Standard Component Commodity Usage Guides (CUGs) for Charge-Coupled Devices (CCDs)

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Abstract

GSFC Safety and Mission Assurance (SMA) Reliability and Risk Assessment Branch works to develop analytical and risk assessment processes for spacecraft and payload standard components to identify conformance risks and mitigations while increasing safety of Earth and Space systems exploration. The goals of this project were to examine the heritage (i.e., performance, reliability, & anomaly history) of payload standard components, for risk-based mission assurance while creating a compressed cataloguing/referencing system for engineers, known as a Commodity Usage Guides (CUGs). Commodity Usage Guides allow the user to quickly locate aggregated instrument heritage and reliability data in order to make risk-based decisions for future component integration. Charge-coupled devices (CCDs) were the component of interest for this project. The creation of CUGs for payload standard components reduces time spent re-learning past experiences as well as risk-data search time. CUGs are composed of vendor data, lessons learned, associated component risks, and other data found within Engineering Peer-Review (EPR) presentations, Flight Review documents, and the Meta database among other sources.

Introduction & Background

Communicating risk and reliability information within NASA Goddard's missions is crucial to continuing the development of new technology and ensuring GSFC missions achieve their science objectives. The Reliability and Risk Assessment Branch (Code 371) within the SMA directorate is one of GSFC's leaders in communicating this information to missions, and one tool 371 engineers use to provide this information is the Commodity Usage Guides (CUGs). CUGs are helpful in compiling various critical parameters and heritage information for standard payload components, ensuring project personnel inherit the lessons learned from previous experiences.

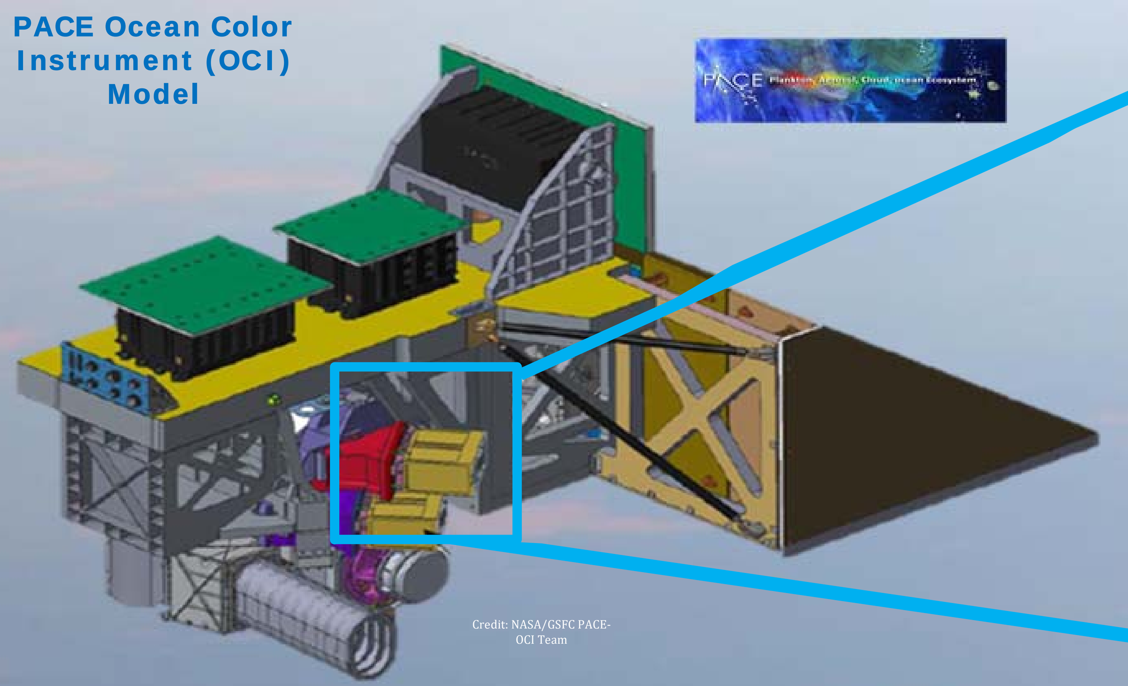
The purpose of this project was to create CUGs for CCDs used within GSFC missions. To formulate a CUG applicable data was aggregated into the CUG template for Charge-Coupled Devices (CCDs)--electro-optical components used to convert photons into digital images and data. CCDs can easily be adapted to a variety of mission requirements making them widely used at GSFC, and therefore suitable for CUGs. Once the CUGs for CCDs are completed the information can be distributed to engineers, scientists and other project members to ensure the lessons learned are passed on to the next mission.

Methods

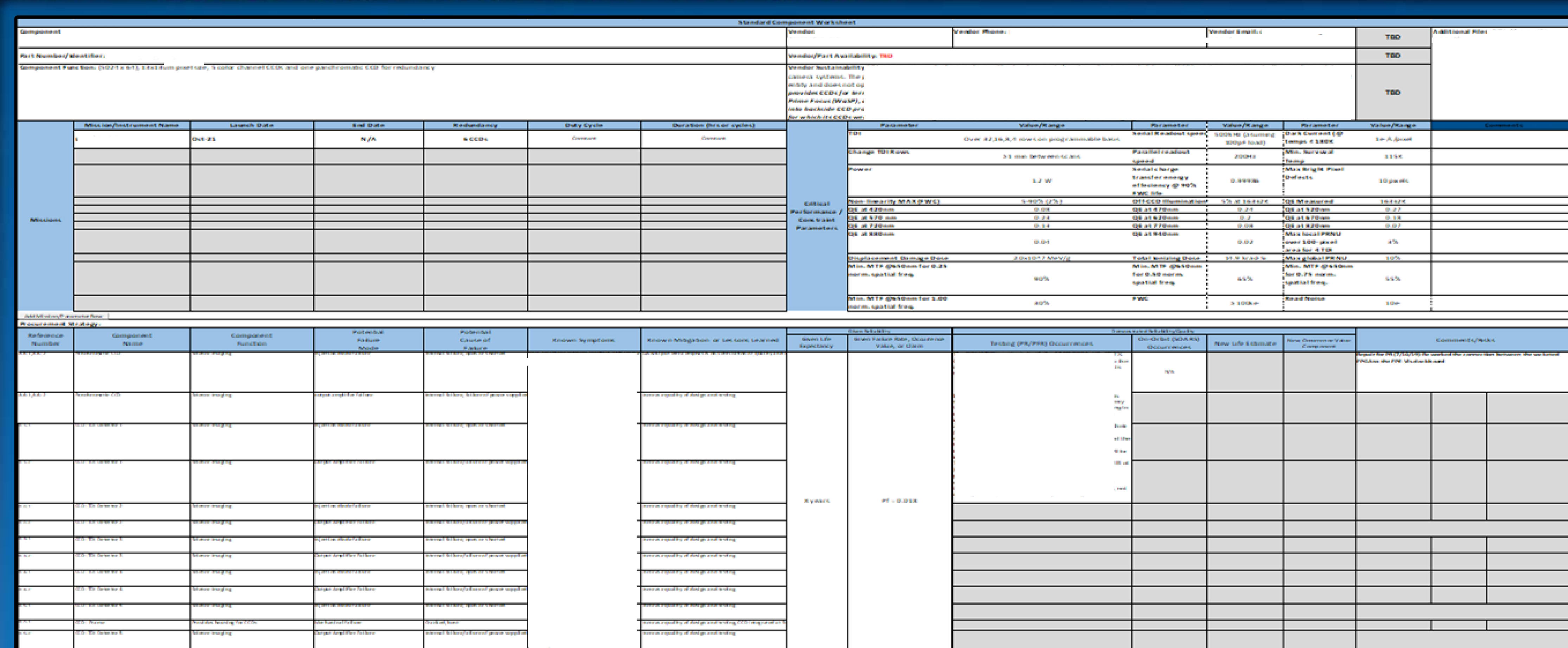
Creating a CUG for CCDs required:

- Conducting research on the component (i.e., physics of operation), understanding uses for CCDs at GSFC, learning the best classification methods
- Determining critical parameters relative to a CCD's function per project to identify risks and potential failure modes.
- Examining issues and anomalies that previous projects experienced—noting frequency in performance deviations.
- Researching disruptions in CCD supply chain or potential vendor risk signs, as found in Supply Chain Assessments, reducing the likelihood of cancelled distribution or manufacturer errors.
- Sourcing data for the CCD CUGs from Meta, TDMS, Vendor Sites, Engineering Peer Reviews & Critical Design Reviews containing data such as Critical Performance Parameters & Failure Mode Assessments.
- Documenting results into the CUG template (see "**CCD Commodity User Guide Snapshot**")

PACE Ocean Color Instrument (OCI) Model



CCD Commodity Usage Guide Snapshot:



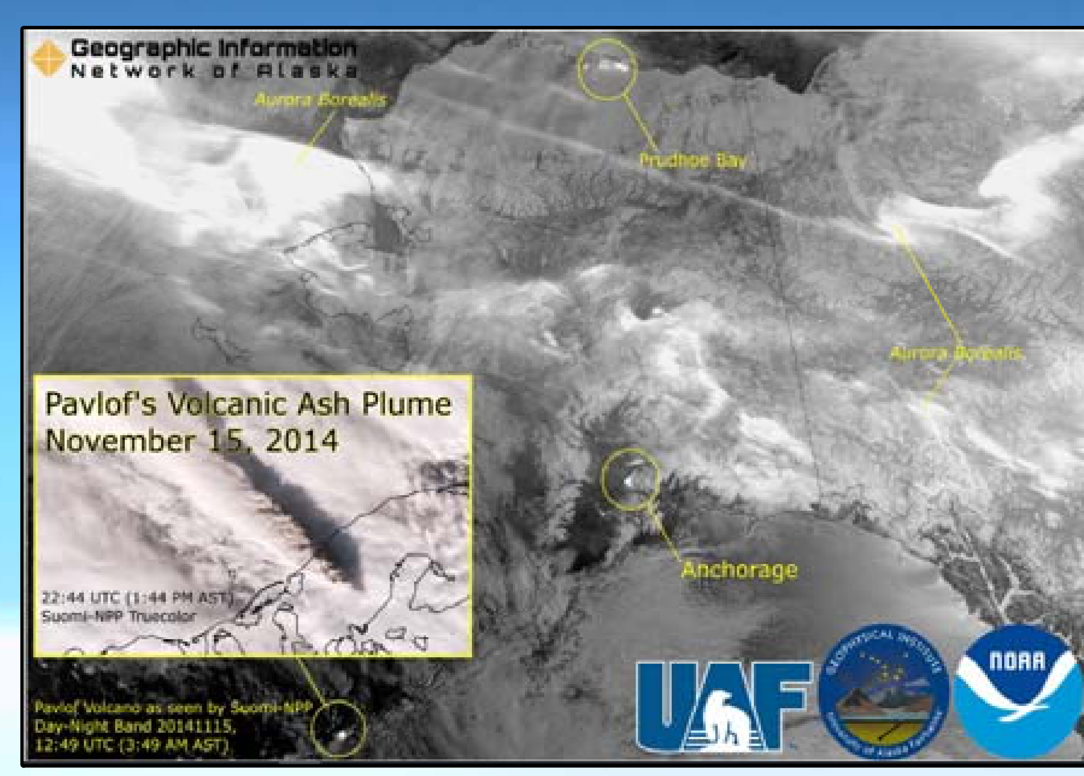
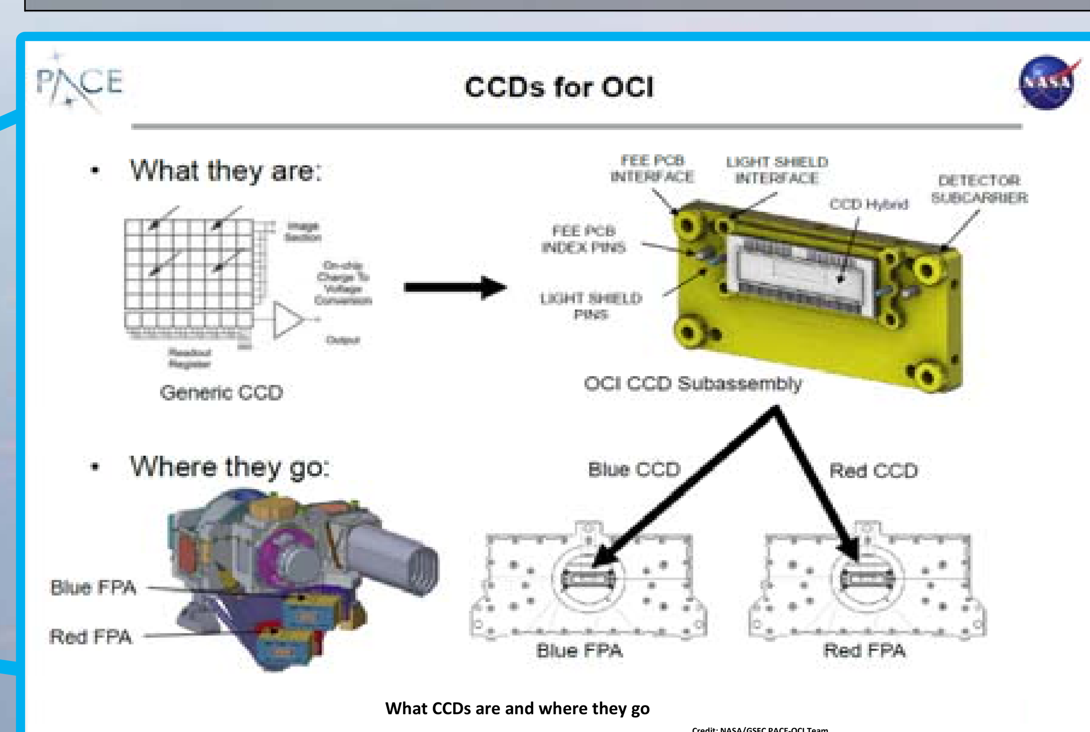


Figure 1: (Above) The Day-Night Band (DNB) CCD on board the Suomi-NPP's VIIRS captured an image of Pavlof's Volcanic Ash Plume, November 15, 2014. GSFC's Joint Polar Satellite System (JPSS-1) also carries this three-gain staged CCD, with JPSS-2 planning to carry a DNB when launched in 2022. [1]

Figure 2 (Below): The CCDs used on the OCI are hyperspectral imaging devices (between the 310 nm & 840 nm) fine-tuned to distinguish between the various wavelengths of UV, visible and IR light corresponding the phytoplankton population concentration, coastal atmospheric conditions. The Ocean Color instrument aims to provide a more accurate understanding of the complex oceanic ecology system that covers nearly 71% of the earth's surface.[2]



CCDs at Goddard

CCDs at Goddard Space Flight Center are used on a number of missions including PACE's Ocean Color Instrument, Hubble's ACS (see **Figure 3**), JPSS's VIIRS instrument, and WFIRST's Wide Field Instrument (WFI). Though they range in performance parameters, the CCDs are crucial to spectrometry, in-orbit geometric calibration, and image-data acquisition. For example, CCDs onboard OSIRIS-REx's OCAMS provide precise light and image read-outs for landing surveys and sample collection while exploring asteroid Bennu.

Figure 3: Holding a Hubble Space Telescope ACS Wide Field Camera CCD, that was launched aboard the 3B Servicing Mission in March 2002. The CCD was designed by SITe, Inc. with a 2048 x 4096 frame. **Source: Pamela C. Sullivan (GSFC 410)**

Results

Results from CCD CUG creation were:

- Learned that it is the role of the CUG to emphasize to the user the anomaly history, vendor reliability, and lessons learned to prevent the repetition of previous performance deviations in future missions.
- Created CUGs for CCDs featured on 18 different missions, 19 scientific instruments from 8 vendors, all with various applications and scientific objectives.
- Reported on CCD critical parameters such as dark current, minimum operating temperatures, and Charge-Transfer Efficiency (CTE) that are can be used by SMA engineers and designers in trade studies, risk assessments, design choices and other risk-informing decisions.
- Identified potential failure modes in CCDs due to unsuitable temperature operations, radiation exposure, dust contamination, and excess dark noise, that are considered when creating contingency plans, updating mission data, and making Bayesian analyses on failure rates based on experience.
- Determined that GSFC CCDs tend to have robust design and high reliability allowing missions to successfully complete science objects.
- Provided CCD CUGs to Code 371 Standard Component CRAE and other engineers who plan to use information for risk assessments and lessons-learned, for current and future CCD implementation.

Conclusion & Moving Forward

Through CUG creation, CCDs were found to be fascinating and robust in design, with few on-orbit and testing anomalies, providing imaging data that enhances NASA science objectives, and have applications on missions such as Hubble, PACE, WFIRST, and OSIRIS-Rex. Using CUGs to collect and share data allows for project schedule, budget, and risk savings by ensuring that lessons learned are transferred, critical parameters are understood, and Supply Chain Assessments are considered. CUGs enable data to be passed from one mission to the next, allowing engineers and designers to make more efficient redundancy choices for Goddard's future missions. Eventually coupled with Inherited Items Risk Assessments (I2RA), CUGs are an efficient data-tracking tool that helps establish a larger risk-based approach to mitigating anomalies, assessing reliability, and developing reliable payload and spacecraft standard components.

The process of researching CUG data for GSFC has highlighted the key role of NASA in revolutionizing scientific and engineering industries; research that can then be integrated into educational outreach opportunities. This internship provided me with the tools to bring an element of sustainability and education into all aspects of my life, both professional and academic.

References & Acknowledgements:

1 Scott, C. A., 2015, "VIIRS Applications: Day-Night Band" Geographic Information Network of Alaska, Presentation (slide 11).

2 NASA Goddard Space Flight Center, et al. "Ocean Color Instrument." NASA PACE - Ocean Color Instrument, ODYSEA LLC, 2018, pace.oceansciences.org/oci.htm.

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Image Source: NASA Earth (2015)