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Moving Image Preservation: Basic Training

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D5: The Mighty VTR

D-5 is one in a series of what are commonly referred to as the "D-series" formats, the line of pioneering digital video formats that first emerged in the mid-1980's. Introduced by Panasonic in 1993, the half-inch digital video tape recorder (VTR) designated as D-5 marked an important move away from analog recording with all of its inherent limitations, such as noise and interference, distortion and instability in the video signal (Luther 4). D-5 also marked a significant step forward for the digital videotape format itself, as its use of component signal processing, 10-bit quantization, and increased playing time compared to previous digital cassette formats made it ideal as a postproduction format that is still widely used today, albeit in a high-definition format, in both filmmaking and broadcast television postproduction. The format's success in these areas of digital content production furthermore also helped to cement Panasonic's status as a flourishing electronics manufacturer in the early 1990's.

D-5 developed in an interesting time for television production, one marked by the gradual, reluctant embrace of digital broadcasting standards. Japanese electronics companies had been developing digital video technologies since the mid-80s, starting with the 1986 release of the 19mm D-1 format. At the same time, the Japan Broadcasting Corporation, also known as the NHK, had invested up to $1.3 billion and fifteen years of research and development into analog high-definition television technologies. By 1991, the production standards for Hi-Vision/MUSE, as the broadcasting/satellite technology would come to be called, had been set in stone. The NHK did not actively encourage the development of digital technology as a result; having invested so much money into Hi-Vision/MUSE, it was of utmost importance to promote the new analog HDTV technology so as to reap the public-broadcast revenue provided by assessing fees on viewers, making the technology available for domestic television studio purchase, and by exporting the technology overseas (Gerbarg 277-79).

Manufacturing companies, such as Sony and Panasonic, wore two faces regarding the digital/analog HDTV divide. It made economic sense to push analog HDTV given the volume of Hi-Vision cameras, recorders and TV sets that had been produced at the behest of the NHK, but these same companies believed that digital transmission and recording would be extremely beneficial for broadcasting. With digital, material can be edited throughout multiple generations with no noticeable loss in picture quality, provided the signal data remains in the digital domain (Anderson 51). In 1993, the MUSE transmission system did not test well compared to digital systems at an FCC Special Panel trial, and it was announced in 1994 that a digital HDTV system would be developed that would replace Hi-Vision/MUSE (Gerbarg 280-1). This did not immediately happen; however, the development of digital technologies such as HDCAM and D-5 VTRs helped to usher in this new digital age of television in both Japan and across the globe.

The Society of Motion Picture Television and Engineers (SMPTE) developed the standard for D-1 ¾-in. (19mm) digital video tape in 1984. The early development of digital video focused largely on video recording and special effects, as these were the two areas where the difference between analog and digital made the largest difference (Luther 56). Many of the digital formats that followed thereafter differed largely in terms of bandwidth and signal processing (Whitaker 283). D-2 video, developed by Ampex in 1988, used the same kind of cartridge as D-1 but was a composite format. Additionally, it sold for about half the price as D-1 and used four audio channels instead of two. Though designated with a larger number, D-2 proved inferior to D-1, largely due to its composite processing signal which proved incompatible with postproduction equipment. In 1991, Panasonic announced the launch of D-3, a new ½-inch composite format based off the D-2 standard. In addition to having a different tape width, the D-3 could also be attached to a half-inch camcorder, something not permissible with bulkier ¾" tape. The appeal of this set up was not lost on television stations, including the BBC and USA Networks, who both claimed D-3 as their in-house standard for television broadcasting (Anderson 244).

D-3 enjoyed an initial period of success, but at the National Association of Broadcasters convention of 1993, Panasonic had announced a long talked-about new digital format which would come to be known as D-5, a ½-inch, 10-bit uncompressed composite format. At this same convention, Sony and Ampex announced the launch of Digital Betacam and DST 600 tape drive, respectively. Representatives from Panasonic Broadcast Europe and Japan's Matsuhita Electric Industrial announced in a publication for a conference held by the International Broadcasting Convention in 1994 that "the D5 is unique in the way that it addresses the challenges presented by changing technology" (110). Matsuhita claimed in 1994 that the Panasonic D-5 VTR was the best video recorder on the market, two weeks after a now-struggling Ampex made a similar claim about the DCT 1700d (Anderson 252).

D-3 and D-5 share the same container as specified in SMPTE 263M, the standard for 1/2-inch digital television recording tape cassettes. SMPTE 263M makes use of three different sizes of cassette, labeled as small, medium and large. The small- and medium-size cassettes use reels with 30-mm and 50-mm hub diameter sizes, respectively, whereas the large reel uses a 44-mm hub. The diameter of the reels in small cassettes is listed as 78.5mm, the minimum desirable length to prevent the occurrence of flange pack, which occurs when tape winds around the reel flanges. In medium and large cassettes, this length is given as 103.5 and 146mm, respectively. Similarly, a maximum length is established to ensure that there is no tape contact with cassette components. The standard thickness of D3 and D5 tape is either 11 or 14 µm, with the length differing depending on its thickness. In a large D5 cassette, the length of the tape is roughly around 1237 m. There are two sets of identification holes in the SMPTE standard D3 cassette, one for the use of the manufacturer (three small holes aligned vertically between the reels) and one for the user (one placed above each reel and one placed in the bottom middle of the cartridge). The holes are used to identify the thickness, hub diameter and magnetic field strength (measured in oersteds) of each cassette, according to the presence or absence of indicator tabs in each of the manufacturer holes. (SMPTE 263M 486).

D3 and D5 cassettes both feature polyester-based leader and trailer tape attached to the hub that measures approximately 12.65 µm wide by 14-36 µm thick. The reels differ in size depending on the size of the protective cassette. When the cassette is either loaded into or removed from a recorder or player, the reels are either unlocked (if loaded) or locked (if removed) by a device called the lighthouse inside the cassette and are held in position by a reel spring. The lid is unlocked by either inserting a cassette into a recorder/player or by exerting pressure on a release pin. When removed from the recorder/player, the lid locks automatically (SMPTE 263M 496). D-5 tape moves at slightly over 168 mm/s, or about twice the speed of D3 tape, in order to maintain a similar track pitch while doubling the number of recording channels (Suesada et al., 509). The D-3 VTR has ten heads, but the D-5 was built with eighteen heads (two sets of four playback heads, two sets of four recording heads, and two erase heads) (Suesada et al., 508). The doubled speed, coupled with the doubled record heads, ensures that D-5 remains backwards compatible with D-3.

Like most professional digital VTRs, D-5 employs an error rate display to monitor recording error rates. Recording is an imperfect process, and in analog recording, noise and dropouts are a common occurrence. Error correction systems in digital VTRs go some way towards "fixing" data by identifying the bits in the data signal which are in error. Digital recorders offer the ability to D-5 machines offer degradation-free post-production environment with no need for regular realignment. That D-5 is uncompressed makes it even more ideal as a postproduction format, as compression techniques impose performance limitations. Compression converts streams of sampled data into blocks, with pauses inserted between each chunk of data. While this allows for some recording benefits insofar as establishing synchronizing patterns is concerned, it can also hamper the quality of the image in shuttle (Watkinson 509-14).

What are ultimately significant, however, are the differences between D-3 and D-5. D-3 employs a composite video signal, in which the luminance (brightness) and chrominance (color) elements of the signal are combined in an encoder, for instance either the NTSC or PAL formats ("Composite Video", NFSA website). Composite video, while acceptable looking, causes problems in post production due to the fact that decoding the signal into pure luminance and chrominance is impossible to perform neatly. Component video, such as D-5, on the other hand, uses a subtractive method that bypasses encoding entirely. The original red, green and blue video signals, collectively known as an RGB signal, are translated into a high-resolution luminance signal (written as Y) and two lower-resolution chrominance signals (written as B-Y and R-Y), which together make one component signal. This leads to improved image quality, but at the expense of higher bandwidth (Mellor 58). The video signal in D-5 is sampled at a rate of 4:2:2, indicating that the luminance signal (the 4) is sampled at twice the rate as that of the chrominance signals (the 2s, which represent B-Y and R-Y). In other words, the red and blue channels of the video signals together take up half the bandwidth of the luminance information. (blackmagic-design.net).

D-5, like all of the digital formats that preceded it, uses a tape-loading mechanism involving three different sizes of cassette accommodated on a single drive by moving reel spindles. Because of this complex cassette design, D-5 is not ideally suited to mass distribution in the same way that simpler formats that require more complex playback mechanisms are (Mee et al., 5.24-25). D-5 employs azimuth recording, an innovation that began with the advent of D-2. Formats such as D-1 had formerly made use of an empty space between video tracks, known as a guard band, to prevent crosswalk between tracks. With D-2, video engineers had figured out how to eliminate the guard band by employing azimuth (rotating from perpendicular to alongside) alignment of the tape to the heads of the VTR. If the heads are misaligned with the track during recording, this causes a severe loss in signal during playback when there is proper head alignment. Azimuth recording allows for the elimination of guard bands, an increase in recording density, and reduces the sensitivity to tracking errors during the recording process (Luther & Inglis, 284).

A number of new advancements were also introduced with the D-5 format, including that of video randomization. Before any outer encoding of data can occur in D-5, a process of randomization must first happen in order to fix the "flat" signal areas in the picture wherein the correlation between video data is high. This process minimizes the recorded video data correlation, and in turn stabilizes the error rate during recording (Suesada et al. 516). D-5 is also unique from D-1, its earlier component digital predecessor, in that it can accept data at either an 18-MHz sampling rate with 8-bit quantization, or at an 13.5-MHz sampling rate with 10-bit quantization. The D-5 can convert from the latter to the former to achieve efficient and identical processing regardless of the input signal (Suesada et al. 515). This also makes the use of D-5 suitable for both standard 4:3 and widescreen 16:9 aspect ratios (Caranicas 7).

In late 1995, a Fox affiliate in Seattle, KCPQ, purchased over twenty D-5 VTRs, as well as a dozen all-digital broadcast monitors. At the time it was the largest sale of D-5 equipment to a television station, priced at roughly $1.5 million. For KCPQ, the D-5 standard was used in most aspects of broadcasting, including master control, production and post-production, and even archiving (Dickson 44-48). In 1997, however, Panasonic announced at the National Association of Broadcasters conference that they would be rolling out a line of D-5 players with built-in 4:1 compression. These video tape recorders are known as HD D-5 VTRs. The same kind of D-5 cassette is used but HD D-

5 cannot play back standard definition D-5 tapes. It can, however, play back several other high definition standards and can also play back and record at different frame rates (Weise and Weyland 193).

By the end of the year 2000, there were four prominent high-definition digital video recorders on the market[1]: Panasonic's D5-HD and D7-HD, Sony's HDCAM, and JVC's D9-HD. Of the four, D5-HD was often recommended as the one most suited for use by broadcast and film postproduction facilities on account of its cost and the quality of its image. By 1999, ABC, CBS, PBS and Fox had adopted the D5-HD as an in-house production standard for program delivery (Bankston & Holben 109-110).

The AJ-HD3000 model of D5-HD VTR can record 10-bit, 4:2:2 sampled full-bandwidth, high-definition digital video with four channels of audio on a ½-inch cassette. Additionally, the player is capable of recording metadata and playback capabilities.

The HD D-5 VTR is capable of high picture quality digital recording of video and audio signals, and is an ideal format for studio work thanks to its compact size, flexibility of function (the VTR can switch between several different system formats for recording and playback purposes), light weight, and low power consumption (Panasonic 6). The VTR comes equipped with a number of input/output functions such as format conversion between HD and SD, a serial digital interface that allows for audio and video to be transferred along the same coaxial cable, and a remote control. Automatic and manual editing (i.e. without registered edit cue points), simultaneous playback monitoring of

[1] As Peter Utz notes in a 2000 article for *Video Systems*, these were by no means the only digital formats that were in use at this point, such as JVC's W-VHS, an analog component video recorder/player used to play HDTV recordings, and D-VHS, sold by JVC and Panasonic and used in recording and playback of MPEG-2 data streams (cf. Utz, "Tale of the Tape", *Video Systems*, Overland Park: Jan. 2000, 26(1), p. 76-80).

video, digital audio, time code and CTL signals, slow motion, jogging and 50x shuttle speed are further features of the HD D-5 VTR. In addition, there is internal monitoring of error rates and a self-generating test signal and color bar generator, used to conduct maintenance and adjustments (Panasonic 7).

HD D-5 is largely used in postproduction of film and broadcast television programs. While uncompressed D-5 can in theory be used in production, a single frame would take up about 1.5 gigabytes' worth of information, more than output computers in most production houses can possibly handle. Hence, HD D-5 must be coupled with a compression processor that can greatly reduce the size of the output without significantly impairing the image quality (Browne 63-64). By way of example, an HDCAM original video camera master can be dubbed onto HD D-5. which can then be transferred to another format such as DVCAM for offline editing (Browne 130-1). On the other end of the scale, a television program, fully assembled with Final Cut Pro, could then be transferred to HD D-5 for the purposes of color correcting. The corrected footage can then be "up-rezed," or increased in resolution, to a format such as Digital Betacam, from which a DVD copy can be made for screening purposes (Browne 142-3). It is beneficial to use D-5, or a similar component digital VTR such as D-1 or Digital Betacam, as the mastering format for color correction since most telecines use component inputs and outputs. Composite formats such as D-3 could still be used but the improvement in quality afforded by a component format like D-5 for color correction is considerably pronounced (Barclay 171).

In March of 2000, *American Cinematographer* reported that the Post House production facility had instituted D-5 as its primary recording format, and furthermore that the entire facility would be outfitted with high-end digital Panasonic equipment. This was indicative of a sea change in the relationship between postproduction facilities and equipment manufacturers in light of the advent of HD video technologies. Many postproduction facilities could not afford to introduce an entirely new line of digital formats into their businesses. In exchange for purchasing Panasonic's equipment, the Post House was able to institute a number of postproduction practices used solely with HD technology, including editing and generating imagery and producing dailies in HD (Kaufman 12). A similar deal was struck with the Four Media Company, who likewise agreed to outfit all of their postproduction facilities with Panasonic's HD equipment. This was no doubt motivated somewhat by Sony's concurrent development and subsequent push of their HDCAM VTR format (*WBE* 14).

D-5, for all that it improved upon its forebears, did manage to enjoy some stiff competition from other formats. D-5's chief competition at the time of its release was Sony's Digital Betacam. Like D-5, digital Betacam employed multi-format playback (some models can play both analog BetacamSP tapes and digital Betacam tapes) and a component recording process with a 4:2:2 compression rate. Digital Betacam also made use of four separate and distinct audio channels, as well as a separate analog cue track used for location specific audio portions of a recording (Weise and Weynand 193). Furthermore, other contemporary high-bitrate recorders such as D6 and HDD1600 actually provided the best image quality but those formats offered that quality at prohibitive prices, making them impractical for television production. Standard definition recorders such as D5 or DVCAM would likewise be unsuitable for heavy-duty production use unless assisted by an encoding processor. In such an event, the quality of the image ran a slight risk of being compromised by compression artifacts, although it definitely existed as a viable option for production houses that could not spend money on HD equipment.

Shortly after D-5 appeared on the market, a number of new digital formats appeared. In 1995, DV was established as the first consumer-grade digital format. The format provided 8-bit recording and 4:1:1 color sampling with 5:1 compression and was developed by a consortium of electronics companies. In addition to regular DV, MiniDV was developed as a more compact version of the DV format that used the same technology and a smaller cassette (Vaughan 213). Based off of the DV template, Panasonic themselves introduced the DVCPRO professional digital videotape recorder at the National Association of Broadcasters 1995 summit in Las Vegas. DVCPRO, known to a lesser extent as D-7, was a 6mm (1/4-inch) tape format that used a component digital 4:1:1 recording format and a 5:1 intra-frame compression scheme, and could play two sizes of cassettes, 63 and 123 minutes in length respectively. As the format was designed with electronic news gathering in mind, the DVCPRO was also fitted out with a camcorder, a portable field edit package, a palm-sized player and a studio VTR (Epstein 21). Not to be outdone, Sony launched a competing product called DVCAM in 1996. Both DVCPRO and DVCAM offered high-quality, low-price digital recording opportunities for industrial and prosumer use. DVCAM, like DVCPRO, uses 8-bit component digital recording, 4:1:1 color sampling, and is NTSC-compatible (in DVCAM's case, with 530-line color resolution). DVCAM was also used for electronic news gathering; along with DVCPRO, the two formats were both heavily used in news coverage of the 2003 war in Iraq (Vaughan 213).

As of this writing, the D-5 format has been in use for fifteen years, counting both its SD and HD incarnations. Programs such as NBC's *Heroes* (Silberg 34), George Lucas' *Star Wars, Episode I: The Phantom Menace*, and ABC's Super Bowl slow-motion replays (*Business Wire*) have made copious use of HD D-5, and it is still used by many postproduction facilities and broadcast stations to this day. Given the sheer amount of overturn in video's relatively brief history of 50-some years, this is fairly remarkable. Many formats, digital or otherwise, led brief lives, their utility hampered by technological restrictions, extravagance in cost, or clumsiness in size. D-5's flexibility, relative affordability and compact ½" container have given it a distinct edge over other digital formats.