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**Joint Polar Satellite System (JPSS)  
Operational Algorithm Description  
(OAD)  
Document for VIIRS Land Surface  
Temperature (LST) Environmental  
Data Records (EDR) Software**

**For Public Release**

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**Goddard Space Flight Center  
Greenbelt, Maryland**

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National Aeronautics and  
Space Administration

**Joint Polar Satellite System (JPSS)  
Operational Algorithm Description (OAD) Document for  
VIIRS Land Surface Temperature (LST) Environmental  
Data Records (EDR) Software  
JPSS Electronic Signature Page**

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**Goddard Space Flight Center  
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## 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:

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## Change History Log

Revision	Effective Date	Description of Changes (Reference the CCR & CCB/ERB Approve Date)
Original	06/03/2011	This version incorporates <b>474-CCR-11-0113</b> which converts D38714, NPOESS Operational Algorithm Description Document for VIIRS Land Surface Temperature (LST) EDR, Rev B, dated 05/19/2010 to a JPSS document, Rev -. This was approved by the JPSS Ground Algorithm ERB on June 3, 2011.
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Revision B	10/09/2012	<b>474-CCR-12-0627:</b> This version authorizes 474-00070, Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for VIIRS Land Surface Temperature (LST) Environmental Data Records (EDR) Software, for the Mx 6.1 - 6.3 IDPS releases. Includes: <b>ECR-ALG-0035</b> which contains Raytheon PCR029764; LST EDR OAD needs to be updated for QF description updated on pages 15-16. Raytheon PCR031222, OAD: Implement 474-CCR-12-0355 (Correction to LST Binary LUT File & Update to Tunable Parameter XML File) (ADR 4608), Updated Tables 3 & 9 and pages 11-12, 14-16.
Revision C	05/14/2013	<b>474-CCR-13-0948:</b> This version authorizes 474-00070, JPSS OAD Document for VIIRS LST 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 D	11/06/2013	<b>474-CCR-13-1288:</b> This version authorizes 474-00070, JPSS OAD Document for VIIRS LST EDR Software, for Mx 8.0 IDPS release. Includes administrative changes authorized by interoffice memo and Raytheon PCR034406; OAD: PRO: 474-CCR-13-1056: Error in LST OAD (DR7203), in section 2.1.4.
Revision E	03/13/2017	<b>474-CCR-17-3243 (ECR-CGS-0734):</b> This version authorizes 474-00070, JPSS OAD Document for VIIRS LST EDR Software, for the Block 2.0 IDPS release. Includes Raytheon PCR045678: Block 2.0: PRO: OAD: CCR: 474-CCR-15-2444: General OAD Clean-up CCR/PCR, affects all 35/37 OADs. All sections and tables may be affected.



# **NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)**

## **OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR VIIRS LAND SURFACE TEMPERATURE (LST) EDR**

**SDRL No. S141  
SYSTEM SPECIFICATION SS22-0096**

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

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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.

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---	3-30-04	Initial Release.	All
A1	2-22-05	Reflects Science To Operational Code Conversion.	Pg 2
A2	8-31-05	Minor Edits On-Going. Implemented TM NP-EMD.2004.510.0047 in B1.3.	All
A3	7-27-07	Updated to match ops code.	All
A4	8-2-07	TMs NP-EMD-2006.510.0081, NP-EMD.2005.510.0132, NP-EMD.2005.510.0133, and NP-EMD.2006.510.0010 have been implemented in B1.5. Delivered to NGST.	All
A5	12-10-07	ECR A-103, EDRPR 1.8 CP 3 updates -Format changes for CDFCB-X compliance - Remove LST Granule Level QF Output and Description.	All
A6	9-12-08	Reformatted document to implement template D41851 format. Modified graceful degradation and data quality notification sections. New cover sheet, update references, acronym list, prepare for peer review. Delivered to NGST.	All
A7	9-15-08	Implemented TM NP-EMD-2008.510.0021	8, 12, 13
A8	12-9-08	Addressed NGST comments from last delivery.	All
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A	3-18-09	Incorporated TIM comments and final preparation for ARB/ACCB.	All
B1	11-04-09	Incorporated RFA No. 376 and updated for SDRL	All
B2	3-3-10	NP-EMD.2009.510.0077_LST_v4.15.1_OAD_Updates-RevB.DOC	All
B	5-19-10	Prepared for TIM/ARB/ACCB	All
C1	8-18-10	Updated Table 1 & 2 due to omission of TM 2010.510.0005.Rev-C	Table 1 & 2
C2	8-27-10	ECR1061/PCR024068 update output range values	Table 7
C3	10-14-10	Updated due to document convergence, to include tech memo 2010.510.0013	All
C4	9-19-11	Updated for PCRs 025898, 026163 and 027081	5, 7, 11- 12, 14 18

**Table of Contents**

1.0 INTRODUCTION..... 1

    1.1 Objective..... 1

    1.2 Scope ..... 1

    1.3 References ..... 1

        1.3.1 Document References ..... 1

        1.3.2 Source Code References ..... 3

2.0 ALGORITHM OVERVIEW ..... 5

    2.1 Land Surface Temperature EDR Description ..... 5

        2.1.1 Interfaces ..... 5

            2.1.1.1 Inputs ..... 6

            2.1.1.2 Outputs ..... 7

        2.1.2 Algorithm Processing..... 7

            2.1.2.1 Main Module – RetrieveLst ..... 8

            2.1.2.2 LST Retrieval Logic..... 8

            2.1.2.3 LST Quality Flag Logic..... 10

            2.1.2.4 LST LUT Coefficient Selection ..... 11

        2.1.3 Graceful Degradation..... 13

            2.1.3.1 Graceful Degradation Inputs ..... 13

            2.1.3.2 Graceful Degradation Processing ..... 14

            2.1.3.3 Graceful Degradation Outputs ..... 14

        2.1.4 Exception Handling ..... 14

        2.1.5 Data Quality Monitoring ..... 14

        2.1.6 Computational Precision Requirements ..... 14

        2.1.7 Algorithm Support Considerations ..... 15

        2.1.8 Assumptions and Limitations ..... 15

            2.1.8.1 Assumptions ..... 15

            2.1.8.2 Limitations..... 15

3.0 GLOSSARY/ACRONYM LIST ..... 16

    3.1 Glossary ..... 16

    3.2 Acronyms..... 19

4.0 OPEN ISSUES ..... 20

**List of Figures**

Figure 1. LST Processing Chain ..... 5  
 Figure 2. IPO Model Interface to INF and DMS ..... 6  
 Figure 3. LST Retrieval Logic Flow ..... 9

**List of Tables**

Table 1. Reference Documents ..... 1  
 Table 2. Source Code References ..... 3  
 Table 3. LST Main Inputs ..... 7  
 Table 4. LST QF/Quality Bit Field Logic Table (Retrieval Cases Only) ..... 11  
 Table 5. LST Core Equations ..... 13  
 Table 6. LST Graceful Degradation ..... 14  
 Table 7. Glossary ..... 16  
 Table 8. Acronyms ..... 19  
 Table 9. TBXs 20

**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 Joint Polar Satellite System (JPSS) 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 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.

**1.2 Scope**

The scope of this document is limited to the description of the core operational algorithm required to create the VIIRS Land Surface Temperature (LST) EDR. The theoretical basis for this algorithm is described in Section 3.3 of VIIRS Land Surface Temperature Algorithm Theoretical Basis Document ATBD, D0001-M01-S01-022.

**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 Land Surface Temperature Algorithm Theoretical Basis Document ATBD	D0001-M01-S01-022	Latest
VIIRS Radiometric Calibration Algorithm Theoretical Basis Document ATBD	D0001-M01-S01-003	Latest
Operational Algorithm Description Document for VIIRS Cloud Mask Environmental Data Records (VCM EDR)	474-00062	Latest

Document Title	Document Number/Revision	Revision Date
Operational Algorithm Description Document for VIIRS Aerosol Products (AOT, APSP & SM) Intermediate Product (IP)/Environmental Data Records (EDR)	474-00073	Latest
Operational Algorithm Description Document for Common Geolocation	474-00091	Latest
Operational Algorithm Description Document for VIIRS Geolocation (GEO) Sensor Data Record (SDR) and Calibration (CAL) SDR	474-00090	Latest
Operational Algorithm Description Document for VIIRS Surface Type (STYP) Environmental Data Records (EDR)	474-00068	Latest
Joint Polar Satellite System (JPSS) Algorithm Specification Part 21	474-00448-01-21 474-00448-02-21 474-00448-03-21 474-00448-04-21	Latest
Joint Polar Satellite System (JPSS) Algorithm Specification Part 6	474-00448-02-06	Latest
Joint Polar Satellite System (JPSS) Algorithm Specification Part 7	474-00448-02-07	Latest
Joint Polar Satellite System (JPSS) Algorithm Specification Part 11	474-00448-02-11	Latest
Joint Polar Satellite System (JPSS) Algorithm Specification Part 12	474-00448-02-12	Latest
Joint Polar Satellite System (JPSS) Algorithm Specification Part 19	474-00448-02-19	Latest
Joint Polar Satellite System (JPSS) Program Lexicon	470-00041	Latest
NGST/SE technical memo – LST OAD Update	NP-EMD.2004.510.0047	19 Nov 2004
NGST/SE technical memo – NPP_VIIRS_IST_LST_STIP_BugsFix	NP-EMD-2006.510.0081	31 Oct 2006
NGST/SE technical memo – LST OAD Update_Drop2.5.2	NP-EMD.2005.510.0132	21 Oct 2005
NGST/SE technical memo – LST_Drop2.5.2_UT	NP-EMD.2005.510.0133	21 Oct 2005
NGST/SE technical memo – NPP_VIIRS_LST_QFFillValues_SPCR_ALG979	NP-EMD.2006.510.0010	30 Jan 2006
NGST/SE technical memo – VIIRS IST EDR and LST EDR AOT Exclusion Implementation	NP-EMD-2006.510.0097, RevB	07 Feb 2007
NGST/SE technical memo – VIIRS LST Quality Flags Update	NP-EMD.2008.510.0021	15 Apr 2008
NGST/SE technical memo – NPP_LST_DegradQF&SurfTypeDefUpdate	NP-EMD.2008.510.0053_RevB	29 May 2009
NGAS/A&DP technical memo – LST_v4.15.1_Code_Updates-RevA	NP-EMD.2009.510.0076	15 Dec 2009
NGAS/A&DP technical memo – LST_v4.15.1_OAD_Updates-RevB	NP-EMD.2009.510.0077	23 Dec 2009
NGST/SE technical memo – Granule-Level Summary Exclusion Flag Definition Rev. C	NP.EMD.2010.510.0005.Rev-C	02 Mar 2010
NGST/SE technical memos: PC_OAD_Last_Drop_Corrections	NPOESS GJM-2010.510.0013	22 Sep 2010
NGST/SE technical memo –	NP.EMD.2010.510.0098	22 Dec 2010

Document Title	Document Number/Revision	Revision Date
LST Baseline Algorithm Mode Switch Setting Instructions		
NGST/SE technical memo – LST OAD Update for baseline algorithm mode switch setting	NP.EMD.2010.510.0099	22 Dec 2010

### 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**

Document Title	Reference Tag/Revision	Revision Date
VIIRS LST Science-grade Software	2.01	Jan 2006
VIIRS LST Operational Software	B1.5 (OAD Rev A4)	Jul 2007
NGST/SE technical memo – NPP_VIIRS_IST_LST_STIP_BugsFix	NP-EMD-2006.510.0081	31 Oct 2006
NGST/SE technical memo – LST_Drop2.5.2_UT	NP-EMD.2005.510.0133	21 Oct 2005
NGST/SE technical memo – NPP_VIIRS_LST_QFFillValues_SPCR_ALG979	NP-EMD.2006.510.0010	30 Jan 2006
NGST/SE technical memo – VIIRS LST Quality Flags Update	NP-EMD.2008.510.0021	15 Apr 2008
VIIRS LST Operational Software	Build 1.5.x.1-L (PCR019663) (OAD Rev A9)	18 Feb 2009
VIIRS LST Science-grade Software Includes TM: NP-EMD.2008.510.0021_NPP_LST_QualityFlagsUpdate	ISTN_VIIRS_NGST_2.5.5_DA TA (ECR A-145)	21 May 2008
VIIRS LST Science-grade Software	ISTN_VIIRS_NGST_2.5.6_DA TA	16 Apr 2009
VIIRS LST Science-grade Software	ISTN_VIIRS_NGST_4.15	27 May 2009
ACCB (no code update)	OAD Rev A	18 Mar 2009
SDRL (no code update)	OAD Rev B1	04 Nov 2009
VIIRS LST Science-grade Software Includes NGAS/A&DP technical memos – LST_v4.15.1_Code_Updates-RevA.DOC NP-EMD.2009.510.0076 (PCR 022280) LST_v4.15.1_OAD_Updates-RevB.DOC NP-EMD.2009.510.0077 (PCR 022281)	ISTN_VIIRS_NGST_4.15.1 (ECR A-264)	11 Jan 2010
VIIRS LST Operational Software Includes PCRs 22280 & 22281	Sensor Characterization (Build SC-8) (OAD Rev B2)	02 Mar 2010
PCR 21488 [TM 2010.510.0005.Rev-C ] (No OAD update required)	Build Sensor Characterization SC-09	05 Apr 2010
ACCB	OAD Rev B	19 May 2010
ECR1061/PCR024068 update output range values	(OAD Rev C2)	27 Aug 2010
Convergence Updates (No code updates)	(OAD Rev C3)	14 Oct 2010
VIIRS LST Science-grade Software Includes NGAS/A&DP technical memos – LST Baseline Algorithm Mode Switch Setting Instructions) LST OAD Update for Baseline Algorithm Mode Switch Setting Instructions	ISTN_VIIRS_NGST_4.15.2 (ECR Alg-0004)	13 Jan 2011
VIIRS LST Operational Software PCR025898 (TM 2010.510.0098)	Build Maintenance Release 1.05.06-F	02 Aug 2011

Document Title	Reference Tag/Revision	Revision Date
PCRs 026163 (TM 2010.510.0099) and 027081 (x-ref PCR025632)	(OAD Rev C4)	19 Sep 2011
OAD transitioned to JPSS Program – this table is no longer updated.		

## 2.0 ALGORITHM OVERVIEW

The purpose of the LST Module is to retrieve the LST for each cloud-free land pixel at VIIRS moderate-resolution. Brightness temperature data from the VIIRS SDR, VIIRS Aerosol Optical Thickness (AOT) Intermediate Product (IP), VIIRS Cloud Mask (VCM) EDR, and VIIRS Surface Type (STYP) EDR are used to decide whether the pixel is processed. A 2-band single split-window algorithm is the operational baseline algorithm and a 4-band dual split-window algorithm is available as an optional algorithm. LST is retrieved using a regression equation with separate coefficients for each of the 17 International Geosphere-Biosphere Program (IGBP) land cover types. Moderate resolution pixel level LST in Kelvin and the associated 3-byte LST quality information are written to the VIIRS LST EDR. The LST Processing Chain is shown in Figure 1.

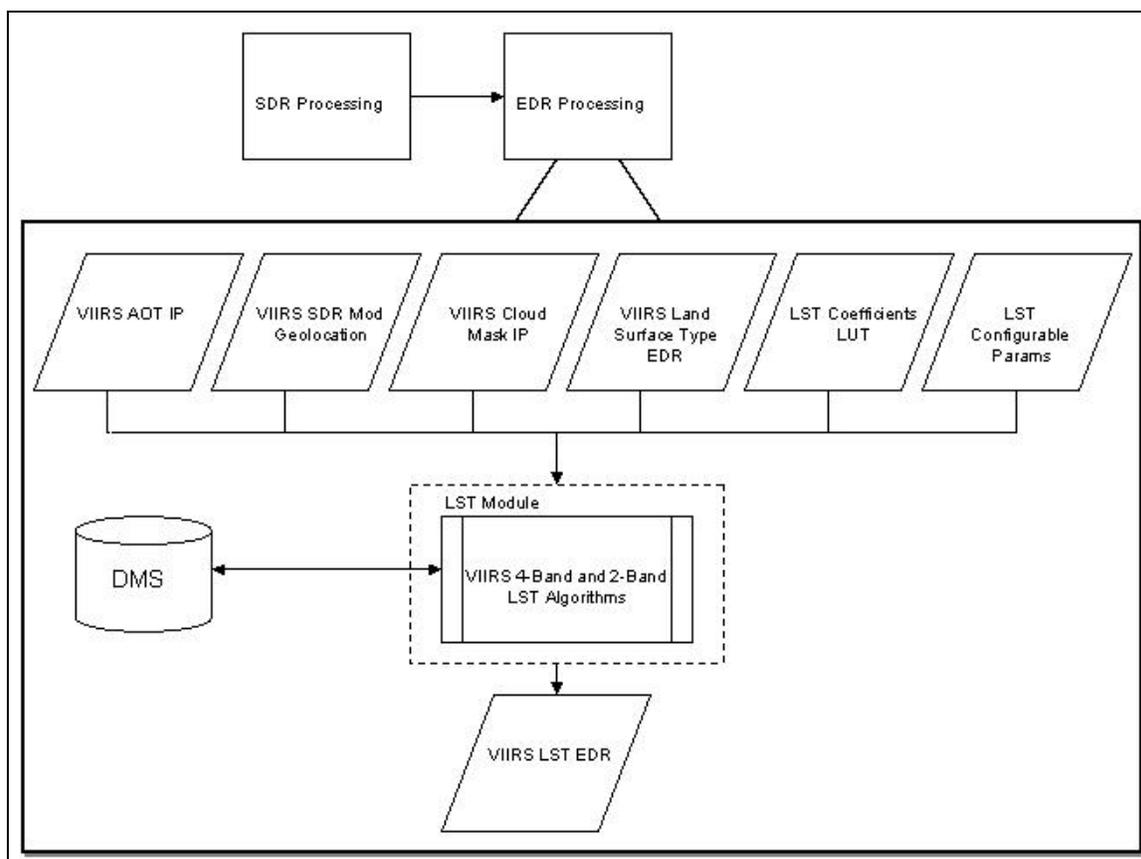


Figure 1. LST Processing Chain

### 2.1 Land Surface Temperature EDR Description

The VIIRS Land Surface Temperature Algorithm Theoretical Basis Document ATBD, D0001-M01-S01-022, describes in detail the VIIRS LST retrieval algorithm.

#### 2.1.1 Interfaces

To begin data processing, the Infrastructure (INF) Subsystem Software Item (SI) initiates the LST algorithm. The INF SI provides tasking information to the algorithm indicating which

granule to process. The Data Management Subsystem (DMS) SI provides data storage and retrieval capability. A library of C++ classes implements the SI interfaces, depicted in Figure 2.

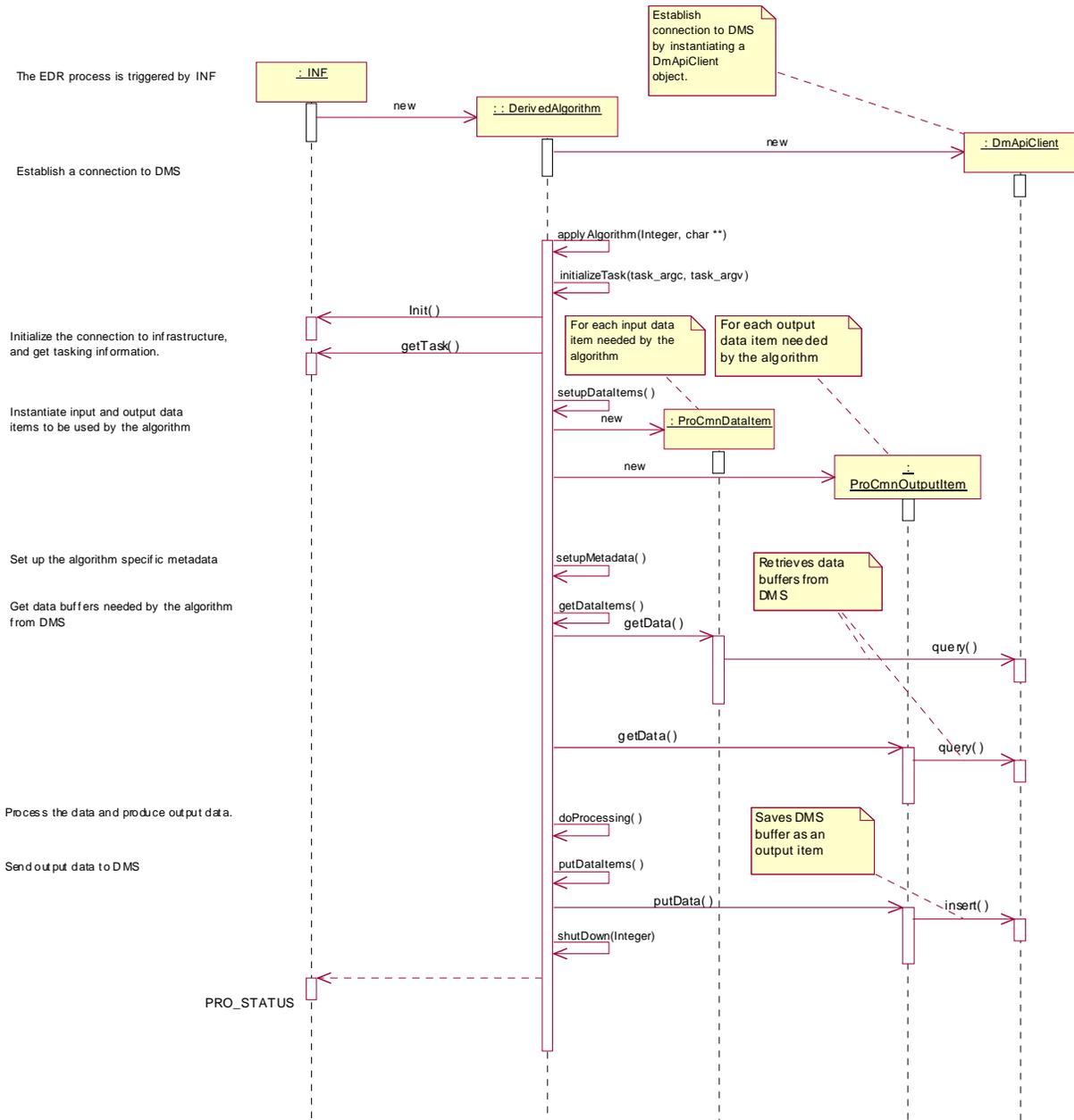


Figure 2. IPO Model Interface to INF and DMS

### 2.1.1.1 Inputs

The LST algorithm requires several types of input data (see Table 3 below); they are summarized in 474-00448-01-21\_JPSS-SRS-Vol-I-Part-21.

**Table 3. LST Main Inputs**

Input	Description	Reference Document
VIIRS M12 SDR Brightness Temperature	VIIRS Top of the atmosphere (TOA) brightness temperatures of Band 12	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS M13 SDR Brightness Temperature	VIIRS Top of the atmosphere (TOA) brightness temperatures of Band 13	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS M15 SDR Brightness Temperature	VIIRS Top of the atmosphere (TOA) brightness temperatures of Band 15	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS M16 SDR Brightness Temperature	VIIRS Top of the atmosphere (TOA) brightness temperatures of Band 16	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS Mod Terrain Corrected Geolocation Data	VIIRS Terrain Corrected Geolocation Data	474-00448-02-06_JPSS-DD-Vol-II-Part-06
VIIRS Cloud Mask EDR	VIIRS Cloud Mask Quality flags	474-00448-02-11_JPSS-DD-Vol-II-Part-11
VIIRS Surface Type EDR	Surface Type EDR	474-00448-02-19_JPSS-DD-Vol-II-Part-19
VIIRS AOT IP	VIIRS Aerosol Optical Thickness	474-00448-02-12_JPSS-DD-Vol-II-Part-12
VIIRS LST LUT	VIIRS LST Lookup Table	474-00448-02-21_JPSS-DD-Vol-II-Part-21
VIIRS LST AC	VIIRS LST Coefficient file	474-00448-02-21_JPSS-DD-Vol-II-Part-21
VIIRS GIP QST	Gridded IP QST	474-00448-02-07_JPSS-DD-Vol-II-Part-7

**2.1.1.2 Outputs**

Refer to the 474-00448-02-21\_JPSS-DD-Vol-II-Part-21, Section 5.1 for a description of outputs of the LST algorithm.

**2.1.2 Algorithm Processing**

The objective of the LST algorithm is to calculate LST at each pixel in a moderate resolution (750 m) granule with all available input. Two similar regression algorithms are used to perform this retrieval:

- 1) The operational baseline algorithm is the 2-band split-window algorithm where only the LWIR band pair M15 and M16 are used. The 2-band split-window algorithm is set as the baseline operational algorithm by a run time switch.
  
- 2) A 4-band dual-split window algorithm is available as an optional algorithm that uses brightness temperatures from two pair of VIIRS wavebands—one pair in the Medium-Wavelength Infrared (MWIR) atmospheric window (Bands M12 and M13) and the other pair in the Long-Wavelength Infrared (LWIR) atmospheric window (Bands M15 and M16), and Quality assessment flags for each pixel are stored in the LST Flag output..

### **2.1.2.1 Main Module – RetrieveLst**

#### **2.1.2.2 LST Retrieval Logic**

The logic flow of the LST retrieval algorithm is provided in Figure 3. The core logic occurs in two functions, `setLstQualFlags()` and `calculateLst()`. In the current implementation, LST QFs additionally serve as decision flags. Their values are used in the decision of whether LST can be retrieved and, if so, which algorithm to use.

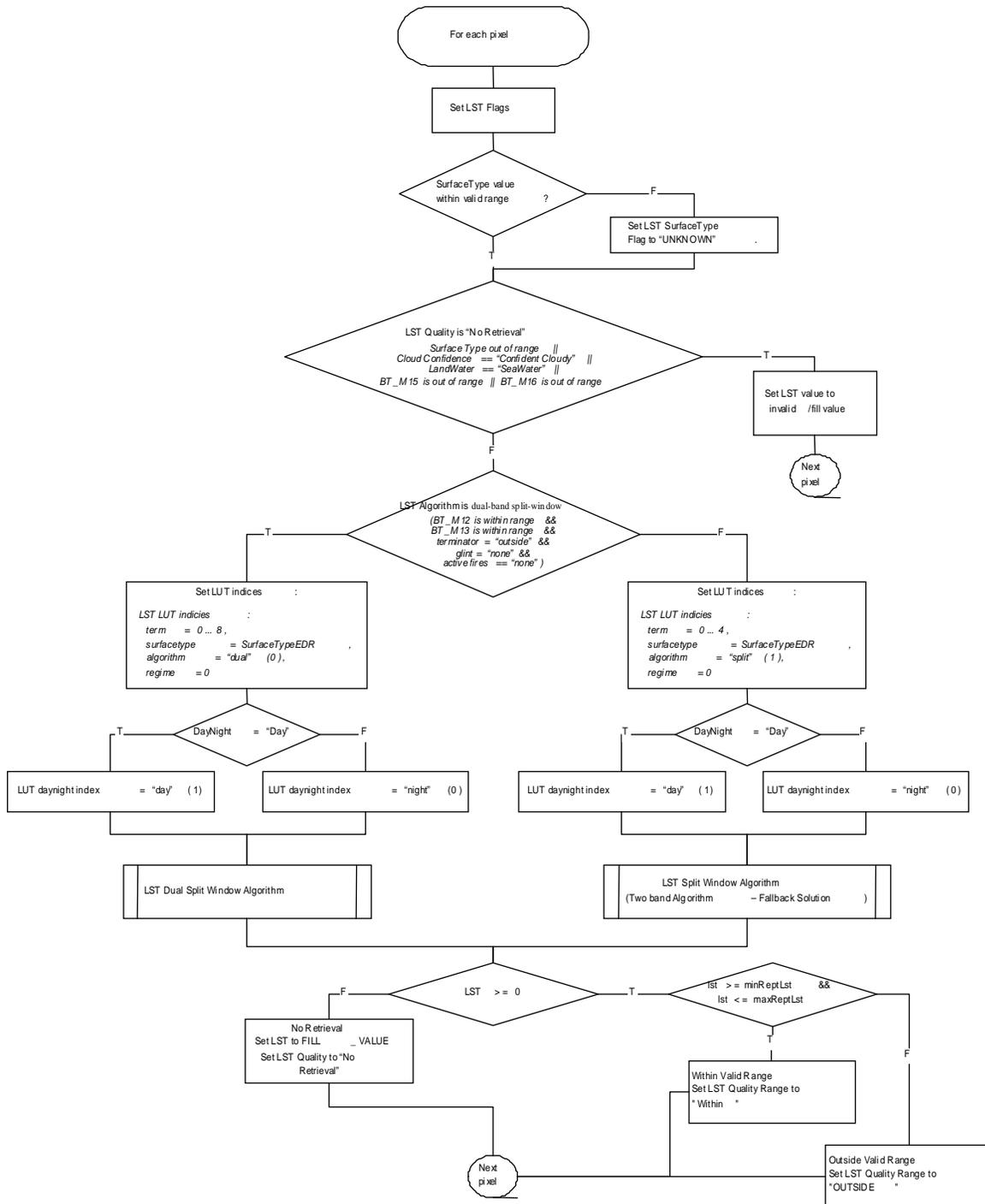


Figure 3. LST Retrieval Logic Flow

LST is not retrieved if any of the following conditions occur:

- The pixel is cloudy (i.e., Cloud Confidence Flag is “Confidently Cloudy”), or
- The pixel is an ocean pixel (i.e., LandWater Flag is “SeaWater”), or
- Band M15 brightness temperature is outside the LST defined range, or
- Band M16 brightness temperature is outside the LST defined range, or
- Land STYP is outside the LST defined range.

These pixels are marked with an LST QF of “No Retrieval” and are output with fill values.

For pixels that are processed, LST is retrieved by either the 2-band, split-window algorithm or an optional 4-band dual split window algorithm. The 2-band split-window algorithm is used as the operational baseline algorithm. The optional 4-band, dual split-window algorithm is available but may be used only under optimal conditions: no solar glint, no active fires, outside the terminator, and “in-range” brightness temperatures for the M12 and M13 bands. If the 4-band dual split-window algorithm is optionally invoked the algorithm will automatically revert to the split-window algorithm for non-optimal conditions. See Table 5, Section 2.1.2.3, for the logic to algorithm is used. The 2-band, split window algorithm is set as the operational baseline algorithm by a run time algorithm mode switch (*algmode*). A switch value of “1” specifies that the 2-band split window algorithm will be used as the baseline operational algorithm. A switch value of “0” specifies that the optional dual split-window algorithm is to be used. The run time algorithm mode switch should be set to 1 as the default run mode for initial operations at IDPS, corresponding to use of the 2-band split-window algorithm as the baseline algorithm. Determination of whether the 2-band split-window LST algorithm should remain as the baseline algorithm will be made during calibration/validation of the LST algorithm. If it is determined as a result of performance evaluated during calibration/validation that the 2-band split window algorithm should no longer be the baseline algorithm then the algorithm mode switch should be set to 0 resulting in the 4-band, dual split-window algorithm being used.

Core equations for the dual-band split-window and split-window fallback algorithms are specified in Table 10. The implementation is presented in `calculateLst()`. The daytime dual-band split-window algorithm varies slightly from its nighttime counterpart in that a solar zenith angle correction is made for the daytime retrieval.

For an off-nominal condition where a negative LST is retrieved, the LST field is filled and the LST quality bit field is set to “No Retrieval”.

The list of configurable algorithm parameters can be found in JPSS-DD-Vol-II-Part-21, Table 7.2.2.2-1.

### 2.1.2.3 LST Quality Flag Logic

The LST Flags consist of three 8-bit words. The QF definition and formats are described in the LST SRS Data Dictionary Volume II 474-00448-02-21-B0200. The logic to set these flags is performed in function `setLstQualFlags()`.

Overall LST pixel quality is represented by the quality bit field and is described in the table below:

**Table 4. LST QF/Quality Bit Field Logic Table (Retrieval Cases Only)**

No Land	M15 & M16 Available	LST >= 0	Degraded – Sensor Zenith Angle > 40	Active Fire	Horizontal Reporting Interval	AOT Range	Thin Cirrus	Cloud Confidence Indicator		
								Confident Clear	Probably Clear	Probably Cloudy
F	T	T	x	x	x	x	yes	Low	Low	Low
F	T	T	x	x	x	out	x	Low	Low	Low
F	T	T	x	x	out	x	x	Low	Low	Low
F	T	T	x	fire	x	x	x	Low	Low	Low
F	T	T	out	no	in	in	no	Medium	Medium	Low
F	T	T	in	no	in	in	no	High	Medium	Low
T	F	F	x	x	x	x	x	No Retrieval	No Retrieval	No Retrieval

LST >= 0: T = True; F = False

Degraded – Sensor Zenith > 40: out = Outside Range, in = Within Range

Active Fire: no = no active fire; fire = active fire

Horizontal Reporting Interval: out = Outside Range, in = Within Range

AOT Range: out = Outside Range, in = Within Range

Thin Cirrus: yes = Thin Cirrus, no = No Thin Cirrus

x = “Indifferent”

Note regarding the Sfc Type QF: The Sfc Type EDR has an array of surface types granulated from the IGBP Sfc Type tiles. However, when that array is copied into the LST EDR Sfc Type qf it is further modified by the Sfc Type EDR snow/ice qf to be snow/ice if that qf was triggered. That Sfc Type EDR snow/ice qf is triggered if the binary snow map EDR input is available (binary snow map is day only, not conf cloudy,  $sza < 85$  deg) and greater than a threshold (0.5). If that qf is not triggered, then the surface type in the LST EDR sfc type qf will remain the same as given in the Sfc Type EDR.

**2.1.2.4 LST LUT Coefficient Selection**

A unique set of regression coefficients is derived offline for each land type. Each LST core equation (Table 6) uses a different set of coefficients for a given land STYP and day/night condition. Access to the coefficients is achieved by setting the values of the indices based on the given pixel viewing conditions and indicating the algorithm approach to be used. Once indices are specified, coefficients are retrieved for the desired LST algorithm by indexing on the “term” index. Currently, the “regime” index is set to “0” and has only one value. It is a placeholder for possible future improvement by further stratification of atmospheric conditions or geolocations. For the dual split-window algorithm, there are nine coefficients. For the split-window fallback algorithm, there are five coefficients. For the latter, four additional zero-valued coefficients are present as “fillers” in the LUT file.

Refer to JPSS-DD-Vol-II-Part-21, Table 7.1.1.2-1 to see the LST LUT format.

Example:

LUTCoeffs[n][1][14][0][0], where n is indexed from 0 to 8, corresponds to the coefficients  $a_0$  to  $a_8$  of the dual split algorithm under daytime viewing conditions with no solar glint or active fire and with a pixel viewing surface type 14.

**Table 5. LST Core Equations**

<b>VIIRS single split-window LST algorithm (Operational Baseline Algorithm)</b>	
Daytime:	$LST = a_0 + a_1 T_{M15} + a_2 (T_{M15} - T_{M16}) + a_3 (\sec\theta - 1) + a_4 (T_{M15} - T_{M16})^2$
Nighttime:	$LST = b_0 + b_1 T_{M15} + b_2 (T_{M15} - T_{M16}) + b_3 (\sec\theta - 1) + b_4 (T_{M15} - T_{M16})^2$
<b>VIIRS dual split-window LST algorithm (Optional Algorithm)</b>	
Daytime:	$LST = a_0 + a_1 T_{M15} + a_2 (T_{M15} - T_{M16}) + a_3 (\sec\theta - 1) + a_4 T_{M12} + a_5 T_{M13} + a_6 T_{M12} \cos\varphi + a_7 T_{M13} \cos\varphi + a_8 (T_{M15} - T_{M16})^2$
Nighttime:	$LST = b_0 + b_1 T_{M15} + b_2 (T_{M15} - T_{M16}) + b_3 (\sec\theta - 1) + b_4 T_{M12} + b_5 T_{M13} + b_6 T_{M12}^2 + b_7 T_{M13}^2 + b_8 (T_{M15} - T_{M16})^2$
where, LST is the retrieved land surface temperature, $a_n$ and $b_n$ are coefficients retrieved from the LST LUT and are dependent on surface type and day/night conditions, $\theta$ is the sensor zenith angle, $\varphi$ is the solar zenith angle, $T_\lambda$ is the brightness temperature at $\lambda =$ VIIRS Band M15, M16, M12 or M13.	
The equations above correspond to the LST ATBD, 474-00051, Section 3.3.2, Equations (14), (15) and (16) with minor modifications (i.e., in order to simplify the software; coefficients for the daytime and nighttime equations for the baseline algorithm are equal).	

### 2.1.3 Graceful Degradation

#### 2.1.3.1 Graceful Degradation Inputs

There are two cases where input graceful degradation is indicated in the Land Surface Temperature EDR.

1. The primary input denoted in the algorithm configuration guide cannot be successfully retrieved but an alternate input can be retrieved.
2. An input retrieved for the algorithm had its N\_Graceful\_Degradation metadata field set to YES (propagation).

Table 6 details the instances of these two cases for LST. Note that the shaded cells indicate that the graceful degradation was done upstream at product production.

**Table 6. LST Graceful Degradation**

<b>Input Data Description</b>	<b>Primary Data Source</b>	<b>1<sup>st</sup> Back-up Data Source</b>	<b>2<sup>nd</sup> Back-up Data Source</b>	<b>3<sup>rd</sup> Back-up Data Source</b>
Surface Type	VIIRS-ST-EDR	VIIRS-GridIP- VIIRS-Qst-Mod- Gran	N/A	N/A
Aerosol Optical Thickness	VIIRS-Aeros-Opt- Thick-IP	VIIRS-ANC- Optical-Depth- Mod-Gran (NAAPS-ANC-Int)	VIIRS-ANC- Optical-Depth- Mod-Gran (NAAPS-ANC-Int) Extended Forecast	VIIRS-ANC- Optical-Depth- Mod-Gran (AOT-ANC) Climatology

**2.1.3.2 Graceful Degradation Processing**

None.

**2.1.3.3 Graceful Degradation Outputs**

None.

**2.1.4 Exception Handling**

When LST cannot be retrieved due to conditions such as invalid SDR data, cloud-contaminated pixel, invalid STYP, or sea-water pixel classification from the VCM EDR Land/Water Flag, LST pixel values are set to NA\_FLOAT32\_FILL.

In addition to this, code is added to check the bounds of the input into the LST EDR. The list of configurable algorithm parameters can be found in JPSS-DD-Vol-II-Part-21, Table 7.2.2.2-1 and contains input values to LST that are configurable and can be changed without having to recompile. The “Range of Values” column lists the current value of this input.

Very few operations in the algorithm (beyond address references) have the potential to cause exceptions. There are no divide operations in any routine that could be a division by zero.

**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. 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. Refer to 474-00448-02-01\_JPSS-DD-Vol-II-Part-1 for more information on Data Quality Notifications.

**2.1.6 Computational Precision Requirements**

The Land Surface Temperature is a scaled value ranging from 0 to 65527. The loss of precision from replacing this value (resolution of the scaled output versus the required accuracy and

precision of the LST EDR) with a scaled 16-bit integer is acceptable. After calculation, the value is scaled by a factor of  $(\text{max value} - \text{min value}) / (2^{16} - 9)$ .

### **2.1.7 Algorithm Support Considerations**

INF and DMS must be running before the Land Surface Temperature algorithm is executed.

### **2.1.8 Assumptions and Limitations**

#### **2.1.8.1 Assumptions**

The LST retrieval algorithm assumes VIIRS 750 M SDR, VIIRS AOT IP, VCM EDR, and VIIRS STYP EDR are available before processing.

#### **2.1.8.2 Limitations**

The LST EDR is retrieved under clear condition with known STYP classification and valid brightness temperatures from at least the VIIRS M15 and M16 bands, and with  $\text{AOT} < 1$  to have a retrieved pixel of high quality. A pixel of low quality is retrieved if AOT is out of the acceptable bounds.

Precipitable Water (PW), atmospheric transmittance and surface emissivity corrections discussed in Section 3.3.4 of the ATBD, D0001-M01-S01-022, are not implemented.

### 3.0 GLOSSARY/ACRONYM LIST

#### 3.1 Glossary

Table 7 contains terms most applicable for this OAD.

**Table 7. Glossary**

<b>Term</b>	<b>Description</b>
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 JPSS, an algorithm consists of: A theoretical description (i.e., science/mathematical basis) A computer implementation description (i.e., method of solution) A computer implementation (i.e., code)
Algorithm Engineering Review Board (AERB)	Interdisciplinary board of scientific and engineering personnel responsible for the approval and disposition of algorithm acceptance, verification, development and testing transitions. Chaired by the Data Process Algorithm Lead, members include representatives from STAR, DPES, IDPS, and Raytheon..
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 GRAVITE facility. Delivered code is executed on compatible GRAVITE 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.
Ancillary Data	Any data which is not produced by the JPSS System, but which is acquired from external providers and used by the JPSS system in the production of JPSS data products.
Auxiliary Data	Auxiliary Data is defined as data, other than data included in the sensor application packets, which is produced internally by the JPSS system, and used to produce the JPSS deliverable data products.
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 JPSS 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.
Model Verification	The process of determining that a model implementation accurately represents the developer's conceptual description and specifications.
Operational Code	Verified science-grade software, delivered by an algorithm provider and verified by GRAVITE, 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.
Raw Data Record (RDR)	[IORD Definition] Full resolution digital sensor data, time referenced and earth located, 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

Term	Description
	<p>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.</p> <p>[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 JPSS (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.</p>
Retrieval Algorithm	<p>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.</p>
Science Algorithm	<p>The theoretical description and a corresponding software implementation needed to produce an NPP/JPSS 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".</p>
Science Algorithm Provider	<p>Organization responsible for development and/or delivery of TDR/SDR or EDR algorithms associated with a given sensor.</p>
Science-Grade Software	<p>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.</p>
SDR/TDR Algorithm	<p>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.</p>
Sensor Data Record (SDR)	<p>[IORD Definition]                      Data record produced when an algorithm is used to convert Raw Data Records (RDRs) to calibrated brightness temperatures with associated ephemeris data. The existence of the SDRs provides reversible data tracking back from the EDRs to the Raw data.</p> <p>[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.</p>
Temperature Data Record (TDR)	<p>[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.</p> <p>[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</p>

Term	Description
	estimated microwave flux from a specified direction, it reports the observed antenna brightness temperature in that direction.

### 3.2 Acronyms

Table 8 contains acronyms most applicable for this OAD.

**Table 8. Acronyms**

<b>Term</b>	<b>Expansion</b>
AM&S	Algorithms, Models & Simulations
API	Application Programming Interfaces
ARP	Application Related Product
DMS	Data Management Subsystem
DQTT	Data Quality Test Table
INF	Infrastructure
ING	Ingest
IP	Intermediate Product
LST	Land Surface Temperature
LUT	Look-Up Table
PW	Precipitable Water
QF	Quality Flag
SDR	Sensor Data Records
SI	Software Item or International System of Units
SST	Sea Surface Temperature
STYP	Surface Type
TBD	To Be Determined
TBR	To Be Resolved
VCM	VIIRS Cloud Mask

**4.0 OPEN ISSUES**

**Table 9. TBXs**

TBX ID	Title/Description	Resolution Date
None		