (SWIR) to enable advanced ocean color and heritage cloud and aerosol particle science.

The HARP-2 and SPEXone are secondary instruments on the PACE observatory, acquired outside of GSFC. The HARP-2 is multi-spectral, wide swath (supporting atmospheric correction of OCI) and hyper angular (good for clouds). The SPEXone is narrow swath and hyperspectral, better for characterizing aerosol microphysical properties.

This three-instrument PACE mission has the following multiple scientific goals:

- Extending key systematic ocean biological, ecological, and biogeochemical climate data records and cloud and aerosol climate data records;
- Making global measurements of ocean color data products that are essential for understanding the global carbon cycle and ocean ecosystem responses to a changing climate;
- Collecting global observations of aerosol and cloud properties, focusing on reducing the largest uncertainties in climate and radiative forcing models of the Earth system; and,
- Improving our understanding of how aerosols influence ocean ecosystems and biogeochemical cycles and how ocean biological and photochemical processes affect the atmosphere.

The PACE satellite is planned for a launch in 2022-2023. The PACE project office at NASA's GSFC is responsible for the satellite development, launch and operations. The mission is planned for launch into a Sun synchronous polar orbit at 676.5 km with an inclination of 98 degrees and a 1 pm local ascending node crossing time. The spacecraft bus will host the OCI, HARP-2, and SPEXone instruments. The GSFC PACE Project office will oversee the mission and the development of the satellite, launch vehicle, mission operations control center, and operations. The Headquarters Program Science will separately fund the science data processing system and competed science teams, which will include field-based vicarious calibration and data product validation efforts to support the Project science team.

NASA Headquarters has directed the mission development to be guided by a Design-to-Cost (DTC) process. All elements of the mission, other than the cost, are in the DTC trade space. At the heart of the DTC process are the mission studies, performed across all the mission elements. The mission studies will be used to define appropriate approaches within and across elements while maximizing science capabilities at a high cost confidence. Mission baseline requirements development is also embedded within the DTC process, as these requirements were not established at the onset of the mission concept development. Baseline mission requirements will be a product of the mission studies and will be defined by the project office as part of the DTC process.

The PACE mission consists of four major segments: space segment (SS), ground segment (GS), science data segment (SDS), and the launch segment (LS).

- The space segment consists of the spacecraft bus, the OCI, and two polarimeters. The spacecraft and OCI are being developed and integrated at GSFC. The polarimeters are contributed instruments. The spacecraft and instruments will be integrated as the PACE observatory at GSFC.
- The GS and associated Mission Operations Center (MOC) will be developed, integrated, and operated at GSFC. The GS provides for the command and control and health and safety monitoring of the PACE observatory on-orbit, as well as ensuring the science data are accounted for and delivered to the SDS. The MOC will house the flight operations team (FOT) and is being managed by the PACE project through observatory

commissioning. After commissioning, the FOT will be managed by the GSFC Earth Science Mission Operations (ESMO) project. The MOC performs all real time operations and off-line operations functions, including planning and scheduling, orbit and attitude analysis, housekeeping telemetry data processing, monitoring/managing the spacecraft and instruments, first line health/safety for the instruments, and housekeeping archiving and analysis.

- The SDS will be located at GSFC, but managed (separately from the project) by the NASA Headquarters Earth Sciences Division. The SDS will ingest, apply calibration and science algorithms, and process the science data, provide science software development and algorithm integration, act as the science data interface to the science team, and deliver of all science data products to the NASA-assigned Distributed Active Archive Center (DAAC).
- The LS is planned for a launch vehicle to be selected and procured by the NASA Launch Services Program at Kennedy Space Center (KSC).

In addition to utilizing GSFC institutional capabilities, the project will utilize the NASA/GSFC institutional capabilities such as the Flight Dynamics Facility (FDF), Near Earth Network (NEN), Ocean Biology Processing Group (OBPG), Space Network (SN), and NASA Integrated Services Network (NISN). PACE plans to generate 3.5 Terabits of science data daily. The data are downlinked from the observatory during 12-14 daily contacts via Ka-band communications to the NEN's ground stations. The observatory will also receive ground commands and transmit real-time housekeeping telemetry via an S-band 2-way link through the NEN during nominal operations. The observatory also has the capability of receiving ground commands and transmitting real-time housekeeping telemetry, via S-Band, through the SN during critical or contingency operations.

1.3 Applicable and Reference Documentation

1. PACE Program Level Requirements Agreement (PLRA), PACE-SYS-REQ-0007
2. PACE Mission Requirements Document (MRD), PACE-SYS-REQ-0019
3. PACE Project Science Requirements Document (PSRD), PACE-SCI-REQ-0027
4. PACE Science Data Segment Performance Requirements Document (SDSRD), PACE-SDS-REQ-0088
5. PACE Project Science to Science Data Segment Interface Control Document, PACE-SCI-ICD-0012
6. PACE Science Data Segment (SDS) to Vicarious Calibration Team (VCT) Interface Control Document, PACE-SCI-ICD-0011

2 OCI VICARIOUS CALIBRATION

2.1 Vicarious Calibration Overview

The ability of an ocean color mission to meet its key science objectives depends primarily upon the quality of the ocean ecosystem, biogeochemistry, and aerosol and cloud data products that can be derived from data collected by the sensor. To produce a time series of spectral data of sufficient quality for ocean color research, the ocean color sensor must meet stringent calibration and validation data requirements for quantifying ocean color sensor performance, satisfying uncertainty requirements of the retrievals, and monitoring its stability over time. PACE science applications require highly accurate remote-sensing reflectances, Rrs(λ) (sr^{-1}). Maintaining sufficient accuracy over the lifetime of the mission requires a robust post-launch calibration program that complements the onboard calibration devices and enables routine verification of the ocean color instrument calibration while on orbit. Highly accurate *in situ* measurements of Rrs(λ) will provide the principal source of surface truth for this operational calibration activity.

Ocean color retrievals benefit from indirect calibration of the satellite ocean color radiometer performed with respect to reference *in situ* measurements of Rrs(λ). Historically, the prelaunch absolute calibrations of heritage missions have not been sufficiently accurate to support ocean color retrievals without this additional on-orbit calibration. This process is referred to as the "vicarious calibration" and, for heritage ocean color missions, as well as for PACE, it requires a dedicated system vicarious calibration (SVC) program. Broadly speaking, vicarious calibration refers to the adjustment of prelaunch calibration coefficients using spectral top-of-atmosphere (TOA) radiances predicted from *in situ* measurements through modeling of atmospheric radiative processes (by applying the same models and codes used for the standard ocean color atmospheric correction process). This assumes that all sources of variability in the radiometric response of the instrument (e.g., temporal stability and response versus scan angle) have been addressed. In practice, the outcome of SVC is the minimization of combined uncertainties resulting from satellite absolute prelaunch calibration and the specific models/algorithms applied to determine primary radiometric products (e.g., Rrs(λ)) from TOA radiance. Vicarious calibration is achieved through the collection of many high-quality, paired satellite-to-*in situ* observations. For any given satellite-*in situ* pair, different observation conditions (e.g., those related to different viewing geometries and atmospheric and marine optical properties) become a source of uncertainties in the vicarious calibration process. However, collecting many paired observations over all seasons minimizes this uncertainty, such that the time series of observations converges on single spectral vicarious calibration gain coefficients with uncertainty defined by target climate change applications of data products. For the SeaWiFS mission, this convergence required more than two years (Figure 1). One goal of the PACE mission is to minimize uncertainties in vicarious calibration gain coefficients within the first year of operation.

The PACE Program Level Requirements Agreement (PLRA) and Mission Requirements Document (MRD) provide uncertainty requirements for spectral ocean reflectances provided by OCI (with baseline requirements from the MRD reproduced here as Table 1). The Mission Requirements Document (MRD) further allocates these uncertainties to Project elements, including OCI (e.g., its Tables 2.19-1 and 2.19-2). The SVC infrastructure presented in this plan must enable vicarious calibration of at least OCI's ultraviolet to near-infrared spectral range. The current total TOA radiance systematic uncertainty budget is 2.0%, 0.5%, and 2.0% for the wavelength ranges 350-400 nm, 400-820 nm, and 865 nm, respectively, with 0.42% allocated to OCI across the 400-865 nm wavelength range [TBR]. Such a level of accuracy has been shown to be achievable with rigorous SVC that provides *in situ* radiometry collected with dedicated systems to ensure a high degree of accuracy and full traceability to SI (Système international d'unités) standards. Most heritage sensors relied on measurements made off Lana'i Hawaii by the Marine Optical BuoY (MOBY), which is positioned at an open ocean location exhibiting: high spatial homogeneity (both for atmospheric and marine optical properties); high stability (within limits of seasonal changes); low cloudiness; and known atmospheric-marine optical properties.

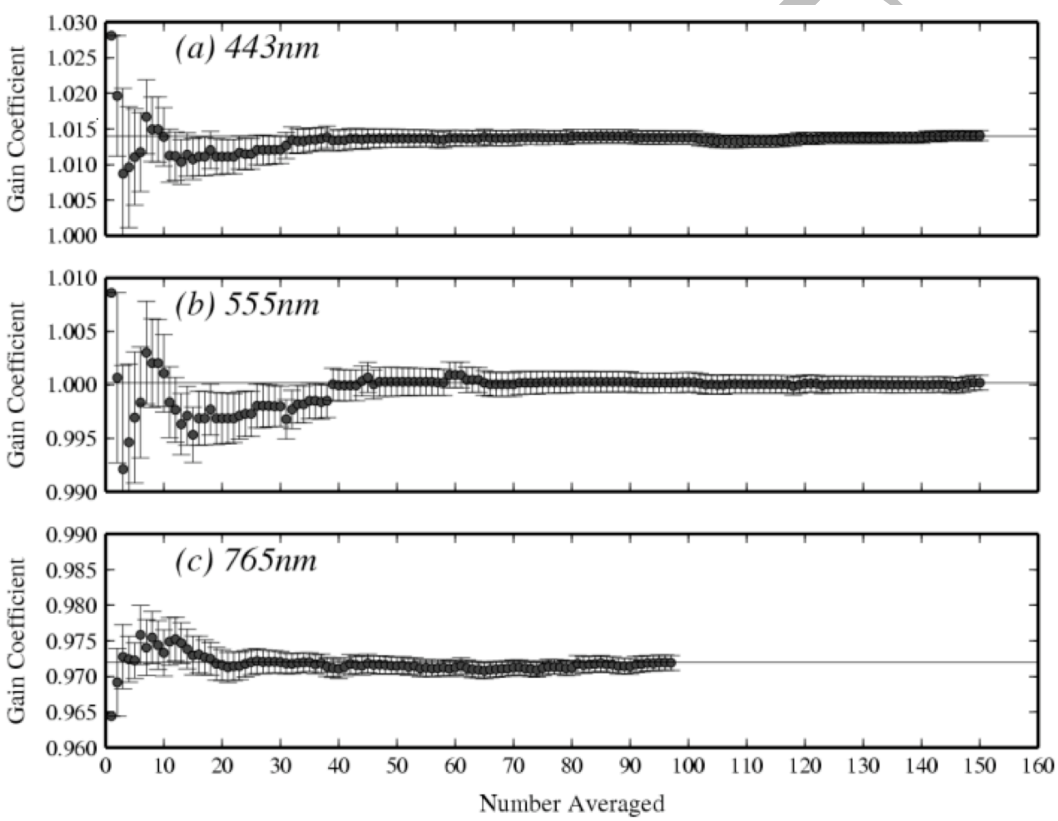

Figure 1. SeaWiFS mean vicarious gains. Horizontal lines show cumulative mean gain coefficients. Solid circles and error bars show individual gain coefficients and the standard error of the mean. From Franz et al., "Sensor-independent approach for the vicarious calibration of satellite ocean color radiometry," Applied Optics 46, 5068-5082 (2007).

Domestic and international efforts have been underway in parallel to develop preliminary designs of sufficiently robust *in situ* vicarious calibration and validation systems in support of current and future ocean color satellite mission. As elaborated upon below, NASA is currently exploring ways to provide or develop *in situ* instruments, systems, and approaches for the SVC of OCI (see Section 2.3.1). The European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) has also invested in SVC development following identification of requirements for the Copernicus Ocean Colour Vicarious Calibration Infrastructure, which focuses on the Sentinel-3 Ocean Colour and Land Instrument (OLCI) (https://www.eumetsat.int/website/wcm/idc/idcplg?IdcService=GET_FILE&dDocName=PDF_COP_OCEAN_COL_CAL&RevisionSelectionMethod=LatestReleased&Rendition=Web).

Table 1. Baseline OCI water-leaving reflectances requirements.

Data Product	Uncertainty
Water-leaving reflectances centered on (±2.5 nm) 350, 360, and 385 nm (15 nm bandwidth)	0.0057 or 20%
Water-leaving reflectances centered on (±2.5 nm) 412, 425, 443, 460, 475, 490, 510, 532, 555, and 583 (15 nm bandwidth)	0.0020 or 5%
Water-leaving reflectances centered on (±2.5 nm) 617, 640, 655, 665, 678, and 710 (15 nm bandwidth, except for 10 nm bandwidth for 665 and 678 nm)	0.0007 or 10%

Each uncertainty is defined as the maximum of the absolute and relative values for Level-2 satellite data processing (geophysical values in the original satellite coordination system). These requirements are defined for ≥50% of the observable deep ocean (≥1000 m).

2.2 Definitions, Roles, and Responsibilities

Several entities work collaboratively to ensure the viability and success of the PACE SVC system. All communicate routinely. The following describes the core entities:

Program Science
Program Science at NASA HQ selects, funds, and provides NASA program management for the dedicated PACE SVC Team(s) through Earth Sciences Division (ESD) Research Opportunities in Space and Earth Science (ROSES) solicitations.

SVC Team(s)
The SVC Team(s) develop, deploy, characterize, and maintain the SVC system(s) and provide SVC data to Project Science and the Science Data Segment.

Science Data Segment
The Science Data Segment (SDS) at GSFC receives SVC data from the SVC Team(s) and executes the vicarious calibration of OCI (that is, derives vicarious calibration gain coefficients).

Project Science
Project Science at GSFC evaluates and assesses the performance of OCI's SVC and approves the vicarious calibration gain coefficients derived by the SDS.

2.3 An OCI Vicarious Calibration System

2.3.1 Selection of the SVC Team

NASA Program Science is currently exploring ways to provide or develop *in situ* instruments, systems, and approaches for the SVC of OCI:

- In the ROSES 2014 call *A.3 Ocean Biology and Biogeochemistry: Ocean Color Remote Sensing Vicarious (In Situ) Calibration Instruments* (https://nspires.nasaprs.com/external/solicitations/summary.do?method=init&solId={E9007FB5-975A-A0C9-B8C6-8D65C78D5552}&path=closedPast), three selections were made to pursue initial technology development for system vicarious calibration of the PACE OCI.

- In the ROSES 2019 call *A.48 The Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) Mission System Vicarious Calibration* (https://nspires.nasaprs.com/external/solicitations/summary!init.do?solId=%7b8C05FAD7-0979-9C9F-09BA-E2DB3906FF67%7d&path=open), NASA requests proposals for the development, implementation, and pre-launch deployment of an *in situ* SVC capability for OCI (to be in the water and tested one-year before the PACE Launch Readiness Date, which is currently August 2022; and (2) development and testing of related/complementary instruments or approaches to be used for validation of OCI ocean color, aerosol, and/or cloud data products. Both deliverables will enable generation of data records of Essential Climate Variables (ECV's, https://gcos.wmo.int/en/essential-climate-variables).

NASA anticipates selecting up to two (2) teams in response to ROSES 2019 A.48 and down-selecting to one (1) team within twelve months of the start dates of the two awards. The final selected team will plan on full deployment and preliminary operation of the SVC system one year before the Launch Readiness Date, which is currently November 2022 (updated from August 2002 as written in ROSES 2019 A.48).

2.3.2 Desired components of an SVC system

2.3.2.1 Instrument characteristics

The required *in situ* SVC instrument(s) system(s) to support PACE ocean color science and applications should include the following features:

1. Spectral range from 345-890 nm at < 3 nm resolution (ideally 1 nm) – such that the spectral range of the SVC system(s) mirror that of OCI;

2. Spectral radiometric uncertainty lower than 4% in the blue-green spectral region and of approximately 5% in the red, combining uncertainty contributions from instrument absolute calibration, characterization (including at least spectral calibration, nonlinearity, stray light perturbation and polarization sensitivity, temperature dependence and, if applicable, geometrical and in water response), environmental perturbation, and data processing (with National Institute for Standards and Technology (NIST) traceability);

3. Spectral radiometric stability on the order of 1% per deployment (with NIST traceability);

4. Capability for autonomous field operation;

5. Capability for operation from launch – one year plus the three years of prime mission life;

6. Full laboratory and field characterization of all of the above requirements versus NIST standards prior to deployment; and,

7. Full autonomous delivery of data, in proper formats, fidelity, and latency, to enable NASA PACE mission science in near real time.

Strategies for verifying instrument performance both pre- and post-launch, including cross comparisons with independent data sources (e.g. additional radiometric instrumentation and/or radiative transfer simulations), will accompany the SVC instrument(s) system(s). Instrument calibration and data (post-)processing algorithms and methods to generate both depth-resolved, calibrated (ir)radiances and $R_{rs}(\lambda)$ will also accompany the SVC instrument(s) system(s) [TBR].

A required deliverable from the ROSES 2019 A.48 solicitation is a fully tested, field deployable instrument at Technology Readiness Level 6 (TRL, https://esto.nasa.gov/technologists_trl.html), with the instrument(s) ready to support the OCI with verified data quality and uncertainties sufficient for satellite remote sensing product validation.

2.3.2.2 Site selection

Instrument(s) deployment methodologies, including deployment site identification, will be determined through selection of the SVC Team (see Section 2.3.1) [TBR]. Recent literature revisited the requirements for a SVC site (Zibordi and Melin 2017).

Ideally, the SVC site will be positioned in a region where variability and complexity of the atmospheric and oceanic optical properties are low to minimize additional sources of uncertainty due to temporal and spatial sampling differences between the satellite observation and the *in situ* measurement. Historically, atmospheric measurements have not accompanied the ocean SVC measurements. Inclusion of additional atmospheric aerosol observations (e.g., sun-photometer measurements) is desirable to support in-depth SVC site characterization, calibration match-up exclusion criteria metrics, and validation of PACE aerosol data products.

Multiple SVC sites, particularly if observational requirements and spectral ranges are coordinated with any international investments and coordination (e.g., Copernicus), will offer additional information and alternative sources of data. These sites should be equivalent in terms of measurement accuracy, traceability, and observation conditions, as different atmospheric complexities might lead to inaccurate determinations of aerosol types and, thus, to the determination of different adjustment factors for the prelaunch calibration coefficients.

Complementary routine field efforts at the SVC site(s) will be conducted to support characterization of the site(s) and any future satellite missions via verification of data quality through the quantification of uncertainties affecting data products.

2.3.2.3 Interactions between the Project and SVC Team(s)

PACE Project Science and Science Data Segment (SDS) members will interface with the awarded SVC Team(s) for implementation, evaluation, and testing of SVC approaches and/or algorithms. Project Science and SDS designees will participate in vicarious calibration team activities, including scientific discussions, measurement discussions, algorithm development and retrieval activities, and associated algorithm/retrieval testing and implementation activities (as appropriate). This will be done to resolve any outstanding data processing and distribution issues for PACE mission data prior to launch and post-launch. Strategies and standing / routine schedules for interaction with the Project Science and SDS teams including, but not limited to, data transfers, data formats, data processing and post-processing strategies, sharing of algorithms and software, acceptable data collection latencies (the PACE Project expects both within-deployment and post-deployment-calibration delivery of SVC data), and SVC support for PACE instrument data reprocessings will be defined upon selection of the SVC Team(s) [TBR].

2.3.2.4 Additional resources

Documents presenting desired capabilities for SVC of ocean color satellite instruments include:

- the PACE Science Definition Team report (https://pace.oceansciences.org/docs/PACE_TM2018-219027_Vol_2.pdf);
- the International Ocean Color Coordinating Group (IOCCG) Report 13 (http://ioccg.org/wp-content/uploads/2015/10/ioccg-report-13.pdf);
- the IOCCG/Committee on Earth Observing Satellites (CEOS) Ocean Color Radiometry-Virtual Constellation white paper on the International Network for Sensor Inter-comparison and Uncertainty assessment for Ocean Color Radiometry (INSITU-OCR) (http://www.ioccg.org/groups/INSITU-OCR_White-Paper.pdf);
- the World Meteorological Organization's "*Systematic Observation Requirements for Satellite-Based Data Products for Climate 2011, Update Supplemental details to the satellite-based component of the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)*" (https://library.wmo.int/doc_num.php?explnum_id=3710); and,
- Zibordi et al., "System vicarious calibration for ocean color climate change application: Requirements for in situ data," Remote Sensing of Environment 159, 361-368, doi:10.1016.j.rse.2014.12.015, (2017).

2.4 Vicarious Calibration Interactions, Schedule, and Lifecycle

The SVC system(s) schedule and lifecycle are as follows [TBR]:

- May 2019: Responses to ROSES 2019 A.48 due.
- Oct 2019: Selected SVC Team(s) begin(s) work.

SVC Team(s) will caucus with Project Science, Program Science, and SDS within 1-2 months of the start date of the award to review the SVC systems and any updates to the OCI concept that were realized since the time of proposal that may have relevance to the SVC design concept(s).

SVC Team(s) will interact with the PACE Project several times each year, including [TBD] participation in prelaunch mission reviews.

- Oct 2020: Down-select to single SVC Team executed.

The SVC Team will continue to interact with the PACE Project several times each year.

- Oct 2021: SVC system preliminary deployment and operation commences.

Preliminary operation will include interaction with Project Science and SDS to evaluate the full SVC process using VIIRS or equivalent satellite data records as a test bed, with the purpose of achieving a high system readiness level before PACE's launch, as well as a full year of SVC site(s) characterization.

- Nov 2022: PACE launch.

On-orbit SVC of OCI commences. Preliminary vicarious calibration coefficients generated during in-orbit checkout (IOC; 60 days).

- Sep 2023: ROSES 2019 A.48 award ends.

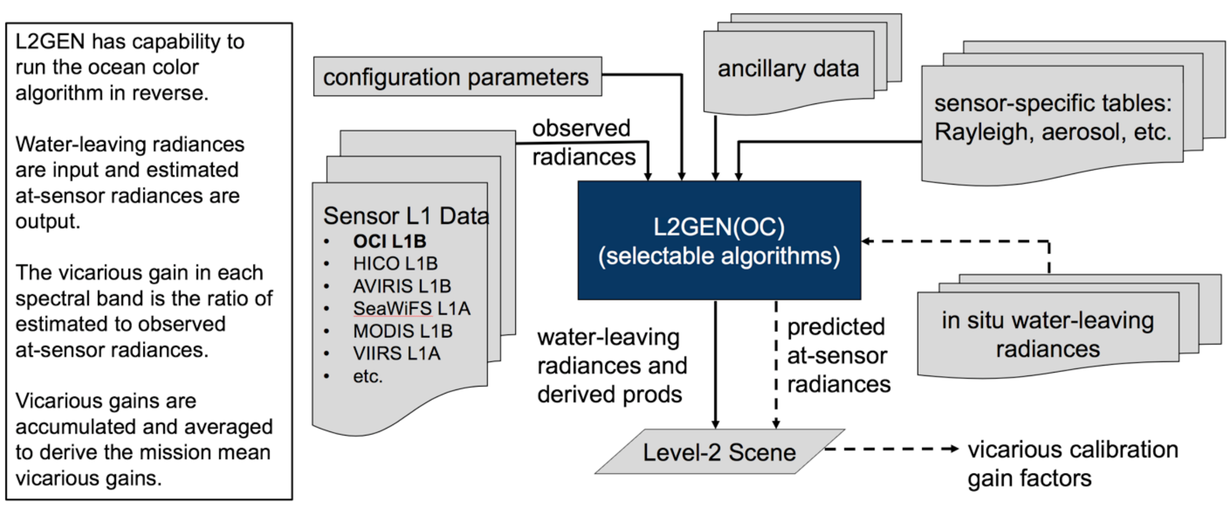

Figure 2. SVC implementation strategy within SDS.

2.5 Methodology

Placeholder – will be made more complete in next draft. System vicarious calibration is the adjustment of prelaunch calibration coefficients using top-of-atmosphere (TOA) radiance predicted from *in situ* measurements through modeling of atmospheric radiative processes (by applying the same models and codes used for the operational atmospheric correction process). See Franz et al. (2007) and references therein for a description of methods. Figure 2 provides an overview of the software implementation for SVC.

2.6 Documentation and Data Distribution

All PACE Level-0, -1, -2, and -3 data products (http://science.nasa.gov/earth-science/earth-science-data/data-processing-levels-for-eosdis-data-products/) and science data processing software/source code/algorithms from all instruments on the observatory and SVC will be incorporated into the NASA OceanColor Web site (http://oceancolor.gsfc.nasa.gov) to be publicly distributed according to NASA SMD open data access policies (https://science.nasa.gov/earth-science/earth-science-data/data-information-policy).

The SVC Team will support the development of and approve the SDS-to-Vicarious Calibration Team (VCT) ICD.

Appendix A <Appendix A Title>

[Notes: The first appendix is lettered "A", followed by consecutive letters for each additional appendix. Provide a title for each appendix. The last Appendix should be the list of Abbreviations and Acronyms]

[Reminder: Insert section breaks at the end of every major section to start the next section on a new page.

Appendix B Abbreviations and Acronyms

INCOMPLETE [Alphabetize list]

GSFC	Goddard Space Flight Center
ITAR	International Trade in Arms Regulation
SBU	Sensitive But Unclassified
TBD	To be determined
TBR	To be revised
TBS	To be scheduled