CCSDS Multispectral & Hyperspectral

Data Compression Working Group

Spring 2016 Meeting Summary

April 5–7, Cleveland, Ohio USA

**Participants:**

* Aaron Kiely (chair), NASA-JPL
* Englin (Mark) Wong (deputy chair), NASA-GSFC
* Raffaele Vitulli, ESA
* Roberto Camarero, CNES
* Penshu Yeh, NASA-GSFC (via teleconference)
* Ian Blanes, Universitat Autònoma de Barcelona (CNES)
* Lucana Santos, Universidad de Las Palmas de Gran Canaria (ESA)
* Enrico Magli, Politecnico di Torino (ESA)
* John Kacner, Air Force Life Cycle Management Center (NASA-JPL)
* Alan Schaar, Air Force Life Cycle Management Center (NASA-JPL)
* Michael Epperly, Southwest Research Institute (NASA-GSFC)
* Gian Paolo Calzolari, ESA

# Status Updates

## CCSDS-120.2-G (Green Book for CCSDS-123.0-B)

CCSDS-120.2-G, the Green Book associated with CCSDS-123.0-B, was published December 2015.

## New Images

In response to Action Item MHDC-A-1510-1, JPL (Kiely) acquired new radiance images from AVIRIS-NG and M3 imaging spectrometers to add to the current corpus of test images, in an effort to increase the pool of hyperspectral images that are relatively free of streaking artifacts and thus appropriate for lossy compression assessment. The new AVIRIS-NG and M3 images can be found in [1] and [2] respectively. Reference [3] describes the new images.

For the sake of making data volume manageable, Kiely selected four “scenes” from each instrument, each scene 512-lines tall.

For both of these instruments, radiometric calibration is performed on the ground and radiance images are stored as 32-bit floating-point samples. Consequently, conversion from floating-point to integer samples is necessary to produce images suitable for input to the compressors being developed by the Working Group. Kiely performed this conversion using two different methods, thus producing two different versions of each image. In the first method, negative radiance values are clipped to zero, and then all samples in the image are scaled by an overall scaling factor and rounded to the nearest integer. In the second method, a different scaling factor is applied to each band, with the scaling factor selected based on the inherent measurement granularity in the band.

Under the first method, one unit of error in the reconstructed image produces the same amount of error in the radiance domain, regardless of band. Under the second method, one unit of error in the reconstructed integer radiance image is about equal to the error that would have been produced by one unit of error in the raw DN image. The scaling methodology and the set of scaling factors used are described in README files included with each set of images.

UAB (Blanes) expressed concern that having two versions of each image could lead to confusion outside of the working group if other compression researchers publish results without clearly indicating which version is being used. A potential solution to this problem is to release only one integer version of each image.

The effort required to produce suitable integer radiance images was larger than anticipated, and faced with limited resources, Kiely did not pursue the acquisition of CRISM imagery as originally intended under this action item. No other WG participants volunteered to investigate the acquisition of CRISM images and so this portion of the action item is dropped.

# CCSDS-122.1-B, Spectral Processing Transform

## Hardware Complexity of Mean and Variance Calculations

In response to Action Item MHDC-A-1510-2, ULPGC (Santos) presented new results [4] describing the hardware implementation complexity associated with the mean and variance calculations in the White Book for CCSDS-1222.1-B. [Lucana please add text here to summarize.] There appears to be no problem that would affect plans to proceed with this part of the standard.

## Cross-Verification of IWT & IPOT

UAB (Blanes) and GSFC (Wong & Yeh) have completed their cross-verification effort and produced a draft Yellow Book [5][6][7], thus completing Action Item MHDC-A-1510-3.

The CCSDS Editor has assigned document number CCSDS-122.11-Y-n to the Yellow Book.

Action Item MHDC-A-1604-1 was created to complete the Yellow Book draft, including the addition of further information on the cross-verification methodology.

[My notes are inconsistent about when we want to submit the Yellow Book to CCSDS management. My notes indicate both of the following:

1. The consensus of the WG is to provide the Yellow Book to CCSDS management once Agency Review of CCSDS-122.1-R is complete, in case this review produces a RID that requires a cross-verification test to be repeated, and thus a revision of the Yellow Book.
2. We’ll have an action item to submit a final Yellow Book shortly after we request that our White Book is promoted to Red Book. (If this is the case then I’ll add a part (b) to MHDC-A-1604-1.)

Ian can you clarify which of these conflicting statements is accurate?]

## Review of White Book

Revisions to the White Book for CCSDS-122.1-B were produced under action items MHDC-A-1510-4, -5, -6, and a revised draft was provided before the meeting [8]. UAB (Blanes) led a discussion of the current White Book [9]. [Ian please provide a summary here including demuxable bitstreams. My note on demuxable bit streams: there is no suggestion to change anything normative about the book, the question is just what non-normative text to add and/or defer to the corresponding Green Book.]

Multi-part action item MHDC-A-1604-2 was created to complete final review the White Book and request promotion to Red Book.

Agency review is also required for Issue 2 of CCSDS-122.0-B, which revises the standard as needed to support to spectral transform stage. The WG agreed to request that the current draft of this revision be promoted to Pink Book to begin Agency Review. [Aaron to add a sentence here once a number has been assigned to the resolution that requests promotion to Pink Book.]

Action Item MHDC-A-1604-3 was created for all WG participants to submit responses to RIDs generated by Agency Review of CCSDS-122.0-B-2 and CCSDS-122.1-B one week before the Fall 2016 meeting, where the RIDs will be reviewed and resolved.

## Green Book

In response to Action Item MHDC-A-1510-7, Blanes developed and delivered to the WG an outline for a Green Book associated with CCSDS-122.1-B [10]. Blanes led a review of the outline and WG participants commented on ways to simplify the Green Book.

The CCSDS Editor has assigned document number CCSDS-120.3-G to this Green Book. The SLS Area Director created resolution SLS-R-2016-04-003 requesting CMC approval to start the Green Book project. Multi-part action item MHDC-A-1604-4 was created to produce a draft Green Book, in anticipation of project approval.

# CCSDS-123.1-B: Near-Lossless Extension of CCSDS-123.0-B

In response to Action Item MHDC-A-1510-8, concept papers describing proposals for CCSDS-123.1-B, the Near-Lossless extension of CCSDS-123.0-B, were submitted by CNES [11], ESA [12][13], and NASA-JPL [14].

All of the proposed compression approaches incorporate quantization internal to the DPCM feedback loop, and all include at least one entropy coding method capable of obtaining bit rates well below one bit per sample to provide improved compression effectiveness of low-entropy data.

## CNES Proposal

CNES (Camarero) gave a presentation outlining the CNES proposal for CCSDS-123.1-B [15]. [Roberto please add a brief summary here.]

## ESA Proposal

ESA (Magli) gave a presentation outlining the ESA proposal for CCSDS-123.1-B [16]. The proposal employs the same predictor as CCSDS-123, and is based on a DPCM feedback loop with a scalar uniform quantizer. Three options for entropy coding are proposed, namely a Golomb encoder (legacy option), a thresholded range encoder with four statistical models for each band, and a bit-plane range encoder. The proposal also includes techniques aiming to provide rate and quality control, namely a block-based rate control algorithm, a slice-based rate control algorithm, and an algorithm that selectively adapts the quantization step size for each pixel of the image in order to obtain a bounded maximum relative error. Although not included in the concept paper, Magli also reports about a modification of the initialization of the predictor in reduced column-oriented mode, which completely avoids using the decoded value of the previous pixels on the same line for the prediction of the current pixel, thereby enabling to pipeline the DPCM loop in a hardware implementation.

## JPL Proposal

JPL (Kiely) gave a presentation outlining the JPL proposal for CCSDS-123.1-B [17]. Key features of JPL’s proposed “FLEX” (FL EXtended) compressor are: uniform scalar quantization with user-selectable quantizer stepsize that can vary for each spectral band; a “generalized prediction representative” framework that allows the CCSDS-123.0 predictor to make predictions based on prediction representatives that need not be equal to reconstructed sample values; and the ability to adaptively switch, on a sample-by-sample basis, between a conditional 2-stage entropy coding method for low-entropy samples and the existing sample-adaptive (GPO2) entropy coding approach for high-entropy samples. Some rate-distortion results were presented to illustrate the benefits of some of the key elements of FLEX, and the presentation provided an overview of the interleaved entropy coding framework used to combine the outputs of the high-entropy and low-entropy coding methods.

## Rate-Distortion Results

In response to action item MHDC-A-1510-9, ESA and JPL submitted rate-distortion performance results for proposed compression approaches to ULPGC (Santos) who tabulated the results in [18][19]. Santos led a discussion comparing the results [20].

Loosely speaking, the rate-distortion results for the proposed compressors suggest similar rate-distortion performance. Direct comparisons between the approaches are complicated by apparent differences in the choices of parameters defined in the CCSDS-123.0-B standard. (JPL-provided lossless compression results for nominal CCSDS-123.0-B performance differ somewhat from the lossless compression results for the ESA compressor using the sample-adaptive entropy coding method, and neither exactly matches results published in the recent Green Book.)

Additionally, the use of generalized prediction representatives by the FLEX compressor means that even if other prediction parameters are fixed, the input to the entropy coder differs from one compressor to the next, and so comparing the effectiveness of the different entropy coding proposals is not straightforward from the data submitted.

## Discussion and Plans

[Ian, you had some discussion of some unpublished results. If you want any of the comments included in the meeting summary, I think this is the place to add it.]

An enthusiastic Blanes led a discussion on how to proceed with the development of CCSDS-123.1-B. With the hope of avoiding a lengthy evaluation and selection process, and more quickly producing a standard, the WG agreed to produce a “skeleton” White Book. The skeleton retains, where feasible, the various elements included in the different proposals as options. Options outlined in the skeleton can then be more completely specified and evaluated to assess their relative merits, and eliminated as warranted based on further analysis.

Multi-part action item MHDC-A-1604-5 produces the skeleton White Book, which is to initially include the following elements:

* Quantization in the DPCM feedback loop with options for:
  + Uniform scalar quantization
  + Double-deadzone quantization
  + Quantizer stepsize either fixed or selectable via HVS metric
  + Placeholder for a quantizer with the idea of preserving something similar to relative error
* Prediction incorporating generalized prediction representatives, including the option of setting the related parameters to zero to effectively bypass this option (see MHDC-A-1604-6b)
* A new optional redefinition of local differences in the first line of an image when column-oriented local sums are used in combination with reduced mode, to facilitate very high throughput implementations (see MHDC-A-1604-5a). [Someone please correct this sentence if it’s not accurate.]
* An option to signal quantization stepsize for each band or spatial region, e.g. every 2*i* lines of the image as part of the encoded bitstream (where *i* is a user-selectable integer parameter) to facilitate rate control (see MHDC-A-1604-6d)
* Entropy coding method TBA (see MHDC-A-1604-6 and -7).
* Context modeling (see MHDC-A-1604-6e)

MHDC-A-1604-6 clarifies some of the elements of proposed compressors.

A major activity in the development of this standard is the selection of an entropy coding method. Action items MHDC-A-1604-7 and -8 provide information to allow a comparison of the compression effectiveness and hardware implementation complexity of the proposed entropy coders, with the goal of selecting an entropy coding method mid-September.

The following timeline is planned for the development of the CCSDS-123.1-B standard:

* Mid-September, 2016: teleconference to attempt to select an entropy coding method. The goal is to select an entropy coder, or identify what further information should be provided at the Fall meeting to make a selection there.
* Fall, 2016: White Book. Identify remaining issues and concerns, establish action items to address them.
* Spring 2017: Review final White Book in anticipation of requesting promotion to Red Book at or shortly after the meeting.
* Early 2018: Blue Book

# Planning/Management

The following table shows the resolution of action items assigned at the Fall 2015 WG meeting. Action items MHDC-A-1510-1 through -11 have been completed.

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| **Action Item No.** | **Description** | **Actionee** | **Status/Reference** |
| MHDC-A-1510-1 | Attempt to acquire Level 1B CRISM and M3 images, AVIRIS-NG samples; upload to CWE. | JPL (Kiely) | Complete [1][2][3] |
| MHDC-A-1510-2 | Assess hardware implementation impact of scaling in the mean and variance calculations for N=4096. | ULPGC (Santos) | Complete [4] |
| MHDC-A-1510-3 | (a) Complete implementation and cross-verification of current draft CCSDS-122.1-B, including corner cases (b) produce Yellow Book | GSFC (Wong & Yeh), UAB (Blanes) | Complete [5][6][7] |
| MHDC-A-1510-4 | Deliver to WG complete CCSDS-122.1-B draft incorporating changes suggested at Fall 2015 & all annexes complete | UAB (Blanes) | Complete [8] |
| MHDC-A-1510-5 | Review CCSDS-122.1-B and deliver suggested edits to UAB: (a) chapter 6 & appendices (b) final review of entire document | (a) JPL (Kiely), (b) ALL | Complete [8] |
| MHDC-A-1510-6 | Deliver complete CCSDS-122.1-B to WG. | UAB (Blanes) | Complete [8] |
| MHDC-A-1510-7 | Present outline of contents for Green Book for CCSDS-122.1-B | UAB (Blanes) | Complete [10] |
| MHDC-A-1510-8 | Submit concept papers for compressors proposed for CCSDS-123.1-B | All | Complete [11][12][13][14] |
| MHDC-A-1510-9 | Submit rate-distortion results to ULPGC (Santos) for compressors proposed for CCSDS-123.1-B: (a) lossless bit rates, (b) bit rates achieved and SNR with variance at maximum error = 1, 2, 3, 4, … 32 | All | Complete [18][19] |
| MHDC-A-1510-10 | Present comparison of compression results delivered under MHDC-A-1510-8 | ULPGC (Santos) | Complete [20] |
| MHDC-A-1510-11 | Present overview of proposed compressors for CCSDS-123.1-B | All | Complete [15][16][17] |

New action items MHDC-A-1604-1 through –8 were created as follows.

|  |  |  |  |
| --- | --- | --- | --- |
| **Action Item No.** | **Description** | **Actionee** | **Due Date** |
| MHDC-A-1604-1 | Complete draft Yellow Book CCSDS-122.11-Y-n, including further detail on cross-verification methodology | UAB & GSFC | July 1, 2016 |
| MHDC-A-1604-2 | Complete White Book for CCSDS-122.1-B: (a) deliver revised draft incorporating edits suggested at Spring 2016 meeting (b) review and submit comments to UAB, (c) incorporate comments, provide updated draft including remarks on de-multiplexable bitstreams, (d) notify UAB and JPL of approval of final draft, or request changes, (e) submit request to Area Director for promotion to Red Book, (f) submit final White Book to Area Director and Editor | (a) UAB  (b) ALL  (c) UAB,  (d) ALL,  (e) JPL, UAB | (a) April 11, 2016;  (b) April 18, 2016;  (c) April 25, 2016;  (d) April 29, 2016;  (e) May 2, 2016 |
| MHDC-A-1604-3 | Review RIDs generated from Agency Review of Pink Book CCSDS-122.0-B-2 and Red Book CCSDS-122.1-R. Submit proposed resolution to JPL. | ALL | October 10, 2016 |
| MHDC-A-1604-4 | Develop draft Green Book CCSDS-120.3-G: (a) produce skeleton GB based on existing available text/notes and WG input received at Spring 2016 meeting, (b) review skeleton GB, suggest changes, volunteer to write sections, (c) write Algorithm Overview section, (d) deliver draft #2 to WG, (e) deliver draft #3 to WG | (a) UAB,  (b) ALL,  (c) GSFC,  (d) UAB,  (e) UAB | (a) May 2, 2016,  (b) May 16, 2016,  (c) June 16, 2016,  (d) July 15, 2016,  (e) October 3, 2016 |
| MHDC-A-1604-5 | Develop skeleton White Book for CCSDS-123.1-B: (a) provide equation(s) and text to specify modified prediction alternative for the first line of an image; (b) deliver skeleton White Book to WG; (c) review and comment on skeleton White Book. | (a) ESA (Magli),  (b) JPL,  (c) ALL | (a) April 29, 2016,  (b) May 20, 2016,  (c) June 24, 2016 |
| MHDC-A-1604-6 | Clarify details of proposed compression approaches: (a) provide further details of proposed entropy coding approaches (description and/or source code) and identify any user-selectable entropy coding parameters and their values, so as to help reproducing entropy coding results; (b) provide results indicating whether the generalized prediction representative framework can be simplified; (c) provide evidence that proposed context model can deliver a compression benefit, or withdraw this option; (d) present suggested approach(es) for signaling quantization stepsizes to facilitate rate control or clarify other unresolved issues in the skeleton White Book. | (a) ESA (Magli),  (b) JPL,  (c) JPL,  (d) ESA/ALL | (a) May 20, 2016,  (b) Fall 2016 WG meeting,  (c) Fall 2016 WG meeting,  (d) Fall 2016 WG meeting |
| MHDC-A-1604-7 | Provide information to compare bit rate performance of entropy coding options proposed for CCSDS-123.1-B: (a) provide to JPL a list of images and quantizer stepsizes (or other prediction-stage options) for which entropy coding stages should be evaluated, (b) deliver images of mapped quantizer indices for the different images and coding options, (c) deliver to ULPGC tables of compressed bit rates for each proposed entropy coding method, (d) compile submitted bit rate tables and upload to CWE, (e) participate in email and/or teleconference discussion to assess whether bit rate results provide basis for selecting entropy coding method. | (a) ALL,  (b) JPL,  (c) ALL,  (d) ULPGC,  (e) ALL | (a) April 29, 2016,  (b) May 20, 2016,  (c) July 22, 2016,  (d) July 29, 2016,  (e) August 1–12, 2016 |
| MHDC-A-1604-8 | Provide information to assess hardware implementation complexity of entropy coding options proposed for CCSDS-123.1-B: (a) identify entropy coder hardware implementation information to be provided by each proposer, (b) provide feedback on proposed information to be assessed, (c) revise the request for information as appropriate, (d) provide requested information to ULPGC | (a) ULPGC,  (b) ALL,  (c) ULPGC,  (d) ALL | (a) April 18, 2016,  (b) May 2, 2016,  (c) May 9, 2016,  (d) July 29, 2016 |

References

Documents referenced in this summary can be found in the CCSDS Collaborative Work Environment (CWE) <http://cwe.ccsds.org/sls/docs> in the “CWE Private” folder of SLS-MHDC.

1. Test Data / AVIRIS-NG
2. Test Data / M3\_radiance
3. /Meeting Materials/2016-Apr/NewImages.pdf
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5. /Meeting Materials/2016-Apr/yellow\_book\_20160330\_mark.pdf
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19. /Meeting Materials/2016-Apr/123-1-LossyComparison.xlsx
20. /Meeting Materials/2016-Apr/RD-Results-Comparison.pptx

This meeting summary document can be found at:

CWE Private / Meeting Materials / 2015-Mar / MHDC-MeetingSummary\_2016Apr.pdf [Aaron to upload the meeting summary once it is complete]