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Second edition

Space data and information transfer systems — Digital motion imagery

Données spatiales et systèmes de transfert d'information - Imagerie du mouvement numérique

PROOF/ÉPREUVE

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by the Consultative Committee for Space Data Systems (CCSDS) (as CCSDS 766.1-B-2, August 2016) and drafted in accordance with its editorial rules. It was assigned to Technical Committee ISO/TC 20, *Space vehicles,* Subcommittee SC 13, *Space data and information transfer systems* and adopted under the "fast-track procedure".

This second edition cancels and replaces the first edition (ISO 21077:2016), which has been technically revised.

The main changes compared to the previous edition are as follows:

— adds support for MPEG4 recording and JPEG2000 transmission.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

CONTENTS

1 INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this document is to provide a common reference and framework of standards for digital motion video and imagery, and to provide recommendations for utilization of international standards for sharing or distributing motion video and imagery between spacecraft elements and ground systems.

The scope of this document includes traditional real-time streaming video and television, including human and robotic spacecraft-to-spacecraft and spacecraft-to-ground systems, as well as video recorded and distributed later, either as a real-time stream or as a file transfer. In this context, real-time streaming includes all modes where video is sent from a spacecraft in a continuous stream and is intended for immediate use when received, regardless of the latency of the transmission path. Other specialized motion imagery applications, such as high-speed scientific motion imagery and multi-spectral motion imagery, are not addressed in this document. However, if a specialized imagery camera system has a requirement to interface to spacecraft systems in a video mode, it would be required to match these interfaces.

Ground-systems-to-ground-systems video distribution is obviously a key component of the entire video system. However, this is not the primary focus of this document. Currently, there are significant differences in the ways mission video products are exchanged between the various space agencies on the ground. This is the result of differences in network topologies between space agencies, and agreements for video sharing. Those differences preclude there being a standard methodology for delivering video imagery between agencies. Prior to the commencement of video transmission between space agencies, system design reviews and performance testing should be done between the ground systems in use to assure operability when video imagery comes from spacecraft.

1.2 APPLICABILITY

This document is a CCSDS Recommended Standard. It is intended for all missions that produce, consume, or transcode video imagery from low-bandwidth video such as web streaming through high-bandwidth video such as high-definition television imagery.

1.3 NOMENCLATURE

1.3.1 NORMATIVE TEXT

The following conventions apply for the normative specifications in this Recommended Standard:

a) the words ‘shall’ and ‘must’ imply a binding and verifiable specification;

b) the word ‘should’ implies an optional, but desirable, specification;

c) the word ‘may’ implies an optional specification;

d) the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

NOTE – These conventions do not imply constraints on diction in text that is clearly informative in nature.

1.3.2 INFORMATIVE TEXT

In the normative sections of this document, informative text is set off from the normative specifications either in notes or under one of the following subsection headings:

– Overview;

– Background;

– Rationale;

– Discussion.

1.4 REFERENCES

The following publications contain provisions which, through reference in this text, constitute provisions of this document. At the time of publication, the editions indicated were valid. All publications are subject to revision, and users of this document are encouraged to investigate the possibility of applying the most recent editions of the publications indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS publications.

[1] *Studio Encoding Parameters of Digital Television for Standard 4:3 and Wide Screen 16:9 Aspect Ratios*. ITU-R BT.601-7. Geneva: ITU, 2011.

[2] *Television—SDTV Digital Signal/Data—Serial Digital Interface*. SMPTE ST 259:2008. White Plains, New York: SMPTE, 2008.

[3] *Digital Interfaces for HDTV Studio Signals*. ITU-R BT.1120-8. Geneva: ITU, 2012.

[4] *1.5 Gb/s Signal/Data Serial Interface*. SMPTE ST 292-1:2012. White Plains, New York: SMPTE, 2012.

[5] *High-Definition Multimedia Interface Specification*. Version 1.4. Sunnyvale, California: HDMI Licensing, LLC, 2009.

[6] *Electrical Characteristics of Low Voltage Differential Signaling (LVDS) Interface Circuits*. Revision A. TIA/EIA-644-A. Arlington, Virginia: TIA, February 2001.

[7] *Serial Digital Interface-Based Transport Interface for Compressed Television Signals in Networked Television Production Based on Recommendation ITU-R BT.1120*. ITU-R BT.1577. Geneva: ITU, 2002.

[8] *Television—Serial Data Transport Interface (SDTI)*. SMPTE ST 305:2005. White Plains, New York: SMPTE, 2005.

[9] *Teletext Systems*. ITU-R BT.653-3. Geneva: ITU, 1998.

[10] *Television—Time and Control Code*. SMPTE ST 12-1:2008. White Plains, New York: SMPTE, 2008.

[11] *Television—Transmission of Time Code in the Ancillary Data Space*. SMPTE ST 12-2:2008. White Plains, New York: SMPTE, 2008.

[12] *Ancillary Data Packet and Space Formatting*. SMPTE ST 291:2011. White Plains, New York: SMPTE, 2011.

[13] *Vertical Ancillary Data Mapping of Caption Data and Other Related Data*. SMPTE ST 334-1:2007. White Plains, New York: SMPTE, 2007.

[14] *Metadata Element Dictionary Structure*. SMPTE ST 335:2012. White Plains, New York: SMPTE, 2012.

[15] *Metadata Dictionary Registry of Metadata Element Descriptions*. SMPTE RP 210.10:2007. White Plains, New York: SMPTE, 2007.

[16] *Ultra High Definition Television—Mapping into Single-link or Multi-link 10 Gb/s Serial Signal/Data Interface*. SMPTE ST 2036-3:2010. White Plains, New York: SMPTE, 2010.

[17] *1280×720, 16:9 Progressively-Captured Image Format for Production and International Programme Exchange in the 60 Hz Environment*. ITU-R BT.1543. Geneva: ITU, 2001.

[18] *1280 x 720 Progressive Image 4:2:2 and 4:4:4 Sample Structure—Analog and Digital Representation and Analog Interface*. SMPTE ST 296:2012. White Plains, New York: SMPTE, 2012.

[19] *Parameter Values for the HDTV Standards for Production and International Programme Exchange*. ITU-R BT.709-5. Geneva: ITU, 2002.

[20] *Television—1920 x 1080 Image Sample Structure, Digital Representation and Digital Timing Reference Sequences for Multiple Picture Rates*. SMPTE ST 274:2008. White Plains, New York: SMPTE, 2008.

[21] *Dual Link 1.5 Gb/s Digital Interface for 1920 x 1080 and 2048 x 1080 Picture Frames*. SMPTE ST 372:2011. White Plains, New York: SMPTE, 2011.

[22] *Television—3 Gb/s Signal/Data Serial Interface*. SMPTE ST 424:2006. White Plains, New York: SMPTE, 2006.

[23] *Ultra High Definition Television—Image Parameter Values for Program Production*. SMPTE ST 2036-1:2009. White Plains, New York: SMPTE, 2009.

[24] *Ultra High Definition Television—Audio Characteristics and Audio Channel Mapping for Program Production*. SMPTE ST 2036-2-2008. White Plains, New York: SMPTE, 2008.

[25] *2048 × 1080 and 4096 × 2160 Digital Cinematography Production Image Formats FS/709*. SMPTE ST 2048-1:2011. White Plains, New York: SMPTE, 2011.

[26] *2048 × 1080 Digital Cinematography Production Image FS/709 Formatting for Serial Digital Interface*. SMPTE ST 2048-2:2011. White Plains, New York: SMPTE, 2011.

[27] *Parameter Values for Ultra-High Definition Television Systems for Production and International Programme Exchange*. ITU-R BT.2020-1. Geneva: ITU, 2014.

[28] *Information Technology—Coding of Audio-Visual Objects—Part 10: Advanced Video Coding*. 8th ed. International Standard, ISO/IEC 14496-10:2014. Geneva: ISO, 2014.

[29] *Advanced Video Coding for Generic Audiovisual Services*. ITU-T H.264. Geneva: ITU, 2012.

[30] *Data Services in Digital Television Broadcasting*. ITU-R BT.1301-1. Geneva: ITU, 2011.

[31] *Interface for Digital Component Video Signals in 525-Line and 625-Line Television Systems Operating at the 4:2:2 Level of Recommendation ITU-R BT.601*. ITU-R BT.656-5. Geneva: ITU, 2007.

[32] *Information Technology—JPEG 2000 Image Coding System: Motion JPEG 2000*. 2nd ed. International Standard, ISO/IEC 15444-3:2007. Geneva: ISO, 2007.

[33] *Information Technology—Generic Coding of Moving Pictures and Associated Audio Information—Part 7: Advanced Audio Coding (AAC)*. 4th ed. International Standard, ISO/IEC 13818-7:2006. Geneva: ISO, 2006.

[34] *Digital Audio Interface—Part 3: Consumer Applications*. Edition 3.1 (2009-12-10). IEC 60958-3:2006+AMD1:2009 CSV. Geneva: IEC, 2009.

[35] *IP over CCSDS Space Links*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 702.1-B-1. Washington, D.C.: CCSDS, September 2012.

[36] J. Postel. *User Datagram Protocol*. STD 6. Reston, Virginia: ISOC, August 1980.

[37] *CCSDS File Delivery Protocol (CFDP)*. Issue 4. Recommendation for Space Data System Standards (Blue Book), CCSDS 727.0-B-4. Washington, D.C.: CCSDS, January 2007.

[38] *Transport of JPEG 2000 Broadcast Profile Video in MPEG-2 TS over IP*. VSF TR-01 2013-04-15. New Jersey: Video Services Forum, April 15, 2013.

2 OVERVIEW

In the early days of human spaceflight, motion imagery was accomplished with motion picture film cameras, set at varying frame rates depending on lighting conditions. Upon safe return the film was processed and eventually shared with the world via documentaries or television. Inevitably live video became operationally desirable for situational awareness and to satisfy the public's interest in high-profile events such as the Moon landings or the Apollo-Soyuz test project. Compromises were made with those first video systems to fit within the constraints of bandwidth, avionics, and transmission systems. Even in the modern era, video systems on spacecraft are a hybrid of analog and digital systems, typically made to work within the existing spacecraft's avionics, telemetry, and command/control systems.

With the advent of digital cameras, encoding algorithms, and modulation techniques, it is desirable to treat video as data and to utilize commercially available technologies to capture and transmit live and recorded motion imagery, possibly in High Definition (HD) or even better. Thus the Recommended Standard addresses:

– Video Interfaces and Characteristics

– Video Formats and Characteristics

  Video data has a number of characteristics which need specification such as frame rate, aspect ratio, bandwidth and compression standards, color sampling, the inclusion of audio, etc.

– Encapsulation and Transmission Protocols

  Video data needs to be encapsulated, transported, and distributed. Although the choice of mechanisms and protocols may not be specific to video data, certain aspects need addressing because of the high bandwidth typically required for video. Thus this part will address encapsulation schemes (e.g., IP), transport protocols, and use of CCSDS Encapsulation Packets.

– Interoperability of Standards

  Future Human Spaceflight endeavors are expected to be collaborations between many agencies, with complex interactions between spacecraft and non-Earth surface systems, with intermediate locations (EVA crew, habitats, etc.) requiring the ability to view video generated by another agency's systems. Therefore interoperability between these systems will be essential to mission success and in some cases crew safety. Such interoperability will only be achieved by use of common references and joint agreement on international standards, either commercial or CCSDS or a combination of the two.

This Recommended Standard does not cover video quality. The intention of this document is to provide a framework of standards to ensure interoperability, not to define a level of quality. What is acceptable video quality varies widely with the application and requirements of users. A science experiment, for example, may have video quality requirements beyond what is available, or practical, within a spacecraft avionics system. The

science team for that experiment might elect to record video on board at high quality and transfer that video as a digital file after the conclusion of the experiment run. They might elect to do that and have a real-time downlink of lesser quality as a confirmation the experiment is working properly. A requirement for real-time video to support a docking event might sacrifice spatial resolution to lower the latency of the real-time video feed. Within the parameters listed in this document and the capabilities of any given spacecraft, users and controllers can determine how equipment should be configured for the best match to requirements.

3 SPECIFICATION

3.1 OVERVIEW

There are many system configurations that can be implemented in spacecraft video systems. Choices of interface standards, resolutions, and frame rates are based on the application, user requirements, available equipment, and spacecraft capability. There are multiple ways for signals to flow from the image source through to the spacecraft avionics system and on to the ground (see figures 3-1 and 3-2). Application of this Recommended Standard limits the overall number of options by limiting the interfaces to those that are in most common use. It should be noted that, while scientific imaging systems are excluded from this Recommended Standard, should a scientific imaging system need to interface to the spacecraft video system, the same interfaces would apply to them. It would be the responsibility of the user to provide a matching interface from the user's imaging system.

3.2 GENERAL

Users shall select from the following interfaces and standards when designing and implementing new video systems for spacecraft.

3.3 INTERFACE STANDARDS

3.3.1 NON-COMPRESSED STANDARD DEFINITION TELEVISION SIGNALS

The interface for non-compressed Standard Definition (SD) television signals shall be Serial Digital Interface (SDI), conforming to

- ITU-R BT.601-7 (reference [1]);
- SMPTE ST 259:2008 (reference [2]).

3.3.2 NON-COMPRESSED HIGH DEFINITION TELEVISION SIGNALS

The interface used for non-compressed high definition television signals shall be one of the following:

- High Definition-Serial Digital Interface (HD-SDI), conforming to
  - ITU-R BT.1120-8 (reference [3]);
  - SMPTE ST 292-1:2012 (reference [4]);
- High Definition Multimedia Interface (HDMI) 1.4 or higher, as defined by the HDMI Founders and licensed by HDMI Licensing, LLC (reference [5]);
- Camera Link Low Voltage Differential Signaling (LVDS) Interface Standard, as defined by the Camera Link Participating Companies (reference [6]).

3.3.3 COMPRESSED DIGITAL TELEVISION SIGNALS

The interface used for compressed digital television signals shall be Digital Video Broadcasting-Asynchronous Interface (DVB-ASI), conforming to

- ITU-R BT.1577 (reference [7]);
- SMPTE ST 305:2005 (reference [8]).

NOTE – DVB-ASI would be used with compressed digital video while still in the serial digital domain. For interfacing to spacecraft systems, Internet Protocol (IP) (see 3.6) is the preferred interface.

3.3.4 TELEVISION TIME CODE AND METADATA

3.3.4.1 Television time code and metadata may be inserted in non-compressed video. If time codes and/or metadata are inserted into non-compressed video, one of the following standards shall be used:

- ITU-R BT.653-3 (reference [9]);
- SMPTE ST 12-1:2008 (reference [10]);
- SMPTE ST 12-2:2008 (reference [11]);
- SMPTE ST 291:2011 (reference [12]);
- SMPTE ST 292-1-2012 (reference [4]);
- SMPTE ST 334-1:2007 (reference [13]);
- SMPTE ST 335:2012 (reference [14]);
- SMPTE RP 210.10:2007 (reference [15]);
- SMPTE ST 2036-3:2012 (reference [16]).

NOTE – The standards listed above are primarily concerned with the serial digital standard-definition and high-definition interfaces listed in 3.3.1 and 3.3.2. Metadata inserted at a camera conforming to HDMI or Camera Link interfaces conform to the serial digital interfaces when those signals are converted.

3.3.4.2 Compressed video signals in 3.3.3, per the standards listed in 3.3.3, shall carry all television time code and metadata information inserted into a non-compressed video stream.

3.4 VIDEO FORMAT AND CHARACTERISTICS

3.4.1 VIDEO RESOLUTIONS

3.4.1.1 Overview

Traditionally, video resolution has been categorized as low resolution, standard definition, high definition, or high resolution. Low resolution is generally defined as less than 640 × 480, standard definition as 640 × 480 and 768 × 576, high definition as 1280 × 720 and 1920 × 1080, and high resolution as anything beyond 1920 × 1080 such as 4K and 8K resolutions. Low resolution was used for streamed Internet video. Standard definition was used for broadcast (pre-HD) and security camera systems. High definition was limited to high-end television broadcast. High resolution was practically non-existent unless it was film based. Now, however, the distinctions are less clear. Laptop computer cameras are now often high definition, with options to stream from 320 × 240 up to 1280 × 720. Standard definition is now in limited use for broadcast television, web streaming, and monitoring applications. High definition has become the norm for broadcast and cable television. High resolution or ultra-high-definition cameras are replacing 35mm motion picture film for imaging requirements beyond HD. Therefore it is more difficult to classify video in terms of resolutions than in terms of application. A given application can have a broad range of resolutions, depending upon the requirements of the user, available equipment, and bandwidth constraints. The specifications below reflect the diversity of choices available for video systems. Higher resolution applications (e.g., 'public affairs', critical operations) can be used to fulfill lower resolution applications (e.g., 'personal video conferencing').

3.4.1.2 Personal Video Conferencing

Personal video conferencing video resolution should be selected from the following range:

– 320 × 240 to 1280 × 720, progressive scan.

NOTE – Selection of resolution is dependent on immediate requirement and available bandwidth.

3.4.1.3 Medical Conferencing

Medical conferencing video resolution should be selected from the following range:

– 320 × 240 to 1280 × 720, bandwidth-dependent progressive or interlace scan:

  • standard definition legacy systems may be 525 or 576 interlace;

  • 640 × 480 and 768 × 576 systems shall conform to ITU-R BT.601-7 (reference [1]) or SMPTE ST 259:2008 (reference [2]).