Effective Date: April 30, 2014
Revision C

GSFC JPSS CMO
May 9, 2014
Released

Joint Polar Satellite System (JPSS) Ground Project
Code 474
474-00063

Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Vegetation Index (VI) Environmental Data Records (EDR) Software

For Public Release

The information provided herein does not contain technical data as defined in the International Traffic in Arms Regulations (ITAR) 22 CFC 120.10. This document has been approved For Public Release to the NOAA Comprehensive Large Array-data Stewardship System (CLASS).

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

Joint Polar Satellite System (JPSS)
Operational Algorithm Description (OAD)
Document for VIIRS Vegetation Index (VI) Environmental Data Records (EDR) Software
JPSS Electronic Signature Page

Prepared By:

Ray Godin
JPSS Data Products and Algorithms EDR Lead
(Electronic Approvals available online at (https://jpssmis.gsfc.nasa.gov/mainmenu_dsp.cfm)

Approved By:

Eric Gottshall
DPA Manager
(Electronic Approvals available online at (https://jpssmis.gsfc.nasa.gov/mainmenu_dsp.cfm)

Goddard Space Flight Center
Greenbelt, Maryland

Preface

This document is under JPSS Ground Algorithm ERB configuration control. Once this document is approved, JPSS approved changes are handled in accordance with Class I and Class II change control requirements as described in the JPSS Configuration Management Procedures, and changes to this document shall be made by complete revision.

Any questions should be addressed to:

JPSS Configuration Management Office
NASA/GSFC
Code 474
Greenbelt, MD 20771

Change History Log

Revision	Effective Date	Description of Changes (Reference the CCR & CCB/ERB Approve Date)
Original	05/20/11	**474-CCR-11-0079:** This version baselines D36951, Operational Algorithm Description Vegetation Index EDR, Rev C, dated 05/19/2010, as a JPSS document version Rev –. This is the version that was approved for NPP launch. Per NPOESS CDFCB - External, Volume V – Metadata, doc number D34862-05, this has been approved for Public Release into CLASS. This CCR was approved by the JPSS Algorithm ERB on May 20. 2011.
Revision A	01/18/2012	**474-CCR-11-0256:** This version baselines 474-00063, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Vegetation Index (VI) Environmental Data Records (EDR) Software, for the Mx 6 IDPS release. This CCR was approved by the JPSS Algorithm ERB on January 18, 2012.
Revision B	05/14/2013	**474-CCR-13-0948:** This version authorizes 474-00063, JPSS OAD Document for VIIRS VI EDR Software, for the Mx 7.0 IDPS release. Includes Raytheon PCR032720; 474-CCR-13-0916/ECR-ALG-0037: Update applicable OAD filenames/template/Rev/etc. for Mx7 Release.
Revision C	04/30/2014	**474-CCR-14-1702:** This version authorizes 474-00063, JPSS OAD Document for VIIRS VI EDR Software, for the Mx 8.4 IDPS release. Includes Raytheon PCR037360; CHILD: PRO: OAD: 474-CCR-13-1218: Additional QFs for VI EDR & Correct Low Sun Angle in Documents (DRs 7038, 4377), in section 2.1.1.1 and Tables 3 & 7.

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

OPERATIONAL ALGORITHM DESCRIPTION FOR VEGETATION INDEX (VI) EDR

SDRL No. S141
SYSTEM SPECIFICATION SS22-0096

RAYTHEON COMPANY
INTELLIGENCE AND INFORMATION SYSTEMS (IIS)
NPOESS PROGRAM
OMAHA, NEBRASKA

This data was developed pursuant to Contract Number F04701-02-C-0502 with the US Government under subcontract number 7600002744. The US Government's right in and to this copyrighted data are as specified in DFAR 252.227-7013, which was made part of the above contract.

IAW DFAR 252.227-7036, Raytheon hereby declares that, to the best of its knowledge and belief, the technical data delivered under Subcontract No. 7600002744 is complete, accurate, and complies with all requirements of the Subcontract.

TITLE: NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS) OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VEGETATION INDEX (VI) EDR

APPROVAL SIGNATURES:

_____

Stephen E. Ellefson Date
ING/PRO Lead

_____

Gabriela A. Ostler Date
Mission Assurance and Enterprise Effectiveness (MAEE)

Northrop Grumman Space & Mission Systems Corp.
Space Technology
One Space Park
Redondo Beach, CA 90278

Engineering & Manufacturing Development (EMD) Phase
Acquisition & Operations Contract

CAGE NO. 11982

Operational Algorithm Description
Vegetation Index EDR

Document Number: D36951
Document Date: Sep 27, 2011 **Revision: D2**

PREPARED BY:

Alain Sei *Date*
AM&S Vegetation Index EDR Lead

Paul D. Siebels *Date*
IDPS PRO SW Manager

ELECTRONIC APPROVAL SIGNATURES:

Roy Tsugawa *Date*
A&DP Lead & ACCB Chair

Stephen E. Ellefson *Date*
IDPS Processing SI Lead

Bob Hughes *Date*
A&DP Deputy & ARB Chair

Prepared by
Northrop Grumman Space Technology
One Space Park
Redondo Beach, CA 90278

Prepared for
Department of the Air Force
NPOESS Integrated Program Office
C/O SMC/CIK
2420 Vela Way, Suite 1467-A8
Los Angeles AFB, CA 90245-4659

Under
Contract No. F04701-02-C-0502

This document has been identified per the NPOESS Common Data Format Control Book – External Volume 5 Metadata, D34862-05, Appendix B as a document to be provided to the NOAA Comprehensive Large Array-data Stewardship System (CLASS) via the delivery of NPOESS Document Release Packages to CLASS.

Northrop Grumman Space & Mission Systems Corp.
Space Technology
One Space Park
Redondo Beach, CA 90278

NORTHROP GRUMMAN
Raytheon

Revision/Change Record

Document Number D36951

Revision	Document Date	Revision/Change Description	Pages Affected
---	4-30-03	Initial Release.	All
A1	12-4-03	Updated to reflect Science To Operational Code Conversion.	All
A2	4-20-05	Reflects NGST comment corrections plus inserted new logo and updated upper right header date, title/signature page dates, Revision/Change Record.	All
A3	6-15-05	Reflects additional comments posted on 19Apr05 to the eRoom “Post-Sci2Ops OAD Review Comments” site.	All
A4	7-1-05	Under Section 1.3.3, Source Code and Test Data References, inserted a more detailed table listing paths to find applicable source code within the ClearCase configuration management tool.	Pg 2
A5	7-12-05	Per Dan Antzoulatos’ request, changed the wording of information added by the 01 Jul 2005 Revision/Change Record line.	Pg 2
A6	6-15-07	Logo, cleanup updates. Delivered to NGST.	All
A7	12-10-07	ECR A-103, EDRPR 1.8 CP 3 updates -Format changes for CDFCB-X compliance- removed Table 5. Granule Level Quality Flag Structure. Output section tables have been updated.	All
A8	1-4-08	Reformatted to new template. Updated in response to comments from NGST. Tech Memo NP-EMD-2006.510.0042 implemented. Prepared for delivery to NGST.	All
A9	1-8-08	ECR A-103 Action Item updates to add Datatype field in Table 4. VVI Output Contents.	All
A10	6-12-08	Updated data quality monitoring section. Implemented tech memo NP-EMD.2008.510.0006_NPP_Cirrus_flag_testing_update_for_Vegetation_Index.	10
A11	10-29-08	Prepared for TIM/ACCB.	All
A	12-17-08	Addressed TIM/ACCB comments. ECR A-177 Rev. A.	All
B1	04-27-09 09-28-09	Updated with IDPS PCR020193 Table 7. Updated with PCR21119 changes	8 5 & 7
B2	1-20-09	Updated for TIM/ARB; updated SCN; updated Table1, added TM 2009.510.0069 (PCR22065) into Tables 1 & 2 (no actual OAD updates associated with this TM)	All
B	3-17-10	Incorporated TIM comments and prepared for ACCB	All
C1	3-31-10	Incorporated TM 2010.510.0005 updates.	Tables 1 & 2
C	5-19-10	Prepared for TIM/ARB/ACCB	All
D1	10-13-10	Updated due to document convergence	All

Northrop Grumman Space & Mission Systems Corp. **Space Technology** One Space Park Redondo Beach, CA 90278	NORTHROP GRUMMAN Raytheon

Revision/Change Record			**Document Number D36951**
D2	09-27-11	Updated OAD for PCR026626.	ALL

Table of Contents

List of Figures

List of Tables

1.0 INTRODUCTION

1.1 Objective

The purpose of the Operational Algorithm Description (OAD) document is to express, in computer-science terms, the remote sensing algorithms that produce the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) end-user data products. These products are individually known as Raw Data Records (RDRs), Temperature Data Records (TDRs), Sensor Data Records (SDRs) and Environmental Data Records (EDRs). In addition, any Intermediate Products (IPs) produced in the process are also described in the OAD.

The science basis of an algorithm is described in a corresponding Algorithm Theoretical Basis Document (ATBD). The OAD provides a software description of that science as implemented in the operational ground system -- the Data Processing Element (DPE).

The purpose of an OAD is two-fold:

1. Provide initial implementation design guidance to the operational software developer.
2. Capture the “as-built” operational implementation of the algorithm reflecting any changes needed to meet operational performance/design requirements.

An individual OAD document describes one or more algorithms used in the production of one or more data products. There is a general, but not strict, one-to-one correspondence between OAD and ATBD documents. This particular document describes operational software implementation for the Visible/infrared Imager/Radiometer Suite (VIIRS) Vegetation Index (VI) Environmental Data Record (EDR).

1.2 Scope

The scope of this document is limited to the description of the core operational algorithms required to create the VIIRS VI EDR. It provides a general overview and is intended to supplement in-line software documentation and interface control documentation for maintenance of the operational software. The theoretical basis for this algorithm is described in Section 3.3 of the VIIRS Vegetation Index (VVI) Algorithm Theoretical Basis Document ATBD, 474-00039.

1.3 References

1.3.1 Document References

The science and system engineering documents relevant to the algorithms described in this OAD are listed in Table 1.

Table 1. Reference Documents

Document Title	Document Number/Revision	Revision Date
VIIRS Vegetation Index (VVI) Algorithm Theoretical Basis Document ATBD	474-00039	Latest
VIIRS Vegetation Index Unit Level Detailed Design	Y2499 Ver. 5 Rev. 4	May 2003
VIIRS Radiometric Calibration Algorithm Theoretical Basis Document ATBD	474-00027	Latest
VIIRS Radiometric Calibration Component Detailed	Y2490 Ver. 5 Rev. 4	30 Sep 2004

Document Title	Document Number/Revision	Revision Date
Design Document		
VIIRS Algorithm Verification Status Report	D36812 Rev. 2.04	02 Dec 2003
NPOESS Calibration/Validation Plan	D34484 Draft Version 3.0	17 Dec 2002
JPSS Environmental Data Record (EDR) Production Report (PR) for NPP	474-00012	Latest
JPSS Environmental Data Record (EDR) Interdependency Report (IR) for NPP	474-00007	Latest
NPP Mission Data Format Control Book and App A (MDFCB)	429-05-02-42_MDFCB	Latest
JPSS Common Data Format Control Book - External -–Block 1.2.2 (All Volumes)	474-00001-01-B0122 CDFCB-X Vol I 474-00001-02-B0122 CDFCB-X Vol II 474-00001-03-B0122 CDFCB-X Vol III 474-00001-04-01-B0122 CDFCB-X Vol IV Part 1 474-00001-04-02-B0122 CDFCB-X Vol IV Part 2 474-00001-04-03-B0122 CDFCB-X Vol IV Part 3 474-00001-04-04-B0122 CDFCB-X Vol IV Part 4 474-00001-05-B0122 CDFCB-X Vol V 474-00001-06-B0122 CDFCB-X Vol VI 474-00001-08-B0122 CDFCB-X Vol VIII	Latest
JPSS Common Data Format Control Book - External - Block 1.2.3 (All Volumes)	474-00001-01-B0123 CDFCB-X Vol I 474-00001-02-B0123 CDFCB-X Vol II 474-00001-03-B0123 CDFCB-X Vol III 474-00001-04-01-B0123 CDFCB-X Vol IV Part 1 474-00001-04-02-B0123 CDFCB-X Vol IV Part 2 474-00001-04-03-B0123 CDFCB-X Vol IV Part 3 474-00001-04-04-B0123 CDFCB-X Vol IV Part 4 474-00001-05-B0123 CDFCB-X Vol V 474-00001-06-B0123 CDFCB-X Vol VI 474-00001-08-B0123 CDFCB-X Vol VIII	Latest
NPP Command and Telemetry (C&T) Handbook	D568423 Rev. C	30 Sep 2008
JPSS CGS Data Processor Inter-subsystem Interface Control Document (DPIS ICD) Vol I – IV	IC60917-IDP-002	Latest
Joint Polar Satellite System (JPSS) Program Lexicon	470-00041	Latest
NGST/SE technical memo – VegIndex_QF_Memo	NP-EMD-2005.510.0025	17 Jan 2005
NGST/SE technical memo – NPP_VIIRS_VI_EVI_Range	NP-EMD-2006.510.0042	28 Jun 2006
NGST/SE technical memo – _Cirrus_flag_testing_update_for_Vegetation_Index	NP-EMD.2008.510.0006	18 Jan 2008
Operational Algorithm Description Document for VIIRS Surface Reflectance IP	474-00069	Latest
NGAS/SE technical memo – Vegetation_Index_fill_Value_Processing_Update	NP-EMD.2009.510.0069	03 Dec 2009
NGAS/SE technical memo – Granule-Level Summary Exclusion Flag Definition Rev.	NP-EMD-2010.510.0005.Rev-C	02 Mar 2010

Document Title	Document Number/Revision	Revision Date
C		
Joint Polar Satellite System (JPSS) Common Ground System (CGS) IDPS Pro Software User's Manual Part 2	UG60917-IDP-026	Latest

1.3.2 Source Code References

The science and operational code and associated documentation relevant to the algorithms described in this OAD are listed in Table 2.

Table 2. Source Code References

Reference Title	Reference Tag/Revision	Revision Date
VIIRS Vegetation Index (VVI) science-grade software	ISTN_VIIRS_NGST_2.2(OAD Rev ---)	30 May 2003
VIIRS Vegetation Index (VVI) operational software	B1.3 (OAD Rev A3)	15 Jun 2005
VIIRS Vegetation Index (VVI) science-grade software	ISTN_VIIRS_NGST_2.2.1	20 Aug 2007
VIIRS Vegetation Index (VVI) operational software	B1.5 (OAD Rev A8)	04 Jan 2008
NGST/SE technical memo – Cirrus_flag_testing_update_for_Vegetation_Index	NP-EMD.2008.510.0006	18 Jan 2008
VIIRS Vegetation Index (VVI) operational software	Build 1.5.x.1 (OAD Rev A10)	12 Jun 2008
ACCB (no code changes)	OAD Rev A	17 Dec 2008
VIIRS Vegetation Index (VVI) operational software PCRs20193 & 21119	B1.5.post-x (OAD Rev B1)	27 Apr 2009 28 Sep 2009
NGAS/SE technical memo – Vegetation_Index_fill_Value_Processing_Update (PCR22065)	NP-EMD.2009.510.0069 (OAD Rev B2)	03 Dec 2009
ACCB (no code changes)	OAD Rev B	17 Mar 2010
PCR 02283	Sensor Characterization Build SC-8 (OAD Rev C1)	31 Mar 2010
ACCB	OAD Rev C	19 May 2010
Convergence (No Code Updates)	(OAD Rev D1)	13 Oct 2010
PCR026626 (OAD changes for ADL)	(OAD Rev D2)	27 Sep 2011
OAD transitioned to JPSS Program – this table is no longer updated.		

2.0 ALGORITHM OVERVIEW

The VIIRS Vegetation Index (VVI) consists of two vegetation indices--Normalized Difference Vegetation Index (NDVI) from top-of-atmosphere (TOA) reflectances and Enhanced Vegetation Index (EVI) from top of canopy (TOC) reflectances. These indices are produced at the VIIRS image channel resolution (i.e. nominally 375m at nadir).

The VIIRS Vegetation Index EDR is computed after the RDR, SDR, and intermediate products processing is complete. The processing relationship is illustrated in Figure 1 below.

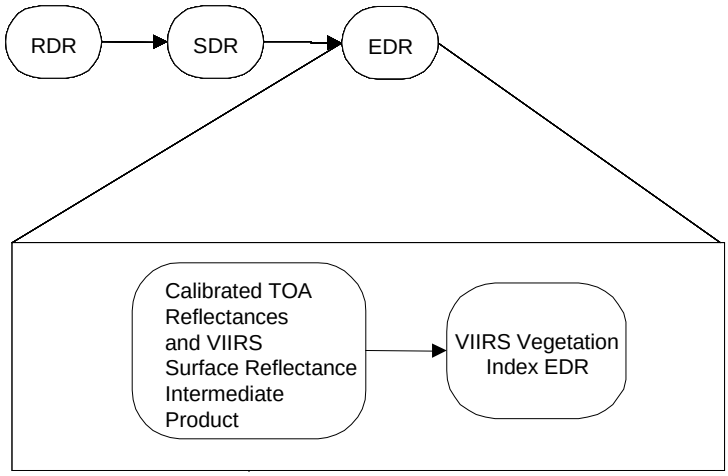

Figure 1. Processing Chain Associated with VIIRS Vegetation Index EDR

2.1 Algorithm: Vegetation Index Environmental Data Record Description

2.1.1 Interfaces

To begin processing the data, the Infrastructure (INF) Software Item (SI) initiates the VIIRS Vegetation Index algorithm. The INF SI provides tasking information to the algorithm indicating which granule is processed. The Data Management Subsystem (DMS) SI provides data storage and retrieval capability. A library of C++ classes is used to implement the SI interfaces. More information regarding these topics is found in document UG60917-IDP-026 with reference in particular to sections regarding PRO Common (CMN) processing and the IPO Model.

2.1.1.1 Inputs

The VIIRS Vegetation Index EDR requires: calibrated TOA reflectances (bands I1, I2), SDR auxiliary data (solar zenith angle), and Surface Reflectance (bands I1, I2, M3, Land Quality Flags).

VVI is calculated for all land retrievals with a solar zenith angle less than or equal to 85 degrees but is required to meet specification performance at angles less than 65 degrees. “Land” is

allowed to include inland water bodies, rivers, and coastal areas. Pixels labeled as “confidently clear”, “probably clear”, “probably cloudy”, or “confidently cloudy” by the Surface Reflectance Land Quality Flags are processed but flagged accordingly. This same quality flag also indicates whether sufficient aerosol is present to warrant flagging the pixel as obscured, i.e., AOT>1. Table 3 describes the VVI EDR Inputs. Refer to the CDFCB-X, 474-00001, for a detailed description of the inputs.

Table 3. VVI EDR Inputs

Input	Type	Description	Units/Valid Range
Reflectance_Img	Float	Calibrated TOA Reflectances for band I1	Please refer to VIIRS Radiometric Calibration Document, D43777
Reflectance_Img	Float	Calibrated TOA Reflectances for band I2	Please refer to VIIRS Radiometric Calibration Document, D43777
SolZenAng_Img	Float	Solar zenith angle at each pixel from VIIRS SDR IMG geolocation structure	Radians / 0 – 2Pi
VIIRS Surface Reflectance IP	Float	Surface Reflectance (TOC) for band I1	Please refer to 474-00069
VIIRS Surface Reflectance IP	Float	Surface Reflectance (TOC) for band I2	Please refer to 474-00069
VIIRS Surface Reflectance IP	Float	Surface Reflectance (TOC) for band M3	Please refer to 474-00069
VIIRS Surface Reflectance IP	Bytes	Land Quality Flags in moderate resolution 56-bit unsigned integer array	Please refer to 474-00069
VVI Retrieval Coefficients	Structure	Vegetation Index Coefficients for TOC EVI processing, I1, M3, and C	Please refer to CDFCB-X, 474-00001, Table 3.2.2.5.20-1, VIIRS Vegetation Index EDR Tunable Parameters
VI DQTT	Structure	Reports erroneous pixels through a DQN	Performs a bitmask tests on LQFs

2.1.1.2 Outputs

2.1.1.2.1 Granule Level Summary Quality Flags

There are two granule level summary quality flags each for NDVI and EVI--the percent of retrievals with high quality and the percent of pixels with one or more exclusion condition. See the CDFCB-X, 474-00001, Vol. IV, Part 3, Table 5.4.7.4-1 for more details.

2.1.1.2.1.1 Summary NDVI Quality

For a NDVI retrieval to be classified as high quality, the following six conditions must be met (otherwise, the retrieval is classified as low quality): (1) VIIRS SDR Band I1 top of atmosphere reflectance is good; (2) VIIRS SDR Band I2 top of atmosphere reflectance is good; (3) Cloud confidence is confidently clear; (4) No thin cirrus; (5) Solar Zenith Angle is less than 65 degrees and (6) No Sun Glint. The percentage is the number of retrievals with high quality divided by the total number of retrievals (i.e. non fill pixels) multiplied by 100 percent.

2.1.1.2.1.2 Summary EVI Quality

For an EVI retrieval to be classified as high quality, the following eight conditions must be met (otherwise, the retrieval is classified as low quality): (1) VIIRS SR IP for Band I1 is good; (2) VIIRS SR IP for Band I2 is good; (3) VIIRS SR IP for Band M3 is good; (4) Cloud confidence is confidently clear; (5) No thin cirrus; (6) Solar Zenith Angle is less than 65 degrees; (7) No Sun Glint and (8) EVI is within range. The percentage is the number of retrievals with high quality divided by the total number of retrievals (i.e. non fill pixels) multiplied by 100 percent.

2.1.1.2.1.3 NDVI Exclusion Summary

For NDVI, a pixel is considered excluded if one or more of the following conditions are detected:

(1) Cloud confidence isn't confidently clear;
(2) Solar Zenith Angle is greater than 85 degrees or
(3) Surface is classified as ocean or coastal.

The percentage is the number of pixels with one or more exclusion condition divided by the total number of pixels less trimmed pixels multiplied by 100 percent.

2.1.1.2.1.4 EVI Exclusion Summary

For EVI, a pixel is considered excluded if one or more of the following conditions are detected: (1) Cloud confidence isn't confidently clear; (2) Solar Zenith Angle is greater than 85 degrees; (3) Surface is classified as ocean or coastal or (4) Aerosol Optical Thickness is greater than one. The percentage is the number of pixels with one or more exclusion condition divided by the total number of pixels less trimmed pixels multiplied by 100 percent.

2.1.1.2.2 VVI Output Contents

The VVI EDR contains two fields that are written to the DMS in internal IDPS data format. Table 4 describes the VVI Output Contents. Refer to the CDFCB-X, 474-00001, for a detailed description of the outputs.

Table 4. VVI Output Contents

Output	Type	Description	Units/Valid Range
TOA_NDVI	Unsigned Integer	Top of Atmosphere (TOA) NDVI at imagery resolution	-1 to +1
TOC_EVI	Unsigned Integer	Top of Canopy (TOC) EVI at imagery resolution	-1 to +4
Byte 0 VVI EDR Quality Flags	Byte	Vegetation Index Quality Byte 0 Flags. See Table 5 for detailed description.	N/A
Byte 1 VVI EDR Quality Flags	Byte	Vegetation Index Quality Byte 1 Flags. See Table 6 for detailed description.	N/A
Byte 2 VVI EDR Quality Flags	Byte	Vegetation Index Quality Byte 2 Flags. See Table 7 for detailed description.	N/A
NDVI Scale	Float	NDVI scale factor	N/A
NDVI Offset	Float	NDVI offset	N/A
EVI Scale	Float	EVI scale factor	N/A
EVI Offset	Float	EVI offset	N/A

Output	Type	Description	Units/Valid Range
VVI DQN	Structure	This optional output item is only produced if an erroneous pixel is found during processing.	Internal format.

Table 5. QF1 (Byte 0) Quality Flag Structure

Byte	VIIRS VI Flag	Result	Bits
0	Overall NDVI Quality	1 = High 0 = Low NOTE: NDVI quality is set to high (1) if ALL of these conditions are met: 1) I1 TOA reflectance flag = avail 2) I2 TOA reflectance flag = avail 3) Cloud Confidence flag = confidently clear 4) Thin Cirrus flag = no thin cirrus 5) Solar Zenith Angle < 65 deg 6) Sun glint (Geometry based) = none	1
	Overall EVI Quality	1 = High 0 = Low NOTE: EVI quality is set to high (1) if ALL of these conditions are met: 1) I1 Surface reflectance flag = avail 2) I2 Surface reflectance flag = avail 3) M3 Surface reflectance flag = avail 4) Cloud Confidence flag = confidently clear 5) Thin Cirrus flag = no thin cirrus 6) Solar Zenith Angle < 65 deg 7) Sun glint (Geometry based) = none 8) EVI range flag = in range	1
	I1 TOA Reflectance	1 = Not Available 0 = Available	1
	I2 TOA Reflectance	1 = Not Available 0 = Available	1
	I1 Surface Reflectance	1 = Not Available 0 = Available	1
	I2 Surface Reflectance	1 = Not Available 0 = Available	1
	M3 Surface Reflectance	1 = Not Available 0 = Available	1
	EVI Range	1 = Out of Range 0 = In Range	1

Table 6. QF2 (Byte 1) Quality Flag Structure

Byte	VIIRS VI Flag	Result	Bits
1	*Land/Water	101 = Coastal 011 = Sea Water 010 = Inland Water 001 = Land / No Desert 000 = Land & Desert	3
	*Cloud Confidence	11 = Confidently Cloudy 10 = Probably Cloudy 01 = Probably Clear 00 = Confidently Clear	2
	*Sun Glint	11 = Geometry & Wind 10 = Wind Speed Based 01 = Geometry Based 00 = None	2
	*Thin Cirrus (reflective)	1 = Cloud 0 = No Cloud	1

* Copied from Surface Reflectance IP

Table 7. QF3 (Byte 2) Quality Flag Structure

Byte	VIIRS VI Flag	Result	Bits
2	Stratification – Solar Zenith Angle	1 = 65 Degrees <= SZA <= 85 Degrees 0 = SZA < 65 Degrees or SZA > 85 Degrees	1
	*Excl – AOT > 1.0	1 = AOT > 1.0 0 = AOT <= 1.0	1
	Excl – Solar Zenith Angle > 85 Deg	1 = SZA > 85 degrees 0 = SZA <= 85 degrees	1
	*Snow/Ice	0 = False (no) 1 = True (yes)	1
	*Adjacent to Clouds	0 = False (no) 1 = True (yes)	1
	*Aerosol Quantity	00 = Climatology 01 = Low 10 = Average 11 = High	2
	*Cloud Shadows	0 = False (no) 1 = True (yes)	1

* Copied from Surface Reflectance IP

2.1.2 Algorithm Processing

This section provides a summary of the as-built VVI operational code. Figure 2 shows the Vegetation Index Data Flow.

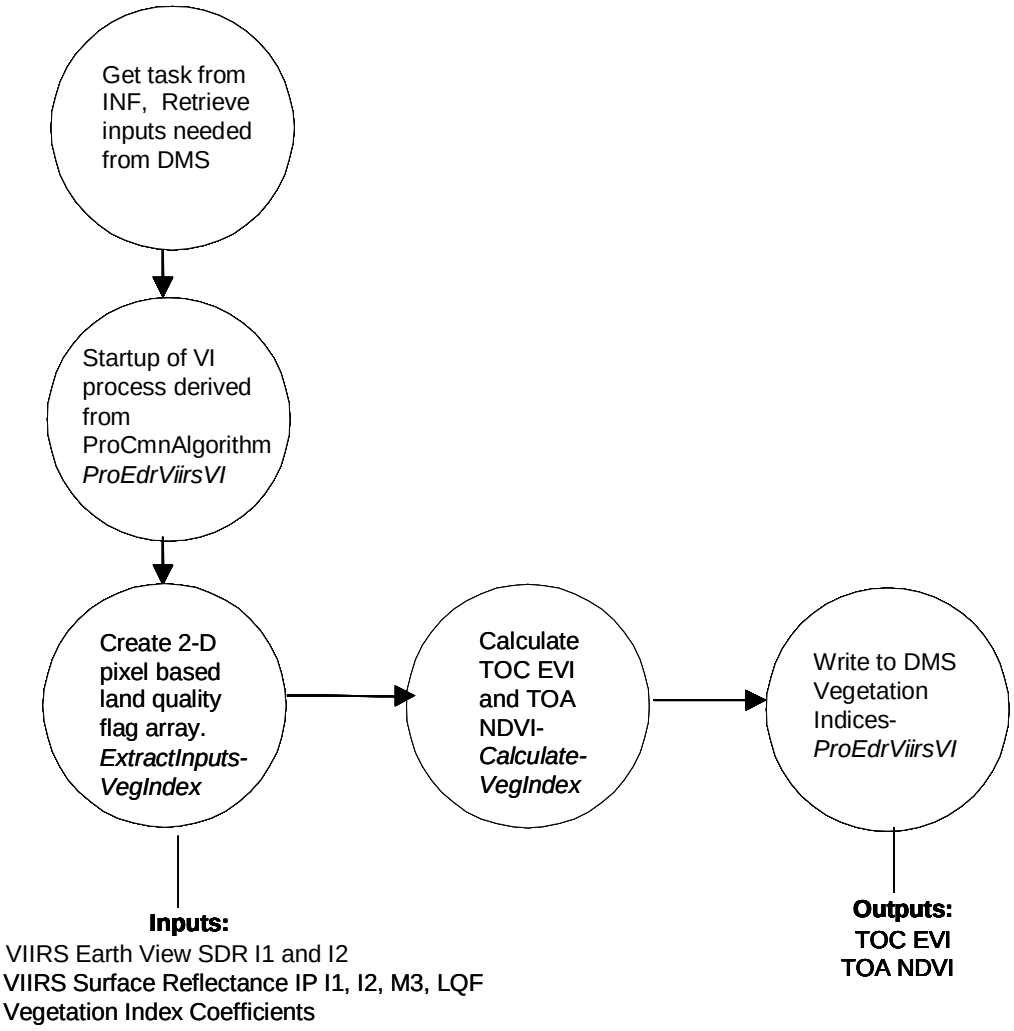

Figure 2. Data Flow Diagram of Overall VVI EDR Call Sequence from the Main Program

2.1.2.1 Main Module - ProEdrViirsVI.cpp

This is the Vegetation Index derived algorithm and is a subclass from the ProCmnAlgorithm of the common I/O design. ProEdrViirsVI creates a list of input data items that are read from DMS and passes all of the required data into the algorithm for processing. The input list includes a Vegetation Index Data Quality Threshold Table (DQTT) and the output includes a list of Data Quality Notifications if any were produced. When the algorithm has finished, the output data items are written to DMS. Refer to UG60917-IDP-026 for more information.

2.1.2.2 Calculate_VegIndex

This function calculates: (1) the top of canopy EVI from VIIRS bands M3, I1, and I2 and (2) the top of atmosphere NDVI from VIIRS bands I1 and I2.

2.1.2.2.1 EVI

The following algorithm is used to calculate the top of canopy EVI:

TOC EVI = (1 + VegIndex_Coeffs.EVI)*(SurfReflect.I2 – SurfReflect.I1)/ (SurfReflect.I2 + VegIndex _Coeffs.EVI.I1* SurfReflect.I1 – VegIndex_Coeffs.EVI.M3 * SurfReflect.M3 + VegIndex_Coeffs.EVI)

Where VegIndex_Coeffs.EVI are unitless coefficients used to compute EVI. EVI ranges from -1 to 4; pixels with EVI values outside of this range are assigned a fill value of 65528.

Note that under thin cirrus conditions for a given pixel no Surface Reflectance IP value is produced and so accordingly no EVI may be computed.

2.1.2.2.2 NDVI

The following algorithm is used to calculate the top of atmosphere NDVI:

TOA NDVI = (TOAReflect.I2 – TOAReflect.I1) / (TOAReflect.I2 + TOAReflect.I1)

NDVI ranges from -1 to 1; pixels with NDVI values outside of this range are assigned a fill value of 65528.

2.1.3 Graceful Degradation

2.1.3.1 Graceful Degradation Inputs

There is one case where input graceful degradation is indicated in the Vegetation Index EDR

1. An input retrieved for the algorithm has its N_Graceful_Degradation metadata field set to YES (propagation).

2.1.3.2 Graceful Degradation Processing

None.

2.1.3.3 Graceful Degradation Outputs

None.

2.1.4 Exception Handling

Software was added to check for divide by zero situations for TOA NDVI and TOC EVI.

Pixels trimmed Onboard and Onground are not processed.

NDVI is not calculated if Calibrated Reflectance I1 or I2 contain FILL value. NDVI is instead set to a FILL value.

EVI is not calculated if Surface Reflectance I1, I2, or M3 contain FILL value. EVI is instead set to a FILL value.

2.1.5 Data Quality Monitoring

Each algorithm uses specific criteria contained in a Data Quality Threshold Table (DQTT) to determine when a Data Quality Notification (DQN) is produced. The DQTT contains the

threshold used to trigger the DQN as well as the text contained in the DQN. If a threshold is met, the algorithm stores a DQN in DMS indicating the test(s) that failed and the value of the DQN attribute. For more algorithm specific detail refer to the CDFCB-X, 474-00001.

2.1.6 Computational Precision Requirements

The VVI algorithm requires input items to be a combination of 32-bit floating-point precision values and unsigned 8-bit integers. The 32-bit floating-point precision items are VIIRS Calibrated TOA Reflectances (bands I1, I2), VIIRS Surface Reflectance IP (bands I1, I2, M3), and the VVI coefficients. The unsigned 8-bit integer item is the Land Quality Flags from the moderate surface reflectance.

The output values of the algorithm are unsigned 16-bit integers with a measurement precision of 0.0002 NDVI units.

2.1.7 Algorithm Support Considerations

DMS should be up and running. All the data (primary or secondary) needed for the VVI calculations must be available in the DMS for the successful completion of the process.

INF must be running so the process can retrieve the tasks send messages to INF upon successful completion or failure to complete the process.

A C++ compiler is necessary to compile the VVI source code.

The PRO Common library is available.

The imake files can create the Makefile used to compile VVI.

2.1.8 Assumptions and Limitations

2.1.8.1 Assumptions

The baseline software assumes co-registration exists between the channels, and assumes nesting of the imagery pixels around the moderate pixels.

2.1.8.2 Limitations

Retrievals are not performed under nighttime conditions. This is defined as instances where the solar zenith angle exceeds 85 degrees.

Retrievals are not performed under confident cloudy conditions.

Retrievals are not performed over ocean surfaces.

Retrievals of EVI and other surface parameters are questionable under conditions of extreme aerosol loading, such as events associated with volcanic eruptions or biomass burning, and retrievals of EVI over snow are not guaranteed to meet the performance specification.

If for any reason the TOA or Surface Reflectance data is not available in DMS, the Vegetation Index algorithm is not performed.

3.0 GLOSSARY/ACRONYM LIST

3.1 Glossary

Table 8 contains terms most applicable for this OAD.

Table 8. Glossary

Term	Description
Algorithm	A formula or set of steps for solving a particular problem. Algorithms can be expressed in any language, from natural languages like English to mathematical expressions to programming languages like FORTRAN. On NPOESS, an algorithm consists of: 1. A theoretical description (i.e., science/mathematical basis) 2. A computer implementation description (i.e., method of solution) 3. A computer implementation (i.e., code)
Algorithm Configuration Control Board (ACCB)	Interdisciplinary team of scientific and engineering personnel responsible for the approval and disposition of algorithm acceptance, verification, development and testing transitions. Chaired by the Algorithm Implementation Process Lead, members include representatives from IWPTB, Systems Engineering & Integration IPT, System Test IPT, and IDPS IPT.
Algorithm Verification	Science-grade software delivered by an algorithm provider is verified for compliance with data quality and timeliness requirements by Algorithm Team science personnel. This activity is nominally performed at the IWPTB facility. Delivered code is executed on compatible IWPTB computing platforms. Minor hosting modifications may be made to allow code execution. Optionally, verification may be performed at the Algorithm Provider's facility if warranted due to technical, schedule or cost considerations.
EDR Algorithm	Scientific description and corresponding software and test data necessary to produce one or more environmental data records. The scientific computational basis for the production of each data record is described in an ATBD. At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance.
Environmental Data Record (EDR)	*[IORD Definition]* Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to geophysical parameters (including ancillary parameters, e.g., cloud clear radiation, etc.). *[Supplementary Definition]* An Environmental Data Record (EDR) represents the state of the environment, and the related information needed to access and understand the record. Specifically, it is a set of related data items that describe one or more related estimated environmental parameters over a limited time-space range. The parameters are located by time and Earth coordinates. EDRs may have been resampled if they are created from multiple data sources with different sampling patterns. An EDR is created from one or more NPOESS SDRs or EDRs, plus ancillary environmental data provided by others. EDR metadata contains references to its processing history, spatial and temporal coverage, and quality.
Model Validation	The process of determining the degree to which a model is an accurate representation of the real-world from the perspective of the intended uses of the model. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management]
Model Verification	The process of determining that a model implementation accurately represents the developer's conceptual description and specifications. [Ref.: DoDD 5000.59-DoD Modeling and Simulation Management]
Operational Code	Verified science-grade software, delivered by an algorithm provider and verified by IWPTB, is developed into operational-grade code by the IDPS IPT.
Operational-Grade Software	Code that produces data records compliant with the System Specification requirements for data quality and IDPS timeliness and operational infrastructure. The software is modular relative to the IDPS infrastructure and compliant with IDPS application programming interfaces (APIs) as specified for TDR/SDR or EDR code.

Term	Description
Raw Data Record (RDR)	*[IORD Definition]* Full resolution digital sensor data, time referenced, with absolute radiometric and geometric calibration coefficients appended, but not applied, to the data. Aggregates (sums or weighted averages) of detector samples are considered to be full resolution data if the aggregation is normally performed to meet resolution and other requirements. Sensor data shall be unprocessed with the following exceptions: time delay and integration (TDI), detector array non-uniformity correction (i.e., offset and responsivity equalization), and data compression are allowed. Lossy data compression is allowed only if the total measurement error is dominated by error sources other than the data compression algorithm. All calibration data will be retained and communicated to the ground without lossy compression. *[Supplementary Definition]* A Raw Data Record (RDR) is a logical grouping of raw data output by a sensor, and related information needed to process the record into an SDR or TDR. Specifically, it is a set of unmodified raw data (mission and housekeeping) produced by a sensor suite, one sensor, or a reasonable subset of a sensor (e.g., channel or channel group), over a specified, limited time range. Along with the sensor data, the RDR includes auxiliary data from other portions of NPOESS (space or ground) needed to recreate the sensor measurement, to correct the measurement for known distortions, and to locate the measurement in time and space, through subsequent processing. Metadata is associated with the sensor and auxiliary data to permit its effective use.
Retrieval Algorithm	A science-based algorithm used to 'retrieve' a set of environmental/geophysical parameters (EDR) from calibrated and geolocated sensor data (SDR). Synonym for EDR processing.
Science Algorithm	The theoretical description and a corresponding software implementation needed to produce an NPP/NPOESS data product (TDR, SDR or EDR). The former is described in an ATBD. The latter is typically developed for a research setting and characterized as "science-grade".
Science Algorithm Provider	Organization responsible for development and/or delivery of TDR/SDR or EDR algorithms associated with a given sensor.
Science-Grade Software	Code that produces data records in accordance with the science algorithm data quality requirements. This code, typically, has no software requirements for implementation language, targeted operating system, modularity, input and output data format or any other design discipline or assumed infrastructure.
SDR/TDR Algorithm	Scientific description and corresponding software and test data necessary to produce a Temperature Data Record and/or Sensor Data Record given a sensor's Raw Data Record. The scientific computational basis for the production of each data record is described in an Algorithm Theoretical Basis Document (ATBD). At a minimum, implemented software is science-grade and includes test data demonstrating data quality compliance.
Sensor Data Record (SDR)	*[IORD Definition]* Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to calibrated brightness temperatures with associated ephemeris data. Temperature Data Records (TDRs) are geolocated, antenna temperatures with all relevant calibration data counts and ephemeris data to revert from T-sub-a into counts. The existence of the SDRs provides reversible data tracking back from the EDRs to the Raw data. *[Supplementary Definition]* A Sensor Data Record (SDR) is the recreated input to a sensor, and the related information needed to access and understand the record. Specifically, it is a set of incident flux estimates made by a sensor, over a limited time interval, with annotations that permit its effective use. The environmental flux estimates at the sensor aperture are corrected for sensor effects. The estimates are reported in physically meaningful units, usually in terms of an angular or spatial and temporal distribution at the sensor location, as a function of spectrum, polarization, or delay, and always at full resolution. When meaningful, the flux is also associated with the point on the Earth geoid from which it apparently originated. Also, when meaningful, the sensor flux is converted to an equivalent top-of-atmosphere (TOA) brightness. The associated metadata includes a record of the processing and sources from which the SDR was created, and other information needed to understand the data.

Term	Description
Temperature Data Record (TDR)	*[IORD Definition]* Temperature Data Records (TDRs) are geolocated, antenna temperatures with all relevant calibration data counts and ephemeris data to revert from T-sub-a into counts. *[Supplementary Definition]* A Temperature Data Record (TDR) is the brightness temperature value measured by a microwave sensor, and the related information needed to access and understand the record. Specifically, it is a set of the corrected radiometric measurements made by an imaging microwave sensor, over a limited time range, with annotation that permits its effective use. A TDR is a partially-processed variant of an SDR. Instead of reporting the estimated microwave flux from a specified direction, it reports the observed antenna brightness temperature in that direction.

3.2 Acronyms

Table 9 contains terms most applicable for this OAD.

Table 9. Acronyms

Term	Expansion
AM&S	Algorithms, Models & Simulations
AOT	Aerosol Optical Thickness
API	Application Programming Interfaces
ARP	Application Related Product
CDFCB-X	Common Data Format Control Book - External
DMS	Data Management Subsystem
DQTT	Data Quality Test Table
DPIS ICD	Data Processor Inter-subsystem Interface Control Document
EVI	Enhanced Vegetation Index
GMVI	Gridded Monthly Vegetation Index
GVI	Global Vegetation Index
GWVI	Gridded Weekly Vegetation Index
INF	Infrastructure
ING	Ingest
IP	Intermediate Product
LUT	Look-Up Table
MDFCB	Mission Data Format Control Book
MVI	MODIS Vegetation Index
NDVI	Normalized Difference Vegetation Index
QF	Quality Flag
SDR	Sensor Data Record
SI	International System of Units
TBD	To Be Determined
TBR	To Be Resolved
TOA	Top of the Atmosphere
VI	Vegetation Index
VVI	VIIRS Vegetation Index

4.0 OPEN ISSUES

Table 10. TBXs

TBX ID	Title/Description	Resolution Date
None		