Compact Ocean Wind Vector Radiometer (COWVR) Project

Temperature Sensor Data Record Data Product Description Document

B10.0

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CHANGE LOG

DATE	SECTIONS CHANGED	REASON FOR CHANGE	REVISION
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4/15/21	Many	Release 6 updates	
11/15/21	Many	Release 7 updates	v7
9/20/22	4.1, 4.3, 4.5-4.7, 5.3, 5.8, 6.2	Release 7.3.5 updates	v7.3.5
02/22/2023		Release 7.4.0, and separation into TSDR only DPDD	Initial Release
08/15/2023	4.3, 4.8	Release 8.0	
09/09/2024	4.3, 4.8	Release 10.0	v10.0.1

Table of Contents

1 Introduction

1.1. Purpose and Scope

This Compact Ocean Wind Vector Radiometer (COWVR) Data Product Description Document (DPDD) describes the contents of the COWVR mission data products.

1.2. Mission Description

The United States Space Force (USSF), Space Systems Command, Development Corps for Innovation and Prototyping (SSC/DCI) is flying the JPL-provided Compact Ocean Wind Vector Radiometer (COWVR) and Temporal Experiment for Storms and Tropical Systems (TEMPEST) instruments as part of the Space Test Program - Houston 8 (STP-H8) technology demonstration mission.

The primary objective of STP-H8 Mission is to characterize and demonstrate the end-to-end COWVR performance relative to the Department of Defense (DoD) legacy microwave sensor WindSat on-orbit performance and mission requirements. A successful COWVR mission will demonstrate a lower-cost sensor architecture for providing imaging passive microwave data, including ocean surface vector wind (OSVW) products for DoD. The TEMPEST instrument, was included as an STP-H8 mission enhancement, in support of the SSC/DCI objective of Tropical Cyclone Intensity (TCI) tracking. The STP-H8 payload module with the COWVR and TEMPEST instruments was launched on December 21, 2021 and was installed on the International Space Station (ISS), Japanese Experiment Module – Exposed Facility (JEM-EF) on January 7, 2022. Both COWVR and TEMPEST are currently operating nominally on-orbit.

1.3. Instrument Description

The Compact Ocean Wind Vector Radiometer (COWVR) sensor is a fully polarimetric, conically imaging microwave radiometer, operating at 18.7 GHz, 23.8 GHz, and 34.5 GHz, for measuring ocean surface vector winds (OSVW). The novel COWVR design features include:

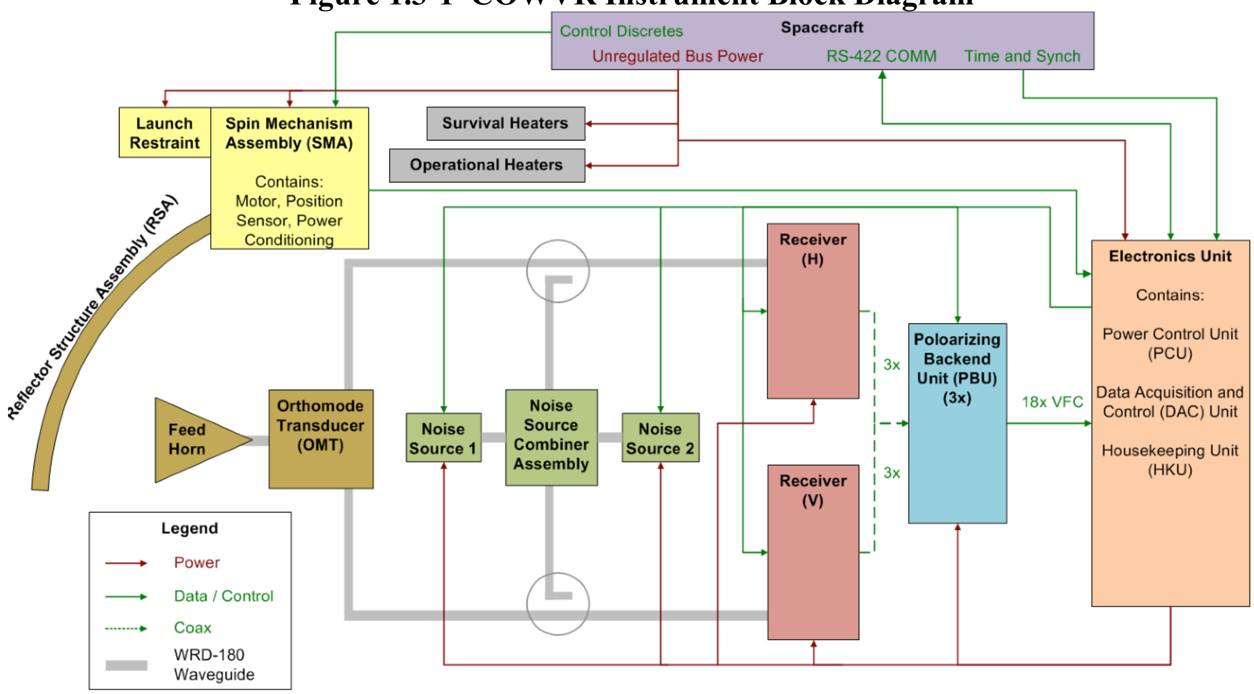
- the use of a single multi-frequency feed horn enabling a simple antenna rotating about the feed axis (as opposed to having to spin the entire radiometer system)
- internal polarimetric calibration sources which eliminate the need for an external warm load and cold sky reflector simplifying the mechanical design
- a compact MMIC receiver implementation, lowering the system mass, power and volume

Figure 1.3-1 shows the instrument block diagram and components. Subsystems are defined as follows:

- The Electronics Unit (EU) contains three sub-elements. The Power Control Unit (PCU) provides power to all secondary power from the unregulated spacecraft bus to the instrument electronics, excluding the mechanism (motor, motor controller, and position sensor). The Data Acquisition and Control (DAC) unit communicates with the spacecraft, supplies all RF control signals, and receives all RF and housekeeping data. The Housekeeping Unit (HKU) reads all engineering voltages and temperatures and supplies them to the DAC.

- The RF Subsystem consists of the feed horn, orthomode transducer (OMT), waveguides, Noise Source Combiner Assembly (NSCA), two noise sources, two receivers, and the Polarimetric Backend Unit (PBU).
- The Mechanical and Thermal Subsystem (MTS) consists of the launch restraint, thermal control system, reflector structure assembly (RSA), Spin Mechanism Assembly (SMA), and all structures to support the various instrument sub-element chassis. The SMA includes the motor, motor controller, position sensor, and mechanism power conditioning board.

Figure 1.3-1 COWVR Instrument Block Diagram



1.4. *Document Structure*

1.4.1. Applicable Documents

Figure 1.4-1 illustrates the COWVR requirements flow. This document is consistent and responsive to the requirements in the following requirements:

- COWVR Data Product Requirements Document (DPRD) (D-80123)

1.4.2. Acronyms

ACS	Attitude and Control System
AMR	Advanced Microwave Radiometer
ATBD	Algorithm Theoretical Basis Document

APC	Antenna Pattern Correction
CALNS	Calibration Noise Source
CFOV	Composite Field of View (weighted average of IFOV main beam measurements calculated on the ground by re-sampling algorithm)
CM	Center of Mass
CSEQ	Configuration Sequence
CSEQ	Configuration Sequence
DAC	Data Acquisition
EPBR	Electronic Polarization Basis Rotation
EPOI	Effective Product of Inertia
ES	Electronics Subsystem
II&T	Instrument Integration and Test
MSEQ	Measurement Sequence
IFOV	Instantaneous Field of View (measured main beam)
MIC	Microwave Integrated Circuit
MMIC	Monolithic Microwave Integrated Circuit
OSTM	Ocean Surface Topology Mission
OSVW	Ocean Surface Vector Winds
OMT	Ortho-mode Transducer
PBU	Polarimetric Backend Unit
PCU	Power Converter Unit
PL	Payload
PPS	Pulse Per Second
RFI	Radio Frequency Interference
RSS	Root Sum (of) Squares
SMDE	Spin Mechanism Drive Electronics
TB	Brightness Temperature
VFC	Voltage to Frequency Converter
VNA	Vector Network Analyzer

2 Overview of COWVR

Conically imaging passive microwave radiometer systems such as the Special Sensor Microwave Imager (SSM/I, SSMIS), the Advanced Microwave Scanning Radiometer (AMSR-E, AMSR-2) and WindSat, have been providing critical environmental data for over 30 years. But over this time, the overall sensor design has remained largely unchanged. These conical sensors have three basic attributes; (1) A large, massive spun portion containing the radiometer and electronics system; (2) A de-spun external un-polarized warm target and cold sky reflector and; (3) a large feedhorn array and individual receivers for each frequency and polarization. These design attributes drive the instrument mechanical complexity, spacecraft accommodation (e.g. momentum compensation) and instrument cost. For example, the WindSat needed to offset 189 Nms of spun momentum from the sensor (Koss and Woolaway, 2006). The sensors that were in development for NPOESS (CMIS and later MIS) were each expected to exceed 300 kg, 300 W and cost more than $100M (Chauhan, 2003). It is clear that a simplified design solution is needed to reduce the sensor mass, power, cost and accommodation, yet maintain the legacy performance.

The COWVR instrument uses an entirely different design to eliminate the instrument mechanical complexity that drives mass, power and cost. The enabling design features include (1) the use of a single multi-frequency feed horn permitting a simple antenna rotating about the feed axis, as opposed to having to spin the entire radiometer system and pass signals through the spin assembly; (2) internal calibration sources which enable fully polarimetric calibration and eliminate the need for an external warm load and cold sky reflector simplifying the mechanical design and enabling a complete 360° scan and; (3) a compact highly integrated MMIC polarimetric combining receiver implementation, lowering the system mass and power which in turn makes the system well suited for deployment on smaller class, lower cost satellites.

An illustration of the COWVR instrument design is shown in Figure 2-1. The instrument includes a single stationary multi-frequency feed horn that illuminates rotating reflector generating a 360° un-blocked conical scan. The reflector rotates at 30 RPM and provides a spatial resolution <35km and a swath width of 1012 km from the mission orbit altitude of 450km. After the feed, an orthomode transducer is used to separate the signal into two linear orthogonal components which are then fed via waveguide into MMIC multi-frequency receivers to amplify and filter the signals. The output from the receivers is input to a hybrid combining polarimetric backend unit which performs the analog in-phase and quadrature phase cross-correlation of the two signals to produce the +45, -45 and left and right circular polarized outputs.

The instrument is calibrated using PIN-diode switches internal to the receivers and a correlated noise source. The switches are used to toggle each receiver between an ambient reference load and the antenna. The correlated noise source is capable of generating known polarized signals by injecting correlated noise with a defined phase offset between the two receiver chains.

Because the feedhorn is fixed, the instrument polarization is fixed to the instrument frame and rotates relative to the Earth polarization basis. Because the instrument measures the full stokes vector, which completely describes the polarization state of the scene, a simple geometric transform is used in ground processing to rotate the polarization from the fixed instrument frame to the Earth frame. This technique has been previously used in groundbased and airborne radiometer systems and is commonly referred to as Electronic Polarization Basis Rotation (EPBR) (Gasiewski et al., 1992; Lahtinen et al,. 2003). This actually presents a calibration advantage which is discussed further in the COWVR calibration plan.

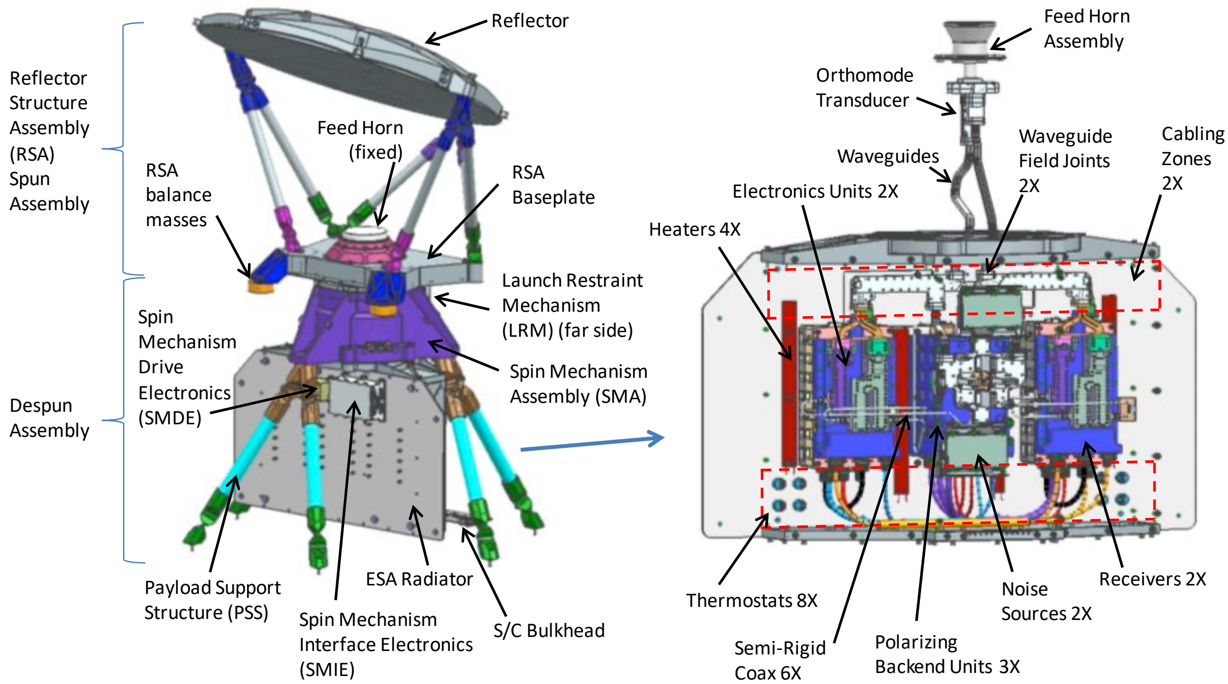


Figure 2-1. CAD representation of the COWVR instrument.

3 Data Products Overview

The COWVR ground data processing system (GDPS) produces three main data products, the Raw Data Record (RDR), Temperature Sensor Data Record (TSDR) and Environmental Data Record (EDR). Each file uses the Hierarchical Data Format, Version 5 (HDF-5) format. The RDR contains the raw unmodified COWVR telemetry packets converted into the HDF format along with raw unmodified spacecraft attitude and ephemeris for a time range that bounds the COWVR telemetry in the file. The STDR contains calibrated, geo-located antenna temperature and brightness temperatures along with the sensor telemetry used to derive those values. This product is best suited for a cal/val user or sensor expert. The EDR contains retrieval products and brightness temperatures and is best suited for the user interested in geophysical interpretation of the sensor data. This document describes the TSDR product, and some intermediate ancillary data.

4 Temperature Sensor Data Record (TSDR) Product Format Description

The TSDR contains 5 groups described below:

- **Metadata** : contains top level information about the file contents
- **Frameheader**: provides time formation for each packet in the file
- **Geolocation and Flags**: provides geolocation and geometric information for spacecraft and each COWVR observation as well as surface flags
- **Instrument Temperatures**: provides time series of COWVR measured instrument temperatures
- **Channel Ordered Counts**: provides times series of radiometer counts organized by frequency and polarization
- **Calibration:** Provides computed calibration data from the COWVR internal sources
- **Calibrated Scene Temperatures:** Provides calibration antenna and brightness temperatures

4.1. Metadata

Name	Data Type	Dimensions	Unit	Description	Minimum	Maximum
InputPointer	VarLenStr	InputPtr		A pointer to one or more data granules that provide the major input that was used to generate this product.		
AncillaryDataDescriptors	VarLenStr	AncFile		The file names of the ancillary data files that were used to generate this product (ancillary data sets include all input files except for the primary input files).		
CollectionLabel	VarLenStr	Scalar		Label of the data collection containing this product.		
SizeMBECSDataGranule	Float32	Scalar	Mbyte	The size of this data granule in megabytes.		
RangeBeginningDate	FixLenStr	Scalar		The date on which the earliest data contained in the product were acquired (yyyy-mm-dd).		
RangeEndingDate	FixLenStr	Scalar		The date on which the latest data contained in the product were acquired (yyyy-mm-dd).		
RangeBeginningTime	FixLenStr	Scalar		The time at which the earliest data contained in the product were acquired (hh:mm:ss.mmmZ).		
RangeEndingTime	FixLenStr	Scalar		The time at which the latest data contained in the product were acquired (hh:mm:ss.mmmZ).		

ProductionDateTime	FixLenStr	Scalar		The date and time at which the product was created (yyyy-mm-ddThh:mm:ss.mmmZ).		
SISName	VarLenStr	Scalar		The name of the document describing the contents of the product.		
SISVersion	VarLenStr	Scalar		The version of the document describing the contents of the product.		
BuildId	VarLenStr	Scalar		The ID of build that included the software that created this product.		
GranuleNumber	Singed32	Scalar		Granule counter for the mission		
ChunkNumber	Singed16	Scalar		A chunk counter used when the granule is subdivided for processing		
QAGranulePointer	VarLenStr	Scalar		A pointer to the quality assessment product that was generated with this product.		
GranulePointer	VarLenStr	Scalar		The filename of this product.		
LongName	VarLenStr	Scalar		A complete descriptive name for the data type of this product.		
ShortName	VarLenStr	Scalar		The short name identifying the data type of this product.		
ProducerAgency	VarLenStr	Scalar		Identification of the agency that provides the project funding.		
ProducerInstitution	VarLenStr	Scalar		Identification of the institution that provides project management.		
ProductionLocation	VarLenStr	Scalar		Facility in which this file was produced.		
ProductionLocationCode	FixLenStr	Scalar		One-letter code in filename indicating the ProductionLocation.		
ProcessingLevel	VarLenStr	Scalar		Indicates data level (Level 0, Level 1A, Level 1B, Level 1C, Level 2) in this product.		
InstrumentShortName	VarLenStr	Scalar		The name of the instrument that collected the telemetry data.		
PlatformLongName	VarLenStr	Scalar		The long name of the platform hosting the instrument.		
PlatformShortName	VarLenStr	Scalar		The short name of the platform hosting the instrument.		
PlatformType	VarLenStr	Scalar		The type of platform associated with the instrument which acquires the accompanying data.		
ProjectId	VarLenStr	Scalar		The project identification string.		
DataFormatType	FixLenStr	Scalar		A character string thst indentifies the internal format of the data product.		
HDFVersionId	VarLenStr	Scalar		A character string that identifies the version of the HDF (Hierarchical Data Format) software that was used to generate this data file		
CalSmoothingHalfWidth	Float32	Scalar	s	Calibration smoothing window half-width		

4.2. FrameHeader

Name	Data Type	Dimensions	Unit	Description	Minimum	Maximum
frame_time_string	FixLenStr24	FrameRate_Arry		UTC instrument packet time.		
frame_time_tai93	Float64	FrameRate_Array	s	TAI93 instrument packet time.		
frame_qual_flag	IntBitfield16	FrameRate_Array	none	Packet processing bit field; 0: prev pkt missing, 1: used corrected timecode, 2: post-corr timecode gap, 3: out of time order, 4: unsynced pps rollover, 6: is diag pkt, 7: is download pkt, 8: is unknown pkt, 9: no valid epr counts, 12: exceeded 2 epr rollovers, 13: encoder gap exceeds 1s, 14: rejected non-mono encoder time.		
frame_index	Signed16	FrameRate_Array	none	Orbit granule frame index array for chunking realignment.		

4.3. GeolocationAndFlags

Name	Data Type	Dimensions	Unit	Description	Minimum	Maximum
obs_qual_flag	IntBitfield32	ObsRate_Array	none	Obs quality bit field; 0: invalid time, 1: not nominal pkt, 2: bad angle time interp, 3: bad angle invalid epr index, 4: bad angle any reason, 5: suspect angle (vel interp) 6: skipped cal 7: not sci obs 8: missing posterior cal 9: missing prior cal 10: invalid input cals 11: cal code buffer error 12: cal degraded 13: bad smoothed hk 14: degraded smoothed hk 15: failed path loss inversion 16: non-monotonic time 17: bad geo scan ang, 18: bad geo sc telem, 19: bad geo earth intersect, 20: bad geo range error, 21: failed geosat lat lon 24: RFI 25: sup arm obstruct, 26: solar arr obstruct,	0	28

				27: cfov avg degraded, 28: cfov avg incomplete		
obs_index	Signed32	ObsRate_Array	none	Orbit granule obs index array for chunking realignment.		
time_string	FixLenStr	ObsRate_Array		UTC Earth observation time.		
time_tai93	Float64	ObsRate_Array	s	TAI93 Earth observation time.		
sat_pos_eci	Float32	ObsRate_Spatial_Array	meter	Spacecraft position in the Earth Centered Inertial (ECI) coordinates (X, Y, Z)		
sat_pos_ecr	Float32	ObsRate_Spatial Array	meter	Spacecraft position in the Earth Centered Rotational (ECR) coordinates (X, Y, Z)		
sat_vel_ecr	Float32	ObsRate_Spatial_Array	m/s	Spacecraft velocity in ECR coordinates (dx/dt, dy/dt, dz/dt)		
sat_vel_eci	Float32	ObsRate_Spatial_Array	m/s	Spacecraft velocity in ECI coordinates (dx/dt, dy/dt, dz/dt)		
refl_borsight_ecr	Float32	ObsRate_Spatial_Array		Reflected boresight unit vector wrt Earth normal, in the Earth Centered Rotational (ECR) coordinates (X, Y, Z).		
refl_borsight_at_geostat_dist	Float32	ObsRate_Array	m	Magnitude of reflected boresight vector extended to geostationary altitude.		
refl_borsight_at_geostat_lat	Float32	ObsRate_Array	Deg	Latitude of reflected boresight vector extended to geostationary altitude.	-180	180
refl_borsight_at_geostat_lon	Float32	ObsRate_Array	Deg	Longitude of reflected boresight vector extended to geostationary altitude.	-180	180
sat_lat	Float32	ObsRate_Array	deg	Sub-satellite latitude.	-90	90
sat_lon	Float32	ObsRate_Array	deg	Sub-satellite longitude.	-180	180
sat_alt	Float32	ObsRate_Array	m	Satellite altitude above Earth WGS84 elipsoid.		
deploy_arm_roll	Float32	ObsRate_Array	Deg	Roll angle evaluated at COWVR deployment arm (Euler order: 3,2,1).	-180	180
deploy_arm_pitch	Float32	ObsRate_Array	Deg	Pitch angle evaluated at COWVR deployment arm (Euler order: 3,2,1).	-180	180
deploy_arm_yaw	Float32	ObsRate_Array	Deg	Yaw angle evaluated at COWVR deployment arm (Euler order: 3,2,1).	-180	180
cowvr_roll	Float32	ObsRate_Array	deg	COWVR roll angle (Euler order: 3,2,1).	-180	180
cowvr_pitch	Float32	ObsRate_Array	deg	COWVR pitch angle (Euler order: 3,2,1).	-180	180
cowvr_yaw	Float32	ObsRate_Array	deg	COWVR yaw angle (Euler order: 3,2,1).	-180	180
sat_solar_zen	Float32	ObsRate_Array	deg	The zenith angle of the Sun from the COWVR deployment arm.	0	180
sat_solar_az	Float32	ObsRate_Array	deg	The azimuth angle of the Sun from the COWVR deployment arm.	0	360
sat_lunar_zen	Float32	ObsRate_Array	deg	The zenith angle of the moon from the COWVR deployment arm.	0	180
sat_lunar_az	Float32	ObsRate_Array	deg	The azimuth angle of the moon from the COWVR deployment arm.	0	360
sat_caa	Float32	ObsRate_Array	Deg	The azimuth angle of the instrument boresight from the COWVR deployment arm.	0	360
instr_boresight_ecr	Float32	ObsRate_Spatial_Array	m	Boresight unit vector (projected from instrument) in the Earth Centered Rotational (ECR) coordinates (X, Y, Z)		
instr_h_pol_ecr	Float32	ObsRate_Spa		H-pol unit vector in the Earth Centered		

		tial_Array		Rotational (ECR) coordinates (X, Y, Z).		
earth_norm_ecr	Float32	ObsRate_Spatial_Array		Earth normal unit vector at obs point in the Earth Centered Rotational (ECR) coordinates (X, Y, Z).		
eph_source_flag	Signed8	ObsRate_Array	none	Ephemeris source; -1: unspecified, 0: transition, 1: gps, 2: issbad sto.	-1	2
att_source_flag	Signed8	ObsRate_Array	none	Attitude source; -1: unspecified, 0: transition, 1: flexcore nominal, 2: flexcore trac1 only, 3: flexcore trac2 only, 4: direct trac1, 5: direct trac2, 6: fixed tracker, 7: issbad sto.	-1	7
obs_lat	Float32	ObsRate_Array	deg	Observation latitude on Earth WGS84 ellipsoid.	-90	90
obs_lon	Float32	ObsRate_Array	deg	Observation longitude on Earth WGS84 ellipsoid.	-180	180
instr_scan_ang	Float32	ObsRate_Array	deg	Boresight scan angle in the instrument coordinate frame.	0	360
sc_scan_ang	Float32	ObsRate_Array	deg	Boresight scan angle relative to the spacecraft velocity vector in the spacecraft coordinate frame.	0	360
earth_pol_rot	Float32	ObsRate_Array	deg	Geometric polarization rotation angle wrt vertical at Earth observation.	0	360
earth_inc_ang	Float32	ObsRate_Array	deg	Boresight incidence angle at Earth observation	0	180
earth_az_ang	Float32	ObsRate_Array	deg	Boresight azimuth angle at Earth observation	0	360
sun_glint_ang	Float32	ObsRate_Array	deg	Angle between specular reflection vector and vector to Sun relative to surface normal	0	180
sc_att_flag	Signed8	ObsRate_Array	none	0: nominal spacecraft attitude, 1: off-nominal spacecraft attitude, -1: unknown	-1	1
fore_aft_flag	Signed8	ObsRate_Array	none	0 : observation is forward scan, 1: observation is aft scan, -1: unknown	-1	1
sea_ice_flag	Signed8	ObsRate_Array	none	(Not yet implemented) 0 : no ice, 1: possible ice, 2: ice, -1: unknown	-1	2
land_flag	Signed8	ObsRate_Array	none	0 :ocean, 1: coast, 2: land, -1: unknown	-1	1
asc_desc_flag	Signed8	ObsRate_Array	none	Satellite orbit node; 0: descending, 1: ascending, -1: unknown	-1	1
rfi_flag	Signed8	ObsRate_Array	none	COWVR RFI flag (0=no reflection)	0	1
solar_array_flag	Signed8	ObsRate_Array	none	COWVR solar array obstruction flag (0=unobstructed)	0	1
support_arm_flag	Signed8	ObsRate_Array	none	COWVR support arm obstruction flag (0= unobstructed)	0	1
ufo_obstruction_flag	Signed8	ObsRate_Array	none	(Not yet implemented in TSDR, present in EDR) COWVR unknown obstruction flag (0=unobstructed)	0	1
sun_glint_flag	Signed8	ObsRate_Array	none	COWVR sun glint flag (0=limited glint)	0	1
direct_rfi_flag	Signed8	ObsRate_Array	none	COWVR direct RFI flag (0=no reflection)	0	1
earth_tb_flag	Signed8	ObsRate_Array	none	COWVR composite flag for observed earth brightness temperature (0=good)	0	1

4.4. Ancillary

anc_tec	Float32	ObsRate_Array	TEC unit	Line-of-sight ancillary total electron content		
anc_mag	Float32	ObsRate_Spatial_Array	Gauss	Ancillary magnetic field vector		
far_rot_ang	Float32	ObsRate_SpectralCh_Array	deg	Faraday rotation angle computed from ancillary TEC and magnetic field information	0	360
anc_sst	Float32	ObsRate_Array	K	Amcillary sea surface temperature		
anc_wind_speed	Float32	ObsRate_Array	m/s	Ancillary surface wind speed		
anc_wind_dir	Float32	ScanAlongTrack_ScanCrossTrack_Array	deg	Ancillary wind direction relative to North		

4.5. InstrumentTemperatures

Name	Data Type	Dimensions	Unit	Description	Minimum	Maximum
hk_counts	Unsigned16	FrameRate_DemuxCh_Array	none	Raw housekeeping counts after channel demuxing.		
hk_counts_cal_lo	Unsigned16	FrameRate_Array	none	Calibration low reference count for demuxed housekeeping channel.		
hk_counts_cal_hi	Unsigned16	FrameRate_Array	none	Calibration high reference count for demuxed housekeeping channel.		
temp_cal_lo	Float32	FrameRate_Array	K	Calibration low temperature reference for demuxed housekeeping channel.		
temp_cal_hi	Float32	FrameRate_Array	K	Calibration high temperature reference for demuxed housekeeping channel.		
temp_recv_34	Float32	FrameRate_Array	K	Measured temperature of vPol receiver for 34 GHz detector channel.		
temp_recv_1823	Float32	FrameRate_Array	K	Measured temperature of vPol receiver for 18/23 GHz detector channels.		
temp_rech_34	Float32	FrameRate_Array	K	Measured temperature of hPol receiver for 34 GHz detector channel.		
temp_rech_1823	Float32	FrameRate_Array	K	Measured temperature of hPol receiver for 18/23 GHz detector channel.		
temp_pbu2	Float32	FrameRate_Array	K	Measured temperature of polarimetric backend unit #2.		

temp_pbu3	Float32	FrameRate_Array	K	Measured temperature of polarimetric backend unit #3.		
temp_ns1	Float32	FrameRate_Array	K	Measured temperature of noise source #1.		
temp_ns2	Float32	FrameRate_Array	K	Measured temperature of noise source #2.		
temp_dac	Float32	FrameRate_Array	K	Measured temperature of data acquisition controller.		
temp_pcu1	Float32	FrameRate_Array	K	Measured temperature of power converter unit #1.		
temp_pcu2	Float32	FrameRate_Array	K	Measured temperature of power converter unit #2.		
temp_feed_horn	Float32	FrameRate_Array	K	Measured temperature of feed horn.		
temp_omt_h	Float32	FrameRate_Array	K	Measured temperature of hPol orthomode transducer.		
temp_omt_v	Float32	FrameRate_Array	K	Measured temperature of vPol orthomode transducer.		
temp_wg_h	Float32	FrameRate_Array	K	Measured temperature of hPol wave guide.		
temp_wg_v	Float32	FrameRate_Array	K	Measured temperature of vPol wave guide.		
temp_rech_dplxr	Float32	FrameRate_Array	K	Measured temperature of hPol receiver diplexer.		
temp_recv_dplxr	Float32	FrameRate_Array	K	Measured temperature of vPol receiver diplexer.		
temp_nsca_h	Float32	FrameRate_Array	K	Measured temperature of hPol noise source combiner assembly.		
temp_nsca_v	Float32	FrameRate_Array	K	Measured temperature of vPol noise source combiner assembly.		
temp_coupler_h	Float32	FrameRate_Array	K	Measured temperature of hPol coupler.		
temp_coupler_v	Float32	FrameRate_Array	K	Measured temperature of vPol coupler.		

4.6. ChannelOrderedCounts

Name	**Data Type**	**Dimensions**	**Unit**	**Description**	**Minimum**	**Maximum**
rcfg1	Unsigned8	ObsRate_Array	none	Instrument radiometer configuration for current acquisition; b7: ND13; b6: ND12; b5: ND11; b4: RF1; F3: Dicke1; b0-b2: Spare.		
rcfg2	Unsigned8	ObsRate_Array	none	Instrument radiometer configuration for current acquisition; b7: ND13; b6: ND12; b5: ND11; b4: RF1; F3: Dicke1; b0-b2: Spare.		
ta18_counts	Unsigned16	ObsRate_PolMeas_Array	none	Raw detector counts per measured polarization (V, H, P, M, L, R) for 18 GHz channel.	0	65535
ta23_counts	Unsigned16	ObsRate_PolMeas_Array	none	Raw detector counts per measured polarization (V, H, P, M, L, R) for 23 GHz channel.	0	65535

ta34_counts	Unsigned16	ObsRate_PolMeas_Array	none	Raw detector counts per measured polarization (V, H, P, M, L, R) for 34 GHz channel.	0	65535

4.7. Calibration

Name	Data Type	Dimensions	Unit	Description	Minimum	Maximum
cal_accum_time_tai93	FixLenStr	CalAccumRate_Array	Float64	TA93 time of calibration extraction.		
cal_accum_time_string	FixLenStr	CalAccumRate_Array	Float64	UTC time of calibration extraction.		
cal_time_string	FixLenStr	CalRate_Array		UTC time of current calibration point.		
cal_time_tai93	Float64	CalRate_Array	s	TA93 time of current calibration point.		
t_cal_matrix	Float32	CalRate_SpectralCh_Five_Five_Array	K	Intermediate 5x5 tcal matrix		
tref_stokes	Float32	CalAccumRate_SpectralCh_Stokes_Array	K	Reference stokes temperatures.		
tnd1_stokes	Float32	CalAccumRate_SpectralCh_Stokes_Array	K	Effective stokes noise temperatures for source #1.		
tnd2_stokes	Float32	CalAccumRate_SpectralCh_Stokes_Array	K	Effective stokes noise temperatures for source #2.		
cal_nd1_ar_diff	Float32	CalAccumRate_SpectralCh_PolMeas_Array	counts	ND1 counts deflection for (v-ant, h-ref)		
cal_nd1_ra_diff	Float32	CalAccumRate_SpectralCh_PolMeas_Array	counts	ND1 counts deflection for (v-ref, h-ant)		
cal_nd1_aa_diff	Float32	CalAccumRate_SpectralCh_PolMeas_Array	counts	ND1 counts deflection for (v-ant, h-ant)		
cal_nd2_aa_diff	Float32	CalAccumRate_SpectralCh_PolMeas_Array	counts	ND2 counts deflection for (v-ant, h-ant)		
cal_rr_count	Float32	CalAccumRate_SpectralCh_PolMeas_Array	counts	Counts for (v-ref, h-ref).		
gain_mag_v	Float64	CalRate_SpectralCh_Array	counts / K	Gain magnitude scale factor on vPol elements of gain matrix.		

gain_mag_h	Float64	CalRate_SpectralCh_Array	1 / K	Gain magnitude scale factor on hPol elements of gain matrix.		
gain_mag_v_smoothed	Float64	CalRate x SpectralCh	counts / K	Gain magnitude for vPol at calibration time after weighted smoothing across multiple calibrations.		
gain_mag_h_smoothed	Float64	CalRate_SpectralCh_Array	counts / K	Gain magnitude for hPol at calibration time after weighted smoothing across multiple calibrations.		
gain	Float64	CalRate_SpectralCh_PolMeas_Stokes_Array	counts / K	Derived 6x4 gain matrix that relates 6-element counts vector to 4-element TA vector.		
gain_smoothed	Float64	CalRate_SpectralCh_PolMeas_Stokes_Array	counts / K	Gain matrix at calibration time after weighted smoothing across multiple calibrations.		
inv_gain	Float64	CalRate_SpectralCh_Stokes_PolMeas_Array	K	Inverse of 6x4 gain matrix (currently computed as diagnostic).		
inv_gain_smoothed	Float64	CalRate_SpectralCh_Stokes_PolMeas_Array	K/ counts	Inverse of smoothed gain matrix.		
offset	Float64	CalRate_SpectralCh_PolMeas_Array	counts	Derived 6-element gain offset vector.		
offset_smoothed	Float64	CalRate_SpectralCh_PolMeas_Array	counts	Gain offset at calibration time after weighted smoothing across multiple calibrations.		
cal_qual_flag	IntBitfield 16	CalRate_SpectralCh_Array	none	Calibration quality bit field; 0: invalid ns mask, 1: bad temps, 2: failed precond, 3: offset invalid, 4: gain invalid, 5: rev gain invalid, 6: outside cal smoothing window, 7: incomplete smoothed hk, 8: incomplete smoothed cal hk, 15: unexpected error.		
cal_smoothed_qual_flag	IntBitfield 16	CalRate_SpectralCh_Array	counts	Calibration quality bit field; 0: invalid ns mask, 1: bad temps, 2: failed precond, 3: offset invalid, 4: gain invalid, 5: rev gain invalid, 6: outside cal smoothing window, 7: incomplete smoothed hk, 8: incomplete smoothed cal hk, 15: unexpected error.		
ensemble_cal_qual_flag	IntBitField 16	CalRate_Array	counts	Calibration quality bit field; 0: invalid ns mask, 1: bad temps, 2: failed precond, 3: offset invalid, 4: gain invalid, 5: rev gain invalid,		

				6: outside cal smoothing window, 7: incomplete smoothed hk, 8: incomplete smoothed cal hk, 15: unexpected error.		

4.8. CalibratedSceneTemperatures

Name	Data Type	Dimensions	Unit	Description	Minimum	Maximum
ta18_internal	Float32	ObsRate_Stokes_Array	K	Derived 18 GHz stokes antenna temperature at internal calibration plane.		
ta23_internal	Float32	ObsRate_Stokes_Array	K	Derived 23 GHz stokes antenna temperature at internal calibration plane.		
ta34_internal	Float32	ObsRate_Stokes_Array	K	Derived 34 GHz stokes antenna temperature at internal calibration plane.		
ta18	Float32	ObsRate_Stokes_Array	K	Derived 18 GHz stokes antenna temperature at feedhorn.		
ta23	Float32	ObsRate_Stokes_Array	K	Derived 23 GHz stokes antenna temperature at feedhorn.		
ta34	Float32	ObsRate_Stokes_Array	K	Derived 34 GHz stokes antenna temperature at feedhorn.		
tb18_earth	Float32	ObsRate_Stokes_Array	K	Derived 18 GHz stokes antenna temperature integrated over the visible Earth		
tb23_earth	Float32	ObsRate_Stokes_Array	K	Derived 23 GHz stokes antenna temperature integrated over the visible Earth		
tb34_earth	Float32	ObsRate_Stokes_Array	K	Derived 34 GHz stokes antenna temperature integrated over the visible Earth.		
tb18_ifov_if	Float32	ObsRate_Stokes_Array	K	Derived 18 GHz stokes brightness temperature at the instantaneous field of view (instrument polarization frame).		
tb23_ifov_if	Float32	ObsRate_Stokes_Array	K	Derived 23 GHz stokes brightness temperature at the instantaneous field of view (instrument polarization frame).		
tb34_ifov_if	Float32	ObsRate_Stokes_Array	K	Derived 34 GHz stokes brightness temperature at the instantaneous field of view (instrument polarization frame).		
tb18_ifov_pre_correct	Float32	ObsRate_Stokes_Array	K	Derived 18 GHz stokes brightness temperature, instantaneous field of view before bias correction.		
tb23_ifov_pre_correct	Float32	ObsRate_Stokes_Array	K	Derived 23 GHz stokes brightness temperature, instantaneous field of view before bias correction.		
tb34_ifov_pre_correct	Float32	ObsRate_Stokes_Array	K	Derived 34 GHz stokes brightness temperature, instantaneous field of view before bias correction.		
tb18_ifov	Float32	ObsRate_Stokes_Array	K	Derived 18 GHz stokes brightness temperature at the instantaneous field of view (Earth polarization frame).		
tb23_ifov	Float32	ObsRate_Stokes_Array	K	Derived 23 GHz stokes brightness temperature at the instantaneous field of view (Earth polarization frame).		
tb34_ifov	Float32	ObsRate_Stokes_Array	K	Derived 34 GHz stokes brightness temperature at the instantaneous field of		

				view (Earth polarization frame).		
tb18_cfov	Float32	ObsRate_Stokes_Array	K	Derived 18 GHz stokes brightness temperature at the composite field of view (Earth polarization frame).		
tb23_cfov	Float32	ObsRate_Stokes_Array	K	Derived 23 GHz stokes brightness temperature at the composite field of view (Earth polarization frame).		
tb34_cfov	Float32	ObsRate_Stokes_Array	K	Derived 34 GHz stokes brightness temperature at the composite field of view (Earth polarization frame).		
tb18_stdev	Float32	ObsRate_Stokes_Array	K	Spatial variance of 18 GHz Stokes brightness temperature (Earth polarization frame).		
tb23_stdev	Float32	ObsRate_Stokes_Array	K	Spatial variance of 23 GHz Stokes brightness temperature (Earth polarization frame).		
tb34_stdev	Float32	ObsRate_Stokes_Array	K	Spatial variance of 34 GHz Stokes brightness temperature (Earth polarization frame).		
tb18_cfov_perc_bad	Unsigned 8	ObsRate_Array		Weighted percent of possible neighboring IFOV omitted due to flagged or missing data		
tb18_cfov_perc_degraded	Unsigned 8	ObsRate_Array		Weighted percent of possible neighboring IFOV with degraded quality		
tb23_cfov_perc_bad	Unsigned 8	ObsRate_Array		Weighted percent of possible neighboring IFOV omitted due to flagged or missing data		
tb23_cfov_perc_degraded	Unsigned 8	ObsRate_Array		Weighted percent of possible neighboring IFOV with degraded quality		
tb34_cfov_perc_bad	Unsigned 8	ObsRate_Array		Weighted percent of possible neighboring IFOV omitted due to flagged or missing data		
tb34_cfov_perc_degraded	Unsigned 8	ObsRate_Array		Weighted percent of possible neighboring IFOV with degraded quality		

5 Resampled Ancillary Product (Intermediate)

The AncResamp intermediate product contains 3 groups described below:

- **Metadata**: contains top level information about the file contents
- **Geolocation**: provides geolocation and geometric information for spacecraft and each COWVR observation
- **Ancillary**: provides additional information such as meteorological data needed for calculations.

5.1. Metadata

Name	Data Type	Dimensions	Unit	Description	Minimum	Maximum
InputPointer	VarLenStr	InputPtr		A pointer to one or more data granules that provide the major input that was used to generate this product.		
AncillaryDataDescriptors	VarLenStr	AncFile		The file names of the ancillary data files that were used to generate this product (ancillary data sets include all input files except for the primary input files).		
CollectionLabel	VarLenStr	Scalar		Label of the data collection containing this product.		
SizeMBECSDataGranule	Float32	Scalar	Mbyte	The size of this data granule in megabytes.		
RangeBeginningDate	FixLenStr	Scalar		The date on which the earliest data contained in the product were acquired (yyyy-mm-dd).		
RangeEndingDate	FixLenStr	Scalar		The date on which the latest data contained in the product were acquired (yyyy-mm-dd).		
RangeBeginningTime	FixLenStr	Scalar		The time at which the earliest data contained in the product were acquired (hh:mm:ss.mmmZ).		
RangeEndingTime	FixLenStr	Scalar		The time at which the latest data contained in the product were acquired (hh:mm:ss.mmmZ).		
ProductionDateTime	FixLenStr	Scalar		The date and time at which the product was created (yyyy-mm-ddThh:mm:ss.mmmZ).		
SISName	VarLenStr	Scalar		The name of the document describing the contents of the product.		
SISVersion	VarLenStr	Scalar		The version of the document describing the contents of the product.		
BuildId	VarLenStr	Scalar		The ID of build that included the software that created this product.		

GranuleNumber	Singed32	Scalar		Granule counter for the mission		
ChunkNumber	Singed16	Scalar		A chunk counter used when the granule is subdivided for processing		
QAGranulePointer	VarLenStr	Scalar		A pointer to the quality assessment product that was generated with this product.		
GranulePointer	VarLenStr	Scalar		The filename of this product.		
LongName	VarLenStr	Scalar		A complete descriptive name for the data type of this product.		
ShortName	VarLenStr	Scalar		The short name identifying the data type of this product.		
ProducerAgency	VarLenStr	Scalar		Identification of the agency that provides the project funding.		
ProducerInstitution	VarLenStr	Scalar		Identification of the institution that provides project management.		
ProductionLocation	VarLenStr	Scalar		Facility in which this file was produced.		
ProductionLocationCode	FixLenStr	Scalar		One-letter code in filename indicating the ProductionLocation.		
ProcessingLevel	VarLenStr	Scalar		Indicates data level (Level 0, Level 1A, Level 1B, Level 1C, Level 2) in this product.		
InstrumentShortName	VarLenStr	Scalar		The name of the instrument that collected the telemetry data.		
PlatformLongName	VarLenStr	Scalar		The long name of the platform hosting the instrument.		
PlatformShortName	VarLenStr	Scalar		The short name of the platform hosting the instrument.		
PlatformType	VarLenStr	Scalar		The type of platform associated with the instrument which acquires the accompanying data.		
ProjectId	VarLenStr	Scalar		The project identification string.		
DataFormatType	FixLenStr	Scalar		A character string thst indentifies the internal format of the data product.		
HDFVersionId	VarLenStr	Scalar		A character string that identifies the version of the HDF (Hierarchical Data Format) software that was used to generate this data file		

5.2. Geolocation

Name	Data Type	Dimensions	Unit	Description	Minimum	Maximum
obs_index	Signed32	ObsRate_Array	none	Orbit granule obs index array for chunking realignment.		
time_string	FixLenStr	ObsRate_Array		UTC Earth observation time.		
time_tai93	Float64	ObsRate_Array	s	TAI93 Earth observation time.		
obs_qual_flag	IntBitfield32	ObsRate_Array	none	Obs quality bit field; 0: prev pkt missing, 1: not nominal pkt, 2: bad angle time interp, 3: bad angle invalid index, 4: suspect angle non-adj indices, 17: bad geo no scan ang, 18: bad geo sc telem, 19: bad geo earth intersect, 20: bad geo range error,		
obs_lat	Float32	ObsRate_Array	deg	Observation latitude on Earth WGS84 ellipsoid.	-90	90
obs_lon	Float32	ObsRate_Array	deg	Observation longitude on Earth WGS84 ellipsoid.	-180	180

5.3. Ancillary Parameters

anc_tec	Float32	ObsRate_Array	TEC unit	Line-of-sight ancillary total electron content		
anc_mag	Float32	ObsRate_Spatial_Array	Gauss	Ancillary magnetic field vector		
Beam_land_frac	Float32	ObsRate_SpectralCh_Array		Fraction of land in antenna main beam	0	1
anc_sst	Float32	ObsRate_Array	K	Amcillary sea surface temperature		
anc_wind_speed	Float32	ObsRate_Array	m/s	Ancillary wind speed		
anc_wind_dir	Float32	ScanAlongTrack_ScanCrossTrack_Array	deg	Ancillary wind direction relative to N		

6 Data Product Names

6.1. Product types and names

NOAA names for COWR data products:

RDR is Raw Data Record

TSDR is Temperature Sensor Data Record for sensor brightness temperature

EDR in Environmental Data Record (COWVR only)

NASA/JPL names for COWVR data products:

L0 extracts raw telemetry to H5 (note time-ordering for us is done upstream).

L1a applies DN-to-EU conversion on housekeeping, also geolocates science observations.

L1b applies calibration to the raw sensor counts to radiances (brightness temperatures).

L1c uses the scan geometry to resample the radiance to what Shannon calls cumulative FOV.

L2 retrieves the geophysical variables, such as wind speeds.

L1c is not an official NASA level, but missions sometimes use this to label processing needed between L1b (calibration) and L2.

There a mapping between the NOAA names and the NASA/JPL names is

RDR = L0

TSDR = L1c

EDR = L2

Our order of processing is mapped into separate executables for convenience. Not all the steps need to result in granules for data archive/distribution (or vise-versa).

For the processing of pre-launch ground test data, most data can only be processed through L1a, and a limited set can be processed through L1b. None can go further for the pre-launch ground test data.

6.2. File Naming Format

Two types of naming formats are used, one for the telemetry data downloaded from the ISS through the HOSC, and the product files generated in the GDPS.

6.2.1. *Telemetry file name format*

Telemetry file names will take the form:

APID(apid)_SEQ(SSSSSS)_StartDateTime(YYYYMMDDThhmmss)_FulfilledDateTime(YYYYMMDDThhmmss)_Duration(mmm)_Location(C).ext

where:

apid - the 4 digit APID of the telemetry data (see section 6)
SSSSSS - the granule ID of the product. It is generated from a sequence number calculated from the number of hours since the launch of the COWVR instrument
YYYYMMDDThhmmss - The year, month, date, hour, minute, second of the starting time of the requested data, with a "T" separator between the date and time.
mmm - Duration of the requested data in minutes
C - Location code that the data came from:
S: Simulated
H: HOSC low (2 hour) latency data
N: HOSC nominal (24 hour) latency data
J: JPL
L: Legacy files
P: Production
T: Test
ext - file extension:
pkt: Instrument packets
met: Metadata file describing packet file
XFR: Transfer notification file containing file name and md5sum of packet file
h5: HDF-5 file format

6.2.2. *Science Data Products*

inst_typ.GID(SSSSSS).StartDateTime(YYYYMMDDThhmmss).EndDateTime(YYYYMMDDTmmhhss).CollectionLabel(cv),LocationCode(C),ProductionTime(YYYYMMDDThhmmss).ext

where:

inst - Instrument: COWVR, TEMPEST
typ - Data type: RDR, L1A, L1B, GAIN, ANE, GEO, ANC, L1C, TSDR, EDR
GID - Granule ID; number of hours since defined epoch 2022-01-01
StartDateTime - Requested starting date and time of data
EndDateTime - Requested ending data and time of data
cv - Collection label (currently "v2")
All other fields same as in 8.2.1

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