The Consultative Committee for Space Data Systems

Draft Recommendation for
Space Data System Standards

DIGITAL MOTION IMAGERY

DRAFT RECOMMENDED STANDARD

CCSDS 766.1-P-2.1

PINK BOOK

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FOREWORD

This document identifies which television and video industry standards should be utilized for interoperability between spacecraft, spacecraft-to-ground, ground-to-spacecraft, and ground-to-ground applications. The international television and video industries have many standards and interfaces for acquiring, recording and distributing live and recorded video. That flexibility can lead to complexity when attempting to share or monitor video from acquisition to monitoring or recording locations. This document provides system designers a sub-set of the larger industry set of standards to choose from, depending on the application and purpose of the video system.

Through the process of normal evolution, it is expected that expansion, deletion, or modification of this document may occur. This Recommended Standard is therefore subject to CCSDS document management and change control procedures, which are defined in the *Organization and Processes for the Consultative Committee for Space Data Systems* (CCSDS A02.1-Y-4). Current versions of CCSDS documents are maintained at the CCSDS Web site:

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PREFACE

This document is a draft CCSDS Recommended Standard. Its 'Pink Book' status indicates that the CCSDS believes the document to be technically mature and has released it for formal review by appropriate technical organizations. As such, its technical contents are not stable, and several iterations of it may occur in response to comments received during the review process.

Implementers are cautioned **not** to fabricate any final equipment in accordance with this document's technical content.

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 766.1-B-1	Digital Motion Imagery, Recommended Standard, Issue 1	May 2015	Original issue, superseded
CCSDS 766.1-B-2	Digital Motion Imagery, Recommended Standard, Issue 2	August 2016	Current issue
CCSDS 766.1-P-2.1	Digital Motion Imagery, Draft Recommended Standard, Issue 2.1	August 2020	Current draft update: adds support for H.265

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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.

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

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[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.~~

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

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

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

[24] *2048 × 1080 and 4096 × 2160 Digital Cinematography Production Image Formats FS/709*. SMPTE ST 2048-1:2011. White Plains, New York: SMPTE, 2011.

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[42] *Professional Media over Managed IP Networks*. SMPTE ST 2110. White Plains, New York: SMPTE, 2017.

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[47] *Analogue Video Standard for Aircraft System Applications*. Revision 5. STANAG-3350. Brussels, Belgium: NSO, 2018.

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 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 AND HIGHER TELEVISION SIGNALS

3.3.2.1 Non-Compressed High Definition

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

a) ~~High Definition Serial Digital Interface (HD~~ SDI~~)~~, conforming to

1) Digital Interfaces for HDTV Studio Signals, ITU-R BT.1120-8 (reference [3]);

2) 1.5 Gb/s Signal/Data Serial Interface, SMPTE ST 292-1:2012 (reference [4]);

3) 3 Gb/s Signal/Data Serial Interface, SMPTE ST 424:2012 (reference [21]);

4) 6 Gb/s Signal/Data Serial Interface, SMPTE ST 2081 (reference [39]);

5) 12 Gb/s Signal/Data Serial Interface, SMPTE ST 2082 (reference [40]);

6) Fiber Optic versions of the 1.5, 3, 6, & 12 Gb/s serial digital interface, conforming to SMPTE ST 297-1:2015 (reference [43]);

NOTE – SMPTE ST424:2012, can be used in multiples of 4 to carry a single 12 Gb/s signal, typically a UHD 60 FPS signal. Some UHD equipment utilizing SDI interfaces only achieves 12 Gb/s using 4–3 Gb/s links (known as Quad 3G). It is recommended that a UHD video system utilizing 12 Gb/s be done primarily with single link 12 Gb/s. That may require converters to and from Quad 3G until the adoption of single stream 12 Gb/s is widespread.

b) 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]).~~

c) IP for high-speed video, SMPTE ST 2022-6:2012 (reference [41]);

d) IP for high-speed video, SMPTE ST 2110-10/20/21/30/31/40/50 (reference [42]).

NOTES

1 The choice between SMPTE 2022-6 and 2110-10 is a user choice determined by how the different parts of a video signal: for example, image audio, and metadata (essences, in industry jargon), need to be accessed. SMPTE 2022-6 does not allow separation or modification of any of the three essences. SMPTE 2110-10 splits the essences into discrete packets to allow easy access to any essence stream for modification or replacement. Typically, 2022 is used for transmission and 2110 for studio type applications. Signals can be transcoded as required between 2022-6 and 2110-10.

2 There are multiple Machine Vision Protocols that might be utilized, such as CameraLink (reference [6]), CameraLink HS (reference [45]), CoaXPress, (reference [38]), GigE Vision (reference [44]), or USB 3 Vision (reference [46]). These interface protocols are standard, but in most cases, the data formats are proprietary from each manufacturer and not interoperable. If Machine Vision protocols are utilized, the system developer will be required to interface with the video system of the spacecraft utilizing whichever protocol from 3.3.2 is selected.

3.3.2.2 Camera Synchronization

NOTE – Camera synchronization is done to assure all the cameras in a system are sampling the same row of pixels at the same time. If video synchronization is needed, the signals are different, depending upon the video format used.

3.3.2.2.1 The synchronization signal for SD cameras shall be as defined by STANAG 3350 (reference [47], Class B for ITU-R BT.601-7 (reference [1]), and Class C for SMPTE ST 259:2008 (reference [2]).

3.3.2.2.2 For HD, Ultra High Definition (UHD), and Full Ultra High Definition (FUHD), one of the following two standards shall be used:

a) Tri-Level Sync, as defined in ITU-R BT.1543 (reference [17]), SMPTE ST 296:2011 (reference [18]) and SMPTE ST 274:2008 (reference [20]).

b) Precision Time Protocol (PTP), derived from Network Time Protocol (NTP) as described in SMPTE ST 2110-10 (reference [42]).

NOTES

1 Synchronizing cameras is done to facilitate a clean switch between sources in non-compressed video systems. A clean switch causes less disruptions with video encoders and other devices downstream of the switch. This may not be an issue for a spacecraft video system. If so, then a synchronization signal/system is not required.

2 Tri-level sync is common for use with SDI-based video systems. PTP is common for IP-based video systems. There are also a number of video synchronization units that can derive timing references from NTP.

3 The distribution of synchronizing signals is different depending upon the format of the synchronizing signal and the camera interface. For Stanag 3350 and Tri-Level Sync signals, the sync signal generator generally has multiple outputs, or a distribution amplifier may be used, and a cable with the sync signal has to be supplied to each device in the system that requires synchronization. It is not good practice to use a 'loop-through' sync connection. If the device receiving the sync signal is removed for some reason and the sync signal not restored to the downstream devices, none of those devices will be synchronized.

4 PTP synchronization will be used primarily with video cameras and sources that connect via IP. The PTP signal can be derived by the video source from the IP connection.

3.3.3 COMPRESSED DIGITAL TELEVISION SIGNALS

The interface used for compressed digital television signals shall be either Internet Protocol (IP) or Digital Video Broadcasting-Asynchronous Interface (DVB-ASI~~), conforming to~~). IP is the preferred method.

NOTE – DVB-ASI would be used with compressed digital video while still in the serial digital domain. DVB-ASI is considered to be a legacy standard, with possible use in dedicated video systems utilizing serial protocols instead of IP. New video systems rely almost exclusively on IP for all data transmission.

DVB-ASI shall conform to:

a) ITU-R BT.1577 (reference [7]);

b) 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:

a) ITU-R BT.653-3 (reference [9]);

b) SMPTE ST 12-1:2008 (reference [10]);

c) SMPTE ST 12-2:2008 (reference [11]);

d) SMPTE ST 291:2011 (reference [12]);

e) SMPTE ST 292-1-2012 (reference [4]);

f) SMPTE ST 334-1:2007 (reference [13]);

g) SMPTE ST 335:2012 (reference [14]);

h) SMPTE RP 210.10:2007 (reference [15]);

i) 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~~UHD and ~~8K~~FUHD resolutions (3840x2160 and 7680x4320, respectively). 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~~1920 × 1080. 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, UHD and FUHD 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~~1920 x 1080, 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 1920 x 1080, 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]).

NOTE – Lower resolution personal video conferencing and medical conferencing applications are most likely to be performed using a personal computer or tablet-type device. All video encoding would be handled internally. Connection to the spacecraft avionics system would be through wired or wireless data connections independent of any video systems. Transmission to the ground would also be handled as part of standard data protocols and also independent of dedicated video transmission.

3.4.1.4 Situational Awareness

Situational awareness video resolution should be selected from the following range:

– 640 × 480 to ~~1280 × 720~~1920 x 1080, bandwidth dependent:

a) interlace scan for legacy SD systems shall conform to

1) ITU-R BT.601-7 (reference [1]); or

2) SMPTE ST 259:2008 (reference [2]);

b) progressive scan for HD systems shall conform to

1) ITU-R BT.1543 (reference [17]);~~ or~~

2) SMPTE ST 296:2011 (reference [18]); or

3) SMPTE ST 274:2008 (reference [20]).

NOTE – Situational awareness may be required in situations in which only low-bandwidth transmission is available, such as S-Band, which would likely limit resolution to as low as 320 × 240. In cases such as this, best effort is acceptable. The requirement to have visual confirmation of events may be higher than a specific resolution. This should be considered the exception and not the norm.

3.4.1.5 Public Affairs

3.4.1.5.1 Public affairs video resolution should be selected from the following range:

– 640 × 480 to 1920 x 1080, bandwidth dependent:

a) Interlace scan for legacy SD systems shall conform to

1) ITU-R BT601-7 (reference [1]); or

2) SMPTE ST 259:2008 (reference [2]);

b) Progressive scan for HD systems shall conform to

1) ITU-R BT.1543 1280 (reference [17]); ~~or~~

2) SMPTE ST 296:2011 (reference [18]); or

3) SMPTE ST 274:2008 (reference [20]).

3.4.1.5.2 Multiple resolutions may be used to accommodate mission requirements.

NOTE – There are situations in which HD formats are not required. It saves considerable bandwidth to use SD systems. Whether these are US or European standard resolutions and frame rates is not an issue. Regardless of the actual video format, the interface standards allow virtually all current equipment to route and encode the video. Once encoded and packetized, it is not an issue for spacecraft avionics as the video is compatible data packets. That part of the system is format agnostic. Regardless of the interface chosen for a particular spacecraft, routing and encoding utilize the same components.

3.4.1.6 High Resolution Digital Imaging

3.4.1.6.1 High resolution digital imaging video resolution should have a minimum resolution of 1920 × 1080, progressive scan:

a) 1080 HD systems shall conform to

1) ITU-R BT.709-5 (reference [19]); or

2) SMPTE ST 274:2008 (reference [20]);

b) Up to 30 FPS systems shall conform to

1) ITU-R BT.1120-8 (reference [3]); or

2) SMPTE ST 292-1:2012 (reference [4]);

c) Above 30 FPS shall conform to

1) ITU-R BT.1120-8 (reference [3]); or

~~• SMPTE ST 372:2011 (reference [21]); or~~

2) SMPTE ST 424:2006 (reference [21]).

3.4.1.6.2 Systems above 1920 × 1080, UHD, and FUHD shall conform to:

a) SMPTE ST 2036 Standards Suite, ST 2036 1–3:

1) ST 2036-1:2009 Image Parameter Values for Program Production—Ultra High Definition Television (reference [22]);

2) ST 2036-2:2008 Ultra High Definition Television—Audio Characteristics and Audio Channel Mapping for Program Production (reference [23]);

- ~~ST 2036-3:2010 Mapping into Single link or Multi link 10 Gb/s Ultra High Definition Television Serial Signal/Data Interface (reference [16]);~~

b) SMPTE ST 2048 Standards Suite ST 2048-1–2:

1) ST 2048-1:2011 2048 × 1080 and 4096 × 2160 Digital Cinematography Production Image Formats FS/709 (reference [24]);

2) ST 2048-2:2011 2048 × 1080 Cinematography Production Image FS/709 Formatting for Serial Digital Interface (reference [25]);

c) ~~ITU-R BT.2020-1 (06/2014)~~ITU-R BT.2020-2 (10/2015) Parameter Values for Ultra-High Definition Television Systems for Production and International Programme Exchange (reference [26]).

NOTE – 1920 × 1080 and above is to accommodate users with special requirements. Typically, these systems will have on-board recording and downlink video as file transfers. Any real-time requirement will include that the video system provide a compatible signal to spacecraft video systems.

3.4.1.7 Spacecraft to Spacecraft

Spacecraft-to-spacecraft video resolution should follow 3.4.1.2–3.4.1.6.

NOTE – Selection of spacecraft-to-spacecraft video resolution is dependent on mission requirements.

3.4.2 FRAME RATE

3.4.2.1 Video frame rates shall be selected from the following ranges for the following applications:

a) personal video conferencing: 10 – 60 Frames Per Second (FPS);

b) medical video: 10 – 60 FPS;

c) situational awareness: 25 – 60 FPS;

d) public affairs: 24, 25, or 60 FPS;

e) high resolution digital imaging: 24 – 120 FPS.

~~NOTE – These are considered optimum frame rates for these applications. However, bandwidth constraints may not allow even the lower frame rates to be utilized. In these cases, best effort should be made to accommodate the recommendations based on available bandwidth for imaging applications.~~

~~**3.4.2.2 Spacecraft-to-spacecraft frame rates should be selected from 3.4.2.1 a) e), above, depending on application.**~~

NOTES

1 These are considered optimum frame rates for these applications. However, bandwidth constraints may not allow even the lower frame rates to be utilized. In these cases, best effort should be made to accommodate the recommendations based on available bandwidth for imaging applications.

2 Spacecraft-to-spacecraft frame rates are dependent on mission requirements.

3 The listing of specific video applications above does not necessarily imply discrete equipment sets dedicated for each application. Most cameras, for example, can be used at multiple resolutions and frame rates allowing them to be used for multiple applications.

3.4.3 ASPECT RATIO

Aspect ratio of original material shall be maintained from origination through delivery to end user.

NOTE – By definition within industry standards, HDTV, UHD, and FUHD resolution video ~~has~~have an aspect ratio of 16:9.

3.4.4 VIDEO COMPRESSION

3.4.4.1 Overview

~~The two~~There are three compression standards listed below. Each have different applications. ~~MPEG-4~~H.264, Advanced Video Coding (AVC) (references [27] and [28]) Part 10 is primarily intended for real-time applications in which live, or nearly live, video needs to be monitored at a ground location during an event or experiment. ~~MPEG-4~~H.264 may also be used for recording applications in which the quality level is determined to be sufficient. ~~JPEG2000~~H.265 High Efficiency Video Coding (HEVC) (reference [37]) is a more advanced video codec now in widespread use. H.265 can be used to give higher video quality than H.264 at the same data rates, or equivalent video quality at lower data rates, up to 50 persent less than to H.264. JPEG2000 (reference [31]) is intended for requirements for higher quality or when each individual frame needs to be maintained intact. The data rate required for JPEG2000 would normally preclude JPEG2000 from being used for live transmission. The normal operating mode for JPEG2000 is to record the video and downlink it later as a data file. However, if the bandwidth is available, live transmission of JPEG2000 offers very low latency and may be preferable for operations in which low video latency is preferable.

3.4.4.2 Compression Standards

The following video compression standards shall be used as indicated:

a) ~~MPEG-4~~H.264 Part 10 (references [27] and [28]) for real-time transmission and recording:

1) 0.5 to 25 Mb/s—application and user requirement-driven data rates;

2) 8-bit sampling;

3) constant bit rate or variable bit rate acceptable—defined by interface to spacecraft system;

4) Group of Pictures (GOP) from 1 – 30—defined by user requirement;

5) Constrained Baseline Profile for conferencing type applications (Personal and Medical Video Conferencing);

6) Main Profile for SD applications;

7) High Profile for HD applications;

8) metadata as required by user:

i) shall conform to

– ITU-R BT.1301-1 (reference [29]); or

– SMPTE ST 291:2011 (reference [12]); or

– ITU-R BT.656-4 (reference [30]) for ancillary data; or

– SMPTE ST 335:2001 (reference [14]); or

– SMPTE RP 210.10:2007 (reference [15]);

ii) shall be read and passed by encode/decode systems;

iii) may include system status and control feedback data;

iv) may include embedded television time code conforming to

– ITU-R BT.1301-1 (reference [29]); or

– SMPTE ST 12-1:2008 (reference [10]); or

– SMPTE ST 12-2:2008 (reference [11]).

NOTE – Per specification and established practice, embedded television time code is used as the time reference for the MPEG transport stream time code value.

b) H.265 (reference [37]) for real-time transmission and recording:

   1) 0.5 to 25 Mb/s—application and user requirement-driven data rates;

   2) 8-bit or 10-bit sampling (Main 10, Main 4:2:2 10, and Main 4:4:4 Profiles);

   3) constant bit rate or variable bit rate acceptable—defined by interface to spacecraft system;

   4) Group of Pictures (GOP) —defined by user requirement;

   5) Up to H.265 Level 3.1 for conferencing type applications (Personal And Medical Video Conferencing);

   6) Level 3.1 for SD applications;

   7) Levels 4, 4.1, 5, and 5.1 for HD and UHD applications;

   8) Levels 6, 6.1, and 6.2 for UHD and FUHD applications;

   9) metadata as required by user

      i) shall conform to one of the following:

         – ITU-R BT.1301-1 (reference [29]),

         – SMPTE ST 291:2011 (reference [12]),

         – ITU-R BT.656-4 (reference [30]) for ancillary data,

         – SMPTE ST 335:2001 (reference [14]), or

         – SMPTE RP 210.10:2007 (reference [15]);

      ii) shall be read and passed by encode/decode systems;

      iii) may include system status and control feedback data;

      iv) may include embedded television time code conforming to one of the following:

         – ITU-R BT.1301-1 (reference [29]),

         – SMPTE ST 12-1:2008 (reference [10]), or

         – SMPTE ST 12-2:2008 (reference [11]).

      NOTE – Per specification and established practice, embedded television time code is used as the time reference for the MPEG transport stream time code value.

c) JPEG2000 (reference [31]) for analysis and high-quality recording requirements for video stored and transferred as files and real-time transmission:

1) 45 to 140+ Mb/s—application and user requirement-driven;
2) 10-bit (or greater) sampling;
3) metadata as required by user~~:~~
   i) shall conform to one of the following:
      – SMPTE ST 291:2011 (reference [12]),~~; or~~
      – ITU-R BT.653-3 (reference [9]) for ancillary data,~~; or~~
      – SMPTE ST 335:2001 (reference [14]),~~;~~ or
      – SMPTE RP 210.10:2007 (reference [15]);
   ii) shall be read and passed by encode/decode systems;
   iii) may include system status and control feedback data;
   iv) may include embedded television time code.

3.4.5 COLOR SAMPLING

Color sampling should be as follows:

a) 4:2:0 for real-time requirements;
b) 4:2:2 for high resolution digital imaging:
   1) science and engineering;
   2) production and digital cinema applications;
c) 4:4:4 for special applications.

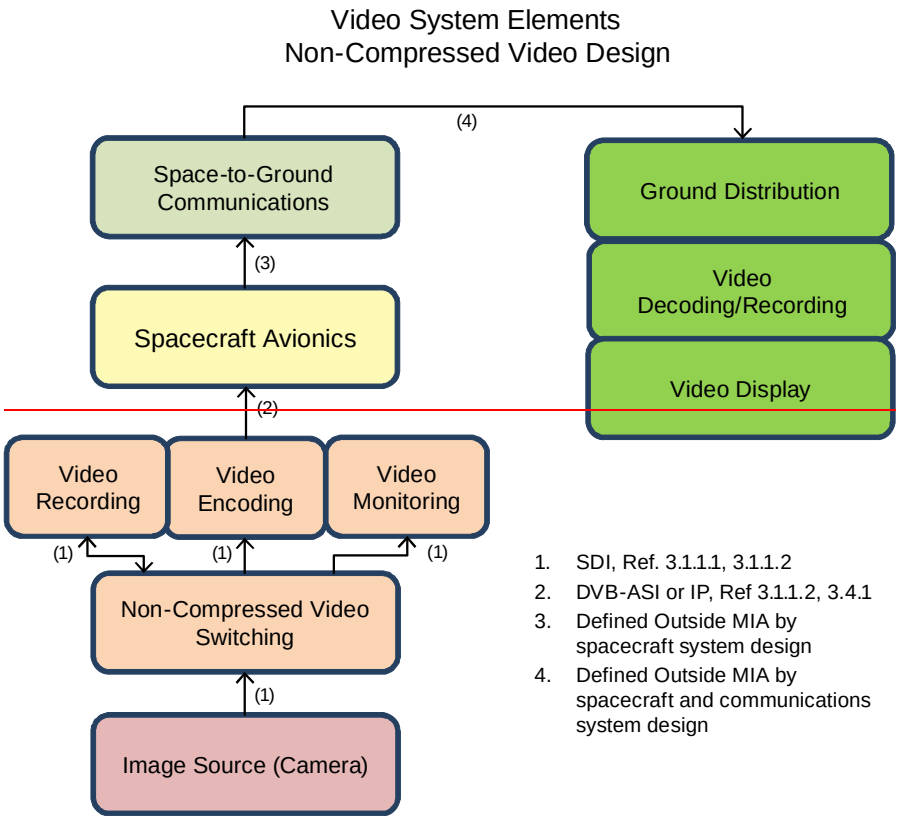
3.4.6 DYNAMIC RANGE

In addition to handling Standard Dynamic Range (SDR) imagery, all systems shall be capable of passing imagery created in High Dynamic Range (HDR), with associated decoding metadata.

Note: HDR is primarily a camera function. Most non-compressed transmission systems can pass HDR without modification. Encoding systems for HDR typically have additional software to handle compressing an HDR image stream. However, on-board displays, unless they are HDR equipped, will show an image of apparent compressed dynamic range, appearing as if there is very low contrast in the image. HDR for real-time work will need an HDR-capable monitor.

3.4.7 DISCUSSION—VIDEO SYSTEM BLOCK DIAGRAMS

The diagrams below illustrate typical video system connectivity and what interfaces are associated with each stage in the system for a typical human spaceflight video system. These diagrams assume separate components for each of these functions. While the same functions occur with the use of a laptop- or tablet-based video system used for medical or personal video conferencing, they are internal with an IP connection to the spacecraft avionics system for transmission.



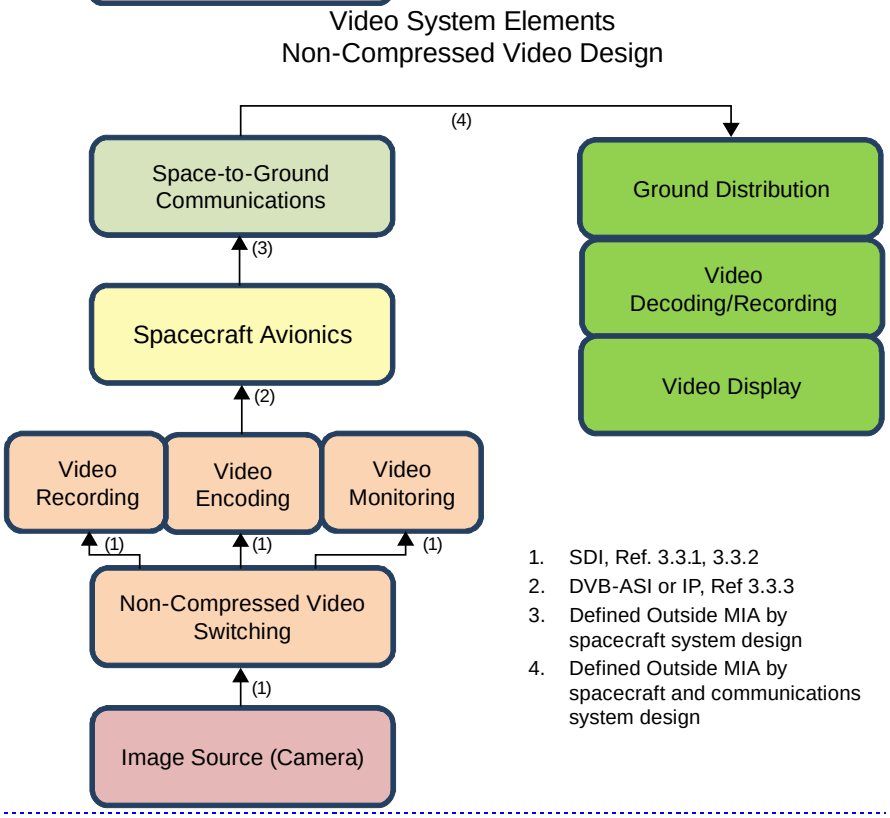


Figure 3-1: Video System Elements—Non-Compressed Video Design

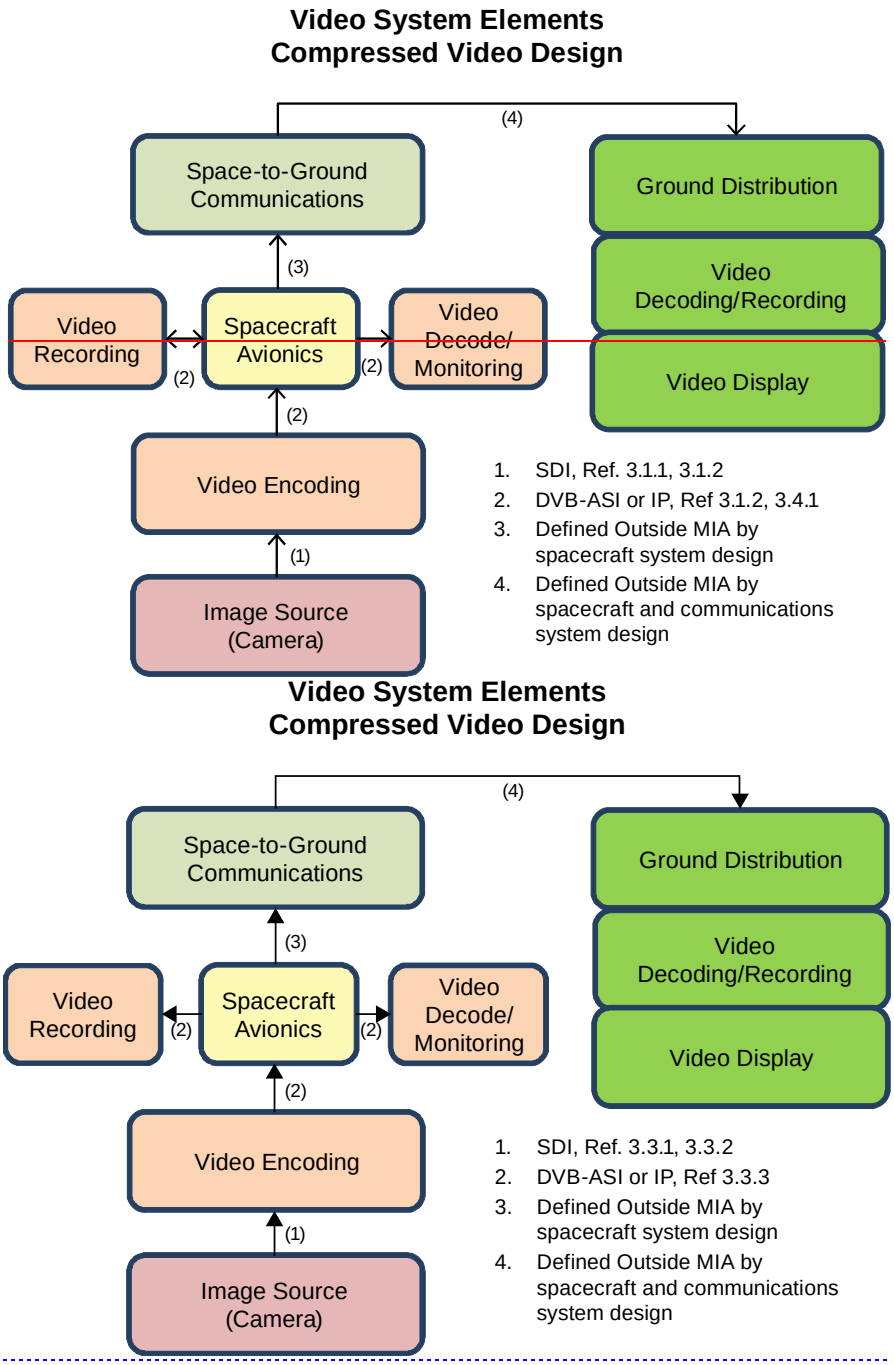


Figure 3-2: Video System Elements—Compressed Video Design

3.5 AUDIO

3.5.1 AUDIO AS PART OF VIDEO STREAM

Audio as part of a video stream should conform to the following standards:

– Advanced Audio Cod~~ec~~ing (AAC) (reference [32]) for compressed audio;

– AES/EBU-3 (reference [33]) for uncompressed audio.

NOTE – Generally, audio as part of a compressed bitstream for live applications (~~MPEG-4~~H.264) will be compressed. There are several different audio codecs available. AAC was chosen as the highest quality, most widely used audio codec for this application. Non-compressed AES/EBU-3 is another possibility supported by a number of audio/video codecs. It is less common, but might be a requirement based on user needs.

3.5.2 DISCUSSION—AUDIO SEPARATE FROM VIDEO STREAM

For those applications in which audio is distributed separately from video, audio/video synchronization (lip sync) is handled on the ground. Time stamps in the audio stream, corresponding to time stamps in the video stream, are recommended to aid in synchronization.[1]

3.6 REAL-TIME NETWORKED VIDEO DISTRIBUTION

3.6.1 GENERAL

If video data is distributed via IP and/or bundle protocol networks, the following recommendations must be followed.

3.6.1 ~~INTERNET PROTOCOL TRANSPORT STREAM~~

3.6.2 REAL-TIME VIDEO ENCAPSULATION AND TRANSMISSION[2]

3.6.2.1 RTP data conveyed over IP-based networks must follow the IETF RTP standards.

3.6.2.2 Secure RTP may be used; if this is the case, the missions Management Information Base must be extended with the necessary primitives to control key management, etc.

3.6.2.3 RTP data conveyed over Bundle Protocol networks must be compliant with CCSDS 766.3-R-1 Specification for RTP as Transport for Audio and Video over DTN

3.6.2.4 RTP-based decoders must have sufficient buffering to manage out-of-order arrival.

[1] ~~It is anticipated the Voice Working Group standard will address this issue with standard practices to be employed for audio/video synchronization.~~

[2] ~~Delay Tolerant Networking is being standardized as an internetworking layer for CCSDS missions. Future missions may want to consider transmitting real-time video encoded with MPEG-4 or file-based video encoded with JPEG2000via DTN Bundle Protocol (reference [D9]) bundles. Annex C presents a narrative of the classes of real-time video transmission still under development by the DTN working group.~~

3.6.3 INTERNET PROTOCOL TRANSPORT STREAM

~~**3.6.1.1** MPEG-4-encoded video shall be formatted as Transport Stream (TS) with Packet Identification (PID) for transport in IP datagrams.~~

3.6.3.1 If MPEG-2 Transport Streams are used, video shall be encapsulated with unique Packet Identifiers (PIDS) for transport in MPEG-2 Transport Streams.

3.6.3.2 If multiple programs are encapsulated in a single Multi-Program Transport Stream (MPTS), each program shall have a unique channel number.

NOTE – There is no requirement that channel numbers are consistent; the choice of channel numbers is implementation-specific.

3.6.3.3 JPEG2000 for transmission shall adhere to Video Services Forum (VSF) TR-01 Transport of JPEG2000 Broadcast Profile video in ~~MPEG-2 TS over IP~~MPEG TS (reference [36]).

NOTE – TR-01 maps JPEG2000 encoding to an MPEG~~2~~ Transport Stream. This makes JPEG2000 compatible with ~~the same IP connections used for MPEG-4 compression~~MPEG-TS interfaces as used for H.264 and H.265 compression.

3.6.3.4 IP datagrams shall be encapsulated for transmission over the CCSDS space link as specified in reference [34].

3.6.3.5 It is not recommended to transport Transport Stream datagrams over Bundle Protocol networks.

~~**3.6.2 ELEMENTARY STREAM**~~

~~**3.6.2.1** Real-time video and audio elementary streams may be transmitted via User Datagram Protocol (UDP) (reference [36]).~~

~~**3.6.2.2** IP datagrams containing User Datagrams with real-time video and audio elementary streams shall be encapsulated for transmission over the CCSDS space link as specified in reference [35].~~

3.6.4 JITTER AND BIT ERROR RATES

~~Real~~For Transport-Stream based networks, the real-time video delivery jitter and Bit Error Rate (BER) shall be limited as follows:

- jitter (packet delay variation) not to exceed 10 ms (assumes 300 ms decoder buffer);
- BER not to exceed 1×10^{-6}.

However, it cannot be assumed that Bundle Protocol networks will possess similar quantities. Therefore buffering should be used to ensure a smooth input from the space-based network into decoders.

~~NOTES~~

~~1 Use of elementary streams is possible for lower bandwidth video applications, such as personal video conferencing. However, commercial hardware decoders do not recognize elementary streams, so transport stream should be used exclusively for video systems interfacing directly to spacecraft avionics. Also, audio cannot be embedded with video when using elementary stream for compressed video transport. Audio and video in an elementary stream are not synchronized for transmission.~~

~~2 Real Time~~

NOTE – Real-time Transport Protocol (RTP) and Hypertext Transfer Protocol (HTTP) are commonly used for video transmission. HTTP is common for computer-based applications, such as family video conferencing. In this application, it is not only acceptable, but may be the only methodology available on that type of platform. However, for higher bandwidth video transmission in which transport streams are utilized, HTTP is not efficient. ~~RTP is acceptable, but UDP offers better performance over space based networks.~~ The use of Transmission Control Protocol (TCP) for video over space-based networks is also not recommended.

3.7 RECORDED VIDEO AND AUDIO

3.7.1 ACQUISITION AND STORAGE OF VIDEO DATA

3.7.1.1 Recordings shall be file based.

NOTE – This is required to allow for transfer of recorded video data via established file transfer methodologies. This standard does not dictate how an application might create a video file, and specific file formats will vary based on systems being used.

3.7.1.2 Encoding shall be ~~MPEG-4~~H.264, H.265, or JPEG 2000, dependent upon the application.

3.7.1.3 Specific file formats will change based on systems being used. Data rates to be used for recording shall be determined by user requirements.

3.7.2 FILE TRANSFER OF RECORDED VIDEO

3.7.2.1 Recorded File Transmission

Recorded video shall be transmitted as files via the CCSDS File Delivery Protocol (CFDP) Class 1 or Class 2 (reference [35]).

~~3.7.2.2 Discussion—CFDP~~

~~CFDP supports four classes that are distinct from the three video classes:~~

~~– Class 1—Unreliable CFDP Transfer;~~

~~– Class 2—Reliable CFDP Transfer;~~

~~– Class 3—Unreliable Transfer Via One Or More Waypoints In Series;~~

~~– Class 4—Reliable Transfer Via One Or More Waypoints In Series.~~

~~When using CFDP to transfer video, one of the following mechanisms is used:~~

~~– Class 1—Unreliable CFDP transfer over a reliable UT layer;~~

~~– Class 2—Reliable CFDP.~~

3.7.2.2 CFDP

3.7.2.2.1 Discussion

CFDP provides the following two classes for file transmission:

- Class 1—Unreliable CFDP transfer over a reliable UT layer;
- Class 2—Reliable CFDP.

3.7.2.2.2 Requirements

Class-1 CFDP should be used for the transmission of video data files. For reliable transmission, class-1 CFDP should be used over a reliable UT layer, with closure requested.

3.8 DISTRIBUTION OF VIDEO DATA

~~3.8.1 REAL-TIME DISTRIBUTION~~

~~Real-time video shall be distributed as MPEG-4 program streams with resolution and frame rate dependent on available bandwidth and user requirements.~~

~~3.8.2 DELAYED DISTRIBUTION~~

~~Video files should be distributed on the ground via established file distribution methodologies.~~

~~NOTE For file transfer of video, this will likely be recorded JPEG 2000, as MPEG-4 will be used for real-time distribution.~~

~~**3.8.3 END USER CAPABILITIES**~~

~~End user capabilities should include:~~

- ~~decoding capability for real-time video distribution;~~
- ~~format conversion as required to meet local user requirements for display (i.e., conversion from 525i to 625i and vice versa, 50/60 Hz frame rate conversion, up-conversion or down-conversion);~~
- ~~ability to record data stream from real-time applications;~~
- ~~ability to participate in and store video files from transfer operations;~~
- ~~ability to decode and play the stored files.~~

3.8.1 DISCUSSION

Generally, the requirements stated in 3.6 may be reused for ground-segment data distribution. However, some requirements might need to be expanded in order to satisfy the unique requirements of various user classes and capabilities.

3.8.2 REQUIREMENTS

3.8.2.1 Ground segments shall provide a decoding capability for real-time video distribution.

NOTE – Format conversion may be required to meet local user requirements for display (i.e., conversion from 525i to 625i and vice versa, 50/60 Hz frame rate conversion, up-conversion, or down-conversion);

3.8.2.2 Ground segments shall have the ability to record data streams from real-time applications.

3.8.2.3 Ground segments shall have the ability to use and store video files from transfer operations.

3.8.2.4 Ground segments shall have the ability to decode and play the stored files.

ANNEX A

PROTOCOL IMPLEMENTATION CONFORMANCE STATEMENT (PICS) PROFORMA

(NORMATIVE)

A1 INSTRUCTIONS FOR COMPLETING THE PICS PROFORMA

A1.1 OVERVIEW

A1.1.1 Columns

A1.1.1.1 General

In order to reduce the size of tables in the PICS proforma, notations have been introduced that have allowed the use of a multi-column layout, where the columns are headed 'Status' and 'Support'. The definition of each of these follows.

A1.1.1.2 Status Column

The 'Status' column indicates the level of support required for conformance to the standard. The values are as follows:

M Mandatory support is required.

O Optional support is permitted for conformance to the standard. If implemented, it must conform to the specifications and restrictions contained in the standard. These restrictions may affect the optionality of other items.

O.*n* The item is optional, but support of at least one of the options labeled with the same number *n* is mandatory. The definitions for the qualification statements used in this annex are written under the tables in which they first appear.

C.*n* The item is conditional (where *n* is the number which identifies the applicable condition). The definitions for the conditional statements used in this annex are written under the tables in which they first appear.

n/a The item is not applicable.

A1.1.1.3 Support Column

The ‘Support’ column is completed by the supplier or implementer to indicate the level of implementation of each feature. The proforma has been designed such that the only entries required in the ‘Support’ column are:

Y Yes, the feature has been implemented.

N No, the feature has not been implemented.

– The item is not applicable.

A1.1.2 Item Reference Numbers

Within the PICS proforma, each line that requires implementation detail to be entered is numbered at the left hand edge of the line. This numbering is included as a means of uniquely identifying all possible implementation details within the PICS proforma. The need for such unique referencing has been identified by the testing bodies.

The means of referencing individual responses is to specify the following sequence:

a) a reference to the smallest subclause enclosing the relevant item;

b) a solidus character, ‘/’;

c) the reference number of the row in which the response appears;

d) if, and only if, more than one response occurs in the row identified by the reference number, then each possible entry is implicitly labeled a, b, c, etc., from left to right, and this letter is appended to the sequence.

A2 COMPLETION OF THE PICS

The implementer shall complete all entries in the column marked ‘Support’. In certain clauses of the PICS proforma, further guidance for completion may be necessary. Such guidance shall supplement the guidance given in this clause and shall have a scope restricted to the clause in which it appears. In addition, other specifically identified information shall be provided by the implementer where requested. No changes shall be made to the proforma except the completion as required. Recognizing that the level of detail required may, in some instances, exceed the space available for responses, a number of responses specifically allow for the addition of appendices to the PICS.

A3 REFERENCED BASE STANDARDS

Motion Imag~~in~~ery and Applications (MIA, this document) is the only base standard referenced in the PRL. In the tables below, numbers in the Reference column refer to applicable subsections within this document.

A4 GENERAL INFORMATION

A4.1 IDENTIFICATION OF THE PICS

Date of statement (yyyy-mm-dd)	
PICS version	
System Conformance Statement cross-reference	
Other information	

A4.2 IDENTIFICATION OF THE SYSTEM SUPPLIER / TEST LABORATORY CLIENT

Organization name	
Contact name	
Address	
Telephone	
E-mail	
Other information	

A4.3 IDENTIFICATION OF THE IMPLEMENTATION UNDER TEST

Implementation name	
Implementation version	
Encoder name	
Decoder name	
Camera	
Software viewer	
Special configuration	
Other information	

A4.4 EQUIPMENT CONFIGURATION FOR VIDEO FORMAT IN DETAILS (ENCODER/DECODER)

Source Device IP address	
Source Device Netmask	
Source Device Gateway	
Destination IP Addresses	
Network Protocol	
Source /destination UDP ports	
Bandwidth	

A4.5 GLOBAL STATEMENT OF CONFORMANCE

Are all mandatory features implemented? (Yes or No)	

NOTE – If a positive response is not given to this box, then the implementation does not conform to the standard.

A5 SIGNAL INTERFACES

Item	Protocol Feature	Reference	Status	Support
1	Non-Compressed Standard Definition Television Signals	3.3.1	O.1	
2	Non-Compressed High Definition Television Signals	3.3.2	O.1	
3	Camera Synchronization	3.3.2.2	O	
4	Compressed Digital Television Signals	3.3.3	O	

A6 SUPPORTED VIDEO RESOLUTIONS

Item	Protocol Feature	Reference	Status	Support
1	Personal Video Conferencing	3.4.1.2	O.2	
2	Medical Conferencing	3.4.1.3	O.2	
3	Situational Awareness	3.4.1.4	O.2	
4	Public Affairs	3.4.1.5	O.2	
5	High Resolution Digital Imaging	3.4.1.6	O.2	

A7 INTEROPERABILITY

Item	Protocol Feature	Reference	Status	Support
1	Acquisition and storage of video data	3.7.1	M	
2	Real time distribution	3.8.2.1	C	
3	Delayed distribution	3.8.2.2	O	
4	End User Capabilities	3.8.2.3–3.8.2.4	M	

A8 COMPRESSION

A8.1 H.264: STANDARD DEFINITION 240P TO 576I; HIGH DEFINITION 720P-1080P

~~MPEG-4~~	~~High Definition 720p~~			
Item	Protocol Feature	Reference	Status	Support
H.264.1	Mpeg 2 /TS stream (7 TS packet /UDP Frame) Transmission Only	3.6.3	O.3	
H.264.2	RTP	3.6.2	O.3	
~~2~~	~~Elementary Stream~~	~~3.6.2~~	~~O.3~~	
H.264.3	Codec ~~Mpeg-4~~H.264, part 10	3.4.4.2a)	O	
H.264.4	Color code 4:2:0/4:2:2	3.4.5	O~~.4~~	
H.264.5	Video ~~Format (720p)~~Formats	3.4.1.2-3.4.1.5	O~~.4~~	
H.264.6	HD H.264 High profile. Level 4.0	3.4.4.2a)	O	
H.264.7	GOP < 31	3.4.4.2a)	O	
H.264.8	Constant Bit Rate (CBR)	3.4.4.2a)	O.4	
H.264.9	Variable Bit Rate (VBR)	3.4.4.2a)	O.4	
H.264.10	Embedded audio	3.5.1	O	

A8.2 H.265: STANDARD DEFINITION, 240P -576I; HIGH DEFINITION 720P-1080P; UHD, FUHD—2160P, 4320P

Item	Protocol Feature	Reference	Status	Support
H.265.1	Mpeg 2 /TS stream (7 TS packet/ UDP Frame) Transmission Only	3.6.3	O.3	
H.265.2	RTP	3.6.2	O.3	
H.265.3	Codec H.265	3.4.4.2b)	O	

H.265.4	Color code 4:2:0/4:2:2	3.4.5	O	
H.265.5	Video Formats	3.4.1.2-3.4.1.5, 3.4.1.6.1–3.4.1.6.2	O	
H.265.6	H.265 Levels 3.1, 4, 4.1, 5, 5.1, 6, 6.1, 6.2	3.4.4.2b)	O	
H.265.7	GOP	3.4.4.2b)	O	
H.265.8	CBR	3.4.4.2b)	O.4	
H.265.9	VBR	3.4.4.2b)	O.4	
H.265.10	Embedded audio	3.5.1	O	

~~JPEG2000~~	~~High Definition 720p~~			

A8.3 JPEG2000: HIGH DEFINITION 720P-1080P; UHD, FUHD—2160P, 4320P

Item	Protocol Feature	Reference	Status	Support
JPEG2000.1~~a~~	Mpeg 2 /TS stream (7 TS packet/ UDP Frame) Transmission Only	3.6.3	O~~.3~~	
JPEG2000.2~~a~~	Color code 4:2:0/4:2:2	3.4.5	O~~.5~~	
JPEG2000.3~~a~~	Codec JPEG2000	3.4.4.2c)	M	
JPEG2000.4~~a~~	Video ~~Format (720p)~~Formats	3.4.1.2-3.4.1.5, 3.4.1.6.1–3.4.1.6.2	O~~.5~~	
JPEG2000.5~~a~~	CBR	3.4.4.2c)	O	
JPEG2000.6	VBR	3.4.4.2c)	O	
JPEG2000.7~~6a~~	Embedded Audio	3.5.1	O	

A9 SUPPORTED OPERATIONS

Item	Protocol Feature	Reference	Status	Support
1	Personal Video Conferencing	3.4.1.2	O.~~6~~5	
2	Medical Conferencing	3.4.1.3	O.~~6~~5	
3	Situational Awareness	3.4.1.4	O.~~6~~5	
4	Public Affairs	3.4.1.5	O.~~6~~5	
5	High Resolution Digital Imaging	3.4.1.6	O.~~6~~5	

ANNEX B

SECURITY, SANA, AND PATENT CONSIDERATIONS

(INFORMATIVE)

B1 SECURITY CONSIDERATIONS

B1.1 INTRODUCTION

Aside from the generic security needs of computing systems, security concerns are applicable to motion imagery where there are specific requirements to ensure that transmitted imagery not be disclosed, altered, spoofed, or redistributed without authorization.

Robotic space systems that transmit imagery frequently need the capability to control access to the imagery, whether for proprietary reasons or for national security. Human space applications frequently have the additional requirements to provide private video teleconferencing capabilities for communications with families, physicians, ground operations personnel, and/or news media outlets. Ground systems that receive and/or redistribute motion imagery have additional threats and countermeasures as well.

The focus of this discussion is on the specific protocols and methods recommended earlier in this document. It may be necessary to implement security services at other layers within the protocol stack, to account for distributed processing and cross support, to account for different classes of data or end users, or to account for protection of data during unprotected portions of the complete end-to-end transmission (e.g., across ground networks). The specification of security services at other layers is outside the scope of this document.

B1.2 SECURITY CONCERNS WITH RESPECT TO THE CCSDS DOCUMENT

The most common method of applying security to digital video and audio streams is through the use of multimedia *container* formats. Containers provide a file-based mechanism for exchanging, processing, and storing interleaved fragments of video, audio, metadata, and/or other data such as subtitles and still images. Most container files may be read or written by ordinary computer systems in the same manner as other files.

The ‘MP4’ standard, ISO/IEC 14496-14 (reference [C6]), is a multimedia container format standard specified as a part of ~~MPEG-4~~H.264 and also used in H.265. The ‘Secure JPEG 2000’ standard, ISO/IEC 15444-8 (reference [C7]), is a multimedia container format standard specified as a part of JPEG 2000.

B1.3 DATA PRIVACY

The first major area of security concern is *privacy*, the requirement that the imagery not be disclosed to any other than the intended recipient(s). Limited privacy can be achieved through the use of data *scrambling*, which weakly obfuscates the data stream using a reversible non-cryptographic mechanism, or through employment of protected data transport at lower layers and restricting distribution.

Better privacy can be achieved using cryptographic techniques, which may be applied to all or part of a container format. Since any transcoding or decoding system must be able to read and pass metadata in order to process the stream, imagery metadata must be visible at these points. It is therefore highly desirable to have the capability to perform selective encryption of container file fields (e.g., imagery but not metadata, or imagery and imagery metadata but not cryptographic metadata). 'Secure JPEG 2000' includes mechanisms for selective encryption of JPEG 2000 image content and metadata. ~~Various proprietary methods also exist for encrypting MP4 streams.~~Additionally, the MPEG transport stream includes facilities such as MPEG-CENC to encrypt data that are typically used for pay-per-view television. This allows H264 & H265 streams to be encrypted via a standard mechanism.

The encryption of RTP data is also robust and well-established, and a variety of mechanisms can be used, such as Secure RTP. If MPEG transport streams are transmitted via RTP, secure RTP may be used to ensure data privacy.

B1.4 DATA INTEGRITY

The second major area of security concern is *data integrity*, the requirement that the imagery not be altered, whether to introduce false imagery or to interfere with decoding. Integrity verification mechanisms can be used for data validation to prevent security problems due to non-compliant malignant data. Like privacy, data integrity is commonly provided at other layers of the protocol stack or through a container format. 'Secure JPEG 2000' includes mechanisms for cryptographic verification of JPEG 2000-compliant data.

B1.5 AUTHENTICATION OF COMMUNICATING ENTITIES

Source authentication is the requirement that the imagery be attributable to a known origin. Closely related to data integrity, it can also be used for data validation. Source authentication, if provided, is commonly provided at other layers of the protocol stack or through a container format. 'Secure JPEG 2000' includes digital signature mechanisms for authentication of JPEG 2000-compliant data.

B1.6 CONTROL OF ACCESS TO RESOURCES

The third major area of security concern is *access control*, the requirement that the imagery be restricted from unauthorized further use by the recipient(s). Access control is commonly provided at other layers of the protocol stack. Various methods also exist for attempting

access control through the inclusion of proprietary metadata in a container format, although it should be noted that many similar techniques in the past have been defeated by determined attackers. As discussed in B1.3 above, some protocols provide for selective encryption of imagery (e.g., high-resolution imagery encrypted while metadata or a low-resolution preview is unencrypted). This method may be used to provide controlled access to imagery.

B1.7 AUDITING OF RESOURCE USAGE

Auditing of imagery usage falls under the controversial category of so-called *Digital Rights Management* (DRM), i.e., 'copy protection'. As discussed with respect to access control in B1.6 above, copy protection is commonly an application of proprietary techniques to container formats. A more robust mechanism is the use of digital *watermarking* to embed identifying data within imagery or metadata in order to provide legally actionable evidence of the data's origin that is difficult to remove from second- or later-generation copies. 'Secure JPEG 2000' includes digital watermarking mechanisms for JPEG 2000-compliant data.

B1.8 POTENTIAL THREATS AND ATTACK SCENARIOS

It is possible to interfere with the decoder at the receiving end by injecting non-compliant data streams. This attack can result in a denial of service (if the decoder crashes) or a system compromise (if the decoder is software-based). Deliberate overflow of receiving buffers is a widespread attack method in ground-based computing systems.

With some digital imagery formats, it is possible to embed arbitrary data within the metadata sent as part of the overall imagery stream, and thereby use the ancillary data as a covert channel for transmitting other, unrelated information. This technique is called *Steganography*.

B1.9 CONSEQUENCES OF NOT APPLYING SECURITY TO THE TECHNOLOGY

If confidentiality is not implemented, imagery might be visible to unauthorized entities resulting in disclosure of sensitive or private information.

Without source authentication or integrity verification, valid imagery could be corrupted, or invalid imagery substituted in its place. Without access controls, authorized entities might be able to redistribute sensitive or proprietary information to unauthorized third parties.

B2 SANA CONSIDERATIONS

The recommendations of this document do not require any action from SANA.

NOTE – The systems described in this document are either standalone or connect to existing communications facilities. Those communication facilities, however, would require a SANA registry entry. Motion Imagery is another service among many utilizing a given spacecraft's communication system and therefore does not require an additional SANA entry.

B3 PATENT CONSIDERATIONS

It is expected that implementation of this Recommended Standard by space-agency users will occur through the use of commercial off-the-shelf equipment that implements the referenced standards, and that patent-rights issues for such equipment will have been settled between the equipment manufacturer and the patent-right holders. It is not expected that space-agency users will develop new equipment based on the standards referenced herein. Therefore, patent rights for the referenced standards are outside the scope of this Recommended Standard.

~~ANNEX C~~

~~DTN BUNDLE PROTOCOL FOR VIDEO TRANSMISSION~~

~~(INFORMATIVE)~~

~~C1 MODE 1 REAL TIME DELIVERY, BEST EFFORT~~

~~Mode 1 provides best-effort delivery of data and should be used for unicast or multicast data delivery when the data is to be utilized immediately upon arrival (perhaps for near-real-time decision making). The data will be forwarded using the DTN Bundle Protocol without custody transfer and will be available to the receiving CODEC/application on a best-effort basis. Therefore the data will be 'played' in the order it is received. Missing, damaged, or out-of-order packets will be ignored with subsequent CODEC responses being typical. Additional items such as excessive latency or jitter may be deleterious to the CODEC response.~~

~~C1 MODE 2 DELAYED DELIVERY, WITH PACKET RESTORATION~~

~~Mode 2 provides delivery of data with the prospect of no packets dropped and should be used for single or multi-transport of data when the data can be utilized after a sufficient latency to allow reassembly of the data. The data will be available to a CODEC/application once the underlying protocol has sufficient time to reassemble the data stream.~~

~~Therefore the data will be 'played' in its entirety subject to data being wholly lost on a frame basis. Missing and damaged bundles will be forwarded prior to reassembly with out-of-order bundles to be made available to the end CODEC/application. Additional items such as excessive latency or jitter will not affect CODEC/application response.~~

~~C3 STORE AND FORWARD ISSUES~~

~~The Delay Tolerant Networking Bundle Protocol (DTN-BP) enables store and forward operation when multiple hops or links are required to send data from source to receiver. There is an additional space link reliability protocol available known as Licklider Transmission Protocol (LTP), which will note loss of DTN bundles (which would contain $1-n$ video frames depending on system design) and request retransmission of missing bundles.~~

~~Use of the LTP reliability mechanism will result in delivery of out-of-order video frames to the application layer (because of the lag in retransmitting missing bundles). This may or may not be acceptable to the end-user application, and consideration of this out-of-order condition must be made.~~

~~In current lab experiments, it has been seen that an effective use of DTN to transmit video is to transmit bundles unreliably, accept the consequences of missing data for the real-time viewing of the video stream, and use another mechanism for recovery of missing data. This mechanism could be an application buffer to store retransmitted bundles separately for later reconstruction of the video stream in non-real time, or to record the video on board and later transmit as a video file for playback after the file is completely received without errors. Further experimentation is required to provide definite parameters for the transmission of video using DTN.~~[3]

~~[3] As this is refined, it will be added to the MIA specifications.~~

ANNEX C

INFORMATIVE REFERENCES

(INFORMATIVE)

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[C4] H. Schulzrinne, et al. *RTP: A Transport Protocol for Real-Time Applications*. STD 64. Reston, Virginia: ISOC, July 2003.

[C5] J. Postel. *Transmission Control Protocol*. STD 7. Reston, Virginia: ISOC, September 1981.

[C6] *Information Technology—Coding of Audio-Visual Objects—Part 14: MP4 File Format*. International Standard, ISO/IEC 14496-14:2003. Geneva: ISO, 2003.

[C7] *Information Technology—JPEG 2000 Image Coding System: Secure JPEG 2000*. International Standard, ISO/IEC 15444-8:2007. Geneva: ISO, 2007.

[C8] *Licklider Transmission Protocol (LTP) for CCSDS*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 734.1-B-1. Washington, D.C.: CCSDS, May 2015.

[C9] *CCSDS Bundle Protocol Specification*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 734.2-B-1. Washington, D.C.: CCSDS, ~~forthcoming~~September 2015.

ANNEX D

ABBREVIATIONS

(INFORMATIVE)

AAC	Advanced Audio Codec
AES	Audio Engineering Society
BER	Bit Error Rate
CBR	Constant Bit Rate
CFDP	CCSDS File Delivery Protocol
DRM	Digital Rights Management
DTN	Delay Tolerant Networking
DTN-BP	Delay Tolerant Networking Bundle Protocol
DVB-ASI	Digital Video Broadcasting-Asynchronous Interface
EBU	European Broadcasting Union
EVA	Extra-Vehicular Activity
FPS	Frames Per Second
FUHD	Full Ultra High Definition (8K video)
GOP	Group of Pictures
HD	High Definition
HDMI	High Definition Multimedia Interface
HDR	High Dynamic Range
HD-SDI	High Definition-Serial Digital Interface
HTTP	Hypertext Transfer Protocol
JPEG	Joint Photographic Experts Group
IETF	Internet Engineering Task Force
IP	Internet Protocol
ITU	International Telecommunications Union
JIIA	Japan Industrial Imaging Association
LTP	Licklider Transport Protocol

LVDS	Low Voltage Differential Signaling
NTP	Network Time Protocol
PID	Packet Identification
PTP	Precision Time Protocol
RTP	Real Time Transport Protocol
SD	Standard Definition
SDI	Serial Digital Interface
SDR	Standard Dynamic Range
SMPTE	Society of Motion Picture and Television Engineers
STANAG	Standarization Agreement, North Atlantic Treaty Organization (NATO)
TCP	Transmission Control Protocol
TS	Transport Stream
UDP	User Datagram Protocol
UHD	Ultra High-Definition (4K video)
USB	Universal Serial Bus
UT	Unitdata Transfer
VSF	Video Services Forum