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DIGITAL TELEVISION STANDARDS for NASA

Version 2.0

NASA TECHNICAL STANDARD

FOREWORD

This standard is approved for use by the National Aeronautics and Space Administration (NASA) Headquarters and all NASA Centers and is intended to provide a common framework for consistent practices across NASA programs.

This standard was developed by the NASA Digital Television Working Group (DTVWG) and by the NASA Office of the Chief Information Officer, Architecture and Operations Division, to assist the development and implementation of Digital Television (DTV) systems that support the Agency.

Since the 1980s, the technology and equipment used for the acquisition, contribution, production, and distribution of television has been moving from the traditional world of analog signals, recording formats, and signal processing into the digital realm. Digital video systems, starting with cameras and recorders for image acquisition, through systems for program contribution and production, to final signal distribution are now in use in most television facilities. The commencement of commercial terrestrial DTV broadcasting in 1998 signified the general availability of end-to-end DTV capability in the United States.

The U.S. standard for terrestrial DTV broadcasting established by the Federal Communications Commission (FCC) is based on work recorded in document A/53, prepared by the Advanced Television Systems Committee (ATSC). In addition to specifying a method for broadcasting a digital representation of the traditional U.S. 525-line interlace scan television format, the ATSC A/53 document detailed many new television formats and variations for both Standard and High Definition Television (SDTV and HDTV). Although the FCC adopted most aspects of the ATSC recommendations when it established the standard for U.S. DTV broadcasting, it declined to specify the use of any particular picture format or formats. However, the formats listed in table 3 of the ATSC A/53 document are generally accepted in the television industry as the formats to be used for broadcasting. The result of this action has been that instead of just one format of television for all uses, there are now many different available types and levels of quality of DTV.

During the era of a single analog U.S. standard video signal format, American National Standards Institute (ANSI)/Society of Motion Picture and Television Engineers (SMPTE) 170M-1994, there has been no real need for NASA to develop Agency-wide television signal standards. The fact that there are so many new and different picture formats and signal processing methods now available has shown the reason for NASA to establish standards for DTV. These standards are needed so that there may be common methods developed for the acquisition and production of DTV information and for the distribution and interchange of DTV signals and video products both within and external to the Agency.

Requests for information, corrections, or additions to this standard should be directed to the NASA DTV Program Office (*http://dtv.msfc.nasa.gov*), Mail Code EO50, Marshall Space Flight Center (MSFC), Huntsville, AL 35812. Requests for general information concerning standards should be sent to the NASA Technical Standards Program Office, Office of the Chief Engineer, NASA Headquarters, Washington, DC 20546. This and other NASA standards may be viewed and downloaded from the NASA Standards Home Page: *http://standards.nasa.gov*.

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Chief Information Officer

REVISION HISTORY

Version 1.0: Original approved document, April 4, 2000.

Version 2.0: Update to include corrections and additional DTV guidelines, September 18, 2007.

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DIGITAL TELEVISION STANDARDS FOR NASA

1. SCOPE AND APPLICABILITY

1.1 Scope. The DTV system standards described in this document are associated with those industrial or professional systems used to produce full-motion and full-resolution digital video imagery that is suitable for critical closed-circuit or broadcast use and that is normally distributed over wide-bandwidth communications systems designed for the transmission of television. It is not the intention of the DTVWG or the Office of the Chief Information Officer to imply or endorse the use of any specific commercial vendor standards, designs, or hardware.

For the purposes of this document, the uses for critical video acquisition, contribution, production, and distribution within NASA are considered as falling into one of two broad categories: Engineering and Publication. (These categories were previously called Analysis and Program.) Engineering video is defined as video imagery that is acquired primarily for the purpose of being used by NASA or other authorized personnel, either in real time or post event, to observe, analyze, or document a NASA technical or operational activity. Examples of Engineering video include imagery of space launch and space flight activities, flight vehicle tests, laboratory and facility testing, scientific experiments, and training. Systems used for critical Engineering video acquisition normally require the highest technical imaging performance. Some less critical Engineering video, which may include general surveillance imagery not meant to capture important details or aspects of the activity or video unlikely to be used as source material for Publication video programs, may have reduced image performance requirements. Publication video is defined as video imagery that is acquired primarily for the purpose of being integrated into live television segments or edited programs that are created for disseminating information concerning NASA activities within the Agency and/or for release to the news media or the public. Examples of these programs include educational or training videos, televised briefings or press conferences, video-file material, live shots, and video coverage of other NASA events. Systems used for Publication video often strive for high artistic as well as high technical imaging performance, although it is acknowledged that video of any quality may be considered usable for coverage of a newsworthy or historically significant event. It is also noted that Publication video programs may be produced partially or in their entirety using video imagery originally acquired for Engineering purposes. NASA organizations must determine their needs and select and use video equipment and systems capable of satisfying whichever are their most critical imagery requirements.

These DTV standards shall apply to all NASA Center systems infrastructure used to acquire, produce, and distribute Engineering and Publication video. It is recognized that the specific analysis needs or unique constraints associated with certain flight, test, or laboratory imaging could require the use of specialized imagery systems that may not precisely adhere to these DTV standards. If any programs or projects that use specialized systems require NASA Center DTV infrastructure services, they shall be required to convert their nonstandard signals or products to meet the NASA DTV infrastructure standards at an interface point.

This document does not, at this time, discuss or provide standards for the implementation of digital video other than regular full-motion and full-resolution systems or video that uses other than wideband communications systems designed specifically for standard video transmission. These other motion imagery categories include systems used for video surveillance, for very high-speed imagery, for teleconferencing video, or for the streaming distribution of live video or on-demand video segments to viewers over a computer intranet or the Internet.

1.2 Applicability. This standard recommends engineering practices for NASA programs and projects. It may be cited in contracts and program documents as a technical requirement or as a reference for guidance. Adherence to this standard and its provisions is the responsibility of program/project management and the performing organization. It is recognized that some specific circumstances, such as activities jointly pursued with a commercial or international partner, may involve or require the use of DTV equipment that varies from these standards. However, organizations are otherwise obliged to use systems that adhere to the guidance within this document unless there are specific functional or performance requirements of a particular DTV application, project, or program that prohibit the use of these standards. Inquiries regarding exceptions to this standard should be directed to the NASA DTV Program Control Board. Information about requesting an exception is available through the DTV Working Group voting member at each Center or at *http://dtv.msfc.nasa.gov*.

2. ACRONYMS AND DEFINITIONS

2.1 Acronyms

2.1.1	AES/EBU	Audio Engineering Society/European Broadcasting Union
2.1.2	ANSI	American National Standards Institute
2.1.3	ATSC	Advanced Television Systems Committee
2.1.4	AVC	Advanced Video Coding
2.1.5	CCD	Charge Coupled Device
2.1.6	CODEC	EnCOder/DECoder or COmpression/DECompression
2.1.7	DCT	Discrete Cosine Transform
2.1.8	DTV	Digital Television
2.1.9	DTVWG	Digital Television Working Group
2.1.10	DVD	Digital Versatile Disc
2.1.11	FCC	Federal Communications Commission
2.1.12	GOP	Group Of Pictures
2.1.13	HDSDI	High Definition Serial Digital Interface
2.1.14	HDTV	High Definition Television
2.1.15	IEEE	Institute of Electrical and Electronic Engineers
2.1.16	ISO	International Organization for Standardization
2.1.17	MPEG	Moving Pictures Experts Group
2.1.18	NTSC	National Television Standards Committee
2.1.19	SDI	Serial Digital Interface
2.1.20	SDTV	Standard Definition Television
2.1.21	SMPTE	Society of Motion Picture and Television Engineers

2.2 Definitions.

2.2.1 Acquisition. The initial capture of video imagery.

2.2.2 Acquisition Equipment. Equipment used for the initial capture of video imagery. It can be Production Level (defined below) quality, but in the case of High Definition Television (HDTV) field camcorders, it may have to compromise some aspects of image quality in order to have a one-piece camcorder configuration.

2.2.3 Contribution Level. A lower quality of video distribution between facilities that is still acceptable for use for production or postproduction.

2.2.4 Distribution Level. A lower quality of video distribution between facilities or from facilities to users acceptable for final user viewing, but not for production or postproduction.

2.2.5 Engineering Video. Video acquired primarily to observe, analyze, or document a NASA technical or operational activity.

2.2.6 High Definition Television (HDTV). Video with ≥720 active scan lines.

2.2.7 Interlace Scan. Video scanning method in which each image frame is scanned in two parts or fields. One field consists of the odd-numbered scan lines; the second, the even-numbered scan lines. Sometimes referred to as 2:1 scanning.

2.2.8 Pixel. In digital television, the smallest element in the makeup of an image.

2.2.9 Production, Postproduction. Manipulation of images by switching, special effects, or editing to create a video program. Production is generally real-time creation for immediate release. Postproduction is generally not done in real time and is associated with editing for the creation of recorded video programs.

2.2.10 Production Level. The highest quality of video used within a facility for live programming or for the manipulation of video imagery after acquisition (postproduction).

2.2.11 Progressive Scan. Video scanning method in which each image frame is scanned in one continuous pass without dividing the frame into fields (see Interlace Scan). Sometimes referenced to as 1:1 scanning.

2.2.12 Publication Video. Video acquired primarily for the purpose of disseminating information concerning NASA activities within the Agency or to the news media and the public.

2.2.13 Scan Line. The smallest vertical unit of a video picture; it runs horizontally across the screen. Pixels make up scan lines.

2.2.14 Standard Definition Television (SDTV). Video with <720 active scan lines. For U.S. systems, this is 480 or 486 active scan lines.

2.2.15 Segmented Frame. Video scanning method in which each image frame is initially scanned in one continuous pass (see Progressive Scan) but then divided into two fields for recording or transmission, one field consisting of the odd-numbered scan lines, the second consisting of the even-numbered lines.

2.2.16 Video Frame. Total scan lines that compose a complete video picture. Analogous to a frame of film in a motion picture.

3. NASA DTV STANDARDS

This document establishes three major categories of NASA DTV standards:

- Acquisition and Production Picture Formats
- Video/Audio Signal Sampling Representation and Compression
- Interfaces

The DTVWG has engaged in considerable analysis, testing, and debate regarding these areas and has arrived at the conclusions detailed in this section. The rationale for these choices is contained in the appendices to this document.

The Foreword of this document states that these NASA standards are needed so that there may be common methods developed for the acquisition and production of DTV information and for the distribution and interchange of DTV signals and video products both within and external to the Agency. These standards are also intended to establish minimum levels for functional and quality performance characteristics considered acceptable for critical NASA video requirements. This position has been taken to help avoid the types of problems that have occurred in producing video products of historic events due to the use of lower quality recording formats such as VHS, 8-mm, and U-matic to acquire NASA video in the past. Thus, these standards provide guidance to NASA organizations for the selection of hardware and software to satisfy DTV requirements. Some DTV equipment and systems in the marketplace vary in functional capabilities and/or do not meet the performance specifications of these standards for critical applications. NASA organizations may be tempted to use equipment other than that which meets these standards due to its lower cost or because of other considerations such as the compact size or low weight of some available items. However, as stated earlier in section 1.2, "Applicability," organizations are otherwise obliged to use systems that adhere to the guidance within this document unless there are specific functional or performance requirements of a particular DTV application, project, or program that prohibit the use of these standards.

The referenced applicable standards are published by organizations such as the American National Standards Institute (ANSI), the Audio Engineering Society/European Broadcasting Union (AES/EBU), the Institute of Electrical and Electronic Engineers (IEEE), and the Society of Motion Picture and Television Engineers (SMPTE). Moving Picture Experts Group (MPEG) standards are published by the International Organization for Standardization (ISO).

3.1 Acquisition and Production Picture Formats

The tables in this section list the DTV picture format standards selected for the acquisition and production of standard and high-definition television. The selection of a DTV picture format includes the selection of an individual frame size in horizontal and vertical pixels, the image aspect ratio, the scanning method used, and the frame rate. For the acquisition of most high-definition video, the NASA standard shall be 720 progressive (720P) at 59.94 frames per second. For the transfer of motion picture film-based imagery material to high-definition video or for the acquisition of selected Publication category video that specifically requires the highest static image resolution, an optional alternative to 720P is to use 1080 progressive or segmented frame at 23.98, 29.97, or 59.94 frames per second. For the acquisition of standard-definition video, the NASA standard shall be 480 interlace at 29.97 frames per second.

Table IA. High Definition Television Format

ACTIVE PICTURE PIXEL SIZE (HxV)	PICTURE ASPECT RATIO	SCANNING METHOD	FRAME RATE	APPLICABLE STANDARD
1280x720*	16:9	Progressive (1:1)	59.94 Hz	SMPTE 296M-2001

*Also acceptable for many applications is acquisition equipment that processes or records HDTV using fewer than 1280 horizontal luminance samples down to ¾ square pixel format (i.e., 960 pixels) using subsampling, offset pixels, or similar techniques to reduce bandwidth requirements. The horizontal resolution of the camera or recorder output signal shall be scaled to a full 1280 pixels. The suitability of using these systems for a particular application will need to be determined by the user.

Note: For HDTV distributed for final viewing, terrestrial broadcast standards for 720P stipulate using 1280 horizontal pixels.

Table IB. Optional HDTV Format for Film Transfer and Special Publication

ACTIVE PICTURE PIXEL SIZE (HxV)	PICTURE ASPECT RATIO	SCANNING METHOD	FRAME RATE	APPLICABLE STANDARD
1920x1080**	16:9	Progressive (1:1) or Segmented Frame	23.98 Hz,*** 29.97 Hz, or 59.94 Hz	SMPTE 274M-2003

**It is recommended that equipment or systems that process or record HDTV using less than 1920 horizontal luminance samples not be used for acquisition to maintain the highest quality of master video transfers from film.

***See DTV Recommended Practices on the DTV web site, http://dtv.msfc.nasa.gov/ for advice on choice of frame rate.

Note: It is expected that video material acquired in this format would typically be transferred to another picture format for production or for final distribution.

Table II. Standard Definition Television Format

ACTIVE PICTURE PIXEL SIZE (HxV)	PICTURE ASPECT RATIO	SCANNING METHOD	FRAME RATE	APPLICABLE STANDARD
720x480/486 (Non-square Pixel)	4:3 or 16:9	Interlace (2:1)	29.97 Hz	ANSI/SMPTE 125M-1995 (4:3) ANSI/SMPTE 267M-1995 (16:9)

Note: SDTV distributed for final viewing may also be encoded using fewer than 720 horizontal pixels (e.g. 704, 640, 544, 528, 480, or 352) to reduce bandwidth requirements; however, terrestrial broadcast standards for 480I stipulate using 704 or 640 horizontal pixels.

3.2 Video/Audio Signal Sampling Representation and Compression

The tables in this section list the DTV standards for signal sampling representation and compression.

Table III. Video Signal Sampling Representation—HDTV and SDTV

FUNCTION	SIGNAL SAMPLING REPRESENTATION	WORD LENGTH
Acquisition for Critical Engineering or Publication	Complete chroma information sampling on every video line. Signal representation may be 4:4:4, 4:2:2, 4:1:1, 3:1:1, etc. Luminance or chroma image subsampling or resolution filtering may be performed per the specific recording format.	8-bit minimum
Acquisition for Noncritical Engineering	4:4:4, 4:2:2, 4:1:1, or 4:2:0. Luminance or chroma image subsampling or resolution filtering may be performed per the specific recording format.	8-bit minimum
Video Editing or Duplication Using 3:1:1, 4:1:1, or 4:2:0 Acquisition Formats	Editing and duplication may be accomplished using acquisition formats if transfers and manipulation of the recorded bit stream occur unaltered in a native (e.g., DV) or "dub" mode such that no decoding and re-encoding of the video signal is performed.	8-bit minimum
Production and Postproduction	4:4:4 or 4:2:2. No luminance or chroma image subsampling. No resolution filtering.	8-bit minimum
Intra-Center Transfer for Contribution	Any component signal representation that meets user-defined requirements.	8-bit minimum
Inter-Center and External Transfer for Contribution	4:2:2. No luminance or chroma image subsampling. No resolution filtering.	8-bit minimum
Distribution for Viewing	4:2:0.	8-bit
Archiving	Use a production-quality format for completed video programs. May use an acquisition format for original material or material "cuts only" edited from an acquisition format.	8-bit minimum

Table IV. Video Compression—HDTV and SDTV

FUNCTION	COMPRESSION
Acquisition for Critical Engineering or Publication	Dependent upon the characteristics of the specific recording format and compression method used, but shall be intraframe-based. If using intra-frame 4:2:2 MPEG-2 or DV, shall use a video data rate of no less than 100 Mbps for HDTV and no less than 30 Mbps for SDTV. If using 4:1:1 DV, shall use a video data rate of no less than 25 Mbps for SDTV. Also may use systems that employ other compression codecs at data rates that provide equal or better performance.
Acquisition for Noncritical Engineering	Defined by user requirements.
Video Editing or Duplication Using 3:1:1, 4:1:1, or 4:2:0 Acquisition Formats	Editing and duplication may be accomplished using acquisition formats if transfers and manipulation of the recorded bit stream occur unaltered in a native (e.g., DV) or "dub" mode such that no decoding and re-encoding of the video signal is performed.
Production and Postproduction	Intraframe compression; less than or equal to 5:1 if 4:2:2 MPEG-2. Also may use systems that employ other compression codecs at data rates that provide equal or better performance.
Intra-Center Transfer for Contribution	Defined by user requirements.
Inter-Center and External Transfer for Contribution	HDTV: If MPEG-2, 4:2:2 Profile @ High Level; GOP size less than or equal to 15 frames; video data rate greater than or equal to 30 Mbps. SDTV: If MPEG-2, 4:2:2 Profile @ Main Level; GOP size less than or equal to 15 frames; video data rate greater than or equal to 8 Mbps. Also may use systems that employ other compression codecs at data rates that provide equal or better performance.
Distribution for Viewing	HDTV: If MPEG-2, Main Profile @ High Level; GOP size defined by user; video data rate greater than or equal to 12 Mbps. SDTV: If MPEG-2, Main Profile @ Main Level; GOP size defined by user; video data rate greater than or equal to 3 Mbps (if subsampled). Also may use systems that employ other compression codecs at data rates which provide equal or better performance.
Archiving	Use a production-quality format for completed video programs. May use an acquisition format for original material or material "cuts only" edited from an acquisition format.

Table V. Audio Signal Sampling Representation and Compression

FUNCTION	APPLICABLE STANDARD
Acquisition, Production, Postproduction, and Archiving	AES3, 48 KHz audio signal sampling.
Intra-Center Transfer for Contribution	Defined by user requirements.
Inter-Center and External Transfer for Contribution	MPEG-1 Layer 2 (ISO 11172-3) at a data rate of greater than or equal to 128 Kbps per channel.
Distribution for Viewing	ATSC/Dolby AC-3 (Dolby Digital) or MPEG-1 Layer 2 (ISO 11172-3).

3.3 Interfaces

Standardized data transfer interfaces need to be established for the distribution of DTV within and between the NASA Centers and for the release of digital video to external NASA customers, the news media, and the public. Interfaces are also needed for receiving digital video from flight vehicles such as the Space Shuttle, the International Space Station (ISS), and the vehicles of future programs. The initial specifications of signal interfaces for transmission applications are listed in the tables below. These define interfaces for the transfer of uncompressed or compressed DTV between a source and a destination or between a source and a transmission path. That path may involve an interface to a transport or network mechanism, such as with Internet Protocol (IP), or directly to a physical medium, such as with a cable or fiber. Further specifications for other interfaces, will be developed as technology changes.

Table VI. Uncompressed Signal Transmission—HDTV and SDTV

FORMAT	INTERFACE DATA RATE	WORD LENGTH	APPLICABLE STANDARD
HDTV	1483.5 Mbps	10-bit	SMPTE 292M-2004.
SDTV	270/360 Mbps	10-bit	ANSI/SMPTE 259M-1997 Levels C and D.

Table VII. Compressed Signal Transmission—HDTV and SDTV

FORMAT	INTERFACE DATA RATE	WORD LENGTH	APPLICABLE STANDARD
HDTV and SDTV	270 Mbps	8-bit minimum	Digital Video Broadcasting Asynchronous Serial Interface (DVB-ASI).
SDTV	100/200/400/ 800 Mbps	8-bit minimum	Institute of Electrical and Electronic Engineers (IEEE) 1394.

APPENDIX A

DISCUSSION OF PICTURE FORMATS

HDTV

In making the original choice of an HDTV picture format for NASA, the DTV Standards sub-group to the DTVWG considered several constraints. One assumed constraint was that available equipment would typically not work to more than one format, so a single HDTV picture format standard would need to be chosen. Another constraint, given existing standards, was the need to be able to transfer signals using equipment that conformed to the SMPTE 292M-1996 High Definition Serial Digital Interface (HDSDI). Another desire was to ensure compatibility with the broadcast television community by choosing from among the ATSC defined picture formats.

Since these original studies, some of these assumptions have been challenged. Equipment exists that can operate in more than one picture format standard. However, the transferring of imagery from one HDTV standard to another, while possible, may introduce image degradation or other problems. So it is still considered desirable to use one Agency picture format standard for acquisition, contribution, and production rather than having Centers, projects, programs, or organizations choose their own, and perhaps different, standards. Most equipment still uses the HDSDI interface, although the DVB-ASI interface can also be used for the transfer of compressed HDTV signals. Plus, in addition to normal terrestrial and satellite transmission methods, options for transferring contribution video now include real-time or non-real-time transmission as serial streams or as files over computer networks using the Internet Protocol. The desire for commonality with the broadcast television community cannot be completely fulfilled because that group does not use a single picture format standard. Another recognized factor is that broadcasters often acquire or produce video in one format and distribute to the public in another, particularly with scripted programs. So having an Agency standard HDTV picture format in common with broadcasters is not possible for all cases.

As defined by the ATSC, HDTV has three major picture formats: 1280x720 progressively scanned at 24, 30, or 60 frames per second (FPS) (720P@24/30/60); 1920x1080 progressively scanned at 24 or 30 FPS (1080P@24/30); and 1920x1080 interlace scanned at 30 FPS (1080I@30). The last format is sometimes referred to as 1080I@60 by some in the video industry indicating the fields per second or vertical refresh rate of the interlaced image. Note that the frame rates may be even integers or slightly offset values such as 29.97 and 59.94 FPS to ease compatibility with the existing NTSC infrastructure. However, the integer values are often listed for brevity even though the actual frame rate used may be an offset value. All standard HDTV formats use a square pixel representation and a 16:9 image aspect ratio. Interlace scan HDTV was first developed in the late 1970s. It was initially an analog method with 1,125 total lines per frame, of which 1,035 were active image lines, although the number of active lines was later increased to 1080. The image is scanned using a two-to-one interlace method similar to the existing NTSC 525-line system. With this method, two fields, one for the even-numbered lines and one for the odd lines, are sequentially scanned to capture each video frame. Since this method also displays the two fields in sequence, it provides an image refresh rate that is twice the actual frame rate. This characteristic acts as a type of analog compression that was very useful during the era of picture-tube displays. With the progressive method, each complete video frame is captured in one continuous scan. The display refresh rate using this method is normally the same as the frame rate. A variant of progressive scan is segmented frame, which initially scans the entire image but transfers the image in two segments similar to interlace fields. Although acquisition and production are done in several different formats, all HDTV broadcast distribution in the U.S. is done in either 720P@59.94 or 1080I@29.97.

A series of tests was conceived and conducted by the DTVWG to compare available interlace scan and progressive scan HDTV equipment. The 1080I@30 and 720P@60 formats were compared. A report on the results of these tests can be found on the NASA DTV Web site (*http://dtv.msfc.nasa.gov/*) or can be obtained from the NASA DTV Project Office. The tests demonstrated comparable resolution and quality from the two formats when images were viewed in real time. Interlace video displayed some image artifacts that are introduced by the scanning method, but these are not significant for most general viewing. No similar artifacts appeared to be introduced by progressive scanning. However, when the video was captured and analyzed in still frame (and additionally in still field for interlace video), significant differences between the scanning methods became apparent. It was shown that interlace artifacts can alter the appearance of an object. It has been determined by research, and verified by equipment manufacturers, that the scanning characteristics of the Charge Coupled Device (CCD) image sensors used in higher quality interlace HDTV cameras cause considerable distortion of fine-detail image material that appears 1 to 2 video lines (pixels) tall. Better quality progressive scan HDTV cameras also use CCD sensors, but the scanning characteristics of these devices are different. Similar image detail distortions do not occur when true progressive scan image sensors are used. Additional tests were performed to assess the results of transcoding from one format to the other. These tests showed that progressive scan source video transcodes to interlace without generating additional artifacts, but that artifacts existing in interlace scan source video carry over when transcoded to progressive. Both formats produced excellent results when down-converted to 525-line interlace scan video. The artifacts associated with interlace scanning effectively negate some of the originally expected resolution advantage of 1080I@30 over 720P@60. The results of this testing, along with knowledge gained from other research, have proven to the DTVWG the general superiority of the progressive scan method over the traditional interlaced method for HDTV acquisition and production, particularly for Engineering video requirements. It is also generally accepted within the television production and broadcast communities that progressive scan master recordings are superior for transcoding to all DTV formats. Thus, progressive scan HDTV was chosen by the DTVWG to be the NASA standard for acquisition.

The DTVWG considered the use of the 1920x1080 progressive @ 60 FPS (1080P@60) format (thought to be the "Holy Grail" of HDTV). SMPTE 274M defines 1080P@60, but the ATSC standard distribution formats do not include it. The limited amount of available equipment that supports this format is normally used only in very-high-end applications. Use of this format with current technology usually requires either the use of a form of mezzanine compression or the use of a dual HDSDI link connection (SMPTE 372M), although the television industry also has worked to develop a serial digital interchange standard based on a data transfer rate of approximately 3 Gbps (SMPTE 424M). Since the use of 1080P@60 acquisition is not currently practical for most NASA applications (and budgets), it is not to be considered for the principal HD picture format standard at this time. The use of 1080P@60 is allowed as an optional format for selected applications. Broad use of 1080P@60 remains a goal if and when future developments allow the practical use of this format.

Some within NASA had originally suggested the initial use of 1080I@30 HDTV equipment, with a later transition to a progressive format. It was argued that, at that time, interlace equipment was already widely available, that 1080I provided much higher spatial resolution than existing

NTSC, and that the 60-Hz field rate provided high temporal resolution. This course of action was not recommended by the DTVWG because of the issues associated with interlace scanning artifacts, the demonstrated advantages of progressive scanning, and the problems and expense that could be associated with performing an additional format transition. The DTVWG recommended making no further acquisition of interlace scan HDTV equipment and limiting the use of this format to equipment already purchased within the Agency. The DTVWG continues to recommend the use of a progressive scan HDTV acquisition standard.

The task at hand was to choose a progressive scan format that may be considered an interim HDTV format, if assuming a long-term goal of migrating to 1080P@60. However, the group also needed to consider that this might remain the NASA HDTV format for a considerable time if 1080P@60 does not become a practical or affordable alternative in the near future. The choice then appeared to be between 1080P@24/30, which favors higher spatial resolution, and 720P@60, which favors higher temporal resolution.

The DTVWG originally noted that few available HDTV displays had the resolution capability to show a dramatic image difference between 1080P and 720P. That has changed as monitors of several display technologies capable of displaying 1080P have become more prevalent. Also noted is that some playback systems and displays convert 720P or 1080I input signals to 1080P for display, similar to how some standard-definition DVD video systems convert the 480I recordings and display 480P or 1080I. However, many HDTV camcorders and some broadcasters horizontally subsample the video, reducing any spatial resolution advantage of originating in 1080. Also noted is that 1080P@24/30 exhibits substantial flicker if displayed in its native format. More likely, 1080P@24/30 would have to be converted to 1080I@30 for distribution or display, thus losing some of the benefit of progressive scanning.

The capability of the 720P@60 format to acquire 60 progressively scanned frames per second is a very important consideration. Many researchers and operational groups within the Agency have expressed a preference for a high television frame rate, and as well for progressive scanning. The 720P@60 format provides double the temporal resolution of the 1080P@30 format. This attribute is very useful in that it allows this format to capture twice as much information about fast-moving events. In commercial broadcasting, this format has shown an advantage in the coverage of high-motion events such as sports. Since most HDTV monitors can now display 720P@60 in its native format, all of the temporal as well as spatial information captured by this format can be used.

The DTVWG studied some practical equipment considerations. As this document was originally being prepared, there were two sources of cameras and video recorders for 1080P@24/30. There were four manufacturers of 720P@60 cameras, and two of these made video recorders in the format. Available routing and distribution equipment could support either format. Some HDTV signal processing, test, and production equipment could operate in 1080P@24/30, whereas nearly all such equipment could operate in 720P. With respect to choosing the 1080P@24/30 format, one manufacturer indicated that their existing formats afforded a degree of backward compatibility by means of an ability to play back recordings of interlace scan SDTV and HDTV material on proposed 1080P@24/30 equipment. An opinion supporting this approach was expressed by some due to this proposed capability to play old tapes on newer equipment. Overall, the DTVWG did not consider this to be a significant factor due to the limited amount of NASA-owned interlace scan HDTV equipment. Based on discussions with two major manufacturers of HDTV equipment, it was considered unlikely that future 1080P@60 equipment would provide any such backward compatibility. The DTVWG assumed that some degree of temporal and/or spatial transcoding would be required to convert any existing material to 1080P@60, regardless of which interim HDTV format was chosen. The DTVWG also believed that it would more likely be desired to play any existing interlace scan recordings, either standard- or high-definition, on native-format equipment and perform sophisticated motion-compensated de-interlacing and any needed up-conversion in a separate processor in order to transcode this material more effectively to a progressive scan high-definition format for further production. The overall costs associated with the implementation of either the 720P or 1080P format were expected to be similar.

Another consideration was looking at which HDTV formats were being adopted by others. The International Telecommunications Union (ITU) has issued standards that establish both 1280x720 and 1920x1080 as common image formats. Some broadcast networks have chosen 1080I@30 as their broadcast distribution standard, while others have chosen 720P@60. However, it should be noted that progressive formats such as 720p@24 and 1080P@24 are being commonly used as a video replacement for motion picture film for the acquisition and production for many episodic television productions that are subsequently distributed using 720P@60 or 1080I@30. No network has chosen 1080P as a broadcast standard, although some high-definition optical discs are recorded in a 1080P@24 format. Other U.S. Government agencies, notably the Department of Defense, have standardized on 720P@60. Although there was no clear guidance derived from this particular study, any influence of this factor would seem to lead NASA to follow the choice of other U.S. Government agencies.

It is the opinion of the DTVWG that the temporal resolution advantage of 720P@60 would generally be of more value for a broader range of NASA motion imagery acquisition applications than other HDTV formats. As an interim standard format, 720P@60 provides progressive scanning, the highest available frame rate, and much higher spatial resolution than standard NTSC. The DTVWG also considers 720P@60 to be a suitable permanent HDTV format if acquisition using 1080P@60 never becomes a practical and affordable reality for broad use. As a result, the DTVWG has selected 720P to be the initial NASA HDTV standard picture format for most new video acquisition. An offset frame rate of 59.94 Hz, rather than the integer rate of 60, has been chosen to facilitate real-time down- or up-conversion to or from the legacy NTSC format.

Some special, selected DTV applications can take advantage of the additional spatial resolution of 1080P@24/30 where the lower frame rate of that format is not an issue. One of these is the transfer of motion picture film-based material to video. Another is the acquisition of selected video material in the Publication category that strives for very high static-image quality. For these specific uses, the 1080P format using a frame rate of 23.98, 29.97, or 59.94, as appropriate for the specific material, is an acceptable video acquisition alternative to 720P.

Once video material has been acquired, further decisions are required about the format to be used for contribution, production, and final distribution of the video. In most cases, contribution video should remain in the original acquisition picture format. This is also normally true for production and postproduction as well. However, if productions use a mixture of progressive and interlace source material, it is sometimes preferred to produce in 1080I because many types of equipment used to transcode 1080I to a progressive format actually drop the resolution to 540P during the processing, thus reducing the quality of the interlace video. The choice of a final distribution format may depend on the distribution media or method. In many cases, distribution in the normal broadcast picture format standards of 720P@60 or 1080I@30 is appropriate. In some circumstances, distribution in 720P or 1080P@24/30 may make more sense, such as if the final product is encoded as an MPEG-4, Windows Media, or Quicktime file.

SDTV

The DTVWG acknowledges that traditional interlace scan, 525-line, 29.97-frame-per-second video will be a part of NASA imaging systems for many years to come. Although progressive scan video has been demonstrated to be superior, the continued use of the vast amount of existing equipment as a means of capturing NASA video imagery cannot be excluded. In recent years, acquisition and production equipment that digitally represents this originally analog standard, typically using 720x480 active pixels, has been commonly available. Note that this SDTV acquisition and production format differs slightly from any of the ATSC distribution formats in that it uses 720 pixels per horizontal line, rather than 704 or 640 (square pixel). This is not really a problem or a constraint because the number of horizontal pixels would normally be resized as needed within a broadcast distribution encoder. Digital 525-line acquisition and production equipment usually conforms, or can be readily adapted to, the SMPTE 259M Serial Digital Interchange (SDI) standard. There are many NASA video requirements that can continue to be adequately satisfied using this format. Thus, the digital representation of traditional 525-line interlace scan video, 480I at a frame rate of 29.97 Hz, is to be the NASA SDTV standard picture format.

There are several variations of SDTV standards that specify a 16:9 image aspect ratio instead of the traditional 4:3. It is presumed that wide-aspect SDTV would be useful for display on wide-aspect monitors and could also be more suitable for up-conversion for use in HDTV production. An alternative method of generating 16:9 aspect video imagery using existing 4:3 aspect equipment is to use the "shoot and protect" technique. This means to shoot the video using the full, standard 4:3 aspect ratio but ensure that important portions of the image fall within a central 16:9 area of the frame. As an option to standard 4:3 aspect ratio equipment, the use of 16:9-capable SDTV systems, which either use an anamorphic squeeze technique or black out upper and lower portions of a 4:3 frame, are allowed under this standard. It is also recommended, but not required, that newly acquired SDTV cameras be capable of operation in both the 4:3 and the 16:9 image aspect ratios.

There are standards for progressive scan SDTV, also known as Extended Definition Television, or EDTV. This format demonstrated superior performance to that of normal interlace scanning. However, only a limited amount of progressive scan SDTV equipment has been available. The members of the DTVWG have felt that adopting a progressive scan STDV standard may be a confusing and unneeded intermediate step between interlaced scan SDTV and the progressive scan HDTV standard. Thus, a progressive scan SDTV system was not initially made a part of this standard. The possible future incorporation of progressive SDTV into this standard will be periodically reviewed.

APPENDIX B

DISCUSSION OF VIDEO/AUDIO SIGNAL SAMPLING REPRESENTATION, COMPRESSION, AND RECORDING FORMATS

Video Signal Sampling Representation

There are many video signal sampling structures used to digitize video. These structures are used to reduce the amount of raw image data to be processed without severely affecting the image content. Generally, the chroma (color) information is not sampled at the same resolution as the luminance (black-and-white) portion of the picture. The human eye perceives most resolution from luminance information. This practice allows color information to be subsampled, compared to luminance, without an apparent loss of image detail. As image luminance information and information in the green color spectrum are almost equal, luminance can be used to derive the green information. Red and blue information is then often subsampled to reduce overall bandwidth requirements. There are sampling structures that perform full bandwidth sampling, but these are primarily used for very-high-end video and still or computer graphics imaging systems. This type of sampling is expressed as 4:4:4, indicating that within a 4x4 block of luminance pixels, there is also a 4x4 block of both red and blue. For production video systems, 4:2:2, with a 4x4 luminance sample and two 2x2 blocks of red and blue, is the preferred standard. Acceptable acquisition formats for critical use sometimes use less than 4:2:2 but always perform complete color information sampling on every line of video. Other common sampling structures for acquisition formats are 4:1:1 and 3:1:1. SDTV systems such as DV, DVCAM, DVCPRO, and Digital 8mm use 4:1:1. The sampling structure used by the Sony HDCAM format is 3:1:1. The 4:1:1 and 3:1:1 formats provide a compromise among cost, complexity, resolution, and bandwidth requirements for acquisition systems. The most important factor in sampling video for critical acquisition, contribution, or production is to perform some sampling of all color signal information components on every scan line. This is necessary to have sufficient color information for further postproduction processing of the video. The 4:2:0 method samples the red or blue color components on every other video line. This method is used in consumer and lower quality industrial acquisition formats. It is also used for distribution to users on systems including DVD video, direct broadcast satellite, ATSC terrestrial broadcast, and Quadrature Amplitude Modulation (QAM) cable TV transmissions. Sampling at 4:2:0 is generally considered acceptable for the distribution of a finished product for user viewing, but not for the acquisition, contribution, or production of video for critical Engineering or Publication applications because of the limitations introduced by the reduction in color information.

Data word length refers to the number of bits used to represent the voltage level of a signal sample. In all cases, the minimum word length for NASA DTV systems shall be 8 bits. The formats of the SDI and HDSDI transmission standards allow the use of word lengths up to 10 bits. The use of more than 8-bit words to represent a signal sample provides a higher fidelity video signal with a better signal-to-noise ratio. Equipment that uses a word length of 10 bits or more is highly recommended for production systems and may also be used for acquisition or contribution systems. Most available distribution systems and media use 8-bit words, which shall be the minimum NASA standard for the distribution of signals, programs, and media for final viewing.

Video Signal Compression

Video compression is employed to enable the very high bit rate of uncompressed video to be reduced so that transmission or recording systems with limited bandwidth capabilities can be used or so that many video signals can fit within a given bandwidth. Compression for DTV uses multiple standards, depending upon the specific requirements and application. Unlike the compression normally used for data files, most digital video compression is lossy. A video signal that is compressed, transmitted, decompressed, and then reconstructed is no longer identical to the original signal. Typically, a higher amount of compression used results in a lower fidelity reconstructed video signal.

Many video compression systems in common use are based on the use of some form of Discrete Cosine Transform (DCT) encoding. Other available systems use wavelet encoding. Current systems for compressing DTV operate at data rates that range from less than 12 to 360 Mbps for HDTV and from less than 3 to nearly 100 Mbps for SDTV. The compression format used by many types of signal distribution equipment is MPEG-2, which is also the standard codec used for digital broadcast, cable, satellite, and DVD video distribution. The DTV working group has tested various MPEG-2 equipment and has developed recommendations for the selection of parameters such as the composition of the Group of Pictures (GOP) and data rate. Other available equipment uses different compression formats, including newer standard codecs such as H.264/MPEG-4 Part 10 Advanced Video Coding (AVC) and VC-1, plus some proprietary codecs. These newer codecs can provide similar performance to that of MPEG-2 at significantly lower bit rates, although there may also be an increase in encoder and decoder complexity and processing time. High-definition optical disc formats can use several different codecs, including MPEG-2, AVC and VC-1. Available equipment for acquisition, contribution, and production uses provide a variety of video compression techniques, so attempting to establish specific Agency standards for these systems is not really practical, although some guidelines for various quality levels have been developed based on testing and experience.

In order to maintain high quality, production systems must use higher data rates and low-ratio, intraframe compression on nonsubsampled or resolution-filtered video. If using intraframe 4:2:2 MPEG-2 or DV compression, production equipment should use a compression ratio of 5:1 or less. For acquisition systems, it is often necessary to use somewhat more compression than for production equipment, but it is preferred to use intraframe compression in this case also. This better captures temporal information. Video with significant changes from frame to frame severely challenges interframe (GOP-type) compression systems. Compression requirements for contribution video are less stringent than for acquisition or production. An HDTV signal compressed to about 30 to 45 Mbps using 4:2:2 MPEG-2 with a long GOP can be used as a contribution source, such as for media release or for input into production systems. This also represents a good range of target rates so that E-3 (34.368 Mbps) and T-3 (44.736 Mbps) long-haul transmission services can be used. DTVWG tests have shown that low-motion NASA SDTV can be compressed using 4:2:2 MPEG-2 with a long GOP to as low as 8 Mbps and still be used as a contribution source. Compressing an HDTV signal to 19.4 Mbps or less, using the ATSC A/53 transmission standard, results in a picture that is suitable for real-time viewing but has typically lost too much information to be usable as a contribution input for production. The compression of progressive source material has been shown to be more efficient than the compression of interlace material. Tests have shown that the viewing quality of 4:2:0 MPEG-2 compressed 720P can be adequate with average rates of 12 Mbps. Low-motion, subsampled SDTV 4:2:0 MPEG-2 compressed to as low as 3 Mbps can still provide good viewing quality. However, whenever possible, a data rate higher than these minimums should be used.

Audio Signal Sampling and Compression

The digital audio production standard is AES3 (also called AES/EBU). AES3 defines a high-fidelity, uncompressed stereo audio signal with an approximate data rate of 3 Mbps. This is more than adequate for most normal Agency use. However, there may be a requirement for six or more production audio channels. Since most video recorders can record no more than four audio channels and most distribution infrastructures can distribute only two audio channels, a technique for adding production-grade audio tracks to allow six or more channels of sound is needed. The Dolby E system is a popular solution available to accomplish this. One significant feature of Dolby E is that the interface to other equipment is at the normal AES3 level. Dolby E allows up to eight channels of audio to be compressed into an AES3 channel. Using AES3 as a common standard allows Dolby E or another similar system to be added without modification to existing digital audio systems.

The digital standard for audio that accompanies a long-haul contribution video signal is MPEG-1 Layer 2 (ISO 11172-3). This compression method can incorporate digital audio input signals sampled at several rates, including 32, 44.1, and 48 KHz. Using this method, the audio data rate can be reduced significantly and still maintain a level of quality suitable for production use. It has been demonstrated that 16-bit, 48-KHz sampled audio can be reduced to 128 Kbps with no readily detected change from the original signal.

The FCC standard for audio to accompany U.S. broadcast DTV is Dolby AC-3 (also called Dolby Digital). AC-3 provides the capability to transmit compressed digital mono-, stereo-, or multichannel audio. AC-3 includes a system for multiplexing up to five full-bandwidth audio channels and one reduced-bandwidth, low-frequency effects (subwoofer) channel into a single digital signal. Because of the reduced bandwidth of the sixth channel, this is usually called a 5.1-channel sound system. Audio that has been encoded with AC-3 into 5.1 channels has been processed such that it is not possible to decode the sound into 6 discrete channels of sufficient fidelity for production. AC-3 processing takes advantage of many psycho-acoustic characteristics of human hearing to reduce bandwidth. The result of this processing is that individual channels will often be missing large amounts of audio information because sound in one channel masks the lack of sound in another.

Recording Formats

Tape, disc, and solid-state formats can be used for recording DTV, and there are multiple variations of each type available. Videotape recording formats are typically restricted by the signal sampling and compression designs of specific vendor equipment. Data tape, solid-state, and magnetic or optical disc-based formats can be more flexible regarding signal sampling and compression choices, depending on how the compressors are integrated into the system design. A vendor that packages a codec with his system may only offer support of certain compression schemes. Other vendors market their products as a general-purpose recorder able to accept almost any data format.

There are several professional digital videotape recording formats that support HDTV. The Philips/YEM D6 format recorder is an uncompressed data recorder that can record HDTV. Panasonic produces the HD-D5 format, which was originally designed as an SMPTE 125/259M recorder for standard-definition component serial digital video at 270 Mbps. With the addition of a codec and SMPTE 292M inputs and outputs, the D5 became an HDTV intraframe recorder. There is no subsampling of luminance or chroma in HD-D5. Panasonic also has DVCPRO-HD, which uses ¼" tape and records at approximately 100 Mbps. It is capable of working in both interlace and progressive modes, although the horizontal resolution is reduced from 1920 to

1280 horizontal luminance pixels in the 1080i mode and from 1280 to 960 pixels in the 720p mode. Sony makes HDCAM, which is a 145-Mbps, 1080-line-based HDTV recording system. HDCAM initially captures a 4:2:2 sampled picture at full 1920x1080 resolution and then performs subsampling. Horizontal resolution is reduced from 1920 to 1440 pixels in luminance and from 960 to 480 pixels in each of the color channels. The end result is a picture that is sampled at 3:1:1 based on a 1440x1080 picture. HDCAM-SR is a higher quality variant of this format that records 1080 video at full resolution. Some other HD formats are no longer available. Sony formerly made a 1" reel-to-reel uncompressed HDTV recorder, the HDD-1000, but it is no longer manufactured. JVC made the D9-HD (Digital-S100) tape format that had the same electrical characteristics as DVCPRO-HD but used a ½" tape format.

As SDTV became popular, several other video recording formats were introduced. These included tape formats such as DV, DVCAM, DVCPRO, DVCPRO-50, Digital-S, Digital Betacam, Betacam SX, and MPEG-IMX. Other consumer formats that record directly to DVD video, hard disc drives, or solid-state memory also appeared. The most common signal interface for professional SDTV digital recorders is SMPTE 259M. There are other available interfaces, such as Institute of Electrical and Electronic Engineers (IEEE) 1394 (also known as Firewire and iLink). IEEE 1394 is primarily used as an interface between DV-based acquisition/recording equipment and desktop computer-based nonlinear editors. IEEE 1394 cannot normally be routed over long distances, which precludes its use as a primary interface for distribution.

Other professional acquisition formats that record using other than tape media are available. Some can also record either SDTV or HDTV. Sony has the XDCAM/XDCAM-HD format, which records 480 or 1080 video on optical discs. The Panasonic P2 and Grass Valley Infinity formats record 480, 720, or 1080 video on solid-state memory. A newer, improved version of the P2 format uses an intraframe version of the AVC/H.264 codec to provide performance at a 100 Mbps rate that is similar to that of the HD-D5 format, but at less than half the bit rate. The Ikegami Editcam uses a hard disc drive pack or solid-state memory to record HD video.

As the development of DTV equipment has progressed, there have been lower cost HDTV acquisition systems developed and introduced for the consumer and industrial markets. These include the HDV and AVCHD camcorder formats, which have been available in both interlace and progressive models. HDV is based on the DV tape format but uses the MPEG-2 codec to compress an HDTV signal to fit within the 25 Mbps recording capability of the DV tape. Tests were performed by the DTVWG on several higher grade HDV camcorders to gauge their performance. In general, the camera performance of these units was quite good, even though they used very small image sensors and lower cost lenses. However, the performance of the recording portion was not. The recordings showed considerable compression artifacts. The AVCHD format uses the AVC codec at low bit rate and also highly compresses an HDTV signal. AVCHD typically uses solid-state, hard drive, or optical disc recording. These HDV and AVCHD systems are not considered suitable acquisition formats for most NASA HD requirements, principally because they use 4:2:0 signal sampling and also employ a very high amount of interframe video compression, which causes visible image artifacts. Although it may be tempting to use this equipment because of its compact size and relatively low cost, the use of equipment in these formats is discouraged. It is expected that the development of HDTV acquisition systems will continue and that other formats using AVC, VC-1, MJPEG-2000, or other codecs will appear.

There are separate units that record using other media. Some record video directly to optical disc. Like the lower cost HDTV acquisition systems, these typically use 4:2:0 sampling and a high amount of interframe compression, resulting in distribution-quality recordings at best. There are also several recorders available that use hard disc drives and a variety of different codecs. Some compact units that use an IEEE 1394 interface can serve as portable outboard recorders attached to DV-based camcorders. Some fixed units are PC-based; others are rack-mount units. Other higher quality units can be used as a substitute for a tape recorder. A particular hard drive recorder format that has met several critical NASA Engineering, plus some Publication, video requirements is marketed by Quvis. This format uses a wavelet-based codec. It meets all NASA specifications in this standard for acquisition and for production-level recording. It uses 4:2:2 sampling, up to 12-bit words, has no resolution subsampling, and uses intraframe compression. It is also multiformat, being able to record both SDTV and HDTV.

A primary issue with both SDTV and HDTV acquisition formats that use less than full resolution and other than 4:2:2 sampling, such as DV, DVCAM, DVCPRO, HDCAM, HDV, and AVCHD, plus many hard drive, solid-state, and optical disc recorders, is the inability of these formats to withstand multiple decoding and re-encoding cycles without degrading the image. As discussed earlier, the process of encoding a video signal eliminates some of the original image information. The more an image is compressed, the more information becomes irretrievably lost. Performing successive decode and re-encode cycles, as is done when transferring a signal between devices that use compression, will result in picture degradation. If the production processing needed to fulfill a particular video requirement is limited to simple cuts-only editing and duplication, then using an acquisition format to produce a video product is acceptable. Studio versions of acquisition recorders have “dub” mode capability, which allows a bit-for-bit clone of the original material to be made when editing and duplicating. However, complex video production incorporating keying, animation, graphics, and other effects often requires multiple cycles to and from tape, even when nonlinear editing is employed. Manufacturer tests from Panasonic, along with anecdotal information from Sony and Turner Entertainment, indicate that HDCAM and DVCPRO-HD begin to develop compression artifacts starting with the fifth decode/encode cycle. Testing by Turner Entertainment indicated that an HDTV recorder that does not subsample luminance and chroma and that keeps compression at 5:1 or less shows no compression artifacts after 20 decode/encode cycles.

Several non-tape recorders, including the Quvis hard disc format, the DV or 100 Mbps AVC Intra versions of the P2 solid state system, the Infinity solid state system, the Editcam hard disc format, and the standard definition XDCAM optical disc system meet or exceed the NASA standards for acquisition systems for critical Engineering and Publication applications. Available component digital videotape recording formats that also meet or exceed these standards include the following:

HDTV: HD-D5, D6, D12 (DVCPRO-HD), HDCAM-SR (for 1080P only).
SDTV: Preferred 4:2:2 systems: D1, D5, D9 (Digital-S), D10 (MPEG-IMX), Digital Betacam, and DVCPRO-50. Allowed 4:1:1 systems: Digital 8mm, DV, DVCAM, D7 (DVCPRO).

Most contemporary postproduction is performed using nonlinear editors that typically use either no compression or compression schemes that meet or exceed the NASA standards for production systems. Available component digital tape-recording formats that also meet or exceed these standards include the following:

HDTV: HD-D5, D6, HDCAM-SR (for 1080P only).
SDTV: D1, D5, D9 (Digital-S), D10 (MPEG-IMX), Digital Betacam, and DVCPRO-50.

APPENDIX C

DISCUSSION OF INTERFACES

Within the video industry, the realm of interfaces for DTV is an area that is not completely settled. As this situation becomes more stable with the maturity of regular DTV program production and distribution, it may be necessary to update existing or to introduce new interface standards for NASA. Listed below are examples of the information needed to specify interfaces:

- Electronic Medium
  - Satellite
  - Terrestrial

- Recorded Medium
  - Videotape Formats
  - Disc, Solid-State, or Other Media Formats

- Signal Characteristics
  - Physical Interface
  - Electrical Interface
  - Signal Protocol
  - Transmission Type
  - Transmission Protocol

There exist signal standards for the transfer of uncompressed DTV from one piece of equipment to another. SMPTE 292M-2004 is the High Definition Serial Digital Interface (HDSDI) standard for HDTV and uses a data transfer rate of approximately 1.5 Gbps. SMPTE 259M-1997 is the Serial Digital Interface (SDI) standard for SDTV and nominally transfers at a rate of 270 Mbps but can also be used at 360 Mbps. There also exist standards for the transfer of compressed DTV between pieces of equipment. One of these is the Digital Video Broadcasting Asynchronous Serial Interface (DVB-ASI) standard, which defines a method for transferring compressed video over a standard 270 Mbps SMPTE 259M system interface. There is also the Institute of Electrical and Electronic Engineers (IEEE) 1394 (also called Firewire and iLink) interface standard, which is primarily used to connect equipment that uses the DV standard.

Other interfaces for DTV systems internal to NASA will need to be defined for several areas. One of these is between systems for receiving from or transmitting to spacecraft and systems that provide ground video distribution and processing services. As spacecraft such as the Space Shuttle and the International Space Station develop DTV capabilities, those systems will need to provide interfaces compliant with the ground DTV system standards. This rule will also need to apply to other NASA program or project spacecraft, aircraft, test facility, and laboratory video as well. If particular imaging requirements make the use of nonstandard or unique video systems necessary, the signals generated by these systems will need to be converted in order for these projects to be able to use the video recording, production, and distribution services provided by the standards-based ground infrastructure. This infrastructure includes services to support the distribution of information as required by the NASA Charter. Programs or projects that use nonstandard video methods will probably also need to provide the equipment used to distribute, record, and display that imagery in its native format.

Another internal area needing DTV interface definition is the transfer of video between NASA Centers. While the responsibility for providing inter-Center video distribution services belongs to the NASA Integrated Services Network (NISN), the technical specifications for the interface to these services will be defined by the DTVWG and used by all of NASA to ensure a quality DTV interchange capability. The current inter-Center multichannel DTV capability, some mission video support systems that transfer video packaged in the Internet Protocol, and systems that use more traditional video transmission techniques have been configured with equipment that uses the standard DTV signal interfaces described above.

The definition of interfaces for the transfer of DTV external to NASA is also necessary. External interfaces include other Government agencies; NASA partners such as the Canadian Space Agency (CSA), the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), and the Russian Space Agency (RKA); universities; industry; and the news media. In many cases, transfer of digital video only requires informing those organizations in which picture format NASA DTV will be distributed and which signal transfer interface is to be used, but in others it may require negotiating specific signal conventions, formats, or conversion responsibilities.