

University of Victoria



CSC 461 Project Report

Multimedia Analysis of IMAX Technology

Michelle Watson V00917147

Amy Finck V00878512

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1.0 Introduction

The evolution of cinema has been deeply intertwined with technological advancements, and one of the companies that has been on the forefront of these advancements has been the Canadian IMAX Corporation. Since its debut at Expo 67 in Montreal, IMAX has continually reshaped the landscape of cinema. From the pioneering use of the 70mm 15 perforation film format to the evolution of laser projection technologies, IMAX has captivated audiences with larger-than-life cinematic experiences. This report embarks on a journey through IMAX's history, exploring its technological milestones. It then examines its visual and audio specifications, and what makes these specifications different from traditional cinema. As a means of surveying the current landscape of IMAX theatres, it examines the technology employed in the three IMAX theatres in British Columbia. Finally we will look to the future of IMAX, and discuss where we may see continuing technological advancements.

2.0 Project Overview

2.1 Objectives and Background

The project aims to conduct a comprehensive analysis and survey of the IMAX multimedia system, a leader in the cinematic, immersive experience industry. The IMAX system delivers an unparalleled combination of exceptional audio, video, and images through cutting-edge technologies. The IMAX experience distinguishes itself from conventional films due to its exceptionally high resolution, expansive screens, and state-of-the-art visual and auditory immersion. This project analyzes the methods employed by IMAX to present content to the user, delving into representation features such as aspect ratio, resolutions, frame rates, audio formats, spatial sound technologies, and more.

Furthermore, this project investigates any compression strategies executed by IMAX to manage and deliver the vast file and data sizes associated with high-quality, large-format films.

The approach taken for this project is a comprehensive survey of IMAX theatres, gathering data on their audio systems, video projection technologies, image display mechanisms, and post-production

processes. The technologies employed by the standard movie theatre are compared to the IMAX technologies, in order to gain a wider understanding of theatres as a whole, as well as be able to determine in what departments IMAX deviates from them. This project is important in uncovering valuable insights into the advanced multimedia technologies utilised by IMAX while aiming to identify what makes IMAX so unique, as well as potential areas for enhancement in the future.

2.2 Scope and Limitations

The aim of this report is to provide readers with an understanding of what makes IMAX specifications unique in cinema, as well as allow them to understand the underlying technology that allows for these specifications. We also aimed to provide our reader with an understanding of the history, current state, and the future of IMAX. As IMAX has produced many new technologies over the years, we attempted to focus on those that have had the greatest impact on cinema. In order to demonstrate the state of current IMAX theatres, we limited our scope to only theatres in British Columbia as our readers are most likely to be familiar with these theatres.

To research this report, we surveyed a variety of sources. We found much of our information directly from IMAX, as well as many trade publications. However, many of the technologies IMAX employs are proprietary and we were therefore limited in the information we could access.

2.3 Team Member Contributions

Our goal for this project was to distribute the work evenly. We worked together on the project proposal until it was completed so that we could ensure we had the same expectations. We also worked on the October 23rd update together, and split the work evenly. As agreed upon by both, Amy completed the majority of the midterm update while Michelle completed the majority of the November 20th update. We created our presentation slides together, and divided up the content evenly.

The contributions to this report are summarised in Table 1. This table lists the main contributors to each section, however both Amy and Michelle were involved in reviewing and editing each section.

Section	Contributors
2.1	Amy
2.2	Amy
2.3	Amy, Michelle
3.0	Michelle
4.1	Michelle, Amy
4.2	Michelle, Amy
5.1	Michelle
5.2	Michelle
6.1	Amy
6.2	Amy
6.3	Amy
7.1	Michelle
7.2	Michelle
7.3	Michelle
8.0	Amy
9.0	Amy, Michelle

3.0 History of IMAX

The world was first exposed to the company now known as IMAX at the Expo 67 in Montreal in 1967 [1]. The eventual creators of IMAX, Roman Kroitor, Graeam Ferguson, and Robert Kerr, were all displaying films at this expo. Roman Kroitor's film 'Labyrinthe' was deemed the most ambitious film at the Expo since it used three theatres that the audience passed through; The first theatre utilised two 70mm film reels, one projected vertically and the other horizontally, while another theatre employed 35mm film [1]. Graeam Ferguson and Robert Kerr's film 'Polar Life' was displayed in a circular theatre that rotated around the audience with the goal of making the audience feel as though they were in the movie [1]. Both of these films eventually became known as the birth of IMAX due to the clear popularity of big-screen, immersive film formats, which became the goal of IMAX. The

company was initially called 'Multi-Screen Corporation' because they were producing multiscreen movies. After witnessing the popularity of the large screen format after Expo 67, Ferguson and Kroitor decided to move towards implementing high-quality, large-format projectors using the 70mm format [1]. The initial creation of IMAX was based on the Expo's vision of providing sensory immersion for audiences and in the many years since, IMAX has continuously innovated and proved their ability to do this. While IMAX is best known for the 70mm format that allowed them to deliver visual experiences audiences had never before seen, they have moved through many visual and audio formats while pursuing the goal of an immersive theatre experience.

The IMAX Corporation debuted 'Tiger Child' at the Expo 70 in Osaka, Japan which is considered to be the first IMAX format film which used the 70mm 15 perforation format that IMAX would become known for [2]. The company's next big milestone was installing the first permanent IMAX theatre at the Cinesphere on the Ontario Place grounds in Toronto, Ontario. 'North of Superior', directed by Graeam Ferguson, was the first film to be shown at the installation [2]. This IMAX theatre was created in 1971 and is still there today, but is currently closed due to construction on the public Ontario Place grounds to build a private spa [2]. The Cinesphere features a 24.38 metre by 18.28 metre IMAX screen [3]. The films were initially only displayed with a 70mm projector, but in 2011 it was renovated for 3D projection capabilities and in 2017 the 'IMAX with Laser' technology was added to the theatre [3]. The IMAX with Laser technology was actually tested and refined at the Cinesphere while it was closed for renovations in 2014 [3].

4.0 Visual Specifications

4.1 15/70 mm Film Format

There are many technologies that IMAX uses to provide its large, high quality video projection that sets it apart from common film formats and theatres. Their most known and first major technological advancement was the use of the 15/70 film format. The standard for film at the time was, and still largely is for movies that still use film, 35 mm film. This means that the width of the film strips is

approximately 35 mm in length, and has four perforations per frame. IMAX is largely known for the use of 70 mm film [4]. Each frame is 15 perforations wide, so this format is often referred to as 15/70. This makes it the largest commercial film format in motion picture history [5]. A comparison of 35mm film and 70mm film can be seen in Figure 1.

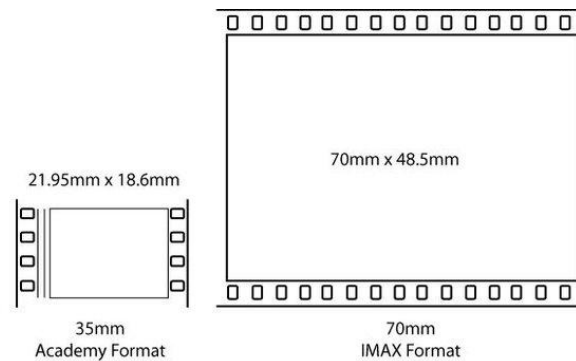


Figure 1. Comparison of 35mm and 70mm film [6]

70mm film was used in the film industry well before the creation of the IMAX 15/70 film, but it was vertically oriented and typically only has 5 perforations per frame. This makes the ratio of width to height larger than 35mm film. This format was once a common form to produce high quality films, but is rarely seen today [4]. The increased height of 15/70 film compared to 5/70 allowed for a much larger area per frame, and therefore a higher quality image which could show more of the scene. 70mm film with 5 perforations was only one third the area of the IMAX 15/70mm frame [4].

One other major innovation IMAX made was running the film through the projector horizontally, meaning the width of the film was the height of the frame. This method required innovations in how the projector manipulates the film, which involved using pins and a vacuum to keep the film steady. This technique was called ‘Rolling Loop Technology’, and was patented by IMAX in 1971 [7].

The high image quality provided by the 15/70 film format has allowed IMAX to still look clear on the large screens IMAX is known for. IMAX screens can reach up to 25 metres in width [4]. The intent behind this is to have the screens extend beyond your peripheral vision, in order to provide a fully immersive experience [5]. The frame rate for the 15/70 format is 24 fps, which is the same as for standard cinema. The aspect ratio for this format is 1.43:1.

4.2 Digital and Laser

IMAX has continued to make innovations to its visual format over the years of their existence. They remained analog until 2008, when they launched IMAX digital. The method initially used two 2K Christie projectors with a proprietary method of image processing and it has an aspect ratio of 1.9:1 [4]. This aspect ratio is much more wide than the aspect ratio of the 15/70mm format, so the theatres using digital could not reach the same large screen size [4]. In 2015, it launched a new digital method called 'IMAX with Laser' [4]. This uses two 4k laser projectors and is capable of using the aspect ratio of 1.43:1 that is used for the original 15/70mm format [4]. It is capable of 60 frames per second, compared to the 24 frames per second used in the 15/70 format as well as traditional cinema. IMAX lasers ensure deeper, darker, better colours and an overall improvement in the image quality. Laser provides 50% more brightness than the digital cinema standard DCI specification and it has double the contrast ratio of the 15/70mm film format [8]. Lasers cause less eye strain to look at for the viewer compared to xenon bulbs, and they are cheaper and need to be replaced less frequently than bulbs [9]. However, IMAXs' signature 70/15 format still remains in many theatres.

A colour gamut describes the range of colours that can be output by a device. For modern digital cinemas, the colour gamut that almost all conform to is DCI-P3, which spans an estimated 53.6% of the colour spectrum visible to the human eye [10]. This colour space is visualised in the left side of Figure 2. IMAX with Laser is capable of displaying all colours represented in Rec. 2020, shown on the right side of Figure 2. This colour space covers 75.8% of the colours visible to the human eye [10], which is around a 41% increase in available colours.

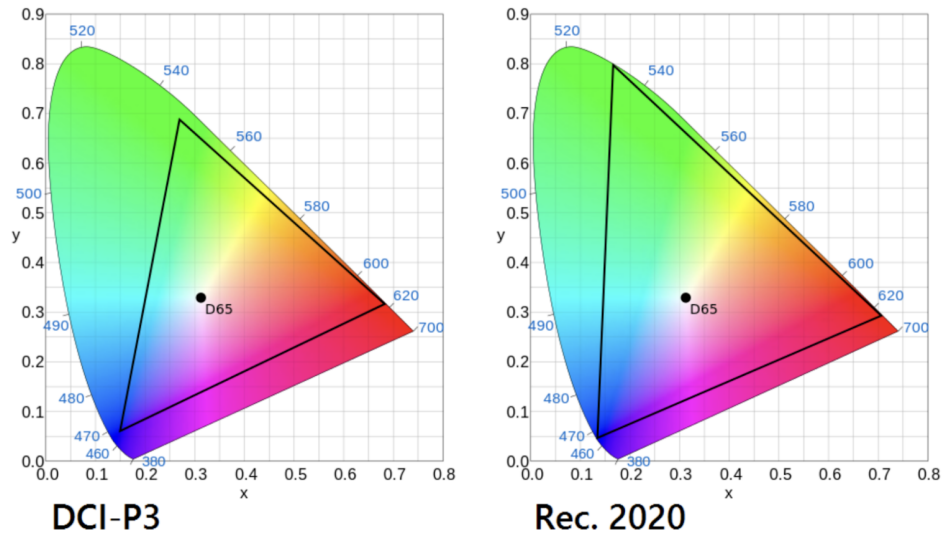


Figure 2. Colour Gamut Rec. 2020 versus DCI-P3. The overall shape is the CIE-1931 colour space, which approximates all colours visible to the human eye. The triangles represent which colours are covered by the given gamut. [11]

5.0 Audio Specifications

5.1 Magnetic Film

While IMAX may be known for their high quality visual specifications, they have also focused on delivering high quality, immersive audio experiences. Traditional 35mm films often embed the audio on the film itself, known as sound-on-film [12]. However, IMAX wanted to use all the available space of their 70mm film, and instead developed a separate magnetic film to store the sound. This magnetic film is 35mm, and features six audio channels to provide an immersive surround sound experience. The magnetic film runs at 45.7 cm per second [13]. In order to keep the audio and visual synched frame by frame, IMAX uses a rotary shaft encoder in the projector and an interlock circuit connected between the projector and the reproducer [13]. The sound reproducer used was called a ‘dubber’ and was located in the projection room [13]. One downside of this method is that it can only produce one hour of playing time because the playback unit is only able to store 1500m of reel [13]. For this reason, IMAX has transitioned to use digital disk playback.

5.2 Digital Disc Playback

In 1988, IMAX acquired Sonics Associates as an affiliate, which was considered a world-leader in sound design to help improve their audio technologies [13]. They were able to design a digital standard for IMAX called DDP, Digital Disc Playback, that provides a frequency response of 20 – 20,000 Hz that is maintained over the entire audio spectrum of ten octaves, compared to the six octaves found in conventional cinemas [13]. This frequency range of 20 - 20,000 Hz is the full frequency that can be detected by human ears [14]. Digital disk playback uses a minimum of six audio channels. Three CD's are used to store each soundtrack, which corresponds to one CD for every two audio channels [13]. Next, the audio goes to the Sonic sound system, then to a computer controlled equalisation unit which matches the sound to the particular theatre, and finally to the power amplifiers [13]. The power amplifiers are able to deliver more than 2000 Watts per channel [13]. The speakers are placed behind the screen and throughout the theatre to create a surround sound effect and immersive experience. IMAX 4K theatres use up to 12 channels of audio, with a minimum of six, compared to the standard 5 channels employed in most theatres. IMAX uses uncompressed digital sound to provide the most full audio possible [15].

5.3 nXos Calibrator

In 2010, IMAX developed the nXos Calibrator, in collaboration with Audyssey, to revolutionise the tuning and monitoring of their audio systems [15]. The audio performance is measured and monitored at multiple locations spaced throughout the theatre using Audyssey's MultEQ XT algorithms [15]. The calibrator is able to surpass manual processes by employing thousands of bands of equalisation and by implementing digital signal processes to monitor and automatically correct the audio if calibration changes are detected [15].

6.0 Evaluation of IMAX Theatres in BC

As there is a large number of possible specifications that IMAX can use, this section of the report aims to delve into the specifications of three IMAX theatres. These three theatres are IMAX Victoria

at the Royal BC Museum, IMAX Science World, and IMAX Langley. These were chosen as they are considered the three true IMAX theatres in BC. There are also several theatres that use 2K digital projectors and smaller screens, but these will not be considered in this section as the quality is more comparable to a traditional movie theatre.

6.1 IMAX Victoria

IMAX Victoria was first opened in 1998 [16], and initially only used the 15/70 analog format. The theatre has 369 seats, and initially had 6 channels of surround sound [16]. In 2014, it announced it would be upgrading to laser projection, and at the time they were one of the first theatres in the world to make the conversion [17]. They initially upgraded to two 2k projectors, and upgraded their screen to the 18.59 metre by 25.9 metre screen they have today, the largest in British Columbia [17]. The theatre director decided to switch to laser projection due to trouble accessing film copies of hollywood movies [17]. He also wanted to upgrade to a larger screen, and said that laser projection is more well suited to this screen size [17]. In 2016, Victoria IMAX completed its upgrade by switching out the dual 2k projectors for the dual 4k projectors that it has today [18]. It also added 6 additional speakers, bringing it up to 12 channels of surround sound audio plus a sub-bass. The new loudspeakers were placed on the ceiling above the audience, as well as on the sides of the theatre [19].

The switch to laser allowed for improved brightness, colour, contrast, and sound. The laser projection allowed for a brightness around 60% higher than could be provided by the xenon bulbs used before the upgrade [20]. The theatre noted that this was particularly useful for 3D, as 3D glasses dim the image. The increased brightness capability meant they could maintain the original brightness while showing 3D movies [20]. Laser also provides higher contrast when compared to IMAX film, as well as a larger colour gamut. Finally, the 12 channel surround sound system allows for almost every seat in the theatre to experience the optimal sound experience [19].

6.2 IMAX Science World

IMAX Science world was built for Expo '86, but opened in 1985 [21]. During the fair, Science World served as the Expo Centre. The top of Science World contains an IMAX theatre which projects films onto the dome ceiling, known as IMAX OMNIMAX. At the world fair, A Freedom to Move was the first film shown in the new OMNIMAX theatre [21]. Its screen is 27 metres in diameter, and five storeys high [21]. The theatre seats 400 people [21]. Its six-channel sound system is made up of 28 speakers in six clusters behind the theatre's screen, along with a subwoofer [21].

The Science World IMAX uses 15/70 analog film. As the film will be projected onto a dome and not a flat surface, the film must be altered to counteract the distortions this would cause. Each frame is converted into a dome shape, as seen in Figure 3. This allows the projected image to appear to maintain its original geometry. However, the distortion of the film does cause some information loss compared to standard 15/70 film.

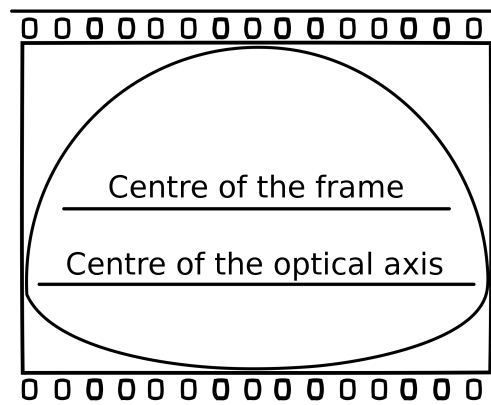


Figure 3. Depiction of OMNIMAX frame format [22]

The six clusters of speakers are kept behind the dome, and the projector is located in the centre of the dome and projects upwards. The seats are angled back, so that the viewers can look at the projected screen above, as can be seen in Figure 4.

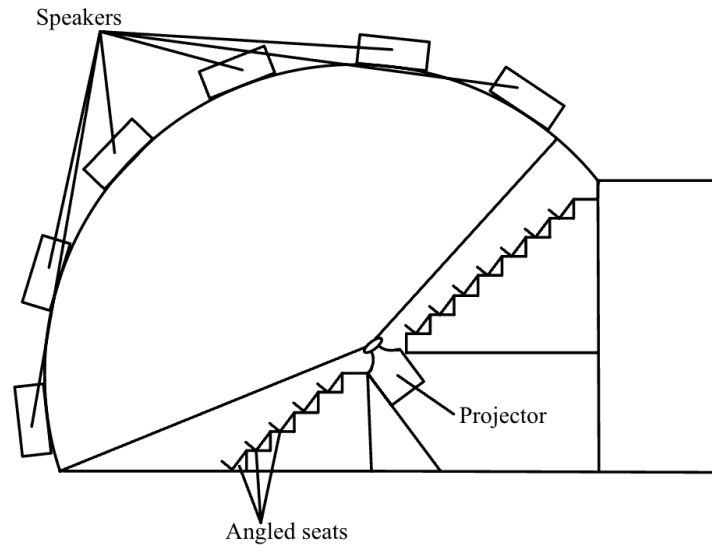


Figure 4. Diagram of Science World OMNIMAX theatre

IMAX Science world is not currently in operation, due to leaks in the dome structure. However, it has received funding to repair the structure [23], and will be reopening the OMNIMAX IMAX when these repairs are complete.

While science world has not announced any change in its format as of yet, many dome structures have been switching to laser. IMAX first launched a dome theatre with laser in 2018, and since then many have followed suit [4]. Laser OMNIMAX theatres use a single 4K GT laser projector, as opposed to the dual 4K laser projectors used for flat screens [4]. The projector is still placed in the centre of the dome on an elevator, which is the same placement as the non-laser dome theatres [4]. This format cannot do frame rates higher than 48 fps and the 48fps is only achieved by dropping to 2K resolutions. According to IMAX, they do not have any plans to improve this resolution.

6.3 IMAX Langley

IMAX Langley was opened on May 12th, 1999 as part of the Famous Players Colossus Cinema, which was taken over by cineplex in 2005 and renamed Cineplex Langley [24]. The IMAX screen is 16 by 21.3 metres in size, and it seats 254 [25]. Unlike many IMAX theatres in recent years, this

theatre has continued to use the 15/70 analog standard since its opening. As a result, it is one of only 10 theatres left in Canada that can still play 15/70 film reels [26].

The Langley IMAX theatre recently gained attention as it was one of only 30 theatres worldwide that screened the movie “Oppenheimer” from its original 15/70 film reel [27]. The release of this movie sparked an increased interest in the 70mm IMAX format, with some fans travelling for hours to reach a theatre capable of screening the movie on film. [12]

7.0 Future of IMAX

IMAX remains at the forefront of providing immersive viewing experiences by constantly evolving to meet industry and consumer demands. This section delves into a variety of new technologies and areas of film viewing that IMAX Corporation is starting to explore. These new technologies include filming with higher resolution cameras, enhancing the displayed image size of streamed films, and improving algorithms to lower distribution costs in streaming to provide the best quality of streamed content.

7.1 Filmed for IMAX

IMAX has been continually evolving its technology to keep up with competitors and to improve their ability to reach more customers. In recent years, they’ve introduced the "Filmed for IMAX" program, certifying high-quality digital cameras for IMAX-format films [28]. A notable development in this program is IMAX's plan to transition to filming with 12K cameras, exemplified by the upcoming film "Koala", which is being shot using the Blackmagic URSA Mini Pro 12K [28]. The perceived resolution of images captured by these 12K cameras is roughly equivalent to those of images captured by 70mm film [28]. IMAX theatre screens are only able to display up to 4K resolution, but filming in the 12K format is still incredibly useful. According to Amezdroz, the filmmaker for Koala, the extra resolution provides more flexibility for post-processing methods such as stretching and image manipulation, without distorting the picture [28]. Many movies also now incorporate forms of CGI and visual effects which have more seamless integration when the initial quality is at higher resolution

[30]. Additionally the additional pixel data helps with 3D tracking and stabilizing a shot in post-production [30]. Lastly, when shooting at 4K for a 4K resolution screen, there is no ability to crop the frame size but with 12K cameras, there is room to reframe the scene without losing any sharpness [28].

7.2 'LieMAX'

While IMAX with Laser uses dual 4K lasers capable of maintaining high quality on a large screen, IMAX has also created lower cost digital IMAX systems in recent years. This has allowed for a massive increase in the number of IMAX theatres being created. It also allowed existing traditional movie theatre auditoriums to convert into IMAX theatres without having to dramatically increase their screen size. In 2007 there were only 299 IMAX theatres worldwide, and by 2017 there were over 1,300 [31]. In 2023, there were only 30 theatres that were playing the Oppenheimer film using the 15/70mm analog format, which shows how many of the new theatres were made for digital formats [31] [27]. The new digital format that has allowed for theatres to transition to IMAX provides a much lower quality at only 2K resolution, so it cannot be displayed on the same massive screen as the analog format [4]. This caused most digital theatres to be opened in regular movie theatres with just slightly larger screen size when compared to a traditional screen [29]. The aspect ratio of the digital format is 1.9:1, where the 15/70mm aspect ratio is 1.43:1, so these new theatres are moving away from the square screen into a rectangular screen which causes a large portion of the image to be cropped out [4]. Some film enthusiasts have termed these theatres 'LieMAX' since they do not meet the IMAX expectations of a large screen with stunning audio and visual quality [32]. The opening of these theatres has resulted in the average screen size of an IMAX screen to decrease as the number of total IMAX theatres increases.

7.3 IMAX at Home

While IMAX is continually expanding the quality of their technologies and the number of theatres, they also have been looking to gain prominence outside of IMAX theatres [33]. This vision for the future, termed "IMAX 3.0," aims to deliver high-quality entertainment experiences on screens of

various sizes, expanding beyond traditional theatres. They have introduced 'Stream Smart,' developed in collaboration with Disney, with the goal of delivering high-quality video at reduced distribution costs [34]. 'Stream Smart' uses the SSIMPLUS algorithm which optimises the bitrates of common video codecs, such as AVC, HEVC, and AV1, to reduce distribution costs by 15-30% [34]. When the success criteria of the SSIMPLUS algorithm is compared to the success criteria of video quality metrics, VMAF, SSIM, and PSNR, it has consistency across all content types, impairments, and content attributes, which the others do not fully require [34].

Another technology advancement that IMAX has recently debuted is 'IMAX Enhanced', which is a program to bring the most immersive viewing experience that is possible outside of an IMAX theatre [33]. This technology was made in collaboration with Disney+ to bring the IMAX experience to the homes of Disney+ subscribers [35]. 'IMAX Enhanced' combines the streaming with high-quality at home sound systems and projectors. It has an expanded aspect ratio, of 1.9:0, which is able to fill up more of the height of the screen. This allows for 26% more picture on the screen when compared to 4K blu-ray widescreen, as shown in figure 5 [36]. All devices that are supported by Disney+ are able to view this expanded aspect ratio, which makes it more accessible to the public [36].



Figure 5. IMAX Enhanced vs 4K Blu-ray Frame Size [37]

The sound system for 'IMAX Enhanced' builds off the DTS format to provide the full range of sound that is available in IMAX theatres [36]. The soundtracks for 'IMAX Enhanced' streams are provided by the IMAX Signature Sound and it is made to best replicate the in-theatre sound at home [37]. The compatible devices will auto detect that it is an enhanced film and will enable bass management

settings to best deliver the sounds [38]. There are a variety of channel setups that are compatible with this system, which mostly carry over from DTS:X layouts, such as the 7.1.4 layout that is shown in figure 6. The 7.1.4 layout means there are seven surround speakers, one subwoofer, and four height speakers, which are located near the ceiling [38]. The subwoofer is a type of speaker that is dedicated to reproducing low-frequency sounds to handle the bass response.

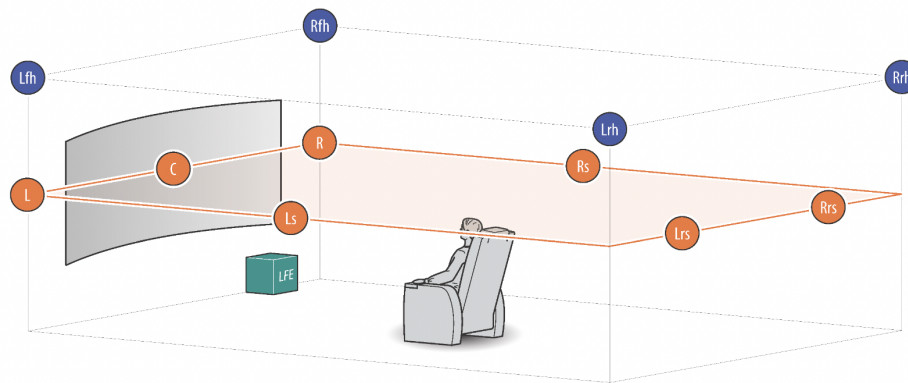


Figure 6. IMAX Enhanced 7.1.4 Sound System Layout [38]

8.0 Conclusion

The history of IMAX is marked by a continuous pursuit of immersive cinematic experiences. From its inception at Expo 67 in Montreal, to the creation of the 15/70 film format, to the widespread adoption of IMAX with Laser, the company has consistently pushed the boundaries of visual and audio technologies.

The technology IMAX is most known for is the 15/70 film format. The film captures the image horizontally, and allows for incredible quality when compared to 35mm film. While this format is still loved by many, IMAX has been transitioning from analog to digital projection systems for several years. The introduction of IMAX with Laser technology further enhanced brightness, colour, and contrast, and was adopted by many theatres which previously used analog film. The development of Digital Disk Playback and the nXos Calibrator showcased IMAX's dedication to achieving optimal audio quality and calibration.

Examining specific IMAX theatres in British Columbia, such as IMAX Victoria, Science World, and Langley, reveals the diverse array of specifications that IMAX theatres may employ, as well as the changes that many IMAX theatres have been going through.

Looking ahead, IMAX continues to evolve with initiatives like the "Filmed for IMAX" program, introducing higher-resolution cameras for an even more immersive experience. However, the proliferation of digital IMAX theatres, often referred to as 'LieMAX,' raises questions about maintaining the original IMAX standards in terms of screen size and quality.

IMAX's future endeavours extend beyond traditional theatres, with the exploration of home entertainment through "IMAX at Home" initiatives. The development of "IMAX Enhanced" and collaborations with streaming platforms like Disney+ aim to deliver high-quality content to audiences beyond the confines of a dedicated IMAX theatre.

In the constantly changing landscape of cinematic technology, IMAX's continued innovation positions it as a key player in shaping the future of immersive visual and audio experiences. Whether in theatres or the comfort of home, IMAX continues to redefine the boundaries of cinematic excellence.

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