CGMS-48-NOAA-WP-03

Prepared by NOAA
Agenda Item: 4.1
Discussed in WG-1

IMPLEMENTATION OF CGMS BEST PRACTICES FOR LEO DIRECT BROADCAST DATA AT NOAA

Working Paper summary: This paper presents status of implementation at NOAA of the CGMS Agency Best Practices in support to Local and Regional Processing of LEO Direct Broadcast data (CGMS/DOC/18/1008274) for the NOAA-15, NOAA-18, NOAA-19, S-NPP, and NOAA-20 missions.

Action/Recommendation proposed:

WG-I members are invited to take note and comment on the status of implementation at NOAA of the CGMS Best Practices in support to local and regional processing of LEO direct broadcast data.

IMPLEMENTATION OF CGMS BEST PRACTICES FOR LEO DIRECT BROADCAST DATA AT NOAA

1 INTRODUCTION

This paper describes the implementation status of the Coordination Group for Meteorological Satellites (CGMS) agency best practices in support to local and regional processing of Low Earth Orbiting (LEO) Direct Broadcast (DB) data at the National Oceanic and Atmospheric Administration (NOAA). The Best Practice document is labelled CGMS/DOC/18/1008274 and it is available at: https://www.cgms-info.org/documents/CGMS_BP_LEO_DBD_Jun2018.pdf

The Best Practices reflect the commitments taken by the CGMS agencies operating DB satellites with respect to the coordination and support provided to the DB user community. By adopting the Best Practices, CGMS Agencies are also increasing users' access to data, improving timeliness of satellite data in environmental models, and reducing demands on alternative data distribution systems.

This paper focuses on the Polar Operational Environmental Satellites (POES) legacy missions (NOAA-15, NOAA-18, NOAA-19); Suomi National Polar-orbiting Partnership (S-NPP) mission; and NOAA-20 mission. The JPSS-2 Satellite High-Rate Data (HRD) to Direct Broadcast Stations (DBS) Radio Frequency (RF) Interface Control Document (ICD) is described as well.

The Office of Satellite and Product Operations, National Environmental Satellite, Data, and Information Service (NESDIS) represents NOAA for this effort. Other NOAA offices are assisting OSPO.

2 STATUS OF IMPLEMENTATION

NOAA complies with all nine of the Best Practices in regards to the newest satellites, S-NPP and NOAA-20. NOAA continues to support the Best Practice effort by participating in the Intersessional and formal WG-I meetings.

2.1 BP.01 Global Specification for Direct Broadcast

Best Practice BP.01 Description: Operators should implement the agreed CGMS Direct Broadcast Services: Low-Rate Picture Transmission (LRPT)/ Advanced High Resolution Picture Transmission (AHRPT) Global Specification (Document No. CGMS 04). The document is available at: https://www.cgms-info.org/documents/Direct_Broadcast_Services__LRPT_AHRPT_Global_Specification,_Issue_2_01.pdf

2.1.1 POES

Not applicable.

2.1.2 S-NPP and NOAA-20

The HRD builds upon a set of applicable Consultative Committee for Space Data Systems (CCSDS) standards as described in the Joint Polar Satellite System 1 (JPSS-1) Spacecraft High Rate Data (HRD) to Direct Broadcast Stations (DBS) Radio Frequency (RF) Interface Control Document (ICD) (2014)

The Mission Data Formatter (MDF) within the Command and Data Processor (CDP) enables CCSDS Channel Access Data Units (CADU) to be generated from CCSDS Advanced Orbiting Systems (AOS) transfer frames provided by the CDP flight software.

The Joint Polar Satellite System (JPSS) Common Data Format Control Book – External (CDFCB-X), Volume VII – Part 1, JPSS Downlink Data Formats is available on the National Aeronautics and Space Administration (NASA) Direct Readout Laboratory website: https://directreadout.sci.gsfc.nasa.gov/links/rsd_eosdb/PDF/474-00001-07-01_JPSS-CDFCB-X-Vol-VII-Part-1_0122-_20120126.pdf

2.2 BP.02 Timely provision of Space-to-Ground Interface Control Documents

Best Practice BP.02 Description: CGMS operators should provide up-to-date and satellite-specific Space-to-Ground Interface Control Documents in English language at least 3 years before the launch of each satellite, including at least:

a) Frequency usage

b) Polarization

c) Encoding

d) G/T requirements

e) Data stream layout and content

f) Conformance with CCSDS.

g) Conformance with the CGMS Global Specification (see section 1)

2.2.1 POES

Compliant. NESDIS updated the NOAA-KLM User Guide in 2014 and the revised version is available at:
https://www1.ncdc.noaa.gov/pub/data/satellite/publications/podguides/N-15%20thru%20N-19/pdf/0.0%20NOAA%20KLM%20Users%20Guide.pdf

Another resource is the: User's Guide for Building and Operating Environmental Satellite Receiving Stations (2009) which available at:
http://noaasis.noaa.gov/NOAASIS/pubs/Users_Guide-Building_Receive_Stations_March_2009.pdf

2.2.2 S-NPP and NOAA-20

Compliant. The Joint Polar Satellite System 1 (JPSS-1) Spacecraft HRD to DBS RF ICD is available to the public at: https://directreadout.sci.gsfc.nasa.gov/links/rsd_eosdb/PDF/JPSS-1SpacecraftHRDtoDBSRFICDRev-May302012-470-REF-00184.pdf

The ICD is listed as a reference on the WMO SATURN webpage titled JPSS-1 Data Access Mechanisms: https://www.wmo-sat.info/satellite-user-readiness/jpss-1-data-access-mechanisms-2/

2.2.3 JPSS-2

Compliant. The JPSS-2 High Rate Data (HRD) will have some differences compared to the NOAA-20 (JPSS-1) HRD. The JPSS Program briefed HRD users on the differences during a HRD User Group meeting in November 2018. NOAA briefed the changes during the WG-I Intersessional WebEx in March 2019. The JPSS Program posted the JPSS-2 Satellite High-Rate Data (HRD) to Direct Broadcast Stations (DBS) Radio Frequency (RF) Interface Control Document (ICD) on the JPSS website in April 2019. The document is available on the JPSS website at: https://www.jpss.noaa.gov/assets/pdfs/technical_documents/472-00340-J2HRDtoDBSRFICD-RevB.pdf

The JPSS-2 High Rate Data (HRD) differences compared to the NOAA-20 (JPSS-1) HRD are:

- The modulation type is offset quadrature phase shift keying (OQPSK) (NOAA-20 is QPSK).
- The data rate for JPSS-2 will increase to 25 Mbps (NOAA-20 data rate is 15 Mbps).
- Both missions use Reed-Solomon (RS) block coding. The JPSS-2 HRD Interleaves five blocks (I=5) and NOAA-20 interleaves four blocks I=4).
- The JPSS Program briefed the HRD User Group on the changes on November 8, 2018.

Table 1. Differences between NOAA-20 HRD and JPSS-2 HRD

	NOAA-20	JPSS2 Spacecraft to DBS X-Band HRD Downlink
Center Frequency	7812 MHz	7812 MHz
Data Rate[1]	15 Mbps	25 Mbps

[1]Bit transition rate, measured after Reed-Solomon coding and prior to modulation.

Assigned Bandwidth (-20 dB)	30 MHz	50 MHz
Bit error Rate(BER)	10-8	10-8
PCM Format	NRZ-M	NRZ-M
Convolutional Coding Rate 1/2 length 7. G1 and G2-Invert	15Mbps I + 15 Mbps Q	25Mbps I + 25 Mbps Q
Modulation	QPSK	OQPSK Offset Quadrature Phase Shift Keying
Polarization	RHCP	RHCP
Antennas	1	1 prime 1 redundant
Block Coding: (255,223) Reed Solomon RS	Interleave=4 4 x 32 = 128 Parity Bytes	Interleave=5 5 x 32 = 160 Parity Bytes
Information Field	4 x 223 = 892 Bytes	5 x 223 = 1115 Bytes
Power Level	7,8 Watt	10 Watt (end-of life)
Antenna pattern 62 degrees nadir coverage	NOAA-20 Antenna Gain at ±62° = 5.87 dBi NOAA-20 EIRP = 42.9 dBm See JPSS-1 HRD DBS RF ICD, App B	JPSS-2//3/4 Antenna Gain at ±62° = 6.2 dBi JPSS-2/3/4 EIRP = 45.02 dBm

2.3 BP.03 Provision of Current Orbit Information

Best Practice BP.03 Description: CGMS operators should ensure timely provision of accurate and up-to-date orbit information based on their operational orbit determination and knowledge of satellite manoeuvres. The orbit information should be made available to Direct Broadcast reception station operators:

a) In TLE format via FTP or HTTP over the Internet;

b) Additionally, if required for the processing and geolocation of the sensor data, in the relevant mission specific format via FTP or HTTP over the Internet and/or via the satellite's Direct Broadcast signal;

c) Additionally, if the satellite operator chose to do so, in TLE format via the satellite's Direct Broadcast signal.

The satellite operator shall document:

d) The details of how and where the orbit information is made available;

e) For any mission specific format, the format definition and its application.

General Comment: NOAA is moving away from FTP or HTTP over the Internet and moving to secure protocols such as HTTPS.

2.3.1 POES

Compliant. An overview of the NESDIS Polar Earth Location Process is available at http://www.ospo.noaa.gov/Products/ppp/overview.html

NOAA NESDIS documents:

- The details of how and where the orbit information is made available;
- For any mission specific format, the format definition and its application.

NESDIS OSPO maintains the POES Webpage at:
https://www.ospo.noaa.gov/Operations/POES/index.html

That webpage has a link for the POES Two-Line Orbital Elements (TLE). The link for the POES TLEs is: http://www.celestrak.com/NORAD/elements/noaa.txt

2.3.2 S-NPP and NOAA-20

Compliant. The JPSS Field Terminal Support (FTS) provides Mission Support Data (ancillary data, auxiliary data and Mission Notices) and the necessary hardware and software specifications needed for processing the broadcasts. FTS distributes S-NPP and NOAA-20 (JPSS-1) TLEs, predicted post-maneuver TLEs, and definitive ephemeris files.

Orbital data is also provided on the FTS web portal, to assist the DB community in locating the satellites of interest:
https://noaasis.noaa.gov/POLAR/JPSS/field_terminal_support.html

Spacecraft ephemeris and attitude information is included in the HRD broadcast from S-NPP and JPSS-1, and it is used for real-time geolocation processing in CSPP.

2.4 BP.04 Provision and maintenance of Product Processing software packages

Best Practice BP.04 Description: Each LEO satellite operator should therefore ensure that:

a) Software packages for the relevant instruments are made available with a test version made available prior to launch and the operational version made available after end of commissioning of the satellite and as soon as feasible for the satellite operator;

b) To enable deployment of the software packages within organisations not permitting installation of pre-compiled software, source code should be made available;

c) Global and local product processing shall be harmonised in that brightness temperature products derived from both paths agree within tolerances that are not greater than few tenths (goal is 10%) of the respective performance requirements for bias error at a reference brightness temperature;

d) User support and maintenance services are available for the duration of the mission;

e) Notifications for software changes are provided to the user community;

f) Complete and comprehensive user documentation and S/W release documentation is supplied in English language;

g) The s/w installation procedure is user friendly;

h) The software package is executable on a standard computer platform, typically Linux/x86-64, providing a performance compatible with the timeliness requirements defined in the Guide to DBNet (CGMS-44-WMO-WP-10);

i) For reasons of performance, it should be possible to configure the software to process only the instruments and processing levels required locally;

j) Test data for verifying the installation of the S/W packages are made available.POES

Compliant. The Community Satellite Processing Package (CSPP) supports the Direct Broadcast (DB) meteorological and environmental satellite community through the packaging and distribution of open source science software.

CSPP Software processes the following NOAA-18 and NOAA-19 data: AVHRR (Clouds, Aerosols, Land Surface, SST, Visualization), HIRS (Atmospheric Profiles), and AMSU and MHS (Atmospheric Profiles, Precipitation).

2.4.1 S-NPP and NOAA-20

NOAA’s implementation complies with the elements of BP.04 as follows:

a) Software packages for the relevant instruments are made available prior to launch. Software is available for download prior to launch. CSPP CSPP software processes S-NPP and JPSS data from VIIRS, CrIS, and ATMS. Instructions for downloading CSPP software are on the CSPP Home Page located at: http://cimss.ssec.wisc.edu/cspp/

CSPP includes the RT-STPS Pre-Processor, developed and maintained by NASA DRL. Information about RT-STPS is available at: https://directreadout.sci.gsfc.nasa.gov/?id=dspContent&cid=69

The NASA DRL Simulcast Quality Monitoring Tool has been used to monitor the S-NPP and NOAA-20 HRD performance. More information is available at:

https://directreadout.sci.gsfc.nasa.gov/?id=dspContent&cid=70

b) In regards to making source code available, NOAA agrees with the BP.04 wording with a minor condition. For U.S. government agencies, the scope of licensing rights generally depends upon the source of the funding (i.e., government, mixed, or private), the nature of the data (commercial or non-commercial), and any negotiated terms of the contract. Also, NOAA must comply with deemed export control rules. Hence, as long as NOAA has unlimited rights to the source code and complies with all applicable laws, regulations, and policies, then NOAA should be able to make it available.

c) In regards to harmonizing global and local product processing, the CSPP software is compliant

d) In regards to user support and maintenance services CSPP is compliant. CSPP is sponsored by the JPSS Program Science Office.

e) Notifications for CSPP software changes are posted on the CSPP Website.

f) CSPP documentation is on the CSPP website: http://cimss.ssec.wisc.edu/cspp/

g) The s/w installation procedure is user friendly.

h) The CSPP software package is executable on a standard computer platform, typically Linux/x86-64, providing a performance compatible with the timeliness requirements defined in the Guide to DBNet (CGMS-44-WMOWP-10).

i) The CSPP software enables users to configure the software to process only the instruments and processing levels required locally.

j) Test data for verifying the installation of the CSPP software packages are available from the CSPP program.

2.5 BP.05 Provision of auxiliary data for instrument product processing

Best Practice BP.05 Description: Each operator of instruments requiring auxiliary data for the product processing must make available the necessary auxiliary data on the Internet in a user-friendly and timely manner. Announcements of the availability

of new auxiliary data should be issued giving the Direct Broadcast reception station operators sufficient time to update their systems.

2.5.1 POES

Not applicable.

2.5.2 S-NPP and NOAA-20

Compliant. S-NPP and JPSS-1 (NOAA-20) auxiliary data are available on FTS. The FTS landing page is located at:
https://www.noaasis.noaa.gov/POLAR/JPSS/field_terminal_support.html

2.6 BP.06 Recommendations of channel selection for hyperspectral instruments

Best Practice BP.06 Description: Each CGMS operator of hyperspectral instrument is responsible for defining a recommended channel selection scheme for global NWP purposes. The channel selection shall be made available to DB station operators prior to the launch of the first instrument and subsequently whenever the channel selection is modified.

2.6.1 POES

Not applicable.

2.6.2 S-NPP and NOAA-20

Compliant. Users are notified of any changes through Environmental Satellite Processing Center (ESPC) Notifications.

2.7 BP.07 Spacecraft and Instrument Operational Status

Best Practice BP.07 Description: Each CGMS operator to publish and maintain up to date spacecraft and instrument operational status information on the Internet. The CGMS operators should establish a scheme to review on a regular basis that the published status information is up to date.

2.7.1 POES

Compliant. Operationally implemented, see
http://www.ospo.noaa.gov/Operations/POES/status.html

2.7.2 S-NPP and NOAA-20

Compliant. NOAA-20 is operational status is available at:
http://www.ospo.noaa.gov/Operations/POES/status.html

Product maturity level is available at:
https://www.star.nesdis.noaa.gov/jpss/AlgorithmOperational.php

2.8 BP.08 Operational Announcements

Best Practice BP.08 Description: Each CGMS operator to announce planned operations and status changes as well as any observed degradation of the spacecraft and its instruments via e-mail and optionally via other channels.

2.8.1 POES

Compliant. ESPC Notifications are issued for both planned and unplanned events. The Notifications are also at: http://www.ospo.noaa.gov/Operations/messages.html

Contact the ESPC Help Desk to receive ESPC Notifications: ESPCOperations@noaa.gov

2.8.2 S-NPP and NOAA-20

Compliant. Environmental Satellite Processing Center (ESPC) Notifications are issued for both planned and unplanned events. The Notifications are also available at: http://www.ospo.noaa.gov/Operations/messages.html

Contact the ESPC Help Desk to receive ESPC Notifications: ESPCOperations@noaa.gov

2.9 BP.09 Satellite Direct Broadcast and Reception Station Performance Requirements

Best Practice BP.09 Description: When planning, designing, and developing satellite Direct Broadcast (DB) downlink capabilities, the CGMS agencies will strive to minimize, when possible, negative impacts on the DB community by communicating with manufacturers and users; coordinating with the other CGMS agencies; and considering these potential impacts during the CGMS agency's decision-making process.

The performance of the satellite's DB X-Band (7.8 GHz, ITU MetSat Band) downlink should be sufficient for nominal data reception at any reception station within the satellite's footprint at elevations above 5 degrees and a G/T value of at least 21.20 dB/K. The calculation of the satellite DB performance shall include an allocation of at least 7.05 dB for reception station losses, rain and atmospheric losses, and link budget margin. The G/T is defined at the input of the IF receiver, at 5 degree antenna elevation and clear sky conditions.

A reception station operator may be required to establish a reception station with additional performance margin to account for local conditions, including climate, RF interference or the impact of an antenna radome.

2.9.1 POES

Not applicable.

2.9.2 S-NPP and NOAA-20

Compliant. The Link Budget in Appendix A.1 demonstrates a positive margin when assuming Reference Rain and Atmospheric losses and Station Reference Performance.

3 ACTIONS AND/OR RECOMMENDATIONS FOR CONSIDERATION BY CGMS WG-I

WG-I members are invited to take note and comment on the status of implementation at NOAA of the CGMS Best Practices in support to local and regional processing of LEO direct broadcast data.

APPENDIX A. Supporting information for BP.09

Link Analysis for HRD Downlink JPSS Payload Science Downlink (5 deg) at 15 Mbps				
Parameter	Symbol	Value	Unit	Source
Frequency	f	7.812	GHz	JPSS RF IRD 472-00173
Transmitter Power	p	7.8	Watt	Tx RF Po @ < 35° C
Total Transmit Power	P	38.92	dBm	P = 10 log(p)+30
S/C Antenna Gain	Gt	5.50	dBi	Ant Gain at ± 62°
Passive Loss	Li	-2.00	dB	Coax Cable, Filter, Switch Losses
Equiv. Isotropic Radiated Power	EIRP	42.4	dBm	EIRP = P+Gt+Li
Propagation Path Length	S	2835	km	Alt=824km, Elev Angle=5°
Free Space Dispersion Loss	Ls	-179.4	dB	Ls = -92.44 - 20log(S) - 20log(f)
Polarization Loss	Lp	-0.26	dB	Tx Ant AR Loss in Gain, Tx AR=3.58dB, Rx AR=2dB
Rain & Atmospheric Loss	La	-3.65	dB	NPP HRD IRD 429-03-02-24, Appendix A
Multipath Loss	Lc	-0.20	dB	JPSS RF IRD 472-00173
Ground Antenna Pointing Loss		-1.00	dB	JPSS RF IRD 472-00173, 3 Meter Ground Antenna
Ground Station G/T	Grp	22.70	dB/K	JPSS RF IRD 472-00173, 3 Meter Ground Antenna
Total Received Power/T		-119.34	dBm/K	
Boltzmann's Constant	k	-198.6	dBm/Hz-K	$k = 10\log(1.38*10^{-23})$
Total Received Power/kT		79.26	dB-Hz	
DATA CHANNEL (QPSK)				
Data Power/kT		79.26	dBm/Hz/KT	
Information Rate		71.18	dB-Hz	15 Mbps with Reed Solomon
Available E_b/N_o		8.08	dB	
Rqd E_b/N_o 10^{-5} BER from Viterbi		4.40	dB	JPSS RF IRD 472-00173
Implementation Loss		-2.50	dB	JPSS RF IRD 472-00173
Available Signal Margin		**1.18**	**dB**	**1 dB Margin Required**

The reception station losses (a), (c), (d), (e) rain and atmospheric losses (b), and link budget margin (f) add up to 8.79 dB, giving a positive margin of 1.74 dB relative to the 7.05 dB defined in BP.09 and sufficient for nominal data reception at any reception station within the satellite's footprint at elevations above 5 degrees.