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| **Joint Video Experts Team (JVET)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29**  22nd Meeting, by teleconference, 20–28 Apr. 2021 | Document: JVET-V\_Notes\_d1 |

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| *Title:* | **Meeting Report of the 22nd Meeting of the Joint Video Experts Team (JVET), by teleconference, 20–28 April 2021** | | |
| *Status:* | Report document from the chairs of JVET | | |
| *Purpose:* | Report | | |
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| *Source:* | Chairs of JVET | | |

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# Summary

The Joint Video Experts Team (JVET) of ITU-T WP3/16 and ISO/IEC JTC 1/ SC 29 held its twenty-second meeting during 20–28 April 2021 as an online-only meeting. It had previously been planned to be in Geneva, CH, but this plan was changed due to the difficulties resulting from the COVID-19 pandemic. For ISO/IEC purposes, JVET is alternatively designated ISO/IEC JTC 1/SC 29/WG 5, and this was the third meeting as WG 5. The JVET meeting was held under the chairmanship of Dr Gary Sullivan (Microsoft/USA) and Dr Jens-Rainer Ohm (RWTH Aachen/Germany). For rapid access to particular topics in this report, a subject categorization is found (with hyperlinks) in section 2.14 of this document. It is further noted that the unabbreviated name of JVET was formerly known as “Joint Video *Exploration* Team”, but the parent bodies modified it when entering the phase of formal development of Versatile Video Coding (VVC) in April 2018. Furthermore, starting from the twentieth meeting, work items which had originally been conducted by the Joint Collaborative Team on Video Coding (JCT-VC) were continued in JVET as a single joint team, and explorations towards possible future need of standardization in the area of video coding are also conducted by JVET, as negotiated by the parent bodies.

The JVET meeting began at approximately 1310 hours UTC on Tuesday 20 April 2021. Meeting sessions were held on all days except the weekend days of Saturday and Sunday 17 and 18 April 2021, until the meeting was closed at approximately XXXX hours UTC on Wednesday 28 April 2021. Approximately XXX people attended the JVET meeting, and approximately XX input documents (not counting crosschecks), 12 AHG reports, 3 CE/EE summary reports, and X BoG reports were discussed. The meeting took place in a coordinated fashion with a teleconference meeting of SG16 – one of the two parent bodies of the JVET, under whose auspices this JVET meeting was held. The subject matter of the JVET meeting activities consisted of work on further development and maintenance of the twin-text video coding technology standards *Advanced Video Coding* (AVC), *High Efficiency Video Coding* (HEVC), *Versatile Video Coding* (VVC)*, Coding-independent Code Points (Video)* (CICP), and *Versatile Supplemental Enhancement Information Messages for Coded Video Bitstreams* (VSEI), as well as related technical reports, software and conformance packages. As a primary goal, the JVET meeting reviewed the work that was performed in the interim period since the twenty-first JVET meeting in producing the following documents:

* JVET-U1000 Meeting report
* JVET-U1004 Errata report items for VVC, HEVC, AVC, Video CICP, and CP usage TR
* JVET-U1100 Common Test Conditions for HM Video Coding Experiments
* JVET-U2002 Algorithm description for Versatile Video Coding and Test Model 12 (VTM 12)
* JVET-U2005 New level and additional SEI messages for VVC (Draft 2)
* JVET-U2006 Additional SEI messages for VSEI (Draft 2)
* JVET-U2008 Conformance testing for versatile video coding (Draft 6)
* JVET-U2009 Reference software for versatile video coding (Draft 2)
* JVET-U2012 JVET common test conditions and evaluation procedures for 360° video
* JVET-U2016 Common Test Conditions and evaluation procedures for neural network-based video coding technology
* JVET-U2017 Common Test Conditions and evaluation procedures for enhanced compression tool testing
* JVET-U2018 Common Test Conditions for High Bit Depth and High Bit Rate Coding
* JVET-U2021 VVC verification test plan (Draft 5)
* JVET-U2022 CE on Entropy Coding for High Bit Depth and High Bit Rate Coding
* JVET-U2023 Exploration Experiment on Neural Network-based Video Coding
* JVET-U2024 Exploration Experiment on Enhanced Compression beyond VVC capability

Further important goals were reviewing the results of the CE on Entropy Coding for High Bit Depth and High Bit Rate Coding, of the EE on Neural Network-based Video Coding, of the EE on Enhanced Compression beyond VVC capability, of other technical input on novel aspects of video coding technology, and plan next steps for investigation of candidate technology towards further standard development.

The JVET produced XX output documents from the current meeting (update):

* JVET-U1004 Errata report items for VVC, HEVC, AVC, Video CICP, and CP usage TR
* JVET-U1100 Common Test Conditions for HM Video Coding Experiments
* JVET-U2002 Algorithm description for Versatile Video Coding and Test Model 12 (VTM 12)
* JVET-U2005 New level and additional SEI messages for VVC (Draft 2)
* JVET-U2006 Additional SEI messages for VSEI (Draft 2)
* JVET-U2008 Conformance testing for versatile video coding (Draft 6)
* JVET-U2009 Reference software for versatile video coding (Draft 2)
* JVET-U2012 JVET common test conditions and evaluation procedures for 360° video
* JVET-U2016 Common Test Conditions and evaluation procedures for neural network-based video coding technology
* JVET-U2017 Common Test Conditions and evaluation procedures for enhanced compression tool testing
* JVET-U2018 Common Test Conditions for High Bit Depth and High Bit Rate Coding
* JVET-U2021 VVC verification test plan (Draft 5)
* JVET-U2022 CE on Entropy Coding for High Bit Depth and High Bit Rate Coding
* JVET-U2023 Exploration Experiment on Neural Network-based Video Coding
* JVET-U2024 Exploration Experiment on Enhanced Compression beyond VVC capability

For the organization and planning of its future work, the JVET established XX “ad hoc groups” (AHGs) to progress the work on particular subject areas. At this meeting, X Core Experiment (CE) and X Exploration Experiments (EE) were defined. The next eight JVET meetings were planned for Wed. 7 – Fri. 16 July 2021, online under ISO/IEC SC 29 auspices, during Fri. 8 – Fri. 15 October 2021 under ISO/IEC SC 29 auspices in Antalya, TR, during January 2022 under ITU-T SG16 auspices in Geneva, CH, during Fri. 22 – Fri. 29 April 2022 under ISO/IEC SC 29 auspices in Miami, US, during Fri. 15 – Fri. 22 July 2022 under ISO/IEC SC 29 auspices in Cologne, DE, during October 2022 under ITU-T SG16 auspices in Geneva, CH, during January 2023 under ISO/IEC SC 29 auspices, location t.b.d., and during …

The document distribution site <https://jvet-experts.org/> was used for distribution of all documents. It was noted that the previous site <http://phenix.int-evry.fr/jvet/> is still accessible, but was converted to read-only.

The reflector to be used for discussions by the JVET and all its AHGs is the JVET reflector:  
[jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de) hosted at RWTH Aachen University. For subscription to this list, see <https://lists.rwth-aachen.de/postorius/lists/jvet.lists.rwth-aachen.de/>.

# Administrative topics

## Organization

The ITU-T/ISO/IEC Joint Video Experts Team (JVET) is a group of video coding experts from the ITU-T Study Group 16 Visual Coding Experts Group (VCEG) and the ISO/IEC JTC 1/SC 29/WG 5. The parent bodies of the JVET are ITU-T WP3/16 and ISO/IEC JTC 1/SC 29.

The Joint Video Experts Team (JVET) of ITU-T WP3/16 and ISO/IEC JTC 1/ SC 29 held its twenty-second meeting during 20–28 April 2021 as an online-only meeting, using Zoom teleconferencing tools. For ISO/IEC purposes, JVET is alternatively designated ISO/IEC JTC 1/SC 29/WG 5, and this was the third meeting as WG 5. The JVET meeting was held under the chairmanship of Dr Gary Sullivan (Microsoft/USA) and Dr Jens-Rainer Ohm (RWTH Aachen/Germany).

It is further noted that the unabbreviated name of JVET was formerly known as “Joint Video *Exploration* Team”, but the parent bodies modified it when entering the phase of formal development of the *Versatile Video Coding* (VVC) and *Versatile Supplemental Enhancement Information Messages for Coded Video Bitstreams* (VSEI) standards. Furthermore, starting from the twentieth meeting, work items which had originally been conducted by the Joint Collaborative Team on Video Coding (JCT-VC) were continued to be conducted in JVET as a single joint team, as negotiated by the parent bodies. This particularly consists of work on:

* *High Efficiency Video Coding* (HEVC) and its extensions, the development of associated conformance test sets, reference software, verification testing, and non-normative guidance information,
* Specification of *Coding-independent Code Points (Video)* (CICP), and associated technical report(s),
* Maintenance and minor enhancement work on the *Advanced Video Coding* (AVC) standard, associated conformance test sets and reference software.

Furthermore, explorations towards possible future need of standardization in the area of video coding are also conducted by JVET. Currently, the following topics are under investigation:

* Exploration on Neural Network-based Video Coding
* Exploration on Enhanced Compression beyond VVC capability

This report contains three important annexes, as follows:

* Annex A contains a list of the documents of the JVET meeting
* Annex B contains a list of the meeting participants, as recorded by the teleconferencing tool used for the meeting
* Annex C contains the meeting recommendations of ISO/IEC JTC 1/SC 29/WG 5 for purposes of results reporting to ISO/IEC.

## Meeting logistics

Information regarding logistics arrangements for the meeting had been provided via the email reflector [jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de) and at <http://wftp3.itu.int/av-arch/jvet-site/2022_04_V_Virtual/>.

## Primary goals

As a primary goal, the JVET meeting reviewed the work that was performed in the interim period since the twentieth JVET meeting in producing the following documents:

* JVET-U1004 Errata report items for VVC, HEVC, AVC, Video CICP, and CP usage TR
* JVET-U1100 Common Test Conditions for HM Video Coding Experiments
* JVET-U2002 Algorithm description for Versatile Video Coding and Test Model 12 (VTM 12)
* JVET-U2005 New level and additional SEI messages for VVC (Draft 2)
* JVET-U2006 Additional SEI messages for VSEI (Draft 2)
* JVET-U2008 Conformance testing for versatile video coding (Draft 6)
* JVET-U2009 Reference software for versatile video coding (Draft 2)
* JVET-U2012 JVET common test conditions and evaluation procedures for 360° video
* JVET-U2016 Common Test Conditions and evaluation procedures for neural network-based video coding technology
* JVET-U2017 Common Test Conditions and evaluation procedures for enhanced compression tool testing
* JVET-U2018 Common Test Conditions for High Bit Depth and High Bit Rate Coding
* JVET-U2021 VVC verification test plan (Draft 5)
* JVET-U2022 CE on Entropy Coding for High Bit Depth and High Bit Rate Coding
* JVET-U2023 Exploration Experiment on Neural Network-based Video Coding
* JVET-U2024 Exploration Experiment on Enhanced Compression beyond VVC capability

Further important goals were reviewing the results of the CE on Entropy Coding for High Bit Depth and High Bit Rate Coding, of the EE on Neural Network-based Video Coding, of the EE on Enhanced Compression beyond VVC capability, of other technical input on novel aspects of video coding technology, and plan next steps for investigation of candidate technology towards further standard development.

## Documents and document handling considerations

### General

The document distribution site <https://jvet-experts.org/> was used for distribution of all documents. It was noted that the previous site <http://phenix.int-evry.fr/jvet/> is still accessible, but was converted to read-only.

Registration timestamps, initial upload timestamps, and final upload timestamps are listed in Annex A of this report.

The document registration and upload times and dates listed in Annex A and in headings for documents in this report are in Paris/Geneva time. Dates mentioned for purposes of describing events at the meeting (other than as contribution registration and upload times) follow the local time at the meeting facility.

Highlighting of recorded decisions in this report is practised as follows:

* Decisions made by the group that might affect the normative content of a future standard are identified in this report by prefixing the description of the decision with the string “Decision:”.
* Decisions that affect one of the various software packages but have no normative effect are marked by the string “Decision (SW):”.
* Decisions that fix a “bug” in one of the test model descriptions such as VTM, HM, etc. (an error, oversight, or messiness) or in the associated software package are marked by the string “Decision (BF):”.
* Decisions that are merely editorial without effect on the technical content of a draft standard are marked by the string "Decision (Ed.):". Such editorial decisions are merely suggestions to the editor, who has the discretion to determine the final action taken if their judgment differs.

This meeting report is based primarily on notes taken by the JVET chairs. The preliminary notes were also circulated publicly by ftp and http during the meeting on a daily basis. It should be understood by the reader that 1) some notes may appear in abbreviated form, 2) summaries of the content of contributions are often based on abstracts provided by contributing proponents without an intent to imply endorsement of the views expressed therein, and 3) the depth of discussion of the content of the various contributions in this report is not uniform. Generally, the report is written to include as much information about the contributions and discussions as is feasible (in the interest of aiding study), although this approach may not result in the most polished output report.

### Late and incomplete document considerations

The formal deadline for registering and uploading non-administrative contributions had been announced as Tuesday, 13 April 2021. Any documents uploaded after 1159 hours Paris/Geneva time on Wednesday 14 April 2021 were considered “officially late”, giving a grace period of 12 hours to accommodate those living in different time zones of the world. The deadline does not apply to AHG reports, and other such reports which can only be produced after the availability of other input documents.

All contribution documents with registration numbers higher than JVET-V0133 were registered after the “officially late” deadline (and therefore were also uploaded late). However, some documents in the “late” range might include break-out activity reports that were generated during the meetings, and are therefore better considered as report documents rather than as late contributions. Also, all cross-check reports were uploaded late.

In many cases, contributions were also revised after the initial version was uploaded. The contribution document archive website retains publicly accessible prior versions in such cases. The timing of late document availability for contributions is generally noted in the section discussing each contribution in this report.

One suggestion to assist with the issue of late submissions was to require the submitters of late contributions and late revisions to describe the characteristics of the late or revised (or missing) material at the beginning of discussion of the contribution. This was agreed to be a helpful approach to be followed at the meeting.

The following technical design proposal contributions were registered and/or uploaded late:

* JVET-V0XXX (a proposal on …), uploaded 04-XX after deadline.
* ...

It may be observed that some of the above-listed contributions were submissions made in response to issues that arose in discussions during the meeting or from the study of other contributions, and thus could not have been submitted by the ordinary deadline.

The following other document not proposing normative technical content, but with some need for consideration, were registered and/or uploaded late:

* JVET-V0XXX (a document on …), uploaded 04-XX.
* …

All cross-verification reports at this meeting were registered late, and/or uploaded late. In the interest of brevity, these are not specifically identified here. Initial upload times for each document are recorded in Annex A of this report.

The following contribution registrations were noted that were later cancelled, withdrawn, never provided, were cross-checks of a withdrawn contribution, or were registered in error: JVET-V0154.

“Placeholder” contribution documents that were basically empty of content, or lacking any results showing benefit for the proposed technology, and obviously uploaded with an intent to provide a more complete submission as a revision, had been agreed to be considered unacceptable and to be rejected in the document management system until a more complete version was available (which would then typically be counted as a late contribution). At the current meeting, this situation did not apply.

Contributions that had significant problems with uploaded versions were not observed.

As a general policy, missing documents were not to be presented, and late documents (and substantial revisions) could only be presented when there was a consensus to consider them and there was sufficient time available for their review. Again, an exception is applied for AHG reports, CE and HLS topic summaries, and other such reports which can only be produced after the availability of other input documents. There were no objections raised by the group regarding presentation of late contributions, although there was some expression of annoyance and remarks on the difficulty of dealing with late contributions and late revisions.

It was remarked that documents that are substantially revised after the initial upload can also be a problem, as this becomes confusing, interferes with study, and puts an extra burden on synchronization of the discussion. This can especially be a problem in cases where the initial upload is clearly incomplete, and in cases where it is difficult to figure out what parts were changed in a revision. For document contributions, revision marking is very helpful to indicate what has been changed. Also, the “comments” field on the web site can be used to indicate what is different in a revision although participants tend to seldom notice what is recorded there.

A few contributions may have had some problems relating to IPR declarations in the initial uploaded versions (missing declarations, declarations saying they were from the wrong companies, etc.). These issues were corrected by later uploaded versions in a reasonably timely fashion in all cases (to the extent of the awareness of the responsible coordinators).

Some other errors were noticed in other initial document uploads (wrong document numbers or meeting dates or meeting locations in headers, etc.) which were generally sorted out in a reasonably timely fashion. The document web site contains an archive of each upload.

### Outputs of the preceding meeting

All output documents of the previous meeting, particularly the meeting report JVET-U1000, the Errata report items for VVC, VSEI, HEVC, AVC, Video CICP, and CP usage TR JVET-U1004, the Common Test Conditions for HM Video Coding Experiments JVET-U1100, the Algorithm description for Versatile Video Coding and Test Model 12 (VTM 12) JVET-U2002, the New level and additional SEI messages for VVC (Draft 2) JVET-U2005, the Additional SEI messages for VSEI (Draft 2) JVET-U2006, the Conformance testing for VVC (Draft 6) JVET-U2008, the Reference software for versatile video coding (Draft 2) JVET-U2009, the JVET common test conditions and evaluation procedures for 360° video JVET-U2012, the Common Test Conditions and evaluation procedures for neural network-based video coding technology JVET-U2016, the Common Test Conditions and evaluation procedures for enhanced compression tool testing JVET-U2017, the Common test conditions for high bit depth and high bit rate video coding JVET-U2018, the VVC verification test plan (Draft 5) JVET-U2021, the Description of the CE on Entropy Coding for High Bit Depth and High Bit Rate Coding JVET-U2022, the Description of the EE on Neural Network-based Video Coding JVET-U2023, and the Description of the EE on Enhanced Compression beyond VVC capability JVET-U2024 had been completed and were approved. The software implementations of VTM (versions 12.0 and 12.1) , HM 16.23, and HDRTools (versions 0.20 and 0.21) were also approved.

The available output documents of the previous meeting and the software had been made available in a reasonably timely fashion.

## Attendance

The list of participants in the JVET meeting can be found in Annex B of this report.

The meeting was open to those qualified to participate either in ITU-T WP3/16 or ISO/IEC JTC 1/‌SC 29/‌WG 5 (including experts who had been personally invited as permitted by ITU-T or ISO/IEC policies).

Participants had been reminded of the need to be properly qualified to attend. Those seeking further information regarding qualifications to attend future meetings may contact the responsible coordinators.

It was further announced that it is necessary to register for the meeting through the ISO Meetings website for ISO/IEC experts or through the Q6/16 rapporteur for ITU-T experts. The password had been sent to registered participants via these channels. Links to the Zoom sessions (without password) were available in the posted meeting logistics information and the calendar of meeting sessions in the JVET web site. No particular problems were observed that resulted in interference with the meeting, nor was anybody identified who would have attended sessions without being authorized.

The following rules were initially set up for the Zoom teleconference meeting:

* Use the “hand-raising” function to enter yourself in the queue to speak (unless otherwise instructed by the session chair). If you are dialed in by phone, request your queue position verbally.
* Stay muted unless you have something to say. People were muted by default when they join and would need to unmute themselves to speak. The chair may mute anyone who is disrupting the proceedings (e.g. by forgetting they have a live microphone while chatting with their family or by causing bad noise or echo).
* Identify who you are and your affiliation when you begin speaking.
* Use your full name and company/organization affiliation in your joining information, as the participation list of Zoom would also be used to compile attendance records.
* Turn on the chat window and watch for chair communication and side commentary there as well as by audio.
* Avoid overloading people’s internet connections by not using video for the teleconferencing calls – only voice and screen sharing. Extensive use of screen sharing is encouraged.

## Agenda

The agenda for the meeting, for the further development and maintenance of the twin-text video coding technology standards *Advanced Video Coding* (AVC), *High Efficiency Video Coding* (HEVC), *Versatile Video Coding* (VVC)*, Coding-independent Code Points (Video)* (CICP), and *Versatile Supplemental Enhancement Information Messages for Coded Video Bitstreams* (VSEI), as well as related technical reports, software and conformance packages, was as follows:

* Opening remarks and review of meeting logistics and communication practices
* Code of conduct policy reminder
* IPR policy reminder and declarations
* Contribution document allocation
* Review of results of the previous meeting
* Reports of *ad hoc* group (AHG) activities
* Report of core experiment on entropy coding for high bit depth and high bit rate coding
* Report of exploration experiments on neural-network-based video coding
* Report of exploration experiments on enhanced compression beyond VVC capability
* Consideration of contributions on high-level syntax
* Consideration of contributions and communications on project guidance
* Consideration of video coding technology contributions
* Consideration of contributions on conformance and reference software development
* Consideration of contributions on coding-independent code points for video signal type identification
* Consideration of contributions on errata relating to standards in the domain of JVET
* Consideration of contributions on technical reports relating to standards and exploration study activities in the domain of JVET
* Consideration of contributions providing non-normative guidance relating to standards and exploration study activities in the domain of JVET
* Consideration of information contributions
* Coordination of visual quality testing
* Coordination activities with other organizations
* Approval of output documents and associated editing periods
* Future planning: Determination of next steps, discussion of working methods, communication practices, establishment of coordinated experiments (if any), establishment of AHGs, meeting planning, other planning issues
* Other business as appropriate for consideration

The plans for the times of meeting sessions were established as follows, in UTC (2 hours behind the time in Geneva, Paris; 7 hours ahead of the time in Los Angeles, etc.). No session should last longer than 2 hrs.

* 1300–1500 1st “afternoon” session [break after 2 hours]
* 1520–1720 2nd “afternoon” session
* [“evening” break – nearly 4 hours]
* 2100–2300 1st “night” session [break after 2 hours]
* 2320–0120+1 2nd “night” session

It was also pointed out that the session times had been changed from meeting to meeting, such that different time zones of the world might be treated approximately equally fair either in one meeting or another. For the current meeting, the same session times were used as in the 19th JVET meeting (which used to be the second meeting conducted as online meeting)

* 1. ***ISO Code of Conduct reminder***

Participants were reminded of the ISO Code of Conduct, found at [Ed. (GJS): Add IEC code of conduct]

<https://www.iso.org/publication/PUB100397.html>.

This includes points relating to:

* Respecting others
* Behaving ethically
* Escalating and resolving disputes
* Working for the net benefit of the international community
* Upholding consensus and governance
* Agreeing to a clear purpose and scope
* Participating actively and managing effective representation

## IPR policy reminder

Participants were reminded of the IPR policy established by the parent organizations of the JVET and were referred to the parent body websites for further information. The IPR policy was summarized for the participants.

The ITU-T/ITU-R/ISO/IEC common patent policy shall apply. Participants were particularly reminded that contributions proposing normative technical content shall contain a non-binding informal notice of whether the submitter may have patent rights that would be necessary for implementation of the resulting standard. The notice shall indicate the category of anticipated licensing terms according to the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form.

This obligation is supplemental to, and does not replace, any existing obligations of parties to submit formal IPR declarations to ITU-T/ITU-R/ISO/IEC.

Participants were also reminded of the need to formally report patent rights to the top-level parent bodies (using the common reporting form found on the database listed below) and to make verbal and/or document IPR reports within the JVET necessary in the event that they are aware of unreported patents that are essential to implementation of a standard or of a draft standard under development.

Some relevant links for organizational and IPR policy information are provided below:

* <http://www.itu.int/ITU-T/ipr/index.html> (common patent policy for ITU-T, ITU-R, ISO, and IEC, and guidelines and forms for formal reporting to the parent bodies)
* <http://ftp3.itu.int/av-arch/jvet-site> (JVET contribution templates)
* <http://www.itu.int/ITU-T/dbase/patent/index.html> (ITU-T IPR database)
* <http://www.itscj.ipsj.or.jp/sc29/29w7proc.htm> (JTC 1/‌SC 29 Procedures)

It is noted that the ITU TSB director’s AHG on IPR had issued a clarification of the IPR reporting process for ITU-T standards, as follows, per SG 16 TD 327 (GEN/16):

“TSB has reported to the TSB Director’s IPR Ad Hoc Group that they are receiving Patent Statement and Licensing Declaration forms regarding technology submitted in Contributions that may not yet be incorporated in a draft new or revised Recommendation. The IPR Ad Hoc Group observes that, while disclosure of patent information is strongly encouraged as early as possible, the premature submission of Patent Statement and Licensing Declaration forms is not an appropriate tool for such purpose.

In cases where a contributor wishes to disclose patents related to technology in Contributions, this can be done in the Contributions themselves, or informed verbally or otherwise in written form to the technical group (e.g. a Rapporteur’s group), disclosure which should then be duly noted in the meeting report for future reference and record keeping.

It should be noted that the TSB may not be able to meaningfully classify Patent Statement and Licensing Declaration forms for technology in Contributions, since sometimes there are no means to identify the exact work item to which the disclosure applies, or there is no way to ascertain whether the proposal in a Contribution would be adopted into a draft Recommendation.

Therefore, patent holders should submit the Patent Statement and Licensing Declaration form at the time the patent holder believes that the patent is essential to the implementation of a draft or approved Recommendation.”

The responsible coordinators invited participants to make any necessary verbal reports of previously-unreported IPR in technology that might be considered as prospective candidate for inclusion in future standards, and opened the floor for such reports: No such verbal reports were made.

## Software copyright disclaimer header reminder

It was noted that the VTM software implementation package uses the same software copyright license header as the HEVC reference software, where the latter had been agreed at the 5th meeting of the JCT-VC and approved by both parent bodies at their collocated meetings at that time. This license header language is based on the BSD license with a preceding sentence declaring that other contributor or third party rights, including patent rights, are not granted by the license, as recorded in [N 10791](http://phenix.it-sudparis.eu/mpeg/doc_end_user/current_document.php?id=27881&id_meeting=16) of the 89th meeting of ISO/IEC JTC 1/‌SC 29/‌WG 11. Both ITU and ISO/IEC will be identified in the <OWNER> and <ORGANIZATION> tags in the header. This software is used in the process of designing the VTM software, and for evaluating proposals for technology to be potentially included in the design. This software or parts thereof might be published by ITU-T and ISO/IEC as an example implementation of a future video coding standard and for use as the basis of products to promote adoption of such technology.

Different copyright statements shall not be committed to the committee software repository (in the absence of subsequent review and approval of any such actions). As noted previously, it must be further understood that any initially-adopted such copyright header statement language could further change in response to new information and guidance on the subject in the future.

These considerations apply to the 360Lib video conversion software and HDRTools as well.

Software packages that had been developed in prior work of the JCT-VC have similar considerations and are maintained according to the past practice in that work.

## Communication practices

The documents for the meeting can be found at <https://jvet-experts.org/>. It was noted that the previous site <http://phenix.int-evry.fr/jvet/> is still accessible, but was converted to read-only. It was reminded to send a notice to the chairs in cases of changes to document titles, authors etc.

JVET email lists are managed through the site <https://lists.rwth-aachen.de/postorius/lists/jvet.lists.rwth-aachen.de/>, and to send email to the reflector, the email address is [jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de). Only members of the reflector can send email to the list. However, membership of the reflector is not limited to qualified JVET participants.

It was emphasized that reflector subscriptions and email sent to the reflector must use real names when subscribing and sending messages and subscribers must respond to inquiries regarding the nature of their interest in the work. The current number of subscribers on the JVET email list was 1300. Furthermore, the JCT-VC email list currently had 1293 subscribers (as of 20 April 2021). Future discussions should be conducted on the JVET reflector rather than the JCT-VC reflector (or JVT reflector), while the old reflectors should be retained for archiving purposes.

For distribution of test sequences, a password-protected ftp site had been set up at RWTH Aachen University, with a mirror site at FhG-HHI. Accredited members of JVET may contact the responsible JVET coordinators to obtain the password information (but the site is not open for use by others).

## Terminology

* **ACT**: Adaptive colour transform
* **AFF**: Adaptive frame-field
* **AI**: All-intra
* **AIF**: Adaptive interpolation filtering
* **ALF**: Adaptive loop filter
* **AMP**: Asymmetric motion partitioning – a motion prediction partitioning for which the sub-regions of a region are not equal in size (in HEVC, being N/2x2N and 3N/2x2N or 2NxN/2 and 2Nx3N/2 with 2N equal to 16 or 32 for the luma component)
* **AMVP**: Adaptive motion vector prediction
* **AMT or MTS**: Adaptive multi-core transform, or multiple transform selection
* **AMVR**: (Locally) adaptive motion vector resolution
* **APS**: Adaptation parameter set
* **ARC**: Adaptive resolution conversion (synonymous with DRC, and a form of RPR)
* **ARSS**: Adaptive reference sample smoothing
* **ATMVP** or “subblock-based temporal merging candidates”: Alternative temporal motion vector prediction
* **AU**: Access unit
* **AUD**: Access unit delimiter.
* **AVC**: Advanced video coding – the video coding standard formally published as ITU-T Recommendation H.264 and ISO/IEC 14496-10.
* **BA**: Block adaptive.
* **BC**: See CPR or IBC.
* **BCW**: Biprediction with CU based weighting
* **BD**: Bjøntegaard-delta – a method for measuring percentage bit rate savings at equal PSNR or decibels of PSNR benefit at equal bit rate (e.g., as described in document VCEG-M33 of April 2001).
* **BDOF**: Bi-directional optical flow (formerly known as **BIO**).
* **BDPCM**: Block-wise DPCM.
* **BL**: Base layer.
* **BMS**: Benchmark set (no longer used), a former preliminary compilation of coding tools on top of VTM, which provide somewhat better compression performance, but are not deemed mature for standardzation.
* **BoG**: Break-out group.
* **BR**: Bit rate.
* **BT**: Binary tree.
* **BV**: Block vector (used for intra BC prediction).
* **CABAC**: Context-adaptive binary arithmetic coding.
* **CBF**: Coded block flag(s).
* **CC**: May refer to context-coded, common (test) conditions, or cross-component.
* **CCALF**: Cross-component ALF.
* **CCLM**: Cross-component linear model.
* **CCP**: Cross-component prediction.
* **CE**: Core Experiment – a coordinated experiment conducted toward assessment of coding technology.
* **CG**: Coefficient group.
* **CGS**: Colour gamut scalability (historically, coarse-grained scalability).
* **CIIP**: Combined inter/intra prediction.
* **CL-RAS**: Cross-layer random-access skip.
* **CPB**: Coded picture buffer.
* **CPMV**: Control-point motion vector.
* **CPMVP**: Control-point motion vector prediction (used in affine motion model).
* **CPR**: Current-picture referencing, also known as IBC – a technique by which sample values are predicted from other samples in the same picture by means of a displacement vector called a block vector, in a manner conceptually similar to motion-compensated prediction.
* **CST**: Chroma separate tree.
* **CTC**: Common test conditions.
* **CVS**: Coded video sequence.
* **DCI**: Decoder capability information.
* **DCT**: Discrete cosine transform (sometimes used loosely to refer to other transforms with conceptually similar characteristics).
* **DCTIF**: DCT-derived interpolation filter.
* **DF**: Deblocking filter.
* **DMVR**: Decoder-side motion vector refinement.
* **DoCR**: Disposition of comments report.
* **DPB**: Decoded picture buffer.
* **DPCM**: Differential pulse-code modulation.
* **DPS**: Decoding parameter sets.
* **DRC**: Dynamic resolution conversion (synonymous with ARC, and a form of RPR).
* **DT**: Decoding time.
* **DQ**: Dependent quantization.
* **ECS**: Entropy coding synchronization (typically synonymous with WPP).
* **EMT**: Explicit multiple-core transform.
* **EOTF**: Electro-optical transfer function – a function that converts a representation value to a quantity of output light (e.g., light emitted by a display.
* **EPB**: Emulation prevention byte (as in the emulation\_prevention\_byte syntax element).
* **ECV**: Extended Colour Volume (up to WCG).
* **EL**: Enhancement layer.
* **EOS**: End of (coded video) sequence.
* **ET**: Encoding time.
* **FRUC**: Frame rate up conversion (pattern matched motion vector derivation).
* **GCI**: General constraints information.
* **GDR**: Gradual decoding refresh.
* **GOP**: Group of pictures (somewhat ambiguous).
* **GPM**: Geometry partitioning mode
* **GRA**: Gradual random access
* **HBD**: High bit depth
* **HDR**: High dynamic range.
* **HEVC**: High Efficiency Video Coding – the video coding standard developed and extended by the JCT-VC, formalized by ITU-T as Rec. ITU-T H.265 and by ISO/IEC as ISO/IEC 23008-2.
* **HLS**: High-level syntax.
* **HM**: HEVC Test Model – a video coding design containing selected coding tools that constitutes our draft standard design – now also used especially in reference to the (non-normative) encoder algorithms (see WD and TM).
* **HMVP**: History based motion vector prediction.
* **HRD**: Hypothetical reference decoder.
* **HyGT**: Hyper-cube Givens transform (a type of NSST).
* **IBC** (also **Intra BC**): Intra block copy, also known as CPR – a technique by which sample values are predicted from other samples in the same picture by means of a displacement vector called a block vector, in a manner conceptually similar to motion-compensated prediction.
* **IBDI**: Internal bit-depth increase – a technique by which lower bit-depth (8 bits per sample) source video is encoded using higher bit-depth signal processing, ordinarily including higher bit-depth reference picture storage (ordinarily 12 bits per sample).
* **IBF**: Intra boundary filtering.
* **ILP**: Inter-layer prediction (in scalable coding).
* **ILRP**: Inter-layer reference picture.
* **IPCM**: Intra pulse-code modulation (similar in spirit to IPCM in AVC and HEVC).
* **IRAP**: Intra random access picture.
* **ISP**: Intra subblock partitioning
* **JCCR**: Joint coding of chroma residuals
* **JEM**: Joint exploration model – the software codebase for future video coding exploration.
* **JM**: Joint model – the primary software codebase that has been developed for the AVC standard.
* **JSVM**: Joint scalable video model – another software codebase that has been developed for the AVC standard, which includes support for scalable video coding extensions.
* **KLT**: Karhunen-Loève transform.
* **LB** or **LDB**: Low-delay B – the variant of the LD conditions that uses B pictures.
* **LD**: Low delay – one of two sets of coding conditions designed to enable interactive real-time communication, with less emphasis on ease of random access (contrast with RA). Typically refers to LB, although also applies to LP.
* **LFNST**: Low-frequency non-separable transform
* **LIC**: Local illumination compensation.
* **LM**: Linear model.
* **LMCS**: Luma mapping with chroma scaling (formerly sometimes called “in-loop reshaping”)
* **LP** or **LDP**: Low-delay P – the variant of the LD conditions that uses P frames.
* **LUT**: Look-up table.
* **LTRP**: Long-term reference picture.
* **MANE**: Media-aware network element.
* **MC**: Motion compensation.
* **MCP**: Motion compensated prediction.
* **MCTF**: Motion compensated temporal pre-filtering.
* **MDNSST**: Mode dependent non-separable secondary transform.
* **MIP**: Matrix-based intra prediction
* **MMLM**: Multi-model (cross component) linear mode.
* **MMVD**: Merge with MVD.
* **MPEG**: Moving picture experts group (an alliance of working groups and advisory groups in ISO/IEC JTC 1/‌SC 29, one of the two parent bodies of the JVET).
* **MPM**: Most probable mode (in intra prediction).
* **MRL**: Multiple reference line intra prediction.
* **MV**: Motion vector.
* **MVD**: Motion vector difference.
* **NAL**: Network abstraction layer.
* **NSQT**: Non-square quadtree.
* **NSST**: Non-separable secondary transform.
* **NUH**: NAL unit header.
* **NUT**: NAL unit type (as in AVC and HEVC).
* **OBMC**: Overlapped block motion compensation (e.g., as in H.263 Annex F).
* **OETF**: Opto-electronic transfer function – a function that converts to input light (e.g., light input to a camera) to a representation value.
* **OLS**: Output layer set.
* **OOTF**: Optical-to-optical transfer function – a function that converts input light (e.g. l,ight input to a camera) to output light (e.g., light emitted by a display).
* **operation point**: A temporal subset of an OLS.
* **PDPC**: Position-dependent (intra) prediction combination.
* **PERP**: Padded equirectangular projection (a 360° projection format).
* **PH**: Picture header.
* **PHEC**: Padded hybrid equiangular cubemap (a 360° projection format).
* **PMMVD**: Pattern-matched motion vector derivation.
* **POC**: Picture order count.
* **PoR**: Plan of record.
* **PROF**: Prediction refinement with optical flow
* **PPS**: Picture parameter set (as in AVC and HEVC).
* **PTL**: Profile/tier/level combination.
* **QM**: Quantization matrix (as in AVC and HEVC).
* **QP**: Quantization parameter (as in AVC and HEVC, sometimes confused with quantization step size).
* **QT**: Quadtree.
* **RA**: Random access – a set of coding conditions designed to enable relatively-frequent random access points in the coded video data, with less emphasis on minimization of delay (contrast with LD).
* **RADL**: Random-access decodable leading (type of picture).
* **RASL**: Random-access skipped leading (type of picture).
* **R-D**: Rate-distortion.
* **RDO**: Rate-distortion optimization.
* **RDOQ**: Rate-distortion optimized quantization.
* **RDPCM**: Residual DPCM
* **ROT**: Rotation operation for low-frequency transform coefficients.
* **RPL**: Reference picture list.
* **RPLM**: Reference picture list modification.
* **RPR**: Reference picture resampling (e.g., as in H.263 Annex P), a special case of which is also known as ARC or DRC.
* **RPS**: Reference picture set.
* **RQT**: Residual quadtree.
* **RRU**: Reduced-resolution update (e.g. as in H.263 Annex Q).
* **RVM**: Rate variation measure.
* **SAO**: Sample-adaptive offset.
* **SBT**: Subblock transform.
* **SbTMVP**: Subblock based temporal motion vector prediction.
* **SCIPU**: Smallest chroma intra prediction unit.
* **SD**: Slice data; alternatively, standard-definition.
* **SDH**: Sign data hiding.
* **SDT**: Signal-dependent transform.
* **SE**: Syntax element.
* **SEI**: Supplemental enhancement information (as in AVC and HEVC).
* **SH**: Slice header.
* **SHM**: Scalable HM.
* **SHVC**: Scalable high efficiency video coding.
* **SIF**: Switchable (motion) interpolation filter.
* **SIMD**: Single instruction, multiple data.
* **SMVD**: Symmetric MVD.
* **SPS**: Sequence parameter set (as in AVC and HEVC).
* **STMVP**: Spatial-temporal motion vector prediction.
* **STRP**: Short-term reference picture.
* **STSA**: Step-wise temporal sublayer access.
* **TBA/TBD/TBP**: To be announced/determined/presented.
* **TGM**: Text and graphics with motion – a category of content that primarily contains rendered text and graphics with motion, mixed with a relatively small amount of camera-captured content.
* **TMVP**: Temporal motion vector prediction.
* **TS**: Transform skip.
* **TSRC**: Transform skip residual coding.
* **TT**: Ternary tree.
* **UCBDS**: Unrestricted center-biased diamond search.
* **UGC**: User-generated content.
* **UWP**: Unequal weight prediction.
* **VCEG**: Visual coding experts group (ITU-T Q.6/16, the relevant rapporteur group in ITU-T WP3/16, which is one of the two parent bodies of the JVET).
* **VPS**: Video parameter set – a parameter set that describes the overall characteristics of a coded video sequence – conceptually sitting above the SPS in the syntax hierarchy.
* **VQA**: Visual quality assessment.
* **VT**: Verification testing.
* **VTM**: VVC Test Model.
* **VUI**: Video usability information.
* **VVC**: Versatile Video Coding, the standardization project developed by JVET.
* **WAIP**: Wide-angle intra prediction
* **WCG**: Wide colour gamut.
* **WG**: Working group, a group of technical experts (usually used to refer to WG 11, a.k.a. MPEG).
* **WPP**: Wavefront parallel processing (usually synonymous with ECS).
* Block and unit names in HEVC:
  + **CTB**: Coding tree block (luma or chroma) – unless the format is monochrome, there are three CTBs per CTU.
  + **CTU**: Coding tree unit (containing both luma and chroma, synonymous with LCU), with a size of 16x16, 32x32, or 64x64 for the luma component.
  + **CB**: Coding block (luma or chroma), a luma or chroma block in a CU.
  + **CU**: Coding unit (containing both luma and chroma), the level at which the prediction mode, such as intra versus inter, is determined in HEVC, with a size of 2Nx2N for 2N equal to 8, 16, 32, or 64 for luma.
  + **PB**: Prediction block (luma or chroma), a luma or chroma block of a PU, the level at which the prediction information is conveyed or the level at which the prediction process is performed in HEVC.
  + **PU**: Prediction unit (containing both luma and chroma), the level of the prediction control syntax within a CU, with eight shape possibilities in HEVC:
    - **2Nx2N**: Having the full width and height of the CU.
    - **2NxN (or Nx2N)**: Having two areas that each have the full width and half the height of the CU (or having two areas that each have half the width and the full height of the CU).
    - **NxN**: Having four areas that each have half the width and half the height of the CU, with N equal to 4, 8, 16, or 32 for intra-predicted luma and N equal to 8, 16, or 32 for inter-predicted luma – a case only used when 2N×2N is the minimum CU size.
    - **N/2x2N** paired with **3N/2x2N** or **2NxN/2** paired with **2Nx3N/2**: Having two areas that are different in size – cases referred to as AMP, with 2N equal to 16 or 32 for the luma component.
  + **TB**: Transform block (luma or chroma), a luma or chroma block of a TU, with a size of 4x4, 8x8, 16x16, or 32x32.
  + **TU**: Transform unit (containing both luma and chroma), the level of the residual transform (or transform skip or palette coding) segmentation within a CU (which, when using inter prediction in HEVC, may sometimes span across multiple PU regions).
* Block and unit names in VVC:
  + **CTB**: Coding tree block (luma or chroma) – there are three CTBs per CTU in a P or B slice or in an I slice that uses a single tree, and one CTB per luma CTU and two CTBs per chroma CTU in an I slice that uses separate trees.
  + **CTU**: Coding tree unit (synonymous with LCU, containing both luma and chroma in a P or B slice or in an I slice that uses a single tree, containing only luma or only chroma in an I slice that uses separate trees), with a size of 16x16, 32x32, 64x64, or 128x128 for the luma component.
  + **CB**: Coding block, a luma or chroma block in a CU.
  + **CU**: Coding unit (containing both luma and chroma in P/B slice, containing only luma or chroma in I slice), a leaf node of a QTBT. It’s the level at which the prediction process and residual transform are performed in JEM. A CU can be square or rectangle shape.
  + **PB**: Prediction block, a luma or chroma block of a PU.
  + **PU**: Prediction unit, has the same size as a CU in the VVC context.
  + **TB**: Transform block, a luma or chroma block of a TU.
  + **TU**: Transform unit, has the same size as a CU in the VVC context.

## Opening remarks

Remarks during the opening session of the meeting Tuesday 20 April at 1300 UTC (chaired by GJS and JRO) were as follows.

* Timing and organization of online meetings, calendar
* Standards publication status – to be updated (with dates)
  + Working practices TR published in ISO/IEC and ITU-T
  + HEVC Amd.1 (additional SEI) and Amd.2 (shutter interval) in final publication stage in ISO/IEC
  + CICP usage 3rd ed. clarify publication status
  + The following freely available standards published here in ISO/IEC:  
    <https://standards.iso.org/ittf/PubliclyAvailableStandards/index.html>
    - ISO/IEC 23002-7:2021, 1st edition
    - ISO/IEC 23008-2:2020, 4th edition
    - ISO/IEC 23090-3:2021, 1st edition
    - ISO/IEC 23091-2:2019, 1st edition
* Draft standards progression status
  + VVC conformance – DIS ballot to be started soon, FDIS in October
  + VVC reference SW – DIS ballot to be started soon, FDIS in October
  + AVC additional SEI – CDAM this meeting, new draft 3
  + VSEI extensions – CDAM this meeting, new draft
  + VVC operation range extensions – CDAM this meeting, new draft
  + CICP v2 – FDIS in ISO/IEC and ITU-T consent this meeting (include errata items)
  + Further consent items for ITU-T:
    - HEVC shutter interval SEI and errata items
    - AVC annotated regions and shutter interval SEI messages, and errata items
    - CICP usage TR 3rd ed.
  + The request for free availability in ISO/IEC has to be made for each Edition, Amendment and Corrigendum, and these will also need a request form to be filled and be approved in the Recommendations. Freely available URL on ITU part should be provided for the following parts:
    - ISO/IEC 23008-2:2020/Amd 1 and Amd 2?
    - ISO/IEC DIS 23091-2, 2nd edition
    - ISO/IEC 23002-7:2021/Amd 1 – could be later
    - ISO/IEC 23090-3:2021/Amd 1 – could be later
* The meeting logistics, agenda, working practices, policies, and document allocation were reviewed.
  + The meeting is conducted using Zoom
  + Having text and software available is crucial (and not just arriving at the end of the meeting).
  + There were no objections voiced in the opening plenary to the consideration of late contributions.
* The results of the previous meeting and the meeting report were reviewed.
* There was somewhat less of a problem of late non-cross-check documents and no “placeholders” (see section 2.4.2).
* The primary goals of the meeting were
  + Errata
  + Conformance and software for VVC & VSEI
  + Verification test planning
  + Extensions of VVC
    - High bit rate / high bit depth
  + Additional SEI messages for VSEI
  + Explorations
    - Neural network based video coding
    - Enhanced compression beyond VVC
* Funding of verification testing activities: Thank resolution, resolution calling for funding wrt upcoming tests.
* Conformance: Thank resolution to companies who provided bitstreams
* Liaisons?
* Number of documents increased, but if possible not conduct sessions in parallel
* Scheduling was discussed
* Principles of standards development were discussed.

## Scheduling of discussions

The plans for the times of meeting sessions were established as follows, in UTC (2 hours behind the time in Geneva, Paris; 7 hours ahead of the time in Los Angeles, etc.). No session should last longer than 2 hrs.

* 1300–1500 1st “afternoon” session [break after 2 hours]
* 1520–1720 2nd “afternoon” session
* [“evening” break – nearly 4 hours]
* 2100–2300 1st “night” session [break after 2 hours]
* 2320–0120+1 2nd “night” session

Sessions were announced via the calendar in the JVET document site at least 22 hrs. in advance. Particular scheduling notes are shown below, although not necessarily 100% accurate or complete:

* Tue. 20 April, 1st day
  + Session 1:
    - 1310–1350 Opening remarks, review of practices, agenda, IPR reminder
    - 1400–1510 Reports of AHGs 1–5
  + Session 2:
    - 1530–1720 Reports of AHGs 6–12
  + Session 3:
    - 2100–2300 Review of CE and related
  + Session 4:
    - 2320–0120 Review of CE and related
* Wed. 21 April, 2nd day
  + Session 5:
    - 1430-1540 Review of CE and related
  + Session 6:
    - 1600-1720 Review of CE and related
  + Session 7:
    - 2100-2300 Review of EE1 and related
  + Session 8:
    - 2320-0120 Review of EE1 and related
* Thu. 22 April, 3rd day
  + Session 9:
    - …

## Contribution topic overview

The approximate subject categories and quantity of contributions per category for the meeting were summarized as follows (note that the noted document counts do not include crosschecks, and may not be completely accurate):

* AHG reports (section 3)
* Project development (section 4)
  + Deployment of standards (3)
  + Text development and errata reporting (2)
  + Test conditions (1)
  + Verification testing (4)
  + Test Material (1)
  + Quality assessment (1)
  + Conformance test development (0)
  + Software development (1)
  + Implementation studies (5)
  + Complexity analysis (0)
  + Encoder optimization (4)
  + Profile/tier/level specification (0) – Joint Meeting
* Low-level tool technology proposals (section 5) with subtopics
  + AHG8: High bit depth and high bit rate coding (25) (section 5.1)
  + AHG11: Neural network-based technology (18) (section 5.2)
  + AHG12: Enhanced compression beyond VVC capability (26) (section 5.3)
* High-level syntax (HLS) proposals (section 6) with subtopics
  + AHG9: SEI message studies and proposals (11) (section 6.1)
  + Non-SEI HLS aspects (4) (section 6.2)
* Joint meetings, plenary discussions, BoG reports (1), summary of actions (section 7)
* Project planning (section 8)
* Establishment of AHGs (section 9)
* Output documents (section 10)
* Future meeting plans and concluding remarks (section 11)

The document counts above do not include cross-checks and summary reports.

# AHG reports (12)

These reports were discussed Tuesday 20 April 2021 during 1400–1510 UTC and 1530-1720 UTC (chaired by GJS & JRO)

[JVET-V0001](https://jvet-experts.org/doc_end_user/current_document.php?id=10779) JVET AHG report: Project management (AHG1) [J.-R. Ohm, G. J. Sullivan]

The work of the JVET overall had proceeded well in the interim period with an increased number of input documents (as compared to the previous two meetings) submitted to the current meeting. Intense discussion had been carried out on the group email reflector, and all output documents from the preceding meeting had been produced.

Output documents from the preceding meeting had been made initially available at the JVET web site (<https://jvet-experts.org/>) or the ITU-based JVET site (<http://wftp3.itu.int/av-arch/jvet-site/2021_01_U_Virtual/>). It is noted that the previous document site <http://phenix.int-evry.fr/jvet/> is still accessible, but was converted to read-only.

The list of documents produced included the following, particularly:

* The meeting report (JVET-U1000) [Posted 2021-02-12]
* Errata report items for VVC, HEVC, AVC, Video CICP, and CP usage TR (JVET-U1004) [Posted 2021-03-05]
* Common Test Conditions for HM Video Coding Experiments (JVET-U1100) [Posted 2021-02-08, last update 2021-02-16]
* Algorithm description for Versatile Video Coding and Test Model 12 (VTM 12) (JVET-U2002) [Posted 2021-04-12]
* New level and additional SEI messages for VVC (Draft 2) (JVET-U2005) [Posted 2021-03-05]
* Additional SEI messages for VSEI (Draft 2) (JVET-U2006) [Posted 2021-03-05]
* Conformance testing for versatile video coding (Draft 6) (JVET-U2008) [Posted 2021-03-31]
* Reference software for versatile video coding (Draft 2) (JVET-U2009) [Posted 2021-04-20]
* JVET common test conditions and evaluation procedures for 360° video (JVET-U2012) [Posted 2021-03-16]
* Common Test Conditions and evaluation procedures for neural network-based video coding technology (JVET-U2016) [Posted 2021-02-03, last update 2021-02-06]
* Common Test Conditions and evaluation procedures for enhanced compression tool testing (JVET-U2017) [Posted 2021-01-29]
* Common Test Conditions for High Bit Depth and High Bit Rate Coding (JVET-U2018) [Posted 2021-01-16, last update 2021-01-29]
* VVC verification test plan (Draft 5) (JVET-U2021) [Posted 2021-03-02]
* CE on Entropy Coding for High Bit Depth and High Bit Rate Coding (JVET-U2022) [Posted 2021-01-15, last update 2021-03-26]
* EE on Neural Network-based Video Coding (JVET-U2023) [Posted 2021-01-15, last update 2021-01-29]
* EE on Enhanced Compression beyond VVC capability (JVET-U2024) [Posted 2021-01-16, last update 2021-02-17]

The twelve *ad hoc* groups had made progress, and reports from those activities had been submitted. Furthermore, one core experiment (CE) on entropy coding for high bit depth and high bit rate coding, and two exploration experiments (EE) on neural network-based video coding and on enhanced compression beyond VVC capability, were conducted.

Due to issues associated with the COVID-19 pandemic, a conversion of the meeting to be conducted only online was again necessitated.

During the interim period, two meetings of AHG4 (for preparing the verification tests), and two meetings of AHG11 (for discussing the exploration experiment on neural network-based video coding), were held.

Software integration was finalized approximately according to the plan. Significant activities were also conducted on preparation of verification tests, and on development of VVC conformance testing.

Various problem reports relating to asserted bugs in the software, draft specification text, and reference encoder description had been submitted to an informal "bug tracking" system. That system is not intended as a replacement of our ordinary contribution submission process. However, the bug tracking system was considered to have been helpful to the software coordinators and text editors. The bug tracker reports had been automatically forwarded to the group email reflector, where the issues were discussed – and this is reported to have been helpful.

Roughly 100 input contributions (not counting the AHG, CE and EE summary reports and crosschecks) had been registered for consideration at the current meeting.

It is further noted that, starting from the twentieth JVET meeting, work items which had originally been conducted by the Joint Collaborative Team on Video Coding (JCT-VC) were continued to be conducted in JVET as a single joint team, as negotiated by the parent bodies. This particularly consists of work on

* *High Efficiency Video Coding* (HEVC) and its extensions, the development of associated conformance test sets, reference software, verification testing, and non-normative guidance information,
* Specification of *Coding-independent Code Points (Video)* (CICP), and associated technical report(s),
* Maintenance and minor enhancement work on the *Advanced Video Coding* (AVC) standard, associated conformance test sets and reference software.

To retain a consistent numbering scheme, the number range of output documents starting from 1001 was reserved for the previous JCT-VC topic items listed above, whereas the number range starting from 2001 was retained for VVC, VSEI and future exploration activities. Duplication of AHGs was avoided by merging previous JCT-VC AHGs with the corresponding AHGs of JVET.

A preliminary basis for the document subject allocation and meeting notes for the 22nd meeting had been made publicly available on the ITU-hosted ftp site <http://wftp3.itu.int/av-arch/jvet-site/2021_04_V_Virtual/>.

[JVET-V0002](https://jvet-experts.org/doc_end_user/current_document.php?id=10780) JVET AHG report: Draft text and test model algorithm description editing (AHG2) [B. Bross, J. Chen, C. Rosewarne, F. Bossen, J. Boyce, S. Kim, S. Liu, J.-R. Ohm, G. J. Sullivan, A. Tourapis, Y.-K. Wang, Y. Ye]

Output documents produced:

JVET-U1004 Errata report items for VVC, VSEI, HEVC, AVC, Video CICP, and CP usage TR

This document contains a list of reported errata items for VVC, VSEI, HEVC, AVC, Video CICP, and the TR on usage of video signal type code points, for tracking purposes. Some of the items have been confirmed by the JVET and have been agreed to require fixing, while some other items have not yet been confirmed. This document also provides publication status backgrounds of these standards.

Incorporated items at the JVET-U meeting:

• For VVC (the changes are included in an attachment to this document):

o Some minor editorial corrections and improvements (JVET-U0073, JVET-U0085, and one item from Hendry)

o Fixes for tickets #1416, #1428, #1432, #1454, and #1469

• For AVC: Added a reference to JVET-T1006-v1 for the errata changes, and removed the actual errata text changes from this document. (JVET-U0049)

JVET-U2002 Algorithm description for Versatile Video Coding and Test Model 12 (VTM 12)

The VVC Test Model 12 (VTM12) algorithm description and encoding method document was produced, with the following additions compared to the previous release:

• Refinement of high precision (1/16 pel) motion compensation and motion vector storage

• Added reference picture resampling

JVET-U2005 New level and additional SEI messages for VVC (Draft 2)

This document contains the draft text for changes to the Versatile Video Coding (VVC) standard (ITU T H.266 | ISO/IEC 23090-3), mainly for the addition of Level 6.3 and the SEI manifest and SEI prefix indication SEI messages, but also including SEI payload type values and other interfaces for SEI messages added to the VSEI specification, as well as some technical corrections.

Draft 2 incorporated items:

• Text changes for clarification of 1) the exact meaning of a parameter set being referenced and 2) that the decoding of non-VCL NAL units in a PU after the last VCL NAL unit of the picture in decoder is deferred after all slices of the picture are decoded (JVET-U0073-v3)

• Addition of SEI payload type values 165 (alpha\_channel\_info), 177 (depth\_representation\_info), 179 (multiview\_acquisition\_info), and 205 (scalability\_dimension\_info) (JVET-U0082

• Addition of SEI payload type value 206 (extended\_drap\_indication) and text on the use of the extended dependent random access point (EDRAP) indication SEI message (JVET-U0084)

• Text changes for inclusion of the decoded picture hash SEI message to the list VclAssociatedSeiList, not imposing the same content requirement for repeated user-defined SEI messages, and rules for inclusion of SEI messages in prefix and suffix SEI NAL units (JVET-U0085-v2)

• Fix for ticket #1448

JVET-U2006 Additional SEI messages for VSEI (Draft 2)

This document contains the draft text for changes to the versatile supplemental enhancement information messages for coded video bitstreams (VSEI) standard (Rec. ITU-T H.274 | ISO/IEC 23002-7), to specify additional SEI messages, including the annotated regions SEI message, the alpha channel information SEI message, the depth representation information SEI message, the multiview acquisition information SEI message, the scalability dimension information SEI message, and the extended dependent random access point (DRAP) indication SEI message. The draft text also includes text changes for some technical corrections and editorial improvements.

Draft 2 incorporated items:

• Addition of the alpha channel information SEI message, the depth representation information SEI message, the multiview acquisition information SEI message, and the scalability dimension information SEI message (JVET-U0082)

• Addition of the extended DRAP indication SEI message (JVET-U0084)

• Some minor editorial corrections and improvements (JVET-U0086)

• Fix for ticket #1412: change the coding of ffi\_display\_elemental\_periods\_minus1 from u(4) to u(8)

Related input contributions

The following input contributions were noted as relevant to the work of this ad hoc group:

• JVET-V0072 AHG2: Proposal to remove some RPL constraints (Nokia, LGE, Bytedance)

• JVET-V0111 AHG2: On Decoding Unit Information for VVC Version 1 (Sharp)

Recommendations

The AHG recommends to:

• Approve JVET-U1004, JVET-U2002, JVET-U2005, and JVET-U2006 documents as JVET outputs,

• Compare the VVC documents with the VVC software and resolve any discrepancies that may exist, in collaboration with the software AHG,

• Encourage the use of the issue tracker to report issues with the text of both the VVC specification text and the algorithm and encoder description,

• Continue to improve the editorial consistency of VVC text specification and Test Model documents,

• Ensure that, when considering changes to VVC, properly drafted text for addition to the VVC Test Model and/or the VVC specification text is made available in a timely manner,

• Review AHG2 related contributions and act on them if found to be necessary.

[JVET-V0003](https://jvet-experts.org/doc_end_user/current_document.php?id=10781) JVET AHG report: Test model software development (AHG3) [F. Bossen, X. Li, K. Sühring, K. Sharman, V. Seregin]

The software model versions prior to the start of the meeting were:

• VTM 12.1 (Mar. 2021)

• HM-16.23 (Mar. 2021)

• HM-16.21+SCM-8.8 (Mar. 2020)

• SHM 12.4 (Jan. 2018)

• HTM 16.3 (Jul. 2018)

• JM 19.0

• JSVM 9.19.15

• JMVC 8.5

• 3DV ATM 15.0 (no version history)

• HDRTools 0.21 (Jan. 2021)

Software for MFC and MFCD is only available published by ITU-T and ISO/IEC. It is planned to create repositories with the latest versions available in ITU-T H.264.2 (02/2016). All development history is lost.

Software development

Development was continued on the GitLab server, which allows participants to register accounts and use a distributed development workflow based on git.

The server is located at:

https://vcgit.hhi.fraunhofer.de

The registration and development workflow are documented at:

https://vcgit.hhi.fraunhofer.de/jvet/VVCSoftware\_VTM/wikis/VVC-Software-Development-Workflow

Although the development process is described in the context of the VTM software, it can be applied to all other software projects hosted on the GitLab server as well.

Only SHM and HTM are still located in subversion repositories. It is suggested to convert and move these repositories to GitLab as well.

VTM related activities

The VTM software can be found at

https://vcgit.hhi.fraunhofer.de/jvet/VVCSoftware\_VTM/

The software development continued on the GitLab server. VTM versions 11.1 and 11.2 were tagged on Jan. 15 and Jan. 18, and VTM version 12.0 was tagged on Feb. 16. VTM version 12.1 was tagged on Mar 31. VTM 12.2 is expected during the 22nd JVET meeting.

VTM 11.1 was tagged on Jan. 15, 2021. Changes include:

• JVET-R0264: IRAP constraint

• JVET-T0053: Adding support for Annotated Regions SEI message

• Fix #1422: dpb parameters inference when subLayerInfoFlag = 0

• Fix access to data that might be deleted

• Fix memory allocation when decoding a stream changing bitdepth between CVS

• Fix #1439: GOP32 configuration for larger intra periods

• Fix #1442: Fix for PTL signalling in VPS

• Fix handling of suffix APS NAL units

• Fix #1438: Decoder crashes when decoding multi-layer bitstream

• Fix handling of suffix APS NAL units in RASL skipped pictures.

• Fix #1411: Decoder crash when decoding a CRA picture following an EOS

• Fix #1419: apply reference pic marking before getting a new pic buffer

• Update README file to include git retrieval

• Update copyright header to include year 2021

• Fix for minimum functionality of StreamMergeApp with VTM 11.0

VTM 11.2 was tagged on Jan. 18, 2021. Changes include:

• Add bound checks and use correct index for m\_vpsMaxTidIlRefPicsPlus1

• Fix #1394: correctly determine whether a NAL unit is a VCL unit

• Remove unused code and fix indentation and braces

• Remove macros from previous cycle

VTM 12.0 was tagged Feb. 16, 2021. Changes include:

• JVET-U0081: ALF filter optimization with filter strength target

• JVET-U0103: SIMD implementation for high bit depth coding

• JVET-U2018: Updated configuration file for HBD CTC

• JVET-U2018: Update sequence configuration files

• Fix #1451: Align SW with spec for RPR/4:4:4 combination

• Fix #1452: use "true" original for HDR metrics

• Fix #1453: use 64-bit variables for RPR to prevent overflow

• Fix #1456: Incorrect DPB flush when mixed NALU types is enabled

• Fix #1457: rplIdx variable for list 1 is not always set in parseSliceHeader()

• Cleanup: fix return type of PPS::getMixedNaluTypesInPicFlag

• Fix compilation when JVET\_R0351\_HIGH\_BIT\_DEPTH\_ENABLED is set to 1

• Fix: #1460: init MTS coeff Constraint in MTS loop during Intra Search

• Fix for ticket #1458: printout wPSNR for hbd ctc

• Enable processing of low bit depth content with JVET\_U0103\_HIGH\_BIT\_DEPTH\_SIMD

• Fix #1459: Modify ALF AVX2 code from JVET-U0103

• Refactor: rename ALF APS ID related functions and variables

• remove unused code and fix indentation and braces

VTM 12.1 was tagged on Mar 31, 2021. Changes include:

• Fix #1466: fix check on SPS virtual boundaries constraint.

• Fix #1465: skip mixed nalu leading pictures when beginning a stream

• Fix #1464: Non-conforming values of sn\_subpic\_id\_len\_minus1

• Fix #1467: Replace std::sort() with std::stable\_sort() to avoid cross-platform performance mismatch

• Fix #1468: bugfix parcat: remove duplicate prefix sei for IDR

• Add decoded picture hash SEI writing for subpictures in subpic merger app

• Fix call to initSEIScalableNesting

• Fixes for tickets #961, #1455 and #1447: Decoding and verifying of GDR conformance streams

• Fix tickets #1461, #1462, #1463: chroma dQP bug fixes and configuration parameters improvements.

• Fix #1471: DebugBitstream feature

• Add verification of subpicture based decoded picture hashes

• Fix !2018: ignore slice-level setting when feature is not used

• Reduced the memory required by EncModeCtrl by ~1GB

• Fix ticket #1377: remove ENABLE\_SPLIT\_PARALLELISM

• Fix bad bitstream generation: wrong parameter to rpcSlice->setUseChromaQpAdj() in initEncSlice().

• fix initialization of m\_initialCpbRemovalOffset in SEIBufferingPeriod class

• Fix non\_ref\_pic compliance check

• Fix CHECK statements

• Fix naming and error messages for VLC length calculation

• Fix #1475: Use SMultiValueInput<uint32\_t> instead of SMultiValueInput<uint8\_t>

• Fix braces and indentation and remove trailing spaces

VTM 12.2 is expected to be tagged during the 22nd JVET meeting. Changes include:

• JVET-U0097: GDR Software

• Fix #1444: fix picture output order in multilayer streams

• Fix #1449: output only layers in active OLS

• Fix #1474: remove erroneous skipped pictures detection in checkRPL

• Fix #1476: fix picture output before GDR

The following tables show **VTM 12.1** performance over **HM 16.23**:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **All Intra Main10** |  |  |
|  |  |  | **Over HM-16.23** |  |  |
|  | Y | U | V | EncT | DecT |
| Class A1 | -29,04% | -32,17% | -34,07% | 1560% | 171% |
| Class A2 | -29,29% | -23,92% | -21,06% | 2503% | 182% |
| Class B | -21,73% | -26,96% | -30,76% | 2767% | 185% |
| Class C | -22,54% | -18,95% | -22,70% | 3869% | 199% |
| Class E | -25,76% | -25,91% | -24,46% | 2251% | 173% |
| **Overall** | -25,06% | -25,37% | -26,85% | 2574% | 183% |
| Class D | -18,47% | -13,31% | -13,42% | 4424% | 187% |
| Class F | -39,33% | -39,73% | -42,22% | 4761% | 178% |
|  |  |  |  |  |  |
|  |  |  | **Random access Main10** |  |  |
|  |  |  | **Over HM-16.23** |  |  |
|  | Y | U | V | EncT | DecT |
| Class A1 | -39,63% | -39,43% | -46,23% | 682% | 163% |
| Class A2 | -43,41% | -41,01% | -40,23% | 757% | 174% |
| Class B | -36,50% | -49,27% | -47,74% | 751% | 164% |
| Class C | -32,82% | -35,20% | -37,22% | 1020% | 174% |
| Class E |  |  |  |  |  |
| **Overall** | -37,52% | -41,90% | -43,13% | 801% | 168% |
| Class D | -30,74% | -31,79% | -31,42% | 1138% | 167% |
| Class F | -45,76% | -49,18% | -50,10% | 561% | 147% |
|  |  |  |  |  |  |
|  |  |  | **Low delay B Main10** |  |  |
|  |  |  | **Over HM-16.23** |  |  |
|  | Y | U | V | EncT | DecT |
| Class A1 |  |  |  |  |  |
| Class A2 |  |  |  |  |  |
| Class B | -29,24% | -34,80% | -32,41% | 750% | 149% |
| Class C | -25,89% | -17,42% | -17,95% | 924% | 179% |
| Class E | -28,73% | -33,03% | -26,38% | 372% | 146% |
| **Overall** | -28,00% | -28,56% | -26,08% | 675% | 158% |
| Class D | -25,01% | -12,57% | -11,79% | 959% | 190% |
| Class F | -40,20% | -41,56% | -41,87% | 495% | 142% |
|  |  |  |  |  |  |
|  |  |  | **Low delay P Main10** |  |  |
|  |  |  | **Over HM-16.23** |  |  |
|  | Y | U | V | EncT | DecT |
| Class A1 |  |  |  |  |  |
| Class A2 |  |  |  |  |  |
| Class B | -33,97% | -37,79% | -34,99% | 695% | 162% |
| Class C | -27,68% | -17,28% | -18,05% | 844% | 192% |
| Class E | -32,32% | -36,86% | -30,30% | 367% | 155% |
| **Overall** | -31,46% | -30,72% | -28,17% | 632% | 169% |
| Class D | -26,32% | -11,99% | -10,87% | 893% | 199% |
| Class F | -39,97% | -41,10% | -41,48% | 527% | 146% |

According to common test conditions in random access configuration HM is using a GOP size of 16 pictures compared to VTM using a GOP of 32 pictures. Random access points are inserted approximately every second aligned with a GOP boundary of GOP 32 in both VTM and HM. VTM uses two more reference pictures in random access than HM (due to more memory being availably in typical level settings).

The following tables show **VTM 12.1** performance compared to **VTM 11.0**:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **All Intra Main10** |  |  |
|  |  |  | **Over VTM-11.10** |  |  |
|  | Y | U | V | EncT | DecT |
| Class A1 | 0,00% | 0,00% | 0,00% | 100% | 101% |
| Class A2 | 0,00% | 0,00% | 0,00% | 100% | 99% |
| Class B | 0,00% | 0,00% | 0,00% | 99% | 102% |
| Class C | 0,00% | 0,00% | 0,00% | 99% | 102% |
| Class E | 0,00% | 0,00% | 0,00% | 100% | 101% |
| **Overall** | 0,00% | 0,00% | 0,00% | 100% | 101% |
| Class D | 0,00% | 0,00% | 0,00% | 100% | 98% |
| Class F | 0,00% | 0,00% | 0,00% | 93% | 103% |
|  |  |  |  |  |  |
|  |  |  | **Random access Main10** |  |  |
|  |  |  | **Over VTM-11.10** |  |  |
|  | Y | U | V | EncT | DecT |
| Class A1 | 0,00% | 0,00% | 0,00% | 100% | 99% |
| Class A2 | 0,00% | 0,00% | -0,01% | 100% | 99% |
| Class B | 0,00% | 0,00% | 0,00% | 100% | 98% |
| Class C | 0,00% | 0,00% | -0,01% | 100% | 99% |
| Class E |  |  |  |  |  |
| **Overall** | 0,00% | 0,00% | 0,00% | 100% | 98% |
| Class D | 0,00% | 0,00% | 0,00% | 100% | 100% |
| Class F | 0,00% | 0,00% | 0,00% | 98% | 100% |
|  |  |  |  |  |  |
|  |  |  | **Low delay B Main10** |  |  |
|  |  |  | **Over VTM-11.10** |  |  |
|  | Y | U | V | EncT | DecT |
| Class A1 |  |  |  |  |  |
| Class A2 |  |  |  |  |  |
| Class B | 0,01% | 0,01% | -0,34% | 98% | 95% |
| Class C | -0,01% | 0,35% | -0,30% | 100% | 98% |
| Class E | 0,05% | -0,38% | -0,11% | 101% | 100% |
| **Overall** | 0,01% | 0,03% | -0,27% | 99% | 97% |
| Class D | -0,05% | 0,09% | -0,09% | 100% | 100% |
| Class F | 0,00% | -0,26% | 0,06% | 99% | 101% |
|  |  |  |  |  |  |
|  |  |  | **Low delay P Main10** |  |  |
|  |  |  | **Over VTM-11.10** |  |  |
|  | Y | U | V | EncT | DecT |
| Class A1 |  |  |  |  |  |
| Class A2 |  |  |  |  |  |
| Class B | 0,01% | -0,03% | -0,03% | 99% | 96% |
| Class C | -0,01% | 0,10% | 0,08% | 99% | 101% |
| Class E | -0,02% | -0,03% | 0,15% | 101% | 98% |
| **Overall** | -0,01% | 0,02% | 0,05% | 100% | 98% |
| Class D | 0,02% | -0,03% | -0,01% | 101% | 100% |
| Class F | -0,08% | -0,24% | -0,14% | 99% | 100% |

Full results are attached to this AHG report as Excel files.

Issues in VTM 12.x affecting conformance

The following issues in VTM master branch (Apr 20, 2021) affect conformance:

• Handling of NoOutputOfPriorPicFlag is disabled due to crash issues (issue #1415)

• The macro GDR\_LEAK\_TEST was disabled due to causing mismatches with conformance streams (MR2050).

• Missing HLS features (see sections below)

However, there are no known issues in VTM that affect processing of current JVET conformance bitstreams.

Status of implementation of proposals of previous JVET meetings

The following list contains all adoptions of the Q and R meetings that were not marked as merged (or submitted) or specification only change in the software coordinator tracking sheet:

• JVET-Q0112

• JVET-Q0154: Disallow mixing of GDR and IRAP (Disallow mixing of GDR with any non-GDR).

• JVET-Q0164

• JVET-Q0402

• JVET-Q0443: Modification of the subpicture level SEI message semantics to impose a constraint on MinCR.

• JVET-R0178: Require that when no\_aps\_constraint\_flag is equal to 1, sps\_lmcs\_enabled\_flag and sps\_scaling\_list\_enabled\_flag shall be equal to 0

• JVET-R0221

• JVET-R0046: Change the description of the bitstream extraction process per the value of max\_tid\_il\_ref\_pics\_plus1[ ][ ] (aspect 1.2 per JVET-R0046-v4).

• JVET-R0065: Specify that GDR AUs shall be complete – i.e., all of the layers in the CVS shall have a picture in the AU (as with IRAP AUs).

• JVET-R0191: Update the range value for num\_ols\_hrd\_params\_minus1.

• JVET-R0222 aspect 1: Infer vps\_max\_sublayers\_minus1 to be equal to 6 when sps\_video\_parameter\_set\_id is equal to 0 (i.e. VPS is not present). The exact editorial expression is at the discretion of the editor.

• JVET-S0196 (JVET-S0144 item 17)

• JVET-S0227 (JVET-S0144 item 22)

• JVET-S0077 (JVET-S0139 item 5)

• S0174 aspect 2 (JVET-S0139 item 18.b)

• S0156 aspect 3 (JVET-S0139 item 21)

• JVET-S0139 item 26 (no source listed)

• S0188 aspect 1 (JVET-S0139 item 28)

• JVET-S0139 item 40 (item does not exist)

• JVET-S0042 (JVET-S0142 item 1.b)

• JVET-S0174 aspect 1 (JVET S0143 item 19)

• JVET-S0096 aspect 3 (JVET-S0140 item 10)

• JVET-S0096 aspect 4 (JVET-S0140 item 13)

• JVET-S0159 aspect 3 (JVET-S0140 item 16)

• JVET-S0171 (JVET-S0256)

• JVET-S0118 (JVET-S0141 item 7)

• JVET-S0102 (JVET-S0141 item 9.a)

• JVET-S0117 (JVET-S0141 item 11)

• JVET-S0157 item 2 (JVET-S0141 item 13)

• JVET-S0157 item 4 (JVET-S0141 item 14)

• JVET-S0175 aspect 3 (JVET-S0141 item 16)

• JVET-S0175 aspect 1, 2 (JVET-S0141 item 17)

• JVET-S0175 aspects 4 and 5 (JVET-S0141 item 18)

• JVET-S0175 aspect 6 (JVET-S0141 item 19)

• JVET-S0198/ JVET-S0223 (JVET-S0141 item 24)

• JVET-S0173 aspect 2 (JVET-S0141 item 40.b)

• JVET-S0173 item 1 (JVET-S0141 item 51)

• JVET-S0173 item 3 (JVET-S0141 item 52)

• JVET-S0173 item 5 (JVET-S0141 item 53)

• JVET-S0173 item 6 (JVET-S0141 item 54)

• JVET-S0173 item 4 (JVET-S0141 item 56)

• JVET-S0176 item 4 (JVET-S0141 item 60)

• JVET-S0154 aspect 5 (JVET-S0141 item 68)

• JVET-S0154 aspect 6 (JVET-S0141 item 69)

• JVET-S0154 aspect 8 (JVET-S0141 item 71)

• JVET-S0095 aspect 5 (JVET-S0145 item 5)

• JVET-S0095 aspect 6 (JVET-S0145 item 6)

• JVET-S0100 aspect 1, depends on JVET-R0193 (JVET-S0147 item 2)

• FINB ballot comments Make high tier support up to 960.

• JVET-T0055 aspect 4

• JVET-T0055 item 2

Status of proposals of the 21st JVET meeting (Online)

The following list contains all adoptions of the U meeting that were not marked as merged or specification only change in the software coordinator tracking sheet:

• JVET-U0082 (Scalability dimension SEI message and three HEVC SEI messages)

• JVET-U0084 (Cross RAP referencing (CRR) SEI message)

• JVET-U0085 (VVC Errata)

• JVET-U0086 (VSEI Errata)

It was clarified during the AHG report that U0085 and U0086 do not affect the software. The missing new SEI message SW is to be considered in the context of the VSEI amendment.

HM related activities

HM 16.23 was tagged on Mar. 24, 2021. Changes include:

• Typo corrected (SEIPreferredTransferCharacteristics)

• Enable TemporalFilter for random access configurations, except class F

• Backport of SEIRemovalApp from VTM

• Merge VTM readme file with build instructions.

• Fix segment coding mismatch for HDR (delta qp)

• Updated HDR config files

The following actions have yet to be included:

• JCTVC-AM0023 (Illustration of the film grain characteristics SEI message in HEVC)

• JCTVC-AJ0028 (Encoder-only Supplemental Motion Vector Estimation for Point cloud Coding content).

• JVET-T0050: Add ability to detect static objects to encoder

The contributors og AJ0028 had been informed about the unsuitable quality of the software, but did not respond within the past few meeting cycles. It is suggested during the AHG report to remove this item from the list. Merge requests on the other two items are available, but merging is pending final review.

As reported in the previous report, further information on lambda optimisation in HM would be appreciated, including comparison of allocation of bits within the GOP structures between HM and VTM.

The HEVC bug tracker lists:

• 38 tickets for “HM”, most of which are more than 5 years old,

• 1 ticket for “HM RExt”, which was created during this reporting period,

• 7 tickets for “HM SCC”, all of which are at least 3 years old,

Help to address these tickets would be appreciated.

SCM related activities

There had not been any further developments to SCC’s SCM during this meeting cycle.

SHM related activities

There had not been any further developments to SHVC’s SHM during this meeting cycle.

HTM related activities

There had not been any updates to the HTM of MV-HEVC and 3D-HEVC.

HDRTools related activities

HDRTools version 0.21 was tagged on Jan. 19, 2021. Changes include:

• Fix Y4M frame rate issue

A few days earlier version 0.20 was tagged with the following changes:

• Add output support for Y4M

• Add AOM CTC downscaling/upscaling filters (for Adaptive Streaming conditions)

• Support Gaussian Window SSIM

• XYB color format support

• Fixed WT distortion metric

A new release is intended to be released during the meeting which will include the following updates:

• Add PNG reading and writing (using libpng)

• Add libpng submodule and configure cmake to update it if the LIBPNG option is enabled

• Setup CI running build on linux and windows instances

• Cleanup README

• Bugfix for parsing the last line of the config file

• Allow ~ (HOME) to be present in config file parameters

• Add JVET based MS-SSIM

• Fix copyright for new JVET based MS-SSIM

• Fix issue with the ouput frame rate not beeing copied from the input

• Add special handling of the "unknown" frame rate (F0:0)

JM, JSVM, JMVM related activities

There had not been any updates to the JM, JSVM and JMVM software.

Bug tracking

The bug tracker for VTM and specification text is located at:

https://jvet.hhi.fraunhofer.de/trac/vvc

The bug tracker uses the same accounts as the HM software bug tracker. Users may need to log in again due to the different sub-domain. For spam fighting reasons account registration is only possible at the HM software bug tracker at

https://hevc.hhi.fraunhofer.de/trac/hevc

Please file all issues related to the VVC reference software into the bug tracker. Try to provide all the details, which are necessary to reproduce the issue. Patches for solving issues and improving the software are always appreciated.

Software repositories

Git repositories that were previously assigned to the JCT-VC group on the GitLab server were re-assigned to the JVET group. The old URLs are still working and will forward the user to the new location, with the display of a warning suggesting to update bookmarks to the new location.

The subversion repositories for SHM and HTM were converted to git and are now stored on the GitLab server to unify access and development process.

CTC alignment

The following differences were found in CTC alignment between HEVC and VVC:

- For HM two test configurations are described: one for 8-bit coding bit depth for Main profile and a second one for 10-bit coding bit depth for Main 10. VTM only specifies a 10-bit test case. These should be aligned, so that the same templates can be used.

Merging of CTC documents related to HEVC and VVC in each area of interest should be considered.

Recommendations

The AHG recommends to:

- Continue to develop reference software

- Improve documentation, especially the software manual

- Encourage people to test VTM and other reference software more extensively outside of common test conditions.

- Encourage people to report all (potential) bugs that they are finding.

- Encourage people to submit bit-streams/test cases that trigger bugs in VTM and other reference software.

- Encourage people to submit non-normative changes that either reduce encoder run time without significantly sacrificing compression performance or improve compression performance without significantly increasing encoder run time

- Design and add configuration files to the VTM software for testing of HLS features

- Review VTM-related contributions and determine whether features should be added (or removed) from the software

- Continue to investigate the merging of branches.

- Keep common test conditions aligned for the different standards.

It is noted that there is a document JVET-U0079 that proposes substantial cleanup of the software.

[JVET-V0004](https://jvet-experts.org/doc_end_user/current_document.php?id=10782) JVET AHG report: Test material and visual assessment (AHG4) [V. Baroncini, T. Suzuki, M. Wien, E. François, S. Liu, A. Norkin, A. Segall, P. Topiwala, S. Wenger, Y. Ye]

AHG meetings were held related to the preparation of the VVC verification tests in the SDR HD, 360° video and HDR categories on 2021-2-18 and 2021-3-25, respectively. The reports of these meetings are provided in the input documents JVET-V0042 and JVET-V0044.

The status of the discussion in the SDR HD and 360° video categories was reflected in the verification test plan document JVET-U2021. In the SDR HD low delay category, a set of 6 sequences was selected including three test sequences representing the conversational application scenario and three test sequences representing the gaming-type application scenario. Out of the four test sequences under consideration in the conversational application scenario, the verification test coordinators selected three as per request of the AHG meeting. The resulting set considered for subjective assessment includes the test sequence Beatriz, OfficeWalkAtWall, and OfficeWalkCeiling. For the SDR HD and 360° video categories, bitstreams for the rate points and configurations defined in JVET-U2021 were generated and verified for HM-16.22 and VTM-11.0 by JVET members in an off-line activity. For the SDR RA category, additional bitstreams for VVenC-0.3 bitstreams were provided as an additional test case.

The verification test coordinators are in contact with laboratories who offered support in contributing to the testing procedure. However, due to the COVID-19 situation, the activities for formal subjective assessments have been strongly reduced in many countries which impacts the progress of the VVC verification tests. A recent update on the local conditions in Italy opened the possibility for performing visual tests which is currently ongoing.

In the HDR category, efforts have been extended to identify suitable test sequences for both, PQ and HLG, including experts viewing sessions for determination of a QP range suitable for covering the intended subjective quality range.

Test sequences

The test sequences used for CfP/CTC are available on ftp://jvet@ftp.ient.rwth-aachen.de in directory “/jvet-cfp” (accredited members of JVET may contact the JVET chairs for login information).

Due to copyright restrictions, the JVET database of test sequences is only available to accredited members of JVET (i.e. members of ISO/IEC MPEG and ITU-T VCEG).

Copyright licenses have been updated for the following HDR PQ content located at ftp://jvet@ftp.ient.rwth-aachen.de, in folder /ctc/hdr:

• Market3\_1920x1080p\_50\_10b\_pq\_709\_ct2020\_420\_rev1.zip

• SunRise\_1920x1080p\_25\_10b\_pq\_709\_ct2020\_420\_rev1.7z

Related contributions

The following related contribution is submitted.

JVET-V0041 “AHG4: Status Report on SDR HD and 360 Video Verification Test Preparation” [M. Wien, V. Baroncini, Y. Ye (AHG coordinators)]

JVET-V0042 “AHG4: Agenda and report of the AHG meeting on the SDR HD and 360 video verification test preparation on 2021-02-18” [M. Wien, V. Baroncini, Y. Ye (AHG coordinators)]

JVET-V0043 “ AHG4: Status Report on HDR Video Verification Test Preparation” [A. Segall, M. Wien, V. Baroncini, K. Andersson]

JVET-V0044 “AHG4: Agenda and report of the AHG meeting on the HDR verification test preparation on 2021-03-25” [A. Segall, M. Wien, V. Baroncini (AHG coordinators)]

JVET-V0045 “Aerial 4K HDR (HLG) Test Data” [Pankaj Topiwala (FastVDO)]

The AHG reports JVET-V0042 and JVET-V0044 include a summary of the discussion of JVET-V0041, JVET-V0043. The contributions related to the verification tests should be further discussed during the meeting.

Recommendations

The AHG recommends:

• To review the input contributions related to the verification test preparation.

• To continue to discuss and to update the non-finalized categories of the verification test plan.

• To create a BoG to progress the update of the verification test plan.

• To collect volunteers to conduct the verification test, including volunteers to encode.

• To review the set of available test sequences for the verification tests and potentially collect more test sequences with a variety of content.

• To continue to collect new test sequences available for JVET with licensing statement.

Some expert viewing may be necessary during the meeting.

It is further suggested to merge the available test data into one ftp site (including previous JCT-VC test sets).

[JVET-V0005](https://jvet-experts.org/doc_end_user/current_document.php?id=10783) JVET AHG report: Conformance testing (AHG5) [J. Boyce, W. Wan, E. Alshina, F. Bossen, I. Moccagatta, K. Kawamura, K. Sühring, X. Xu]

The progress on the Conformance testing specification is consistent with the preliminary timeline agreed at the 16th JVET meeting, as follows:

• 17th meeting Jan. 2020: Preliminary guidelines for bitstream preparation (e.g., naming conventions),

improved list of conformance bitstreams

• 18th meeting Apr. 2020: Final guidelines for bitstream preparation and improved list of conformance

bitstreams with identified responsible experts, initial bitstreams provided

• 19th meeting July 2020: Confirmed list of bitstreams to be included in v1, collection of bitstream

candidates for CD ballot at next meeting

• 20th meeting Oct. 2020: CD of conformance specification

• 21st meeting Jan. 2021: Final bitstreams provided, DIS ballot in ISO/IEC

• 22nd meeting April 2021: No action pending DIS ballot

• 23rd meeting July 2021: Final conformance specification

Status on bitstream submission

The status at the time of preparation of this report is as follows:

• 104 bitstream categories have been identified

• At least one bitstream has been submitted in each identified category

• 282 total bitstreams have been provided, checked, and made available

Activities and Discussion

The AHG activities are on schedule with the preliminary timeline shown in section 2.

JVET-V2008 “Conformance testing for Versatile Video Coding (Draft 6)” was published on 31 Mar 2021. DIS in document WG05 N00037 was submitted based on JVET-V2008, but at the time of preparation of this report the MPEG DIS ballot has not been issued.

All provided bitstreams can be decoded using VTM12.1, although issues related to picture output remain in multilayer bitstreams (see VTM tickets 1444 and 1449). It is expected that VTM12.2 will correctly process all bitstreams.

Since JVET-V2008 was published, 28 revised bitstreams have been provided in 5 categories, as follows:

- OPI\_B\_Nokia: fixed incorrect aud\_pic\_type, from ticket 1477

- OLS\_\*\_Tencent: Added missing picture hash SEI messages

- VPS\_C\_ERICSSON: fixed incorrect aud\_pic\_type, from ticket 1477

- 8b422\_\*\_Sony

- 10b422\_\*\_Sony

There are not currently any known issues with the provided conformance bitstream packages, except for one (see below). If no issues are raised in the future, the expectation is that the bitstream providers will not need to provide any additional updated versions of the bitstreams.

Several conformance tickets were opened regarding provided conformance bitstreams (see “Conformance tickets” tab on https://jvet.hhi.fraunhofer.de/trac/vvc/ ). Revised bitstreams were submitted to address all tickets, except ticket 1446 related to SLICES\_A\_HUAWEI\_2.

The regular JVET e-mail reflector was used for discussions (jvet@lists.rwth-aachen.de).

The AHG5 chairs and JVET chairs can be reached at jvet-conformance@lists.rwth-aachen.de. Participants should not subscribe to this list but may send emails to it.

There are no related input contributions.

The procedure to exchange the bitstream (ftp cite, bitstream files, etc.) is specified in Sec 2 “Procedure” of [JVET-R2008](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=8861). The ftp and http sites for downloading bitstreams are

<ftp://ftp3.itu.int/jvet-site/bitstream_exchange/VVC>

<https://www.itu.int/wftp3/av-arch/jvet-site/bitstream_exchange/VVC/>

The ftp site for uploading bitstream file is as follows.

<ftp://ftp3.itu.int/jvet-site/dropbox/>

(user id: avguest, passwd: Avguest201007)

If using FileZilla, the following configuration is suggested:



The AHG recommends the following:

• Thank all conformance bitstream providers for contributing bitstream packages

• Encourage conformance bitstream providers to review and revise text descriptions of provided bitstreams for the Conformance specification

• Encourage all JVET participants to review submitted bitstreams, provide feedback, and consider if the flexibility of the tested tool is sufficiently exercised, including consideration of input contribution JVET-U0108

• Output an updated conformance draft specification from this meeting

It is noted that there was an email by Christian Herglotz of FAU pointing out that some block sizes were missing in some bitstreams (based on information extracted from FAU’s bitstream analyser). This should be further clarified.

Resolution thanking the companies (Jill Boyce provides list).

[JVET-V0006](https://jvet-experts.org/doc_end_user/current_document.php?id=10784) JVET AHG report: 360° video coding, software and test conditions (AHG6) [J. Boyce, Y. He, K. Choi, J.-L. Lin, Y. Ye]

There is no update for 360Lib. The latest version is 360Lib-12.0 released on Dec. 29, 2020.

Software repository and versions

The 360Lib software is developed using a Subversion repository located at:

https://jvet.hhi.fraunhofer.de/svn/svn\_360Lib/

The released version of 360Lib-12.0 can be found at:

https://jvet.hhi.fraunhofer.de/svn/svn\_360Lib/tags/360Lib-12.0/

360Lib-12.0 testing results with VTM-12.0 can be found at:

ftp.ient.rwth-aachen.de/ahg/testresults/360Lib-12.0/VTM-12.0-360Lib-12.0\_CTC.xlsm

360Lib bug tracker

https://hevc.hhi.fraunhofer.de/trac/jem/newticket?component=360Lib

Table 1 is for the projection formats comparison using VTM-12.0 according to 360-degree video CTC (JVET-U2012) compared to that using VTM-11.0. Table 2 compares generalized cubemap (GCMP) coding and padded equi-rectangular projection (PERP) coding using VTM-12.0.

Table 3 is for PERP coding comparison between VTM-12.0 and HM-16.16. Table 4 is to compare GCMP coding with VTM-12.0 with and CMP coding with HM-16.16.

**Table 1. VTM-12.0 vs VTM-11.0 (VTM-11.0 as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **PERP: VTM-12.0 over VTM-11.0** | | | | | |
|  | **End-to-end**  **WS-PSNR** | | | **End-to-end**  **S-PSNR-NN** | | |
|  | Y | U | V | Y | U | V |
| Class S1 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Class S2 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| **Overall** | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |

**Table 2. VTM-12.0 PHEC vs PERP (PERP as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **PHEC Over PERP** | | | | | |
|  | **End-to-end WS-PSNR** | | | **End-to-end S-PSNR-NN** | | |
|  | Y | U | V | Y | U | V |
| Class S1 | -11.41% | -5.70% | -6.34% | -11.39% | -5.64% | -6.29% |
| Class S2 | -3.67% | 0.69% | 0.85% | -3.66% | 0.78% | 0.92% |
| **Overall** | -8.32% | -3.14% | -3.46% | -8.30% | -3.07% | -3.41% |

**Table 3. VTM-12.0 PERP vs HM-16.16 PERP (HM-16.16 PERP as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **VTM-12.0 PERP - Over HM-16.16 PERP** | | | | | |
|  | **End-to-end WS-PSNR** | | | **End-to-end S-PSNR-NN** | | |
|  | Y | U | V | Y | U | V |
| Class S1 | -30.20% | -37.96% | -40.49% | -30.19% | -37.98% | -40.46% |
| Class S2 | -36.18% | -36.80% | -39.08% | -36.16% | -36.83% | -39.14% |
| **Overall** | -32.59% | -37.50% | -39.93% | -32.58% | -37.52% | -39.93% |

**Table 4. VTM-12.0 GCMP vs HM-16.16 CMP (HM-16.16 CMP as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **VTM-12.0 GCMP - Over HM-16.16 CMP** | | | | | |
|  | **End-to-end WS-PSNR** | | | **End-to-end S-PSNR-NN** | | |
|  | Y | U | V | Y | U | V |
| Class S1 | -33.93% | -39.31% | -41.57% | -33.86% | -39.30% | -41.54% |
| Class S2 | -37.68% | -38.05% | -40.15% | -37.67% | -38.05% | -40.18% |
| **Overall** | -35.43% | -38.81% | -41.00% | -35.38% | -38.80% | -41.00% |

HM is without padding (but the version with padding should already be in the software, as it was developed in context of verification test). This should also be included in CTC. Revisit – clarify if this can be done via config file, or requires a new version of the CTC document.

It is further noted that virtual boundary is not enabled in CTC for VTM in GCMP case.

The AHG recommends:

• To continue software development of the 360Lib software package.

[JVET-V0007](https://jvet-experts.org/doc_end_user/current_document.php?id=10785) JVET AHG report: Coding of HDR/WCG material (AHG7) [A. Segall, E. François, W. Husak, S. Iwamura, D. Rusanovskyy]

The primary activity of the AhG was related to the mandates of (i) comparing the performance of the VTM for HDR/WCG content, (ii) study of objective metrics, (iii) coordinating with AHG8 on preparing HDR material in 12 bit 4:2:0 format, and (iv) coordinating with AHG4 in preparation for verification testing for HDR video content. This work is described in the following subsection.

Anchor Generation

The AhG generated CTC anchors for the VTM according to JVET-T2011. A summary of the performance is provided below, and more detailed information may be found in the included XLS data.

VTM 12.0 versus VTM 11.0

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra** | | | | | | | | | |
|  | **Over VTM-10.0** | | | | | | | | | |
|  |  |  | **wPSNR** | | | **PSNR** | | |  |  |
|  | DE100 | PSNR-L100 | Y | U | V | Y | U | V | EncT | DecT |
| Class H1 | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 99% | 97% |
| Class H2 |  |  |  |  |  | 0.00% | 0.00% | 0.00% | 98% | 95% |
| **Overall** | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 99% | 96% |
|  |  |  |  |  |  |  |  |  |  |  |
|  | **Random Access** | | | | | | | | | |
|  | **Over VTM-10.0** | | | | | | | | | |
|  |  |  | **wPSNR** | | | **PSNR** | | |  |  |
|  | DE100 | PSNR-L100 | Y | U | V | Y | U | V | EncT | DecT |
| Class H1 | 8.27% | 6.16% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100% | 99% |
| Class H2 |  |  |  |  |  | 0.00% | 0.00% | 0.00% | 100% | 98% |
| **Overall** | 8.27% | 6.16% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 100% | 99% |

2.2 Objective Metrics

During the interim period, it was determined that there was an error in the calculation of the HDR metrics when the temporal prefilter was enabled (using the prefiltered as original). This affected the calculation of DE100 and PSNR-L100 in VTM11.0.

A fix was created and integrated into VTM-12.0 to address this error, and the effect can be seen in the results above. More information can be found at https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/1452.

The AHG coordinated with AHG8 to review the configuration files used to generated the 12-bit HLG 4:2:0 content.

The AHG coordinated with AHG4 to prepare for the HDR verification test dry run. It is specifically highlighted that AHG4 received and studied three, new HDR sequences during the AHG period. AHG7 provided support in preparing and converting the sequences.

There are six contributions related to HDR video coding.

|  |  |  |
| --- | --- | --- |
| [JVET-V0007](file:///C:\\Users\\ohm\\AppData\\Local\\Temp\\Temp1_JVET-V0007-v1.zip\\current_document.php?id=10785) | JVET AHG report: Coding of HDR/WCG material (AHG7) | A. Segall, E. François, W. Husak, S. Iwamura, D. Rusanovskyy |
| [JVET-V0043](file:///C:\\Users\\ohm\\AppData\\Local\\Temp\\Temp1_JVET-V0007-v1.zip\\current_document.php?id=10689) | AHG4: Status Report on HDR Video Verification Test Preparation | [A. Segall](mailto:asegall@sharplabs.com), [M. Wien](mailto:wien@lfb.rwth-aachen.de), [V. Baroncini](mailto:baroncini@gmx.com), [K. Andersson](mailto:kenneth.r.andersson@ericsson.com) |
| [JVET-V0044](file:///C:\\Users\\ohm\\AppData\\Local\\Temp\\Temp1_JVET-V0007-v1.zip\\current_document.php?id=10691) | AHG4: Agenda and report of the AHG meeting on the HDR verification test preparation on 2021-03-25 | [A. Segall](mailto:asegall@sharplabs.com), [M. Wien](mailto:wien@lfb.rwth-aachen.de), [V. Baroncini (AHG coordinators)](mailto:baroncini@gmx.com) |
| [JVET-V0045](file:///C:\\Users\\ohm\\AppData\\Local\\Temp\\Temp1_JVET-V0007-v1.zip\\current_document.php?id=10692) | Aerial 4K HDR (HLG) Test Data | [Pankaj Topiwala (FastVDO)](mailto:pankajtva@gmail.com) |
| JVET-V0078 | AHG10: QP control for very smooth blocks | K. Andersson, J. Enhorn, J. Ström (Ericsson) |
| [JVET-V0107](file:///C:\\Users\\ohm\\AppData\\Local\\Temp\\Temp1_JVET-V0007-v1.zip\\current_document.php?id=10755) | Editorial suggestion for JVET CTC on HDR/WCG | [D. Rusanovskyy (Qualcomm)](mailto:dmytror@qti.qualcomm.com), [T.Hashimoto (Sharp)](mailto:tomonori.hashimoto@sharp.co.jp) |

The AHG recommends the following:

• Review all input contributions

[JVET-V0008](https://jvet-experts.org/doc_end_user/current_document.php?id=10786) JVET AHG report: High bit depth, high bit rate, and high frame rate coding (AHG8) [A. Browne, T. Ikai, D. Rusanovskyy, M. Sarwer, X. Xiu]

The AHG used the main JVET reflector, jvet@lists.rwth-aachen.de, with [AHG8] in message headers. A message was sent to the reflector with respect to the conversion of HLG content within the CTC on 27th January, a CE change notification on 25th March, and a formal kick-off message was sent on 29th March. In addition to the messages on the reflector, the the co-chairs received a question about the calendar for establishing a 12-bit profile for VVC.

The primary activities of the AhG were the updates to the high bit depth CTC (JVET-U2018) and the core experiment on entropy coding for high bit depth and high bit rate coding (JVET-V0022).

As a part of refining the CTC, AhG conducted HDR 12bit test material preparation. This included generation of HDR PQ/HDR HLG test sequences in 4:2:0 format and agreed conversion UHD to HD resolution for HLG sequences. AhG8 would like to thank coordinators of AhG7 for discussion on HDR conversion practices and on HDR metric specification and implementation.

In total, there are 45 high bit depth related contributions, but none related to high frame rate. The following section lists these contributions.

Contributions

The contributions can be split into CE and CE-related (28 contributions), and others (17 contributions).

CE and CE-related

JVET-V0022, “CE: Summary Report on Entropy Coding for High Bit Depth and High Bit Rate Coding”, A.Browne, T. Hashimoto, H. Jhu, D. Rusanovskyy, K. Kawamura, T. Zhou (CE co-ordinators)

JVET-V0046, “CE-1.7: Rice parameter derivation for high bit-depth coding”, T. Hashimoto, T. Ikai (Sharp)

JVET-V0047, “CE-3.1 and CE-3.2: Transform coefficients range extension for high bit-depth coding”, T. Zhou, T. Chujoh, T. Ikai (Sharp)

JVET-V0048, “CE-4.1: Combination of CE-3.1, CE-1.5 and CE-2.1”, T. Zhou, T. Chujoh, T. Ikai (Sharp)

JVET-V0049, “CE-4.2: Combination of CE-3.2, CE-1.5 and CE-2.1”, T. Zhou, T. Chujoh, T. Ikai (Sharp)

JVET-V0050, “CE-1.5, CE-1.6, CE-2.2 and CE-2.3: Rice parameter selection for high bit depths”, A. Browne, S. Keating, K. Sharman (Sony)

JVET-V0051, “CE-4.3 and CE-4.4: Combinations of CE-1.6 and CE-2.3 with CE-3.2”, A. Browne, S. Keating, K. Sharman (Sony)

JVET-V0052, “CE-1.1, CE-1.2 and CE-1.4: On the Rice parameter derivation for high bit-depth coding”, D. Rusanovskyy, M. Karczewicz, L. P. Van, M. Coban (Qualcomm)

JVET-V0053, “CE-4.5, CE-4.6 and CE-4.7: Combinations of RRC tests CE-1.1, CE-1.2 and CE-1.4 with CE-3.1/CE-3.2”, D. Rusanovskyy, M. Karczewicz, L. P. Van, M. Coban (Qualcomm)

JVET-V0054, “CE-2.1: Slice based Rice parameter selection for transform skip residual coding”, H.-J. Jhu, X. Xiu, Y.-W. Chen, W. Chen, C.-W. Kuo, X. Wang (Kwai Inc.)

JVET-V0084, “CE-related: On Rice parameter selection for regular residual coding (RRC) at high bit depths”, A. Browne, S. Keating, K. Sharman (Sony)

JVET-V0085, “CE-related: On Rice parameter selection for transform skip residual coding (TSRC) at high bit depths”, A. Browne, S. Keating, K. Sharman (Sony)

JVET-V0106, “CE-related: On history-enhanced method of Rice parameter derivation for regular residual coding (RRC) at high bit depths”, D. Rusanovskyy, L. Pham Van, M. Coban, M. Karczewicz (Qualcomm)

JVET-V0123, “CE-related: On prefix code length of remaining level coding for high bit depth and high bit rate coding”, Y. Yu, Z. Xie, F. Wang, H. Yu, D. Wang (OPPO)

JVET-V0134, “Crosscheck of CE-1.4 from JVET-V0052 (CE-1.1, CE-1.2 and CE-1.4: On the Rice parameter derivation for high bit-depth coding)”, A. Browne (Sony)

JVET-V0135, “Crosscheck of CE-4.5 and CE-4.7 from JVET-V0053 (CE-4.5, CE-4.6 and CE-4.7: Combinations of RRC tests CE-1.1, CE-1.2 and CE-1.4 with CE-3.1/CE-3.2)”, A. Browne (Sony)

JVET-V0136, “Crosscheck of JVET-V0047 (CE-3.1 and CE-3.2: Transform coefficients range extension for high bit-depth coding)”, A. Browne (Sony)

JVET-V0138, “Crosscheck of CE-1.2 from JVET-V0052 (CE-1.1, CE-1.2 and CE-1.4: On the Rice parameter derivation for high bit-depth coding)”, T. Hashimoto (Sharp)

JVET-V0139, “Cross-check report for CE1.5 and CE1.6 of JVET-V0050 and CE4.3 of JVET-V0051”, D.Rusanovskyy (Qualcomm)

JVET-V0140, “Cross-check report for CE-1.7 of JVET-V0046 and CE-4.2 of JVET-V0049”, D.Rusanovskyy (Qualcomm)

JVET-V0142, “Crosscheck of JVET-V0048 (CE-4.1: Combination of CE-3.1, CE-1.5 and CE-2.1)”, H.-J. Jhu (Kwai Inc.)

JVET-V0143, “Crosscheck of CE-2.2 and CE-2.3 from JVET-V0050 (CE-1.5, CE-1.6, CE-2.2 and CE-2.3: Rice parameter selection for high bit depths)”, H.-J. Jhu (Kwai Inc.)

JVET-V0144, “Crosscheck of CE-4.4 from JVET-V0051 (CE-4.3 and CE-4.4: Combinations of CE-1.6 and CE-2.3 with CE-3.2)”, H.-J. Jhu (Kwai Inc.)

JVET-V0145, “Crosscheck of CE-4.6 from JVET-V0053 (CE-4.5, CE-4.6 and CE-4.7: Combinations of RRC tests CE-1.1, CE-1.2 and CE-1.4 with CE-3.1/CE-3.2)”, T. Zhou (Sharp)

JVET-V0155, “Crosscheck of CE-1.1 from JVET-V0052 (CE-1.1, CE-1.2 and CE-1.4: On the Rice parameter derivation for high bit-depth coding)”, M. G. Sarwer (Alibaba)

JVET-V0156, “Crosscheck of JVET-V0106 (CE-related: On history-enhanced method of Rice parameter derivation for regular residual coding (RRC) at high bit depths)”, M. G. Sarwer (Alibaba)

JVET-V0157, “Crosscheck of JVET-V0084 (CE-related: On Rice parameter selection for regular residual coding (RRC) at high bit depths)”, M. G. Sarwer (Alibaba)

JVET-V0161, “Crosscheck of JVET-V0123 (CE-related: On prefix code length of remaining level coding for high bit depth and high bit rate coding)”, H.-J. Jhu (Kwai Inc.)

Other contributions

JVET-V0059, “AHG8: CABAC-bypass alignment for high bit-depth coding”, M.G. Sarwer, J. Chen, Y. Ye, R. -L. Liao (Alibaba)

JVET-V0066, “AHG8: Encoder improvements to palette coding for high bit depth”, T. Tsukuba, M. Ikeda, T. Suzuki (Sony)

JVET-V0067, “AHG8: A constraint of max transform size for high bit depth and high bit rate coding”, K. Kondo, M. Ikeda (Sony)

JVET-V0068, “AHG8: A constraint of max CTU size for high bit depth and high bit rate coding”, K. Kondo, M. Ikeda (Sony)

JVET-V0121, “AHG8: on coding of last significant coefficient position for high bit depth and high bit rate extensions”, F. Wang, L. Xu, Z. Xie, Y. Yu, H. Yu, D. Wang (OPPO)

JVET-V0122, “AHG8: a full-bypass mode in residual coding for high bit depth and high bit rate extensions”, F. Wang, Z. Xie, Y. Yu, H. Yu, D. Wang (OPPO)

JVET-V0124, “AHG8: Weighted Prediction for VVC High Bit Depth Extension”, Y. Yu, H. Yu, Z. Xie, F. Wang, D. Wang (OPPO)

JVET-V0131, “AHG8: Fixing the forward transform matrices for high bit depth coding”, K. Naser, F. Galpin, F. F. Le Léannec, P. De Lagrange (InterDigital)

JVET-V0133, “AHG8: Content Adaptive Transform Precision for High Bit Depth Coding”, K. Naser, F. Galpin, F. Le Léannec, P. De Lagrange (InterDigital)

JVET-V0141, “Cross-check report of AHG8: CABAC-bypass alignment for high bit-depth coding (JVET-V0059)”, D.Rusanovskyy (Qualcomm)

JVET-V0150, “AHG8: A study on bin rate of VTM-12.0 for high bit depth coding”, T. Tsukuba, M. Ikeda, T. Suzuki (Sony)

JVET-V0158, “Crosscheck of JVET-V0121 (AHG8: on coding of last significant coefficient position for high bit depth and high bit rate extensions)”, M. G. Sarwer (Alibaba)

JVET-V0159, “Crosscheck of JVET-V0067 (AHG8: A constraint of max transform size for high bit depth and high bit rate coding)”, T. Hashimoto (Sharp)

JVET-V0160, “Crosscheck of JVET-V0068 (AHG8: A constraint of max CTU size for high bit depth and high bit rate coding)”, T. Hashimoto (Sharp)

JVET-V0162, “Crosscheck of JVET-V0066 (AHG8: Encoder improvements to palette coding for high bit depth)”, H.-J. Jhu (Kwai Inc.)

JVET-V0163, “Crosscheck of JVET-V0122 (AHG8: a full-bypass mode in residual coding for high bit depth and high bit rate extensions)”, A. Browne (Sony)

JVET-V0166, “Cross-check report on AHG8: Content Adaptive Transform Precision for High Bit Depth Coding (JVET-V0133)”, D. Rusanovskyy (Qualcomm)

Benchmarks

The benchmarks for this section were generated using the high bit depth, high bit rate CTC (JVET-U2018). The HM anchor was generated using the RExt lossy and lossless CTC (JVET-U1100) with content and QP settings taken from JVET-U2018.

VTM 12.0 versus HM16.23

Low QP range

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **HDR PQ** |  |  | **AI** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrY | psnrU | psnrV | EncT | DecT |
| PQ444 | -5.42% | -6.08% | -6.69% | 2996% | 175% |
| PQ422 | -8.17% | -12.30% | -12.82% | 2550% | 169% |
| **Overall** | -6.79% | -9.19% | -9.75% | 2773% | 172% |
|  |  |  |  |  |  |
|  |  |  | **LDB** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrY | psnrU | psnrV | EncT | DecT |
| PQ444 | -6.00% | -4.18% | -5.75% | 300% | 164% |
| PQ422 | -7.21% | -11.17% | -11.80% | 394% | 164% |
| **Overall** | -6.61% | -7.67% | -8.77% | 347% | 164% |
|  |  |  |  |  |  |
|  |  |  | **RA** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrY | psnrU | psnrV | EncT | DecT |
| PQ444 | -6.14% | -4.32% | -5.56% | 343% | 164% |
| PQ422 | -7.47% | -11.50% | -11.72% | 474% | 164% |
| **Overall** | -6.81% | -7.91% | -8.64% | 409% | 164% |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **HDR HLG** |  |  | **AI** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrY | psnrU | psnrV | EncT | DecT |
| HLG444 | -3.39% | -5.40% | -5.68% | 3198% | 171% |
| HLG422 | -3.97% | -6.73% | -6.70% | 2943% | 167% |
| **Overall** | -3.68% | -6.06% | -6.19% | 3070% | 169% |
|  |  |  |  |  |  |
|  |  |  | **LDB** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrY | psnrU | psnrV | EncT | DecT |
| HLG444 | -5.36% | -7.49% | -6.79% | 401% | 158% |
| HLG422 | -4.92% | -8.86% | -7.23% | 495% | 162% |
| **Overall** | -5.14% | -8.18% | -7.01% | 448% | 160% |
|  |  |  |  |  |  |
|  |  |  | **RA** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrY | psnrU | psnrV | EncT | DecT |
| HLG444 | -5.92% | -8.08% | -7.19% | 449% | 157% |
| HLG422 | -5.51% | -9.19% | -7.44% | 612% | 162% |
| **Overall** | -5.72% | -8.64% | -7.32% | 531% | 160% |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SVT RGB** |  |  | **AI** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrG | psnrB | psnrR | EncT | DecT |
| SVT16 | 36.32% | 34.27% | 34.20% | 4934% | 144% |
| SVT12 | 0.13% | 0.68% | 0.58% | 5230% | 138% |
| **Overall** | 18.22% | 17.48% | 17.39% | 5082% | 141% |
|  |  |  |  |  |  |
|  |  |  | **LDB** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrG | psnrB | psnrR | EncT | DecT |
| SVT16 | 20.21% | 21.49% | 21.55% | 584% | 144% |
| SVT12 | -2.91% | -0.57% | -0.55% | 629% | 141% |
| **Overall** | 8.65% | 10.46% | 10.50% | 606% | 143% |
|  |  |  |  |  |  |
|  |  |  | **RA** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrG | psnrB | psnrR | EncT | DecT |
| SVT16 | 17.97% | 20.35% | 20.33% | 722% | 144% |
| SVT12 | -3.26% | -0.83% | -0.82% | 784% | 140% |
| **Overall** | 7.36% | 9.76% | 9.76% | 753% | 142% |

Lossless

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **PQ** | **All Intra** | | | **Low delay B** | | | **Random Access** | | |
| **ratio** | | bit-rate savings | **ratio** | | bit-rate savings | **ratio** | | bit-rate savings |
| HM16.23 | VTM12.0 | HM16.23 | VTM12.0 | HM16.23 | VTM12.0 |
| PQ444 | 2.5 | 2.5 | 3.01% | 3.1 | 3.0 | 4.21% | 3.1 | 3.0 | 3.83% |
| PQ422 | 2.3 | 2.2 | 2.86% | 2.9 | 2.8 | 3.13% | 2.9 | 2.8 | 2.78% |
| **Overall** | **2.4** | **2.4** | **2.93%** | **3.0** | **2.9** | **3.67%** | **3.0** | **2.9** | **3.30%** |
| Enc Time[%] | 7413% | | | 878% | | | 867% | | |
| Dec Time[%] | 158% | | | 139% | | | 140% | | |
|  |  |  |  |  |  |  |  |  |  |
| **HLG** | **All Intra** | | | **Low delay B** | | | **Random Access** | | |
| **ratio** | | bit-rate savings | **ratio** | | bit-rate savings | **ratio** | | bit-rate savings |
| HM16.23 | VTM12.0 | HM16.23 | VTM12.0 | HM16.23 | VTM12.0 |
| HLG444 | 1.8 | 1.7 | 6.56% | 1.9 | 1.9 | 2.10% | 2.0 | 1.9 | 1.87% |
| HLG422 | 1.7 | 1.6 | 7.55% | 1.9 | 1.9 | 2.08% | 1.9 | 1.9 | 1.83% |
| **Overall** | **1.7** | **1.6** | **7.05%** | **1.9** | **1.9** | **2.09%** | **1.9** | **1.9** | **1.85%** |
| Enc Time[%] | 8301% | | | 765% | | | 722% | | |
| Dec Time[%] | 138% | | | 116% | | | 117% | | |
|  |  |  |  |  |  |  |  |  |  |
| **SVT** | **All Intra** | | | **Low delay B** | | | **Random Access** | | |
| **ratio** | | bit-rate savings | **ratio** | | bit-rate savings | **ratio** | | bit-rate savings |
| HM16.23 | VTM12.0 | HM16.23 | VTM12.0 | HM16.23 | VTM12.0 |
| SVT16 | 1.2 | 0.7 | 73.47% | 1.2 | 0.7 | 80.20% | 1.2 | 0.7 | 80.25% |
| SVT12 | 1.3 | 1.0 | 31.02% | 1.3 | 1.0 | 29.88% | 1.3 | 1.0 | 29.30% |
| **Overall** | **1.2** | **0.8** | **52.24%** | **1.3** | **0.8** | **55.04%** | **1.3** | **0.8** | **54.78%** |
| Enc Time[%] | 7727% | | | 831% | | | 802% | | |
| Dec Time[%] | 133% | | | 151% | | | 152% | | |

VTM CE anchor versus HM16.23

The VTM CE anchor consisted of VTM12.0 with the RRC and TSRC rice coding fixes in the initial versions of CE-1.1 and CE-2.1 respectively.

Low QP range

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **HDR PQ** |  |  | **AI** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrY | psnrU | psnrV | EncT | DecT |
| PQ444 | -5.82% | -6.50% | -7.13% | 3068% | 175% |
| PQ422 | -8.66% | -12.78% | -13.32% | 2562% | 169% |
| **Overall** | -7.24% | -9.64% | -10.23% | 2815% | 172% |
|  |  |  |  |  |  |
|  |  |  | **LDB** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrY | psnrU | psnrV | EncT | DecT |
| PQ444 | -6.06% | -4.23% | -5.79% | 301% | 165% |
| PQ422 | -7.30% | -11.23% | -11.86% | 397% | 164% |
| **Overall** | -6.68% | -7.73% | -8.82% | 349% | 164% |
|  |  |  |  |  |  |
|  |  |  | **RA** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrY | psnrU | psnrV | EncT | DecT |
| PQ444 | -6.26% | -4.44% | -5.69% | 347% | 165% |
| PQ422 | -7.61% | -11.64% | -11.85% | 482% | 164% |
| **Overall** | -6.93% | -8.04% | -8.77% | 414% | 164% |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **HDR HLG** |  |  | **AI** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrY | psnrU | psnrV | EncT | DecT |
| HLG444 | -3.75% | -5.67% | -5.96% | 3188% | 171% |
| HLG422 | -4.44% | -7.11% | -7.10% | 2973% | 167% |
| **Overall** | -4.09% | -6.39% | -6.53% | 3080% | 169% |
|  |  |  |  |  |  |
|  |  |  | **LDB** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrY | psnrU | psnrV | EncT | DecT |
| HLG444 | -5.34% | -7.53% | -6.84% | 406% | 159% |
| HLG422 | -4.90% | -8.88% | -7.29% | 503% | 164% |
| **Overall** | -5.12% | -8.20% | -7.06% | 454% | 162% |
|  |  |  |  |  |  |
|  |  |  | **RA** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrY | psnrU | psnrV | EncT | DecT |
| HLG444 | -5.93% | -8.12% | -7.24% | 455% | 157% |
| HLG422 | -5.54% | -9.24% | -7.51% | 616% | 162% |
| **Overall** | -5.73% | -8.68% | -7.37% | 535% | 159% |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SVT RGB** |  |  | **AI** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrG | psnrB | psnrR | EncT | DecT |
| SVT16 | 0.70% | 0.82% | 0.79% | 4842% | 119% |
| SVT12 | -2.54% | -1.95% | -2.03% | 5252% | 137% |
| **Overall** | -0.92% | -0.57% | -0.62% | 5047% | 128% |
|  |  |  |  |  |  |
|  |  |  | **LDB** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrG | psnrB | psnrR | EncT | DecT |
| SVT16 | -0.52% | 1.13% | 1.13% | 572% | 132% |
| SVT12 | -3.31% | -1.05% | -1.02% | 647% | 142% |
| **Overall** | -1.91% | 0.04% | 0.05% | 609% | 137% |
|  |  |  |  |  |  |
|  |  |  | **RA** |  |  |
|  |  |  | **Over HM16.23** |  |  |
|  | psnrG | psnrB | psnrR | EncT | DecT |
| SVT16 | -0.86% | 0.91% | 0.91% | 714% | 132% |
| SVT12 | -3.72% | -1.32% | -1.29% | 802% | 142% |
| **Overall** | -2.29% | -0.21% | -0.19% | 758% | 137% |

Lossless

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **PQ** | **All Intra** | | | **Low delay B** | | | **Random Access** | | |
| **ratio** | | bit-rate savings | **ratio** | | bit-rate savings | **ratio** | | bit-rate savings |
| HM16.23 | VTM\_U\_CE | HM16.23 | VTM\_U\_CE | HM16.23 | VTM\_U\_CE |
| PQ444 | 2.5 | 2.5 | 0.89% | 3.1 | 3.0 | 4.80% | 3.1 | 3.0 | 4.47% |
| PQ422 | 2.3 | 2.3 | -0.18% | 2.9 | 2.8 | 3.40% | 2.9 | 2.8 | 3.13% |
| **Overall** | **2.4** | **2.4** | **0.36%** | **3.0** | **2.9** | **4.10%** | **3.0** | **2.9** | **3.80%** |
| Enc Time[%] | 7206% | | | 976% | | | 983% | | |
| Dec Time[%] | 152% | | | 147% | | | 149% | | |
|  |  |  |  |  |  |  |  |  |  |
| **HLG** | **All Intra** | | | **Low delay B** | | | **Random Access** | | |
| **ratio** | | bit-rate savings | **ratio** | | bit-rate savings | **ratio** | | bit-rate savings |
| HM16.23 | VTM\_U\_CE | HM16.23 | VTM\_U\_CE | HM16.23 | VTM\_U\_CE |
| HLG444 | 1.8 | 1.7 | 3.27% | 1.9 | 1.9 | 4.25% | 2.0 | 1.9 | 4.08% |
| HLG422 | 1.7 | 1.6 | 2.37% | 1.9 | 1.9 | 3.66% | 1.9 | 1.9 | 3.49% |
| **Overall** | **1.7** | **1.7** | **2.82%** | **1.9** | **1.9** | **3.96%** | **1.9** | **1.9** | **3.79%** |
| Enc Time[%] | 7782% | | | 817% | | | 767% | | |
| Dec Time[%] | 132% | | | 128% | | | 126% | | |
|  |  |  |  |  |  |  |  |  |  |
| **SVT** | **All Intra** | | | **Low delay B** | | | **Random Access** | | |
| **ratio** | | bit-rate savings | **ratio** | | bit-rate savings | **ratio** | | bit-rate savings |
| HM16.23 | VTM\_U\_CE | HM16.23 | VTM\_U\_CE | HM16.23 | VTM\_U\_CE |
| SVT16 | 1.2 | 1.2 | 1.46% | 1.2 | 1.2 | 1.18% | 1.2 | 1.2 | 1.11% |
| SVT12 | 1.3 | 1.2 | 3.12% | 1.3 | 1.3 | 2.71% | 1.3 | 1.3 | 2.55% |
| **Overall** | **1.2** | **1.2** | **2.29%** | **1.3** | **1.2** | **1.95%** | **1.3** | **1.2** | **1.83%** |

The AHG recommends the following:

• To review all related contributions;

• To continue high bit depth, high bit rate, and high frame rate studies.

• To consider the timeline for high bit depth profile development in VVC version 2.

No study on HFR so far.

Generally, the gains over HEVC are much lower. For 16 bit, losses are observed even still with the bug-fixed CE anchor.

Target of 12 bit profile? 4:2:0, 4:2:2 or 4:4:4? Needs further consideration, and no contributions on this yet. If 4:2:0 might be interesting for consumer applications, is the low QP range investigation appropriate for that?

One expert mentions that also higher bit depth profiles (14, 16) would be interesting to support emerging types of content.

[JVET-V0009](https://jvet-experts.org/doc_end_user/current_document.php?id=10787) JVET AHG report: SEI message studies (AHG9) [J. Boyce, S. McCarthy, C. Fogg, P. de Lagrange, A. Luthra, G. J. Sullivan, A. Tourapis, Y.-K. Wang, S. Wenger]

At total of 16 contributions are identified relating to AHG9, of which:

• 8 contributions relate to the mandate on the potential needs for additional SEI messages;

• 5 contributions relate to the mandate on SEI messages previously adopted or specified in AVC, HEVC, VVC, or VSEI;

• 1 contribution relates to the mandate on possible need of mandatory post processing in the context of SEI messages; and

• 2 contributions are crosschecks of proposed software that relate to the mandate on showcase and usage information for SEI messages

The following is a list of contributions related to AHG9.

New SEI messages

Post-filtering

JVET-V0058 AHG9: On post-filter SEI [M. M. Hannuksela, E. B. Aksu, F. Cricri, H. R. Tavakoli (Nokia)]

JVET-V0091 AHG9/AHG11: SEI messages for carriage of neural network information for post-filtering [B. Choi, Z. Li, W. Wang, W. Jiang, X. Xu, S. Wenger, S. Liu (Tencent)]

Decoder initialization

JVET-V0081 AHG9: On the decoder initialization information [Hendry, S. Lee, S. Kim (LGE), Y.-K. Wang, K. Zhang, L. Zhang, Y. Wang, J. Xu, Z. Deng (Bytedance)]

JVET-V0112 AHG9: On Bitstream Properties Signalling for Decoder Initialization [S. Deshpande (Sharp)]

Other

JVET-V0062 AHG9: Picture quality metrics SEI message [Y. He, M. Coban, M. Karczewicz (Qualcomm)]

JVET-V0069 AHG9: Decoded GDR clean area hash SEI message [L. Wang, S. Hong, K. Panusopone, M. M. Hannuksela (Nokia)]

JVET-V0071 AHG9: Temporal sublayer information SEI message [R. Sjöberg, M. Pettersson, M. Damghanian, J. Ström (Ericsson)]

JVET-V0108 AHG9: Colour Transform Information SEI message [E. François, M. Radosavljevic, P. de Lagrange, F. Leleannec (InterDigital)]

SEI messages previously adopted in AVC, HEVC, VVC, and VSEI

JVET-V0061AHG9: Display orientation information SEI message [Y. He, M. Coban, M. Karczewicz (Qualcomm), J. Boyce (Intel)]

JVET-V0063 AHG9: On the scalability dimension information SEI message [Y. Wang, Y.-K. Wang, L. Zhang (Bytedance)]

JVET-V0064 AHG9: On the MAI, DRI, and ACI SEI messages and their interactions with the SDI SEI message [Y.-K. Wang, Y. Wang, L. Zhang (Bytedance)]

JVET-V0065 AHG9: On the DRAP and EDRAP indication SEI messages [Y.-K. Wang, L. Zhang, Y. Wang (Bytedance)]

JVET-V0093 AHG9: Film grain estimation and film grain synthesis for VVC – SEI message characteristics, film grain estimation and film grain synthesis modules [Miloš Radosavljević, Edouard François (InterDigital)]

On possible mandatory post processing in the context of SEI messages

JVET-V0113 Thoughts on SEI messages [Walt Husak]

Crosschecks

JVET-V0151 Crosscheck of JVET-V0093 (AHG9: Film grain estimation and film grain synthesis for VVC Film grain characteristics SEI message , film grain estimation and film grain synthesis modules) [P. Yin, S.McCarthy (Dolby)]

JVET-V0152 Crosscheck of JVET-V0108 (AHG9: Colour Transform Information SEI message) [F. Pu (Dolby)]

Activities

The regular JVET e-mail reflector was used for discussions (jvet@lists.rwth-aachen.de) with [AHG9] in message headers. There were no emails besides the AHG kickoff message sent to the JVET reflector during the AHG period.

Recommendations

The AHG recommends to:

• Review all related contributions;

• Continue SEI messages studies.

[JVET-V0010](https://jvet-experts.org/doc_end_user/current_document.php?id=10788) JVET AHG report: Encoding algorithm optimization (AHG10) [A. Duenas, A. Tourapis, A. Norkin, R. Sjöberg]

The following input documents were identified to be related to this AHG:

JVET-V0056 [AHG10] GOP-based temporal filter improvements

This contribution proposes a set of changes to the GOP-based temporal filter in the VTM that aim at improving the BD-rate performance. These changes were first proposed in JVET-U0056.

The average Y/U/V BD-rate improvements using the VTM-12 CTC are reported to be equal to −1.4%/−1.0%/−1.1% for RA for the 3 colour components respectively. All BDR numbers were computed using the unfiltered source sequences as the reference.

In addition, the same changes were implemented in the HM where the BD-rate improvements were found to be equal to -1.0%/-1.0%/-1.0% under the same conditions.

The VTM proposal itself is unchanged since JVET-U0056, except for fixing a bug regarding motion compensation of blocks along the edge a picture. The code for the original proposal has been available since 2021-01-22 on the VTM Github.

Subjective viewing has been carried out by the proponents, where the anchor and test were found to have similar quality for all viewed sequences.

Finally, an HM version of the algorithm has been implemented, with similar performance. While the algorithm is the same for the HM implementation, the multiplications for the weights have been slightly modified which is explained in the contribution.

We do observe a relationship of the QP used with both the performance of this scheme as well as its impact on encoder and decoder complexity. In particular, for the lower QP values, i.e. QP values of 22 and 27, quite often a considerable bitrate reduction is observed. For the higher QP values an increase in bitrate for some material was also observed. Although it is not clear how much such numbers could be trusted, at the higher QP values an increase in encoding and decoding time was also observed that might not be reflected in the averages.

The proposal was implemented on top of VTM-12.0. The method is applied for RA coding only. The BD-rate result relative to VTM-12.0 is reported below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Over VTM-12.0** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 | -1.83% | -1.86% | -2.55% | 93% | 95% |
| Class A2 | -1.07% | -0.78% | -0.79% | 97% | 104% |
| Class B | -1.40% | -0.95% | -0.98% | 95% | 93% |
| Class C | -1.19% | -0.57% | -0.30% | 98% | 109% |
| Class E |  |  |  |  |  |
| **Overall** | -1.36% | -1.00% | -1.08% | 96% | 100% |
| Class D | -1.48% | -0.09% | -0.15% | 99% | 106% |
| Class F | 0.00% | 0.00% | 0.00% | 96% | 119% |

It is pointed out that the encoding time may not be reliable, but includes runtime of MCTF.

In addition, these are the results when compared to VTM-12.0 without temporal filtering:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Over VTM-12.0 with MCTF = 0** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 | -4.54% | -8.89% | -8.66% | 90% | 81% |
| Class A2 | -6.21% | -10.83% | -10.59% | 92% | 88% |
| Class B | -7.66% | -9.17% | -9.39% | 94% | 86% |
| Class C | -2.82% | -4.37% | -3.86% | 98% | 95% |
| Class E |  |  |  |  |  |
| **Overall** | -5.45% | -8.17% | -8.01% | 94% | 88% |
| Class D | -0.81% | -3.53% | -3.47% | 98% | 92% |
| Class F | 0.00% | 0.00% | 0.00% | 99% | 100% |

Finally, the contribution presents also results using HM-16.23 compared to the CTC:

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Random Access Main 10** | | |
|  | Y | U | V |
| Class A1 | -1.4% | -1.5% | -1.8% |
| Class A2 | -1.1% | -1.1% | -1.2% |
| Class B | -1.6% | -1.8% | -1.7% |
| Class C | -1.0% | -0.9% | -1.0% |
| Class D | -1.0% | -0.8% | -0.6% |
| Class E |  |  |  |
| Class F | 0.0% | 0.0% | 0.0% |
| **Overall** | -1.0% | -1.0% | -1.0% |
| Enc Time[%] | 107% | | |
| Dec Time[%] | 100% | | |

It is interesting to note that the proposed method, and ignoring the per QP variations mentioned earlier, shows an average decoder complexity reduction on the results. Nevertheless, it is indicated in JVET-U0056 that there seems to be no discernible impact on encoding complexity.

JVET-V0057 [AHG10] Block importance mapping

This contribution proposes a new algorithm for the VTM to signal CTU level QP delta values in pictures that will be used for reference. The QP value to use for each CTU is based on the estimated importance of a given CTU for future pictures and the QP selected is in the range of −2 to +2 relative to the picture QP.

The method was reportedly implemented and tested together with the temporal filter changes first presented in JVET-U0056 under the VTM-12.0 RA test configurations. The method is not proposed to be used for AI or LD configurations.

The average CTC RA Y/U/V BD-rate improvements for the proposed changes together with JVET-V0056 compared to VTM-12 with JVET-V0056 are reported to be −1.4%/−3.9%/−3.8% for RA. Comparing the proposed changes together with JVET-V0056 to the regular VTM-12, the average BD-rates are −2.8%/−5.0%/−4.9%.

It is proposed by the contribution to adopt the algorithm into the VTM software.

Version 2 of this document provides a statement that the results for the HM implementation will be added later on.

The estimation of the difference between pictures is based on calculations performed in the temporal filter. The QP is only modified for frames where the temporal filter is active, i.e., where the POC is divisible by eight.

The contribution proposes that rather than using a fixed QP for each temporal layer, individual QP values for each CTU is set based on how important it is calculated the CTU will be to future pictures. This was proposed to estimate this importance is estimated by measuring the difference between motion compensated pictures.

The contribution indicates that there seems to be no discernible impact on complexity.

The proposal was implemented on top of VTM-12.0 with JVET-V0056 [2]. The method is applied for RA coding only. The BD-rate result relative to VTM-12.0 with JVET-V0056 is reported below. The contribution says that encoding and decoding times are not accurate.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Over VTM-12.0 with V0056** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 | -0.66% | -0.84% | -2.41% | 108% | 114% |
| Class A2 | -1.09% | -4.11% | -2.93% | 108% | 111% |
| Class B | -2.02% | -4.97% | -5.10% | 107% | 116% |
| Class C | -1.56% | -4.88% | -3.94% | 132% | 126% |
| Class E |  |  |  |  |  |
| **Overall** | -1.44% | -3.95% | -3.82% | 114% | 117% |
| Class D | -1.08% | -4.69% | -4.35% | 125% | 152% |
| Class F | -2.61% | -3.48% | -2.13% | 105% | 107% |

In addition, these are the results when comparing the proposal together with JVET-V0056 to VTM-12.0:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Over VTM-12.0** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 | -2.52% | -2.76% | -4.95% | 101% | 109% |
| Class A2 | -2.22% | -4.98% | -3.80% | 105% | 116% |
| Class B | -3.47% | -5.95% | -6.11% | 101% | 108% |
| Class C | -2.76% | -5.50% | -4.30% | 129% | 138% |
| Class E |  |  |  |  |  |
| **Overall** | -2.84% | -5.00% | -4.94% | 109% | 117% |
| Class D | -2.61% | -4.81% | -4.53% | 123% | 161% |
| Class F | -2.61% | -3.48% | -2.13% | 101% | 114% |

The method was also tested on HM-16.23, results will be provided at a later stage.

JVET-V0078 AHG 10: QP control for very smooth blocks

Large transforms are excellent in reducing spatial redundancy. However, when source samples are very smooth the subjective quality can drop very quickly in such areas with too coarse quantization. It is therefore suggested to reduce the QP according to a linear model for very smooth regions to prolong the breakdown of the subjective quality. Since smooth regions are relatively easy to code it is claimed that the overhead in bitrate can be manageable.

The impact on BDR has been tested on HDR:

VTM-12.0 HDR RA CTC (luma/Cb/Cr): 0.14%/0.14%/0.02%

HM-16.22 (TF on) HDR RA CTC (luma/Cb/Cr): 0.49%/-0.36%/-0.28%

It is asserted that the proposal can improve subjective quality of smooth regions for HDR and it is suggested to update the VTM and HM with this functionality. The proposal leads to an objective BDR loss by reducing the QP for smooth blocks. In contrast, it is indicating that the subjective quality can be improved in smooth areas.

Objective results

The method has been tested for HDR RA CTC. It can be noted that there is a drop in BDR by the proposed method and that the drop is slightly larger for the HM than for the VTM. The encoding and decoding times are not reliable.

Table 1: VTM-12.0 for CTC HDR RA

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **PSNR** | | |  |  |
|  | Y | U | V | EncT | DecT |
| Class H1 | 0,17% | 0,19% | 0,07% | 100% | 102% |
| Class H2 | 0,09% | 0,04% | -0,08% | 104% | 122% |
| **Overall** | 0,14% | 0,14% | 0,02% | 101% | 109% |

Table 2: HM-16.22 (TF on) for CTC HDR RA

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **PSNR** | | |  |  |
|  | Y | U | V | EncT | DecT |
| Class H1 | 0,71% | -0,48% | -0,23% | 85% | 85% |
| Class H2 | 0,11% | -0,15% | -0,38% | 84% | 84% |
| **Overall** | 0,49% | -0,36% | -0,28% | 85% | 85% |

No additional objective results requested for H1 sequence class on the HDR RA CTC were presented.

Subjective video quality is best evaluated by playout on an HDR capable TV. To illustrate the subjective quality improvement by the proposed method the contribution contains a snapshot from the 4K HDR PQ Netflix sequence SparksTruckPack (H1 sequence class) and SunsetBeach (H2 sequence class).

2.5 JVET-V0095 AHG10: Using original samples for SAO and ALF optimization

In VTM-12.0, motion compensated temporal pre-filtering (MCTF) is used for the random access (RA) configuration. Samples filtered by the MCTF are used for sample adaptive offset (SAO) and adaptive loop filter (ALF) optimizations. This contribution proposes to use original samples for SAO and ALF optimization as an encoder only modification. Compared to VTM-12.0, the average Y/U/V BD-rates reportedly are -0.22%/-0.09%/-0.08% for RA with similar running time.

In VTM-12.0, the encoder minimizes the rate\*lambda + distortion cost metric for the sample adaptive offset (SAO) and adaptive loop filter (ALF) methods. When motion compensated temporal pre-filtering (MCTF) is enabled for the random access (RA) configuration, it was observed that the SAO and ALF processes minimize the cost for samples filtered by the MCTF. On the other hand, the final PSNR computation that is also used for the BD-rate computation is calculated using original unfiltered input samples.

In the proposal, instead of using samples filtered by the MCTF, the original samples are used to calculate the distortion for SAO and ALF for parameters estimation.

The proposed method was implemented on top of VTM-12.0 and evaluated under the common test conditions for RA and LDB.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Random access Main10** | | | | |
|  | **Over VTM-12.0** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 | -0.15% | -0.02% | -0.17% | 101% | 101% |
| Class A2 | -0.02% | -0.04% | 0.15% | 100% | 99% |
| Class B | -0.10% | 0.18% | 0.12% | 100% | 100% |
| Class C | -0.59% | -0.51% | -0.43% | 100% | 99% |
| Class E |  |  |  |  |  |
| **Overall** | **-0.22%** | **-0.09%** | **-0.08%** | **100%** | **100%** |
| Class D | -0.90% | -0.65% | -0.52% | 98% | 98% |
| Class F | 0.00% | 0.00% | 0.00% | 101% | 101% |
|  |  |  |  |  |  |
|  | **Low delay B Main10** | | | | |
|  | **Over VTM-12.0** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 |  |  |  |  |  |
| Class A2 |  |  |  |  |  |
| Class B | 0.00% | 0.00% | 0.00% | 100% | 101% |
| Class C | 0.00% | 0.00% | 0.00% | 100% | 103% |
| Class E | 0.00% | 0.00% | 0.00% | 101% | 100% |
| **Overall** | **0.00%** | **0.00%** | **0.00%** | **100%** | **101%** |
| Class D | 0.00% | 0.00% | 0.00% | 100% | 98% |
| Class F | 0.00% | 0.00% | 0.00% | 101% | 102% |

JVET-V0066 AHG8: Encoder improvements to palette coding for high bit depth

This contribution proposes two encoder modifications to palette coding for high bit depth:

• Proposal#1 uses on-the-fly bit calculation functions instead of pre-defined lookup tables to reduce memory usage and has no impact to coding performance and can reduce memory size.

• Proposal#2 fixes QP offset derivation used for an error limit to improve coding performance of palette coding.

Proposal#2, it is reported that average bd-rate changes for YUV at normal QP are (-8.70%, -10.86%, -11.66%) for AI and (-6.09%, -8.43%, -9.16%) for RA, and average bd-rate changes for RGB are (-8.51%, -8.65%, -8.32%) for AI and (-5.64%, -5.86%, -5.73%) for RA; average bd-rate changes for YUV at low QP are (-1.80%, -2.08%, -2.09%) for AI and (-1.34%, -1.27%, -1.31%) for RA, and average bd-rate changes for RGB are (-1.87%, -1.93%, -1.96%) for AI and (-1.19%, -1.33%, -1.27%) for RA, respectively.

At the encoder, to retrieve errorLimit from the lookup table, the QP needs to be adjusted to an 8-bit domain QP by a QP offset. However, in the VTM, the QP offset always takes a fixed value of “-12”. This contribution proposes to fix the QP offset based on BitDepth, i.e. considering BdOffset as below.

The QPs used for testing are listed as follow:

 Normal QP (QP=22, 27, 32, 37)

 Low QP (QP=-13, -8, -3, 2, 7, 12)

This contribution reports encoder improvements to palette coding by using on-the-fly bit calculation functions instead of the pre-defined lookup tables and fixing QP Offset derivation used for an error limit. It is recommended to adopt proposed software fixes to the next VTM.

JVET-V0127 An optimized VVC encoder implementation

This contribution reports the performance of an optimized VVC encoder, BVC, developed by Bytedance. A majority of the coding tools and features introduced in VVC have been integrated and optimized in the BVC encoder. In addition, it also includes real-world encoder features like scene change detection, rate control and multi-threading. When compared to the HM and the VTM, the corresponding global BD-rate gain and speedup factors under the Random Access configuration are summarized as follows:

• Fast preset (6 threads): 34.43%, 17x (HM), 131x (VTM)

• Slow preset (6 threads): Will be presented on an update of the contribution.

Simulation Results

For those simulations, 6 threads are used for the BVC encoder. It could be seen that with the fast preset, the BD-rate gain over HM is still approx. 34.43% on average, but a speedup of 17 times and 131 times over the HM and the VTM, respectively is observed.

The slow preset, which is targeting at close performance to VTM, the BD-rate gain over HM is no yet available, but a speedup of more than 7 times over VTM was reported.

**Coding performance of the BVC encoder @ fast preset**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Class** | **RA** | | | | | |
| PSNR BD-rate relative to HM | | | | Speedup | |
| Y (%) | U (%) | V (%) | YUV (%) | vs HM | vs VTM |
| A1 | -35.76 | -43.56 | -48.57 | -38.33 | 22.36 | 148.45 |
| A2 | -36.93 | -45.53 | -45.83 | -39.12 | 18.40 | 133.37 |
| B | -34.12 | -54.24 | -50.68 | -38.70 | 18.05 | 130.91 |
| C | -20.04 | -30.53 | -30.50 | -22.66 | 11.78 | 118.43 |
| **Overall** | **-31.26** | **-44.04** | **-43.91** | **-34.43** | **16.88** | **131.20** |

[JVET-V0011](https://jvet-experts.org/doc_end_user/current_document.php?id=10789) JVET AHG report: Neural network-based video coding (AHG11) [S. Liu, A. Segall, Y. Ye, E. Alshina, J. Chen, F. Galpin, J. Pfaff, S. S. Wang, M. Wien, P. Wu, J. Xu]

The AHG used the main JVET reflector, jvet@lists.rwth-aachen.de, for email exchange with AHG11 included in the subject lines. 16 emails were exchanged on the reflector.

2.1 Technical Evaluation

The AHG made meaningful progress on the mandate to evaluate and quantify potential NN based video coding technologies. This was done in both the context of the EE and non-EE contributions.

A summary of the performance of technology provided as input to the 22nd meeting is provided below:

**EE Technology**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **#** | **Title** | **JVET-U** | **Category** | **Performance** | **Dec.T.** |
| JVET-V0073 | EE1.2: Additional experimental results of NN-based super resolution (JVET-U0053) | JVET-U0053 | SupeRes | RA(4K):**2.5**%(Y) RA(4K):**5.8**%(Y) RA(4K):**6.5**%(Y) | ×0.3 ×1.5 ×1.5 |
| JVET-V0096 | EE1-2.3: Neural Network-based Super Resolution | JVET-U0099 | SupeRes | RA(4K):**8.1**%(Y) AI(4K): **10.8**% (Y) | ×0.3 ×0.4 |
| JVET-V0114 | EE1-1.3: Test on Neural Network-based In-Loop Filter with No Deblocking Filtering stage | JVET-U0115 | NN deblock | RA:**7.2**%(Y); 13% (Ch) RA:**7.5**%(Y); 14% (Ch) | ×137 ×146 |
| JVET-V0115 | EE1-1.4: Test on Neural Network-based In-Loop Filter with Large Activation Layer | JVET-U0104 | NN deblock | RA:**8.3**%(Y); 20% (Ch) RA:**8.5**%(Y); 22% (Ch) | ×337 ×344 |
| JVET-V0137 | EE1-1.1: neural network based in-loop filter using depthwise separable convolution and regular convolution (JVET-U0061) | JVET-U0061 | CNN in-loop | RA:**1.0**%(Y); 6% (Ch) | ×50 |
| JVET-V0149 | EE1: Tests on Decomposition, Compression and Synthesis (DCS)-based Technology (JVET-U0096) | JVET-U0096 | SupeRes | RA(4K):**9.6**%(Y) LD(4K):**17.5**%(Y) | no info |

**Non-EE Technology (Performance)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **#** | **Title** | **Category** | **Performance** | **Dec.T.** |
| [JVET-V0074](https://jvet-experts.org/doc_end_user/current_document.php?id=10722) | AHG11: Separate density attention network for loop filtering | NN In-loop filter | RA: **5**% (Y) 14% (Ch.), in VTM10.0 | ×100 |
| [JVET-V0075](https://jvet-experts.org/doc_end_user/current_document.php?id=10723) | AHG11: Content-adaptive neural network post-processing filter | NN post-filter | RA(C&D classes): **2.5**%(Y), 5%(Ch.) in VTM.11.0 | ×450 |
| [JVET-V0076](https://jvet-experts.org/doc_end_user/current_document.php?id=10724) | AHG11: Deep-learning based inter prediction blending | NN BIO | RA: **0.6** % / **0.9** % (Y) 14% (Ch.), in VTM10.0 | ×11 |
| [JVET-V0090](https://jvet-experts.org/doc_end_user/current_document.php?id=10738) | AHG11: Neural network based temporal processing | NN In-loop filter | RA(C&D classes): **6**%(Y), 6%(Ch.) in VTM.11.0 | ×4000 |
| [JVET-V0091](https://jvet-experts.org/doc_end_user/current_document.php?id=10739) | AHG9/AHG11: SEI messages for carriage of neural network information for post-filtering | HLS |  |  |
| [JVET-V0092](https://jvet-experts.org/doc_end_user/current_document.php?id=10740) | AHG11: Replacing SAO in-loop filter with Neural Networks | NN SAO | K=5 RA: **2.8** % (Y) AI: **3.5** % (Y), in VTM11.0 K=9 RA: **3.5** % (Y) | ×95 (RA) ×350(AI) ×125 (RA) |
| [JVET-V0100](https://jvet-experts.org/doc_end_user/current_document.php?id=10748) | AHG11: Deep In-Loop Filter with Adaptive Model Selection | NN In-loop filter | RA (classes BCD) :**11** % (Y)  AI: **8.8** % (Y), in VTM11.0 | ×290 (RA)  ×143(AI) |
| [JVET-V0101](https://jvet-experts.org/doc_end_user/current_document.php?id=10749) | AHG11: Conditional In-Loop Filter with Parameter Selection | NN In-loop filter | ~JVET-V0100 | ×250 (RA) |
| [JVET-V0102](https://jvet-experts.org/doc_end_user/current_document.php?id=10750) | AHG11 & AHG12: Deep In-Loop Filter with Adaptive Model Selection for Enhanced Compression Beyond VVC Capability | NN In-loop filter | RA (classes BCD) :**9** % (Y) | ×70 (RA) |
| [JVET-V0105](https://jvet-experts.org/doc_end_user/current_document.php?id=10753) | AHG11: neural network-based intra prediction: updated signaling | NN Intra | RA : **1.7** % (Y)  AI: **3.5** % (Y), in VTM11.0 | ×5.5...8.4 (RA)  ×36..63(AI) |

**Non-EE Technology (Features and Characteristics)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **#** | **Features** | **#params** | **kMAC /pixel** | **NN structure** |
| [JVET-V0074](https://jvet-experts.org/doc_end_user/current_document.php?id=10722) | frame level residual scaling, CTU on/off, input: 128x128 YUV444, before SAO | **1 M** | ? | 26\*RB+¯3\*RB­+2\*¯RB2\*­ |
| [JVET-V0075](https://jvet-experts.org/doc_end_user/current_document.php?id=10723) | fine-tuning per content, CTU level Luma/Chroma independent on/off; input: 128x128 YUV444 + QPmap, FineTune per video sequence (only Bias); LZMA2 for updated weights compression | **0.15M** (323 variable) | ? | CONV&B+4\*RB+CONV\*B+LongSkipConnection |
| [JVET-V0076](https://jvet-experts.org/doc_end_user/current_document.php?id=10724) | N=5 and N=6 (different depth of NN), 16bits parameters; input: 16x16 | **6/8K** (13/17KB ) | 11.3 / 16.6 | N\*CONV+LongSkipConnection |
| [JVET-V0090](https://jvet-experts.org/doc_end_user/current_document.php?id=10738) | Different CNN filters for output and for future refPic, NN post != NN in-loop filters | **100M** (5 x 80.9MB ) | 2000 | PCD (Pyramid, Cascading and Deformable) +TSA (Temporal and Spatial Attention) |
| [JVET-V0091](https://jvet-experts.org/doc_end_user/current_document.php?id=10739) | Good to Understand if parameters are sufficient to describe all filters structure |  |  |  |
| [JVET-V0092](https://jvet-experts.org/doc_end_user/current_document.php?id=10740) | Offset are signaled, K masks --> out of CNN, Input: 128x128; 16 bits and 32 bits precision for NN parameters tested --> almost no difference | 1.3M / 2.5M | K\*322 | 10\*CONV |
| [JVET-V0100](https://jvet-experts.org/doc_end_user/current_document.php?id=10748) | Picture on/off control + CTU level model selection (not in AI) New: RB number extended 16-->32, number of channels reduced 128-->96; models "dictionary" depends on QP and resolution | **528**M (24\*22M) | 1400 | ¯32\*RB­ (69 CONV in total) |
| [JVET-V0101](https://jvet-experts.org/doc_end_user/current_document.php?id=10749) | Conditional (QP map is auxiliary input) | **90**M (4\*22M) | 1400 | ¯8\*(RB+FС)­ (69 CONV+ 10 FC total) |
| [JVET-V0102](https://jvet-experts.org/doc_end_user/current_document.php?id=10750) | JVET-V0100 but in top JVET JVET-U0100 | **528**M (24\*22M) | 1400 | ¯32\*RB­ (69 CONV in total) |
| [JVET-V0105](https://jvet-experts.org/doc_end_user/current_document.php?id=10753) | same as JVET-T0073 + new syntax; float and 16bit integer versions, 16bits integer is ~2 times faster than float-point | ~**10**M | 100 | different number of CONV and FC layers depending on Intra block size |

The AHG finalized, conducted and discussed the EE on NN based video coding. This was accomplished mainly with two teleconferences, which were held on January 22nd and April 6th.

A summary report for the EE is available at this meeting as:

|  |  |  |
| --- | --- | --- |
| JVET-V0023 | EE1: Summary of Exploration Experiments on Neural Network-based Video Coding | E. Alshina, S. Liu, W. Chen, Y. Li, R.-L. Liao, Z. Ma, H. Wang |

CTC Refinement and Support

The AHG refined and released the CTC test conditions on April 6th, 2021.

Additionally, to better support the calculation of the MS-SSIM metric according to the test conditions, the AHG did the following:

1. HDRTools was updated to enable support for the MS-SSIM calculuation that is present in VTM 11.0. This was made available in the 0.22-dev branch.

2. A patch for VTM 11.0 was created to enable the output of the MS-SSIM data with high precision. This patch was incorporated into the branched used for the EE tests.

The AHG11 coordinates would like to thank Alexis and Timofey for their generous contributions.

Anchors for the NN-based video coding activity were created and released on March 2, 2021. The anchors were announced on the reflector and made available on the Git repository used for the AhG activity: https://vcgit.hhi.fraunhofer.de/jvet-ahg-nnvc/nnvc-ctc/-/tree/master

It is noted that the anchor data includes performance data for QP points 22, 27, 32, 37, 42 and 47. The largest QP point was generated to support the EE test on super-resolution methods.

The AHG coordinated with SC29/AHG5 to prepare a viewing procedure for EE contributions. Sequences were selected for five proposals included in the EE, with each proponent selecting two to three sequences/QP pair that illustrated the visual benefit of the proposal. These selections could include results from either the RA and LDB configurations.

The decoded sequences were encapsulated in an MP4 container and uploaded to the JVET FTP upload directory. With close coordination with SC29/AHG5, it is intended to perform remote viewing sessions to understand the visual benefit of the approaches. This will tentatively be done by viewing each sequence multiple times, in order to give participants the opportunity to focus and evaluate different aspects of the sequences.

While not explicitly in the AHG mandates, the AHG did receive a comment regarding licensing terms and conditions (e.g., for training materials). The comment was posted on the reflector on April 6, 2021 and is highlighted in case it is useful for further discussion: Revisit – joint meeting with parent bodies?

There are 18 input contriubtions related to the AHG mandates. Seven of the contributions are directly relatd to the EE activity, while the remaining 11 contributions are related to AHG11 but not directly part of the EE. The list of input contributions is provided below.

EE Related Input Contributions

|  |  |  |
| --- | --- | --- |
| [JVET-V0073](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10721) | EE1.2: Additional experimental results of NN-based super resolution (JVET-U0053) | [T. Chujoh](mailto:chujoh.takeshi@sharp.co.jp), T. Ikai (Sharp) |
| [JVET-V0096](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10744) | EE1-2.3: Neural Network-based Super Resolution | [A. M. Kotra](mailto:akotra@qti.qualcomm.com), K. Reuzé, [J. Chen](mailto:cjianle@qti.qualcomm.com), H. Wang, M. Karczewicz, J. Li (Qualcomm) |
| [JVET-V0114](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10763) | EE1-1.3: Test on Neural Network-based In-Loop Filter with No Deblocking Filtering stage | [H. Wang](mailto:hongtaow@qti.qualcomm.com), [J. Chen](mailto:cjianle@qti.qualcomm.com), [A. M. Kotra](mailto:akotra@qti.qualcomm.com), [K. Reuzé](mailto:kreuz@qti.qualcomm.com), [M. Karczewicz (Qualcomm)](mailto:martak@qti.qualcomm.com) |
| [JVET-V0115](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10764) | EE1-1.4: Test on Neural Network-based In-Loop Filter with Large Activation Layer | [H. Wang](mailto:hongtaow@qti.qualcomm.com), [J. Chen](mailto:cjianle@qti.qualcomm.com), [A. M. Kotra](mailto:akotra@qti.qualcomm.com), [K. Reuzé](mailto:kreuz@qti.qualcomm.com), [M. Karczewicz (Qualcomm)](mailto:martak@qti.qualcomm.com) |
| [JVET-V0137](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10798) | EE1-1.1: neural network based in-loop filter using depthwise separable convolution and regular convolution (JVET-U0061) | [Z. Li](mailto:zeqiangli@tencent.com), C. Auyeung, [X. Xu](mailto:xiaozhongxu@tencent.com), W. Wang, X. Li, S. Liu (Tencent) |
| [JVET-V0148](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10809) | Crosscheck of JVET-V0096 (EE1-2.3: Neural Network-based Super Resolution) | [T. Ikai](mailto:ikai.tomohiro@sharp.co.jp), [T. Chujoh (Sharp)](mailto:chujoh.takeshi@sharp.co.jp) |
| [JVET-V0149](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10810) | EE1: Tests on Decomposition, Compression and Synthesis (DCS)-based Technology (JVET-U0096) | [Ming Lu](mailto:luming@smail.nju.edu.cn), [Zhan Ma (NJU)](mailto:mazhan@nju.edu.cn), Zhenyu Dai, Dong Wang (OPPO) |

Non-EE contributions

|  |  |  |
| --- | --- | --- |
| Reporting | | |
| [JVET-V0011](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10789) | JVET AHG report: Neural network-based video coding (AHG11) | S. Liu, A. Segall, Y. Ye, E. Alshina, J. Chen, F. Galpin, J. Pfaff, S. S. Wang, M. Wien, P. Wu, J. Xu |
| Loop Filtering | | |
| [JVET-V0055](https://jvet-experts.org/doc_end_user/current_document.php?id=10703) | Improved end to end deep intra frame compression with cross channel context model and loop filter | [C. Ma](mailto:changyue.mcy@alibaba-inc.com), [Z. Wang](mailto:baixiu.wz@alibaba-inc.com), [R.-L. Liao](mailto:ruling.lrl@alibaba-inc.com), [Y. Ye (Alibaba)](mailto:yan.ye@alibaba-inc.com) |
| [JVET-V0074](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10722) | AHG11: Separate density attention network for loop filtering | [Z. Wang](mailto:baixiu.wz@alibaba-inc.com), C. Ma, R.-L. Liao, Y. Ye (Alibaba) |
| [JVET-V0075](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10723) | AHG11: Content-adaptive neural network post-processing filter | Y. Lam, M. Santamaria, J. Lainema, F. Cricri, R. Ghaznavi-Youvalari, A. Zare, H. Zhang, H. R. Tavakoli, M. M. Hannuksela (Nokia) |
| [JVET-V0092](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10740) | AHG11: Replacing SAO in-loop filter with Neural Networks | [P. Bordes](mailto:philippe.bordes@interdigital.com), [F. Galpin](mailto:franck.galpin@interdigital.com), [T. Dumas](mailto:thierry.dumas@interdigital.com), [P. Nikitin (InterDigital)](mailto:pavel.nikitin@interdigital.com) |
| [JVET-V0100](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10748) | AHG11: Deep In-Loop Filter with Adaptive Model Selection | [Y. Li](mailto:yue.li@bytedance.com), [L. Zhang](mailto:lizhang.idm@bytedance.com), [K. Zhang (Bytedance)](mailto:zhangkai.video@bytedance.com) |
| [JVET-V0101](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10749) | AHG11: Conditional In-Loop Filter with Parameter Selection | [Y. Li](mailto:yue.li@bytedance.com), [L. Zhang](mailto:lizhang.idm@bytedance.com), [K. Zhang (Bytedance)](mailto:zhangkai.video@bytedance.com) |
| [JVET-V0102](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10750) | AHG11 & AHG12: Deep In-Loop Filter with Adaptive Model Selection for Enhanced Compression Beyond VVC Capability | [Y. Li](mailto:yue.li@bytedance.com), [L. Zhang](mailto:lizhang.idm@bytedance.com), [K. Zhang (Bytedance)](mailto:zhangkai.video@bytedance.com) |
| Inter Prediction | | |
| [JVET-V0076](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10724) | AHG11: Deep-learning based inter prediction blending | [F. Galpin](mailto:franck.galpin@interdigital.com), [P. Bordes](mailto:philippe.bordes@interdigital.com), [T. Dumas](mailto:thierry.dumas@interdigital.com), [A. Robert](mailto:antoine.robert@interdigital.com), [P. Nikitin](mailto:pavel.nikitin@interdigital.com), [F. Le Leannec (InterDigital)](mailto:Fabrice.LeLeannec@interdigital.com) |
| [JVET-V0090](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10738) | AHG11: Neural network based temporal processing | [B. Choi](mailto:bdchoi@tencent.com), [Z. Li](mailto:zeqiangli@tencent.com), [W. Wang](mailto:rickweiwang@tencent.com), [W. Jiang](mailto:vwjiang@tencent.com), [X. Xu](mailto:xiaozhongxu@tencent.com), [S. Liu (Tencent)](mailto:shanl@tencent.com) |
| High Level Syntax | | |
| [JVET-V0091](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10739) | AHG9/AHG11: SEI messages for carriage of neural network information for post-filtering | [B. Choi](mailto:bdchoi@tencent.com), [Z. Li](mailto:zeqiangli@tencent.com), [W. Wang](mailto:rickweiwang@tencent.com), [W. Jiang](mailto:vwjiang@tencent.com), [X. Xu](mailto:xiaozhongxu@tencent.com), [S. Wenger](mailto:swenger@tencent.com), [S. Liu (Tencent)](mailto:shanl@tencent.com) |
| Intra Prediction | | |
| [JVET-V0105](file:///\\\\Users\\asegall\\Documents\\Standards%20Proposals\\2021_04_Online\\JVET-V0011\\current_document.php%3fid=10753) | AHG11: neural network-based intra prediction: updated signaling | [T. Dumas](mailto:thierry.dumas@interdigital.com), [F. Galpin](mailto:franck.galpin@interdigital.com), [P. Bordes](mailto:philippe.bordes@interdigital.com), [P. Nikitin (InterDigital)](mailto:pavel.nikitin@interdigital.com) |

The AHG recommends:

* Review all input contributions
* Further discuss and define of common test conditions and exploration experiments as appropriate
* Perform viewing of the neural network-based video coding tools during the meeting, in coordination with SC29/AHG5.
* Continue investigating neural network-based video coding tools, including coding performance and complexity;

[JVET-V0012](https://jvet-experts.org/doc_end_user/current_document.php?id=10790) JVET AHG report: Enhanced compression beyond VVC capability (AHG12) [M. Karczewicz, Y. Ye, B. Bross, X. Li, K. Naser, H. Yang]

The primary activity of the AHG was the “Exploration experiment on enhanced compression beyond VVC capability” (JVET-U2024). The first indication of the achievable improvement over VVC are the results of this experiment. For example, the combined improvement of the package proposed in JVET-U0100 and bilateral filter over VTM 11 for AI and RA configurations are:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | All Intra Main10 | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 | -5.72% | -9.69% | -10.65% | 183% | 227% |
| Class A2 | -5.43% | -7.88% | -5.91% | 179% | 205% |
| Class B | -4.96% | -7.14% | -7.55% | 214% | 175% |
| Class C | -5.97% | -7.43% | -7.67% | 212% | 168% |
| Class E | -6.13% | -7.97% | -6.80% | 219% | 193% |
| Overall | -5.58% | -7.89% | -7.69% | 203% | 189% |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Random Access Main 10 | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 | -12.10% | -13.42% | -15.89% | 245% | 442% |
| Class A2 | -13.44% | -14.36% | -14.21% | 229% | 490% |
| Class B | -11.49% | -12.16% | -11.57% | 217% | 388% |
| Class C | -13.30% | -13.15% | -13.04% | 215% | 365% |
| Class E |  |  |  |  |  |
| Overall | -12.49% | -13.12% | -13.35% | 224% | 411% |

In addition, Intra Template Matching method also evaluated in this EE provides average {Y, U, V} BD-rate savings of {6.47%, 6.13%, 6.16%} for TMG class in AI configuration.

In addition to six EE2 contributions, 20 related contributions were received which can be subdivided as follows:

Partitioning

JVET-V0083, “EE2 related: asymmetric binary tree splitting on top of VVC”, F. Le Léannec, K. Naser, T. Dumas, A. Robert, F. Galpin, E. Francois (InterDigital)

JVET-V0097, “AHG12: Unsymmetric partitioning methods in video coding”, K. Zhang, L. Zhang, Z. Deng, N. Zhang, Y. Wang (Bytedance)

In Loop Filters

JVET-V0080, “AHG12: Extensions to CCALF”, S. Keating, A. Browne, K. Sharman (Sony)

JVET-V0104, “EE2-related: TU-level adaptive self-guided filter”, W. Yin, K. Zhang, L. Zhang, Y. Wang, H. Liu (Bytedance)

JVET-V0102, “AHG11 & AHG12: Deep In-Loop Filter with Adaptive Model Selection for Enhanced Compression Beyond VVC Capability”, Y. Li, L. Zhang, K. Zhang (Bytedance)

JVET-V0153, “AHG12: Cross-component Sample Adaptive Offset”, C.-W. Kuo, X. Xiu, Y.-W. Chen, H.-J. Jhu, W. Chen, X. Wang (Kwai)

Intra

JVET-V0098, “EE2-related: Template-based intra mode derivation using MPMs”, Y. Wang, L. Zhang, K. Zhang, Z. Deng, N. Zhang (Bytedance)

JVET-V0110, “AHG12: Two additional reference sample sets for CCLM”, C.-Y. Teng, Y.-C. Yang (FG Innovation)

JVET-V0087, “EE2-Related: Improvements of Decoder-Side Intra Mode Derivation” J. Zhao, S. Paluri, S. Kim (LGE)

Inter

JVET-V0086, “EE2-related: OBMC fixes and updates”, A. Robert, F. Galpin, F. Le Léannec, T. Poirier (InterDigital)

JVET-V0089, “EE2-related: Inter coding modes modifications”, A. Robert, F Le Léannec, F. Galpin, T. Poirier (InterDigital)

JVET-V0099, “AHG12: Adaptive Reordering of Merge Candidates with Template Matching”, N. Zhang, K. Zhang, L. Zhang, H. Liu, Z. Deng, Y. Wang (Bytedance)

JVET-V0103, “AHG12: Geometric prediction mode with motion vector differences”, Z. Deng, K. Zhang, L. Zhang, N. Zhang, Y. Wang (Bytedance)

JVET-V0117, “EE2-related: Combination of GPM and template matching”, R.-L. Liao, Y. Ye, X. Li, J. Chen (Alibaba)

JVET-V0118, “EE2-related: Extension of template matching to Affine, CIIP, GPM merge modes, and boundary sub-blocks”, C.-C. Chen, V. Seregin, Y.-J. Chang, Z. Zhang, H. Huang, Y. Zhang, M. Karczewicz (Qualcomm)

JVET-V0125, “AHG12: Evaluation of GPM with MMVD for coding efficiency improvement over VVC”, X. Xiu, H.-J. Jhu, C.-W. Kuo, W. Chen, Y.-W. Chen, X. Wang (Kwai)

JVET-V0126, “EE-related: Modified OBMC”, Y. Kidani, K. Kawamura, K. Unno (KDDI)

JVET-V0129, “AHG12: 3D Geometry for Global Motion Compensation”, H. Golestani, C. Rohlfing, M. Wien (RWTH Aachen)

Transforms

JVET-V0116, “Enhanced Intra MTS and LFNST for compression beyond VVC”, B. Ray, L. Kerofsky, M. Coban, M. Karczewicz, H. Egilmez, V. Seregin (Qualcomm)

JVET-V0119, “AHG12: LFNST extension with large kernel”, M. Koo, J. Zhao, J. Lim, S. Kim (LGE)

Recommendations

The AHG recommends:

• To review all the related contributions.

• To encourage contribution of new test sequences, especially 8k resolution, which might be included in future test conditions.

It is suggested to clarify at some point the purpose of these explorations, and how rigid JVET has to be in investigating the practicality of the technology. This depends on the question how “long term” a real standards development would be.

Several experts suggested to act at the current moment in an “inclusive” manner to be able judging the potential benefit, but also investigate the complexity vs. benefit tradoff.

It is commented that visual quality should also be considered.

# Project development (21)

## Deployment of standards (3)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0020](https://jvet-experts.org/doc_end_user/current_document.php?id=10760) Deployment status of the HEVC standard [G. J. Sullivan]

[JVET-V0021](https://jvet-experts.org/doc_end_user/current_document.php?id=10690) Deployment status of the VVC standard [G. J. Sullivan]

[JVET-V0167](https://jvet-experts.org/doc_end_user/current_document.php?id=10830) Updated information on the TV 3.0 project Call for Proposals from the Brazilian Digital Terrestrial TV Forum [M. Raulet, T. Biatek, T. Guionnet (Ateme), B. Bross (Fraunhofer HHI), P. de Lagrange, R. Schaefer, M. Kerdranvat, E. François (InterDigital)] [late]

## Text development and errata reporting (2)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0072](https://jvet-experts.org/doc_end_user/current_document.php?id=10720) AHG2: Proposal to remove some RPL constraints [A. Hallapuro, M. M. Hannuksela (Nokia), Hendry (LGE), Y.-K. Wang (Bytedance)]

[JVET-V0111](https://jvet-experts.org/doc_end_user/current_document.php?id=10759) AHG2: On Decoding Unit Information for VVC Version 1 [S. Deshpande (Sharp)]

## Test conditions (1)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0107](https://jvet-experts.org/doc_end_user/current_document.php?id=10755) Editorial suggestion for JVET CTC on HDR/WCG [D. Rusanovskyy (Qualcomm), T.Hashimoto (Sharp)] [late]

## Verification testing (4)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0041](https://jvet-experts.org/doc_end_user/current_document.php?id=10687) AHG4: Status Report on SDR HD and 360 Video Verification Test Preparation [M. Wien, V. Baroncini, Y. Ye]

[JVET-V0042](https://jvet-experts.org/doc_end_user/current_document.php?id=10688) AHG4: Agenda and report of the AHG meeting on the SDR HD and 360 video verification test preparation on 2021-02-18 [M. Wien, V. Baroncini, Y. Ye]

[JVET-V0043](https://jvet-experts.org/doc_end_user/current_document.php?id=10689) AHG4: Status Report on HDR Video Verification Test Preparation [A. Segall, M. Wien, V. Baroncini, K. Andersson]

[JVET-V0044](https://jvet-experts.org/doc_end_user/current_document.php?id=10691) AHG4: Agenda and report of the AHG meeting on the HDR verification test preparation on 2021-03-25 [A. Segall, M. Wien, V. Baroncini]

## Test material (1)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0045](https://jvet-experts.org/doc_end_user/current_document.php?id=10692) Aerial 4K HDR (HLG) Test Data [Pankaj Topiwala (FastVDO)]

## Quality assessment (1)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0168](https://jvet-experts.org/doc_end_user/current_document.php?id=10831) AHG4: An approach to objective video quality assessment for both full and no reference cases [P. Topiwala, W. Dai, J. Pian (FastVDO)] [late] [miss]

## Conformance test development (0)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

## Software development (1)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0079](https://jvet-experts.org/doc_end_user/current_document.php?id=10727) Reference software cleaning proposal [F. Galpin, T. Poirier, P. De Lagrange, F. Le Léannec, E. Francois (InterDigital)]

## Implementation studies (5)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0070](https://jvet-experts.org/doc_end_user/current_document.php?id=10718) VVC Software Decoder for Mobile Platforms [W.-L. Feng, F.-L. Luo, Y.-S. He, Z.-H. Liu, S.-M. Meng, X. Wen (Kwai Inc.)]

[JVET-V0088](https://jvet-experts.org/doc_end_user/current_document.php?id=10736) Multi-thread VTM decoder: information update [F. Hiron, R. Jullian, F. Urban, P. de Lagrange (InterDigital)]

[JVET-V0127](https://jvet-experts.org/doc_end_user/current_document.php?id=10776) An optimized VVC encoder implementation [J. Cui, Y. Fan, Y. He, X. Jiang, H. Liu, H. Shi, H. Yang, H. Yang, H. Yin, J. Zhang, L. Zhang (Bytedance)]

[JVET-V0128](https://jvet-experts.org/doc_end_user/current_document.php?id=10777) Performance of a VVC software decoder – BVC [Y. He, L. Li, Y. Li, H. Yin, J. Zhang, L. Zhang, Y. Zhang (Bytedance)]

[JVET-V0132](https://jvet-experts.org/doc_end_user/current_document.php?id=10793) VVC software decoder implementation for mobile devices [L. Yu, Z. Cui, L. Wang, J. Cheng, Z. Huang, L. Xu (Alibaba)]

## Complexity analysis (0)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

## AHG10: Encoding algorithm optimization (4)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0056](https://jvet-experts.org/doc_end_user/current_document.php?id=10704) [AHG10] GOP-based temporal filter improvements [P. Wennersten, C. Hollmann, J. Ström (Ericsson)]

[JVET-V0057](https://jvet-experts.org/doc_end_user/current_document.php?id=10705) [AHG10] Block importance mapping [P. Wennersten, C. Hollmann, J. Ström (Ericsson)]

[JVET-V0078](https://jvet-experts.org/doc_end_user/current_document.php?id=10726) AHG 10: QP control for very smooth blocks [K. Andersson, J. Enhorn, J. Ström (Ericsson)]

[JVET-V0095](https://jvet-experts.org/doc_end_user/current_document.php?id=10743) AHG10: Using original samples for SAO and ALF optimization [N. Hu, V. Seregin, M. Karczewicz (Qualcomm)]

## Profile/tier/level specification (0)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

# Low-level tool technology proposals (69)

## AHG8: High bit rate and high bit depth coding for VVC (25)

### General (1)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0150](https://jvet-experts.org/doc_end_user/current_document.php?id=10811) AHG8: A study on bin rate of VTM-12.0 for high bit depth coding [T. Tsukuba, M. Ikeda, T. Suzuki (Sony)] [late]

### CE contributions: Entropy Coding for High Bit Depth and High Bit Rate Coding (11)

Contributions in this area were discussed in session 3 at 2100–2310 UTC on Tuesday 20 April 2021 (chaired by JRO and GJS).

[JVET-V0022](https://jvet-experts.org/doc_end_user/current_document.php?id=10701) CE: Summary Report on Entropy Coding for High Bit Depth and High Bit Rate Coding [A. Browne, T. Hashimoto, H. Jhu, D. Rusanovskyy, K. Kawamura, T. Zhou]

This contribution provides a summary report for the Core Experiment on entropy coding for high bit depth and high bit rate coding. A total of 20 tests have been completed within the CE between the JVET U and V meetings to study and evaluate technologies related to Rice parameter derivation. The scope of this experiment covered tests on changes to the regular residual coding (RRC) (8 tests), transform skip residual coding (TSRC) (3 tests) and transform clipping (2 tests). In addition 7 tests have been completed in a second stage on combinations of RRC/TSRC tests with transform clipping tests. Results have been integrated on and tested against the Anchor CE software, which comprised integration of low complexity methods proposed in the CE of the U meeting, namely the RRC method of CE1.1 and the TSRC method of CE2.1.

In this report, coding performance and complexity are reported and analyzed. Test results against CE anchors are provided to show the coding efficiency and complexity trade-off of each tool. Where appropriate results are also provided for lossless conditions and screen content. Cross-check results for the performed tests are submitted as separate documents and their summaries are integrated in this contribution.

CE Anchor

The source code anchor for the CE was VTM12.0 modified with the lowest complexity rice coding modifications proposed in the CE of the U meeting. These changes consisted of the RRC modifications of CE1.1 and the TSRC modifications of CE2.1.

The anchor was generated using the high bit depth (HBD), high bit rate (HBR), high frame rate (HFR) CTC (JVET-U2018), which includes simulations within a standard QP range (QPs 22,27,32,37 for 12 bit YUV 4:2:0) and a low QP range (QPs 12,7,2,-3,-8,-13 for 12 bit YUV 4:2:2/4:4:4, -8,-13,-18,-23,-28,-33 for 16 bit RGB).

In addition to testing against VTM12.0, the CE anchor was also tested against HM16.23 configured for lossy and lossless coding using RExt test conditions (JVET-U1100) adjusted for the content and low QP range of JVET-U2018.

Table 1.1. Simulation results for CE Anchor and its RRC and TSRC components vs. VTM12.0, 12 bits data, HBD/HFR CTC, LowQP test configuration.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | | **HDR HLG** | | | **SVT12 RGB** | | | |
|  | wY | wU | wV | Y | U | V | Aver.GBR | G | B | R |
| **AI** | **CE Anchor** | -0.49% | -0.49% | -0.52% | -0.44% | -0.35% | -0.36% | -2.68% | -2.73% | -2.67% | -2.64% |
| **RRC** | -0.50% | -0.53% | -0.56% | -0.33% | -0.33% | -0.34% | -2.53% | -2.62% | -2.48% | -2.48% |
| **TSRC** | -0.10% | -0.06% | -0.07% | -0.21% | -0.15% | -0.15% | -1.55% | -1.45% | -1.62% | -1.57% |
| **LDB** | **CE Anchor** | -0.07% | -0.06% | -0.05% | 0.02% | -0.02% | -0.06% | -0.50% | -0.45% | -0.53% | -0.53% |
| **RRC** | -0.07% | -0.08% | -0.08% | -0.03% | -0.02% | -0.05% | -0.37% | -0.31% | -0.40% | -0.40% |
| **TSRC** | 0.00% | 0.00% | -0.01% | 0.05% | 0.00% | -0.04% | -0.40% | -0.38% | -0.42% | -0.40% |
| **RA** | **CE Anchor** | -0.13% | -0.13% | -0.14% | -0.01% | -0.04% | -0.06% | -0.54% | -0.51% | -0.56% | -0.54% |
| **RRC** | -0.14% | -0.15% | -0.15% | -0.04% | -0.04% | -0.05% | -0.42% | -0.40% | -0.43% | -0.43% |
| **TSRC** | 0.00% | 0.00% | -0.01% | 0.03% | 0.00% | -0.02% | -0.39% | -0.37% | -0.41% | -0.38% |

Table 1.2. Simulation results for CE Anchor and its RRC and TSRC components vs. VTM12.0, 16 bits data, HBD/HFR CTC, LowQP test configuration.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Test** | **SVT16 RGB** | | | |
|  | Aver.GBR | G | B | R |
| **AI** | **CE Anchor** | -24.70% | -25.62% | -24.25% | -24.24% |
| **AnchorRRC** | -24.35% | -25.14% | -23.95% | -23.95% |
| **AnchorTSRC** | -21.64% | -22.27% | -21.36% | -21.30% |
| **LDB** | **CE Anchor** | -16.38% | -16.99% | -16.06% | -16.09% |
| **RRC** | -15.83% | -16.66% | -15.29% | -15.55% |
| **TSRC** | -13.60% | -13.97% | -13.41% | -13.41% |
| **RA** | **CE Anchor** | -15.56% | -15.70% | -15.50% | -15.48% |
| **RRC** | -15.15% | -15.26% | -15.04% | -15.14% |
| **TSRC** | -12.80% | -12.67% | -12.89% | -12.84% |

Table 1.3. Run time estimates for CE Anchor and its RRC and TSRC components vs. VTM12.0, HBD/HFR CTC, LowQP test configuration.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | **HDR HLG** |  | **SVT RGB** | |
|  | Enc | Dec | Enc | Dec | Enc | Dec |
| **AI** | **CE Anchor** | 101% | 95% | 100% | 96% | 98% | 89% |
| **RRC** | 102% | 99% | 101% | 100% | 99% | 89% |
| **TSRC** | 100% | 99% | 99% | 99% | 101% | 98% |
| **LDB** | **CE Anchor** | 101% | 100% | 99% | 98% | 99% | 94% |
| **RRC** | 102% | 103% | 102% | 100% | 99% | 95% |
| **TSRC** | 100% | 100% | 100% | 100% | 99% | 99% |
| **RA** | **CE Anchor** | 99% | 101% | 100% | 100% | 95% | 89% |
| **RRC** | 102% | 103% | 101% | 99% | 99% | 95% |
| **TSRC** | 100% | 99% | 100% | 100% | 98% | 98% |

Table 1.4. Simulation results for CE Anchor and its RRC and TSRC components vs. VTM12.0, HBD/HFR CTC, NormQP test configuration.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | | | | **HDR HLG** | | |
|  | DE100 | PSNR-L100 | wY | wU | wV | Y | U | V |
| **AI** | **CE Anchor** | 0.02% | 0.00% | 0.00% | 0.01% | 0.04% | 0.01% | -0.02% | -0.06% |
| **RRC** | 0.02% | 0.00% | 0.00% | 0.01% | 0.04% | 0.00% | -0.02% | -0.06% |
| **TSRC** | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| **RA** | **CE Anchor** | -0.07% | 0.01% | 0.01% | -0.04% | -0.16% | 0.04% | -0.16% | 0.02% |
| **RRC** | -0.09% | -0.01% | -0.01% | -0.06% | -0.18% | 0.03% | -0.17% | 0.00% |
| **TSRC** | 0.01% | 0.01% | 0.01% | 0.01% | 0.01% | 0.01% | 0.01% | 0.01% |

Table 1.5. Run time estimates for CE Anchor and its RRC and TSRC components vs. VTM12.0, HBD/HFR CTC, LowQP test configuration.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| NormQP | **Test** | **HDR PQ** | | **HDR HLG** |  |
|  | Enc | Dec | Enc | Dec |
| **AI** | **CE Anchor** | 100% | 99% | 99% | 100% |
| **RRC** | 100% | 98% | 101% | 101% |
| **TSRC** | 100% | 100% | 100% | 100% |
| **RA** | **CE Anchor** | 102% | 102% | 101% | 101% |
| **RRC** | 99% | 99% | 100% | 100% |
| **TSRC** | 100% | 100% | 100% | 101% |

As the results are for camera-captured content, the benefit for TSRC is only margjnal.

Results compared to HM in the following

Table 1.7. Simulation results for CE Anchor vs. HM16.23, 12 bits data, HBD/HFR CTC for VTM , RExt CTC for HM, LowQP test configuration.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **HDR PQ** | | | **HDR HLG** | | | **SVT12 RGB** | | | |
| wY | wU | wV | Y | U | V | Aver.GBR | G | B | R |
| **AI** | -7.24% | -9.64% | -10.23% | -4.09% | -6.39% | -6.53% | -2.17% | -2.54% | -1.95% | -2.03% |
| **LDB** | -6.68% | -7.73% | -8.82% | -5.12% | -8.20% | -7.06% | -1.79% | -3.31% | -1.05% | -1.02% |
| **RA** | -7.61% | -11.64% | -11.85% | -5.73% | -8.68% | -7.37% | -2.11% | -3.72% | -1.32% | -1.29% |

Table 1.8. Simulation results for CE Anchor vs. HM16.23, 16 bits data, HBD/HFR CTC for VTM, RExt CTC for HM, LowQP test configuration.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Test** | **SVT16 RGB** | | | |
| Aver.GBR | G | B | R |
| **AI** | 0.77% | 0.70% | 0.82% | 0.79% |
| **LDB** | 0.58% | -0.52% | 1.13% | 1.13% |
| **RA** | 0.32% | -0.86% | 0.91% | 0.91% |

Table 1.9. Run time estimates for CE Anchor vs. HM16.23, HBD/HFR CTC for VTM, RExt CTC for HM, LowQP test configuration.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Test** | **HDR PQ** | | **HDR HLG** |  | **SVT RGB** | |
| Enc | Dec | Enc | Dec | Enc | Dec |
| **AI** | 2815% | 172% | 3080% | 169% | 5047% | 128% |
| **LDB** | 349% | 164% | 454% | 162% | 609% | 137% |
| **RA** | 414% | 164% | 535% | 159% | 758% | 137% |

Table 1.10. Simulation results for CE Anchor vs. HM16.23, lossless configuration, HBD/HFR CTC for VTM, RExt CTC for HM, LowQP test configuration.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **PQ** | **All Intra** | | | **Low delay B** | | | **Random Access** | | |
| **ratio** | | bit-rate savings | **ratio** | | bit-rate savings | **ratio** | | bit-rate savings |
| HM16.23 | VTM\_U\_CE | HM16.23 | VTM\_U\_CE | HM16.23 | VTM\_U\_CE |
| PQ444 | 2.5 | 2.5 | 0.89% | 3.1 | 3.0 | 4.80% | 3.1 | 3.0 | 4.47% |
| PQ422 | 2.3 | 2.3 | -0.18% | 2.9 | 2.8 | 3.40% | 2.9 | 2.8 | 3.13% |
| **Overall** | **2.4** | **2.4** | **0.36%** | **3.0** | **2.9** | **4.10%** | **3.0** | **2.9** | **3.80%** |
| Enc Time[%] | 7206% | | | 976% | | | 983% | | |
| Dec Time[%] | 152% | | | 147% | | | 149% | | |
|  |  |  |  |  |  |  |  |  |  |
| **HLG** | **All Intra** | | | **Low delay B** | | | **Random Access** | | |
| **ratio** | | bit-rate savings | **ratio** | | bit-rate savings | **ratio** | | bit-rate savings |
| HM16.23 | VTM\_U\_CE | HM16.23 | VTM\_U\_CE | HM16.23 | VTM\_U\_CE |
| HLG444 | 1.8 | 1.7 | 3.27% | 1.9 | 1.9 | 4.25% | 2.0 | 1.9 | 4.08% |
| HLG422 | 1.7 | 1.6 | 2.37% | 1.9 | 1.9 | 3.66% | 1.9 | 1.9 | 3.49% |
| **Overall** | **1.7** | **1.7** | **2.82%** | **1.9** | **1.9** | **3.96%** | **1.9** | **1.9** | **3.79%** |
| Enc Time[%] | 7782% | | | 817% | | | 767% | | |
| Dec Time[%] | 132% | | | 128% | | | 126% | | |
|  |  |  |  |  |  |  |  |  |  |
| **SVT** | **All Intra** | | | **Low delay B** | | | **Random Access** | | |
| **ratio** | | bit-rate savings | **ratio** | | bit-rate savings | **ratio** | | bit-rate savings |
| HM16.23 | VTM\_U\_CE | HM16.23 | VTM\_U\_CE | HM16.23 | VTM\_U\_CE |
| SVT16 | 1.2 | 1.2 | 1.46% | 1.2 | 1.2 | 1.18% | 1.2 | 1.2 | 1.11% |
| SVT12 | 1.3 | 1.2 | 3.12% | 1.3 | 1.3 | 2.71% | 1.3 | 1.3 | 2.55% |
| **Overall** | **1.2** | **1.2** | **2.29%** | **1.3** | **1.2** | **1.95%** | **1.3** | **1.2** | **1.83%** |

Questions:

- Would the anchor change of Rice parameter improve VVC performance in lossless coding also for 10 bit data? Possibly, but was not investigated.

- What is the gain of anchor versus HM in normal QP range? JVET-V0150 might give an answer.

**Tests on** Regular **Residual Coding (RRC)**

This test category includes 8 tests studying proposed changes in the Regular Residual Coding (RRC) method of VVC for purpose of High Bit Depth Coding.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Test** | **Tester** | **Description Document** | **Cross checker** | **Cross-chek document** |
| CE-1.1 | Dmytro Rusanovskyy  (Qualcomm) | [JVET-V0052](https://jvet-experts.org/doc_end_user/current_document.php?id=10699) | Mohammed Golam Sarwer (Alibaba) | JVET-V0156 |
| CE-1.2 | Dmytro Rusanovskyy  (Qualcomm) | [JVET-V0052](https://jvet-experts.org/doc_end_user/current_document.php?id=10699) | Tomonori Hashimoto  (Sharp) | JVET-V0138 |
| CE-1.3 | Widthrawn | | | |
| CE-1.4 | Dmytro Rusanovskyy  (Qualcomm) | [JVET-V0052](https://jvet-experts.org/doc_end_user/current_document.php?id=10699) | Adrian Browne  (Sony) | JVET-V0134 |
| CE-1.5 | Adrian Browne  (Sony) | [JVET-V0050](https://jvet-experts.org/doc_end_user/current_document.php?id=10697) | Dmytro Rusanovskyy  (Qualcomm) | [JVET-V0139](https://jvet-experts.org/doc_end_user/current_document.php?id=10800) |
| CE-1.6 | Adrian Browne  (Sony) | [JVET-V0050](https://jvet-experts.org/doc_end_user/current_document.php?id=10697) | Dmytro Rusanovskyy  (Qualcomm) | [JVET-V0139](https://jvet-experts.org/doc_end_user/current_document.php?id=10800) |
| CE-1.7 | Tomonori Hashimoto  (Sharp) | [JVET-V0046](https://jvet-experts.org/doc_end_user/current_document.php?id=10693) | Dmytro Rusanovskyy  (Qualcomm) | [JVET-V0140](https://jvet-experts.org/doc_end_user/current_document.php?id=10801) |
| CE-1.8 | Withdrawn | | | |

Table 2.2. Simulation results for RRC tests, 12 bits data, CE CTC, LowQP test configuration.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | | **HDR HLG** | | | **SVT12 RGB** | | | |
|  | wY | wU | wV | Y | U | V | Aver.GBR | G | B | R |
| **AI** | **CE1.1** | -0.04% | 0.00% | 0.00% | -0.04% | 0.07% | 0.07% | -0.24% | -0.35% | -0.19% | -0.19% |
| **CE1.2** | -0.09% | -0.06% | -0.07% | -0.10% | -0.03% | -0.04% | -0.41% | -0.45% | -0.39% | -0.39% |
| **CE1.3** |  |  |  |  |  |  |  |  |  |  |
| **CE1.4-A** | -0.33% | -0.24% | -0.24% | -0.50% | -0.30% | -0.32% | -1.43% | -1.64% | -1.32% | -1.34% |
| **CE1.4-B** | -0.33% | -0.23% | -0.25% | -0.50% | -0.30% | -0.32% | -1.43% | -1.64% | -1.32% | -1.33% |
| **CE1.5** | -0.22% | -0.12% | -0.13% | -0.42% | -0.23% | -0.23% | -1.36% | -1.60% | -1.24% | -1.24% |
| **CE1.6** | -0.22% | -0.11% | -0.12% | -0.41% | -0.22% | -0.22% | -1.34% | -1.58% | -1.21% | -1.22% |
| **CE1.7** | -0.09% | -0.07% | -0.07% | -0.08% | -0.03% | -0.03% | -0.37% | -0.42% | -0.34% | -0.34% |
| **CE1.8** |  |  |  |  |  |  |  |  |  |  |
| **LDB** | **CE1.1** | -0.01% | -0.03% | -0.02% | -0.03% | -0.01% | 0.00% | -0.05% | -0.05% | -0.05% | -0.05% |
| **CE1.2** | 0.03% | 0.03% | 0.02% | 0.02% | 0.05% | 0.06% | -0.19% | -0.20% | -0.19% | -0.19% |
| **CE1.3** |  |  |  |  |  |  |  |  |  |  |
| **CE1.4-A** | -0.06% | -0.07% | -0.08% | -0.02% | -0.01% | 0.01% | -0.66% | -0.71% | -0.63% | -0.63% |
| **CE1.4-B** | -0.06% | -0.08% | -0.09% | -0.06% | -0.01% | 0.00% | -0.66% | -0.71% | -0.63% | -0.63% |
| **CE1.5** | -0.02% | -0.03% | -0.06% | -0.03% | -0.01% | -0.01% | -0.62% | -0.69% | -0.58% | -0.58% |
| **CE1.6** | -0.03% | -0.04% | -0.06% | -0.04% | -0.02% | -0.01% | -0.60% | -0.68% | -0.57% | -0.56% |
| **CE1.7** | 0.01% | 0.00% | 0.02% | 0.02% | 0.04% | 0.06% | -0.15% | -0.16% | -0.14% | -0.14% |
| **CE1.8** |  |  |  |  |  |  |  |  |  |  |
| **RA** | **CE1.1** | -0.01% | -0.03% | -0.03% | -0.01% | 0.00% | 0.00% | -0.06% | -0.06% | -0.06% | -0.05% |
| **CE1.2** | -0.01% | -0.01% | -0.02% | 0.01% | 0.03% | 0.03% | -0.17% | -0.19% | -0.15% | -0.16% |
| **CE1.3** |  |  |  |  |  |  |  |  |  |  |
| **CE1.4-A** | -0.08% | -0.07% | -0.09% | -0.04% | -0.01% | -0.01% | -0.57% | -0.66% | -0.53% | -0.54% |
| **CE1.4-B** | -0.08% | -0.08% | -0.09% | -0.04% | -0.02% | -0.02% | -0.57% | -0.65% | -0.53% | -0.54% |
| **CE1.5** | -0.04% | -0.03% | -0.04% | -0.04% | -0.03% | -0.03% | -0.57% | -0.67% | -0.51% | -0.52% |
| **CE1.6** | -0.03% | -0.03% | -0.04% | -0.04% | -0.02% | -0.02% | -0.55% | -0.66% | -0.50% | -0.50% |
| **CE1.7** | 0.00% | 0.00% | -0.01% | 0.01% | 0.03% | 0.05% | -0.12% | -0.15% | -0.10% | -0.10% |
| **CE1.8** |  |  |  |  |  |  |  |  |  |  |

Table 2.3. Simulation results for RRC tests, 16 bits data, CE CTC, LowQP test configuration.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Test** | **SVT16 RGB** | | | |
|  | Aver.GBR | G | B | R |
| **AI** | **CE1.1** | -0.71% | -0.67% | -0.72% | -0.73% |
| **CE1.2** | -0.79% | -0.79% | -0.79% | -0.79% |
| **CE1.3** |  |  |  |  |
| **CE1.4-A** | -2.30% | -2.72% | -2.09% | -2.08% |
| **CE1.4-B** | -2.27% | -2.70% | -2.05% | -2.04% |
| **CE1.5** | -2.27% | -2.80% | -2.02% | -2.00% |
| **CE1.6** | -2.26% | -2.78% | -2.00% | -1.98% |
| **CE1.7** | -0.66% | -0.59% | -0.69% | -0.70% |
| **CE1.8** |  |  |  |  |
| **LDB** | **CE1.1** | -0.58% | -0.53% | -0.61% | -0.62% |
| **CE1.2** | -0.66% | -0.61% | -0.69% | -0.70% |
| **CE1.3** |  |  |  |  |
| **CE1.4-A** | -1.55% | -1.51% | -1.58% | -1.57% |
| **CE1.4-B** | -1.53% | -1.49% | -1.55% | -1.54% |
| **CE1.5** | -1.33% | -1.30% | -1.35% | -1.34% |
| **CE1.6** | -1.32% | -1.31% | -1.34% | -1.32% |
| **CE1.7** | -0.73% | -0.67% | -0.75% | -0.76% |
| **CE1.8** |  |  |  |  |
| **RA** | **CE1.1** | -0.51% | -0.50% | -0.50% | -0.52% |
| **CE1.2** | -0.60% | -0.61% | -0.58% | -0.60% |
| **CE1.3** |  |  |  |  |
| **CE1.4-A** | -1.45% | -1.43% | -1.46% | -1.45% |
| **CE1.4-B** | -1.45% | -1.43% | -1.47% | -1.46% |
| **CE1.5** | -1.23% | -1.24% | -1.24% | -1.23% |
| **CE1.6** | -1.23% | -1.24% | -1.22% | -1.21% |
| **CE1.7** | -0.66% | -0.67% | -0.64% | -0.66% |
| **CE1.8** |  |  |  |  |

Table 2.4. Reported run-time estimates RRC tests, CE CTC, LowQP test configuration.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | **HDR HLG** | | **SVT12 RGB** | | **SVT16 RGB** | |
|  | Enc | Dec | Enc | Dec | Enc | Dec | Enc | Dec |
| **AI** | **CE1.1** | 101% | 100% | 100% | 100% | 103% | 103% | 104% | 102% |
| **CE1.2** | 102% | 102% | 102% | 103% | 102% | 103% | 101% | 99% |
| **CE1.3** |  |  |  |  |  |  |  |  |
| **CE1.4-A** | 102% | 101% | 103% | 101% | 106% | 108% | 109% | 121% |
| **CE1.4-B** | 103% | 102% | 104% | 103% | 107% | 108% | 109% | 124% |
| **CE1.5** | 101% | 100% | 103% | 103% | 104% | 109% | 109% | 128% |
| **CE1.6** | 102% | 100% | 103% | 102% | 105% | 109% | 111% | 128% |
| **CE1.7** | 101% | 100% | 103% | 100% | 105% | 101% | 109% | 97% |
| **CE1.8** |  |  |  |  |  |  |  |  |
| **LDB** | **CE1.1** | 100% | 99% | 101% | 98% | 103% | 105% | 104% | 103% |
| **CE1.2** | 100% | 100% | 103% | 101% | 101% | 101% | 100% | 99% |
| **CE1.3** |  |  |  |  |  |  |  |  |
| **CE1.4-A** | 103% | 105% | 102% | 101% | 105% | 111% | 117% | 115% |
| **CE1.4-B** | 104% | 108% | 103% | 102% | 106% | 114% | 118% | 119% |
| **CE1.5** | 101% | 101% | 100% | 101% | 101% | 107% | 117% | 119% |
| **CE1.6** | 101% | 101% | 101% | 101% | 101% | 105% | 117% | 117% |
| **CE1.7** | 101% | 100% | 101% | 100% | 103% | 101% | 106% | 99% |
| **CE1.8** |  |  |  |  |  |  |  |  |
| **RA** | **CE1.1** | 101% | 98% | 101% | 100% | 103% | 103% | 106% | 102% |
| **CE1.2** | 104% | 103% | 102% | 101% | 102% | 103% | 102% | 99% |
| **CE1.3** |  |  |  |  |  |  |  |  |
| **CE1.4-A** | 104% | 101% | 103% | 101% | 105% | 108% | 121% | 119% |
| **CE1.4-B** | 103% | 101% | 103% | 102% | 106% | 107% | 120% | 117% |
| **CE1.5** | 101% | 100% | 101% | 101% | 100% | 106% | 114% | 117% |
| **CE1.6** | 100% | 99% | 101% | 101% | 101% | 106% | 114% | 116% |
| **CE1.7** | 101% | 100% | 101% | 100% | 103% | 101% | 106% | 99% |
| **CE1.8** |  |  |  |  |  |  |  |  |

Table 2.5. Simulation results for RRC tests, HBD/HBR/HFR CTC, NormQP test configuration.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | | | | **HDR HLG** | | |
|  | DE100 | PSNR-L100 | wY | wU | wV | Y | U | V |
| **AI** | **CE1.1** | -0.07% | -0.01% | -0.02% | 0.07% | -0.07% | -0.01% | -0.04% | 0.03% |
| **CE1.2** | 0.01% | -0.03% | -0.03% | 0.09% | -0.08% | -0.01% | -0.10% | 0.05% |
| **CE1.3** |  |  |  |  |  |  |  |  |
| **CE1.4-A** | 0.02% | -0.02% | -0.03% | 0.12% | -0.06% | -0.01% | -0.02% | 0.04% |
| **CE1.4-B** | 0.00% | -0.02% | -0.02% | 0.06% | -0.07% | -0.01% | 0.00% | -0.04% |
| **CE1.5** | -0.01% | 0.00% | 0.00% | -0.05% | -0.06% | 0.00% | 0.00% | 0.10% |
| **CE1.6** | -0.01% | 0.00% | 0.00% | -0.05% | -0.06% | 0.00% | 0.00% | 0.10% |
| **CE1.7** | -0.03% | -0.02% | -0.02% | 0.11% | -0.02% | -0.01% | 0.03% | -0.03% |
| **CE1.8** |  |  |  |  |  |  |  |  |
| **RA** | **CE1.1** | -0.03% | 0.02% | 0.00% | -0.29% | -0.05% | 0.00% | -0.11% | -0.21% |
| **CE1.2** | 0.09% | 0.03% | 0.02% | -0.14% | -0.22% | -0.01% | 0.11% | -0.30% |
| **CE1.3** |  |  |  |  |  |  |  |  |
| **CE1.4-A** | 0.10% | -0.02% | -0.03% | -0.17% | -0.15% | 0.02% | -0.07% | 0.01% |
| **CE1.4-B** | -0.01% | -0.03% | -0.05% | -0.29% | -0.25% | 0.00% | -0.02% | -0.09% |
| **CE1.5** | 0.25% | -0.01% | -0.03% | 0.12% | 0.20% | 0.02% | 0.10% | 0.14% |
| **CE1.6** | 0.25% | -0.01% | -0.02% | 0.12% | 0.21% | 0.02% | 0.10% | 0.14% |
| **CE1.7** | -0.16% | -0.06% | -0.04% | -0.24% | -0.04% | 0.00% | -0.03% | -0.06% |
| **CE1.8** |  |  |  |  |  |  |  |  |

Table 2.6. Run-time estimates for RRC tests, CE CTC, NormQP test configuration.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | **HDR HLG** | |
|  | Enc | Dec | Enc | Dec |
| **AI** | **CE1.1** | 100% | 98% | 99% | 97% |
| **CE1.2** | 100% | 99% | 100% | 101% |
| **CE1.3** |  |  |  |  |
| **CE1.4-A** | 101% | 96% | 101% | 99% |
| **CE1.4-B** | 101% | 100% | 100% | 97% |
| **CE1.5** | 98% | 99% | 98% | 99% |
| **CE1.6** | 98% | 100% | 98% | 99% |
| **CE1.7** | 101% | 100% | 102% | 100% |
| **CE1.8** |  |  |  |  |
| **RA** | **CE1.1** | 98% | 98% | 98% | 98% |
| **CE1.2** | 100% | 101% | 100% | 100% |
| **CE1.3** |  |  |  |  |
| **CE1.4-A** | 99% | 99% | 98% | 98% |
| **CE1.4-B** | 98% | 99% | 96% | 98% |
| **CE1.5** | 101% | 101% | 102% | 102% |
| **CE1.6** | 101% | 101% | 102% | 102% |
| **CE1.7** | 100% | 100% | 100% | 100% |
| **CE1.8** |  |  |  |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Table 2.7. Simulation results for RRC tests, CE CTC, lossless test configuration. | **Test** | bit-rate saving | |  |  |
|  |  | HDR PQ | HLG PQ | SVT12 | SVT16 |
| **AI** | **CE1.1** | -0.98% | -1.50% | -1.38% | 0.10% |
|  | **CE1.2** | -0.57% | -1.16% | -0.42% | -0.82% |
|  | **CE1.3** |  |  |  |  |
|  | **CE1.4-A** | -2.31% | -3.49% | -2.88% | -1.38% |
|  | **CE1.4-B** | -2.03% | -3.06% | -2.84% | -1.38% |
|  | **CE1.5** | -1.81% | -2.96% | -2.91% | -1.46% |
|  | **CE1.6** | -1.82% | -2.97% | -2.92% | -1.47% |
|  | **CE1.7** | -1.20% | -1.70% | -1.53% | -0.20% |
|  | **CE1.8** |  |  |  |  |
| **LDB** | **CE1.1** | -1.55% | -2.51% | -0.77% | 0.17% |
|  | **CE1.2** | -1.03% | -1.78% | -0.59% | -0.52% |
|  | **CE1.3** |  |  |  |  |
|  | **CE1.4-A** | -3.06% | -4.30% | -1.51% | -0.39% |
|  | **CE1.4-B** | -2.87% | -4.05% | -1.51% | -0.38% |
|  | **CE1.5** | -2.29% | -3.36% | -1.56% | -0.40% |
|  | **CE1.6** | -2.30% | -3.38% | -1.61% | -0.43% |
|  | **CE1.7** | -1.96% | -3.02% | -1.45% | -0.09% |
|  | **CE1.8** |  |  |  |  |
| **RA** | **CE1.1** | -1.63% | -2.58% | -0.71% | 0.18% |
|  | **CE1.2** | -0.99% | -1.74% | 0.60% | -0.44% |
|  | **CE1.3** |  |  |  |  |
|  | **CE1.4-A** | -2.98% | -4.22% | -1.42% | -0.37% |
|  | **CE1.4-B** | -2.79% | -3.98% | -1.42% | -0.36% |
|  | **CE1.5** | -2.22% | -3.29% | -1.49% | -0.39% |
|  | **CE1.6** | -2.23% | -3.31% | -1.53% | -0.42% |
|  | **CE1.7** | -2.00% | -3.05% | -1.39% | -0.08% |
|  | **CE1.8** |  |  |  |  |

“Local methods”: 1.2, 1.2, 1.7

“History based”: 1.4, 1.5, 1.6

The anchor still had losses versus HM in 16 bit coding. This would be compensated with local methods, an be converted into small gain with history based.

Would be interesting to analyse the gain directly compared to HM. Seems to become lower for higher bit depth.

Tests on Transform Skip Residual Coding (TSRC)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Test** | **Proponent(s)** | **Description Document** | **Cross checker** | **Cross-chek document** |
| CE-2.2 | Sony | [JVET-V0050](https://jvet-experts.org/doc_end_user/current_document.php?id=10697) | Kwai | [JVET-V0143](https://jvet-experts.org/doc_end_user/current_document.php?id=10804) |
| CE-2.3 | Sony | [JVET-V0050](https://jvet-experts.org/doc_end_user/current_document.php?id=10697) | Kwai | [JVET-V0143](https://jvet-experts.org/doc_end_user/current_document.php?id=10804) |

Table 3.2. Simulation results for TSRC tests, 12 bits data, CE CTC, LowQP test configuration.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | | **HDR HLG** | | | **SVT12 RGB** | | | |
|  | wY | wU | wV | Y | U | V | Aver.RGB | G | B | R |
| **AI** | **CE-2.2** | -0.02% | -0.02% | -0.03% | -0.07% | -0.09% | -0.09% | -0.14% | -0.13% | -0.14% | -0.13% |
| **CE-2.3** | -0.02% | -0.03% | -0.03% | -0.06% | -0.09% | -0.09% | -0.12% | -0.12% | -0.12% | -0.12% |
| **LDB** | **CE-2.2** | 0.01% | -0.02% | -0.03% | 0.01% | 0.00% | -0.01% | -0.09% | -0.11% | -0.07% | -0.08% |
| **CE-2.3** | 0.01% | -0.03% | -0.03% | 0.01% | 0.00% | -0.01% | -0.07% | -0.09% | -0.05% | -0.06% |
| **RA** | **CE-2.2** | 0.02% | 0.00% | -0.02% | 0.01% | 0.00% | -0.01% | -0.09% | -0.10% | -0.08% | -0.09% |
| **CE-2.3** | 0.02% | 0.00% | -0.02% | 0.02% | 0.00% | 0.00% | -0.07% | -0.08% | -0.05% | -0.07% |

Table 3.3. Simulation results for TSRC tests, 16 bits data, CE CTC, LowQP test configuration.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Test** | **SVT16 RGB** | | | |
|  |  | Aver.RGB | G | B | R |
| **AI** | **CE-2.2** | -0.20% | -0.26% | -0.17% | -0.16% |
| **CE-2.3** | -0.18% | -0.24% | -0.15% | -0.14% |
| **LDB** | **CE-2.2** | -0.14% | -0.14% | -0.14% | -0.12% |
| **CE-2.3** | -0.08% | -0.10% | -0.08% | -0.07% |
| **RA** | **CE-2.2** | -0.15% | -0.13% | -0.16% | -0.15% |
| **CE-2.3** | -0.10% | -0.10% | -0.10% | -0.10% |

Table 3.4. Reported run-time estimates TSRC tests, CE CTC, LowQP test configuration.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | **HDR HLG** | | **SVT12 RGB** | | **SVT16 RGB** | |
|  | Enc | Dec | Enc | Dec | Enc | Dec | Enc | Dec |
| AI | **CE-2.2** | 98% | 99% | 99% | 100% | 99% | 101% | 100% | 100% |
| **CE-2.3** | 98% | 98% | 98% | 98% | 101% | 100% | 100% | 100% |
| LDB | **CE-2.2** | 97% | 97% | 101% | 101% | 101% | 105% | 102% | 105% |
| **CE-2.3** | 98% | 96% | 99% | 99% | 101% | 104% | 101% | 103% |
| RA | **CE-2.2** | 101% | 102% | 100% | 101% | 99% | 103% | 101% | 104% |
| **CE-2.3** | 101% | 102% | 100% | 100% | 99% | 102% | 100% | 103% |

Table 3.5. Simulation results for TSRC tests, HBD/HBR/HFR CTC, NormQP test configuration.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | | | | | | **HDR HLG** | | | | |
|  | dE100 | L100 | wY | wU | wV | Enc | Dec | Y | U | V | Enc | Dec |
| **AI** | **CE-2.2** | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 97% | 98% | 0.00% | 0.00% | 0.00% | 97% | 98% |
| **CE-2.3** | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 99% | 99% | 0.00% | 0.00% | 0.00% | 97% | 98% |
| **RA** | **CE-2.2** | -0.03% | -0.02% | -0.02% | -0.02% | -0.04% | 101% | 101% | -0.01% | -0.03% | 0.07% | 102% | 102% |
| **CE-2.3** | -0.03% | -0.02% | -0.02% | -0.02% | -0.03% | 101% | 101% | -0.01% | -0.03% | 0.07% | 101% | 102% |

Table 2.6. CE2.1/CE2.2/CE2.3 simulation results, 12 bits data (8 bit data increased to 12), SCC TGM, LowQP test configuration.(Compared to VTM12.0, anchor included below).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **SCC TGM** | | | | | |
|  | Aver.RGB | G | B | R | Enc | Dec |  |
| **AI** | **CEAnc (CE1.1+CE2.1)** | -3.00% | -3.03% | -2.98% | -2.99% | 100% | 98% |  |
| **CE2.1 encoder fix+CE1.1** | -3.06% | -3.11% | -3.03% | -3.04% | 101% | 96% |  |
| **CE2.2+CE1.1** | -3.26% | -3.38% | -3.20% | -3.19% | 105% | 99% |  |
| **CE2.3+CE1.1** | -3.23% | -3.37% | -3.15% | -3.17% | 105% | 99% |  |
| **LDB** | **CEAnc (CE1.1+CE2.1)** | -1.16% | -1.23% | -1.11% | -1.14% | 100% | 99% |  |
| **CE2.1 encoder fix+CE1.1** | -1.54% | -1.46% | -1.57% | -1.58% | 101% | 99% |  |
| **CE2.2+CE1.1** | -1.76% | -1.76% | -1.76% | -1.75% | 103% | 100% |  |
| **CE2.3+CE1.1** | -1.68% | -1.41% | -2.25% | -1.40% | 103% | 100% |  |
| **RA** | **CEAnc (CE1.1+CE2.1)** | -1.13% | -0.93% | -1.48% | -1.00% | 101% | 99% |  |
| **CE2.1 encoder fix+CE1.1** | -1.67% | -1.75% | -1.70% | -1.56% | 101% | 99% |  |
| **CE2.2+CE1.1** | -2.78% | -2.51% | -2.74% | -3.11% | 105% | 101% |  |
| **CE2.3+CE1.1** | -2.32% | -2.13% | -2.36% | -2.48% | 105% | 101% |  |

Gain of 2.2/2.3 compared to the anchor is roughly 0.2% for AI/LB, 1% for RA (for TGM class). No relevant gain for camera captured content. These numbers are however not for native 12 bit data.

**Transform Coefficient Clipping**

This category includes tests CE3.1 and CE3.2 that are studing methods proposed in JVET-U0052.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Test** | **Proponent(s)** | **Document description** | **Cross-checker(s)** | **Cross-check document** |
| CE-3.1 | Sharp | JVET-V0047 | Sony | JVET-V0136 |
| CE-3.2 | Sharp | JVET-V0047 | Sony, Qualcomm | JVET-V0136 |

Table 4.2. CE3.1/CE3.2 simulation results, 12 bits data, CE CTC, LowQP test configuration.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | | **HDR HLG** | | | **SVT12 RGB** | | | |
|  | wY | wU | wV | Y | U | V | Aver.RGB | G | B | R |
| **AI** | **CE-3.1** | -1.23% | -1.69% | -1.82% | -0.47% | -0.83% | -0.86% | -1.11% | -0.80% | -1.25% | -1.27% |
| **CE-3.2** | -1.12% | -1.55% | -1.67% | -0.43% | -0.76% | -0.79% | -0.92% | -0.67% | -1.04% | -1.06% |
| **LDB** | **CE-3.1** | -0.67% | -0.65% | -0.72% | -0.62% | -0.80% | -0.84% | -0.70% | -0.79% | -0.65% | -0.66% |
| **CE-3.2** | -0.64% | -0.61% | -0.68% | -0.58% | -0.74% | -0.78% | -0.61% | -0.69% | -0.57% | -0.58% |
| **RA** | **CE-3.1** | -0.60% | -0.63% | -0.69% | -0.50% | -0.73% | -0.78% | -0.63% | -0.61% | -0.64% | -0.65% |
| **CE-3.2** | -0.57% | -0.59% | -0.66% | -0.47% | -0.67% | -0.73% | -0.56% | -0.53% | -0.57% | -0.58% |

Table 4.3. CE3.1/CE3.2 simulation results, 16 bits data, CE CTC, LowQP test configuration.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Test** | **SVT16 RGB** | | | |
|  |  | Aver.RGB | G | B | R |
| **AI** | **Vs. VTM12** | -6.53% | -6.82% | -6.39% | -6.37% |
| **Vs. CE anchor** | -0.53% | -0.69% | -0.45% | -0.45% |
| **LDB** | **Vs. VTM12** | -2.92% | -2.98% | -2.91% | -2.88% |
| **Vs. CE anchor** | -0.22% | -0.20% | -0.23% | -0.22% |
| **RA** | **Vs. VTM12** | -2.77% | -2.60% | -2.88% | -2.83% |
| **Vs. CE anchor** | -0.22% | -0.05% | -0.32% | -0.30% |

Table 4.4. Reported run-time estimates RRC tests, CE CTC, LowQP test configuration.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | **HDR HLG** | | **SVT12 RGB** | | **SVT16 RGB** | |
|  | Enc | Dec | Enc | Dec | Enc | Dec | Enc | Dec |
| AI | **CE-3.1** | 101% | 94% | 108% | 93% | 95% | 87% | 107% | 98% |
| **CE-3.2** | 101% | 95% | 107% | 94% | 95% | 90% | 95% | 90% |
| LDB | **CE-3.1** | 100% | 98% | 102% | 95% | 94% | 93% | 103% | 100% |
| **CE-3.2** | 100% | 98% | 101% | 96% | 100% | 93% | 103% | 100% |
| RA | **CE-3.1** | 100% | 99% | 102% | 97% | 98% | 96% | 102% | 99% |
| **CE-3.2** | 100% | 94% | 101% | 90% | 99% | 83% | 102% | 89% |

Table 4.5. CE3.1/CE3.2 simulation results, 12 bits data, HBD/HBR/HFR CTC, NormQP test configuration.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | | | | | | **HDR HLG** | | | | |
|  | dE100 | L100 | wY | wU | wV | Enc | Dec | Y | U | V | Enc | Dec |
| **AI** | **CE3.1** | 0.02% | 0.02% | 0.01% | 0.04% | -0.01% | 100% | 100% | 0.01% | -0.11% | -0.14% | 102% | 100% |
| **CE3.2** | -0.07% | -0.01% | -0.01% | 0.12% | 0.01% | 100% | 100% | 0.00% | -0.05% | 0.00% | 101% | 100% |
| **RA** | **CE3.1** | 0.00% | 0.02% | 0.02% | -0.23% | -0.30% | 101% | 100% | 0.01% | -0.06% | 0.20% | 106% | 100% |
| **CE3.2** | -0.05% | -0.02% | 0.00% | -0.40% | -0.41% | 101% | 99% | 0.03% | -0.23% | 0.15% | 106% | 102% |

To assess performance of the coding with extended precision of transform coefficients (18 bits instead of 15 bits of anchor) for 12 bit data coding, coding gain improvement reported by CE3.1 over different codebase is summarized in the Table 4.6. Test CE3.1 was selected for this summarization, since it does not change Log2TransformRange derivation for 12 bits data compared to the respective anchors (e.g. VTM12.0).

Results of CE3.1-VTM provides coding gain achieved by CE3.1 being integratated in the VTM12.0 and tested against the corresponding VTM12.0 anchor. Results of CE3.1-CE provides coding gain achieved by CE3.1 being integratated in the VTM12.0 and tested against the corresponding VTM12.0 anchor.

Table 4.6. CE3.1 simulation results, 12 bits data, HBD/HBR/HFR CTC, LowQP test configuration.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | | **HDR HLG** | | | **SVT12 RGB** | | | |
|  | wY | wU | wV | Y | U | V | R | G | B | Aver.RGB |
| **AI** | **CE3.1-VTM** | -1.71% | -2.18% | -2.34% | -0.90% | -1.18% | -1.21% | -3.50% | -3.86% | -3.86% | -3.74% |
| **CE3.1-CE** | -1.23% | -1.69% | -1.82% | -0.47% | -0.83% | -0.86% | -0.80% | -1.25% | -1.27% | -1.11% |
| **LDB** | **CE3.1-VTM** | -0.74% | -0.71% | -0.78% | -0.60% | -0.82% | -0.90% | -1.22% | -1.15% | -1.16% | -1.18% |
| **CE3.1-CE** | -0.67% | -0.65% | -0.72% | -0.62% | -0.80% | -0.84% | -0.79% | -0.65% | -0.66% | -0.70% |
| **RA** | **CE3.1-VTM** | -0.73% | -0.76% | -0.83% | -0.51% | -0.77% | -0.84% | -1.11% | -1.15% | -1.16% | -1.14% |
| **CE3.1-CE** | -0.60% | -0.63% | -0.69% | -0.50% | -0.73% | -0.78% | -0.61% | -0.64% | -0.65% | -0.63% |

The latter table shows that the benefit of using extended precision flag also with 12 bit data is larger when used on top of VTM than on top of CE anchor (results 3.1-CE are equivalent with table 4.2)

From the discussion:

It is noted that both 3.1 and 3.2 change the binarization (by implementing the extended precision mechanism of HEVC) also for the case of 12 bit data. The anchor is VVC without enabling extended precision. In the tests CE1.x and CE2.x, the extended precision flag was only enabled for 16 bit data. Table 4.2 shows there is also some benefit for 12 bit data.

3.1 is using the HEVC method (as the CE anchor), but implements an additional clipping to 20 bit maximum precision (the anchor would have 22 in case of 16 bit data). 3.2 decreases precision relative to the HEVC method for 12 bit data, but performs the same clipping. Table 4.3 indicates that this additional clipping may have some benefit compared to the HEVC method.

The reason for the benefit of clipping might be that entropy coding uses less bits.

The runtime results from table 4.4 may not be reliable. Decoder run time decrease might not be expected in 12 bit case.

All methods from CE 1.x, 2.x, 3.x have negligible impact in normal QP range.

Subsequent results show combinations.

Table 5.2. Simulation results for combined tests, 12 bits data, CE CTC, LowQP test configuration.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | | **HDR HLG** | | | **SVT12 RGB** | | | |
|  | wY | wU | wV | Y | U | V | Aver.GBR | G | B | R |
| **AI** | **CE4.1** | -1.42% | -1.80% | -1.93% | -0.89% | -1.01% | -1.04% | -1.81% | -1.86% | -1.77% | -1.79% |
| **CE4.2** | -1.32% | -1.66% | -1.78% | -0.85% | -0.96% | -0.99% | -1.78% | -1.85% | -1.73% | -1.75% |
| **CE4.3** | -1.31% | -1.65% | -1.77% | -0.84% | -0.95% | -0.97% | -1.75% | -1.82% | -1.71% | -1.73% |
| **CE4.4** | -1.14% | -1.57% | -1.68% | -0.47% | -0.81% | -0.83% | -0.93% | -0.68% | -1.05% | -1.07% |
| **CE4.5-CE3.1** | -1.24% | -1.63% | -1.76% | -0.49% | -0.71% | -0.74% | -1.04% | -0.87% | -1.11% | -1.13% |
| **CE4.5-CE3.2** | -1.14% | -1.51% | -1.62% | -0.45% | -0.66% | -0.69% | -0.95% | -0.83% | -1.00% | -1.03% |
| **CE4.6-CE3.1** | -1.30% | -1.72% | -1.86% | -0.54% | -0.85% | -0.88% | -1.40% | -1.16% | -1.51% | -1.54% |
| **CE4.6-CE3.2** | -1.20% | -1.59% | -1.71% | -0.51% | -0.80% | -0.82% | -1.26% | -1.07% | -1.35% | -1.37% |
| **CE4.7-A-CE3.1** | -1.52% | -1.89% | -2.02% | -0.95% | -1.07% | -1.10% | -1.93% | -1.89% | -1.94% | -1.97% |
| **CE4.7-A-CE3.2** | -1.42% | -1.75% | -1.87% | -0.91% | -1.02% | -1.05% | -1.89% | -1.88% | -1.88% | -1.90% |
| **CE4.7-B-CE3.1** | -1.52% | -1.88% | -2.02% | -0.95% | -1.07% | -1.11% | -1.92% | -1.89% | -1.93% | -1.95% |
| **CE4.7-B-CE3.2** | -1.42% | -1.74% | -1.88% | -0.91% | -1.02% | -1.05% | -1.88% | -1.88% | -1.87% | -1.89% |
| **LDB** | **CE4.1** | -0.70% | -0.69% | -0.74% | -0.65% | -0.82% | -0.87% | -1.07% | -1.20% | -1.00% | -1.01% |
| **CE4.2** | -0.66% | -0.65% | -0.72% | -0.61% | -0.77% | -0.81% | -1.04% | -1.16% | -0.98% | -0.99% |
| **CE4.3** | -0.66% | -0.64% | -0.71% | -0.61% | -0.78% | -0.80% | -1.03% | -1.15% | -0.97% | -0.98% |
| **CE4.4** | -0.63% | -0.63% | -0.70% | -0.57% | -0.75% | -0.79% | -0.62% | -0.70% | -0.58% | -0.59% |
| **CE4.5-CE3.1** | -0.69% | -0.67% | -0.73% | -0.63% | -0.81% | -0.84% | -0.79% | -0.88% | -0.74% | -0.75% |
| **CE4.5-CE3.2** | -0.65% | -0.63% | -0.69% | -0.59% | -0.76% | -0.80% | -0.70% | -0.78% | -0.65% | -0.66% |
| **CE4.6-CE3.1** | -0.64% | -0.63% | -0.68% | -0.56% | -0.73% | -0.75% | -0.83% | -0.92% | -0.77% | -0.79% |
| **CE4.6-CE3.2** | -0.62% | -0.59% | -0.65% | -0.53% | -0.69% | -0.72% | -0.76% | -0.84% | -0.71% | -0.72% |
| **CE4.7-A-CE3.1** | -0.72% | -0.70% | -0.76% | -0.63% | -0.80% | -0.83% | -1.10% | -1.19% | -1.04% | -1.06% |
| **CE4.7-A-CE3.2** | -0.69% | -0.67% | -0.74% | -0.59% | -0.74% | -0.79% | -1.06% | -1.15% | -1.01% | -1.02% |
| **CE4.7-B-CE3.1** | -0.72% | -0.70% | -0.75% | -0.63% | -0.78% | -0.83% | -1.09% | -1.18% | -1.04% | -1.05% |
| **CE4.7-B-CE3.2** | -0.69% | -0.67% | -0.74% | -0.59% | -0.74% | -0.77% | -1.06% | -1.14% | -1.01% | -1.02% |
| **RA** | **CE4.1** | -0.63% | -0.65% | -0.72% | -0.55% | -0.75% | -0.81% | -0.99% | -1.05% | -0.95% | -0.96% |
| **CE4.2** | -0.60% | -0.62% | -0.68% | -0.51% | -0.70% | -0.85% | -0.96% | -1.02% | -0.92% | -0.94% |
| **CE4.3** | -0.60% | -0.63% | -0.69% | -0.50% | -0.69% | -0.75% | -0.95% | -1.02% | -0.91% | -0.93% |
| **CE4.4** | -0.56% | -0.58% | -0.65% | -0.45% | -0.67% | -0.72% | -0.57% | -0.54% | -0.58% | -0.60% |
| **CE4.5-CE3.1** | -0.61% | -0.64% | -0.71% | -0.51% | -0.73% | -0.80% | -0.73% | -0.71% | -0.74% | -0.75% |
| **CE4.5-CE3.2** | -0.58% | -0.61% | -0.68% | -0.48% | -0.68% | -0.73% | -0.65% | -0.62% | -0.66% | -0.68% |
| **CE4.6-CE3.1** | -0.60% | -0.63% | -0.69% | -0.47% | -0.69% | -0.74% | -0.76% | -0.75% | -0.76% | -0.78% |
| **CE4.6-CE3.2** | -0.57% | -0.60% | -0.67% | -0.44% | -0.64% | -0.68% | -0.70% | -0.69% | -0.70% | -0.72% |
| **CE4.7-A-CE3.1** | -0.67% | -0.70% | -0.77% | -0.53% | -0.73% | -0.78% | -0.98% | -1.01% | -0.96% | -0.98% |
| **CE4.7-A-CE3.2** | -0.64% | -0.66% | -0.73% | -0.49% | -0.68% | -0.74% | -0.95% | -0.98% | -0.93% | -0.95% |
| **CE4.7-B-CE3.1** | -0.68% | -0.69% | -0.76% | -0.53% | -0.73% | -0.79% | -0.98% | -1.01% | -0.96% | -0.98% |
| **CE4.7-B-CE3.2** | -0.65% | -0.67% | -0.73% | -0.50% | -0.68% | -0.74% | -0.95% | -0.97% | -0.93% | -0.95% |

Table 5.3. Simulation results for combined tests, 16 bits data, CE CTC, LowQP test configuration.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Test** | **SVT16 RGB** | | | |
|  | Aver.GBR | G | B | R |
| **AI** | **CE4.1** | -2.45% | -2.96% | -2.21% | -2.18% |
| **CE4.2** | -2.45% | -2.96% | -2.21% | -2.18% |
| **CE4.3** | -2.44% | -2.94% | -2.20% | -2.17% |
| **CE4.4** | -0.63% | -0.80% | -0.54% | -0.54% |
| **CE4.5-CE3.1** | -1.21% | -1.39% | -1.12% | -1.13% |
| **CE4.5-CE3.2** | -1.21% | -1.39% | -1.12% | -1.13% |
| **CE4.6-CE3.1** | -1.24% | -1.40% | -1.16% | -1.17% |
| **CE4.6-CE3.2** | -1.24% | -1.40% | -1.16% | -1.17% |
| **CE4.7-A-CE3.1** | -2.48% | -2.90% | -2.27% | -2.26% |
| **CE4.7-A-CE3.2** | -2.48% | -2.90% | -2.27% | -2.26% |
| **CE4.7-B-CE3.1** | -2.45% | -2.88% | -2.24% | -2.22% |
| **CE4.7-B-CE3.2** | -2.45% | -2.88% | -2.24% | -2.22% |
| **LDB** | **CE4.1** | -1.40% | -1.39% | -1.41% | -1.40% |
| **CE4.2** | -1.40% | -1.39% | -1.41% | -1.40% |
| **CE4.3** | -1.39% | -1.40% | -1.40% | -1.38% |
| **CE4.4** | -0.27% | -0.26% | -0.28% | -0.27% |
| **CE4.5-CE3.1** | -0.80% | -0.78% | -0.82% | -0.81% |
| **CE4.5-CE3.2** | -0.80% | -0.78% | -0.82% | -0.81% |
| **CE4.6-CE3.1** | -0.87% | -0.86% | -0.88% | -0.87% |
| **CE4.6-CE3.2** | -0.87% | -0.86% | -0.88% | -0.87% |
| **CE4.7-A-CE3.1** | -1.62% | -1.60% | -1.64% | -1.63% |
| **CE4.7-A-CE3.2** | -1.62% | -1.60% | -1.64% | -1.63% |
| **CE4.7-B-CE3.1** | -1.60% | -1.57% | -1.62% | -1.60% |
| **CE4.7-B-CE3.2** | -1.60% | -1.57% | -1.62% | -1.60% |
| **RA** | **CE4.1** | -1.31% | -1.22% | -1.36% | -1.35% |
| **CE4.2** | -1.31% | -1.22% | -1.36% | -1.35% |
| **CE4.3** | -1.32% | -1.23% | -1.35% | -1.38% |
| **CE4.4** | -0.27% | -0.10% | -0.36% | -0.35% |
| **CE4.5-CE3.1** | -0.77% | -0.59% | -0.86% | -0.85% |
| **CE4.5-CE3.2** | -0.77% | -0.59% | -0.86% | -0.85% |
| **CE4.6-CE3.1** | -0.85% | -0.68% | -0.94% | -0.93% |
| **CE4.6-CE3.2** | -0.85% | -0.68% | -0.94% | -0.93% |
| **CE4.7-A-CE3.1** | -1.52% | -1.41% | -1.58% | -1.57% |
| **CE4.7-A-CE3.2** | -1.52% | -1.41% | -1.58% | -1.57% |
| **CE4.7-B-CE3.1** | -1.53% | -1.41% | -1.59% | -1.58% |
| **CE4.7-B-CE3.2** | -1.53% | -1.41% | -1.59% | -1.58% |

Difficult to draw conclusions from the combinations, as it would be necessary to compare various tables. This should be done offline by Excel.

Complexity analysis for CE1.x:

|  |  |  |  |
| --- | --- | --- | --- |
| **Test** | **Complexity increase vs. VVC, per TU4x4.** | **Memory requirement** | **Dependencies** |
| *CE-1.1* | 32 | 1 LUT of 4 entries  1 LUT of 5 entries |  |
| *CE-1.2* | 48 |  |  |
| *CE1.4* | 68 (Total):   * 48 in critical pass, * 20 in non-critical pass. | 3 variables (3x4 bits). | Cross-TU dependency.  CE1.4-A: No cross-CTU.  CE1.4-B: Cross-CTU. |
| *CE1.5* | 95 (Total)   * 32 in critical pass * 63 in non-critical pass | 8 variables (8 \* 10 bits)  6 \* 16 \* 2 bits LUT | Cross-subTU  Cross-TU  Cross-CTU |
| *CE1.6* | 95 (Total)   * 32 in critical pass * 63 in non-critical pass | 8 variables (8 \* 10 bits)  6 \* 16 \* 2 bits LUT | Cross-TU  Cross-CTU |
| *CE1.7* | 48 | No | No |

The numbers above are just counting operations, but not documenting what types of operations. More details can be found in the last meeting’s BoG report and in the detailed CE contributions.

Complexity analysis for CE2.x:

|  |  |  |  |
| --- | --- | --- | --- |
| **Test** | **Complexity increase vs. VVC, per TU4x4.** | **Memory requirement** | **Dependencies** |
| *CE-2.1* | 1 condition and 1 add per slice | No memory increase | No Dependency |
| *CE-2.2* | 61 (Total)   * 16 in critical pass * 45 in non-critical pass | 2 variables (2 \* 10 bits) | Cross-subTU  Cross-TU  Cross-CTU |
| *CE-2.3* | 61 (Total)   * 16 in critical pass * 45 in non-critical pass | 2 variables (2 \* 10 bits) | Cross-TU  Cross-CTU |

Complexity analysis for CE3.x/CE4.x still to be done.

Further analysis should be provided in comparison to HEVC low QP range 12 bit:

* Comparing CE anchor (available)
* Comparing anchor plus extended precision flag
* Comparing CE1.4 as a representative of better compression in entropy coding plus extended precision flag

Based on that, a reasonable compression vs. complexity tradeoff for a 12 bit profile could be discussed.

Similar analysis for 16 bit case, but invoking the 20-bit clipping from 3.1 additionally, to see how much gain is possible compared to HEVC.

Revisit after offline analysis

The additional methods from CE2.x show relatively low gain (1% for RA in TGM compared to anchor), while they introduce quite some complexity. The TSRC modification from the anchor already provides most of the gain that is possible by resolving the Rice parameter problem.

[JVET-V0046](https://jvet-experts.org/doc_end_user/current_document.php?id=10693) CE-1.7: Rice parameter derivation for high bit-depth coding [T. Hashimoto, T. Ikai (Sharp)]

[JVET-V0047](https://jvet-experts.org/doc_end_user/current_document.php?id=10694) CE-3.1 and CE-3.2: Transform coefficients range extension for high bit-depth coding [T. Zhou, T. Chujoh, T. Ikai (Sharp)]

[JVET-V0048](https://jvet-experts.org/doc_end_user/current_document.php?id=10695) CE-4.1: Combination of CE-3.1, CE-1.5 and CE-2.1 [T. Zhou, T. Chujoh, T. Ikai (Sharp)]

[JVET-V0049](https://jvet-experts.org/doc_end_user/current_document.php?id=10696) CE-4.2: Combination of CE-3.2, CE-1.5 and CE-2.1 [T. Zhou, T. Chujoh, T. Ikai (Sharp)]

[JVET-V0050](https://jvet-experts.org/doc_end_user/current_document.php?id=10697) CE-1.5, CE-1.6, CE-2.2 and CE-2.3: Rice parameter selection for high bit depths [A. Browne, S. Keating, K. Sharman (Sony)]

[JVET-V0051](https://jvet-experts.org/doc_end_user/current_document.php?id=10698) CE-4.3 and CE-4.4: Combinations of CE-1.6 and CE-2.3 with CE-3.2 [A. Browne, S. Keating, K. Sharman (Sony)]

[JVET-V0052](https://jvet-experts.org/doc_end_user/current_document.php?id=10699) CE-1.1, CE-1.2 and CE-1.4: On the Rice parameter derivation for high bit-depth coding [D. Rusanovskyy, M. Karczewicz, L. P. Van, M. Coban (Qualcomm)]

[JVET-V0053](https://jvet-experts.org/doc_end_user/current_document.php?id=10700) CE-4.5, CE-4.6 and CE-4.7: Combinations of RRC tests CE-1.1, CE-1.2 and CE-1.4 with CE-3.1/CE-3.2 [D. Rusanovskyy, M. Karczewicz, L. P. Van, M. Coban (Qualcomm)]

[JVET-V0054](https://jvet-experts.org/doc_end_user/current_document.php?id=10702) CE-2.1: Slice based Rice parameter selection for transform skip residual coding [H.-J. Jhu, X. Xiu, Y.-W. Chen, W. Chen, C.-W. Kuo, X. Wang (Kwai Inc.)]

[JVET-V0171](https://jvet-experts.org/doc_end_user/current_document.php?id=10834) CE-1.8: Results of Rice Parameter Derivation with Content Adaptation [K. Kawamura, K. Unno (KDDI)] [late]

TBP? Is it included in CE summary?

[JVET-V0134](https://jvet-experts.org/doc_end_user/current_document.php?id=10795) Crosscheck of CE-1.4 from JVET-V0052 (CE-1.1, CE-1.2 and CE-1.4: On the Rice parameter derivation for high bit-depth coding) [A. Browne (Sony)] [late]

[JVET-V0135](https://jvet-experts.org/doc_end_user/current_document.php?id=10796) Crosscheck of CE-4.5 and CE-4.7 from JVET-V0053 (CE-4.5, CE-4.6 and CE-4.7: Combinations of RRC tests CE-1.1, CE-1.2 and CE-1.4 with CE-3.1/CE-3.2) [A. Browne (Sony)] [late]

[JVET-V0136](https://jvet-experts.org/doc_end_user/current_document.php?id=10797) Crosscheck of JVET-V0047 (CE-3.1 and CE-3.2: Transform coefficients range extension for high bit-depth coding) [A. Browne (Sony)] [late]

[JVET-V0138](https://jvet-experts.org/doc_end_user/current_document.php?id=10799) Crosscheck of CE-1.2 from JVET-V0052 (CE-1.1, CE-1.2 and CE-1.4: On the Rice parameter derivation for high bit-depth coding) [T. Hashimoto (Sharp)] [late]

[JVET-V0139](https://jvet-experts.org/doc_end_user/current_document.php?id=10800) Cross-check report for CE1.5 and CE1.6 of JVET-V0050 and CE4.3 of JVET-V0051 [D. Rusanovskyy (Qualcomm)] [late]

[JVET-V0140](https://jvet-experts.org/doc_end_user/current_document.php?id=10801) Cross-check report for CE-1.7 of JVET-V0046 and CE-4.2 of JVET-V0049 [D. Rusanovskyy (Qualcomm)] [late]

[JVET-V0142](https://jvet-experts.org/doc_end_user/current_document.php?id=10803) Crosscheck of JVET-V0048 (CE-4.1: Combination of CE-3.1, CE-1.5 and CE-2.1) [H.-J. Jhu (Kwai Inc.)] [late]

[JVET-V0143](https://jvet-experts.org/doc_end_user/current_document.php?id=10804) Crosscheck of CE-2.2 and CE-2.3 from JVET-V0050 (CE-1.5, CE-1.6, CE-2.2 and CE-2.3: Rice parameter selection for high bit depths) [H.-J. Jhu (Kwai Inc.)] [late]

[JVET-V0144](https://jvet-experts.org/doc_end_user/current_document.php?id=10805) Crosscheck of CE-4.4 from JVET-V0051 (CE-4.3 and CE-4.4: Combinations of CE-1.6 and CE-2.3 with CE-3.2) [H.-J. Jhu (Kwai Inc.)] [late]

[JVET-V0145](https://jvet-experts.org/doc_end_user/current_document.php?id=10806) Crosscheck of CE-4.6 from JVET-V0053 (CE-4.5, CE-4.6 and CE-4.7: Combinations of RRC tests CE-1.1, CE-1.2 and CE-1.4 with CE-3.1/CE-3.2) [T. Zhou (Sharp)] [late]

[JVET-V0155](https://jvet-experts.org/doc_end_user/current_document.php?id=10816) Crosscheck of CE-1.1 from JVET-V0052 (CE-1.1, CE-1.2 and CE-1.4: On the Rice parameter derivation for high bit-depth coding) [M.G. Sarwer (Alibaba)] [late] [miss]

### CE related contributions: Entropy Coding for High Bit Depth and High Bit Rate Coding (4)

Contributions in this area were discussed in session 4 at 2330–0105 UTC on Tuesday/Wednesday 20/21 April 2021 (chaired by JRO and GJS).

[JVET-V0084](https://jvet-experts.org/doc_end_user/current_document.php?id=10732) CE-related: On Rice parameter selection for regular residual coding (RRC) at high bit depths [A. Browne, S. Keating, K. Sharman (Sony)]

This contribution describes modifications to the method for the selection of Rice parameters for regular residual coding, for consideration in VVC version 2. The modifications offer BD-rate gains when residual coefficient values become larger but do not affect version 1 operating points. It is suggested that the modification extends the operating point of the existing residual coding method to be applicable at all currently considered bit depths. A further modification is described which alters the template function used to calculate a clipped sum of neighbouring coefficients used during Rice parameter evaluation. Results are provided both with and without this further modification.

Using the high bit depth, high bit rate CTC the following AI results were obtained for the low QP range against the CE anchor:

With template modification:

PQ: -0.29%/-0.18%/-0.18%

HLG: -0.56%/-0.34%/0.35%

SVT-12: -1.67%/-1.26%/-1.27%

SVT-16: -2.94%/-2.09%/-2.07%

Without template modification

PQ: -0.26%/-0.16%/-0.16%

HLG: -0.53%/-0.33%/-0.34%

SVT-12: -1.65%/-1.26%/-1.26%

SVT-16: -2.94%/-2.10%/-2.08%

Based on CE-1.6, history based method using counters, but is claimed to have various simplifications. Operates on sub-TU basis. Improved results compared to CE-1.6. Compared to CE-1.4 (which is better than CE1.6 generally), it is sometimes better, sometimes worse.

Would require more analysis on complexity in comparison to other proposals and the CE anchor.

Why is decoder runtime increased significantly for SVT class? Analysis shows that more 4x4 blocks are used than with other methods, which is closer to the worst case scenario.

[JVET-V0157](https://jvet-experts.org/doc_end_user/current_document.php?id=10818) Crosscheck of JVET-V0084 (CE-related: On Rice parameter selection for regular residual coding (RRC) at high bit depths) [M. G. Sarwer (Alibaba)] [late] [miss]

[JVET-V0085](https://jvet-experts.org/doc_end_user/current_document.php?id=10733) CE-related: On Rice parameter selection for transform skip residual coding (TSRC) at high bit depths [A. Browne, S. Keating, K. Sharman (Sony)]

This contribution describes modifications to the method for the selection of Rice parameters for transform skip residual coding, for consideration in VVC version 2. The modifications offer BD-rate gains, particularly for screen content, when residual coefficient values become larger but do not affect version 1 operating points. It is suggested that the modification extends the operating point of the existing residual coding method to be applicable at all currently considered bit depths.

Using the high bit depth, high bit rate CTC the following BD-rate results were obtained for screen content coding:

AI: -0.41%/-0.14%/-0.25%

RA: -0.86%/-0.85%/-0.86%

LDB: -0.59%/-1.08%/-0.32%

Similar to method CE2.3, simplification conceptually similar to V0084 with single threshold. Gain too low to be considered.

[JVET-V0169](https://jvet-experts.org/doc_end_user/current_document.php?id=10832) Crosscheck of JVET-V0085 (CE-related: On Rice parameter selection for transform skip residual coding (TSRC) at high bit depths) [?? (Sharp)] [late] [miss]

[JVET-V0106](https://jvet-experts.org/doc_end_user/current_document.php?id=10754) CE-related: On history-enhanced method of Rice parameter derivation for regular residual coding (RRC) at high bit depths [D. Rusanovskyy, L. Pham Van, M. Coban, M. Karczewicz (Qualcomm)]

This contribution describes a history-based extension of Rice parameters derivation for regular residual coding (RRC), for VVCv2 development. It is advocated that a local (template based) methods of Rice parameter derivation in RRC, can be further improved by enabling history (across TUs) utilization during the template computation. One example of such history-based extension is currently being studied in CE1.4, where local method of CE1.2 is being extended with a history usage. This proposal present additional example of history-based extension for local CE1.1 derivation and present improvement provided by the said extension compare to the local methods.

It is asserted by the proponent, that proposed history-enhancement for local RRC derivation provides a complexity and dependency scalable RRC parameter derivation method with each component (of the method) providing a gain in all tested class. Method is proposed for adoption to VVCv2.

The following results (against the CE anchor) are reported for the described inhere local CE1.1 and CE1.2 RRC methods and their enhanced versions, respectively:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Test** | **HDR PQ** | | | **HDR HLG** | | | **SVT12 RGB** | **SVT16 RGB** |
|  | wY | wU | wV | Y | U | V | Aver.GBR | Aver.GBR |
| **AI** | **CE1.1** | -0.08% | -0.07% | -0.08% | -0.07% | -0.02% | -0.02% | -0.27% | -0.71% |
| **CE1.2** | -0.09% | -0.06% | -0.07% | -0.10% | -0.03% | -0.04% | -0.41% | -0.79% |
| **CE1.1+Hist** | -0.31% | -0.21% | -0.22% | -0.45% | -0.25% | -0.26% | -1.33% | -2.36% |
| **CE1.2+Hist** | -0.33% | -0.23% | -0.25% | -0.50% | -0.30% | -0.32% | -1.43% | -2.27% |
| **LDB** | **CE1.1** | -0.02% | -0.02% | -0.04% | -0.01% | 0.00% | 0.01% | -0.13% | -0.58% |
| **CE1.2** | 0.03% | 0.03% | 0.02% | 0.02% | 0.05% | 0.06% | -0.19% | -0.66% |
| **CE1.1+Hist** | -0.09% | -0.10% | -0.12% | -0.05% | -0.04% | -0.05% | -0.67% | -1.71% |
| **CE1.2+Hist** | -0.06% | -0.08% | -0.09% | -0.06% | -0.01% | 0.00% | -0.66% | -1.53% |
| **RA** | **CE1.1** | -0.02% | -0.03% | -0.03% | -0.01% | 0.00% | 0.00% | -0.12% | -0.51% |
| **CE1.2** | -0.01% | -0.01% | -0.02% | 0.01% | 0.03% | 0.03% | -0.17% | -0.60% |
| **CE1.1+Hist** | -0.11% | -0.10% | -0.12% | -0.07% | -0.05% | -0.06% | -0.60% | -1.61% |
| **CE1.2+Hist** | -0.08% | -0.08% | -0.09% | -0.04% | -0.02% | -0.02% | -0.57% | -1.45% |

Proponents claim that the history based extension mechanism might be useful in a potential 16 bit profile, when a 12 bit profile uses a local based method such as CE1.1 (complexity scalable solution).

Question: Would this be a benefit for implementation? Would the same devices be used for 12 and 16 bit profiles? It would nevertheless simplify a unified specification.

CE1.1 is claimed to be similarly complex as the anchor. Would it be possible to extend the CE anchor by history based extension? In principle yes.

The anchor should be included in the complexity analysis of CE1. It is mentioned that the anchor had been specified in JVET-U0064 which was decided to become the anchor in the last meeting. One expert mentioned that a possibly simpler method had earlier been proposed in JVET-T0105 which had similar performance for 12 bit data.

[JVET-V0156](https://jvet-experts.org/doc_end_user/current_document.php?id=10817) Crosscheck of JVET-V0106 (CE-related: On history-enhanced method of Rice parameter derivation for regular residual coding (RRC) at high bit depths) [M. G. Sarwer (Alibaba)] [late] [miss]

[JVET-V0123](https://jvet-experts.org/doc_end_user/current_document.php?id=10772) CE-related: On prefix code length of remaining level coding for high bit depth and high bit rate coding [Y. Yu, Z. Xie, F. Wang, H. Yu, D. Wang (OPPO)]

This contribution proposes a modification to the prefix code length of remaining level coding for high bit-depth and high bit-rate coding. A smaller fixed value equal to 1 or 4 is proposed to be used in the VTM12 or on the top of CE anchor. Simulations results show that there are gain for SVT 16 bit video while there are loss for 12 bit video.

Over VTM12, SVT 16:

AI: -19.45% (Y), -17.97%(U), -17.97%(V); LDB:-11.39%(Y),-10.79%(U),-10.80%(V); RA: -10.38%(Y), -10.27%(U), -10.24%(V)

Over CE anchor, SVT 16:

AI:-0.3% (Y),-0.25%(U), -0.25%(V); LDB:-0.06%(Y),-0.07%(U),-0.07%(V); RA: -0.02%(Y), -0.06%(U), -0.05%(V)

It is suggested that a smaller fixed number of prefix code length could be used for 16-bit video while retaining the current prefix code length unchanged for 12-bit input video.

Compared to CE anchor, still loss is observed for 12 bit data. Also for 16 bit data, some CE proposals showed better performance.

Benefit of the method compared to other proposals not obvious.

[JVET-V0161](https://jvet-experts.org/doc_end_user/current_document.php?id=10822) Crosscheck of JVET-V0123 (CE-related: On prefix code length of remaining level coding for high bit depth and high bit rate coding) [H.-J. Jhu (Kwai Inc.)] [late]

### Adaptation of other tools for high bit rate and high bit depth (9)

Contributions in this area were discussed in session 8 at 0105–0120 UTC and sessions 9/10 at 1430-XXXX UTC on Wednesday 21April 2021 (chaired by JRO and GJS).

[JVET-V0059](https://jvet-experts.org/doc_end_user/current_document.php?id=10707) AHG8: CABAC-bypass alignment for high bit-depth coding [M. G. Sarwer, J. Chen, Y. Ye, R. -L. Liao (Alibaba)]

In the last JVET meeting, a CABAC bypass alignment flag (similar to HEVC range extension) was proposed in JVET-U0069 to improve the throughput of the CABAC engine in high bit-rate applications. It was generally agreed that CABAC bypass alignment method in JVET-U0069 could improve the throughput in very high bit-rate professional applications, however, further study was recommended to investigate at which level (i.e. profile level, sequence level etc) this functionality is desirable. This contribution proposed to enable CABAC bypass alignment method in VVC High Throughput 4:4:4 16 Intra Profile.

Same as JVET-U0069, this contribution proposes two alignment options. In the first option, the bypass alignment is applied only to coefficient coding within a coefficient group (CG), without affecting the coding of sb\_coded\_flag of a transform block (TB). In the second option, in addition to CABAC bypass alignment, it is also proposed to switch to bypass coding of sb\_coded\_flag after the limit of context coded bins has been reached for the current TB. It is asserted that with the second option, alignment is needed only once after the limit of the context coded bins has been reached for the TB.

Following results are reported. Note that only SVT 16-bit sequences will be affected by the proposed changes as all other sequences are 12-bit sequences.

As compared to CE-1 anchor (low QP):

* Option1: SVT-16 bit sequences:
  + All Intra: 0.47%(G), 0.49% (B), 0.49 % (R), 100% (EncT), 93%(DecT)
  + LDB: 0.55%(G), 0.55 % (B), 0.55 % (R), 100% (EncT), 94%(DecT)
  + Random access: 0.57%(G), 0.56 % (B), 0.56 % (R), 100% (EncT), 93%(DecT)
* Option2: SVT-16 bit sequences:
  + All Intra: 0.47%(G), 0.49 % (B), 0.49 % (R), 99% (EncT), 94%(DecT)
  + LDB: 0.55%(G), 0.54 % (B), 0.54 % (R), 100%(EncT), 94%%(DecT)
  + Random access: 0.57%(G), 0.56 % (B), 0.56 % (R), 100%(EncT), 94%(DecT)

From the discussion:

* Should there be two 16 bit profiles?
* If yes, should they be “onion shell” structured, i.e. high throughput below the non-restricted?
* How does definition of a profile relate to the benefit compared to HEVC?
* The lack of gain may also be related to the current test data, and the versatility of VVC should include that it is able to support 16 bit

Revisit.

[JVET-V0141](https://jvet-experts.org/doc_end_user/current_document.php?id=10802) Cross-check report of AHG8: CABAC-bypass alignment for high bit-depth coding (JVET-V0059) [D. Rusanovskyy (Qualcomm)] [late]

[JVET-V0066](https://jvet-experts.org/doc_end_user/current_document.php?id=10714) AHG8: Encoder improvements to palette coding for high bit depth [T. Tsukuba, M. Ikeda, T. Suzuki (Sony)]

[JVET-V0162](https://jvet-experts.org/doc_end_user/current_document.php?id=10823) Crosscheck of JVET-V0066 (AHG8: Encoder improvements to palette coding for high bit depth) [H.-J. Jhu (Kwai Inc.)] [late]

[JVET-V0067](https://jvet-experts.org/doc_end_user/current_document.php?id=10715) AHG8: A constraint of max transform size for high bit depth and high bit rate coding [K. Kondo, M. Ikeda (Sony)]

[JVET-V0159](https://jvet-experts.org/doc_end_user/current_document.php?id=10820) Crosscheck of JVET-V0067 (AHG8: A constraint of max transform size for high bit depth and high bit rate coding) [T. Hashimoto (Sharp)] [late] [miss]

[JVET-V0068](https://jvet-experts.org/doc_end_user/current_document.php?id=10716) AHG8: A constraint of max CTU size for high bit depth and high bit rate coding [K. Kondo, M. Ikeda (Sony)]

[JVET-V0160](https://jvet-experts.org/doc_end_user/current_document.php?id=10821) Crosscheck of JVET-V0068 (AHG8: A constraint of max CTU size for high bit depth and high bit rate coding) [T. Hashimoto (Sharp)] [late] [miss]

[JVET-V0121](https://jvet-experts.org/doc_end_user/current_document.php?id=10770) AHG8: On coding of last significant coefficient position for high bit depth and high bit rate extensions [F. Wang, L. Xu, Z. Xie, Y. Yu, H. Yu, D. Wang (OPPO)]

[JVET-V0158](https://jvet-experts.org/doc_end_user/current_document.php?id=10819) Crosscheck of JVET-V0121 (AHG8: on coding of last significant coefficient position for high bit depth and high bit rate extensions) [M. G. Sarwer (Alibaba)] [late] [miss]

[JVET-V0122](https://jvet-experts.org/doc_end_user/current_document.php?id=10771) AHG8: A full-bypass mode in residual coding for high bit depth and high bit rate extensions [F. Wang, Z. Xie, Y. Yu, H. Yu, D. Wang (OPPO)]

[JVET-V0163](https://jvet-experts.org/doc_end_user/current_document.php?id=10824) Crosscheck of JVET-V0122 (AHG8: a full-bypass mode in residual coding for high bit depth and high bit rate extensions) [A. Browne (Sony)] [late] [miss]

[JVET-V0124](https://jvet-experts.org/doc_end_user/current_document.php?id=10773) AHG8: Weighted Prediction for VVC High Bit Depth Extension [Y. Yu, H. Yu, Z. Xie, F. Wang, D. Wang (OPPO)]

[JVET-V0131](https://jvet-experts.org/doc_end_user/current_document.php?id=10792) AHG8: Fixing the forward transform matrices for high bit depth coding [K. Naser, F. Galpin, F. F. Le Léannec, P. De Lagrange (InterDigital)]

[JVET-V0170](https://jvet-experts.org/doc_end_user/current_document.php?id=10833) Crosscheck of JVET-V0131 (AHG8: Fixing the forward transform matrices for high bit depth coding) [H.-J. Jhu (Kwai Inc.)] [late] [miss]

[JVET-V0133](https://jvet-experts.org/doc_end_user/current_document.php?id=10794) AHG8: Content Adaptive Transform Precision for High Bit Depth Coding [[K. Naser](mailto:karam.naser@interdigital.com), F. Galpin, F. Le Léannec, P. De Lagrange (InterDigital)]

[JVET-V0166](https://jvet-experts.org/doc_end_user/current_document.php?id=10828) Cross-check report on AHG8: Content Adaptive Transform Precision for High Bit Depth Coding (JVET-V0133) [D. Rusanovskyy (Qualcomm)] [late] [miss]

## AHG11: Neural network-based video coding (18)

### General (0)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

### EE1 contributions: Neural network-based video coding (7)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-U0023](https://jvet-experts.org/doc_end_user/current_document.php?id=10634) EE Summary Report: Neural Network-based Video Coding [E. Alshina, S. Liu, W. Chen, Y. Li, R.-L. Liao, Z. Ma, H. Wang]

[JVET-V0073](https://jvet-experts.org/doc_end_user/current_document.php?id=10721) EE1.2: Additional experimental results of NN-based super resolution (JVET-U0053) [T. Chujoh, T. Ikai (Sharp)]

[JVET-V0096](https://jvet-experts.org/doc_end_user/current_document.php?id=10744) EE1-2.3: Neural Network-based Super Resolution [A. M. Kotra, K. Reuzé, J. Chen, H. Wang, M. Karczewicz, J. Li (Qualcomm)]

[JVET-V0148](https://jvet-experts.org/doc_end_user/current_document.php?id=10809) Crosscheck of JVET-V0096 (EE1-2.3: Neural Network-based Super Resolution) [T. Ikai, T. Chujoh (Sharp)] [late]

[JVET-V0114](https://jvet-experts.org/doc_end_user/current_document.php?id=10763) EE1-1.3: Test on Neural Network-based In-Loop Filter with No Deblocking Filtering stage [H. Wang, J. Chen, A. M. Kotra, K. Reuzé, M. Karczewicz (Qualcomm)]

[JVET-V0115](https://jvet-experts.org/doc_end_user/current_document.php?id=10764) EE1-1.4: Test on Neural Network-based In-Loop Filter with Large Activation Layer [H. Wang, J. Chen, A. M. Kotra, K. Reuzé, M. Karczewicz (Qualcomm)]

[JVET-V0137](https://jvet-experts.org/doc_end_user/current_document.php?id=10798) EE1-1.1: neural network based in-loop filter using depthwise separable convolution and regular convolution (JVET-U0061) [Z. Li, C. Auyeung, X. Xu, W. Wang, X. Li, S. Liu (Tencent)] [late]

[JVET-V0149](https://jvet-experts.org/doc_end_user/current_document.php?id=10810) EE1: Tests on Decomposition, Compression and Synthesis (DCS)-based Technology (JVET-U0096) [M. Lu, Z. Ma (NJU), Z. Dai, D. Wang (OPPO)] [late]

### EE1 related contributions: Neural network-based video coding (0)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

### Tools in “hybrid” architectures (9)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0074](https://jvet-experts.org/doc_end_user/current_document.php?id=10722) AHG11: Separate density attention network for loop filtering [[Z. Wang](mailto:baixiu.wz@alibaba-inc.com), C. Ma, R.-L. Liao, Y. Ye (Alibaba)]

[JVET-V0075](https://jvet-experts.org/doc_end_user/current_document.php?id=10723) AHG11: Content-adaptive neural network post-processing filter [Y. Lam, M. Santamaria, J. Lainema, F. Cricri, R. Ghaznavi-Youvalari, A. Zare, H. Zhang, H. R. Tavakoli, M. M. Hannuksela (Nokia)]

[JVET-V0076](https://jvet-experts.org/doc_end_user/current_document.php?id=10724) AHG11: Deep-learning based inter prediction blending [F. Galpin, P. Bordes, T. Dumas, A. Robert, P. Nikitin, F. Le Léannec (InterDigital)]

[JVET-V0090](https://jvet-experts.org/doc_end_user/current_document.php?id=10738) AHG11: Neural network based temporal processing [B. Choi, Z. Li, W. Wang, W. Jiang, X. Xu, S. Liu (Tencent)]

[JVET-V0092](https://jvet-experts.org/doc_end_user/current_document.php?id=10740) AHG11: Replacing SAO in-loop filter with Neural Networks [P. Bordes, F. Galpin, T. Dumas, P. Nikitin (InterDigital)]

[JVET-V0100](https://jvet-experts.org/doc_end_user/current_document.php?id=10748) AHG11: Deep In-Loop Filter with Adaptive Model Selection [Y. Li, L. Zhang, K. Zhang (Bytedance)]

[JVET-V0101](https://jvet-experts.org/doc_end_user/current_document.php?id=10749) AHG11: Conditional In-Loop Filter with Parameter Selection [Y. Li, L. Zhang, K. Zhang (Bytedance)]

[JVET-V0105](https://jvet-experts.org/doc_end_user/current_document.php?id=10753) AHG11: neural network-based intra prediction: updated signaling [T. Dumas, F. Galpin, P. Bordes, P. Nikitin (InterDigital)]

[JVET-V0102](https://jvet-experts.org/doc_end_user/current_document.php?id=10750) AHG11 & AHG12: Deep In-Loop Filter with Adaptive Model Selection for Enhanced Compression Beyond VVC Capability [Y. Li, L. Zhang, K. Zhang (Bytedance)]

Also under 5.3.4.

### “End to end” architecture concepts (1)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0055](https://jvet-experts.org/doc_end_user/current_document.php?id=10703) Improved end to end deep intra frame compression with cross channel context model and loop filter [C. Ma, Z. Wang, R.-L. Liao, Y. Ye (Alibaba)]

### NN related HLS signalling (1)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0091](https://jvet-experts.org/doc_end_user/current_document.php?id=10739) AHG9/AHG11: SEI messages for carriage of neural network information for post-filtering [B. Choi, Z. Li, W. Wang, W. Jiang, X. Xu, S. Wenger, S. Liu (Tencent)]

## AHG12: Enhanced compression beyond VVC capability (26)

### General (0)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

### EE2 contributions: Enhanced compression beyond VVC capability (6)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0024](https://jvet-experts.org/doc_end_user/current_document.php?id=10825) EE2: Summary Report on Enhanced Compression beyond VVC capability [V. Seregin, J. Chen, S. Esenlik, F. Le Léannec, L. Li, J. Ström, M. Winken, X. Xiu, K. Zhang]

[JVET-V0077](https://jvet-experts.org/doc_end_user/current_document.php?id=10725) EE2-3.8: Multiple Hypothesis Prediction [M. Winken, J. Pfaff, B. Bross, H. Schwarz (HHI)]

[JVET-V0082](https://jvet-experts.org/doc_end_user/current_document.php?id=10730) EE2-4.1: Results for dependent quantization with 8 states [H. Schwarz, P. Haase, T. Nguyen, J. Pfaff, D. Marpe, T. Wiegand (HHI)]

[JVET-V0094](https://jvet-experts.org/doc_end_user/current_document.php?id=10742) EE2: Bilateral filter in VTM, EE2 and VVenC [J. Ström, P. Wennersten, K. Andersson, R. Sjöberg (Ericsson), S. Ikonin, E. Alshina (Huawei)]

[JVET-V0147](https://jvet-experts.org/doc_end_user/current_document.php?id=10808) Cross-check of JVET-V0094: EE2: Bilateral filter in VTM, EE2 and VVenC [A. Henkel (HHI)] [late]

[JVET-V0120](https://jvet-experts.org/doc_end_user/current_document.php?id=10769) EE2: Tests of compression efficiency methods beyond VVC [Y.-J. Chang, C.-C. Chen, J. Dong, N. Hu, H. Huang, M. Karczewicz, B. Ray, V. Seregin, Y. Zhang, Z. Zhang (Qualcomm)]

[JVET-V0146](https://jvet-experts.org/doc_end_user/current_document.php?id=10807) Crosscheck of Decoder Side Refinement tools in JVET-V0120 and Additional Results [S. Esenlik, E. Alshina (Huawei)] [late]

[JVET-V0130](https://jvet-experts.org/doc_end_user/current_document.php?id=10791) EE2: Intra Template Matching [K. Naser, T. Poirier, F. Le Léannec, G. Martin-Cocher (InterDigital)]

[JVET-V0146](https://jvet-experts.org/doc_end_user/current_document.php?id=10807) Crosscheck of Decoder Side Refinement tools in JVET-V0120 and Additional Results [S. Esenlik, E. Alshina (Huawei)] [late]

### EE2 related contributions: Enhanced compression beyond VVC capability (8)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0083](https://jvet-experts.org/doc_end_user/current_document.php?id=10731) EE2 related: asymmetric binary tree splitting on top of VVC [F. Le Léannec, K. Naser, T. Dumas, A. Robert, F. Galpin, E. François (InterDigital)]

[JVET-V0086](https://jvet-experts.org/doc_end_user/current_document.php?id=10734) EE2-related: OBMC fixes and updates [A. Robert, F. Galpin, F. Le Léannec, T. Poirier (InterDigital)]

[JVET-V0087](https://jvet-experts.org/doc_end_user/current_document.php?id=10735) EE2-Related: Improvements of Decoder-Side Intra Mode Derivation [J. Zhao, S. Paluri, S. Kim (LGE)]

[JVET-V0165](https://jvet-experts.org/doc_end_user/current_document.php?id=10827) Crosscheck of JVET-V0087 (EE2-Related: Improvements of Decoder-Side Intra Mode Derivation) [Y.-J. Chang (Qualcomm)] [late] [miss]

[JVET-V0089](https://jvet-experts.org/doc_end_user/current_document.php?id=10737) EE2-related: Inter coding modes modifications [A. Robert, F. Le Léannec, F. Galpin, T. Poirier (InterDigital)]

[JVET-V0098](https://jvet-experts.org/doc_end_user/current_document.php?id=10746) EE2-related: Template-based intra mode derivation using MPMs [Y. Wang, L. Zhang, K. Zhang, Z. Deng, N. Zhang (Bytedance)]

[JVET-V0104](https://jvet-experts.org/doc_end_user/current_document.php?id=10752) EE2-related: TU-level adaptive self-guided filter [W. Yin, K. Zhang, L. Zhang, Y. Wang, H. Liu (Bytedance)]

[JVET-V0117](https://jvet-experts.org/doc_end_user/current_document.php?id=10766) EE2-related: Combination of GPM and template matching [R.-L. Liao, Y. Ye, X. Li, J. Chen (Alibaba)]

[JVET-V0164](https://jvet-experts.org/doc_end_user/current_document.php?id=10826) Crosscheck of JVET-V0117 (EE2-related: Combination of GPM and template matching) [C.-C. Chen, H. Huang (Qualcomm)] [late] [miss]

[JVET-V0118](https://jvet-experts.org/doc_end_user/current_document.php?id=10767) EE2-related: Extension of template matching to Affine, CIIP, GPM merge modes, and boundary sub-blocks [[C.-C. Chen](mailto:chunchic@qti.qualcomm.com), [V. Seregin](mailto:vseregin@qti.qualcomm.com), [Y.-J. Chang](mailto:yjchang@qti.qualcomm.com), [Z. Zhang](mailto:zhizhang@qti.qualcomm.com), [H. Huang](mailto:hanhuang@qti.qualcomm.com), Y. Zhang, M. Karczewicz (Qualcomm)]

### Technology elements beyond EE2 (12)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0080](https://jvet-experts.org/doc_end_user/current_document.php?id=10728) AHG12: Extensions to CCALF [S. Keating, A. Browne, K. Sharman (Sony)]

[JVET-V0097](https://jvet-experts.org/doc_end_user/current_document.php?id=10745) AHG12: Unsymmetric partitioning methods in video coding [K. Zhang, L. Zhang, Z. Deng, N. Zhang, Y. Wang (Bytedance)]

[JVET-V0099](https://jvet-experts.org/doc_end_user/current_document.php?id=10747) AHG12: Adaptive Reordering of Merge Candidates with Template Matching [N. Zhang, K. Zhang, L. Zhang, H. Liu, Z. Deng, Y. Wang (Bytedance)]

[JVET-V0102](https://jvet-experts.org/doc_end_user/current_document.php?id=10750) AHG11 & AHG12: Deep In-Loop Filter with Adaptive Model Selection for Enhanced Compression Beyond VVC Capability [Y. Li, L. Zhang, K. Zhang (Bytedance)]

[JVET-V0103](https://jvet-experts.org/doc_end_user/current_document.php?id=10751) AHG12: Geometric prediction mode with motion vector differences [Z. Deng, K. Zhang, L. Zhang, N. Zhang, Y. Wang (Bytedance)]

[JVET-V0110](https://jvet-experts.org/doc_end_user/current_document.php?id=10758) AHG12: Two additional reference sample sets for CCLM [C.-Y. Teng, Y.-C. Yang (FG Innovation)]

[JVET-V0116](https://jvet-experts.org/doc_end_user/current_document.php?id=10765) Enhanced Intra MTS and LFNST for compression beyond VVC [B. Ray, L. Kerofsky, M. Coban, M. Karczewicz, H. Egilmez, V. Seregin (Qualcomm)]

[JVET-V0119](https://jvet-experts.org/doc_end_user/current_document.php?id=10768) AHG12: LFNST extension with large kernel [M. Koo, J. Zhao, J. Lim, S. Kim (LGE)]

[JVET-V0125](https://jvet-experts.org/doc_end_user/current_document.php?id=10774) AHG12: Evaluation of GPM with MMVD for coding efficiency improvement over VVC [X. Xiu, H.-J. Jhu, C.-W. Kuo, W. Chen, Y.-W. Chen, X. Wang (Kwai)]

[JVET-V0126](https://jvet-experts.org/doc_end_user/current_document.php?id=10775) EE-related: Modified OBMC [Y. Kidani, K. Kawamura, K. Unno (KDDI)]

[JVET-V0129](https://jvet-experts.org/doc_end_user/current_document.php?id=10778) AHG12: 3D Geometry for Global Motion Compensation [H. Golestani, C. Rohlfing, M. Wien (RWTH Aachen)]

[JVET-V0153](https://jvet-experts.org/doc_end_user/current_document.php?id=10814) AHG12: Cross-component Sample Adaptive Offset [C.-W. Kuo, X. Xiu, Y.-W. Chen, H.-J. Jhu, W. Chen, X. Wang (Kwai)] [late]

# High-level syntax (HLS) proposals (15)

## AHG9: SEI message studies and proposals (11)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0058](https://jvet-experts.org/doc_end_user/current_document.php?id=10706) AHG9: On post-filter SEI [M. M. Hannuksela, E. B. Aksu, F. Cricri, H. R. Tavakoli (Nokia)]

[JVET-V0061](https://jvet-experts.org/doc_end_user/current_document.php?id=10709) AHG9: Display orientation information SEI message [Y. He, M. Coban, M. Karczewicz (Qualcomm), J. Boyce (Intel)]

[JVET-V0062](https://jvet-experts.org/doc_end_user/current_document.php?id=10710) AHG9: Picture quality metrics SEI message [Y. He, M. Coban, M. Karczewicz (Qualcomm)]

[JVET-V0063](https://jvet-experts.org/doc_end_user/current_document.php?id=10711) AHG9: On the scalability dimension information SEI message [Y. Wang, Y.-K. Wang, L. Zhang (Bytedance)]

[JVET-V0064](https://jvet-experts.org/doc_end_user/current_document.php?id=10712) AHG9: On the MAI, DRI, and ACI SEI messages and their interactions with the SDI SEI message [Y.-K. Wang, Y. Wang, L. Zhang (Bytedance)]

[JVET-V0065](https://jvet-experts.org/doc_end_user/current_document.php?id=10713) AHG9: On the DRAP and EDRAP indication SEI messages [Y.-K. Wang, L. Zhang, Y. Wang (Bytedance)]

[JVET-V0069](https://jvet-experts.org/doc_end_user/current_document.php?id=10717) AHG9: Decoded GDR clean area hash SEI message [L. Wang, S. Hong, K. Panusopone, M. M. Hannuksela (Nokia)]

[JVET-V0071](https://jvet-experts.org/doc_end_user/current_document.php?id=10719) AHG9: Temporal sublayer information SEI message [R. Sjöberg, M. Pettersson, M. Damghanian, J. Ström (Ericsson)]

[JVET-V0093](https://jvet-experts.org/doc_end_user/current_document.php?id=10741) AHG9: Film grain estimation and film grain synthesis for VVC – SEI message characteristics, film grain estimation and film grain synthesis modules [Miloš Radosavljević, Edouard François (InterDigital)]

[JVET-V0151](https://jvet-experts.org/doc_end_user/current_document.php?id=10812) Crosscheck of JVET-V0093 (AHG9: Film grain estimation and film grain synthesis for VVC – SEI message characteristics, film grain estimation and film grain synthesis modules) [P. Yin, S.McCarthy (Dolby)] [late]

[JVET-V0108](https://jvet-experts.org/doc_end_user/current_document.php?id=10756) AHG9: Colour Transform Information SEI message [E. François, M. Radosavljevic, P. de Lagrange, F. Le Léannec (InterDigital)]

[JVET-V0152](https://jvet-experts.org/doc_end_user/current_document.php?id=10813) Crosscheck of JVET-V0108 (AHG9: Colour Transform Information SEI message) [F. Pu (Dolby)] [late] [miss]

[JVET-V0113](https://jvet-experts.org/doc_end_user/current_document.php?id=10762) Thoughts on SEI messages [W. Husak (Dolby)] [late]

## Non-SEI HLS aspects (4)

Contributions in this area were discussed in session X at XXXX–XXXX UTC on XXday 2X April 2021 (chaired by XXX).

[JVET-V0060](https://jvet-experts.org/doc_end_user/current_document.php?id=10708) Constrained RASL encoding for bitstream switching [R. Skupin, C. Bartnik, A. Wieckowski, K. Suehring, Y. Sanchez, B. Bross (HHI)]

[JVET-V0081](https://jvet-experts.org/doc_end_user/current_document.php?id=10729) AHG9: On the decoder initialization information [Hendry, S. Lee, S. Kim (LGE), Y.-K. Wang, K. Zhang, L. Zhang, Y. Wang, J. Xu, Z. Deng (Bytedance)]

[JVET-V0109](https://jvet-experts.org/doc_end_user/current_document.php?id=10757) Early access to decoded samples for cloud rendering/gaming applications [E. Thomas, A. Gabriel, Y. Shiferaw (TNO)]

[JVET-V0112](https://jvet-experts.org/doc_end_user/current_document.php?id=10761) AHG9: On Bitstream Properties Signalling for Decoder Initialization [S. Deshpande (Sharp)]

# Plenary meetings, joint meetings, BoG reports, and liaison communications

## JVET plenaries

Some of the discussions and actions at plenary sessions are noted in this section.

XXday xx April XXXX-XXXX:

* …

## Information sharing meetings

Beyond the joint meetings listed below, information sharing sessions with other WGs of the MPEG community were held on Monday 26 April 0500–XXXX, Wednesday 28 April 0500–XXXX, and Friday 30 April 2100–XXXX. The status of the work in the MPEG WGs was reviewed at these information sharing sessions.

## Joint meeting with XXX

The following topics were discussed in this joint session.

* …

## BoGs (5)

The following break-out groups were established at this meeting and produced the below-listed reports.

## Liaison communications

### Communication with XXXX

An incoming liaison letter was received by JVET as ISO/IEC JTC 1/SC 29/WG 5 and by VCEG, as follows:

# Project planning

## Core experiment and exploration experiment planning

A CE on entropy coding for high bit depths and high bit rates was established, as recorded in output document JVET-U2022.

An EE on neural network-based video coding was established, as recorded in output document JVET-U2023.

An EE on enhanced compression technology beyond VVC capability using techniques other than neural-network technology was also established, as recorded in output document JVET-U2024.

Initial versions of these documents were presented and approved in the plenary on Friday 15 January.

## Drafting of specification text, encoder algorithm descriptions, and software

The following agreement has been established: the editorial team has the discretion to not integrate recorded adoptions for which the available text is grossly inadequate (and cannot be fixed with a reasonable degree of effort), if such a situation hypothetically arises. In such an event, the text would record the intent expressed by the committee without including a full integration of the available inadequate text.

## Plans for improved efficiency and contribution consideration

The group considered it important to have the full design of proposals documented to enable proper study.

Adoptions need to be based on properly drafted working draft text (on normative elements) and HM/VTM encoder algorithm descriptions – relative to the existing drafts. Proposal contributions should also provide a software implementation (or at least such software should be made available for study and testing by other participants at the meeting, and software must be made available to cross-checkers in EEs).

Suggestions for future meetings included the following generally-supported principles:

* No review of normative contributions without draft specification text
* VTM algorithm description text is strongly encouraged for non-normative contributions
* Early upload deadline to enable substantial study prior to the meeting
* Using a clock timer to ensure efficient proposal presentations (5 min) and discussions

The document upload deadline for the next meeting was planned to be Tuesday 13 April 2021.

As general guidance, it was suggested to avoid usage of company names in document titles, software modules etc., and not to describe a technology by using a company name.

## General issues for experiments

It was emphasized that those rules which had been set up or refined during the 12th JVET meeting should be observed. In particular, for some CEs of some previous meetings, results were available late, and some changes in the experimental setup had not been sufficiently discussed on the JVET reflector.

Group coordinated experiments have been planned as follows:

* “Core experiments” (CEs) are the coordinated experiments on coding tools which are deemed to be interesting but require more investigation and could potentially become part of a draft standard by the next meeting or in the near future.
* “Exploration experiments” (EEs) are also coordinated experiments. These are conducted on technology which is not foreseen to become part of a draft standard in near future. Investigating methodology for assessment of such technology can also be an important part of an EE. (Further general rules for EEs, as far as deviating from the CE rules below, should be discussed in a future meeting. For the current meeting, procedures as described in the EE description document are deemed to be sufficient)
* A CE is a test of a specific fully described technology in a specific agreed way. It is not a forum for thinking of new ideas (like an AHG). The CE coordinators are responsible for making sure that the CE description is complete and correct and has adequate detail. Reflector discussions about CE description clarity and other aspects of CE plans are encouraged.
* A description of each experiment is to be approved at the meeting at which the experiment plan is established. This should include the issues that were raised by other experts when the tool was presented, e.g., interference with other tools, contribution of different elements that are part of a package, etc. The experiment description document should provide the names of individual people, not just company names.
* Software for tools investigated in a CE will be provided in one or more separate branches of the software repository. Each CE will have a “fork” of the software, and within the CE there may be multiple branches established by the CE coordinator. The software coordinator will help coordinate the creation of these forks and branches and their naming. All JVET members will have read access to the CE software branches (using shared read-only credentials as described below).
* During the experiment, revisions of the experiment plans can be made, but not substantial changes to the proposed technology.
* The CE description must match the CE testing that is done. The CE description needs to be revised if there has been some change of plans.
* The CE summary report must describe any changes that were made in the process of finalizing the CE.
* By the next meeting it is expected that at least one independent cross-checker will report a detailed analysis of each proposed feature that has been tested and confirm that the implementation is correct. Commentary on the potential benefits and disadvantages of the proposed technology in cross-checking reports is highly encouraged. Having multiple cross-checking reports is also highly encouraged (especially if the cross-checking involves more than confirmation of correct test results). The reports of cross-checking activities may (and generally should) be integrated into the CE report rather than submitted as separate documents.

It is possible to define sub-experiments within particular CEs, for example designated as CEX.a, CEX.b, etc., where X is the basic CE number.

As a general rule, it was agreed that each CE should be run under the same testing conditions using one software codebase, which should be based on the group test model software codebase. An experiment is not to be established as a CE unless there is access given to the participants in (any part of) the CE to the software used to perform the experiments.

The general agreed common conditions for single-layer coding efficiency experiments for SDR video are described in the prior output document JVET-T2010.

Experiment descriptions should be written in a way such that it is understood as a JVET output document (written from an objective “third party perspective”, not a proponent perspective – e.g. not referring to methods as “improved”, “optimized”, etc.). The experiment descriptions should generally not express opinions or suggest conclusions – rather, they should just describe what technology will be tested, how it will be tested, who will participate, etc. Responsibilities for contributions to CE work should identify individuals in addition to company names.

CE descriptions contain a basic description of the technology under test, but should not contain excessively verbose descriptions of a technology (at least not unless the technology is not adequately documented elsewhere). Instead, the CE descriptions should refer to the relevant proposal contributions for any necessary further detail. However, the complete detail of what technology will be tested must be available – either in the CE description itself or in documents that are referenced in the CE description that are also available in the JVET document archive.

Any technology must have at least one cross-check partner to establish a CE – a single proponent is not enough. It is highly desirable have more than just one proponent and one cross-checker.

The CE development workflow is described at:

<https://vcgit.hhi.fraunhofer.de/jvet/VVCSoftware_VTM/wikis/Core-experiment-development-workflow>

CE read access is available using shared accounts: One account exists for MPEG members, which uses the usual MPEG account data. A second account exists for VCEG members with account information available in the TIES system at:

<https://www.itu.int/ifa/t/2017/sg16/exchange/wp3/q06/vceg_account.txt>

Some agreements relating to CE activities were established as follows:

* Only qualified JVET members can participate in a CE.
* Participation in a CE is possible without a commitment of submitting an input document to the next meeting. Participation is requested by contacting the CE coordinator.
* All software, results, and documents produced in the CE should be announced and made available to JVET in a timely manner.
* A JVET CE reflector will be established and announced on the main JVET reflector. Discussion of logistics arrangements, exchange of data, minor refinement of the test plans, and preparation of documents shall be conducted on the JVET CE reflector, with subject lines prefixed by “[CEx: ]”, where “x” is the number of the CE. All substantial communications about a CE other than such details shall take place on main JVET reflector. In the case that large amounts of data are to be distributed, it is recommended to send a link to the data rather than the data itself, or upload the data as an input contribution to the next meeting.

General timeline for CEs

T1= 3 weeks after the JVET meeting: To revise the CE description and refine questions to be answered. Questions should be discussed and agreed on JVET reflector. Any changes of planned tests after this time need to be announced and discussed on the JVET reflector. Initially assigned description numbers shall not be changed later. If a test is skipped, it is to be marked as “withdrawn”.

T2 = Test model software release + 2 weeks: Integration of all tools into a separate CE branch of the VTM is completed and announced to JVET reflector.

* Initial study by cross-checkers can begin.
* Proponents may continue to modify the software in this branch until T3.
* 3rd parties are encouraged to study and make contributions to the next meeting with proposed changes

T3: 3 weeks before the next JVET meeting or T2 + 1 week, whichever is later: Any changes to the CE test branches of the software must be frozen, so the cross-checkers can know exactly what they are cross-checking. A software version tag should be created at this time. The name of the cross-checkers and list of specific tests for each tool under study in the CE plan description shall be documented in an updated CE description by this time.

T4: Regular document deadline minus 1 week: CE contribution documents including specification text and complete test results shall be uploaded to the JVET document repository (particularly for proposals targeting to be promoted to the draft standard at the next meeting).

The CE summary reports shall be available by the regular contribution deadline. This shall include documentation about crosscheck of software, matching of CE description and confirmation of the appropriateness of the text change, as well as sufficient crosscheck results to create evidence about correctness (crosscheckers must send this information to the CE coordinator at least 3 days ahead of the document deadline). Furthermore, any deviations from the timelines above shall be documented. The numbers used in the summary report shall not be changed relative to the description document.

CE reports may contain additional information about tests of straightforward combinations of the identified technologies. Such supplemental testing needs to be clearly identified in the report if it was not part of the CE plan.

New branches may be created which combine two or more tools included in the CE document or the VTM (as applicable).

It is not necessary to formally name cross-checkers in the initial version of the CE description document. To adopt a proposed feature at the next meeting, we would like see comprehensive cross-checking done, with analysis that the description matches the software, and recommendation of value of the tool given tradeoffs.

The establishment of a CE does not indicate that a proposed technology is mature for adoption or that the testing conducted in the CE is fully adequate for assessing the merits of the technology, and a favourable outcome of CE does not indicate a need for adoption of the technology into a standard.

Availability of spec text is important to have a detailed understanding of the technology and also to judge what its impact on the complexity of the spec will be. There must also be sufficient time to study it in detail. CE contributions without sufficiently mature draft spec text in the CE input document should not be considered for adoption.

Lists of participants in CE documents should be pruned to include only the active participants. Read access to software will be available to all members.

# Establishment of ad hoc groups

The ad hoc groups established to progress work on particular subject areas until the next meeting are described in the table below. The discussion list for all of these ad hoc groups was agreed to be the main JVET reflector ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de)).

Initial review of AHG plans was conducted in session 20 on Thursday 14 January 2021. Further review was conducted in session 22 on Friday 15 January 2021.

|  |  |  |
| --- | --- | --- |
| **Title and Email Reflector** | **Chairs** | **Mtg** |
| **Project Management (AHG1)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Coordinate overall JVET interim efforts. * Supervise AHG studies. * Report on project status to JVET reflector. * Provide a report to the next meeting on project coordination status. | J.-R. Ohm, G. J. Sullivan (co-chairs) | N |
| **Draft text and test model algorithm description editing (AHG2)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Produce and finalize draft text outputs of the meeting (JVET-U2005 and JVET-U2006). * Collect reports of errata for the VVC, VSEI, HEVC, AVC, CICP, the codepoint usage TR specification and the published HDR-related technical reports and produce the JVET-U1004 errata output collection. * Produce and finalize JVET-U2002 VVC Test Model 12 (VTM 12) Algorithm and Encoder Description. * Propose improvements to the JCTVC-AN1002 HEVC Test Model 16 (HM 16) Update 14 of Encoder Description * Coordinate with the test model software development AhG to address issues relating to mismatches between software and text. * Collect and consider errata reports on the texts | B. Bross, J. Chen, C. Rosewarne (co-chairs), F. Bossen, J. Boyce, S. Kim, S. Liu, J.‑R. Ohm, G. J. Sullivan, A. Tourapis, Y.-K. Wang, Y. Ye (vice-chairs) | N |
| **Test model software development (AHG3)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Coordinate development of test models (VTM, HM, SCM, SHM, HTM, MFC, MFCD, JM, JSVM, JMVM, 3DV-ATM, and HDRTools) software and associated configuration files. * Produce documentation of software usage for distribution with the software. * Enable software support for recently standardized additional SEI messages. * Discuss and make recommendations on the software development process. * Propose improvements to the guideline document for developments of the test model software. * Perform comparative tests of test model behaviour using common test conditions. * Suggest configuration files for additional testing of tools. * Investigate how to minimize the number of separate codebases maintained for group reference software. * Coordinate with AHG on Draft text and test model algorithm description editing (AHG2) to identify any mismatches between software and text, and make further updates and cleanups to the software as appropriate. * Coordinate with AHG6 for integration with 360lib software. | F. Bossen, X. Li, K. Sühring (co-chairs), K. Sharman, V. Seregin, A. Tourapis (vice‑chairs) | N |
| **Test material and visual assessment (AHG4)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Produce the draft verification test plan JVET-U2021 and develop proposed improvements for verification testing of VVC capability. * Maintain the video sequence test material database for testing the VVC and HEVC standards and potential future extensions, as well as exploration activities. * Study coding performance and characteristics in relation to video test materials, including new test materials. * Identify and recommend appropriate test materials for testing the VVC standard and potential future extensions, as well as exploration activities. * Identify missing types of video material, solicit contributions, collect, and make available a variety of video sequence test material. * Maintain and update the directory structure for the test sequence repository as necessary. * Collect information about test sequences that have been made available by other organizations, particularly including Rep. ITU-R BT.2245. * Prepare availability of viewing equipment and facilities arrangements for future meetings. | V. Baroncini, T. Suzuki, M. Wien (co-chairs), E. François, S. Liu, A. Norkin, A. Segall, P. Topiwala, S. Wenger, Y. Ye (vice-chairs) | Tel.  2 weeks notice |
| **Conformance testing (AHG5)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Produce the JVET-U2008 draft conformance testing specification and develop proposed improvements. * Study the requirements of VVC, HEVC, and AVC conformance testing to ensure interoperability. * Maintain and update the conformance bitstream database. * Study additional testing methodologies to fulfil the needs for VVC conformance testing. | J. Boyce and W. Wan (co-chairs), E. Alshina, F. Bossen, I. Moccagatta, K. Kawamura, K. Sühring, X. Xu (vice-chairs) | N |
| **360° video coding, software and test conditions (AHG6)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study the effect on compression and subjective quality of different projections formats, resolutions, and packing layouts. * Solicit additional test sequences, and evaluate suitability of test sequences on head-mounted displays and normal 2D displays. * Study the effect of viewport resolution, field of view, and viewport speed/direction on visual comfort. * Prepare and deliver the 360Lib-12 software version and common test condition configuration files according to JVET-U1012. * Generate CTC anchors and PERP results for the VTM according to JVET-U1012. * Coordinate with AHG4 in preparation for verification testing for 360° video content. * Produce documentation of 360° software usage for distribution with the software. | J. Boyce and Y. He (co-chairs), K. Choi, J.-L. Lin, Y. Ye (vice-chairs) | N |
| **Coding of HDR/WCG material (AHG7)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study and evaluate available HDR/WCG test content. * Study objective metrics for quality assessment of HDR/WCG material, including investigation of the correlation between subjective and objective results. * Compare the performance of the VTM and HM for HDR/WCG content. * Generate CTC anchors for the VTM according to JVET-T2011. * Study the luma/chroma bit allocation in the HDR CTC, especially for HLG content. * Coordinate with AHG 8 on preparing HDR material in 12 bit 4:2:0 format, and support in generating the HDR anchors for the CE. * Coordinate with AHG4 in preparation for verification testing for HDR video content. * Study additional aspects of coding HDR/WCG content. | A. Segall (chair), E. François, W. Husak, S. Iwamura, D. Rusanovskyy (vice-chairs) | N |
| **High bit depth, high bit rate, and high frame rate coding (AHG8)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study the benefits and characteristics of VVC coding tools for high bit depth, high bit rate, and high frame rate coding. * Study lossless coding characteristics of VVC. * Identify technologies for future extension of VVC to support such application usage. * Discuss and refine the JVET-U2018 testing conditions for high bit depth, high bit rate, and high frame rate coding. * Finalize, conduct and coordinate the work on the core experiment JVET-U2022. * Identify suitable test material for testing of high bit depth, high bit rate, and high frame rate coding in coordination with AHG4 and AHG7. * Study VVC entropy decoding throughput in the cases of high bit depth, high bit rate, and high frame rate coding. | A. Browne and T. Ikai (co-chairs), D. Rusanovskyy, M. Sarwer, X. Xiu (vice-chairs) | Tel.  2 weeks notice |
| **SEI message studies (AHG9)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study the SEI messages in VSEI, VVC, HEVC and AVC. * Collect software and SEI showcase and usage information for SEI messages, including encoder and decoder implementations and bitstreams for demonstration and testing. * Identify potential needs for additional SEI messages. * Investigate the possible need of mandatory post processing in the context of SEI messages * Study SEI messages defined in HEVC and AVC for potential use in the VVC context. * Coordinate with AHG3 for software support of SEI messages. | J. Boyce, S. McCarthy (co-chairs), C. Fogg, P. de Lagrange, A. Luthra, G. J. Sullivan, A. Tourapis, Y.-K. Wang, S. Wenger (vice-chairs) | N |
| **Encoding algorithm optimization (AHG10)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study the impact of using techniques such as tool adaptation and configuration, and perceptually optimized adaptive quantization for encoder optimization. * Study the impact of non-normative techniques of pre processing for the benefit of encoder optimization. * Study encoding techniques of optimization for objective quality metrics and their relationship to subjective quality. * Consider neural network-based encoding optimization technologies for video coding standards. * Investigate other methods of improving objective and/or subjective quality, including adaptive coding structures and multi-pass encoding. * Study methods of rate control and rate-distortion optimization and their impact on performance, subjective and objective quality. | A. Duenas, A. Tourapis (co-chairs), A. Norkin, R. Sjöberg (vice-chairs) | N |
| **Neural network-based video coding (AHG11)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Evaluate and quantify performance improvement potential of NN based video coding technologies compared to existing video coding standards such as VVC, including both individual coding tools and novel architectures. * Finalize, conduct and discuss the EE on neural network-based video coding JVET-U2023. * Solicit input contributions on NN based video coding technologies. * Continue to refine the test conditions for neural network-based video coding, and develop supporting software as needed. * Investigate technical aspects specific to NN-based video coding, such as encoding and decoding complexity of neural networks, design network representation, operation, tensor, on-the-fly network adaption (e.g. updating during encoding) etc; * Study the impact of training (including the impact of loss function) on the performance of candidate technology, and identify suitable video materials for training. * Analyse complexity characteristics, perform complexity analysis, and develop complexity reductions of candidate technology. * Refine testing methods for assessment of the effectiveness and complexity of considered technology. * Review the outcome of the expert viewing conducted at the 21st meeting, refine the methodology, and prepare viewing for the next meeting. * Generate and distribute anchor encodings and develop improvements of the JVET-U2016 common test conditions for NNVC technology. * Coordinate with other relevant groups, including SC29/AG5 on visual quality assessment. | S. Liu, A. Segall, Y. Ye (co‑chairs), E. Alshina, J. Chen, F. Galpin, J. Pfaff, S. S. Wang, M. Wien, P. Wu, J. Xu (vice‑chairs) | Tel. for EE finalization 01-22  Other Tel.  2 weeks notice |
| **Enhanced compression beyond VVC capability (AHG12)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Solicit and study non-neural-network video coding tools with enhanced compression capabilities beyond VVC. * Study the performance and complexity tradeoff of these video coding tools. * Define a common software platform for developing and evaluating video coding tools with promising compression performance. * Refine test conditions in JVET-U2017, generate anchors, identify new test sequences to be added, especially high resolution ones in 8K, in coordination with AHG4. * Investigate methods to reduce simulation time especially in the low delay configuration. * Analyse the results of exploration experiments described in JVET-U2024 in coordination with the EE coordinators. * Coordinate with AHG11 to study the interaction with neural network-based coding tools. | M. Karczewicz and Y. Ye (co-chairs), B. Bross, X. Li, K. Naser, H. Yang (vice chairs) | Tel.  2 weeks notice |

It was confirmed that the rules which can be found in document ISO/IEC JTC 1/SC 29/AG 2 N010 “Ad hoc group rules for MPEG AGs and WGs” (available at <https://www.mpegstandards.org/adhoc/>), are consistent with the operation mode of JVET AHGs. It is however pointed out that JVET does not allow separate AHG reflectors, such that any JVET member is implicitly a member of any AHG. This shall be mentioned in the related WG Recommendations. The list above was also issued as a separate WG 5 document (ISO/IEC JTC 1/SC 29/[WG 5 N 45](https://sd.iso.org/documents/ui/#!/browse/iso/iso-iec-jtc-1/iso-iec-jtc-1-sc-29/iso-iec-jtc-1-sc-29-wg-5/library/2/List%20of%20AHGs%20established%20at%20the%202nd%20WG%205%20meeting)) in order to make it easy to reference.

# Output documents

The following documents were agreed to be produced or endorsed as outputs of the meeting. Names recorded below indicate the editors responsible for the document production. Where applicable, dates of planned finalization and corresponding parent-body document numbers are also noted.

It was reminded that in cases where the JVET document is also made available as a WG 5 output document, a separate version under the WG 5 document header should be generated. This version should be sent to GJS and JRO for upload.

For outgoing liaison letters, see section 7.7. The list of JVET ad hoc groups was also issued as a WG 5 output document [WG 5 N 45](https://sd.iso.org/documents/ui/#!/browse/iso/iso-iec-jtc-1/iso-iec-jtc-1-sc-29/iso-iec-jtc-1-sc-29-wg-5/library/2/List%20of%20AHGs%20established%20at%20the%202nd%20WG%205%20meeting) as noted in section 9.

[JVET-U1000](https://jvet-experts.org/doc_end_user/current_document.php?id=10673) Meeting Report of the 21st JVET Meeting [G. J. Sullivan, J.-R. Ohm] [WG 5 N 30] (2021-02-12)

Initial versions of the meeting notes (d0 … d8) were made available on a daily basis during the meeting.

Remains valid – not updated: [JCTVC-H1001](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=5095) HEVC software guidelines [K. Sühring, D. Flynn, F. Bossen (software coordinators)]

Remains valid – not updated: [JCTVC-AN1002](http://phenix.int-evry.fr/jct/doc_end_user/current_document.php?id=11000) High Efficiency Video Coding (HEVC) Test Model 16 (HM 16) Encoder Description Update 14 [C. Rosewarne (primary editor), K. Sharman, R. Sjöberg, G. J. Sullivan (co-editors)] [WG 11 N 19473]

Remains valid – not updated: [JVET-T1003](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=10535) Revised coding-independent code points for video signal type identification (Draft 2) [G. J. Sullivan, T. Suzuki, A. Tourapis] [WG 5 DIS N 12)]

[JVET-U1004](https://jvet-experts.org/doc_end_user/current_document.php?id=10674) Errata report items for VVC, HEVC, AVC, Video CICP, and CP usage TR [C. Rosewarne, G. J. Sullivan, Y. Syed, Y.-K. Wang] (2021-03-31, near next meeting)

Remains valid – not updated: [JVET-T1005](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=10537) Shutter interval information SEI message for HEVC (Draft 3) [S. McCarthy, G. J. Sullivan, Y.-K. Wang] [WG 5 FDAM N 8]

This is planned be Consented by ITU-T SG 16 in April 2021.

Remains valid – not updated: [JVET-T1006](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=10538) Annotated regions and shutter interval information SEI messages for AVC (Draft 2) [J. Boyce, S. McCarthy, Y.-K. Wang] [WG 5 WD N 16]

Remains valid – not updated: [JCTVC-V1007](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=10312) SHVC Test Model 11 (SHM 11) Introduction and Encoder Description [G. Barroux, J. Boyce, J. Chen, M. M. Hannuksela, Y. Ye] [WG 11 N 15778]

Remains valid – not updated: [JVET-T1008](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=10539) Usage of video signal type code points (Draft 2 for version 3) [W. Husak, G. J. Sullivan, Y. Syed, A. Tourapis] [WG 5 TR N 14]

This is planned be Consented by ITU-T SG 16 in April 2021.

Remains valid – not updated: [JCTVC-X1009](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=10572) Common Test Conditions for SHVC [V. Seregin, Y. He]

Remains valid – not updated [JCTVC-O1010](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=8511) Guidelines for Conformance Testing Bitstream Preparation [T. Suzuki, W. Wan]

No output: JVET-T1011 through JVET-T1013

Remains valid – not updated [JCTVC-V1014](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=10316) Screen Content Coding Test Model 7 Encoder Description (SCM 7) [R. Joshi, J. Xu, R. Cohen, S. Liu, Y. Ye] [WG 11 N 16049]

Remains valid for HM – not updated: [JCTVC-Z1015](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=10689) Common Test Conditions for Screen Content Coding [H. Yu, R. Cohen, K. Rapaka, J. Xu]

No output: JVET-T1016 through JVET-T1019

Remains valid for HM – not updated: [JCTVC-Z1020](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=10692) Common Test Conditions for HDR/WCG Video Coding Experiments [E. François, J. Sole, J. Ström, P. Yin]

[JVET-U1100](https://jvet-experts.org/doc_end_user/current_document.php?id=10675) Common Test Conditions for HM Video Coding Experiments [K. Sühring, K. Sharman] (2021-02-01)

This was needed to align the intra period; MCTF is also to be enabled in the CTC config files.

Reserved for future use (new edition): [JVET-T2001](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=10540) Versatile Video Coding Editorial Refinements on Draft 10 [B. Bross, J. Chen, S. Liu, Y.-K. Wang] (2020-10-30)

[JVET-U2002](https://jvet-experts.org/doc_end_user/current_document.php?id=10676) Algorithm description for Versatile Video Coding and Test Model 12 (VTM 12) [J. Chen, Y. Ye, S. Kim] [WG 5 N 32] (2021-03-15, near next meeting)

Further editorial improvements.

Remains valid – not updated: [JVET-N1003](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=6638) Guidelines for VVC reference software development [K. Sühring]

Remains valid – not updated: [JVET-T2004](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=10542) Algorithm descriptions of projection format conversion and video quality metrics in 360Lib (Version 12) [Y. Ye, J. Boyce]

It was noted that this includes some “stale” formats are no longer subject of active investigation and had been moved to the last part. It was agreed to consider whether they should be removed when a new version is produced in the future.

[JVET-U2005](https://jvet-experts.org/doc_end_user/current_document.php?id=10677) New level and additional SEI messages for VVC (Draft 2) [F. Bossen, Y.-K. Wang] [WG 5 WD N 33] (2021-03-01)

New payload type numbers are to be added.

[JVET-U2006](https://jvet-experts.org/doc_end_user/current_document.php?id=10678) Additional SEI messages for VSEI (Draft 2) [J. Boyce, Y.-K. Wang] [WG 5 WD N 31] (2021-03-01)

Note: This includes the annotated regions SEI message. It was noted that if we add the shutter interval SEI message to VSEI, we could reference that in the AVC amendment planned as per above (see JVET-T1006) – action on this was expected to be taken in the 22nd meeting when those standard parts are planned to progress to CDAM.

For newly adopted SEI messages at the current meeting, see section 6.1)

Reserved for future use (new edition): [JVET-S2007](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=9679) Versatile supplemental enhancement information messages for coded video bitstreams (Draft 5) [J. Boyce, V. Drugeon, G. J. Sullivan, Y.-K. Wang] [WG 11 N 19472]

[JVET-U2008](https://jvet-experts.org/doc_end_user/current_document.php?id=10679) Conformance testing for versatile video coding (Draft 6) [J. Boyce, E. Alshina, F. Bossen, K. Kawamura, I. Moccagatta, W. Wan] [WG 5 DIS N 37] (2021-03-31)

A corresponding DoCR WG5 N 36 was also reviewed.

[JVET-U2009](https://jvet-experts.org/doc_end_user/current_document.php?id=10680) Reference software for versatile video coding (Draft 2) [F. Bossen, K. Sühring, X. Li] [WG 5 DIS N 39] (2021-03-31)

A corresponding DoCR WG 5 N 38 was also reviewed.

Remains valid – not updated: [JVET-T2010](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=10545) VTM common test conditions and software reference configurations for SDR video [F. Bossen, J. Boyce, X. Li, V. Seregin, K. Sühring]

Remains valid – not updated: [JVET-T2011](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=10533) VTM common test conditions and evaluation procedures for HDR/WCG video [A. Segall, E. François, W. Husak, S. Iwamura, D. Rusanovskyy]

[JVET-U2012](https://jvet-experts.org/doc_end_user/current_document.php?id=10681) JVET common test conditions and evaluation procedures for 360° video [Y. He, J. Boyce, K. Choi, J.-L. Lin] (2021-03-31)

This was agreed to be aligned with other CTC documents.

[Ed. (GJS): Does this need a change to reflect padding for HM CMP?]

[Ed. (GJS): Comment from Minhua, should virtual boundary be used for VVC in this? Should that be in the verification testing?]

Remains valid – not updated: [JVET-T2013](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=10546) VTM common test conditions and software reference configurations for non-4:2:0 colour formats [Y.-H. Chao, Y.-C. Sun, J. Xu, X. Xu]

Remains valid – not updated: [JVET-Q2014](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=9683) JVET common test conditions and software reference configurations for lossless, near lossless, and mixed lossy/lossless coding [T.-C. Ma, A. Nalci, T. Nguyen]

Remains valid – not updated: [JVET-Q2015](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=9684) JVET functionality confirmation test conditions for reference picture resampling [J. Luo, V. Seregin]

[JVET-U2016](https://jvet-experts.org/doc_end_user/current_document.php?id=10669) Common Test Conditions and evaluation procedures for neural network-based video coding technology [S. Liu, A. Segall, E. Alshina, R.-L. Liao] (2021-02-05)

[JVET-U2017](https://jvet-experts.org/doc_end_user/current_document.php?id=10682) Common Test Conditions and evaluation procedures for enhanced compression tool testing [M. Karczewicz and Y. Ye] (2021-01-29)

[JVET-U2018](https://jvet-experts.org/doc_end_user/current_document.php?id=10683) Common test conditions for high bit depth and high bit rate video coding [A. Browne, T. Ikai, D. Rusanovskyy, M. Sarwer, X. Xiu] (2021-01-29)

Remains valid – not updated: [JVET-T2020](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=10550) VVC verification test report for UHD SDR video content [V. Baroncini, M. Wien] [WG 5 N 21]

[JVET-U2021](https://jvet-experts.org/doc_end_user/current_document.php?id=10684) VVC verification test plan (Draft 5) [M. Wien, V. Baroncini, A. Segall, Y. Ye] [WG 5 N 34] (2021-03-01)

Changes: Update of QP selection for SDR HD & 360, final definition on gaming and conversational sequences, and timeline for testing SDR HD & 360 and dry run for HDR.

[JVET-U2022](https://jvet-experts.org/doc_end_user/current_document.php?id=10670) Core Experiment on Entropy Coding for High Bit Depth and High Bit Rate Coding [A. Browne, T. Hashimoto, H.-J. Jhu, D. Rusanovskyy] [WG 5 N 35] (2021-02-19)

Plans for this experiment are documented in detail in JVET-U0139. An initial draft was reviewed and approved.

[JVET-U2023](https://jvet-experts.org/doc_end_user/current_document.php?id=10672) Exploration Experiment on Neural Network-based Video Coding [E. Alshina, S. Liu, W. Chen, Y. Li, R.-L. Liao, Z. Ma, H. Wang] [WG 5 N 40] (2021-01-29)

Plans for this experiment are documented in detail in JVET-U0141. An initial draft was reviewed and approved. A telco for further discussion was planned for 01-22.

[JVET-U2024](https://jvet-experts.org/doc_end_user/current_document.php?id=10685) Exploration Experiment on Enhanced Compression beyond VVC capability [ V. Seregin, J. Chen, S. Esenlik, F. Le Léannec, L. Li, M. Winken, J. Ström, X. Xiu, K. Zhang] [WG 5 N 41] (2021-02-15)

Plans for this experiment are documented in detail in JVET-U0140. An initial draft was reviewed and approved. A telco was planned to be organized by AHG12 before finalization. Initial drafts of the experiment descriptions should be made available shortly after the meeting.

# Future meeting plans, expressions of thanks, and closing of the meeting

Future meeting plans were established according to the following guidelines:

* Meeting under ITU-T SG 16 auspices when it meets (ordinarily starting meetings on the Wednesday of the first week and closing it on the Wednesday of the second week of the SG 16 meeting – a total of 8 meeting days), and
* Otherwise meeting under ISO/IEC JTC 1/SC 29/WG 5 auspices when it meets (ordinarily starting meetings on the Friday prior to such meetings and closing it at lunchtime on the last day of the WG 5 meeting – a total of 7.5 meeting days).

In cases where an exceptionally high workload is expected for a meeting, an earlier starting date may be defined. In case of online meetings, no sessions should be held on weekend days. This may imply an earlier starting date as well.

Some specific future meeting plans (to be confirmed) were established as follows:

* Wed. 7 – Fri. 16 July 2021, 23rd meeting, online under ISO/IEC SC 29 auspices.
* Fri. 8 – Fri. 15 October 2021, 24th meeting under ISO/IEC SC 29 auspices in Antalya, TR.
* During January 2022, 25th meeting under ITU-T SG 16 auspices in Geneva, CH.
* Fri. 22 – Fri. 29 April 2022, 26th meeting under ISO/IEC SC 29 auspices in Miami, US.
* Fri. 15 – Fri. 22 July 2022, 27th meeting under ISO/IEC SC 29 auspices in Cologne, DE.
* During October 2022, 28th meeting under ITU-T SG 16 auspices in Geneva, CH.
* During January 2023, 29th meeting under ISO/IEC SC 29 auspices, location t.b.d.
* t.b.d.

The agreed document deadline for the 23rd JVET meeting was planned to be Wednesday 30 June 2021.

Vittorio Baroncini and Mathias Wien were thanked for preparing for the VVC verification test in the categories of HD SDR and 360° video by conducting dry runs with non-expert viewers despite the complications caused by the pandemic situation. It was pointed out that additional support in financing or providing resources for the upcoming series of verification tests would be more than welcome, considering the excellent opportunity for promoting the superiority of VVC over previous standards.

InterDigital was thanked for providing additional gaming test sequences to be used in the VVC verification test.

Tencent was thanked for providing video material for the purpose of neural network training. Mathias Wien was thanked for organizing and conducting expert viewing sessions related to the exploration experiment on neural network-based video coding.

The 22nd JVET meeting was closed at approximately XXXX hours UTC on Wednesday 28 April 2021.

# Annex A to JVET report: List of documents

# Annex B to JVET report: List of meeting participants

The participants of the twenty-first meeting of the JVET, according to an attendance sheet circulated during the meeting sessions (approximately 349 people in total), were as follows:

# Annex C to JVET report: Recommendations of the 3rd meeting of ISO/IEC JTC 1/SC 29/WG 5 MPEG Joint Video Coding Team(s) with ITU-T SG 16

**ISO/IEC JTC 1/SC 29/WG 5 N 29**