After Digital Renovation

– An Experience Sharing from NMNS, Taichung

Chilong Lin[1]
Department of Exhibition, National Museum of Natural Science
1st, Kuan-Chien RD., N Dist. Taichung, 40453 Taiwan, R.O.C.

Abstract

In 2015, after 29 years' service, the original OMNIMAX 15/70 film projector and the GOTO GSS-I star projector in our Space Theatre were renovated with a Digistar 5 projection system which has a 7.5k x 7.5k resolution. Surely the renovation changed the operation mode of the theatre. After the renovation, the annual attendance number and box-office increased about 22% in the first few years. The maintenance cost and human resource are also saved enormously. Here, we will share our experience and analyze some factors which cause to the changes.

1. Introduction

The **Space Theatre** of **National Museum of Natural Science** (NMNS) was opened in mid-1986 as a part of the phase-1 construction of the Museum. It's the first large planetarium in Taiwan which includes one opto-mechanical GSS-I star projector provided by GOTO[2] and one OMNIMAX 15/70 film projector provided by IMAX[3]. The museum was also the first modern museum exhibits science with large amount of interactive, dynamic, hands-on exhibitions and immersive giant screen movies in Taiwan. Both factors made NMNS the most popular science museum in Taiwan until now.

The theatre is a 23 meters tilt dome with 304 seats. It was a part of the phase-1, totally five phases, construction of NMNS. Besides it, the phase-1 construction also includes a **Science Center** with an exhibition of area about 5,000 m^2. However, it is interesting that the annual attendance reached a summit of 659,364 in the year 1990 rather than in 1986, the opening year. After that period, the box-office record decreases gradually down to 253,358 in 2014.

In late 2014, almost 29 years after its first opening, the museum received the

[1] Email: lingo@mail.nmns.edu.tw
[2] https://www.goto.co.jp/english/
[3] IMAX®, The IMAX Experience® and IMAX Is Believing® are trademarks of IMAX Corporation.

budget for a digital renovation of its projection system. Before the renovation, several Mid-Life Upgrade were performed in the latest fifteen years to keep both systems work properly. The renovation was swiftly performed and the theatre was reopened on 1st July, 2015.

In section 2, some more detailed descriptions of the museum and the theatre and analysis of the factors which lead to its success in the past years will be given. In section 3, I would like to discuss briefly the survey performed for the new system before the renovation. The performance of the new system and experiences we learned during past five years will be given in section 4. Since it's about time to start a new survey for the next renovation, I will discuss what we expect to the next renovation and some more discussions will be devoted in section 5.

2. More About the Theatre

The NMNS was constructed in five phases rather than simultaneously. That's a strategy of director Han Pao-Der, the founder and first director of the museum, since he expected such a strategy can give the museum adequate time to train staffs for subsequent constructions and exhibition designs. Concentrating on a specific target at a time led finally to a great success at the opening of the phase-1 construction in mid-1986. That encouraged the government to invest more budgets on the subsequent constructions. It is one of the key factors which brought about the success of the museum. Those five phases are described below:

- Phase 1: The Science Centre and the Space theatre. Opened in 1986.
- Phase 2: The Life Science Hall. Opened in 1988.
- Phase 3: Originally named the Chinese Science Hall and now renovated to the Human Cultures Hall. Opened in 1994.
- Phase 4: The Erath Environment Hall. Opened in 1994.
- Phase 5: The Botanic Garden including a green house. Opened in 1997.

The Space Theatre is a part of the phase-1 construction which was opened in 1986. Accompanying it is a Science Centre which exhibits interactive and hands-on exhibitions of science and technology. The theatre is the first large planetarium and the immersive full-dome IMAX movie is a brand new experience to people in Taiwan. They are very attractive to the public, especially school kids. Visiting NMNS was once a must-have course for school trips in late 1980s and early 1990s. Even for now, it's still the most popular science museum in Taiwan.

There are four theatres now in the museum, they are:

- Space Theatre: Opened in 1986 as a part of the phase 1 construction.

Originally an OMNIMAX 15/70 film projector and a GOTO GSS-I opto-mechanical planetarium.

- 3D Theatre: Opened in 1994 as a part of the phase 3 construction. Originally an iWerks 5/70-3D film projector. Renovated to two 4K digital projectors in 2008.
- Bird-Eye Theatre: It's a bird-eye view, downward looking, theatre. Opened in 1994 as a part of Phase 4 construction. Originally a GOTO 10/70 film projector and renovated to a 4K digital projector in 2013. Scheduled to be closed in 2022.
- Environment Theatre: Also opened in 1994 as a part of phase 4 construction. It's a 360 degrees surrounding, ring-shaped, multimedia theatre on a big turn table. Scheduled to be closed in 2022.

The Space Theatre has a 23 meters tilt dome with 304 seats. As most OMNIMAX theatres did, space theatre plays two films by turns in usual since rewinding the prints are always time-consuming. The length of each show is one hour, including a 30-40 minutes IMAX movie and a 10 minutes long planetarium show before the main show. Besides the talk shows before IMAX movies, the theatre also provide 40 minutes long free planetarium courses at 9 AM on each weekday. But, such courses are provided only for reservations from groups with attendance more than 50 persons. In the science course of the fourth and fifth grades of elementary schools in Taiwan, there are several topics on observations of the moon-phases and season constellations. Such planetarium courses provide a very strong support to schools in and around the Taichung city.

However, success of the theatre also brings about some side effects. Since the profit IMAX movies attract more than 10% the annual attendance and contribute about 20% the box office income of the whole museum, directors of the museum care more about its income than its educational functions. Thus, the free planetarium courses which don't make money for the museum surely get less and less budget from the managerial level of the museum.

As mentioned above, the museum was originally planned to be constructed in four phases. But, a botanical garden with a big greenhouse was added into the plan in early 1990s and opened in 1997. The openings of new constructions always attract visitors and bring about new high tides of the attendance. But it is interesting that such summits did not appear in the years of new openings. They usually fall behind the openings of new exhibition halls two or three years, as shown in Figure 1.

In usual, the expected life time of OMNIMAX is about 20 years and that of GSS-I star projector is 12-15 years. Thus, the Museum started a project to renovate the

theatre equipment in late 1990s. But, owing to the lack of budget, this renovation was postponed for more than 15 years. During that period, several Mid-Life Upgrades were performed to keep the theatre operates properly.

In 1999, the 35mm-film analog soundtrack player of OMNIMAX was upgraded to a DDP-II digital player. In the same year, the console of GSS-I was upgraded and the original PDP-11 server was replaced by a Pentium-II desktop server. In 2003, we replaced those 32 star plates, the core of opto-mechanical planetariums, under the help of its original manufacture, the GOTO INC. At the meantime, the aluminum screen sheets of the dome were also renewed. The upgrades of DDP-II soundtrack player, GSS-I console and star plates cost us about 400,000 USD in total. These MLUs extended the lifetimes of both OMNIMAX and GSS-I for more than ten years until the digital renovation in 2015.

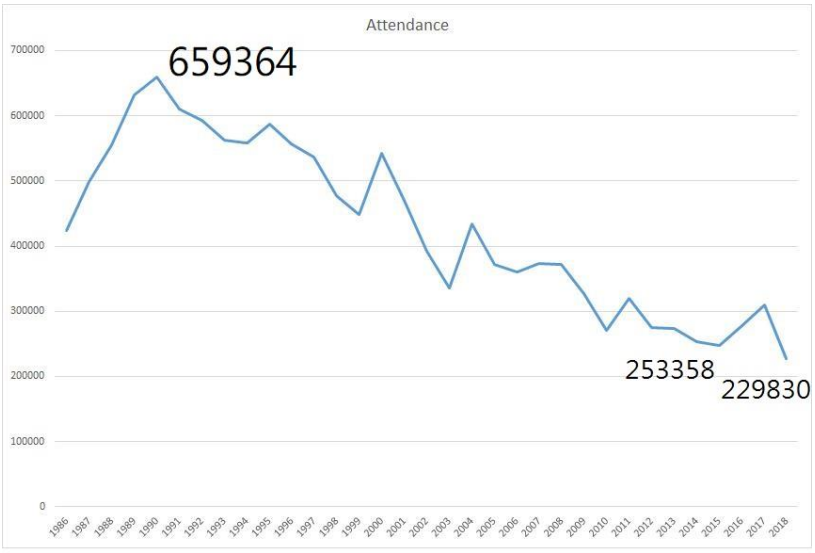

Figure 1: The annual attendance reached its summit 659,364 in 1990 and then decreased gradually to 253,358 in 2014 before the renovation. It increased to 309,834 in 2017 after the renovation. But, it fell to an even lower 229,830 in 2018. Choosing a wrong film and a water-leaking in the computer room could be the major causes of such a recession.

3. Before the Renovation

The survey for new equipment started in late 1990s since both systems were coming close to their expected lifetime and many of their parts were already out of production or supply. At the beginning the considered target was a new opto-mechanical star ball alone. It seems very rational since at that time digital projection technology is still far from mature. As time passed by, new technologies came out and the target changed many times.

In early 2000s IMAX stopped the production of their 15/70 film projectors. That

drove us to consider new digital projection technology for our next playing system. But, at that time the quality of digital projection technology is still much inferior to both 15/70 film projector and opto-mechanical star ball in all respect, no matter in brightness, resolution, saturation, contrast ratio, purchasing price or maintenance cost. Thus, we decided to perform some mid-life upgrades mentioned above to extend the lifetime of them until the digital projection technology becomes mature.

In late 2000s two developments attracted our attentions very much. One is the digital projectors and the other is the laser-illumination technology of digital projectors. If we expect a new projection system performs as well as the original OMNIMAX and GSS-I, the effective resolution must be higher than 4K by 4K and the on-screen brightness should be as bright as the original system. As for the contrast ratio, surely it's the higher the better. However, by the year of 2010, the contrast ratio of most digital projectors on market can reach at most 2000:1.

In early 2010s, a manufacture of digital projectors announced an ultra-high contrast ratio product which reaches the value of 1,500,000:1. The first digital planetarium using such an advanced technology was installed in the Taipei Astronomical Museum[4] (TAM) in 2011. However, the cost of chasing such an ultra-high contrast ratio is to reduce the brightness down to 1,000 lumens for each such projector. That makes most of the 1,500,000 levels of contrast fall below the minimum sensitivity of human eyes. Besides, low brightness usually bring about another side effect of poor colorfulness, or saturation, since the cone cells of human eyes which tell colors are poorly sensitive to light[5].

In 2013, a manufacture of digital projectors announced a new product with 4kx2k resolution, a contrast ratio of 12,000:1 and 18,000 lumens in brightness. As we got a special budget for renovation of the projection system in mid-2014, this was obviously the best choice we have at that time. Subsequently, the renovation was performed swiftly and the theatre was finally reopened on 1st July, 2015. The process of the renovation had been discussed in one of my report published in the 2015 December issue of Planetrian[6].

4. After the Renovation

The expected useful life of our new digital system is 10 years. However, as we already know some important parts won't last so long, several major mid-life

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[4] https://www.tam.gov.taipei/

[5] There are two types of photoreceptor cells, rod cells and cone cells, in the retina of human eyes. The cone cells respond differently to light of different wavelengths, and are thus responsible for color vision and function best in relatively bright light. Thus, under low-brightness circumstances people sees objects but are hard to tell their colors correctly.

[6] Chilong Lin (2015), Digital Renovation of the Space Theater in National Museum of Natural Science, Taichung, *Planetarian* . Vol. 44, No.4, pp. 46

maintenances are already scheduled to be performed in September 2020. One major part is the “T-Cores”, the RGB chip module of digital projectors. Another major part is the computers, 1 Host and 24 GPs, which generate high quality images for the video programs.

It’s easy to realize the replacement of computers since the regular useful life of computers is about 5 years. If you were out of luck, some of them may breakdown even earlier. For example, we met a water-leaking from the ceiling of our computer room in 2018 and it happened just above the computer cabinet. Mainboards of many computers were soaked in water for hours before our staffs found the disaster. Failures did not happen immediately. But, some of them started to break down occasionally months after that disaster. Since then we have replaced five of the computers and will replace several of them every year until the end of its lifetime. However, even without such an accident, we have already planned to purchase some spares every year to keep the system works smoothly.

The T-cores of projectors are usually ignored but they affect the final performance of the projected images crucially. According to our experience of using similar products in our 3D theatres, the RGB chips decay under circumstance of high temperature and high brightness, especially the chip of Blue color. Such decay became obvious after about 5-7 years heavy loading use and the decay goes down faster and faster as it started. Thus, if we expect a ten years lifetime of the digital system, both the T-cores and the computers must be renovated in the mid of its lifetime. The estimated cost for the renovation of computers is about 5% of the original purchasing price of the whole system. While the estimated cost for replacing the T-cores is less than 10%.

Besides these two major items, the annual maintenance fee is about 3.7% of the original purchasing fee. That is about 2/3 the fee we paid before the renovation. While the annual fee for changing the lamps of projectors is about 1.3% of the original purchasing fee. In summary, the elementary operation cost for a 10 years run is estimated to be

- Regular annual fee: 3.7% *10 = 37%,
- Spare computers: 5%,
- T cores: 10%,
- Lamps: 1.3% * 10 = 13%,

  # Total: 65% of the original purchasing fee of the system.

Of course this is a very rough estimate and there are many trivial items not included in it. To our estimate, that could be another 15%-35% in total.

The new digital system saved lots of money and human resources for us. Before that renovation we need at least 3 fulltime staffs on the scene, one in the IMAX

projection room, one at the console and one at the gate. Now we need only two full-time staffs and sometimes one extra part-time staff since there is no more isolated projection room.

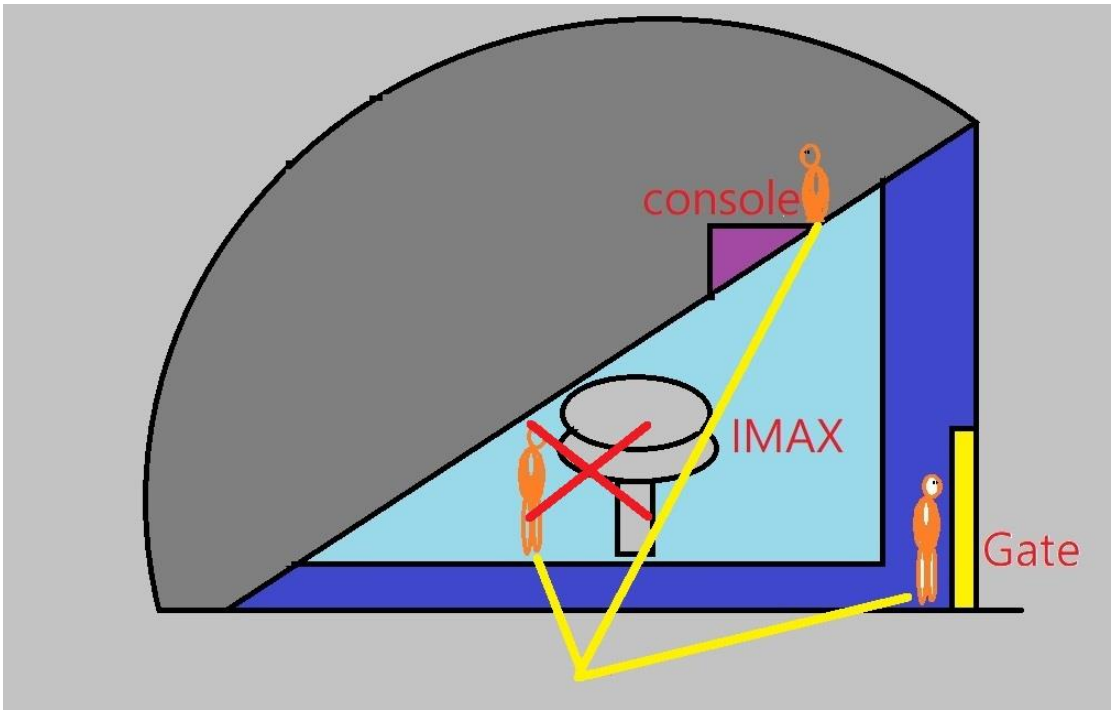

Figure 2: Before the renovation we need at least three full-time staffs at the scene during open hours. Now we need only two to serve at the console and the gate. That just solves the requirement of cutbacks in personnel from the government.

The most admirable and satisfactory performance of the new digital system are its “auto-align” and “auto-blend” functions. Large digital planetariums usually take multiple projectors to project a hemisphere image. How to produce a uniform image across the entire dome was a problem bothering theatre staffs very much since the brightness of projectors decay at different rates. According to our experience, the tortoise shell-like pattern becomes apparent about one week from previous calibration. So we have to perform the alignment and blending every week.

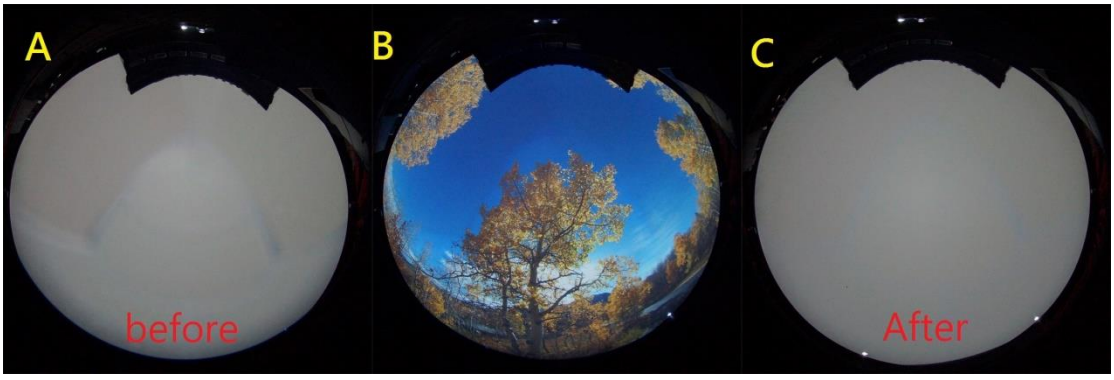

Figure 3: The auto-align and auto-blending can be performed within 30 minutes or shorter. That enables theatre staffs to keep the image quality always in a good condition.

In early years such calibrations were performed manually by well-trained engineers and in usual it takes a whole day. But, as the auto-align and auto-blending functions came to the market, such calibrations can be performed in as short as 30 minutes or less. That enables us to keep the images always in the best condition. Even, for many times the image quality decayed for some unexpected causes like the failure of some of the lamps. Our staffs performed the calibration briefly after the end of daily shows. Sometimes they do not even have to extend their office hours.

In Figure 1, the annual attendances before and after the renovation are presented. The reader may see the number dropped gradually down to 253,358 in 2014 before the renovation. After the renovation, the number began to increase in the first two years, 277,287 in 2016 and 309,834 in 2017. But, suddenly the attendance number in 2018 dropped down to 229,830 which is even lower than the number before the renovation. The number decreased more than 25% when compared with that of 2017.

The causes of such a slump were attributed to two major causes. One is we chose a film unsuitable for a dome theatre. That film was originally produced for flat screen theatres. When screened in a dome theatre the subjects on screen were extended too much which makes the attendances uncomfortable.

The other cause is the water leaking happened in the computer room and unpredictable shutdowns of the theatre after that accident. That accident and subsequent system breakdowns caused cancelation of hundreds reserved shows since we do not have enough spares to replace those failed computers. Even in the year of 2019, we called off tens regular shows for sudden failures of computers and its sound system. That was really a disaster of the theatre and we are still trying to get special budgets to make up the damage it brought about.

In our schedule, all 6 T-cores will be replaced and 4 more spare computers will be delivered to the museum in September 2020. We expect they will maintain the image quality as good as new in next five years.

5. What will be the Next Renovation

As mentioned above, the expected lifetime of our new digital system is about 10 years if the planned replacements of T-cores and GP computers in 2020 were performed successfully. If everything goes smoothly, the next renovation is scheduled to be performed 5 years from now or around 2025. We hope it will not be another 29 years.

Even during the previous renovation we kept our eyes on several new progresses of projection technology. Many interesting technologies attracted our interests very

much for years. Unfortunately, they did not get mature enough at the time we decided to perform the renovation. For instance, one thing attracted us very much is the laser-illuminated digital projector. During the preparation of our previous renovation, we sent staffs to attend the GSCA (Giant Screen Cinema Association[7]) conference for announced demonstration of a laser projector for many years. Finally, that projector was demonstrated in the GSCA 2015 conference held on September 9-11 in San Francisco while our renovation was done and the theatre was reopened on that July 1. Though the projectors now in service are already very economic in maintenance and performed very well. We are still very interested in the laser-illuminated projection technology since the brightness of laser projectors increased dramatically in past few years to satisfy the demand for a digital theatre and their contrast ratio is also improved very much. Both are approaching the ideal projector for a digital planetarium.

Another noteworthy technology is the 8K projectors. The digital system in our planetarium was measured to have a 7.5Kx7.5K resolution with six 4K projectors. If each of them were replaced by an 8K projector, the final performance will be 15K x 15K which is even better than the 10.8K x 10.8K ultimate demand of human eyes[8]. For now there is only one on-stack 8K projector which is effectively four 4K projectors assembled in a same cabinet. However, we expect more similar products will come to the market in the near future. With such projectors, two are already enough to achieve an 8K x 8K resolution which is better than our in-service system with six 4K projectors. We may expect the maintenance will be more economic than those in-service systems. At least, the calibrations between two projectors surely are much easier than among six.

Another performance we care very much is the contrast ratio of the digital projectors. We expect in the next few years there will be many products with contrast ratio higher than 50,000 : 1 come into the market. This is because the ratio between the -4.9 magnitude Venus, which is the brightest star in the night sky if we exclude the sun and moon which are obviously not point-like objects, and 6.5 magnitude stars which are the faintest stars can be seen by naked human eyes is about 36,326 : 1. If we have such high contrast digital projectors, they will enable us to project both the faintest and brightest stars with a single pixel. That will solve the problem of fluffy star points of present digital projectors which have to project bright

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[7] GSCA is an association of Giant Screen Cinemas founded in 2006 with the unification of the Large Format Cinema Association (LFCA) and the Giant Screen Theater Association (GSTA). In early years such 15/70 or 10/70 film projectors were usually coexisted with the opto-mechanical planetariums in a same dome, like our Space Theatre. Many technologies developed for digital planetariums also apply to them. https://www.giantscreencinema.com

[8] The ideal Visual acuity (VA) 20/20 or 1.0 meanings one can tell two points separate 1 arc min (= 1/60 of a degree) apart. That equals to 10,800 points for a 180 degrees semicircle.

stars with multiple pixels.

In the coming future there must be many new and brilliant technologies coming to the world. I cannot wait to see how vivid the scene they will show us.