

**GSFC JPSS CMO
January 25, 2012
Released**

Effective Date: January 18, 2012
Revision A

**Joint Polar Satellite System (JPSS), Ground Project
Code 474
474-00076**

**Joint Polar Satellite System (JPSS)
Operational Algorithm Description (OAD)
Document for Advanced Technology
Microwave Sounder (ATMS) Sensor Data
Record (SDR) 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**

This page intentionally left blank.

Joint Polar Satellite System (JPSS) Operational Algorithm Description (OAD) Document for Advanced Technology Microwave Sounder (ATMS) Sensor Data Record (SDR) Software

JPSS Electronic Signature Page

Prepared by (Book Boss), Reviewed by (if reviewer approved in MIS), Approved by (CCB Chair).

Prepared By:

Neal Baker
JPSS Data Products and Algorithms, Senior Engineering Advisor
(Electronic Approvals available online at (https://jpssmis.gsfc.nasa.gov/mainmenu_dsp.cfm))

Approved By:

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

**Goddard Space Flight Center
Greenbelt, Maryland**

This page intentionally left blank.

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

This page intentionally left blank.

This page intentionally left blank.



NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

OPERATIONAL ALGORITHM DESCRIPTION DOCUMENT FOR ATMS SDR

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

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

**Copyright © 2004-2011
Raytheon Company
Unpublished Work
ALL RIGHTS RESERVED**

Portions of this work are the copyrighted work of Raytheon. However, other entities may own copyrights in the work. Therefore, the recipient should not imply that Raytheon is the only copyright owner in this work.

This documentation/technical data was developed pursuant to Contract Number F04701-02-C-0502 with the US Government under subcontract number 7600002744. The US Government's rights 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 ATMS SDR

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

NORTHROP GRUMMAN

Raytheon



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

CAGE NO. 11982

**Operational Algorithm Description
ATMS SDR**

Document Date: Jun 29, 2011

**Document Number: D39309
Revision: C2**

PREPARED BY:

Degui Gu, CrIMSS Mission and Products *Date*
Lead

Paul D. Siebels *Date*
IDPS Processing SI Software 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



Revision/Change Record

Document No.
D39309

Revision	Document Date	Revision/Change Description	Pages Affected
---	9-17-04	Initial Release.	All
A1	8-12-05	Reflects Science To Operational Code Conversion.	All
A2	11-17-06	Updates for IDPS Build 1.5 PRO ATMS SDR EDR PR Code Review.	All
A3	3-9-07	Updates reflect science code changes in post-drop delivery to IDPS (ISTN_ATMS_NGST_3.1).	All
A4	9-10-07	Updated logo, header, dates, etc. TMs NP-EMD.2007.510.0017, NP-EMD.2007.510.0018 & NP-EMD-2007.510.0039 have been implemented in B1.5.	All
A5	9-17-07	Delivered to NGST.	All
A6	11-21-07	Added ECR-122 updates.	All
A7	12-5-07	Reformatted to new template, updated for comments from previous delivery, delivered to NGST.	All
A8	12-17-07	ECR A-103, EDR-PR 1.8 CP3, and CDFCB-X compliance updates – removed pixel-level quality flag field from the geolocation output.	21
A9	4-11-08	Updated output product descriptions.	13,16
A10	5-14-08	Updated in response to comments from last delivery to NGST.	All
A	05-28-08	Incorporate interim changes and addressed TIM (5/20/08) comments.	All
B1	07-17-08	Updated DMS output structure for SDR GEO product	All
B2	12-01-09	Updated for RFA No. 544, and updated subcontract number	Title Page and Table 1
B3	12-18-09	Updated for Algorithm Tracker IPO-3671 captured in PCR21730	Title Page and Table 5
B4	3-14-10	Updated comment on blackbody resolver counter to capture changes in PCR022860	Page 12 Table 5
B	4-28-10	Updated for PCR 22396 and prepared for TIM/ARB/ACCB	All
C1	11-19-10	Updates for Algorithm Development Library	All
C2	06-29-11	Updated for ISTN_ATMS_SDR_NGST_SC7.1_NG1,(ECR-A0018) and TM 2011.510.0005	All

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 ATMS Verified RDR Description..... 6

 2.1.1 Interfaces 6

 2.1.1.1 Inputs 6

 2.1.1.2 Outputs 7

 2.1.2 Algorithm Processing 7

 2.1.2.1 Create Verified RDRs (ProSdrAtms::createVerifiedAtmsRdr()) 7

 2.1.3 Graceful Degradation..... 8

 2.1.4 Exception Handling 8

 2.1.5 Data Quality Monitoring 8

 2.1.6 Computational Precision Requirements 9

 2.1.7 Algorithm Support Considerations 9

 2.1.8 Assumptions and Limitations 9

 2.2 ATMS SDR Geolocation and Calibration Description..... 9

 2.2.1 Interfaces 9

 2.2.1.1 Inputs 11

 2.2.1.2 Outputs 15

 2.2.2 Algorithm Processing 25

 2.2.2.1 Detailed Design of Radiometric Calibration 26

 2.2.2.1.1 PRT Conversion 27

 2.2.2.1.1.1 Conversion from Counts to Resistance 27

 2.2.2.1.1.2 Conversion from Resistance to Physical Temperature..... 28

 2.2.2.1.2 Calculation of Average Hot Target PRT Temperature, \bar{T}_W 29

 2.2.2.1.3 Shelf Temperature Calculations, T_{SHELF} 30

 2.2.2.1.4 Calculation of Effective Hot Target Temperature 31

 2.2.2.1.5 Calculation of Effective Cold Calibration Brightness Temperature..... 31

 2.2.2.1.6 Average Number of Counts from the Warm Calibration View, C_{WCA} 32

2.2.2.1.7	Average Number of Counts from the Cold Calibration View, C_{CCA}	33
2.2.2.1.8	Scan Position Dependent Correction to Brightness Temperature.....	35
2.2.2.1.9	Missing PRT Count, Warm Count or Cold Count.....	35
2.2.2.2	ProSdrAtms (ProSdrAtms.cpp).....	35
2.2.2.3	calcAtmsSdrs (calcAtmsSdrs.f).....	35
2.2.2.4	Initialize the ATMS SDR Outputs and Flags (init_atms_sdr_flags.f).....	36
2.2.2.5	NeDT Calculation (sdrs.f - routine compute_nedt).....	36
2.2.2.6	Calibration Module (c2k_new.f).....	36
2.2.2.7	ATMS SDR Geolocation (ProSdrAtms::calcGeolocation()).....	39
2.2.2.7.1	Calculation of mid-scan spacecraft position, velocity and attitude.....	41
2.2.2.7.2	Calculation of geolocation.....	41
2.2.2.7.3	Lunar Intrusion Detection.....	42
2.2.3	Graceful Degradation.....	44
2.2.4	Exception Handling.....	44
2.2.5	Data Quality Monitoring.....	44
2.2.5.1	Quality Flags.....	44
2.2.6	Computational Precision Requirements.....	46
2.2.7	Algorithm Support Considerations.....	46
2.2.8	Assumptions and Limitations.....	46
3.0	GLOSSARY/ACRONYM LIST.....	47
3.1	Glossary.....	47
3.2	Acronyms.....	50
4.0	OPEN ISSUES.....	54

List of Figures

Figure 1. Processing Chain..... 5
 Figure 2. IPO Model Interface to INF and DMS 6
 Figure 3. Create Verified ATMS RDR Flow Diagram..... 8
 Figure 4. ATMS SDR Top Level Flow Diagram 25
 Figure 5. ATMS SDR Calibration Flow 38
 Figure 6. ATMS SDR Geolocation Flow Diagram 40

List of Tables

Table 1. Reference Documents 1
 Table 2. Source Code References..... 3
 Table 3. ATMS Verified RDR Algorithm Inputs 7
 Table 4. Counts to Engineering Units Conversions 9
 Table 5. ATMS SDR Algorithm Inputs 11
 Table 6. ATMS SDR Tunable Parameters..... 12
 Table 7. ATMS SDR Outputs..... 15
 Table 8. ATMS SDR Data..... 16
 Table 9. ATMS TDR Data..... 20
 Table 10. ATMS SDR GEO Data..... 23
 Table 11. ATMS SDR IP..... 24
 Table 12. Cold Plate Temperature/Shelf Temperature Matchings..... 27
 Table 13. Calibration Module Inputs 38
 Table 14. Calibration Module Outputs 39
 Table 15. Data Quality Notification Criteria..... 44
 Table 16. Quality Flag Output..... 45
 Table 17. Glossary..... 47
 Table 18. Acronyms 50
 Table 19. TBXs 54

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 Advanced Technology Microwave Sounder (ATMS) Sensor Data Record (SDR).

1.2 Scope

The scope of this document is limited to the description of the core operational algorithm(s) required to create the ATMS SDR. The theoretical basis for the calibration algorithm is described in the Advanced Technology Microwave Sounder (ATMS) SDR Radiometric Calibration Algorithm Theoretical Basis Document, 474-00043. The basis for the geolocation algorithm is described in this document.

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
Advanced Technology Microwave Sounder (ATMS) SDR Radiometric Calibration Algorithm Theoretical Basis Document	474-00043	22 Apr 2011
Software Design Description (SDD) for ATMS SDR	Report #13516, Rev 1.1	12 Nov 2004
JPSS Environmental Data Record (EDR) Production Report for NPP	474-00012 Rev. A	09 Feb 2011

Document Title	Document Number/Revision	Revision Date
JPSS Environmental Data Record (EDR) Interdependency Report (IR) for NPP	474-0007 Rev. A	09 Feb 2011
NPP Mission Data Format Control Book and App A (MDFCB)	472-REF-00057	06 Jan 2011
JPSS Common Data Format Control Book - External - Volume I - Overview	474-00001-01, Rev-	10-Dec-10
JPSS Common Data Format Control Book - External - Volume II - RDR Formats	474-00001-02, Rev-	10-Dec-10
JPSS Common Data Format Control Book - External - Volume III - SDR/TDR Formats	474-00001-03, Rev-	16-Feb-11
JPSS Common Data Format Control Book - External - Volume IV - Part I - IPs, ARPs, and Geolocation Data	474-00001-04-01, Rev-	10-Dec-10
JPSS CDFCB - External - Volume IV - Part II - Imagery, Atmospheric, and Cloud EDRs	474-00001-04-02, Rev-	10-Dec-10
JPSS Common Data Format Control Book - External - Volume IV - Part III - Land and Ocean/Water EDRs	474-00001-04-03, Rev-	10-Dec-10
JPSS Common Data Format Control Book - External - Volume IV - Part IV - Earth Radiation Budget and Space EDRs	474-00001-04-04, Rev-	18-Feb-11
JPSS Common Data Format Control Book - External - Volume V - Metadata	474-00001-05, Rev-	16-Feb-11
JPSS CDFCB - External - Volume VI - Ancillary Data, Auxiliary Data, Messages, and Reports	474-00001-06, Rev-	10-Dec-10
JPSS Common Data Format Control Book - External - Volume VII - Part I - JPSS Downlink Data Formats	474-00001-07-01, Rev-	16-Feb-11
JPSS CDFCB - External - Volume VII - Part 2 - JPSS Downlink Data Formats - CrIS	474-00001-07-02, Rev-	16-Feb-11
JPSS CDFCB - External - Volume VII - Part 3 - JPSS Downlink Data Formats - OMPS	474-00001-07-03, Rev-	16-Feb-11
JPSS CDFCB - External - Volume VII - Part 4 - JPSS Downlink Data Formats - ATMS	474-00001-07-04, Rev-	16-Feb-11
JPSS CDFCB - External - Volume VII - Part 5 - JPSS Downlink Data Formats - VIIRS	474-00001-07-05, Rev -	16-Feb-11
JPSS Common Data Format Control Book - External - Volume VIII - Look Up Table Formats	474-00001-08, Rev -	10-Dec-10
NPP Command and Telemetry (C&T) Handbook	D37005 Rev. D	11 Feb 2009
Operational Algorithm Description Document for Common Geolocation	474-00091, Rev A	27 Jan 2012
Operational Algorithm Description Document for Advanced Technology Microwave Sounder (ATMS) Resampling	474-00092, Rev A	27 Jan 2012
Advanced Technology Microwave Sounder (ATMS) Engineering Telemetry Description Report	NG Electronic Systems 12115G, 12115F, 12115D, 12115C, 12115B	March 2007, September 2005, March 2005, August 2004, June 2002
External Interface Specification for the Advanced Technology Microwave Sounder (ATMS)	NG Report AE-28102	30 Jul 2002
ATMS Calibration Data Book	ATMS PFM P/N 1362460-1 S/N 302, NGES Report 14029B	19 Mar 2007
ATMS Radiometric Math Model	NGES Report 12110C	Oct 2005
JPSS CGS Data Processor Inter-subsystem Interface Control Document (DPIS ICD) Vol I – IV	IC60917-IDP-002, Rev C	29-Sep-11

Document Title	Document Number/Revision	Revision Date
JPSS CGS Acronyms and Glossary	LI60917-GND-005, Rev -	17-Oct-11
NGST/SE technical memo – ATMS SDR Code Post-Drop Code Error Correction	NP-EMD.2005.510.0014	24 Jan 2005
NGST/SE technical memo – ATMS SDR Code Post-Drop Code Error Corrections	NP-EMD.2005.510.0036	17 Mar 2005
NGST/SE technical memo – ATMS SDR Code Post-Drop Test Results Corrections	NP-EMD.2005.510.0039	21 Mar 2005
NPP ATMS Lunar Intrusion Handling Implementation	NP-EMD-2007.510.0018	11 Jan 2007
NGST/SE technical memo – NPP ATMS Quality Flag Description Updates	NP-EMD-2007.510.0017 / Revision A	9 Mar 2007
NGST/SE technical memo – ATMS SDR 3.1 Bug Fix	NP-EMD-2007.510.0039	14 Jun 2007
NGST/SE technical memo – NPP_ATMS_3.1_OAD_update_Rev A	NP-EMD.2007.510.0020 Rev. A	9 Mar 2007
NGST/SE technical memo – ATMS and CrIS data matching	NP-EMD.2004.510.0042 Rev. ---	12 Nov 2004
NGST/SE technical memo – ATMS SDR QF Memo	NP-EMD.2005.510.0098 Rev. ---	24 Aug 2005
NGST/SE technical memo – ATMS_inst2sc	NP-EMD.2011.510.0005-	21 Feb 2011

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
ATMS SDR science-grade software dropped from NGST	ISTN_ATMS_NGST_2.1 (ECR A-032)(OAD D39309 Rev ---)	17 Sep 2004
ATMS SDR science-grade software design Document dropped from NGST (No Code—no OAD)	ISTN_ATMS_NGST_2.1.1	12 Nov 2004
ATMS SDR Tech Memo Document dropped from NGST (Test Data Only—no OAD)	ISTN_ATMS_NGST_2.1_DATAUPDAT E_001 (NP-EMD.2005.510.0039)	21 Mar 2005
ATMS SDR operational code	ATMS SDR Build 1.4 (OAD Rev A1)	12 Aug 2005
ATMS SDR science-grade ATBD dropped from NGST	ISTN_ATMS_NGST_2.1.2	23 Aug 2005
ATMS SDR operational code	ATMS SDR Build 1.4 FO (OAD Rev A2)	17 Nov 2005
ATMS SDR science-grade software dropped from NGST	ISTN_ATMS_NGST_3.1 (ECR A-116)(OAD Rev A3)	06 Apr 2007
NGST/SE technical memo – NPP_ATMS_3.1_OAD_update_Rev A	NP-EMD.2007.510.0020 Rev. A (OAD Rev A4)	9 Mar 2007
ATMS SDR operational code Includes Tech Memos: NP-EMD.2007.510.0017_NPP_ATMS_QF_Updates_Rev A NP-EMD.2007.510.0018_NPP_ATMS_Lunar_Intrusion	ATMS SDR Build 1.5 FO (OAD Rev A5)	17 Sep 2007
ATMS SDR science-grade RDR Data dropped from NGST (No CODE or OAD)	ISTN_ATMS_NPP_PROXY_DATA_NG ST_002	09 Jan 2009
ACCB (No Code updates)	OAD Rev A	28 May 2008
PCR021730 covering IPO-3671 (No Code Updates)	(OAD Rev B3)	18 Dec2009
PCR022860	Build Sensor Characterization SC-8	14 Mar 2010

	(OAD Rev B4)	
ACCB (includes PCR022396: OAD changes on 4/28/10. Code changes are scheduled for shared_csi_b1.5, for Build Maint_1.5.3, in Aug 2010)	OAD Rev B	28 Apr 2010
ATMS SDR operational code updated for ADL compatibility	ATMS SDR Build Mx1.5.4.00 (OAD Rev C1)	29 Sep 2010
ATMS SDR science-grade software Includes TM 2011.510.0005 (PCRs 026136 & 026138)	ISTN_ATMS_SDR_NGST_SC7.1_NG1 (ECR A-0018) Maintenance Build 1.5.5.00 (OAD Rev C2)	10 Mar 2011 & 29 Jun 2011 (OAD)

2.0 ALGORITHM OVERVIEW

The ATMS sensor is part of the Cross-track Infrared and Advanced Technology Microwave Sounding Suite (CrIMSS) that also includes the Cross-track Infrared Sounder (CrIS) sensor. Both are sounding sensors, with ATMS operating in the microwave spectrum and CrIS operating in the infrared spectrum. Together, their mission is to construct atmospheric profiles for temperature, moisture, and pressure within the earth’s atmosphere. Engineering, calibration, and science data from the ATMS sensor, along with spacecraft attitude and ephemeris, and user-supplied tunable processing parameters, are processed by the ATMS SDR Module to produce the ATMS SDR consisting of scene brightness temperature. The ATMS SDR Module also produces the ATMS TDR, ATMS GEO, and ATMS IP outputs. Both the ATMS SDR and CrIS SDR are used as input to CrIMSS Environmental Data Record (EDR) processors to produce CrIMSS sounding EDRs. Figure 1 shows the processing chain.

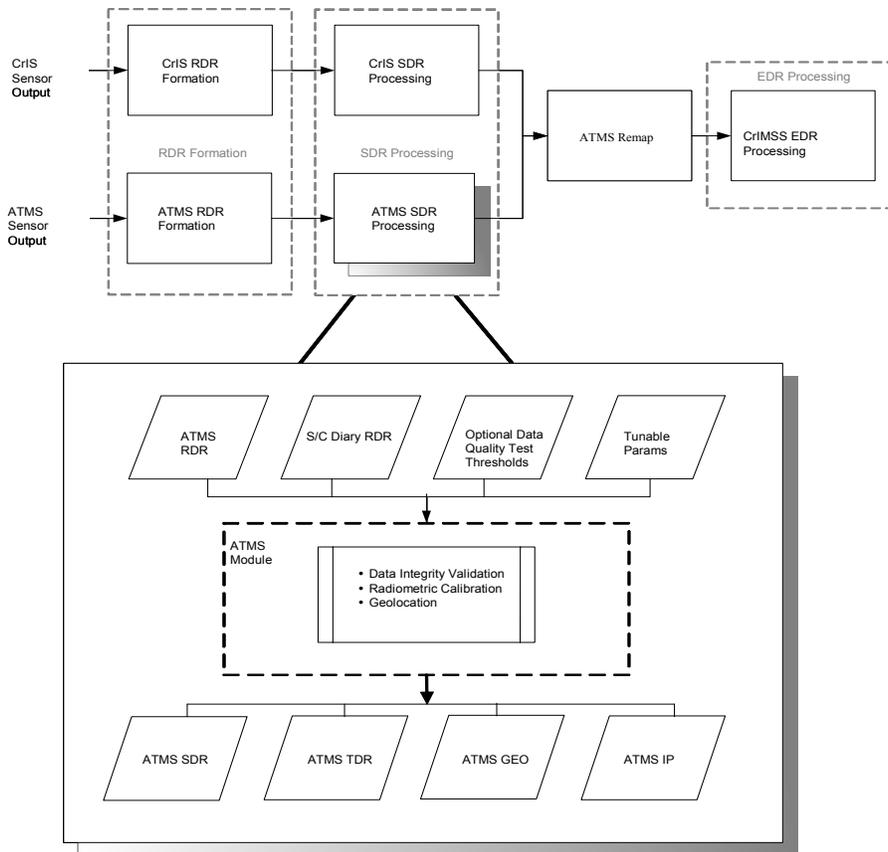


Figure 1. Processing Chain

ATMS SDR processing is handled by two separate algorithms, the Verified RDR algorithm and the Calibration and Geolocation algorithm. Both algorithms are managed within a Controller “algorithm”, which is run as a single process. To begin data processing, the Infrastructure (INF) Subsystem Software Item (SI) initiates the ATMS algorithms. The INF SI provides tasking information to the algorithms indicating which granule to process. The Data Management Subsystem (DMS) SI provides data storage and retrieval capability. ATMS SDR processing is retaskable, so instead of shutting down after processing, it requests additional tasking information from INF and continues processing with this information. A library of C++ classes, depicted in Figure 2, is used to implement the SI interfaces.

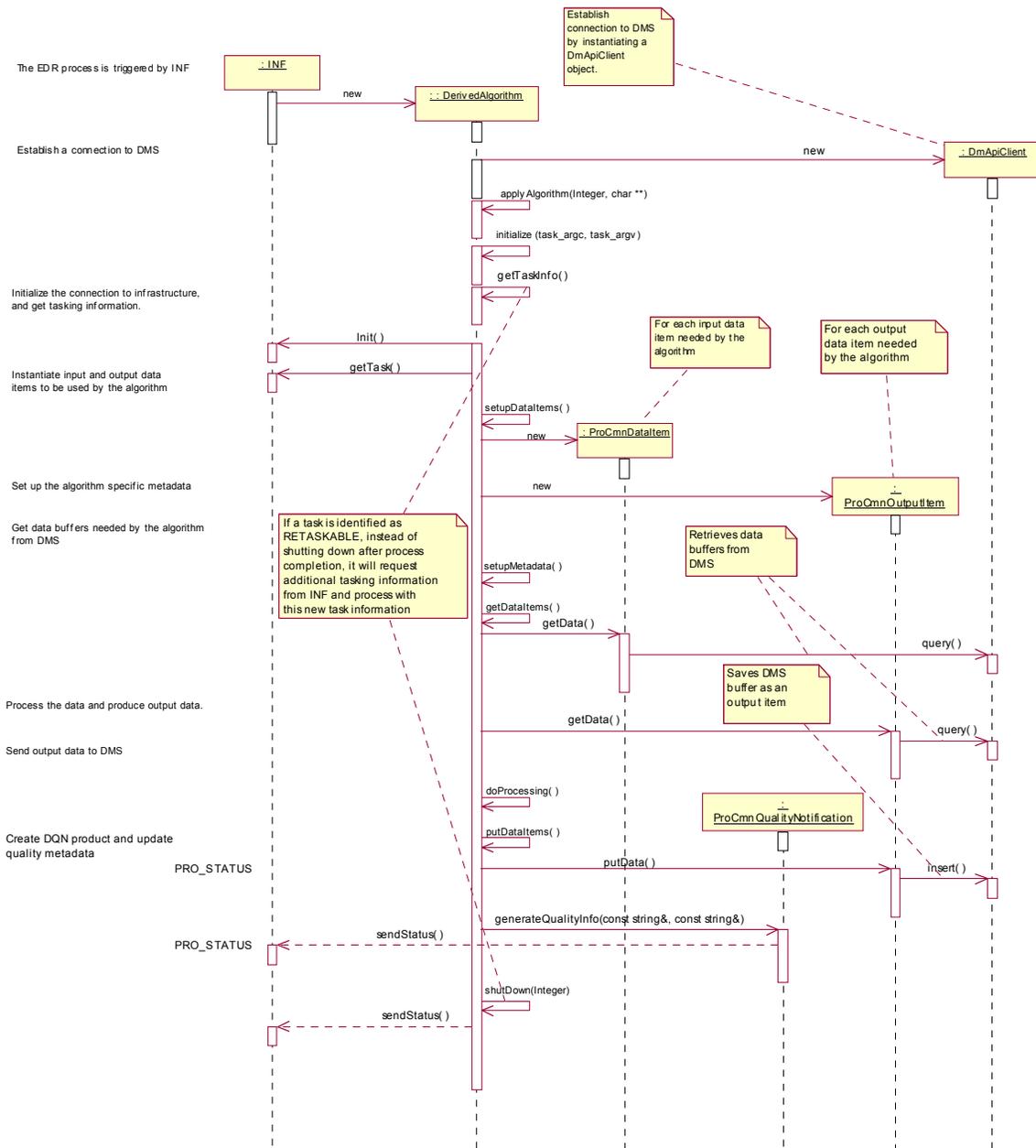


Figure 2. IPO Model Interface to INF and DMS

2.1 ATMS Verified RDR Description

2.1.1 Interfaces

2.1.1.1 Inputs

The inputs to the ATMS Verified RDR algorithm are ATMS Science RDRs and the ATMS Configurable Coefficients file as shown in Table 3

Table 3. ATMS Verified RDR Algorithm Inputs

Input	Description
ATMS science RDR, along with adjacent intrack RDRs.	Science, calibration and engineering sensor data
ATMS SDR Coefficients.	Adjustable ATMS SDR coefficients from DMS.

2.1.1.2 Outputs

The internal output of the ATMS Verified RDR algorithm is a byte-aligned version of the ATMS Science RDR.

2.1.2 Algorithm Processing

ATMS Verified RDR processing retrieves the ATMS Science RDRs from DMS and unpacks and byte-aligns the RDRs to create a Verified RDR. ATMS RDR data in DMS is in CCSDS packet format. This byte-aligned data is used by the Calibration and Geolocation algorithm to create the ATMS SDR and TDR.

The derived algorithm class for the ATMS Verified RDR algorithm, `ProSdrAtmsVerifiedRDR`, is a subclass of the `AutoGeneratedProSdrAtmsVerifiedRDR` class, which is a subclass of the `ProCmnAlgorithm` class. `AutoGeneratedProSdrAtmsVerifiedRDR` is auto generated at build time and contains member functions for setting up data members with addresses to the input and output products in DMS. The derived algorithm class creates a list of input data items read from DMS and passes required data into the algorithm. An internal Verified RDR is created once the algorithm finishes processing this data, and is then passed to the Geolocation and Calibration algorithm as an input.

2.1.2.1 Create Verified RDRs (`ProSdrAtms::createVerifiedAtmsRdr()`)

The Create Verified ATMS RDR flow diagram is shown in Figure 3.

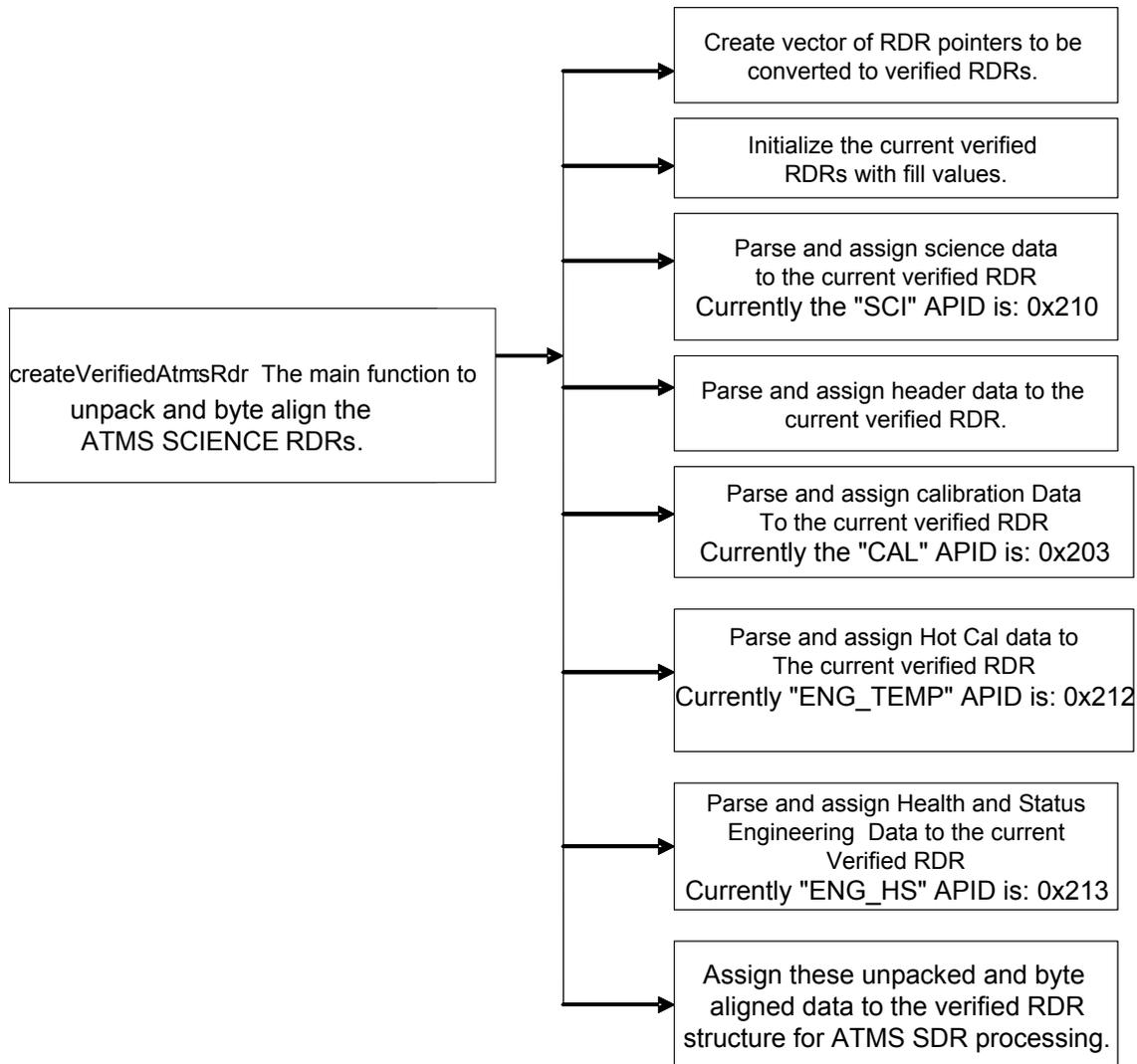


Figure 3. Create Verified ATMS RDR Flow Diagram

ATMS Science RDRs contain science, calibration and engineering application packets. A Verified RDR contains all the data from an RDR that is required for the SDR processing of a tasked granule. The data has been extracted, unpacked and byte aligned from the CCSDS application packets contained in the RDR. In other words, a Verified RDR is a byte-aligned RDR. This unpacked and byte-aligned data is assigned to the internal verified RDR structure, and ATMS SDR processing can use the data from that structure to do further processing.

2.1.3 Graceful Degradation

No graceful degradation is performed.

2.1.4 Exception Handling

No exception handling is performed.

2.1.5 Data Quality Monitoring

No data quality monitoring is performed.

2.1.6 Computational Precision Requirements

There are no computational precision requirements for the ATMS Verified RDR algorithm.

2.1.7 Algorithm Support Considerations

Infrastructure (INF) and DMS must be running before execution of the algorithm.

2.1.8 Assumptions and Limitations

None.

2.2 ATMS SDR Geolocation and Calibration Description

2.2.1 Interfaces

Many of the input and output parameters are in “counts” or unsigned integer data types. Before any of the main SDR processing tasks are performed, conversion of the input into engineering units must first take place. On output, the inverse operation is used to convert the parameters back to their original units, if so specified in Table 7. The “Counts to Engineering Units Conversions” are listed in Table 4.

Table 4. Counts to Engineering Units Conversions

Var. Name	Description	Data Type	Conversion	Units / Range
Time Conversions				
scan_start_time health_time beam_time	Time parameters	real*64	Time * 1.0D-6	IET time
Beam Angle Conversion				
beam_angle	scan angle	real*32	$(360.0 / (2^{16} - 1)) * (\text{beam_angle_counts} - \text{resolver_offset})$	deg / 0.0° – 360.0°
Calibration Parameter Conversions				
pam_kav	PAM resistance for KAV band group	real*32	$2300.0 + (0.006 * \text{pam_kav_scaled})$	ohms /
pam_wg	PAM resistance for WG band group	real*32	$2300.0 + (0.006 * \text{pam_wg_scaled})$	ohms /
prt_coeff_kav (1:ncoef,1:num_prt_kav) where ncoef=4 num_prt_kav=8 Note: outermost loop on PRTs; innermost loop on coeffs	(1, n) resistance R_0 of the n^{th} KAV PRT at the ice point (aka 4-W_PRT_KAV_n_R0),	num_prt_kav x real*32	Coeff R_0 : $1900.0 + (0.003 * \text{prt_coeff_kav_scaled}(1,1:\text{num_prt_kav}))$	ohms/
	(2, n) constant α measured for the n^{th} KAV PRT (aka 4-W_PRT_KAV_n_alpha),	num_prt_kav x real*32	Coeff α : $0.002 + (5.0e-8 * \text{prt_coeff_kav_scaled}(2,1:\text{num_prt_kav}))$	°C ⁻¹ /

Var. Name	Description	Data Type	Conversion	Units / Range
	(3, n) constant δ measured for the n^{th} KAV PRT (aka 4-W_PRT_KAV_n_delta),	num_prt_kav x real*32	Coeff δ : $5.0e-5 * prt_coeff_kav_scaled(3, 1:num_prt_kav)$	$^{\circ}C /$
	(4, n) constant β measured for the n^{th} KAV PRT (aka 4-W_PRT_KAV_n_beta)	num_prt_kav x real*32	Coeff β : $(3.0e-5 * prt_coeff_kav_scaled(4, 1:num_prt_kav)) - 1.0$	$^{\circ}C /$
prt_coeff_wg (1:ncoef,1:num_prt_wg) where ncoef=4 num_prt_wg=7 Note: outermost loop on PRTs; innermost loop on coefs	(1, n) resistance R_o of the n^{th} WG PRT at the ice point (aka 4-W_PRT_WG_n_R0),	num_prt_wg x real*32	Coeff R_o : $1900.0 + (0.003 * prt_coeff_wg_scaled(1,1:num_prt_wg))$	ohms/
	(2, n) constant α measured for the n^{th} WG PRT (aka 4-W_PRT_WG_n_alpha),	num_prt_wg x real*32	Coeff α : $0.002 + (5.0e-8 * prt_coeff_wg_scaled(2, 1:num_prt_wg))$	$^{\circ}C^{-1} /$
	(3, n) constant δ measured for the n^{th} WG PRT (aka 4-W_PRT_WG_n_delta),	num_prt_wg x real*32	Coeff δ : $5.0e-5 * prt_coeff_wg_scaled(3, 1:num_prt_wg)$	$^{\circ}C /$
	(4, n) constant β measured for the n^{th} WG PRT (aka 4-W_PRT_WG_n_beta)	num_prt_wg x real*32	Coeff β : $(3.0e-5 * prt_coeff_wg_scaled(4, 1:num_prt_wg)) - 1.0$	$^{\circ}C /$
warm_bias(1:5)	PRT warm bias: (1) for channel 1 (K band) (2) for channel 2 (Ka band) (3) for channels 3 to 15 (V band) (4) for channel 16 (W band) (5) for channels 17 to 22 (G band)	5 x real*32	$- 7.5e-6 * warm_bias_scaled(1:5)$	$^{\circ}C /$
cold_bias(1:5)	PRT cold bias: (1) for channel 1 (K band) (2) for channel 2 (Ka band) (3) for channels 3 to 15 (V band) (4) for channel 16 (W band) (5) for channels 17 to 22 (G band)	5 x real*32	$1.5e-5 * cold_bias_scaled(1:5)$	$^{\circ}C /$

Var. Name	Description	Data Type	Conversion	Units / Range
quadratic_coeff (1:num_channels) where num_channels=22	Quadratic BT correction factors for each channel (Peak nonlinearity as determined from calibration tests)	num_channels x real*32	$(2.6e-5 * \text{quadratic_coeff_scaled}(1:\text{num_channels})) - 0.85$	K
beam_alignment (1:attitude, 1:beamPosOffset, 1:bands). where attitude = {X, Y, Z} beamPosOffset = {01, 48, 96} bands = 5 Note: outermost loop on band; innermost loop on attitude	Alignment offsets (roll, pitch, yaw offsets per band)	3 x 3 x 5 x real*32	$(2.0e-5 * \text{beam_alignment_scaled}(:, :, :)) - 0.655$	deg
prt_coeff_shelf (1:ncoef, feed) where ncoef=4, feed = {K, V, W, G} Note: outermost loop on feed; innermost loop on coefs	(1, feed) resistance Ro of feed shelf PRT at the ice point (aka feed_SHELF_PRT_R0),	4 x real*32	Coeff Ro: $1900 + (0.003 * \text{prt_coeff_shelf_scaled}(1, \text{feed}))$	ohms/
	(2, feed) constant α measured for feed shelf PRT (aka feed_SHELF_PRT_alpha),	4 x real*32	Coeff α : $0.002 + (5.0e-8 * \text{prt_coeff_shelf_scaled}(2, \text{feed}))$	$^{\circ}\text{C}^{-1}$ /
	(3, feed) constant δ measured for feed shelf PRT (aka feed_SHELF_PRT_delta),	4 x real*32	Coeff δ : $5.0e-5 * \text{prt_coeff_shelf_scaled}(3, \text{feed})$	$^{\circ}\text{C}$ /
	(4, feed) cable resistance Rc to feed shelf PRT (aka feed_SHELF_PRT_RC)	4 x real*32	Coeff Rc: $(0.0003 * \text{prt_coeff_shelf_scaled}(4, \text{feed}))$	ohms

2.2.1.1 Inputs

The implementation of ATMS SDR requires an ATMS Verified RDR, Spacecraft Diary RDRs and adjustable ATMS SDR coefficients (tunable parameters). A general description of the inputs used for ATMS SDR can be found in Table 5. Refer to the CDFCB-X, D34862, for a detailed description of the inputs.

Table 5. ATMS SDR Algorithm Inputs

Input	Description
ATMS Verified RDR.	Byte-aligned data from the ATMS Science RDRs.

Spacecraft Diary RDR, along with adjacent intrack RDRs.	Ephemeris and Attitude Data from DMS.
ATMS SDR Coefficients.	Adjustable ATMS SDR coefficients from DMS.
Optional data quality test thresholds.	Data quality notification threshold values.

See Table 6 for more information about ATMS SDR configurable coefficients.

Table 6. ATMS SDR Tunable Parameters

Input	Type (Bits)	Description/Source	Units/Range
scan_weights_prt_kav (1:num_prt_kav, 1:num_scan_prt)	num_scan_prt x num_prt_kav x real*32	Weighting factors applied to KAV target PRT measurements	-- / 0 – 1
scan_weights_prt_wg (1:num_prt_wg, 1:num_scan_prt)	num_scan_prt x num_prt_wg x real*32	Weighting factors applied to WG target PRT measurements	-- / 0 – 1
weight_threshold_prt	real*32	Minimum normalized weight-sum required for passing the PRT data sufficiency check	-- / 0 – 1
use_quadratic_term	logical*8	Flag indicating use of quadratic term: 0: do not use quadratic term 1: use quadratic term	-- / 0 or 1
use_quadratic_tele	logical*8	Flag indicating source of quadratic coefficients: 0: quadratic coefficients from ancillary file 1: quadratic coefficients from telemetry	-- / 0 or 1
quadratic_rc (1:num_channels,1:4,1:3)	real*32	Quadratic coefficients for 22 channels, four redundancy configurations (RC1, RC2, RC5 and RC6) and three cold plate temperatures (-10°, +5° and +20° C)	K / -0.85 – 0.854
shelf temperature(1:4,1:3)	real*32	Four shelf temperatures (KKA, V, W, G) measured at each of the three cold plate temperatures tested (-10°, +5° and +20° C)	°C / -10 – 50
cold_space_tbs (1:num_channels)	real*32	Brightness temperature of cosmic cold space, with Planck correction applied, for each ATMS channel	K / 2.76 – 4.70
scan_weights_wc (1:num_channels, 1:num_scan_wc)	real*64	Weighting factors applied to hot calibration target data	-- / 0 – 1
weight_threshold_wc	real*32	Minimum normalized weight-sum required for passing the warm count data sufficiency check	-- / 0 – 1
scan_weights_cc (1:num_channels, 1:num_scan_cc)	real*64	Weighting factors applied to cold calibration target data	-- / 0 – 1
weight_threshold_cc	real*32	Minimum normalized weight-sum required for passing the cold count data sufficiency check	-- / 0 – 1
scan_bias (1:num_channels, 1:num_beam_positions)	real*64	Scan-angle dependent BT biases for each channel; coefficient of 0 th order term in brightness temperature equation $T_{corrected} = AT + B$	K / -5 – 5

Input	Type (Bits)	Description/Source	Units/Range
beam_efficiency_correction (1:num_beam_positions, 1:num_channels).	real*64	Scan-angle dependent beam efficiency correction factor for each channel; coefficient of 1 st order term in brightness temperature equation $T_{corrected} = AT + B$	-- / 0 – 1.2
use_beam_align_tele	logical*8	Flag indicating the source of beam alignment errors: 0: beam alignment errors (22 channels) from ancillary file 1: beam alignment errors (five bands) from telemetry	-- / 0 or 1
beam_alignment_error([roll, pitch,yaw],[01,48,96],1:num_channels)	real*32	Bore-sight(beam) alignment errors at scan positions 1, 48 and 96	deg / $-0.655^{\circ} - 0.656^{\circ}$
use_warm_bias_tele	logical*8	Flag indicating the source of warm bias: 0: warm bias (22 channels) from ancillary file 1: warm bias (five bands) from telemetry	-- / 0 or 1
warm_bias_correction(1:num_channels,1:3)	real*64	Warm bias corrections of the form $a_1 + a_2T_R + a_3T_R^2$; T_R is the receiver temperature in degrees C	a_1 : K / -1 – 1 a_2 : KC^{-1} / -1 – 1 a_3 : KC^{-2} / -1 – 1
use_cold_bias_tele	logical*8	Flag indicating the source of cold bias: 0: cold bias (22 channels) from ancillary file 1: cold bias (five bands) from telemetry	-- / 0 or 1
cold_bias_correction(1:num_channels,1:4)	real*32	Cold bias correction for 22 channels and four cold space view groups	K / 0 – 0.6
resolver_offset	int*32	Resolver mechanical offset specific for each instrument; for the PFM, it is 91	count / -200 – 200
prt_convergence	real*32	Convergence criterion for Newton-Raphson computation of temperature from PRT resistance	$^{\circ}C$
prt_loops	int*32	Maximum allowable loops for PRT temperature calculations	-- / 1 – 200
chk_consistency_wc_cc	logical*8	Flag indicating consistency check for warm and cold counts: 0: do not check consistency 1: check consistency	-- / 0 or 1
low_limit_wc (1:num_channels)	int*32	Channel-specific lower limit for warm count	count / 0 – 65535
upp_limit_wc (1:num_channels)	int*32	Channel-specific upper limit for warm count	count / 0 – 65535
max_var_wc (1:num_channels)	int*32	Channel-specific maximum difference among four warm samples	count / 0 – 65535
low_limit_cc (1:num_channels)	int*32	Channel-specific lower limit for cold count	count / 0 – 65535
upp_limit_cc (1:num_channels)	int*32	Channel-specific upper limit for cold count	count / 0 – 65535
max_var_cc (1:num_channels)	int*32	Channel-specific maximum difference among four cold samples	count / 0 – 65535
chk_consistency_prt	logical*8	Flag indicating consistency check for PRTs: 0: do not check consistency 1: check consistency	-- / 0 or 1

Input	Type (Bits)	Description/Source	Units/Range
low_limit_prt(1:2)	real*32	Lower PRT temperature limit for the KAV and WG targets	K / 245 - 340
upp_limit_prt(1:2)	real*32	Upper PRT temperature limit for the KAV and WG targets	K / 245 - 340
max_var_prt(1:2)	real*32	Maximum temperature difference among the PRTs for the KAV and WG targets	K / 0 - 10
num_threshold_prt (1:2)	int*32	Minimum number of "good" PRTs in a scan below which all PRTs is considered "bad"	-- / 1 – 8
data_limits (1:2, 1:num_hs_vars), where num_hs_vars = number of telem params in the Eng H&S packet Note: Science code implementation uses 68; Telemetry Description, NGES 12115F, uses 74.	real*32	Minimum and maximum allowed values for Health & Status telemetry	See Table 11-2, Housekeeping Telemetry Limits in the ATMS Calibration Data Book, NGES Report 14029A
threeDBeamWidth (1:num_channels)	real*32	Channel-specific 3dB beamwidths	Deg / 1 - 6
lunarContaminationThreshold (1:num_channels)	real*32	Channel-specific thresholds for cold space view temperature increase caused by lunar contamination	K / 0 - 1
spaceViewResolverCounts (1:4, 1:4)	int*32	Expected count for 4 cold view positions and 4 cold scan profiles	count / 0 – 65535
blackBodyResolverCounts (1:4, 1:4)	int*32	Expected count for 4 warm view positions and 4 warm scan profiles	count / 0 – 65535
epsilonCold	int*32	Allowable deviation from the cold view expected resolver counts	count / 0 - 20
epsilonWarm	int*32	Allowable deviation from the warm view expected resolver counts	count / 0 - 20
allowableDev	int*32	Allowable deviation from the nominal scan period (8/3 sec)	ms / 0 - 20
mapRC(NUM_MAP_RC_SIZE)	Int*32	Map 8 Redundancy Configurations to 4 experimental cases RC1, RC2, RC5 RC6	count / 1 - 4

The following tunable parameters were removed from the Processing Coefficients file and made constants in the source code. This was done so array dimension constants could be defined and used in array declarations and the fact these parameters can affect the number of cross-granules required for processing.

num_scan_prt	int*16	Number of scans for PRT averaging	-- / 1 – 10
num_scan_wc	int*16	Number of scans of hot calibration target data used in calibration; the maximum number of scans for averaging hot calibration of any channel	-- / 1 – 20
num_scan_cc	int*16	Number of scans of cold calibration target data used in calibration; the maximum number of scans for averaging cold calibration of any channel	-- / 1 – 20

Some parameters may be adjusted after some operational experience has been gained after launch.

2.2.1.2 Outputs

The ATMS SDR algorithm creates an ATMS Temperature Data Record (TDR) (uncorrected brightness temperature), ATMS SDR (corrected brightness temperature), ATMS SDR Geolocation Data, and ATMS SDR Intermediate Product (IP) and stores the outputs in DMS. Table 7 shows the ATMS SDR outputs. Refer to the CDFCB-X, D34862, for a detailed description of the outputs.

Table 7. ATMS SDR Outputs

Output	Description
ATMS SDR Data Refer to Table 8.	ATMS SDR contains corrected brightness temperature, noise equivalent delta temperature for cold and warm views, calibration gain factors and quality flags.
ATMS TDR Data Refer to Table 9.	ATMS TDR contains uncorrected brightness temperature and quality flags.
ATMS SDR GEO Data Refer to Table 10.	ATMS SDR Geolocation contains scan’s start and mid times; Solar Zenith Angle, Solar Azimuth Angle, Sensor Zenith Angle, Sensor Azimuth Angle, and Terrain Height, Range; Spacecraft’s position, velocity and attitude at scan’s mid-time; and geodetic latitude and longitude values. Also this contains the Geolocation Error Flag.
ATMS SDR IP Refer to Table 11.	Processing coefficients and other values calculated which are used by cal/val. Warm bias, cold bias, PRT KAV Coefficients , PRT WG Coefficients, PAM resistance counts for KAV and WG, PRT counts for KAV and WG from hot calibration data etc.

Note: The values for the constants referenced in Tables 8 through 11 are as follows:

NUM_ATMS_SCANS	12
NUM_BEAM__POSITIONS	96
NUM_CHANNELS	22
NUM_COLD_SAMPLES	4
NUM_WARM_SAMPLES	4
NUM_HS_WORDS	5
NUM_CAL_SCANS	4
NUM_COMPONENTS	3
NUM_PRT_COEFFS	4
NUM_PRT_KAV	8
NUM_PRT_WG	7
VEC_SIZE	3

VEC_RPY_SIZE

3

Table 8. ATMS SDR Data

Output	Type/size	Description	Units/valid range
Granule level			
quadraticCorrectionFlag	UInt8	This flag is set when quadratic correction is applied to the radiometric transfer function for non-linearity correction. 1 bit/granule.	Unitless
correctedRayleighsTemperatureScale	Float32	Rayleighs Temp scale	Unitless
correctedRayleighsTemperatureOffset	Float32	Reyleighs Temp offset	Unitless
Scan level			
beamTime	Int64 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS	The time in IET of the end of the view period for this observation.	Microsecond
instrumentModeFlag	UInt16 * NUM_CAL_SCANS	Instrument mode word 73 in the Health & Status APID 531	Unitless
healthAndStatusFlag	UInt16 * NUM_CAL_SCANS * NUM_HS_WORDS	Status of Health items (APID531) compared (exceeded) beyond the predetermined range	Unitless
kavPrtConvErrorFlag	UInt8 * NUM_ATMS_SCANS	Divide-by-zero condition or computation loop failed to converge in the K/Ka and V (KAV) Band Platinum Resistance Thermistor temperature computation.	Unitless
wgPrtConvErrorFlag	UInt8 * NUM_ATMS_SCANS	Divide-by-zero condition or computation loop failed to converge in the WG Band Platinum Resistance Thermistor temperature computation.	Unitless
shelfPrtCnvErrorFlag	UInt8 * NUM_ATMS_SCANS	Divide-by-zero condition or computation loop failed to converge in the K/Ka, V, W, G Band Receiver Shelf PRT temperature computation.	Unitless
kavPrtTempLimitFlag	UInt8 * NUM_ATMS_SCANS	Out of range condition for the K/Ka and V Band PRT temperatures.	Unitless
wgPrtTempLimitFlag	UInt8 * NUM_ATMS_SCANS	Out of range condition for the WG Band PRT temperatures.	Unitless
kavPrtTempConsistFlag	UInt8 * NUM_ATMS_SCANS	KAV PRT temperature inconsistency check.	Unitless
wgPrtTempConsitFlag	UInt8 * NUM_ATMS_SCANS	WG PRT temperature inconsistency check.	Unitless
scanFlags	UInt8 * NUM_ATMS_SCANS	Time Sequence Error - The nominal scan period of ATMS is 8/3 sec. The scan start time is defined as the start of sample 1. The scan start time of the	Unitless

Output	Type/size	Description	Units/valid range
		<p>current scan is compared to the scan start time of the previous scan. If the time difference is not within 8/3 sec +/- allowable_dev (initially 18 msec), the Time Sequence Error Flag is set. allowable_dev is a tunable parameter.</p>	
		<p>Data Gap - The Data Gap flag is set if there is a data gap, i.e. missing scan(s), preceding the current scan.</p>	
		<p>KAV PRT Sufficiency - If insufficient KAV PRT data are available, either because of missing data or failing to pass the quality checks, this flag is set.</p>	
		<p>WG PRT Sufficiency - If insufficient WG PRT data are available, either because of missing data or failing to pass the quality checks, this flag is set.</p>	
		<p>Space View antenna position error - There are 4 space view antenna groupings. ATMS is commanded to use one of the 4 groupings. The grouping selected is indicated by the Scan Pattern ID in the INSTRUMENT_MODE (Word 73) in the Health and Status packet. Values are interpreted as: 001, 010, 011, 100 = RAM profiles 1, 2, 3, 4. If any of the actual space view position (as determined from the scan angle counts in the Science Data packet) does not fall within the range of the expected count +/- εc, the Space View Antenna Position Error</p>	

Output	Type/size	Description	Units/valid range
		<p>flag shall be set. The expected counts and ϵc are tunable parameters. ϵc shall be set to 7 counts.</p> <p>Blackbody antenna position error - There are 4 blackbody view positions. If any of the actual blackbody view position (as determined from the scan angle counts in the Science Data packet) does not fall within the range of the expected count +/- ϵw, the Blackbody Antenna Position Error flag is set. The expected counts and ϵw are tunable parameters. ϵw is set to 7 counts.</p>	
Channel level			
correctedRayleighsTemperature	Uint16 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS * NUM_CHANNELS	Calibrated scene brightness temperature for each ATMS channel and beam position. This output is the Rayleigh equivalent temperature and not the Planck blackbody equivalent temperature.	Kelvin
coldNedt	Float32 * NUM_ATMS_SCANS * NUM_CHANNELS	Noise equivalent delta Temperature while viewing cold space	Kelvin
warmNedt	Float32 * NUM_ATMS_SCANS * NUM_CHANNELS	Noise-equivalent delta Temperature while viewing warm target	Kelvin
gainCalibration	Float32 * NUM_ATMS_SCANS * NUM_CHANNELS	Gain factor used in calibrating earth scene brightness temperatures.	Count/Kelvin
channelFlagsByte1	Uint8 * NUM_ATMS_SCANS * NUM_CHANNELS	<p>Moon in Space View - The Moon in Space View flag is set if the Moon appears in any of the four calibration space views. 1 bit/channel/scan</p> <p>Gain Error - If the lowest blackbody count is smaller than or equal to the highest space view count in a scan, the condition is flagged. 1 bit/channel/scan.</p> <p>Calibration With</p>	Unitless

Output	Type/size	Description	Units/valid range
		<p>Fewer Than Preferred Samples - Multiple scans and samples are used for averaging the blackbody PRT temperatures, the blackbody counts and the space view counts. If the scan line is calibrated with fewer than the preferred number of samples and/or scans either because of missing data or some data failing the quality checks, this flag is set. This flag shall be 1 bit/channel/scan.</p> <p>Space View Data Sufficiency Check - If insufficient space view samples are available, either because of missing data or failing to pass the quality checks, this flag is set. 1 bit/channel/scan.</p> <p>Blackbody View Data Sufficiency Check - If insufficient blackbody view samples are available, either because of missing data or failing to pass the quality checks, this flag is set. 1 bit/channel/scan.</p>	
channelFlagsByte2	Uint8 * NUM_ATMS_SCANS * NUM_CHANNELS	<p>Space View out of range condition check</p> <p>BlackBody View out of range condition check.</p>	Unitless
channelFlagsByte3	Uint8 * NUM_ATMS_SCANS * NUM_CHANNELS	<p>Space view inconsistency check</p> <p>BlackBody view inconsistency check</p>	Unitless

Table 9. ATMS TDR Data

Output	Type/size	Description	Units/valid range
Granule level			
quadraticCorrectionFlag	UInt8	This flag is set when quadratic correction is applied to the radiometric transfer function for non-linearity correction. 1 bit/granule.	Unitless
antennaTemperatureScale	Float32	Antenna Temp scale	Unitless
antennaTemperatureOffset	Float32	Antenna Temp offset	Unitless
Scan level			
beamTime	Int64 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS	The time in IET of the end of the view period for this observation.	Microseconds
instrumentModeFlag	UInt16 * NUM_CAL_SCANS	Instrument mode word 73 in the Health & Status APID 531	Unitless
healthAndStatusFlag	UInt16 * NUM_CAL_SCANS * NUM_HS_WORDS	Status of Health items (APID531) compared (exceeded) beyond the predetermined range	Unitless
kavPrtConvErrorFlag	UInt8 * NUM_ATMS_SCANS	Divide-by-zero condition or computation loop failed to converge in the K/Ka and V (KAV) Band Platinum Resistance Thermistor temperature computation.	Unitless
wgPrtConvErrorFlag	UInt8 * NUM_ATMS_SCANS	Divide-by-zero condition or computation loop failed to converge in the WG Band Platinum Resistance Thermistor temperature computation.	Unitless
shelfPrtCnvErrorFlag	UInt8 * NUM_ATMS_SCANS	Divide-by-zero condition or computation loop failed to converge in the K/Ka, V, W, G Band Receiver Shelf PRT temperature computation.	Unitless
kavPrtTempLimitFlag	UInt8 * NUM_ATMS_SCANS	Out of range condition for the K/Ka and V Band PRT temperatures.	Unitless
wgPrtTempLimitFlag	UInt8 * NUM_ATMS_SCANS	Out of range condition for the WG Band PRT temperatures.	Unitless
kavPrtTempConsistFlag	UInt8 * NUM_ATMS_SCANS	KAV PRT temperature inconsistency check.	Unitless
wgPrtTempConsitFlag	UInt8 * NUM_ATMS_SCANS	WG PRT temperature inconsistency check.	Unitless
scanFlags	UInt8 * NUM_ATMS_SCANS	Time Sequence Error - The nominal scan period of ATMS is 8/3 sec. The scan start time is defined as the start of sample 1. The scan start time of the current scan is compared to the scan	Unitless

Output	Type/size	Description	Units/valid range
		<p>start time of the previous scan. If the time difference is not within 8/3 sec +/- allowable_dev (initially 18 msec), the Time Sequence Error Flag is set. allowable_dev is a tunable parameter.</p>	
		<p>Data Gap - The Data Gap flag is set if there is a data gap, i.e. missing scan(s), preceding the current scan.</p>	
		<p>KAV PRT Sufficiency - If insufficient KAV PRT data are available, either because of missing data or failing to pass the quality checks, this flag is set.</p>	
		<p>WG PRT Sufficiency - If insufficient WG PRT data are available, either because of missing data or failing to pass the quality checks, this flag is set.</p>	
		<p>Space View antenna position error - There are 4 space view antenna groupings. ATMS is commanded to use one of the 4 groupings. The grouping selected is indicated by the Scan Pattern ID in the INSTRUMENT_MODE (Word 73) in the Health and Status packet. Values are interpreted as: 001, 010, 011, 100 = RAM profiles 1, 2, 3, 4. If any of the actual space view position (as determined from the scan angle counts in the Science Data packet) does not fall within the range of the expected count +/- ϵ_c, the Space View Antenna Position Error flag shall be set. The expected counts and ϵ_c are tunable parameters. ϵ_c shall be set to 7 counts.</p>	
		<p>Blackbody antenna</p>	

Output	Type/size	Description	Units/valid range
		position error - There are 4 blackbody view positions. If any of the actual blackbody view position (as determined from the scan angle counts in the Science Data packet) does not fall within the range of the expected count +/- ϵw , the Blackbody Antenna Position Error flag is set. The expected counts and ϵw are tunable parameters. ϵw is set to 7 counts.	
Channel level			
antennaTemperature	Uint16 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS * NUM_CHANNELS	Antenna temperature for each ATMS channel and beam position.	Kelvin
channelFlagsByte1	Uint8 * NUM_ATMS_SCANS * NUM_CHANNELS	<p>Moon in Space View - The Moon in Space View flag is set if the Moon appears in any of the four calibration space views. 1 bit/channel/scan</p> <p>Gain Error - If the lowest blackbody count is smaller than or equal to the highest space view count in a scan, the condition is flagged. 1 bit/channel/scan.</p> <p>Calibration With Fewer Than Preferred Samples - Multiple scans and samples are used for averaging the blackbody PRT temperatures, the blackbody counts and the space view counts. If the scan line is calibrated with fewer than the preferred number of samples and/or scans either because of missing data or some data failing the quality checks, this flag is set. This flag shall be 1 bit/channel/scan.</p>	Unitless

Output	Type/size	Description	Units/valid range
		Space View Data Sufficiency Check - If insufficient space view samples are available, either because of missing data or failing to pass the quality checks, this flag is set. 1 bit/channel/scan.	
		Blackbody View Data Sufficiency Check - If insufficient blackbody view samples are available, either because of missing data or failing to pass the quality checks, this flag is set. 1 bit/channel/scan.	
channelFlagsByte2	UInt8 * NUM_ATMS_SCANS * NUM_CHANNELS	Space View out of range condition check	Unitless
		BlackBody View out of range condition check.	
channelFlagsByte3	UInt8 * NUM_ATMS_SCANS * NUM_CHANNELS	Space view inconsistency check	Unitless
		BlackBody view inconsistency check	

Table 10. ATMS SDR GEO Data

Output	Type/size	Description	Units/valid range
Scan level			
scanStartTime	Int64 * NUM_ATMS_SCANS	Starting Time of Scan in IET	Microsecond
scanMidTime	Int64 * NUM_ATMS_SCANS	Mid Time of Scan in IET	Microsecond
scPosition	Float32 * NUM_ATMS_SCANS * VEC_SIZE	Spacecraft position in Earth Centered Rotating (ECR) Coordinates (X, Y, Z) at the midtime of scan.	Meters
scVelocity	Float32 * NUM_ATMS_SCANS * VEC_SIZE	Spacecraft velocity in ECR Coordinates (dx/dt, dy/dt, dz/dt) at the midtime of scan.	Meters/sec
scAttitude	Float32 * NUM_ATMS_SCANS * VEC_RPY_SIZE	Roll, pitch, and yaw at the midtime of scan	Arcseconds
geoQualFlag	UInt8 * NUM_ATMS_SCANS	Attitude and Ephemeris Availability Status	Unitless
Channel level			
Latitude	Float32 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS	Latitude of channel 17 - positive north.	Degree / (-90 – 90)

Output	Type/size	Description	Units/valid range
Longitude	Float32 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS	Longitude of channel 17- Positive east.	Degree / (-180 – 180)
solarZenAngle	Float32 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS	Solar Zenith Angle at the geolocated beam position center.	Degree / (0 – 180)
solarAzmAngle	Float32 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS	Solar Azimuth Angle at the geolocated beam position center.	Degree / (-180 – 180)
senZenAngle	Float32 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS	Satellite Zenith Angle at the geolocated beam position center	Degree / (0 – 70)
senAzmAngle	Float32 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS	Satellite Azimuth Angle at the geolocated beam position center. Positive east of north.	Degree / (-180 – 180)
terrainHeight	Float32 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS	Ellipsoid-Geoid separation	Meter
satelliteRange	Float32 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS	Line of sight distance from the ellipsoid intersection to the satellite	Meter
beamLatitude	Float32 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS * NUM_ATMS_BANDS	Latitude for each beam position for bands {K,A,V,W,G}	Degree / (-90 – 90)
beamLongitude	Float32 * NUM_ATMS_SCANS * NUM_BEAM_POSITIONS * NUM_ATMS_BANDS	Longitude for each beam position for bands {K,A,V,W,G}	Degree / (-180 – 180)

Table 11. ATMS SDR IP

Output	Type/size	Description	Units/valid range
Scan level			
PrtKavCoeffs	Int32 * NUM_CAL_SCANS * NUM_PRT_COEFFS * NUM_PRT_KAV	PRT(KAV) counts-to- temperature conversion coefficients (4x8)	Unitless
prtWgCoeffs	Int32 * NUM_CAL_SCANS * NUM_PRT_COEFFS * NUM_PRT_WG	PRT(WG) counts- to temperature conversion coefficients (4x7)	Unitless
pamKav	Int32 * NUM_CAL_SCANS	PAM resistance counts for KAV	Unitless
pamWg	Int32 * NUM_CAL_SCANS	PAM resistance counts for WG	Unitless
prtKavCounts	Int32 * NUM_ATMS_SCANS * NUM_PRT_KAV	PRT counts (KAV) from hot cal data	Unitless
prtWgCounts	Int32 * NUM_ATMS_SCANS * NUM_PRT_WG	PRT counts (WG) from hot cal data	Unitless
pamKavCounts	Int32 * NUM_ATMS_SCANS	PAM counts (KAV) calibration data	Unitless
pamWgCounts	Int32 * NUM_ATMS_SCANS	PAM counts (WG) calibration data	Unitless
multiplexRef	Int32 * NUM_ATMS_SCANS	Multiplexer reference	Unitless
Channel level			
warmBias	Int32 * NUM_CAL_SCANS * NUM_CHANNELS	Warm target bias corrections	Unitless
coldBias	Int32 * NUM_CAL_SCANS	Cold space bias	Unitless

Output	Type/size	Description	Units/valid range
	* NUM_CHANNELS	corrections	
quadraticCoeff	Int32 * NUM_CAL_SCANS * NUM_CHANNELS	Calibration nonlinearity (quadratic) factors	Unitless

2.2.2 Algorithm Processing

The algorithm uses a Common Geolocation (CMN GEO) library of functions to calculate geodetic latitude and longitude along with sun azimuth and zenith angles. Geolocation is performed using a combination of sensor specific functions and the Common Geolocation library of functions.

The data integrity module checks the quality of radiometric and other data. If the data are not suitable for processing, the proper flags are set and the processor continues with the calibration module. The calibration module converts raw radiometric scene information into brightness temperatures.

The overall ATMS SDR top-level flow diagram is illustrated in Figure 4.

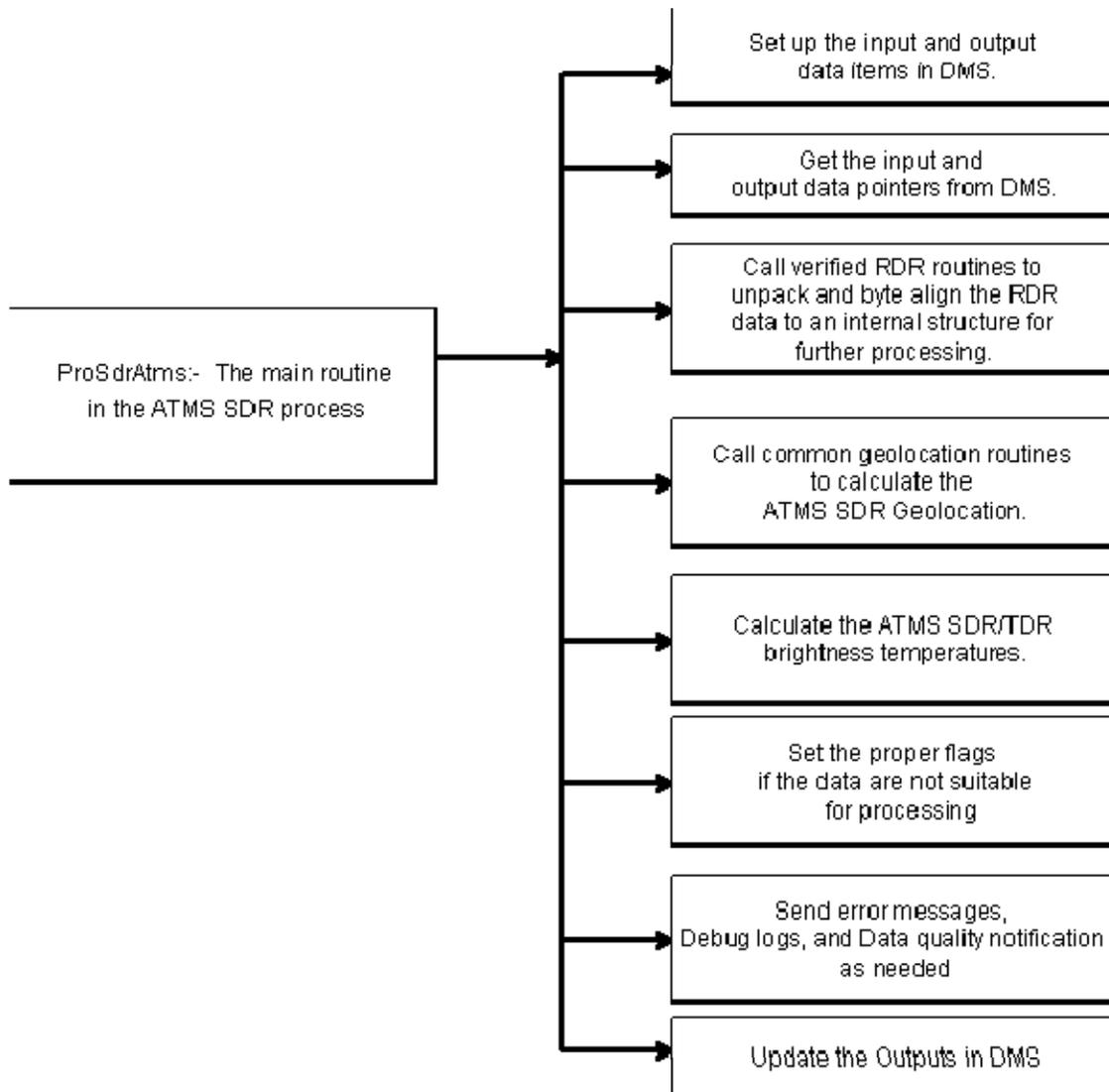


Figure 4. ATMS SDR Top Level Flow Diagram

2.2.2.1 Detailed Design of Radiometric Calibration

The goal of the radiometric calibration module is to convert measured counts from each of the 22 ATMS channels into calibrated scene brightness temperatures. Scene brightness temperatures are related to scene counts by the linear transfer function

$$T_{B,l} = T_{WC} + \frac{C_S - C_{WCA}}{Gain}$$

$$Gain = \left(\frac{C_{WCA} - C_{CCA}}{T_{WC} - T_{CC}} \right)$$

where

- T_{WC} = Effective temperature of warm calibration (hot target)
- C_S = Number of counts for the scene sample
- C_{WCA} = Number of counts from the warm calibration view, averaged over N_{WC} scans
- T_{CC} = Brightness temperature of cold calibration (cold space view) for each channel
- C_{CCA} = Number of counts from the cold calibration view, averaged over N_{CC} scans

The brightness temperature can also be corrected for nonlinearity by the addition of a quadratic term. This correction is applied when the user-input variable `use_quadratic_term` is set to `.true`. The peak nonlinearity can be from telemetry or from the parameter file, which is controlled by the variable `use_quadratic_tele`.

```

if(use_quadratic_term)
  if(use_quadratic_tele)
     $T_{nl} = \text{from\_telemetry}$ 
  else
     $T_{nl} = \text{from\_parameter(LinearlyInterpolated)}$ 
  endif
 $Q = T_{nl} \cdot \left( 1 - 4 \left( \frac{T_{B,l} - T_{CC}}{T_{WC} - T_{CC}} - 0.5 \right)^2 \right)$ 
 $T_B = T_{B,l} + Q$ 
endif
    
```

where

- T_{nl} = Peak nonlinearity, as determined from calibration tests
- $T_{B,l}$ = Brightness temperature assuming linear transfer function.

Non-linearity measurements were taken during the PFM calibration tests at three cold plate temperatures (-10°C, +5°C and +20°C) and four redundancy configurations (RC1, RC2, RC5

and RC6). The quadratic correction coefficients stored in the ATMS instrument memory loads were derived as the median value over the four redundancy configurations for the +5°C cold plate temperature. These values representing the average behavior are transmitted as parts of the Calibration Data package in the telemetry. A user selected option, implemented as a switch in the parameter file, allows the correction to be done either with the coefficients in the telemetry or with those listed in the parameter file. The full set of coefficients for the four redundancy configurations and the three cold plate temperatures are listed in the parameter file. If the option to use the parameter file is chosen, the algorithm selects the appropriate coefficients based on the instrument redundancy configuration and then linearly interpolates them based on the shelf temperatures. Table 12 shows the matches of the shelf temperatures measured to the cold plate temperatures during the calibration tests.

Table 12. Cold Plate Temperature/Shelf Temperature Matchings

Cold Plate		-10°C	+5°C	+20°C
KKA Shelf	Channel 1 - 2	-4	11	26
V Shelf	Channel 3 - 5	2	16	31
W Shelf	Channel 16	-4	11	25
G Shelf	Channel 17 - 22	-5	10	25

If a shelf temperature is outside the range listed in the table, it is assigned the value at the upper or lower bound. If a shelf temperature is unavailable (filled value), the last saved shelf temperature is used. If that is not available either, the non-linearity coefficients for the +5°C cold plate case are used.

For the four redundancy configurations not tested (RC3, RC4, RC7 and RC8), coefficients for the tested configurations are used as substitutes. The mapping: RC3 → RC2, RC4 → RC1, RC7 → RC6 and RC8 → RC5 is used for the substitution.

2.2.2.1.1 PRT Conversion

The hot target physical temperature is determined as a weighted average value derived from the embedded PRTs plus bias-like correction factors. The KAV target contains num_prt_kav (eight) PRTs and the WG target contains num_prt_wg (seven) PRTs. In addition, the instrument is also equipped with shelf PRTs that provide readings of the receiver’s physical temperature which is used to determine the hot target bias and to interpolate the quadratic correction coefficients. Conversion of PRT counts to resistance and resistance to physical temperatures are shown below.

2.2.2.1.1.1 Conversion from Counts to Resistance

Two forms of the counts to resistance equations are used, one for hot target PRTs (4-wire PRTs) and one for the receiver shelf 2-wire PRTs:

$$R_i = R_{ref} \left(\frac{C_i - C_{off}}{C_{ref} - C_{off}} \right), \text{ for hot target 4-wire PRTs}$$

$$R_i = R_{ref} \left(\frac{C_i - C_{off}}{C_{ref} - C_{off}} \right) - R_c, \text{ for receiver shelf 2-wire PRTs}$$

where

- C_i = Number of PRT counts for the i^{th} PRT
- C_{ref} = PAM counts
- C_{off} = Multiplexer reference counts (shorted input) obtained from the most recent Engineering Health and Status data packet, variable 4W_GND_A or 4W_GND_B
- R_{ref} = PAM (Precision Analog Monitor) resistance in ohms
- R_c = Cable resistance to the shelf PRT in ohms
- R_i = PRT resistance in ohms for the i^{th} PRT

All inputs are obtained from telemetry. The case of division-by-zero when $C_{ref} = C_{off}$ occurs is flagged in prt_conversion_kav_flag, prt_conversion_wg_flag or prt_conversion_shelf_flag.

2.2.2.1.1.2 Conversion from Resistance to Physical Temperature

The resistance, R , calculated in Section 2.1.2.1.1.1 is related to the physical temperature, T_c , of a given PRT by the Callendar-Van Dusen equation:

$$R_i = R_{o,i} \left[1 + \alpha_i \left(T_c - \delta_i \left(\frac{T_c}{100} - 1 \right) \right) \left(\frac{T_c}{100} \right) - \beta_i \left(\frac{T_c}{100} - 1 \right) \left(\frac{T_c}{100} \right)^3 \right]$$

where

- T_c = the physical temperature, in degrees Centigrade
- R_i = PRT resistance in ohms calculated in Section 2.1.2.1.1.1
- $R_{o,i}$ = the measured resistance in ohms of the specified PRT at the ice point
- $\alpha_i, \delta_i, \beta_i$ = constants measured for the specified (subscript i) PRT.
Note for the shelf PRTs, β_i is 0.

Note that all PRT constants, R_o , α , δ , and β , are obtained from telemetered data except for the shelf PRT constant β which must be set to zero. For a bad PRT, the flight software sets $R_{o,i}$ to zero.

The above equation is solved for T_c by iteration using the Newton-Raphson method with an initial guess of T_c as

$$T_c = \frac{R_i - R_{o,i}}{R_{o,i} \alpha_i}$$

and a loop count initialization of iloop = 0.

The Newton Raphson method of solution is implemented by performing the algorithm below:

$$\begin{aligned}
 &do \\
 &f(T_c) = R_{o,i} \left[1 + \alpha_i \left(T_c - \delta_i \left(\frac{T_c}{100} - 1 \right) \right) \left(\frac{T_c}{100} \right) - \beta_i \left(\frac{T_c}{100} - 1 \right) \left(\frac{T_c}{100} \right)^3 \right] - R_i \\
 &f'(T_c) = R_{o,i} \alpha_i \left(1 - \delta_i \left(\frac{T_c}{5000} - 0.01 \right) \right) - \beta_i \left(\frac{T_c^3}{2.5 \times 10^7} - \frac{3T_c^2}{1 \times 10^6} \right) \\
 &T_c = T_c - \frac{f(T_c)}{f'(T_c)} \\
 &iloop = iloop + 1 \\
 &while \left(\left(\left| \frac{f(T_c)}{f'(T_c)} \right| > prt_convergence \right) \parallel (iloop < prt_loops) \right)
 \end{aligned}$$

To avoid the off-nominal condition of an infinite iteration, a limit on the number of iteration loops, `prt_loops`, should be set and the loop exited with an error condition if the maximum number of iterations is exceeded. When this happens it is flagged in `prt_conversion_kav_flag`, `prt_conversion_wg_flag` or `prt_conversion_shelf_flag`.

2.2.2.1.2 Calculation of Average Hot Target PRT Temperature, \bar{T}_W

Separate average hot target temperatures are calculated for the KAV and WG targets. These temperatures are determined from multiple PRT temperatures that are weight-averaged over N_p (aka, `num_scan_prt`) scans. Nominally, the current scan, `isc`, is bounded by `istart = isc - (num_scan_prt/2)` and `iend = istart + (num_scan_prt - 1)` scans.

The basic equation for calculating the average hot target temperature for a specified target (i.e., KAV or WG) is

$$\bar{T}_W = \frac{\sum_i^{num_prt} \sum_n^{N_p} T_{K,n,i} W_{n,i}}{\sum_i^{num_prt} \sum_n^{N_p} W_{n,i}}$$

where

$$\begin{aligned}
 T_{K,n,i} &= \text{PRT temperature in Kelvin for the } i^{\text{th}} \text{ PRT at the } n^{\text{th}} \text{ scan} \\
 W_{n,i} &= \text{Scan weights for the } i^{\text{th}} \text{ PRT at the } n^{\text{th}} \text{ scan}
 \end{aligned}$$

If a PRT is deemed to be bad permanently by the user, its weights in the parameter file should be set to zero. It is then excluded from the calibration process and quality checks.

For the calculation of the hot target temperature, the limits check and the self consistency check can be turned on (or off) via `chk_consistency_prt` in the parameter file. The data sufficiency check is designed to be always on.

- 1) PRT quality check – limits

The converted warm load PRT temperatures are checked against predetermined gross limits: `low_limit_prt` and `upp_limit_prt`. Those which fall outside the limits are considered “bad” and flagged by setting the quality flag (`prt_limit_kav_flag` or `prt_limit_wg_flag`) on. Then the PRT temperatures, along with their weights, are set to zeros:

$$T_i < T_{low} \text{ or } T_i > T_{upp} \rightarrow \text{“bad-}T_i\text{”}$$

2) PRT quality check – self consistency

The PRT temperatures are next checked for internal consistency. This is done by comparing all temperatures not flagged as bad with each other. Any PRT’s temperature that differs by more than a fixed limit, `max_var_prt`, from at least two other PRTs’ readings is considered “bad” and flagged by setting the quality flag (`prt_consistency_kav_flag` or `prt_consistency_wg_flag`) on. Then the PRT temperatures, along with their weights, are set to zeros:

$$|T_i - T_j| > \Delta T_{max} \text{ and } |T_i - T_n| > \Delta T_{max} \rightarrow \text{“bad-}T_i\text{”}$$

The number of “good” PRTs is then checked. If there are less than `num_threshold_prt[1]` “good” PRTs for KAV or `num_threshold_prt[2]` for WG, all PRTs within that group are considered “bad”. The PRT temperatures, along with their weights, are set to zeros. The quality flag (`prt_consistency_kav_flag` or `prt_consistency_wg_flag`) is set on.

3) PRT quality check – data sufficiency

If the weight-sum of all (KAV or WG) PRT readings over all `num_scan_prt` scans not flagged as “bad” falls below a specified percentage, `wt_threshold_prt`, of the total weights for PRT averaging, it is not possible to reliably determine this warm load temperature for the current calibration cycle.:

$$(\sum_i W_i) / W_{total} < W_{threshold_prt} \rightarrow \text{“bad-}\bar{T}_w\text{”}$$

where $W_i = 0$ for “bad- T_i ”. The cycle is then flagged by turning `prt_data_sufficiency_kav_flag` or `prt_data_sufficiency_wg_flag` on. Failing the data sufficiency test results in an unsuccessful calibration cycle.

2.2.2.1.3 Shelf Temperature Calculations, T_{SHELF}

Besides being used to determine the quadratic correction to the radiometric transfer function, the receiver temperature is also used to determine a correction to the average hot target temperature determined above. This is implemented by computing the bias as a quadratic polynomial function of the relevant PRT temperature. There are four shelf PRTs: `KKA_SHELF_PRT`, `V_SHELF_PRT`, `W_SHELF_PRT` and `G_SHELF_PRT`.

To calculate the shelf PRT temperature for a specified receiver shelf, the following steps are performed:

Convert the PRT counts to resistance according to the 2-wire shelf PRT equation in Section 2.1.2.1.1.1.

Convert the PRT resistance to physical temperature, T_{SHELF} , according to the algorithm discussed in Section 2.1.2.1.1.2.

If division-by-zero condition exists, or if the computation loop fails to converge, the condition is flagged in `prt_conversion_shelf_flag`. The most recent shelf temperature saved in the buffer `bptemp_backup` is then used. If the temperature is out of range, it is assigned the upper or

lower bound (see Section 2.1.2.1). The shelf temperature in the common buffer `bptemp_backup` is then updated with the current value.

2.2.2.1.4 Calculation of Effective Hot Target Temperature

An effective hot target temperature in Kelvin, with bias added, is calculated for each of the 22 ATMS channels according to the equation below:

$$T_{WC,chan} = \bar{T}_W + \left\{ \begin{array}{l} warmBias_{band} \\ a_{chan,1} + a_{chan,2}T_{SHELF} + a_{chan,3}T_{SHELF}^2 \end{array} \right.$$

where

\bar{T}_W	=	Averaged warm load PRT temperature in Kelvin (Section 2.1.2.1.2)
T_{SHELF}	=	Shelf PRT temperature in degrees Centigrade (Section 2.1.2.1.3)
$warmBias_{band}$	=	PRT warm bias in degrees Centigrade for each of the five bands from telemetry file
$a_{chan,k}$	=	Quadratic correction coefficients, k=1:3, for each ATMS channel from user input

Note that the $warmBias_{band}$ variable is telemetered data; the other variables are user inputs. The option is controlled by the switch `use_warm_bias_tele` in the parameter file. If a shelf PRT temperature is unavailable (filled value), the last saved shelf temperature is used. If that is not available either, then the temperature dependent corrections are ignored by assuming $T_{SHELF} = 0$.

2.2.2.1.5 Calculation of Effective Cold Calibration Brightness Temperature

The cold calibration brightness temperature for each ATMS channel is determined as follows:

$$T_{CC,chan} = T_{cbc,chan} + \left\{ \begin{array}{l} coldBias_{band} \\ coldBias_{chan,sv} \end{array} \right.$$

where

$T_{cbc,chan}$	=	Cosmic background radiometric temperature for each channel in Kelvin
$coldBias_{band}$	=	Cold calibration offset bias for each of the five bands from telemetry
$coldBias_{chan,sv}$	=	Cold calibration offset bias for each of the 22 channels and each of the four space views from user input

The cold bias variable, $coldBias_{band}$, is telemetered data and $coldBias_{chan,sv}$ is user input from the parameter file. This accounts for antenna sidelobe energy. Four sets of $coldBias_{chan,sv}$ parameters corresponding to four space view groups are stored in the parameter file. The space view group currently used as indicated in the telemetry data (Scan Pattern ID bits of Instrument Mode Word in Engineering H&S packet) determines the appropriate set of

$coldBias_{chan,sv}$ to be used. The choice between the bias in the telemetry and that in the parameter file is controlled by the switch `use_cold_bias_tele` in the parameter file.

The cosmic background radiometric temperature is a Rayleigh-Jeans approximation derived from Planck's equation and is read in as user input (see Section 5.3 in the ATMS Radiometric Math Model, NGES Report 12110C, October 2005).

2.2.2.1.6 Average Number of Counts from the Warm Calibration View, C_{wca}

The limits check, the self consistency check and the gain error check are performed if the user-specified parameter `chk_consistency_wc_cc` in the parameter file is turned on. The data sufficiency check is designed to be always on. These checks on warm counts are:

1) Quality check – limits

The warm counts are checked against pre-defined channel-specific gross limits. Those which fall outside the limits are flagged as “bad” by setting them to zero.

$$C_{w_i} < C_{w_{low}} \text{ or } C_{w_i} > C_{w_{upp}} \rightarrow \text{“bad-}C_{w_i}\text{”}$$

2) Quality check – self consistency

The counts are next checked for internal consistency. This is done by checking each count not flagged as “bad” against other counts in the same scan. Any count that differs by more than a fixed limit, `max_var_wc`, from at least two other counts is flagged as “bad”. The count is set to zero.

$$|C_{w_i} - C_{w_j}| > \Delta C_{w_{max}} \text{ and } |C_{w_i} - C_{w_k}| > \Delta C_{w_{max}} \rightarrow \text{“bad-}C_{w_i}\text{”}$$

The number of “good” samples is then checked. If there are less than three “good” samples, all counts within this scan are flagged as “bad” and the counts are set to zeros.

3) Quality check – gain error

If the lowest “good” warm count is smaller than or equal to the highest “good” cold count, all the warm counts and cold counts with this scan are flagged as “bad” and the counts are set to zeros.

4) Quality check – data sufficiency

The counts from the warm calibration views are weight-averaged over N_{wc} scans. Within each scan, at least three “good” warm target samples are present. Otherwise, that scan is excluded in the count averaging. If the weight-sum of all scans not flagged as “bad” falls below a specified percentage, `wt_threshold_wc`, of the total weight for warm count averaging, it is deemed not possible to reliably determine the averaged warm count of this channel for the current calibration cycle. This channel is then flagged by turning `wc_data_sufficiency_flag` on. Failing the data sufficiency test shall result in an unsuccessful calibration cycle for this channel. The brightness temperatures (TK) and corrected brightness temperatures (TKB) are then filled with fill value `ERR_FLOAT32_FILL`.

The process is represented as follows:

$$C_{WC,chan} = \sum_n^{Nwc} \left(scanWeight_wc_{n,chan} \left(\frac{1}{num_samples_{n,chan}} \right)^{num_samples_{n,chan}} \sum_j C_{RWC,j,n,chan} \right)$$

$$W_{WC,chan} = \sum_n^{Nwc} (scanWeight_wc_{n,chan})$$

if ($W_{WC,chan} \geq Weight_threshold_wc$)

$$C_{WCA,chan} = \frac{C_{WC,chan}}{W_{WC,chan}}$$

else

$$C_{WCA,chan} = 0$$

$wc_data_sufficiency_flag = on$

endif

where

- $num_samples_{n,chan}$ = Number of good warm target samples: three or four.
- $C_{RWC,j,n,chan}$ = Number of raw counts from each of the $num_warm_samples$ hot calibration target at each of the Nwc scans and each channel.
- $scanWeight_wc_{n,chan}$ = Normalized weight applied for each scan. Weights are re-set to zero for “bad” or “missing” scans, therefore, $\sum_n scanWeight_wc_{n,chan} \leq 1.0$
- $Weight_threshold_wc$ = Minimum weight percentage required to accept $C_{WCA,chan}$. It is a tunable parameter from user input.

2.2.2.1.7 Average Number of Counts from the Cold Calibration View, C_{CCA}

The limits check, the self consistency check and the gain error check are performed if the user-specified parameter $chk_consistency_wc_cc$ in the parameter file is turned on. The data sufficiency check is designed to be always on. Similar to the warm count quality checks, these checks on cold counts are:

1) Quality check – limits

The cold counts are checked against pre-defined channel-specific gross limits. Those which fall outside the limits are flagged as “bad” by setting them to zero.

$$Cc_i < Cc_{low} \text{ or } Cc_i > Cc_{upp} \rightarrow \text{“bad-}Cc_i\text{”}.$$

2) Quality check – self consistency

The counts are next checked for internal consistency. This is done by checking each count not flagged as “bad” against other counts in the same scan. Any count that differs by more than a fixed limit, max_var_cc , from at least two other counts is flagged as “bad”. The count is set to zero.

$$|Cc_i - Cc_j| > \Delta Cc_{max} \text{ and } |Cc_i - Cc_k| > \Delta Cc_{max} \rightarrow \text{“bad-}Cc_i\text{”}$$

The number of “good” samples is then checked. If there are less than three “good” samples, all counts within this scan are flagged as “bad” and the counts are set to zeros.

3) Quality check – gain error

If the lowest “good” warm count is smaller than or equal to the highest “good” cold count, all the warm counts and cold counts with this scan are flagged as “bad” and the counts are set to zeros.

4) Quality check – data sufficiency

The counts from the cold calibration views are averaged over N_{cc} scans. Within each scan, at least three “good” cold target samples are present. Otherwise, that scan is excluded in the count averaging. If the weight-sum of all scans not flagged as “bad” falls below a specified percentage, $wt_threshold_cc$, of the total weight for cold count averaging, it is deemed not possible to reliably determine the averaged cold count of this channel for the current calibration cycle. This channel is then flagged by turning $cc_data_sufficiency_flag$ on. Failing the data sufficiency test shall result in an unsuccessful calibration cycle for this channel. The brightness temperatures (TK) and corrected brightness temperatures (TKB) are then filled with fill value $ERR_FLOAT32_FILL$.

The process is represented as follows:

$$C_{CC,chan} = \sum_n^{N_{cc}} \left(scanWeight_cc_{n,chan} \left(\frac{1}{num_samples_{n,chan}} \right)^{num_samples_{n,chan}} \sum_j C_{RCC,j,n,chan} \right)$$

$$W_{CC,chan} = \sum_n^{N_{cc}} (scanWeight_cc_{n,chan})$$

if ($W_{CC,chan} \geq Weight_threshold_cc$)

$$C_{CCA,chan} = \frac{C_{CC,chan}}{W_{CC,chan}}$$

else

$$C_{CCA,chan} = 0$$

$cc_data_sufficiency_flag = on$

endif

where

- $num_samples_{n,chan}$ = Number of good cold target samples: three or four.
- $C_{RCC,j,n,chan}$ = Number of raw counts from each of the $num_cold_samples$ cold calibration targets for each of the N_{cc} scans and each ATMS channel.
- $scanWeight_cc_{n,chan}$ = Normalized weight applied for each scan. Weights are reset to zero for “bad” or “missing” scans, therefore, $\sum_n scanWeight_cc_{n,chan} \leq 1.0$
- $Weight_threshold_cc$ = Minimum weight percentage required to

accept $C_{CCA,chan}$. It is a tunable parameter from user input.

2.2.2.1.8 Scan Position Dependent Correction to Brightness Temperature

Once the brightness temperature is calculated for each channel, it is finally adjusted by scan position-dependent correction terms:

$$T_{BB,chan,sp} = beamEfficiencyCorrection_{chan,sp} T_{B,chan,sp} + scanBias_{chan,sp}$$

where

$beamEfficiencyCorrection_{chan,sp}$	=	Scan-position dependent beam efficiency correction factor for each channel
$scanBias_{chan,sp}$	=	Scan-position dependent bias for each channel

Note that *beamEfficiencyCorrection* and *scanBias* are user-input variables.

2.2.2.1.9 Missing PRT Count, Warm Count or Cold Count

The algorithm recognizes a missing PRT count, warm count or cold count by comparing it to the fill value (assumed to be zero). Missing count is excluded in the calibration.

2.2.2.2 ProSdrAtms (ProSdrAtms.cpp)

This is the derived algorithm class for the ATMS SDR Calibration and Geolocation algorithm and is a subclass of the *AutoGeneratedProSdrAtms* class. *ProSdrAtms* reads all data items required by the algorithm from DMS and then geolocates and calibrates the data.

ATMS SDR algorithm uses common geolocation routines to calculate the ATMS SDR geolocation. Since the common geolocation is done in C++, ATMS SDR calculates the data necessary for the common geolocation process in the derived algorithm (*ProSdrAtms*). ATMS SDR calls the common geolocation routines to get the ATMS SDR GEO and it is stored in the DMS with the corresponding granule ID.

After the SDR geolocation, it passes the data into the FORTRAN side of the algorithm to do calibration. The *createAtmsSdr* subroutine calls the other functions to calculate brightness temperatures. The status returned from the algorithm is checked and if the algorithm did not complete successfully, the derived algorithm sends status to INF that the SDR was not generated successfully via the common code. If the algorithm completed successfully, the SDR, TDR, IP, and GEO are stored in DMS with the corresponding Granule ID. Also, it checks the quality of the SDR products and sends Data Quality Notification accordingly.

2.2.2.3 calcAtmsSdrs (calcAtmsSdrs.f)

In FORTRAN, this is the main module for the ATMS SDR calibration process. First associate the pointers in *atms_struct* module with addresses passed in from the derived algorithm (these are pointers to DMS memory). Since the ATMS SDR calibration is done in FORTRAN, the

pointers from the CPP side need to be associated to FORTRAN structures to access DMS memory so that data from DMS can be used for further processing. Then subroutines are called to convert the data from counts to corresponding engineering units and calculate the brightness temperatures.

2.2.2.4 Initialize the ATMS SDR Outputs and Flags (`init_atms_sdr_flags.f`)

`init_atms_sdr_flags` initializes all the sdr flags. Latitude and longitude values are initialized to float fill values in the `ProSdrAtms.cpp`. Corrected and uncorrected brightness temperatures are also initialized to float fill values.

2.2.2.5 NeDT Calculation (`sdrs.f - routine compute_nedt`)

The NEDT calculation is done on the 4 cold sky readings and 4 warm load readings of an individual scan. With only four counts, it has a large variance between scans and needs to be used for quality control with care. It is not averaged over multiple scans. It is not corrected to the 300 K specification value. The gain is calculated using the weighted scan profiles contained in the tunable processing coefficient files. The equation is:

$$\text{NEDT} = G * \text{SQRT} \{ S [(x_i - \bar{x})^2] / 3 \}$$

where G is the gain of the system, x_i are the raw counts, and \bar{x} is the mean value of the four readings.

2.2.2.6 Calibration Module (`c2k_new.f`)

The radiometric calibration algorithm converts radiometric counts from each channel and ATMS beam position into calibrated brightness temperatures, in units of Kelvin. The SDR calibration flowchart of this module is shown in Figure 5. Calibration inputs and calibration outputs are listed in Table 13 and Table 14, respectively.

Each ATMS scan is comprised of radiometric measurements for 22 channels collected from 96 ATMS beam positions and four warm and four cold target calibration positions. The physical temperature of the in-flight hot calibration target is determined from the averaged read-outs from Platinum Resistance Temperature (PRT) sensors. A precision resistor, referred to as a Precision Analog Monitor (PAM), provides a calibration of the resistance-to-digital counts conversion. Warm calibration target readings and cold calibration space view readings are averaged over a number of scans. The number is optimized for the warm and cold readings separately and for each channel. PRT readings are also averaged over a number of scans, `num_scan_prt`. This module also has the capability to apply a quadratic correction coefficient, from telemetry or from user's parameter input, for possible nonlinearity in the counts-to-brightness temperature transfer function, when selected by the user through the variables `use_quadratic_term` and `use_quadratic_tele`.

In the case of a bad PRT, the flight software has the vendor-supplied PRT constant, R_0 (resistance at ice point of the PRT, see Calibration Packet parameters in the NPP MDFCB, GSFC 429-05-02-42), set as zero. If a PRT is deemed to be bad permanently by the user, its weights in the parameter file should be set to zero. It is then excluded from the calibration process and quality checks.

Limits check and self consistency check can be turned on or off through users' parameter input. The data sufficiency check is always on. Those failing to pass the quality checks are flagged and discarded from the average PRT temperature calculation.

Similarly, the same types of quality checks are applied to warm target counts and cold space view counts. Those failing to pass their quality checks are eliminated from the calibration process and their corresponding quality flags are set accordingly.

Error flags set in this module are explained below:

KAV PRT Conversion Error flag is set when conversion of counts to temperature encounters the condition of division-by-zero and/or nonconvergence of the temperature calculation for any KAV PRT.

WG PRT Conversion Error flag is set when conversion of counts to temperature encounters the condition of division-by-zero and/or nonconvergence of the temperature calculation for any WG PRT.

Shelf PRT Conversion Error flag is set when conversion of counts to temperature encounters the condition of division-by-zero and/or nonconvergence of the temperature calculation for any of four shelf PRTs (KKA, V, W, G).

KAV PRT Temperature Limits Check flag is set for a KAV PRT (of eight) when its temperature is out of pre-defined limits. See Section 2.1.2.1.2 for details.

WG PRT Temperature Limits Check flag is set for a WG PRT (of seven) when its temperature is out of pre-defined limits. See Section 2.1.2.1.2 for details.

KAV PRT Temperature Consistency Check flag is set for a KAV PRT when it fails the self consistency check. See Section 2.1.2.1.2 for details.

WG PRT Temperature Consistency Check flag is set for a WG PRT when it fails the self consistency check. See Section 2.1.2.1.2 for details.

KAV PRT Temperature Data Sufficiency Check flag is set when insufficient data are available, either because of missing data or failing to pass the quality checks. See Section 2.1.2.1.2 for details.

WG PRT Temperature Data Sufficiency Check flag is set when insufficient data are available, either because of missing data or failing to pass the quality checks. See Section 2.1.2.1.2 for details.

Space View Data Sufficiency Check flag is set when insufficient space view samples are available, either because of missing data or failing to pass the quality checks. See Section 2.1.2.1.7 for details.

Blackbody Data Sufficiency Check flag is set when insufficient warm target samples are available, either because of missing data or failing to pass the quality checks. See Section 2.1.2.1.6 for details.

Calibration Using Fewer Than Preferred Samples flag is set when a scan line is calibrated by fewer than the preferred number of samples (blackbody count, space view count and PRT)

and/or scans either because of missing data or some data failing the quality checks. See Sections 2.1.2.1.2, 2.1.2.1.6 and 2.1.2.1.7 for details.

The science code implementation of calibration is contained in subroutine c2k_new.f which is called from subroutine sdrone.f.

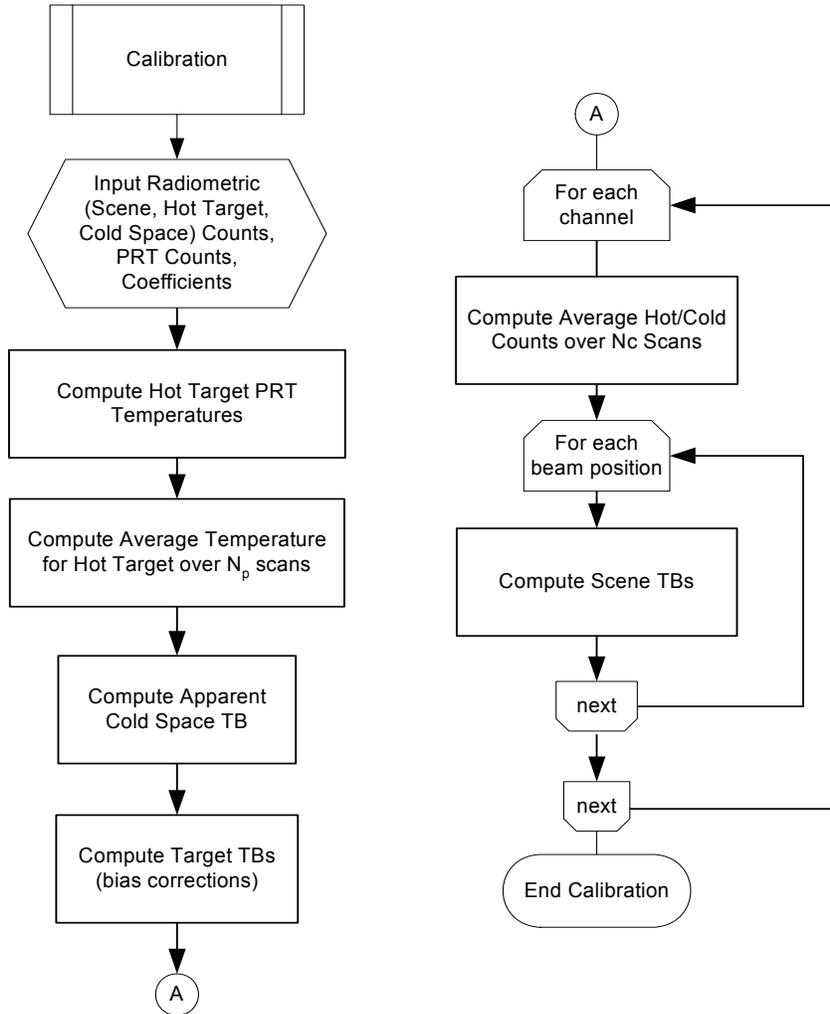


Figure 5. ATMS SDR Calibration Flow

Table 13. Calibration Module Inputs

Input Var. Name	Description	Type	Units
scnt	Scene counts for the current scan	(NUM_CHANNELS * NUM_BEAM_POSITIONS)* REAL * 8	counts
crw	Raw warm counts for each channel over a specified number of scans, num_scans_wc, bounding the current scan	(NUM_CHANNELS * NUM_WARM_SAMPLES * NUM_SCAN_WC) * REAL * 8	counts

Input Var. Name	Description	Type	Units
crc	Raw cold counts for each channel over a specified number of scans, num_scans_wc, bounding the current scan	(NUM_CHANNELS* NUM_COLD_SAMPLES* NUM_SCAN_WC) * REAL *8	counts
num_ptr	Number of PRTs (KAV bands or WG bands)	INTEGER	counts
prtw	Number of counts measured for each KAV or WG PRT over a specified num of scans, num_scans_ptr, bounding the current scan	(num-pts * NUM_SCAN_PTR) INTEGER	counts
scan_weights_ptr	Weights for scan averaging of PRTs	(num_ptr* NUM_SCAN_PTR) REAL	counts
prt_coefficients	PRT coefficients (R0, Alpha, etc)	(NUM_PRT_COEFFS* num_ptr) REAL	counts
prt_bp	PRT "counts" for baseplate	INTEGER	counts
prt_coeff_bp	PRT coefficients for baseplate	(NUM_PRT_COEFFS) REAL	counts
coff	Reference counts for PRT computation	INTEGER	counts
cref	PAM counts for PRT computation	INTEGER	counts
rref	PAM resistance for PRT computation	REAL*8	counts
warm_bias	Warm load bias	(NUM_CHANNELS) REAL	°C
cold_bias	Cold load bias	(NUM_CHANNELS) REAL	°C
quadratic_factors	Quadratic BT correction factors	(NUM_CHANNELS) REAL	K
isc	Current scan number	INTEGER	Index-No unit

Table 14. Calibration Module Outputs

Output Var. Name	Description	Type	Units
tk	Brightness temperature without any corrections applied	num_channels x num_beam_positions x real*32	K
tkb	Brightness temperature with a scan-position dependent beam-efficiency correction and bias applied	num_channels x num_beam_positions x real*32	K

2.2.2.7 ATMS SDR Geolocation (ProSdrAtms::calcGeolocation())

The ATMS SDR geolocation flow diagram is shown in Figure 6.

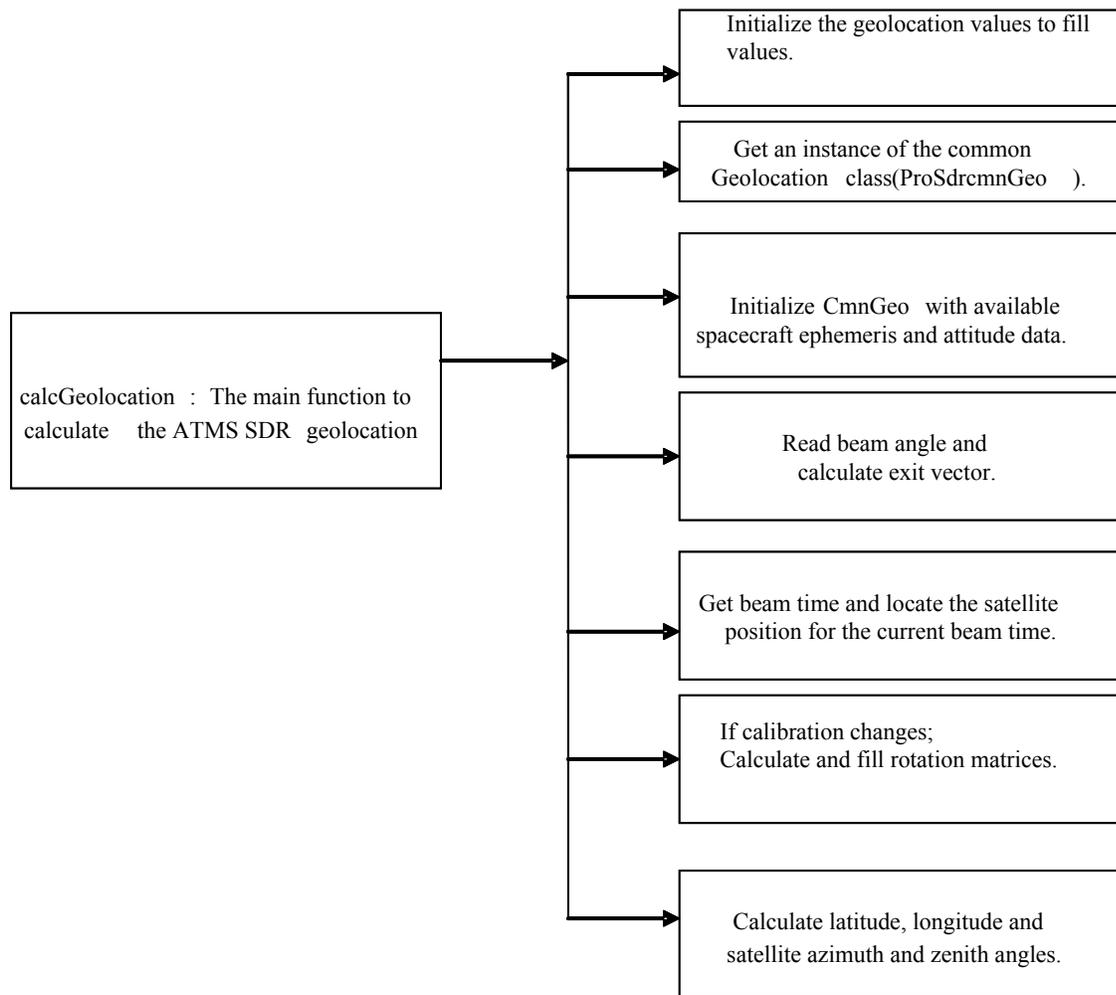


Figure 6. ATMS SDR Geolocation Flow Diagram

IDPS designed and developed a library of functions called Common Geolocation that are used by all the SDR algorithms to calculate geodetic latitude and longitude as well as solar and lunar geometries. For more details on the common geolocation library of functions please refer to the Common Geolocation OAD, 474-00091. ATMS SDR retrieves the Spacecraft Diary RDR Data from DMS, unpacks and byte aligns the spacecraft diary to create the verified spacecraft RDR. ATMS SDR initializes common geolocation structure with satellite attitude and ephemeris data. ATMS SDR gets the beam angle for a given beam position and calculates the exit vector for that beam position. Beam alignment offsets are obtained from RDR calibration packet data for the 5 bands (K, Ka, V, W and G) or from the tunable parameters file for the 22 channels. The option to use beam alignment offsets from either calibration packet data or the tunable parameters file is controlled by a switch in the tunable parameters file. The rotation matrix is calculated using the beam alignment offsets; Common Geolocation functions are then used to apply the rotation matrix to the exit vector (resulting in corrected exit vectors) and calculate the ATMS SDR geodetic latitude, longitude, and other geolocation values. This process is repeated for each earth-view beam position within each scan.

When the band-level beam alignment offsets are used, the corrected exit vectors and geolocation values are calculated at the band-level, where channels belonging to the same

band will have identical geolocation. When the channel-level beam alignment offsets are used, the corrected exit vectors and geolocation values are calculated at the channel-level.

Additionally, only geolocation for a subset of channels (currently channels 1, 2, 3, 16, 17 - representing the 5 bands) is stored in the GEO output product.

The following subsections provide additional details on ATMS geolocation.

2.2.2.7.1 Calculation of mid-scan spacecraft position, velocity and attitude

Spacecraft position, velocity and attitude are calculated for the middle of every scan in the granule. This data is obtained by calling the `ProSdrCmnGeo::satPosAtt()` function and passing it the mid-scan (beam 47) time of a given scan. When the mid-scan time is missing, an estimated mid-scan time is used. The estimated time is calculated based on an offset from the scan start time.

2.2.2.7.2 Calculation of geolocation

Geolocation is calculated for each channel/earth-view beam/scan in the granule. The following section outlines the process.

First, a sensor exit vector is calculated for a given earth-view beam position. The beam angle associated with the beam position is used to calculate a sensor exit vector for that beam position. A sensor exit vector is calculated as follows:

X component = 0.0
Y component = $\sin(\text{beamAngle})$
Z component = $\cos(\text{beamAngle})$

Note: The X component is always zero because the scan is in the Y-Z plane.

Next, satellite attitude and ephemeris data is calculated for the given earth-view beam position. This data is obtained by calling the `ProSdrCmnGeo::satPosAtt()` function and passing it the beam time of the beam position.

A direction cosine matrix for sensor-to-spacecraft rotation (sensor-to-spacecraft rotation matrix) is calculated from the mounting errors in the tunable parameters file. Then a calibration offset rotation matrix is calculated by using the beam alignment offsets for the five bands from verified RDR calibration data or the offsets for the 22 channels from the tunable parameters file. Alignment offsets for each beam position are calculated by interpolating between the 3 beam (1, 48 and 96) offsets - using the first 2 offsets for first half of the scan and last 2 offsets for second half of the scan. Then, the roll, pitch and yaw calibration offsets are translated into a rotation matrix (calibration offset rotation matrix) for the beam position.

The option to use beam alignment offsets from either calibration packet data or the tunable parameters file is controlled by the `useBeamAlignTele` switch. If the switch is set, the code uses alignment offsets from calibration data with the closest time to the given scan start time. In this case, channels belonging to the same band will have identical geolocation.

Next, the sensor-to-spacecraft rotation matrix is multiplied times the calibration offset rotation matrix to produce a combined rotation matrix. The combined rotation matrix is passed to the

Common Geolocation function `ProSdrCmnGeo::ellipIntersect()`, along with the sensor exit vector to create the geolocation data.

`ProSdrCmnGeo::ellipIntersect()` uses the combined rotation matrix to transform the sensor exit vector in sensor coordinates, to the sensor exit vector in spacecraft coordinates. It performs many other calculations to create the final geolocation data (Please see Common Geolocation OAD, 474-00091, for details.).

NOTE: The steps to account for Sensor-to-Spacecraft Rotation are not yet implemented in the operational code.

Any desired rotation matrix is calculated by the following:

```
roll, pitch, yaw → attitude offsets from the calibration data
cosRoll = cos(roll);
sinRoll = sin(roll);
cosPitch = cos(pitch);
sinPitch = sin(pitch);
cosYaw = cos(yaw);
sinYaw = sin(yaw);
```

```
rotation[0][0] = (cosYaw*cosPitch) - (sinYaw*sinRoll*sinPitch)
rotation[0][1] = (sinYaw*cosPitch) + (cosYaw*sinRoll*sinPitch)
rotation[0][2] = (-cosRoll*sinPitch)
rotation[1][0] = (-sinYaw*cosRoll)
rotation[1][1] = (cosYaw*cosRoll)
rotation[1][2] = (sinRoll)
rotation[2][0] = (cosYaw*sinPitch) + (sinYaw*sinRoll*cosPitch)
rotation[2][1] = (sinYaw*sinPitch) - (cosYaw*sinRoll*cosPitch)
rotation[2][2] = (cosRoll*cosPitch)
```

Note: Before the above calculations are performed, the matrices are initialized to be identity matrices, i.e. no rotation.

Finally, the geolocation is obtained for each channel/band of a given beam position by calling the `ProSdrCmnGeo::ellipIntersect()` function and passing it the previously calculated satellite attitude and ephemeris data, rotation matrices and sensor exit vector for the given channel/band / at the given beam position. This function combines the sensor exit vector with the roll, pitch and yaw of the attitude and ephemeris point. This function calculates the geodetic latitude, longitude, satellite azimuth and zenith angles, satellite range.

Terrain height data is obtained for each channel/band of the given beam position by calling the `ProSdrTerrainCorrect::getTerrainInfo()` and passing it the latitude and longitude for the channel/band at the given earth-view beam position.

The solar azimuth and solar zenith are obtained for each channel/band of the given beam position by calling the `ProSdrCmnGeo::sunAngles()` function and passing it the beam time, latitude and longitude of the channel/band at the given earth view beam position.

2.2.2.7.3 Lunar Intrusion Detection

The lunar detection algorithm detects the occurrence of lunar contamination of the cold space view. The check is performed for each channel/cold space view/scan in the granule. Additional

details can be found in the Lunar Intrusion Handling Tech Memo (NP-EMD-2007.510.0018). The following section outlines the process.

First, a sensor exit vector is calculated for a given cold space beam position. The beam angle of a given space view beam position is used to calculate a sensor exit vector for the given position. A sensor exit vector is calculated as follows:

$$\begin{aligned} X \text{ component} &= 0.0 \\ Y \text{ component} &= \sin(\text{beamAngle}) \\ Z \text{ component} &= \cos(\text{beamAngle}) \end{aligned}$$

Note: The X component is always zero because the scan is in the Y-Z plane.

Next, satellite attitude and ephemeris data is calculated for a given cold space view beam position. This data is obtained by calling the ProSdrCmnGeo::satPosAtt() function and passing it the beam time of the beam position.

Next, lunar angles, phase and illumination fraction are calculated for a given cold space view beam position. This data is obtained by calling the ProSdrCmnGeo::moonAngles() function and passing it the beam time of the beam position and the attitude and ephemeris data.

The separation angle between the moon and sun is given by:

$$\Theta = \pi - \text{moonPhase}$$

The angle between the cold space view and the moon is obtained by calling the ProSdrCmnGeo::moonInView() function and passing it the beam time, the rotation matrix, and the sensor exit vector of the beam position.

The cold space view temperature increase caused by the lunar contamination is given as:

$$\Delta T_c = \exp\left[-\frac{\gamma^2}{2\gamma_s^2}\right] \times \beta \times T_{\text{moon}}$$

Where γ : angle between the cold space view and the moon [degrees]

$$\begin{aligned} \gamma_s &= \frac{\gamma_{3dB}}{2.35} \quad \text{where } \gamma_{3dB} \text{ is the 3dB beamwidth [degrees]} \\ \beta &= \frac{1}{2} \left(\frac{r_{\text{moon}}}{\gamma_s} \right)^2 \quad \text{where radius of the moon: } r_{\text{moon}} = 0.255 \text{ deg} \end{aligned}$$

Where β : nominal area ration of moon to FOV

$$\begin{aligned} T_{\text{moon}} &: \text{effective moon temperature [K]} \\ &= 95.21 + 104.63(1 - \cos \theta) + 11.62(1 + \cos 2\theta) \\ \theta &: \text{separation angle between moon and sun } (\theta=180^\circ \text{ in case of Full Moon}) \end{aligned}$$

Finally, the cold space view temperature increase caused by the lunar contamination is calculated. If the lunar intrusion temperature increase (ΔT_c) is larger than the threshold (ΔT_0)

for the given channel, then the cold space view count is set to a fill value (NA_INT32_FILL) in the verified RDR and the Moon In View Quality Flag is set for this scan and channel. The ΔT_0 values are implemented as tunable parameters in the Processing Coefficients file. For now, all values are set to 0.2 K.

2.2.3 Graceful Degradation

No graceful degradation is performed.

2.2.4 Exception Handling

ATMS SDR checks for division-by-zero errors and other error conditions. In the c2K routine it checks for PRT counts for each scan, and if the count is zero then the KAV PRT Error and WG PRT Error quality flags are set. Also it checks to make sure the offset counts and PRT counts are not equal, which can introduce division-by-zero error. In that case also the KAV PRT and WG PRT Error flags are set. There are checks for infinite loops to make sure the PRT temperatures are converging.

2.2.5 Data Quality Monitoring

Data quality tests are performed on the ATMS SDR and TDR and each test can produce a Data Quality Notification (DQN). Table 15 shows current criteria used to determine when a Data Quality Notification is produced. If the thresholds are met, the algorithm stores a DQN to DMS indicating the tests that failed and the number of failures. DQNs are used by DQM for quality monitoring. The table contains the thresholds used to trigger a DQN as well as the text contained in the DQN. The DQN criteria is adjustable and contained in a data quality threshold table (DQTT) produced by DQM. If the ATMS SDR algorithm cannot obtain the DQTT, the algorithm still executes but no DQN tests are run.

Table 15. Data Quality Notification Criteria

Test Description	Threshold	Text	Action
Summary ATMS SDR Quality – Checks if the number of good quality retrievals in the granule is less than a configurable amount.	80%	ATMS Summary Quality Test	Send DQN if less than threshold.
Health and Status – Checks if the number of out-of-range Health & Status items in the granule is greater than a configurable amount.	0%	ATMS Health & Status Quality Test	Send DQN if greater than threshold.
Gain Error – Checks if the number of gain errors in the granule is greater than a configurable amount.	50%	ATMS Gain Error Quality Test	Send DQN if greater than threshold.

2.2.5.1 Quality Flags

Table 16 contains information about the quality flags set in the ATMS SDR outputs.

Table 16. Quality Flag Output

Flag Name	Description	Granule QFs	Values
Summary ATMS SDR Quality	Percent of Good quality retrievals in Granule	This is a metadata flag which is set as part ATMS SDR metadata.	0 – 100%
Instrument Mode	Instrument Mode Word in the Health & Status packet	Set the instrument mode value at granule level.	Integer Value
Health and Status	Status of Health items compared beyond the predetermined range	The flag is 80 bits long, with bits 2 - 71 corresponding to the words 2 – 71. Other 10 bits are reserved.	False True
Quadratic Correction	Quadratic correction applied to the radiometric transfer function for non-linearity correction	This is a granule level 1-bit flag.	False True
Time sequence error	Time sequence error detected	This is a scan level 1-bit flag.	False True
Data Gap	Data gap precedes this scan	This is a scan level 1-bit flag.	False True
KAV PRT Conversion Error	Conversion error occurred for KAV PRTs due to division-by-zero or failure to converge in temperature computation	This is a scan level 8-bits flag. Each bit represents a KAV PRT.	0 or 1 for each bit
WG PRT Conversion Error	Conversion error occurred for KAV PRTs due to division-by-zero or failure to converge in temperature computation	This is a scan level 8-bits flag. Each 0 – 6 bits represents a WG PRT with the last bit reserved.	0 or 1 for each 0 – 6 bits
Shelf PRT Conversion Error	Conversion error occurred for four shelf PRTs due to division-by-zero or failure to converge in shelf temperature computation	This is a scan level 4-bits flag. Each bit represents a shelf PRT (KKA, V, W, G).	0 or 1 for each bit
Space View antenna position error	Questionable calibration because of antenna position error of space view	This is a scan level 1-bit flag.	False True
Blackbody antenna position error	Questionable calibration because of antenna position error of blackbody view	This is a scan level 1-bit flag.	False True
Moon in Space View	Moon in the space view of this channel	This is a 1-bit flag at scan/channel level.	False True
KAV PRT Temperature Limits Check	Each of eight PRTs is checked against a lower and an upper limit.	This is a scan level 8-bit flag. Each bit represents a PRT.	0 or 1 for each bit
WG PRT Temperature Limits Check	Each of seven PRTs is checked against lower and upper limits.	This is a scan level 8-bit flag. Each of Bits 0 - 6 represents a PRT. The last bit is reserved.	0 or 1 for each bit
KAV PRT Temperature Consistency Check	Each of eight PRTs is checked against each other for consistency	This is a scan level 8-bit flag. Each bit represents a PRT.	0 or 1 for each bit
WG PRT Temperature Consistency Check	Each of seven PRTs is checked against each other for consistency	This is a scan level 8-bit flag. Each of Bits 0 - 6 represents a PRT. The last bit is reserved.	0 or 1 for each bit

Flag Name	Description	Granule QFs	Values
KAV PRT Temperature Data Sufficiency Check	Insufficient KAV PRT data for calibration	This is a scan level 1-bit flag.	0 or 1 for each bit
WG PRT Temperature Data Sufficiency Check	Insufficient WG PRT data for calibration	This is a scan level 1-bit flag.	0 or 1 for each bit
Space View Count Limits Check	Each of four cold counts is checked against lower and upper limits	This is a flag of 4-bit/channel/scan. Each bit represents one of four cold space views.	0 or 1 for each bit
Blackbody Count Limits Check	Each of four warm counts is checked against lower and upper limits	This is a flag of 4-bit/channel/scan. Each bit represents one of four warm target views.	0 or 1 for each bit
Space View Count Consistency Check	Each of four cold counts is checked against each other for consistency	This is a flag of 4-bit/channel/scan. Each bit represents one of four cold space views.	0 or 1 for each bit
Blackbody Count Consistency Check	Each of four warm counts is checked against each other for consistency	This is a flag of 4-bit/channel/scan. Each bit represents one of four warm target views.	0 or 1 for each bit
Gain Error	Cold counts checked against warm counts for gain error	This is a flag of 1-bit/channel/scan.	0 or 1 for each bit
Space View Data Sufficiency Check	Insufficient cold space view samples for calibration	This is a flag of 1-bit/channel/scan.	0 or 1 for each bit
Blackbody Data Sufficiency Check	Insufficient warm target samples for calibration	This is a flag of 1-bit/channel/scan.	0 or 1 for each bit
Calibration Using Fewer Than Preferred Samples	Calibration with fewer than preferred numbers of samples for PRT temperatures, cold counts and warm counts	This is a flag of 1-bit/channel/scan.	0 or 1 for each bit
QF1_ATMSSDR GEO	Attitude and Ephemeris Availability Status	This is a flag of 2-bits/scan	0 or 1 for each bit

2.2.6 Computational Precision Requirements

The code uses double precision real variables whenever necessary for computational accuracy.

2.2.7 Algorithm Support Considerations

Infrastructure (INF) and DMS must be running before execution of the algorithm.

2.2.8 Assumptions and Limitations

None.

3.0 GLOSSARY/ACRONYM LIST

3.1 Glossary

The current glossary for the NPOESS program, D35836_G_NPOESS_Glossary, can be found on eRooms. Table 17 contains those terms most applicable for this OAD.

Table 17. Glossary

Term	Description
Algorithm	<p>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:</p> <ol style="list-style-type: none"> 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)	<p>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.</p>
Algorithm Verification	<p>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.</p>
Ancillary Data	<p>Any data which is not produced by the NPOESS System, but which is acquired from external providers and used by the NPOESS system in the production of NPOESS data products.</p>
Auxiliary Data	<p>Auxiliary Data is defined as data, other than data included in the sensor application packets, which is produced internally by the NPOESS system, and used to produce the NPOESS deliverable data products.</p>
EDR Algorithm	<p>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.</p>
Environmental Data Record (EDR)	<p><i>[IORD Definition]</i> 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.).</p> <p><i>[Supplementary Definition]</i> 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.</p>
Operational Code	<p>Verified science-grade software, delivered by an algorithm provider and verified by IWPTB, is developed into operational-grade code by the IDPS IPT.</p>
Operational-Grade Software	<p>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.</p>

Term	Description
Raw Data Record (RDR)	<p><i>[IORD Definition]</i> 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 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><i>[Supplementary Definition]</i> 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.</p>
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)	<p><i>[IORD Definition]</i> 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><i>[Supplementary Definition]</i> 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>

Term	Description
Temperature Data Record (TDR)	<p><i>[IORD Definition]</i> 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><i>[Supplementary Definition]</i> 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.</p>
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]

3.2 Acronyms

The current acronym list for the NPOESS program, D35838_G_NPOESS_Acronyms, can be found on eRooms. Table 18 contains those terms most applicable for this OAD.

Table 18. Acronyms

Acronym	Description
ACO	Atmospheric Correction over Ocean
ADCS	Advanced Data Collection System
ADS	Archive and Distribution Segment
AFB	Air Force Base
AFM	Airborne Fluxes and Meteorology Group
AFSCN	Air Force Satellite Control Network
AFWA	Air Force Weather Agency
AFWWS	Air Force Weather Weapon System
AGE	Aerospace Ground Equipment
AIAA	American Institute of Aeronautics and Astronautics
ANSI	American National Standards Institute
Ao	Operational Availability
AOS	Acquisition of Signal
ATMS	Advanced Technology Microwave Sounder
BIT	Built-in Test
BITE	Built-in Test Equipment
BMMC	Backup Mission Management Center
C2	Command and Control
C3S	Command, Control, and Communications Segment
CCSDS	Consultative Committee for Space Data Systems
CDA	Command and Data Acquisition
CDDIS	Crustal Dynamics Data Information System
CDR	Climate Data Records
CERES	Cloud and Earth Radiant Energy System
CGMS	Coordination Group for Meteorological Satellites
CI	Configured Item
CLASS	Comprehensive Large-Array data Stewardship System
CMIS	Conical Microwave Imager Sounder
CMN GEO	Common Geolocation
CMOC	Cheyenne Mountain Operations Center
COMSAT	Communications Satellite
COMSEC	Communications Security
CONUS	Continental United States
COTS	Commercial Off the Shelf
CrIMSS	Cross-Track Infrared Microwave Sounding Suite
CrIS	Cross-Track Infrared Sounder
CSCI	Computer Software Configured Item
DCP	Data Collection Platforms
DES	Digital Encryption System
DFCB	Data Format Control Book
DHN	Data Handling Node
DMSP	Defense Meteorological Satellite Program
DOC	Department of Commerce
DoD	Department of Defense

Acronym	Description
DRR	Data Routing and Retrieval
EDR	Environmental Data Records
EELV	Evolved Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMD	Engineering and Manufacturing Development
EOL	End of Life
EOS	Earth Observing System
ERBS	Earth Radiation Budget Suite
ESD	Electrostatic Discharge
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EWR	Eastern and Western Ranges
FFRDC	Federally Funded Research and Development Center
FMH	Federal Meteorological Handbook
FNMOC	Fleet Numerical Meteorology and Oceanography Center
FOC	Full Operational Capability
FTS	Field Terminal Segment
FVS	Flight Vehicle Simulator
GFE	Government Furnished Equipment
GIID	General Instrument Interface Document
GN	NASA Ground Network
GPS	Global Positioning System
GPSOS	GPS Occultation Suite
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HIJACK	Data Conversion Software
HRD	High Rate Data
IAW	In Accordance With
ICD	Interface Control Document
IDPS	Interface Data Processor Segment
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGS	International GPS Service
IJPS	Initial Joint Polar System
ILS	Integrated Logistics Support
IOC	Initial Operational Capability
IORD	Integrated Operational Requirements Document
IOT&E	Initial Operational Tests & Evaluation
IP	Intermediate Product
IPL	Integrated Priority List
IPO	Integrated Program Office
IRD	Interface Requirements Document
ISO	International Standards Organization
ITRF	International Terrestrial Reference Frame
ITU	International Telecommunications Union
JPS	Joint Polar System
JSC	Johnson Space Center
JTA	Joint Technical Architecture
km	kilometer
LEO&A	Launch, Early Orbit, & Anomaly Resolution
LOS	Loss of Signal
LRD	Low Rate Data

Acronym	Description
LSS	Launch Support Segment
LST	Local Solar Time
LUT	Look-Up Table or Local User Terminal
LV	Launch Vehicle
MDT	Mean Down Time
Metop	Meteorological Operational Program
MMC	Mission Management Center
MOU	Memorandum of Understanding
MSS	Mission System Simulator
MTBCF	Mean Time Between Critical Failures
MTBDE	Mean Time Between Downing Events
MTTRF	Mean Time to Restore Function
NA	Non-Applicable
NACSEM	NPOESS Acquisition Cost Estimating Model
NASA	National Aeronautics and Space Administration
NAVOCEANO	Naval Oceanographic Office
NCA	National Command Authority
NCEP	National Centers for Environmental Prediction
NDT	Nitrate-Depletion Temperature
NESDIS	National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
NORAD	North American Aerospace Defense Command
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Program
NSA	National Security Agency
NTIA	National Telecommunications Information Agency
OC/C	Ocean Color/Chlorophyll
O&M	Operations and Maintenance
OMPS	Ozone Mapping and Profiling Suite
P3I	Potential Pre-planned Product Improvements
PAM	Precision Analog Monitor
PHS&T	Packaging, Handling, Storage, and Transportation
PIP	Program Implementation Plan
PM&P	Parts, Materials, and Processes
PMT	Portable Mission Terminal
POD	Precise Orbit Determination
POES	Polar Orbiting Environmental Satellite
PRT	Platinum Resistance Temperature
RDR	Raw Data Records
RPIE	Real Property Installed Equipment
RSR	Remote Sensing Reflectance
S&R	Search and Rescue
SARSAT	Search and Rescue Satellite Aided Tracking
SCA	Satellite Control Authority
SDC	Surface Data Collection
SDE	Selective Data Encryption
SDP	Software Development Plan
SDR	Sensor Data Records
SDS	Science Data Segment
SESS	Space Environmental Sensor Suite
SGI®	Silicon Graphics, Inc.

Acronym	Description
SI	International System of Units
SMD	Stored Mission Data
SN	NASA Space Network
SOC	Satellite Operations Center
SRD	Sensor Requirements Documents
SS	Space Segment
SST	Sea Surface Temperature
STDN	Spaceflight Tracking and Data Network
SVE	Space Vehicle Equipment
TBD	To Be Determined
TBR	To Be Resolved
TBS	To Be Supplied
TDR	Temperature Data Records
TDRSS	Tracking and Data Relay Satellite System
TEMPEST	Telecommunications Electronics Material Protected from Emanating Spurious Transmissions
TOA	Top of the Atmosphere
TRD	Technical Requirements Document
TSIS	Total Solar Irradiance Sensor
USAF	United States Air Force
USB	Unified S-band
USG	United States Government
UTC	Universal Time Coordinated
VIIRS	Visible/Infrared Imager Radiometer Suite

4.0 OPEN ISSUES

Table 19. TBXs

TBX ID	Title/Description	Resolution Date
None		