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Moving Image and Sound: Basic Issues and Training

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The ABCs of the GD-ROM

The Gigabyte Disc Read-Only Memory , or GD-ROM, was a relatively short-lived (compared to its contemporary CD-ROM and DVD formats) optical disc based media produced by the partnership of Yamaha and Sega, which was utilized primarily in Sega's console and arcade machines. This paper will cover the history of the media, its physical properties, file structure, the targeted user base, and associated content and equipment used to play these discs. In addition, I will examine why Sega terminated the GD-ROM's production by exploring competing formats, formats that preceded and followed, and shortcomings of the media. Finally, the fact that the GD-ROM is now out of production and is home to original games raises questions and concerns in terms of preservation. I will examine any issues and concerns that have arisen preserving these discs and associated content, as well as list a few solutions which archivists and the community have put forward.

I. Time Period

As previously stated, the GD-ROM was developed by Yamaha exclusively for Sega's home console, the Dreamcast, released in Japan in 1998, as well as its arcade counterpart the NAOMI (New Arcade Operation Machine Idea), which was released around the same time. Although the Dreamcast met an early production demise due to poor sales in 2001, Sega still supported the console, NAOMI, and subsequent Sega arcade platforms such as the NAOMI 2, Chihiro, and

Triforce with new software utilizing the GD-ROM for a few years after that.[1, 2] The website The Dreamcast Junkyard offers the following timeline of the final GD-ROM releases stating, "On January 18th, 2007, Sega announced that by the end of February they would no longer be pressing any new GD-ROM discs."[2]

- 2006 – Last Naomi 2 GD-ROM game, Initial D Arcade Stage Ver.3 - Cycraft Edition, Rev.B [GDS-0039B]
- May 2006 – Last Triforce GD-ROM game, Virtua Striker 4 Ver.2006, Rev D [GDT-0020D]
- September 2006 – Last Chihiro GD-ROM game, Sega Network Taisen Mahjong MJ 3 Evolution, Rev.A [GDX-0021A]
- December 2006 – Last Naomi GD-ROM game, Noukone Puzzle Takoron [GDL-0042]
- March 8, 2007 – Last (official) Dreamcast game, Karous [T-47803M]
- July 27, 2009 – Last Naomi ROM cart. game, Star Horse Progress Returns (satellite) [840-0186C]

As the GD-ROM was never produced for consumer use, these last game pressings marked the end of the disc's life, rendering the format dead.

II. Physical/Chemical Makeup & File Structure

For all intents and purposes, the physical and chemical make-up of a GD-ROM is very similar to the CD-ROM. Even when looking at one of the patents filed with regards to the GD-ROM, in US Patent Number 5,627,895, it still refers to the burgeoning technology as a CD-ROM. It describes it utilizing a plastic substrate with a region of pits for game data and other information, the upper side of which is covered by a metallic layer, possibly aluminum, and

[1] Bill Loguidice, *Vintage Game Consoles : An Inside Look at Apple, Atari, Commodore, Nintendo, and the Greatest Gaming Platforms of all Time*, ed. Matt Barton (Burlington, MA: Focal Press, 2014).
[2] The dreamcast junkyard, 2015, http://www.thedreamcastjunkyard.co.uk/2015/06/guest-article-forensic-examination-of.html.

finally a protective layer is applied on top of that, normally an opaque material listing the game title, trademark, author, and any other relevant information.[3]

One way in which the GD-ROM does differ from a normal CD, is the way in which the regions on the substrate are divided up. A PowerPoint Presentation by Dylan Bromley, a former software Engineer at Sega of America, gives insight into the data areas, file structure, and mastering of the GD-ROMs. He categorizes the data areas into two sections. The inner rings closer to the disc hole are a low-density area, which can hold about 35MB of data, while the outer rings are considered a high-density area, able to hold about 1GB of data. Within these low- and high-density areas are track types which can be read, the first being Compact Disc Digital Audio (CCDA), which are just raw audio files, and then Mode1, which contains the actual game data.

According to Bromley's presentation, there are two sessions present on the disc, each containing specific tracks. Session 1 is the low-density area which contains a Mode1 track which buffers the GD-ROM, allowing it to boot, as well as a CDDA which contains audio that could be played in a normal CD player. Session 2 is in the high-density area which contains a Mode1 track to buffer and finally another Mode1 track containing the game data which contains a .bin file, which is physically the outer most track on the GD-ROM.[3]

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[3] *United States Patent: 5627895 - Electronic Device for Detecting Selected Visually Perceptible Indication Information on an Information Storage Medium for Security Comparison*, ed. Ltd Sega Enterprises JP. http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&co1=AND&d=PTXT&s1=5627895.PN.&OS=PN/5627895&RS=PN/5627895.

The .bin, or binary file, is the first file read in the system and is necessary for the disc to be read at all, and includes the game executable as well as metadata such as the hardware ID, maker ID, device information, release date, and game title.[3]

III. New Technological Capabilities

While the GD-ROM is ostensibly a CD-ROM, there are three key features that were introduced that set them apart.

Firstly, the most obvious feature lies within the name of the GD-ROM, the gigabyte. The CD-ROM's capacity at the time was only 650MB, whereas the GD-ROM could hold up to 1GB. Sega was able to achieve this by packing the pits containing the data closer together in the high-density area of the disc. The GD-ROM drive would then be able to read the disc at a slower speed to scan this higher density area.[4] This leads us to the second new capability, the ability for the GD-ROM to be read at various speeds.

In Electronic Gaming Monthly's teardown of the console in their February 1999 issue, they note that the GD Drive Motor can spin in both CAV and CLV speeds.[5] CAV meaning constant angular velocity, a process in which the motor will spin at a constant speed when reading or writing a disc. A notable example of this is the vinyl record. Because the motor spins at the same speed, the outer edge of the disc is spinning faster, which creates a higher density area of data, hence the higher density areas described in Bromley's presentation. This contrasts

[4] "Sega Dreamcast GD-ROM (1998 - 2001)."https://obsoletemedia.org/gd-rom/ (accessed Oct 10, 2020).
[5] Chris Johnston, "Hands on: Dreamcast
," *Electronic Gaming Monthly,* Feb 01, 1999, 26.

with CLV or constant linear velocity in which the read and write speed remains the same throughout the disc, maintaining the same data density throughout. This method was used in CD-ROMs. This use of CAV and CLV speeds gave the GD-ROM the flexibility to read data at varying degrees, and helps further explain how they were able to get more data on the disc. It is interesting to note that this use of both CAV and CLV was not truly groundbreaking, as this varying read speed was utilized in LaserDiscs, but it was new to the CD-ROM format.

The final new technological capability departs from the storage capacity and into the realm of antipiracy. This technology is listed in US Patent 5,627,895, which goes into great, and sometimes obtuse, detail but the core of the technology utilizes a random number generator built in the GD-ROM drive. The random number generator picks random numbers and selects the corresponding tracks on the GD-ROM to be read. This data is then read off the optical disk, and then compared to reference data stored in the drive and essentially runs a checksum, looking for any discrepancies in the two sets of data. Should this data match, it returns a YES and runs the game. Not surprisingly, should it find any errors, it returns a NO and the game stops running.[6] The way this technology was executed was discovered in large part by the hacking community. Documentation shows that the GD-ROM drive would check to see if it were reading a GD-ROM or a CD-ROM. Should it detect a CD-ROM being inserted, it would scramble the executable from the pirated disc and crash the console.[7]

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[6] *United States Patent: 5627895 - Electronic Device for Detecting Selected Visually Perceptible Indication Information on an Information Storage Medium for Security Comparison*, ed. Sega Enterprises. http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&co1=AND&d=PTXT&s1=5627895.PN.&OS=PN/5627895&RS=PN/5627895.

[7] Fabien Sanglard, "How the Dreamcast Copy Protection was Defeated," https://fabiensanglard.net/dreamcast_hacking/ (accessed 11/16/20,

This data check, along with the inability of a CD-ROM player to read the high-density area of the disc, and the fact that the typical amount of game data found on a GD-ROM could not properly fit on a normal writable CD, were all piracy deterrents introduced to make this optical format more secure than its predecessors.

III. Associated Playback Devices

As stated before, the primary playback device for the GD-ROM was the Sega Dreamcast, but also its arcade counterpart the NAOMI. While initially produced with a ROM board cartridge like many previous arcade cabinets, the boards were subsequently replaced by a much cheaper option, a DIMM board (dual in-line memory module), also known as a RAM stick, which could have games loaded onto it via an external GD-ROM disc drive. This practice continued through the NAOMI 2, Chihiro, and Triforce arcade boards.[8]

IV. Competing Formats

While Sega was clearly pushing the limits of the widely available CD-ROM at the time, creating over a gigabyte of data on each disc, the most notable competing format would have to be the DVD and all of its writable and rewritable iterations. With games becoming more and more complex, storage was becoming an issue for all the visual and audio assets being produced, and so the DVD, with a capacity of about 4GB, would be better compared to the GD-ROM, which both Sony and Nintendo utilized for their own competing consoles, the PlayStation

[8] The dreamcast junkyard, 2015, http://www.thedreamcastjunkyard.co.uk/2015/06/guest-article-forensic-examination-of.html.

2 and GameCube respectively. Sega ultimately went with the GD-ROM due to it being easier and cheaper to produce than their DVD counterparts since to produce the drive, they could utilize previously support CD-ROM drive parts.[9]

V. Main User Groups and Use Environments

The main user groups would be gamers during late 90s and early 2000s, given that this was the time period of the format. The gaming magazine Edge provided an "Dreamcast User Profile" which broke down their demographics of the first million console purchases in Japan. First, they listed the types of players categorizing them as either "light users" or "hardcore players, at 27.7% and 72.3% respectively. Next, they broke it down in terms of sex with 94.2% male and 5.8% female. Finally, they offered the player age range as follows:

- Under 14: 11.6%
- 15-19: 21.4%
- 20-24: 22.7%
- 25-30: 25.4%
- 30-34: 11.7%
- Over 35: 7.3%

While the data only tracks the initial release of the console[10], it would be safe to assume these numbers would not change that much, given the short lifespan of the console.

The other user environment would be the arcades across the world, and while it is hard to find data relating to the GD-ROM specific arcade machines, one can assume that they were

[9] S. Hagiwara and I. Oliver, *Sega Dreamcast: Creating a Unified Entertainment World*, Vol. 19, 1999), 29-35. doi:10.1109/40.809375.

[10] "Sega Faces Up to New Challenge in Japan
." *Edge,* 7-13-, 1999b, 7.

used by the predominantly younger male demographic attracted to the arcades much like the console.

VI. Content Associated with the Format

The content contained of the GD-ROM are exclusively games for the Sega Dreamcast and subsequent arcade hardware.

VII. Formats That Preceded and Followed

As previously stated, the GD-ROM can trace its lineage directly from the CD-ROM which saw widespread use in various markets such as software, music, and videogames. Sega utilized the CD-ROM in its previous console, the Sega Saturn.

When looking at formats that followed the GD-ROM, there are a variety of discontinued high volume optical storage discs like the UDO (Ultra Density Optical) and UMD (Universal Media Disc) which came out after the GD-ROM, but in terms of direct lineage, there are none as Sega exited the hardware development sector of the gaming industry after the Dreamcast.

There is a market for unofficial Dreamcast games produced to this day, made by fans of the hardware. They claim to be printed on MIL-CD, but I am unsure if they are actual MIL-CDs or just CD-ROMs utilizing a MIL-CD exploit by hackers, which will be covered later in this paper.

VIII. Demise of the Format

The DVD being a direct competitor as a high capacity optical disc meant certain doom for the format. Even in 1999, Neil Robison, Sega's director of developer support, was quoted in Electronic Gaming Monthly stating he did not believe the Dreamcast to be a "static machine…but it could be enhanced in a variety of ways." EGM goes on to confirm that "Dreamcast owners will one day be able to upgrade the GD-ROM drive to DVD."[11] It seems the use of the GD-ROM was a short term investment by SEGA to cut costs early on, and that the future of optical media would require higher storage capacities of which the GD-ROM was uncapable.

Some also attribute the fall of the GD-ROM to the fact that the security and anti-piracy measures Sega worked so hard to instate were eventually broken by the hacking community. As stated earlier, the GD-ROM drive would detect whether a CD or GD-ROM were inserted into the system. Were a CD present, the system would scramble the executable file for the game and crash the console. This was finally bypassed by hackers after the Dreamcast Software Development Kit (SDK) was leaked and was used to reverse engineer code that would unscramble the pirated copy on a CD-R and allow it to be played.[12] Sega released a Dreamcast console revision late in the system's lifespan disabling this bypass, but it is clear that the ani-

[11] "Dreamcast Expandability." *Electronic Gaming Monthly,* Sept 01, 1999a, 204.
[12] Sanglard, "How the Dreamcast Copy Protection was Defeated," https://fabiensanglard.net/dreamcast_hacking/ (accessed 11/16/20)

piracy technology the format was championing was not as secure as they had hoped, another contributing reason to why this media became obsolete.

IX. Known Preservation Issues & Concerns

Like most physical media, the mistreatment and deterioration of the physical GD-ROM is of concern. Scratches to the reflective surface or breakage can be a result of mishandling which can render the discs unreadable by the console or arcade cabinet. The rarity of a specific disc can vary from title to title, but as time goes on there can only be less usable GD-ROM copies, making proper care a priority.

Even with proper care and handling, natural deterioration can occur due to the inherent vice of the materials used to create the disc. With regards to optical media this is known as "disc rot." This can occur if the protective layer is accidentally removed which exposes the aluminum layer which can then oxidize, resulting in loss of data and signal.[13] Instances of disc rot for the GD-ROM are purely anecdotal according to relevant online forums as I have been unable to locate a study specifically about the GD-ROM deterioration, but it does seem to exist. The susceptibility to disc rot might vary from print to print, but according to the Canadian Conservation Institute's study on the longevity of optical media, read only CD-ROMs should have an average lifespan of 50-100 years when assuming proper storage and handling.[14] Considering many of these games are twenty years old at the time of writing this paper, a 50-

[13] University of Illinois at Urbana-Champaign, "Optical Media
," https://psap.library.illinois.edu/collection-id-guide/opticalmedia#cd

[14] Canadian Conservation Institute, "Longevity of Recordable CDs, DVDs and Blu-Rays — Canadian Conservation Institute (CCI) Notes 19/1," https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/canadian-conservation-institute-notes/longevity-recordable-cds-dvds.html (accessed Nov 23, 2020).

100 years seems awfully short, which poses a great problem for the long term preservation of the format.

Another prevalent problem in the world of dead or obsolete media is the fact that proprietary machines were needed to play them, the GD-ROM being no exception. As we have seen, the GD-ROM can only be played on the Dreamcast or the relevant arcade cabinet, which have been discontinued as well. From personal experience as well as through extensive troubleshooting online, the GD-ROM drive optical laser used by Sega is not of great quality and is prone to failure after extended use. Because of this, keeping the hardware functioning can prove to be a problem as it would render the discs unplayable. In terms of the arcade counterparts, many arcades have closed since the 90s and 2000s, creating a scarcity of GD-ROM drives from the arcade systems, further hindering any preservation efforts.

Should a museum or archive acquire the necessary components to play the GD-ROM (machine, controller, and input cables), game releases can be region specific, and can only be played on the corresponding region's console. A Japanese exclusive game, for instance, cannot be played on a North American system. Should an institution want to preserve the worldwide GD-ROM catalog, they would need the equivalent system to play them.

Luckily, the practice of emulation can save the content of the GD-ROM drives, preserving the games for posterity; however, in order to extract the data, a GD-ROM drive is needed. Fabien Sanglard describes the process of ripping the data utilizing a Dreamcast as a GD-ROM drive which is connected to a PC through a "Coder's Cable" via the consoles serial port. This process proved to be effective, although timely as each rip could last as long as 18 hours,

producing a custom file format known as a Dreamcast Gigabyte Disc Image (.gdi).[15] The good news is the entire library has been ripped and posted online (through illegal means), but should a specific game go missing at some point in time, the original Dreamcast hardware and a disc would be needed to reproduce it, and as we have seen with the failure-prone optical laser and finite longevity of the GD-ROM itself could pose a problem in the distant future.

X. Conclusion

The GD-ROM was a novel experiment with existing technology that proved to not be long for the world. Already outclassed by its DVD contemporary in terms of raw data storage, its only other contribution to the world of optical media was its enhanced anti-piracy measures, which were eventually broken. Despite these shortcomings, it had a relatively long-life cycle due to its install base of arcade cabinets across the world. What is more important, however, is that the content created for these discs are saved. Many of the games created on the GD-ROM are original material, lacking ports to future consoles. In the effort to preserve game history one must consider the best way to handle and store the physical GD-ROMs, maintain a healthy number of playback devices, and, in the very long term, a good way to keep a high fidelity digital reproduction of each game for future use.

[15] Sanglard, "How the Dreamcast Copy Protection was Defeated," https://fabiensanglard.net/dreamcast_hacking/ (accessed 11/16/20, ; FileInfo, "What is a GDI File?" https://fileinfo.com/extension/gdi (accessed 10/10/2020).

Bibliography

"Dreamcast Expandability." 1999. *Electronic Gaming Monthly*, Sept 01, 204.

"Sega Dreamcast GD-ROM (1998 - 2001)."., last modified -05-23T17:49+00:00, accessed Oct 10, 2020, https://obsoletemedia.org/gd-rom/.

"Sega Faces Up to New Challenge in Japan." 1999b.*Edge*, 7-13-, 7.

United States Patent: 5627895 - Electronic Device for Detecting Selected Visually Perceptible Indication Information on an Information Storage Medium for Security Comparison, edited by Ltd Sega Enterprises JP. http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&co1=AND&d=PTXT&s1=5627895.PN.&OS=PN/5627895&RS=PN/5627895.

Charnock, Tom. 2015. *Forensic Examination of the Dreamcast Corpse - File 2 of 2*. The Dreamcast Junkyard. http://www.thedreamcastjunkyard.co.uk/2015/06/guest-article-forensic-examination-of.html.

FileInfo. "What is a GDI File?", last modified 11/5/20, accessed 10/10/2020, https://fileinfo.com/extension/gdi.

Institute, Canadian C. "Longevity of Recordable CDs, DVDs and Blu-Rays — Canadian Conservation Institute (CCI) Notes 19/1.", last modified -09-14, accessed Nov 23, 2020, https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/canadian-conservation-institute-notes/longevity-recordable-cds-dvds.html.

Johnston, Chris. 1999. "Hands on: Dreamcast." *Electronic Gaming Monthly*, Feb 01, 26-30.

Loguidice, Bill. 2014. *Vintage Game Consoles : An Inside Look at Apple, Atari, Commodore, Nintendo, and the Greatest Gaming Platforms of all Time*, edited by Matt Barton. Burlington, MA: Focal Press.

S. Hagiwara and I. Oliver. 1999. *Sega Dreamcast: Creating a Unified Entertainment World*. Vol. 19. doi:10.1109/40.809375.

Sanglard, Fabien. "How the Dreamcast Copy Protection was Defeated.", last modified December 11, accessed 11/16/20, , https://fabiensanglard.net/dreamcast_hacking/.

University of Illinois at Urbana-Champaign. "Optical Media.", https://psap.library.illinois.edu/collection-id-guide/opticalmedia#cd.