



Recommendations on Preferred Coding and Modulation Schemes

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Membership

The members of the Coding and Modulation Working Group were:

Co-chairmen

Gian Paolo Calzolari	ESA ESOC
Les Deutsch	NASA JPL

Members:

Jean-Marc Soula	CNES
Stefan Veit	DLR
Enrico Vassallo	ESA ESOC
Haleh Safavi	NASA GSFC

Supporting Members:

Victor Sank	NASA GSFC
Jon Hamkins	NASA JPL
Massimo Bertinelli	ESA ESTEC

Contributions from
ASI, CSA, CNES, DLR, ESA, JAXA, and NASA

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I. Introduction

A. The Statement of Problem

CCSDS standards have successfully allowed a new era of international space exploration and cross support, however during the years the number of coding and modulation schemes available in those standards has grown significantly.

Currently, the expectation is all core standards in the IOAG service catalog should be implemented at applicable participating ground stations but this approach would require large investment by Agencies.

Moreover, there is currently no incentive, beyond their superior performance, to use newer (better) standards.

B. The purpose of the Coding and Modulation Working Group (C&MWG)

The C&MWG was chartered by the IOAG at the IOAG-18 meeting (ASI, Rome - February 2014) as a focused sub-team to identify a subset of *preferred* modulation and coding that pertain to these core standards.

C. Process and Recommendations

The IOAG C&MWG has

- Surveyed IOAG member agencies to see which standards are being used today or planned for the future;
- Analyzed the results to identify standards that are most likely to be used in the future;
- Developed a preferred list of core standards for coding and modulation.

The IOAG C&MWG encourage missions seeking cross-support services to choose coding and modulations from the preferred list such that ground stations by member agencies should become capable of supporting the applicable standards from the preferred list.

This DOES NOT place any restrictions on missions using any other standard (or even proprietary) codes or modulations – as long as they do not expect to receive international cross-support standard services.

D. Document Overview

This document contains only findings and non-binding recommendations from the C&MWG to the IOAG.

This document consists of four sections and three appendices. For the remainder of the document the following descriptions apply.

Chapter II provides the (summary) data provided by Agencies during the survey.

Chapter III and IV define respectively the set of preferred Coding and Modulation schemes. It shall be remarked that the performances to be supported by relevant equipment are not addressed in this report.

Appendices are also supplied which provide references, a glossary and acronym list, and the detailed inputs provided by agencies to the WG.

II. The Survey

A. Introduction

The Coding and Modulation Working Group (C&MWG), which was staffed by technical experts appointed by the IOAG agencies, developed a survey template which includes all current CCSDS coding and modulation standards. The four agencies on the team (CNES, DLR, ESA, and NASA) completed the survey first to find any bugs in the process.

The WG then solicited inputs from all IOAG member agencies (September 2014) and held a face-to-face meeting at ESOC in January 2015 where the responses from ASI, CNES, CSA, ESA, DLR, JAXA, and NASA were available.

The WG developed a recommended list based on these inputs.

B. Input by Agencies

Figure 1 shows the data provided for Coding while Figure 2 shows the data provided for Modulation while a legend for the tables is shown in Figure 3. It shall be remarked that some agencies provided tables with input spread over several columns (e.g. for different Ground Assets). The figures show a single column per agency where e.g. the value has been set to *yes* whenever at least one Ground Asset supported that option. Detailed inputs are reported in Appendix C.

It shall be remarked that while a “Yes” in an entry does mean that at least one asset of the agency supports the capability, it does not mean that any mission from that agency has used it or that all Ground Assets in that agency support it.

			NASA	ESA	CNES	DLR	CSA	ASI	JAXA
Coding - Telecommand									
CCSDS 231.0-B	Sec. 3	BCH (with Randomizer) /via CLTU service	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCSDS 231.0-B	Future Sec. TBD	LDPC Codes /via TBD service	Future	Future	No	No	Future	Future	No
Coding - Telemetry									
CCSDS 131.0-B	Sec. 3.3	Convolutional 1/2	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCSDS 131.0-B	Sec. 3.4	Punctured 2/3	No	Yes	Future TBC	Yes	Yes	Future	No
CCSDS 131.0-B	Sec. 3.4	Punctured 3/4	No	Yes	Future TBC	Yes	Yes	Future	No
CCSDS 131.0-B	Sec. 3.4	Punctured 5/6	No	Yes	Future TBC	Yes	Yes	Future	No
CCSDS 131.0-B	Sec. 3.4	Punctured 7/8	No	Yes	Future TBC	Yes	Yes	Future	No
CCSDS 131.0-B	Sec. 4.3	RS (255, 223) E-16	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCSDS 131.0-B	Sec. 4.3	RS (255, 239) E-8	No	Future	Yes	Yes	Yes	Future	No
CCSDS 131.0-B	Sec. 5	Concatenated 1/2 + E=16	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCSDS 131.0-B	Sec. 5	Concatenated 1/2 + E=8	No	Future	Yes	Yes	Future	Future	No
CCSDS 131.0-B	Sec. 5	Concatenated 2/3 + E=16	No	Yes	Future TBC	Yes	Yes	Future	No
CCSDS 131.0-B	Sec. 5	Concatenated 2/3 + E=8	No	Future	No	Yes	Future	Future	No
CCSDS 131.0-B	Sec. 5	Concatenated 3/4 + E=16	No	Yes	Future TBC	Yes	Yes	Future	No
CCSDS 131.0-B	Sec. 5	Concatenated 3/4 + E=8	No	Future	No	Yes	Future	Future	No
CCSDS 131.0-B	Sec. 5	Concatenated 5/6 + E=16	No	Yes	Future TBC	Yes	Yes	Future	No
CCSDS 131.0-B	Sec. 5	Concatenated 5/6 + E=8	No	Future	No	Yes	Future	Future	No
CCSDS 131.0-B	Sec. 5	Concatenated 7/8 + E=16	No	Yes	Future TBC	Yes	Yes	Future	No
CCSDS 131.0-B	Sec. 5	Concatenated 7/8 + E=8	No	Future	No	Yes	Future	Future	No
CCSDS 131.0-B	Sec. 6.3	Turbo 1/2	Yes	Yes	No	Yes	Yes	Future	Yes
CCSDS 131.0-B	Sec. 6.3	Turbo 1/3	Yes	Yes	No	Yes	Yes	Future	No
CCSDS 131.0-B	Sec. 6.3	Turbo 1/4	Yes	Yes	No	Yes	Yes	Future	No
CCSDS 131.0-B	Sec. 6.3	Turbo 1/6	Yes	Yes	No	Yes	Yes	Future	No
CCSDS 131.0-B	Sec. 7.4	LDPC 223/255	Yes	No	No	No	No	Future	No
CCSDS 131.0-B	Sec. 7.4	LDPC 1/2	Yes	Future	No	Yes	Future	Future	No
CCSDS 131.0-B	Sec. 7.4	LDPC 2/3	Future	Future	No	Yes	Future	Future	No
CCSDS 131.0-B	Sec. 7.4	LDPC 4/5	Future	Future	No	No	Future	Future	No
CCSDS 131.0-B	Future chapt 8	LDPC Codes with Slicing	Yes	Future	No	No	Future TBC	Future TBC	No
CCSDS 131.2-B	CCSDS 131.2-B	SCCC	No	Future	No	No	Future	Future	No
CCSDS 131.3-B	CCSDS 131.3-B	SLP over ETSI DVB-S2 Standard	No	No	Future	No	No	Future	No

Figure 1: The Data: Coding

			NASA	ESA	CNES	DLR	CSA	ASI	JAXA
Modulation - Telecommand									
CCSDS 401.0-B	Sec. 2.2.4	PCM/PSK/PM	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCSDS 401.0-B	Sec. 2.2.7	PCM/Bi-Phase/PM	Yes	Yes	Yes	Future	Yes	Future	Yes
CCSDS 401.0-B	Sec. 2.2.8	BPSK	Yes	No	Yes	No	No	Future	No
Modulation - Telemetry									
CCSDS 401.0-B	Sec. 2.3.1, 2.4.3, 2.4.7	PCM/PSK/PM	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCSDS 401.0-B	Sec. 2.3.1 and 2.4.7	PCM/Bi-Phase/PM	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCSDS 401.0-B	Sec. 2.3.2	(Filtered) BPSK ≤ 2 Msps	Yes	Yes	Partial	Yes	Yes	Yes	Yes
CCSDS 401.0-B	Sec. 2.3.2	(Filtered) QPSK ≤ 2 Msps	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCSDS 401.0-B	Sec. 2.3.2	Filtered OQPSK ≤ 2 Msps	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCSDS 401.0-B	Sec. 2.3.2	GMSK ≤ 2 Msps	Partial	Yes	No	Yes	Yes	Yes	No
CCSDS 401.0-B	Sec. 2.4.17A	Filtered OQPSK > 2 Msps	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCSDS 401.0-B	Sec. 2.4.17A	GMSK (BTS=0.25) > 2 Msps	Partial	Yes	No	Yes	Yes	Yes	No
CCSDS 401.0-B	Sec. 2.4.17B	GMSK (BTS=0.5) > 2 Msps	Partial	Yes	No	Yes	Future	Future	No
CCSDS 401.0-B	Sec. 2.4.18	Filtered OQPSK	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCSDS 401.0-B	Sec. 2.4.18	Filtered 8PSK	Future	Yes	Yes	Yes	Yes	Future	No
CCSDS 401.0-B	Sec. 2.4.18	GMSK	Partial	No	Yes	Yes	No	Yes	No
CCSDS 401.0-B	Sec. 2.4.20B	GMSK (BTS=0.5)	Partial	Yes	No	No	Future	Future	No
CCSDS 401.0-B	Sec. 2.4.21A	Filtered OQPSK	Yes	Yes	No	Yes	Future	Future	Yes
CCSDS 401.0-B	Sec. 2.4.21A	GMSK (BTS=0.25)	Partial	Yes	No	Yes	Future	Future	No
Modulation - Space to Space Links									
CCSDS 415.1-B-1	Sec. 4	Spread Spectrum	Yes	Yes (SNIP)	No	No	No	No	Yes (SNIP)

Figure 2: The Data: Modulation








Legend			
	Not placed in "recommended list"	 No	Not used by agency
	Limited to 8PSK-TCM modulation	 Partial	Portion of standard used by agency
		 Yes	Currently used by agency
		 Future	Planned for future use by agency
		 Future TBC	Considered for future use by agency

Figure 3: Legend for Data interpretation

III. Preferred Coding Schemes

A. Preferred Codes for Telecommand

Recommendation R-1: For Telecommand (TC), the **BCH** code (with optional Randomizer) defined in Section 3 of CCSDS 231.0-B and normally provided via SLE CLTU is the preferred code.

B. Possible Preferred Codes for Telecommand

Recommendation R-2: For Telecommand, the **LDPC** codes being added to CCSDS 231.0-B are envisaged to be a **future** preferred code .

C. Preferred Codes for Telemetry

Recommendation R-3: For Telemetry (TM), the **Convolutional code rate $\frac{1}{2}$** defined in Section 3.3 of CCSDS 131.0-B is a preferred code.

Recommendation R-4: For Telemetry, the **Reed-Solomon code (255, 223) E=16** defined in Section 4.3 of CCSDS 131.0-B is a preferred code.

Recommendation R-5: For Telemetry, the **Reed-Solomon code (255, 239) E=8** defined in Section 4.3 of CCSDS 131.0-B is a preferred code only if used in conjunction with the 8PSK-TCM modulation.

Recommendation R-6: For Telemetry, the **concatenation of the Convolutional code rate $\frac{1}{2}$ with the Reed-Solomon code (255, 223) E=16** defined in Section 5 of CCSDS 131.0-B is a preferred code.

Recommendation R-7: For Telemetry, the **Turbo codes** with rates $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, and $\frac{1}{6}$ defined in Section 6.3 of CCSDS 131.0-B are preferred codes.

D. Possible Preferred Codes for Telemetry

A set of coding schemes has been recently added for Telemetry, and a new one is going to be added in short time. As these coding schemes are quite recent and currently under evaluation by agencies for future missions, their evolution and implementations shall be monitored before driving conclusions. They may be subject to designated profiles.

Recommendation R-8: For Telemetry, the **LDPC codes with rates $\frac{223}{255}$, $\frac{1}{2}$, $\frac{2}{3}$, and $\frac{4}{5}$** defined in section 7.4 of CCSDS 131.0-B are envisaged to be a **future** preferred code.

Recommendation R-9: For Telemetry, the **LDPC codes with slicing** being added to CCSDS 131.0-B are envisaged to be a **future** preferred code.

Recommendation R-10: For Telemetry, the **SCCC** codes defined in CCSDS 131.2-B are envisaged to be a **future** preferred code.

Recommendation R-11: For Telemetry, the **DVB-S2** codes defined in CCSDS 131.3-B are envisaged to be a **future** preferred code.

E. Codes for Telemetry not preferred by IOAG

Recommendation R-12: For Telemetry, the **Convolutional codes with rates 2/3, 3/4, 5/6, and 7/8** defined in Section 3.4 of CCSDS 131.0-B are NOT preferred codes.

NOTE – Most agencies have already stopped using these codes and their telemetry performance is less than the unpunctured (7, 1/2) code that is on the “preferred” list.

Recommendation R-13: For Telemetry, the **concatenation of Convolutional code with rates 2/3, 3/4, 5/6, and 7/8 with the Reed-Solomon codes E=16 /E=8** defined in Section 5 of CCSDS 131.0-B are NOT preferred codes.

NOTE - These are the concatenated versions of the codes in R-12. Most agencies have already stopped using the inner convolutional codes and their telemetry performance is less than the concatenated (7, 1/2) + E=16 code that is on the “preferred” list.

Recommendation R-14: For Telemetry, the **Reed-Solomon code (255, 239) E=8** defined in Section 4.3 of CCSDS 131.0-B, when used in conjunction with a modulation other than the 8PSK-TCM, is NOT a preferred code.

NOTE -Most agencies have already stopped using this code and its performance is less than the “preferred” E=16 code. An exception is made for the legacy case of its use in conjunction with 8PSK-TCM modulation.

Recommendation R-15: For Telemetry, the **concatenation of the Convolutional code rate 1/2 with the Reed-Solomon code (255, 239) E=8** defined in Section 5 of CCSDS 131.0-B is NOT a preferred code.

NOTE - Most agencies have already stopped using this code and its performance is less than the “preferred” concatenated (7, 1/2) + E=16 code .

IV. Preferred Modulation Schemes

A. Preferred Modulations for Telecommand

Recommendation R-16: For Telecommand, the **PCM/PSK/PM** modulation defined in Section 2.2.4 of CCSDS 401.0-B is the preferred modulation for low rate telecommand up to 4 kbps.

Recommendation R-17: For Telecommand, the **PCM/Bi-Phase/PM** modulation defined in Section 2.2.7 of CCSDS 401.0-B is the preferred modulation for medium rate telecommand up to 256 kbps.

Recommendation R-18: For Telecommand, the **BPSK** modulation defined in Section 2.2.8 of CCSDS 401.0-B is the preferred modulation for suppressed carrier telecommand up to 2.048 Mb/s.

B. Preferred Modulations for Telemetry

Recommendation R-19: For Telemetry, the **PCM/PSK/PM** modulation defined in Sections 2.3.1, 2.4.3, 2.4.7 of CCSDS 401.0-B is the preferred modulation for low rate residual carrier telemetry with subcarriers.

Recommendation R-20: For Telemetry, the **PCM/Bi-Phase/PM** modulation defined in Sections 2.3.1, 2.4.7 of CCSDS 401.0-B is the preferred modulation for low rate residual carrier telemetry without subcarriers.

Recommendation R-21: For Telemetry, the **(Filtered) BPSK** modulation, the **(Filtered) OQPSK** modulation and the **GMSK** modulation defined in Section 2.3.2 of CCSDS 401.0-B are the preferred modulations for medium rate suppressed carrier telemetry.

Recommendation R-22: For Telemetry, the **Filtered OQPSK** modulation and the **GMSK ($BT_5=0.25$)** modulation defined in Section 2.4.17A of CCSDS 401.0-B are the preferred modulations for telemetry data symbol rates exceeding 2 Ms/s in the bands 2200-2290 MHz and 8450-8500 MHz.

Recommendation R-23: For Telemetry, the **GMSK ($BT_5=0.5$)** modulation defined in Section 2.4.17B of CCSDS 401.0-B is the preferred modulation for telemetry data symbol rates exceeding 2 Ms/s in the bands 2290-2230 MHz and 8400-8450 MHz.

Recommendation R-24: For Telemetry, the **Filtered OQPSK** modulation, the **Filtered 8PSK** modulation and the **GMSK** modulation defined in Section 2.4.18 of CCSDS 401.0-B are the preferred modulations for high telemetry data symbol rates in the 8025-8400 MHz band.

Recommendation R-25: For Telemetry, the **GMSK (BT₅=0.5)** modulation defined in Section 2.4.20B of CCSDS 401.0-B is the preferred modulation for telemetry data symbol rates exceeding 20 Ms/s in the 31.8-32.3 GHz band.

Recommendation R-26: For Telemetry, the **Filtered OQPSK** modulation and the **GMSK (BT₅=0.25)** modulation defined in Section 2.4.21A of CCSDS 401.0-B are preferred modulations for telemetry data symbol rates exceeding 10 Ms/s in the 25.5-27.0 GHz band.

C. Modulations for Telemetry not preferred by IOAG

Recommendation R-27: For Telemetry, the **(Filtered) QPSK** modulation defined in Section 2.3.2 of CCSDS 401.0-B is NOT a preferred modulation for medium rate suppressed carrier telemetry.

NOTE - This modulation is not preferred by IOAG as the Filtered OQPSK modulation provides better performances. However, the capability should be maintained in Ground Tracking Assets for legacy missions.

D. Preferred Modulations for Space to Space Links

These schemes are for a LEO satellite or other satellite below GEO altitude transmitting to a relay satellite at GEO altitude in the 2 GHz frequency band.

Recommendation R-28: For Space to Space links, the **Spread Spectrum** modulation defined in Section 4 of CCSDS 415.1-B is the preferred modulation.

E. Possible Preferred Modulations for Telemetry

A set of modulation schemes for Earth Exploration Satellites is being investigated by CCSDS and it will be considered by IOAG for future missions when the relevant standards are published.

Appendix A: List of Acronyms

ASI	Agenzia Spaziale Italiana
BCH	Bose-Chaudhuri-Hocquenghem
BPSK	Binary Phase Shift Keying
C&MWG	Coding and Modulation Working Group
CCSDS	Consultative Committee for Space Data Systems
CLTU	Command Link Transmission Unit
CNES	Centre National d'Etudes Spatiales
CSA	Canadian Space Agency
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DVB-S2	Digital Video Broadcasting – Satellite 2 nd generation
ESA	European Space Agency
GEO	Geostationary Earth Orbit
GMSK	Gaussian Minimum Shift Keying
IOAG	Interagency Operations Advisory Group
JAXA	Japan Aerospace Exploration Agency
LDPC	Low-Density Parity-Check
LEO	Low Earth Orbit
NASA	National Aeronautics and Space Administration
OQPSK	Offset Quadrature Phase-Shift Keying
PCM	Pulse Code Modulation
PM	Phase Modulation
PSK	Phase Shift Keying
SCCC	Serially Concatenated Convolutional Code
SLE	Space Link Extension
SNIP	Space Network Interface Protocol
TC	Telecommand
TM	Telemetry
WG	Working Group

Appendix B: References

The versions of the documents listed below were the most recent when this report has been produced. CCSDS Blue Books are available at <http://public.ccsds.org/publications/BlueBooks.aspx> .

- [1] CCSDS 131.0-B-2 TM Synchronization and Channel Coding. Blue Book. Issue 2. August 2011.
- [2] CCSDS 131.2-B-1 Flexible Advanced Coding and Modulation Scheme for High Rate Telemetry Applications. Blue Book. Issue 1. March 2012.
- [3] CCSDS 131.3-B-1 CCSDS Space Link Protocols over ETSI DVB-S2 Standard. Blue Book. Issue 1. March 2013.
- [4] CCSDS 401.0-B-25 Radio Frequency and Modulation Systems--Part 1: Earth Stations and Spacecraft. Blue Book. Issue 25. February 2015.
- [5] CCSDS 415.1-B-1 Data Transmission and PN Ranging for 2 GHz CDMA Link via Data Relay Satellite. Blue Book. Issue 1. September 2011.
- [6] CCSDS 912.1-B-3 Space Link Extension – Forward CLTU Service Specification. Blue Book. Issue 3. July 2010.

Appendix C: Detailed Inputs

This Appendix contains the detailed input received by Agencies.

			NASA/DSN	NASA/SN	NASA/NEN	ESA	CNES	DLR	CSA	ASI/NuSTAR	JAXA	NASA/Users	DLR/Users	
Coding - Telecommand														
CCSDS 231.0-B	Sec. 3	BCH (with Randomizer) /via CLTU	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Note 1
CCSDS 231.0-B	Future Sec. TBD	LDPC Codes /via TBD service	Future	Future	Future	Future TBC	No	No	Future	Future	No	Future	No	
Coding - Telemetry														
CCSDS 131.0-B	Sec. 3.3	Convolutional 1/2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
CCSDS 131.0-B	Sec. 3.4	Punctured 2/3	No	No	No	Yes	Future TBC	Yes	Yes	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 3.4	Punctured 3/4	No	No	No	Yes	Future TBC	Yes	Yes	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 3.4	Punctured 5/6	No	No	No	Yes	Future TBC	Yes	Yes	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 3.4	Punctured 7/8	No	No	No	Yes	Future TBC	Yes	Yes	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 4.3	RS (255, 223) E-16	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
CCSDS 131.0-B	Sec. 4.3	RS (255, 239) E-8	No	No	No	Future	Yes	Yes	Yes	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 5	Concatenated 1/2 + E=16	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
CCSDS 131.0-B	Sec. 5	Concatenated 1/2 + E=8	No	No	No	Future	Yes	Yes	Future	Future	No	No	No	Note 4
CCSDS 131.0-B	Sec. 5	Concatenated 2/3 + E=16	No	No	No	Yes	Future TBC	Yes	Yes	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 5	Concatenated 2/3 + E=8	No	No	No	Future	No	Yes	Future	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 5	Concatenated 3/4 + E=16	No	No	No	Yes	Future TBC	Yes	Yes	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 5	Concatenated 3/4 + E=8	No	No	No	Future	No	Yes	Future	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 5	Concatenated 5/6 + E=16	No	No	No	Yes	Future TBC	Yes	Yes	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 5	Concatenated 5/6 + E=8	No	No	No	Future	No	Yes	Future	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 5	Concatenated 7/8 + E=16	No	No	No	Yes	Future TBC	Yes	Yes	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 5	Concatenated 7/8 + E=8	No	No	No	Future	No	Yes	Future	Future	No	No	No	Note 2
CCSDS 131.0-B	Sec. 6.3	Turbo 1/2	Yes	No	No	Yes	No	Yes	Yes	Future	Yes	Yes	No	
CCSDS 131.0-B	Sec. 6.3	Turbo 1/3	Yes	No	No	Yes	No	Yes	Yes	Future	No	Yes	No	
CCSDS 131.0-B	Sec. 6.3	Turbo 1/4	Yes	No	No	Yes	No	Yes	Yes	Future	No	Yes	No	
CCSDS 131.0-B	Sec. 6.3	Turbo 1/6	Yes	No	No	Yes	No	Yes	Yes	Future	No	Yes	No	
CCSDS 131.0-B	Sec. 7.4	LDPC 223/255	Future	Future	Yes	No	No	No	No	Future	No	Yes	No	Note 5
CCSDS 131.0-B	Sec. 7.4	LDPC 1/2	Future	Future	Future	Future TBC	No	Yes	Future	Future	No	Yes	No	Note 5
CCSDS 131.0-B	Sec. 7.4	LDPC 2/3	Future	No	No	Future TBC	No	Yes	Future	Future	No	Future	No	Note 5
CCSDS 131.0-B	Sec. 7.4	LDPC 4/5	Future	No	No	Future TBC	No	No	Future	Future	No	Future	No	Note 5
CCSDS 131.0-B	Future chapt 8	LDPC Codes with Slicing	Future	Future	Yes	Future TBC	No	No	Future TBC	Future TBC	No	Yes	No	Note 5
CCSDS 131.2-B	CCSDS 131.2-B	SCCC	No	No	No	Future	No	No	Future	Future	No	No	No	Note 5
CCSDS 131.3-B	CCSDS 131.3-B	SLP over ETSI DVB-S2 Standard	No	No	No	No	Future	No	No	Future	No	No	No	Note 5

			NASA/DSN	NASA/SN	NASA/NEN	ESA	CNES	DLR	CSA	ASI/NuSTAR	JAXA	NASA/Users	DLR/Users	
Modulation - Telecommand														
CCSDS 401.0-B	Sec. 2.2.4	PCM/PSK/PM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
CCSDS 401.0-B	Sec. 2.2.7	PCM/Bi-Phase/PM	Partial	Yes	Yes	Yes	Yes	Future	Yes	Future	Yes	Yes	Future	
CCSDS 401.0-B	Sec. 2.2.8	BPSK	Partial	Yes	Yes	No	Yes	No	No	Future	No	Yes	No	
Modulation - Telemetry														
CCSDS 401.0-B	Sec. 2.3.1, 2.4.3, 2.4.7	PCM/PSK/PM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
CCSDS 401.0-B	Sec. 2.3.1 and 2.4.7	PCM/Bi-Phase/PM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	
CCSDS 401.0-B	Sec. 2.3.2	(Filtered) BPSK ≤ 2 Msps	Yes	Yes	Yes	Yes	Partial	Yes	Yes	Yes	Yes	Yes	Yes	
CCSDS 401.0-B	Sec. 2.3.2	(Filtered) QPSK ≤ 2 Msps	Partial	Partial	Partial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Future	Note 3
CCSDS 401.0-B	Sec. 2.3.2	Filtered OQPSK ≤ 2 Msps	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Future	
CCSDS 401.0-B	Sec. 2.3.2	GMSK ≤ 2 Msps	Partial	No	No	Yes	No	Yes	Yes	Yes	No	Future TBC	No	
CCSDS 401.0-B	Sec. 2.4.17A	Filtered OQPSK > 2 Msps	Partial	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Future	
CCSDS 401.0-B	Sec. 2.4.17A	GMSK (BTS=0.25) > 2 Msps	Partial	No	No	Yes	No	Yes	Yes	Yes	No	Future TBC	No	
CCSDS 401.0-B	Sec. 2.4.17B	GMSK (BTS=0.5) > 2 Msps	Partial	No	No	Yes	No	Yes	Future	Future	No	Future TBC	No	
CCSDS 401.0-B	Sec. 2.4.18	Filtered OQPSK	Partial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Future	
CCSDS 401.0-B	Sec. 2.4.18	Filtered 8PSK	No	Future	Future	Yes	Yes	Yes	Yes	Future	No	Future	Future TBC	
CCSDS 401.0-B	Sec. 2.4.18	GMSK	Partial	No	No	No	Yes	Yes	No	Yes	No	No	No	
CCSDS 401.0-B	Sec. 2.4.20B	GMSK (BTS=0.5)	Partial	No	No	Yes	No	No	Future	Future	No	Future TBC	No	
CCSDS 401.0-B	Sec. 2.4.21A	Filtered OQPSK	Partial	Yes	Yes	Yes	No	Yes	Future	Future	Yes	Yes	No	
CCSDS 401.0-B	Sec. 2.4.21A	GMSK (BTS=0.25)	Partial	No	No	Yes	No	Yes	Future	Future	No	No	No	
Modulation - Space to Space Links														
CCSDS 415.1-B-1	Sec. 4	Spread Spectrum	No	Yes	No	Partial(SNIP)	No	?	?	?	?	Yes	?	
NOTES														
[Note 1]	Coding and randomization done at MOC as CLTU service used.													
[Note 2]	IOAG to discuss whether recommending that identified TM Coding options be limited to legacy missions.													
[Note 3]	IOAG to discuss whether recommending that identified option be limited to legacy missions.													
[Note 4]	IOAG to discuss whether recommending that identified TM Coding option be limited to 8PSK-TCM modulation (CCSDS 401.0-B Sec. 2.4.18).													
[Note 5]	For the identified options, future evolution and implementations shall be monitored before driving conclusions. Their applicability may be subject to designated profiles.													
[Note LDPC]	For LDPC codes the situation of patents/royalties for commercial developers may need clarifications.													
[Note SC's]	The identification of preferred options for cross support, may impact IOAG Service Catalogs to include the eventually agreed IOAG recommendations													
[Note Users]	The input provided for Users, is shown separately at the end of the main area.													