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18th International Planetarium Society Conference
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Many thanks to all who have contributed to the proceedings.

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CONFERENCE PROCEEDINGS by Subject
Astronomy in Society

how the general public engages with astronomy
A Permanent Planetarium For Sydney

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Abstract. The city of Sydney, Australia, has been without a permanent fixed planetarium since the closure of a successful 40 seat planetarium in 1982. A comparison of cities (population of greater than 2.5 million) in developed countries (gross domestic product per person of greater than US$10,000) shows only 2 cities (4%), including Sydney, are without a planetarium. A worldwide comparison of all cities shows that 74% have at least one planetarium and in developing countries alone 63% of cities have a planetarium. A simple method is outlined to estimate the average number of planetarium seats a city of any population in a developed country can support. This method indicates that a city with a population of 4.35 million (such as Sydney) could be expected to support a combined total of 320 planetarium seats.

INTRODUCTION

Planetaria are a recognised medium for teaching astronomical concepts to people of all ages and all educational backgrounds, with public astronomy education being as important as curriculum based programs [1]. Within Australia there are seven permanent planetaria (see Figure 1), including three facilities built in the last ten years (Canberra, Melbourne and Wollongong) and two that have undergone major refurbishment in the last 5 years (Brisbane and Perth). Sydney, the largest Australian city (population of 4.35 million), does not presently have any facility able to provide all the services a fixed planetarium could offer.

The Museum of Applied Arts and Sciences (MAAS) in Harris Street, Ultimo, operated a planetarium from 1950 to 1982. This planetarium was highly successful attracting a total audience of 55,898 in 1967 [2] yet seated only 40. Since the late 1960s there have been numerous proposals to build on the MAAS success by establishing a larger planetarium in Sydney. For example, a proposal for a planetarium by the Astronomical Society of New South Wales [2], Sydney Planetarium Pty. Ltd. [3], a planetarium and observatory complex for Macquarie University ([4] located 20 km to the north-west of the Sydney CBD) and an underground planetarium complex for Sydney Observatory [5]. Building on this strong support the Sydney Sky Theatre concept has been developed and is described in this paper. Currently operating within the Sydney Metropolitan area there are at least two portable Starlab planetaria and a small Starlab FiberArc planetarium projector at Sydney Observatory seating up to 15 people on bean bags.

FIGURE 1. Location and seating capacity of planetaria in Australia.
WHY A PLANETARIUM?

A planetarium provides a unique environment to stimulate curiosity and wonderment for the universe we live in (see [6, 7, 8, 9]). To avoid the notion that planetaria can be boring, programs must educate while providing an entertaining experience (education can be much more effective if it is enjoyable). The ability of planetaria to accurately recreate the night sky, which is very difficult to do in a classroom or anywhere else, allows visitors to experience a truly beautiful night sky while they learn. As a venue (see [8, 10]) the planetarium offers the most effective use of visual media for education (a picture is worth 1,000 words and an animated 3D graphic is worth 10,000) and acts as a venue for activities associated with the educational message e.g. exhibits, workshops and a science shop.

Planetaria (along with public observatories and visitors centres at major observatories) also act as an interface between research institutions and the public [11, 12, 13]. In this role planetaria help convey the complex ideas that lie at the heart of modern astronomy in a clear, accurate and entertaining manner, which most research institutions do not have the time or resources to do.

SYDNEY - A WORLD COMPARISON

To determine the viability and optimal size of a permanent planetarium for Sydney we adopted a worldwide statistical comparison of cities in developed countries, comparing their population base with the number and size of planetaria that they support. The underlying assumption of this method is that Sydney would be able to support a planetarium of at least the average size found in cities of a similar size.

FIGURE 2. Planetarium size (total number of seats per city) versus city size (Population). This graph represents 148 cities with a population greater than one million from countries with a GDP per person greater than US$10000. Portable planetaria are not included. A line of best fit indicates Sydney with a population of 4.35 million can support on average 320 seats.

Worldwide cities have opted for either one or two large planetaria, one large and several small planetaria or many small planetaria. In order to gain meaningful data it was decided to total the number of planetarium seats (excluding portable planetaria) in each city and use this data as if it represented the size of a single planetarium the city can support. The total number of seats was determined from the compilation of planetaria statistics [14] and from web based databases of planetarium associations (IPS [15], EuroPlaNet [16], S&T [17]).

The census figures [18] for all cities world wide with a population exceeding one million were combined with the total number of planetarium seats for each city, with developed (GDP/person \( \geq \) US$10,000) and developing (GDP/person
countries separated out by their 2006 Gross Domestic Product (GDP) per person in US dollars [19].

Sydney Compared To Cities World Wide

A total of 156 cities have a population exceeding 2.5 million, which includes Sydney and Melbourne. Figure 3a shows that among developed countries, the overwhelming proportion of cities (96%) have at least one permanent planetarium. The only cities in this group that do not have a permanent planetarium (4%) are Sydney and Toronto. Even in the developing countries such as Egypt, Brazil and India, 63% (Figure 3b) of the largest cities have at least one permanent planetarium and world wide 74% (Figure 3c) have planetaria. This alone would suggest that Sydney is capable of sustaining at least one permanent planetarium, but gives no indication of what size Sydney would be able to support.

What Size Planetarium Can Sydney Support?

Figure 2 shows a comparison of the population of each city with the total number of planetarium seats it supports, for 148 cities in developed countries with a population exceeding one million and have fixed planetaria. A power law model was fitted to the data (plotted as a solid line in figure 2) using a least squares algorithm to estimate the average trend and from this, the average number of planetarium seats for a city like Sydney of 4.35 million people is 320. Allowing for two medium sized competing planetaria with 60 seats each (the Canberra Planetarium has 60 seats) this strongly suggests that Sydney can support at least one large planetarium of up to 200 seats. Since no competing permanent planetaria exist in Sydney, a planetarium of this size should be assured viability.

FIGURE 3. These three graphs represent the proportion of cities with a population of greater than 2.5 million that don’t have planetaria or have one or more planetaria for all cities in (a) developed countries with a GDP per person greater than US$10,000; (b) developing countries with a GDP per person less than US$10,000; and (c) all countries. Portable planetaria are not included.
It is interesting to note that the United States city of Atlanta has a similar population to Sydney, yet has one large planetarium of 500 seats combined with three smaller planetaria, each having 120 seats and one of 56 seats, a total of 916 seats. Clearly Sydney as a major international tourist destination, attracting four times as many overseas visitors as Atlanta, 2 million [20] versus 0.5 million [21] visitors, could potentially support a larger planetarium than indicated by the above data.

A PROPOSAL FOR SYDNEY

We propose a planetarium for Sydney called: The Sydney Sky Theatre. The name is intended to convey to everyone the nature of the place and to allow flexibility in what can be done; the sky encompasses the atmosphere and weather as well as space exploration and astronomy.

About 75% [14] of planetaria around the world are attached to museums and other non-profit or government funded institutions. Although many cover their operating costs from ticket admissions, they are not highly profitable.

Realising this we decided to propose a non-profit organisation to establish and then run the planetarium, making it clear to potential supporters that this is not an investment for return on their capital, but an investment in the scientific and cultural literacy of our society.

A Non-profit Development Association

In 1998 The Sydney Sky Theatre Development Association Inc. was established with the following objectives:

- to source funding for the development of one or more planetaria in the Sydney metropolitan area.
- to promote public understanding and awareness of the science of astronomy and space exploration.
- to support and/or actively engage in the establishment of one or more planetaria in the Sydney metropolitan area.
- to promote public understanding and awareness of the science of astronomy and space exploration.

We think this is an exciting opportunity for astronomy education and for Sydney. We will need a lot of support to get this project going and would warmly welcome any offers of assistance.

CONCLUSION

We have shown the city of Sydney is anomalous among similar cities around the world in that it does not have any permanent planetaria. Of all cities in the developed world with a population exceeding 2.5 million people, only 4% (2 cities) don’t have a planetarium. These cities are Sydney and Toronto. Even in developing countries such as Egypt, Brazil and India, most of their largest cities (63%) have one or more permanent planetaria. This alone would suggest that Sydney is capable of sustaining at least one permanent planetarium. We also found that Sydney is capable of sustaining at least one planetarium of up to 200 seats, while allowing room for the development of one or more smaller planetaria with a combined seating capacity of up to 120.

From 2000 to 2005 the number of permanent planetaria opening worldwide has averaged about 35 per year [14], offering hope that some time in the near future Sydney will have its own Planetarium. To achieve this goal we established a non-profit organisation called the Sydney Sky Theatre Development Association Inc. and proposed a planetarium for Sydney called The Sydney Sky Theatre. A similar non-profit corporation is currently proposing to build a new facility named the GeoSpace Planetarium [22] in Toronto Canada to replace the McLaughlin Planetarium that closed in November 1995.

If you would like to join the association, or would like to offer suggestions or advice on any aspect of the project, please come talk to us (website
REFERENCES

Masters Students In Science Communication Are Educated For Work At Planetariums

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Abstract. The Science Communication program for masters students at Dalarna University, Sweden, has been running for four years. An outline of the program is given, including a follow up on the occupations held by the 17 students that have graduated from the program.

INTRODUCTION

At Dalarna University, Sweden, master level studies in science communication are now into its fourth year, and it is possible to draw some conclusions.

Students come from all over the world, to date from 22 countries, namely Australia, Austria, Bangladesh, Botswana, Canada, Cameroon, China, Denmark, Estonia, Finland, Germany, India, Iran, Jordan, Malaysia, Nigeria, Norway, Pakistan, Belarus, Sweden, Thailand, Trinidad and Tobago.

Science communication staff include Professor Lars Broman, Professor Hannu Salmi, Assoc. Professor Ernst van Groningen, Assoc. Professor Jan-Erik Berg, Assistant Professor Maria Björkroth, teachers Per Broman and Dick Nilsson; all part-time.

STUDENT STUDIES RELATED TO PLANETARIUMS

All students are taught the basics of working with a planetarium, and starting with the spring semester 2006, they get to experience running a digital all-color planetarium. Science communication has a semi-permanent dome and an opto-mechanical standard Starlab projector. We have an agreement with Broman Planetarium so we can rent their Starlab digital projector whenever we need it.

Students visit a number of planetariums during study tours, including three smaller ones:
1. Kosmorama Space Theater at Futures' Museum in Borlänge, Sweden,
2. St Exupery Planetarium at the National Museum of Technology History in Oslo, Norway, and
3. the planetarium at Navet in Borås or at Upptech in Jönköping, Sweden, and

and two major ones:
1. Cosmonova at the National Museum of Natural History in Stockholm, Sweden, and
2. Verne Theatre at Heureka in Helsinki, Finland.

To write a planetarium program manuscript and to produce a digitalized planetarium show are among the requirements. Textbooks in scriptwriting are Per Broman's "Creating Manuscripts for Planetarium Programs and Other Multimedia Slide Shows" and the IPS CD "Tips for Excellent Script Writing" by Steve Tidey, editor. Textbooks in planetarium show production are three introductory compendiums by Per Broman on the use of GoldWave, Image Composer, and PowerPoint. The texts are made available to the students for download from the Dalarna University course portal fronter.du.se.

During the first semester, students get hands-on experience of handling a
planetarium, both a mobile StarLab and with a (semi-)permanent Eurodome (see www.planetarium.se). Students do live presentations both with an opto-mechanical projector and a full-dome digital video projector. Student production of slide & audiocassette programs have now been replaced by producing computer & video projector programs. We have for a number of years had a 5m diameter dome but it will (for space reasons) be replaced with a 2.5m diameter dome - small but still adequate for student training.

**MASTERS THESIS AND ARMAND SPITZ SCHOLARSHIPS**

Included in the Masters program is a 3-month internship and thesis field work at a science center, museum, or planetarium. So far, a couple of students each year have chosen to go to a planetarium or a science center with a planetarium somewhere in the world and to subsequently write a thesis in the planetarium field.

Also, every year, two scholarships from the IPS Armand Spitz Fund for Planetarium Education have been available for students from Dalarna University. These are the students who to date have received a US$500 scholarship (included are their fieldwork institution and thesis title):

2004 (reported in Planetarian 4/2004):

Claudette Martin from Canada, H R McMillan Space Centre, Vancouver BC, Canada – Examining Visitor Attitudes and Motivations at a Space Science Centre

Hamid Asgari and Kayvan Seyed Nejadian from Iran (shared), Dalarna University temporary science center – Important Parameters in Designing and Presenting Exhibits and Planetarium Programs in Science Centers: A Visitor-Based Framework

2005 (reported in Planetarian 4/2005):

Miao Xu from China, Orion Planetarium, Jels, Denmark – A Study of Visiting Students Groups to Planetarium Shows

Shibly Ahmed from Bangladesh, South Tyneside College Planetarium, South Tyneside, UK – The History of Planetaria in UK

2006 (reported in Planetarian 4/2006):

Yang Yo from China, Mediendome Kiel, Kiel, Germany (spring fieldwork) – Exploring the Upgrade Space of Planetariums

A fall 2006 scholarship receiver is yet to be decided.

**FUTURE OF STUDENTS AND FUTURE OF SCIENCE COMMUNICATION**

Our students find different occupations after completing their masters studies. To date, these are the occupations of the seventeen alumni's after graduation:

- six work at a science center or planetarium: of these two are directors, two are in permanent positions and two are in temporary positions.
- four are working in related fields - education, etc.
- five have continued studies: of these two are studying for their PhD and two are studying at MSc level.
- two are presently unknown.

We expect that the majority of students will find employment in the field of planetariums and science centers as our program becomes more widely known.

The number of applicants remains high, and the program starting in August 2006 is full. Applications for the program starting in January 2007 are due 1 September 2006. For application information, go to
www.du.se. For subject information, go to www.sciencecommunication.se.

Note added in December 2006: Intake to the program for the spring semester 2007 has been stopped by the University Rector (for unclear reasons and without any formal decision). The future of the program is currently uncertain. However, we are hopeful and have obtained acceptance for Professor van Groningen to replace Professor Broman as Chair of Science Communication, starting 1 January 2007.
Native Brazilian Skies

Alexandre Cherman

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Abstract. Truthful to our mission, the popularization of science in general and astronomy in particular, we present a different view of the sky, based on the knowledge of the native Brazilians.

BRAZILIAN LEGENDS

Brazil is one of the largest countries in the world and it has a vast ethnic variety in its indigenous population. Even though some minor indian settlements can be found near the city of Rio de Janeiro, it is towards the Amazon jungle that they are most common.

FIGURE 1. Map of Brazil, highlighting the cities of Rio de Janeiro, Belém and the Amazon jungle.

The current work is a result of the interaction between some of the astronomers of the Rio de Janeiro Planetarium and the staff of the Belém Planetarium, near the Amazon jungle. It is mostly about the Tembé, Ticuna and Bororo tribes.

FIGURE 2. Map of Brazil, with the three tribes of interest.

BORORO SKIES

The Bororo tribe is one of the most studied tribes in Brazil, in terms of astronomy. As an example, in Figure 3 we show the Rhea constellation (image taken from [1]).

FIGURE 3. The Rhea.
TEMBÉ SKIES

In 1999, there were only 820 known Tembé natives. Figures 4, 5, and 6 show some examples of their constellations.

**FIGURE 4.** The Tapir’s Jaw (*Taurus*).

**FIGURE 5.** The Tortoise (*Corona Borealis*).

**FIGURE 6.** The Tapir (*Milky Way*).

TICUNA SKIES

The Ticunas are a large nation, comprising over 30,000 people. Figures 7 and 8 show some of their constellations.

**FIGURE 7.** Tortoises (*Pleiades*); Alligator’s Jaw (*Hyades*) and Alligator’s Leg (*Orion’s Belt*).

**FIGURE 8.** The Anteater (parts of *Triangulum Australe, Norma* and *Ara*) versus the Jaguar (*Scorpius*).

CONCLUSION

Native Brazilian skies are very rich and, unfortunately, are still a big mystery for
most. Planetaria from different parts of the country are working hard to change that.

ACKNOWLEDGMENTS

The author would like to thank Fernando Vieira (astronomer of the Rio de Janeiro Planetarium) and Michel Sauma (director of Belém Planetarium) and the Planetarium Foundation and the Rio de Janeiro City Hall for funding his trip to Australia.

REFERENCES

Puppets In The Dome

Alexandre Cherman

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Abstract. One of the key issues when writing a planetarium show is how to maintain a young audience's attention. At the Rio de Janeiro Planetarium, we write custom-made scripts using characters created by our own staff. At first, we introduced these characters using still frames. We had to rely on light and sound effects to simulate action with this method. As the technology became cheaper, we started to use computer-animated characters. But, since our budget was always limited, we never got quite the result we wanted. Trying to keep the animation of the characters and keeping to our budget, we started doing shows with puppets. The astronomers write a script, which is played by a company of puppeteers. The play is taped and the tape is projected inside the dome, together with the sky. We have already done two shows with this technique and the public response has been very good.

WHY PUPPETS?

The key issue in developing a planetarium show is how to convey your message (mainly astronomical data). At the Rio de Janeiro Planetarium we have a long standing tradition of developing planetarium shows which use characters and an action plot to deliver our message. We started out using still images, generated by slide projectors. When we opened our new 23 meter dome, in 1998, we entered a new era and began experimenting with computer animation. We rapidly realized it was too expensive and we could never compete with the quality our audience gets from movies. We needed a solution that was animated, inexpensive, easy to produce and attractive to the audience. We opted for puppets.

GETTING STARTED

The first thing we had to do was to find a puppeteer. One of our astronomers (Fernando Vieira), serendiptiously, had attended a puppet presentation with his six year old daughter. The first contacts were made and a partnership was born.

Another astronomer (Alexandre Cherman) wrote a script about two alien brothers who had just won their school science fair, with a project describing the Solar System. And thus we had the embryo for The Science Project.

The script was sent to the puppeteer for his review. A few changes were made and he started to build the puppets.

FROM STAGE TO DOME

The puppeteer had experience doing his shows on stage. But one thing he had already going for him was his ability to manipulate the puppets without being seen by the audience. The technique he uses involves two manipulators per puppet (that is, for an usual puppet). One will handle the arms and the other will handle the head (this one is also the one doing the voice). Both manipulators wear black clothes and stay hidden the whole time.

We first recorded the voices, in a sound studio. We then staged the play and got it on tape. Finally we projected the images, with the original recorded sound, against the dark environment of the dome, with the starfield. We also projected some images
against an all-sky setting, which represents the two boys’ bedroom.

**THE SHOW ITSELF**

The show starts with a transmission coming from another planet, interfering with the dome’s operation. We rapidly find out it is a broadcast from two very happy brothers who have just won their school’s science fair. They explain to the audience that they are so happy that they want to share their work with the children at the Planetarium. And thus it starts.

We talk about the planets and the motions of the Earth and also about constellations and our calendar.

The show ends abruptly when the boys’ mother sends them to bed.

It is aimed at kids around 6 to 8 years old.

**A SECOND (AND THIRD) SHOW**

The original puppet show was such a success that we decided to do another one. This time we gave the puppeteer complete freedom to create a show, aimed at kids from ages 4 to 6.

He came up with *The Adventures of Two Sunbeams*. The show tells us the story of two sunbeams that leave the Sun, heading towards Earth, but get lost along the way.

There are over twenty puppets in this show (e.g. the planets, the Moon, the Sun, and the sunbeams) and not all are astronomical; there are puppets that represent the pollution of Earth’s atmosphere, the rainstorm, the ozone, the chlorophyle and many more.

We are currently producing a third puppet show, aimed once again at little kids. It will be called *Riding with Pegasus* and its main goal is to tell some of the stories about the constellations.

**CONCLUSION**

Puppets are a very inexpensive and fun way to animate your characters inside the dome. We call it “low-cost 3D animation”. We definitely recommend the use of puppets for planetarium shows.

**ACKNOWLEDGMENTS**

The author would like to thank Fernando Vieira (astronomer of the Rio de Janeiro Planetarium and producer of the shows), Heleno Hauer (puppeteer and director of the shows) and the Planetarium Foundation and the Rio de Janeiro City Hall for funding his trip to Australia.
Aboriginal Skies

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Abstract. This paper gives an introduction to the night skies of Aboriginal Australians. Indigenous Australians have been viewing the night skies for 45,000+ years and over this time have been able to develop a complex knowledge of the nightly waltz of stars above.

EARLY ASTRONOMERS

Many believe that the Aboriginal Peoples of Australia were amongst our world's earliest astronomers. According to Prescott (2005) [1] recent estimates of their occupation of the Australian mainland is 45,000+ years, but this could date back further to around 62,000 years. The unforgiving arid environment and the seasonal availability of certain foods meant that a small section of Australia's Indigenous population were semi-nomadic moving from region to region to hunt and gather. It has been estimated that there were 270 distinct language groups within Australia before British colonisation began on mass in 1788. However, that number can be expanded to 600 language groups if different dialects are included separately.

Stellar Knowledge

Sadly, many of these early colonists saw little value in Indigenous knowledge of the night sky. Many of the stories today only survive because of the thoughtfulness of a few individuals at the time. In addition, because Aboriginal Cultures pass a lot of knowledge down through song, dance and oral narration, often only initiated members of the group would stand to inherit this stellar knowledge. Consequently sometimes only one member of the group would hold some of this information and if something happened to that individual the knowledge was often lost to antiquity. Elders would teach the young and initiated members of their group the star patterns and this would as a rule be accompanied by a Dreaming story. [Note: ‘The Dreaming’ is an explanation of how all in the cosmos came into being]. Indigenous Australians prefer the term ‘The Dreaming’, because the word ‘Dreamtime’ often implies a set time in the past To Aboriginal People there is no set time in the Dreaming, it is an ongoing process.

When we make comparison to the 88 constellations used by contemporary astronomers we notice that Aboriginal Peoples often-payed attention to the same parts of sky that so fascinated their western counterparts. For example, when the Pleiades star cluster which is located in the constellation of Taurus would make its first dawn appearance (heliacal rising), the

Figure 1. Distribution of language areas in Australia.
Pitjantjatjara and Yankunytjatjara people who come from Central Australia knew that this was the start of the annual dingo breeding season. Shortly afterward the Pitjantjatjara and Yankunytjatjara communities would raid the dingo lairs killing and feasting on the young pups [2]. The stellar realm of Indigenous Australians often saw the Pleiades as a group of women sitting in the sky, much akin to the more modern European story of the seven sisters. Nonetheless, various groups have seen the Pleiades as a group of kangaroos, a clump of gum trees and the resting place of the dead.

Southern Cross and Orion

Crux, or the ‘Southern Cross’, appears on the flags of Australia, Brazil, New Zealand, Papua New Guinea and Western Samoa. The Ngarrindjeri Peoples who occupy the Coorong and Murray Valley region of South Australia saw the Southern Cross as a giant stingray. This stingray was being pursued by two sharks, marked by the Two Pointers (Alpha and Beta Centauri).

The Aranda People of Central Australia saw the Southern Cross as the talon of an eagle.

Additionally, the Kaurna (pronounced gar-na) People of the Adelaide plains region of South Australia viewed the Southern Cross as the footprint of an Australian wedge-tailed eagle Aquila Audax, which they called Wilto. Furthermore, to the Kaurna the two misty white satellite galaxies the Large and Small Magellanic Clouds were seen as the ashes of two rainbow lorikeets. They believed that the two birds were tricked into the sky then killed and eaten, so that all that remains to be seen today are the ashes of these cooked birds [3]. The Kaurna called the Milky Way ‘Wodliparri’ (wodli meaning hut and parri meaning river), and the ‘Wodliparri’ is a watercourse curving through the ‘Womma’ or the celestial plains. Reeds grow around the lagoons of the ‘Wodliparri’ and a group of young women the ‘Mankamankarrana’ (or the Pleiades) collect roots and vegetables from around it. Also, the Boorong People of northwestern Victoria saw the Pleiades as a group of women clapping to a corroboree – a corroboree is a convention of different Aboriginal groups, where dancing, music and singing often take place.

Additionally, the Kaurna People called the constellation of Orion, ‘Tiinninyarra’, (also sometimes written as ‘Tiinninyarrana’), and the ‘Tiinninyarra’ are a group of young men who are hunting emu, kangaroo and other game of the celestial plain known as the ‘Womma’.

CONCLUSION

In the present day we are left with only snippets of the enormous wealth of stellar knowledge constructed over tens of thousands of years by these early astronomers. Homo sapiens still look up in wonder at the heavens. However, in an expanding urban environment, the light pollution of our cities and towns push some of us further away from these cosmic wonders. The night sky of Aboriginal Australia is filled with information, wonder and edification, and this curiosity plus drive to connect with the cosmos still makes many of us ponder when we view the night sky.

REFERENCES


Some Interesting Planetarium Conferences Prior To The Founding Of IPS

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Abstract. IPS was formed in the early 1970s as a result of the explosion of new planetarium facilities in the United States and elsewhere. Most of the US regional affiliate organizations and a few of the International affiliates predate IPS by only a few years. Other than a few regional affiliate conferences, what meetings were held to address the needs and interests of the early planetarium community? This paper will focus on several such conferences. Interesting highlights and personalities that would have influences for decades to come will be addressed in this look into the planetarium past.

IN THE BEGINNING

Once upon a time there were very few planetariums upon the planet and they were a creation of one company. Each was almost a clone of its cousin. The doors opened and the people came. Eventually more of these magical theaters were created and differences began to emerge. Some were created to serve specialized audiences and the school planetarium was born. Others dared to offer programming that was “non-traditional”. Planetariums continued to proliferate and by the 1950s there were hundreds and by the 1960s, thousands. The diversity and complexity of the installations grew along with the numbers.

In the modern planetarium world it’s easy to assume that the array of technology that is utilized under the dome is a given. How could anybody possibly have operated a facility as effectively without it? We often look back at the early theaters and see them as an anachronism, something that cannot remotely have any relevance to the planetarium environment of today.

But when you delve into albeit sketchy records of the past, some surprising information comes to light.

It’s interesting and often amusing to read articles in early issues of The Planetarian and other publications including various Regional publications, where there were arguments about dome construction techniques, seating orientation, live versus canned programming, programs that were non-astronomical in nature, dome tilt and a host of other sometimes controversial topics of debate.

In 2006, we are fortunate to have various forums including planetarium organizations, consortiums, conferences, publications and digital media, through which to present our ideas. But when we go back beyond a certain threshold there seems to be a void. Back in the early days these multiple channels of exchange and communication didn’t exist for the most part, nor was the need itself there. There was communication between manufacturers and their clients from early on, but nothing close to resembling today’s state of affairs. It was only when our numbers increased significantly, our complexity grew and our differences began to surface, that various modes of information exchange became necessary and practical.
The International Planetarium Directors Conference (IPDC) held their first meeting in May 1959 in New York City. It didn’t meet again until June of 1966 in Munich and then met every three years thereafter. Many Regional organizations were formed in the 60s. In the US, the Middle Atlantic Planetarium Society (MAPS) and the Great Lakes Planetarium Association (GLPA) were formed in 1965, The Southwest Association of Planetariums (SWAP) followed in 1966. By the early 70s there were 7 US Regional organizations. Two non-US Regional organizations, PAC in Canada and EMPA, the first European organization, were also in existence by the early 70s. Most of these organizations held annual conferences.

The beginnings of IPS can be traced back to the 1960s when it became apparent that there was the interest and need for something more than Regional organizations. Von Del Chamberlain took the initiative and organized the Conference of American Planetarium Educators (CAPE) in East Lansing, Michigan. The meeting was held in the fall of 1970 and attracted over 250 participants from throughout the US, Canada, and Europe. Mandates for the formation of IPS (originally ISPE) were put forth at CAPE. In the spring of 1971, Dionysius Simopoulos hosted a gathering of delegates who put together the necessary framework, and ISPE was born. Beginning with Cupertino, California in 1972, conferences have been held every two years since.

THE 1958 AND 1960 SYMPOSIA

Interestingly there were two symposia held in 1958 and 1960, the first at Cranbrook Institute in Michigan and the other at the Cleveland Museum of Natural History. Of significance is the fact that there were very detailed proceedings published from each of the meetings.

The rest of this paper will focus on these two symposia since the proceedings offer many interesting perspectives and parallels to the planetarium of today.

The Cranbrook Symposium, *Planetaria and their Use for Education*, was held September 7-10, 1958 and was the brainchild of its Director, Robert T. Hatt. 101 delegates attended representing 67 of the 120 planetariums in the US. In the 1960 proceedings, the number of US planetariums was reported to be in excess of 200. Other attendees at both symposiums included vendors, architects, educators and museum personnel. The two conferences were funded at least in part by grants from the National Science Foundation. The two conference hosts, Cranbrook and Cleveland, were equipped with a Spitz A-1 projector under a 30-foot dome.

It was reported that the delegates welcomed the opportunity to present their ideas and discuss their problems, and they proposed that the initial meeting be followed by similar ones. They formed a committee to plan a planetarium association and named James A. Fowler of Cranbrook as chairman. No record is known by this author of any organization that resulted from that mandate other than the 1960 meeting itself.

There was discussion about planetarium terminology and indeed the word *planetarium* itself. What was the “correct” word to use for the plural of planetarium? Hatt spoke in favor of *planetaria*. Armand Spitz spoke in favor of *planetariums* (to correspond with museums). The 1960 symposium incidentally was titled *Planetariums and their Use in Education* with only the plural of *planetarium* being different. Perhaps it represented the bias of the organizers.

It was reported that there were off-the-record discussions to define other terminology more specifically. It was suggested by some to call the instrument a “sky projector,” the room, a “sky chamber,” “sky-room”, or “planetarium,” and the building, a “celestium,” “celestarium,” “sky center,” “sky-dome,”
“star dome,” or “stararium.” These discussions were informal and no consensus was reached. Indeed, today there is ongoing discussion and confusion about the terminology. This is even more pronounced in my opinion in recent years with the advent of digital theaters and widely divergent missions of institutions. Will we ever reach a consensus?

Margaret Noble of the Washington DC public schools discussed the importance of classroom activities for pre- and post-planetarium visits. This is a given in the modern planetarium where much of the programming for younger audiences is curriculum-based.

There were discussions about planetarium design including dome construction. Plaster was a common material for dome surfaces. Perforated aluminum was relatively new to the planetarium theater and aluminum as well as plastic were seen as the newest technology. The Morrison Planetarium incidentally, that opened in 1952, was one of the first to use a perforated aluminum dome. Herb Williams of Spitz stated, “Someday when more planetaria are built, something better than a metal ceiling will be used. In fact, our good friend Doctor Spitz, is working on a development of that sort.” No suggestions were offered that shed light on what the material was and to this day perforated aluminum is the material of choice. In fact, several manufacturers have developed dome technology to the point of “seamless” domes, at least as far as the audiences can perceive.

Dome size was the topic of a paper presented by Herb Williams of Spitz. He stated that just a few years earlier Spitz recommended that the ideal dome size was 20 feet. They were now recommending that 24-foot diameters were appropriate for museums and colleges and 30-foot diameters were better suited for “public” planetariums. I find it interesting that they recommended nothing larger than 30 feet due to the projection technology limitations of the equipment. This is in direct conflict with the practice of selling projectors today that have horrible resolution parameters under domes of far larger diameters.

Seating and planetarium design seem to have been popular topics for discussion. The Cranbrook planetarium architect, William Kapp decided against headrests or high-back seats because of soiling that would occur as evidenced by the walls behind the last row of seats. Circular seating was almost universally accepted. Comments by William Hassler of the Fort Worth Planetarium mentioned that slide projection “will, of necessity, be over the heads of some of the audience and will be inconvenient for that reason. I know of no good solution.” Unidirectional seating didn’t really begin to make inroads until the advent of the azimuth axis-equipped instruments in the early 60s. Remarks by Kapp extolled participants to secure and correlate various data on the construction of planetariums in order to avoid the mistakes that are rampant in the design of facilities. But the fact often remains that many architects only ever design one planetarium in their career and often fall short in certain key design areas. By the late 1960s Spitz, Viewlex, and probably other manufacturers were furnishing a considerable amount of information on the various design parameters of the planetarium theater. Today it’s not uncommon to hire a planetarium consultant who can furnish specialized expertise far beyond the experience of your average architect.

Special effects were and always have been of interest to planetarians. The 1958 and 1960 symposia had many papers presented on the topic.

A comet projector described by John Cavanaugh of the North Museum Planetarium in Lancaster, PA, used a filmstrip projector with a comet slide. The slide was then projected onto a small mirror that was attached to the minute hand of an electric clock. During the
course of the show the comet would slowly move across the starfield. (How often today are comets shown moving perceptibly among the stars?) Cavanaugh went on to describe items in their workshop that were useful in constructing special effects. These included lenses, small advertising motors, old electric clocks, rheostats, gold fish bowls and pieces of broken mirror. These same items often occupy bins, shelves, and projection galleries of modern planetariums.

In 1958, George Bunton, the first director of the Morrison Planetarium in San Francisco, astutely noted that while, “the show is no better than the lecturer makes it, we must also admit that the ability of the lecturer is not the only limitation upon the show. The equipment and the way it is used is at least of equal importance.” I visited the Morrison Planetarium while attending the first IPS conference in the San Francisco Bay area in 1972 and was awed by the number and complexity of special effects that were either in use, in readiness, or under development.

Dan Snow, Director of the Cleveland Planetarium described and demonstrated several special effects at both the 1958 and 1960 meetings. Snow was renowned as one of the early proponents of special effects and other new technologies under the dome. In 1960 he argued that slides do in fact have a place in the planetarium (always a controversial topic apparently!) and extolled the use of Kodalith film to mask all but the desired portions.

The widespread use of special effects by the 1970s became the staple of most public planetariums as well as many smaller, educationally oriented facilities. Before long companies like Talent, Charlie Walker, Sky-Skan, Conic Instruments, and others were developing and selling special effects by the hundreds.

Snow also presented a paper about audio. He stated that a good sound system and music and sound effects were important components in planetarium presentations. In discussing a blast-off into space he suggested that some planetarium directors, “may be a little embarrassed by that type of program,” but rationalized it by saying there was simply too much interest in space travel to neglect it. He went on to describe ways in which appropriate sounds could be created and recorded. Classical music seems to have been the music of choice. The synthesizer was still years away and composers such as Mark Mercury, Jonn Serrie, Mark Petersen and other noted planetarium musical artists had yet to make their presence known in domed theaters.

A multitude of other issues were addressed at both Symposia including qualifications of planetarium personnel, specific program topics, planetarium marketing, educational aids and surveys of data about salaries, attendance and others. If you wish to peruse the documents further the 1958 proceedings are cataloged with the Library of Congress (59-11561). There is no mention of the 1960 publication being cataloged but the Cleveland Museum of Natural History has several pristine copies in their archives.

**CONCLUSIONS**

I think we can all agree on the value that this year’s IPS conference holds for our respective roles, just as the early meetings pointed out the value of communication then in a growing and very specialized field. But, how will the issues that seem so important to us this week be viewed decades from now?

Will we be seen as unsophisticated, archaic and rudimentary, as some view today’s earlier generations of Planetarians and Planetariums, or will we be viewed as a generation that pushed the envelope in technology, techniques and thinking?

We can see, when one delves into the records from the past, that many of same arguments and issues are for the most part
as relevant today as they were upwards to a half-century ago. We can also gain a better understanding and appreciation of how those issues were handled in the past and use that knowledge to build a better infrastructure for the future.

I think the conclusions and perceptions by our successors should be obvious.
A Hybrid Show On The Sun

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Abstract. In this paper, I will discuss our experiences in creating a new planetarium show. At the Holt Planetarium, we are known for our fully live and interactive shows. However, with our new show – Our Very Own Star – we wanted to embrace a larger group of planetarians, and so we created both a fully live and a fully recorded version of the show. I will take you through the trials and tribulations of graphics editing, audio editing, and video editing on a budget. We accepted 28 offers from planetaria across the United States to become test sites for this new show. A unique goal in our show development was to make a “hybrid” show. While we highly encourage doing shows live, we recognize this is not possible in all planetaria. As such, we created modular elements that could be done either pre-recorded or live. So, some would do the show completely live, some would do it completely pre-recorded, and some would combine some live segments with some pre-recorded segments. We would leave it up to each individual theater to decide how they would present the show. I will be discussing the feedback we received and what changes we had to make from our original show concept. Funding for the show came from NASA’s Living With A Star program. It will become Planetarium Activities for Student Success (PASS) volume 14 and be published by Learning Technologies, Inc.

A HYBRID SHOW ON THE SUN

At last year’s Western Alliance Conference of Planetariums 2006 in Denver, Colorado, USA, I presented a paper on the latest show from the Holt Planetarium at the Lawrence Hall of Science, Our Very Own Star. Funding for the show came from NASA’s Living With A Star program. This paper will cover the adaptation of that fully live and interactive show into one that could be presented fully recorded – or presented in a hybrid manner with modular sections. The user could decide to present some sections live, and some sections recorded. Developing any kind of recorded program was a definite first for the Holt. We sent out a number of field kits to test sites and received feedback, which I will be going over here.

I have had some previous experience creating graphics from the web or otherwise and splicing together some video elements to show during a program. However, what was new was putting a show together with running narration that had to be synchronized with video.

Software Used

Now, like many planetariums today, we don’t have a large production staff. In fact, our production staff consists of…me. So, I sat down with my Mac and a microphone and created a narration track using Apple’s Sound Studio audio software, and cleaned up the background noise and other effects, with SoundSoap from BIAS.

For the video sequences, I ended up using iMovie and iDVD. Although these last two are relatively simple software programs (and come with any Mac), they are pretty powerful. I was able to easily render my video sequences and burn them to DVDs. One issue I had with iDVD, however, is I felt locked into using pre-packaged menu templates that didn’t quite suit my needs.

I expect these minor issues to change with our recent purchase of Apple’s Final
Cut Studio suite of professional audio and video editing software. I have only played with the software a little bit, but I know I will have greater precision in editing, and more freedom when creating DVDs. There is also the freedom to add more audio tracks to overlay over the narration, which is part of the feedback we received.

A Modular Show

As I already mentioned, our goal was to create a hybrid show, with modular sections that could be done—or not—either live or recorded. Typically, our programs at the Holt run about 45-50 minutes, but our initial inquiries to field testers indicated a desire for a shorter program. So, having modular elements allowed our testers to easily (at least hopefully) choose which elements they would use. Anyone familiar with the Lawrence Hall of Science’s Planetarium Activities for Student Success (or PASS) series of planetarium shows will know that our shows are already organized in sections. In the case of Our Very Own Star, the show is composed of the following sections:

- **Introduction** – shows some atmospheric phenomena caused by the Sun (eg. sun pillars and corpuscular rays).
- **Sun as a Timekeeper** – discusses the rising and setting points of the Sun at different times of the year.
- **Different Views of the Sun** – shows satellite imagery of the Sun and its appearance from the outer edge of the Solar System.
- **A Magnetic Earth Around a Magnetic Sun** – discusses the magnetic nature of the Sun, with the Earth as a reference.
- **Sunspots** – are discussed briefly and are used to introduce the next section.
- **Differential Rotation** – where the audience can see that different parts of the Sun rotate faster than others.
- **Conclusion** – where we wrap it up and bring it back to the beginning.

Each section had to be recorded twice on the DVD—one with narration and once without narration for live presentations. On the DVD then, each section is its own chapter, allowing a user to quickly skip to the section they want. Additionally, any still imagery that a live presenter might refer to in a separate medium (such as a slide or a PowerPoint presentation) was included with the recorded segments so the narration would naturally match with what was being shown to an audience.

Feedback Received From Test Sites

We received feedback from some of our field testers via a couple of online surveys we had set up—one for installation of the show and one for the presentation of the show. Overall, all the respondents had a positive or very positive reaction to the show. There was a slight majority (5/9 or 56%) of testers who did the show as a hybrid program. Most left at least some sections out—either due to time constraints or because of content level. According to the survey data, slightly more than half (6/11 or 54%) had family groups as their primary audience, while about a third (4/11 or 36%) offered the program to school groups, grades 5-8. The rest offered the show to school groups of other ages.

Installation Feedback

We actually had couple of different kinds of installation kits we sent out. All the kits came with the usual suspects – a show DVD and data CD with the script and all of the imagery.

Also, we included sets of Styrofoam balls and magnets to create the magnetic Sun and Earth models, as well as field bits (a.k.a. tiny metal washers) to “map” out the respective magnetic fields of said bodies (Figure 1).
Audiences can model the magnetic fields of the Earth and the Sun.

A key question we asked all of our potential testers is whether or not they had a “fast sun” at their disposal for the Sun as a Timekeeper section. The main idea here is to demonstrate where the Sun rises and sets on the solstices and equinoxes.

Since our star projector at the Holt has a pretty slow annual motion, we created a “fast sun” projector so as not to have this section drag out too long. To create something easily reproducible by other planetariums, Alan Gould came up with a simple design using PVC piping and an ultra-bright LED, on an “equatorial mount” (Figure 2). Some needed this Fast Sun Projector, and some didn’t. In any case there was a certain amount of assembly required to these field kits.

Some of the positive comments we got about installation included the simple design, inclusion of still images on the DVD, having chapters on the DVD, and that assembly was relatively easy, with time. That last comment was interesting since a fair number of testers commented on the difficulty of assembling the magnets on the Styrofoam balls. One person said he would have loved someone else – anyone else – to have created the models for him. These are small and very strong rare-earth magnets, that were, for some, difficult to un-stick from each other and difficult to keep unstuck without bits of finger getting caught inbetween.

Presentation Feedback

Overall, on the presentation side, audiences seemed to like the content, and the show seems to spur questions about the Sun and astronomy. Respondents also liked the modularity and – for those who did live presentations – the hands-on demonstrations and the interaction (especially playing with the Earth and Sun magnetic models). Audiences also liked the Timekeeping section and were surprised by the outcome of the rising and setting patterns, but it was stressed by testers that this section really is done best live (and with a fast sun). Audiences also seemed to enjoy learning about our star (and not some generic star out there).

Some criticism we received was that the show in full is too long, and could in fact be the basis of many shows with a solar theme. Some also felt that the language in parts was too technical and, at the same time, too simple in others. In our introduction section with atmospheric phenomena, one tester felt this was more meteorology than anything to do with astronomy. Also, there was some criticism of focusing only on one benefit of the Sun (namely, timekeeping), and we should include the idea that the Sun is also an energy source that makes life possible to exist and thrive as well as other benefits. Others felt that some sections needed more background information for audiences.
Among the suggestions to improve the program was to have a long and a short version of the Introduction – one that can be looped as the audience is being seated, and then an extended introduction that can be run once everyone is seated. Another asked to include a specific explanation or demonstration to illustrate the real reason why summer is hotter than winter. We also got some suggestions to include more visuals—such as auroras; SOHO images or video; and a graphic that shows the orbital relation of the Sun and Earth at different seasons—and to include more background music. Another idea is to include, however briefly, a comparison of our Sun with other stars (for example, in size and age).

![Horizon Markers](image)

**FIGURE 3.** Horizon marker hooked to the cove are used to make predictions.

We also asked testers to share some of their specific adaptations. At the Holt, we use horizon markers, which are made of wood and have a metal rail hook, for any activity where we ask the audience to predict the rising or setting point of something on the horizon (Figure 3). One person let us know they were using foam board and a bent paper clip as a hook (much cheaper and easier to fabricate, I’m sure). Another person, instead of horizon markers like these put some paper “stars” on their dome that the audience could simply point to, and the presenter could award “prizes” to those who guessed closest.

One drawback to the Magnetic Sun and Earth activity is that it requires passing out a model of the Earth, and then the Sun; passing out field bits (the aforementioned washers); and then modeling a magnetic field. Although we included some plates that could serve as trays to hold and catch stray field bits, one tester suggested that this activity would be best done with better containment, and with a flat surface and lots of patience. In fact, it may be better as an additional pre- or post-program section, which have both been called for.

**CONCLUSION**

Again, overall the feedback has been mostly positive, and the task waiting for me when I get back home is how to incorporate the feedback we have received to create a final product. Our ultimate goal is to publish this show as volume 14 of our PASS series (published by Learning Technologies, Inc.) thereby making it available to all of you. Down the road, we also plan to make this show available in fulldome format – but that’s a new challenge which I will be taking up very soon.

**ACKNOWLEDGMENTS**

Special thanks go to Alan Gould and the entire staff of the Holt Planetarium. Also to Deborah Scherrer of the Stanford SOLAR Center and to NASA’s Living With A Star program for funding this show’s development.
An Astronomical Dimension To Melville’s Moby-Dick

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Abstract. Although published in 1851, it wasn’t until the early 1950’s that Melville’s masterpiece was placed among world class literature. For the past half-century scholars have sought a unifying principle to the novel’s 135 chapters. Some interpreted the nine meetings or “gams” at sea between the Pequod and other whaling ships as the unifying principle, while others suggest proper interpretations of whale encounters unite the chapters. One hundred and fifty years after its publication we now have the hidden principle of Moby-Dick: it is the sky. When the sky is factored into the novel, the entire work opens up a new understanding of characters and chapters, interpretations until now were only understood by Melville. The gams relate to different celestial objects while whale encounters occur during new moon. References to Ahab’s lost leg are tagged to solar eclipses. Melville fashioned the constellation of the ship Pequod. She is clearly visible these July nights moored with sails furled in the Nantucket harbor about to begin her final voyage. Do you have what it takes to come aboard? Fair warning: this discussion of Moby-Dick is not for the timid or faint of heart.

PREVIOUS WORK

James Dean Young argues the nine meetings between the Pequod and other whaling ships defines the structure of Moby-Dick [1]. These meetings on the high seas called “gams” occur between chapters 52 and 131.

Barbara Meldrum interprets the whale encounters as the unifying principle, with the first whale encounter in chapter 48 and the final encounter with Moby Dick in chapter 135.

An astrological structure is presented by John Birk in his book “Tracing the Round: The Astrological Framework of Moby-Dick”[3]. He divides the 135 chapters into six blocks. The blocks correspond to the twelve traditional signs of the zodiac. As the Pequod sails from one ocean to the next in search of the white whale, the ship is travelling along the ecliptic. Birk draws parallels between major characters and astrological signs. As the ship travels along the ecliptic, he notes Melville’s references in the text correspond to constellations north and south of the zodiac.

These authors make use of different themes, but they don’t provide the missing unified structure. The work by Young and Meldrum fail because the first whale encounter and gam occur more than one-third the way into the novel. Accepting their arguments, we must dismiss the first third of the chapters as mere prelude, and not part of the all-encompassing structure. Although Birk’s interpretation includes all 135 chapters, he fails to distinguish between an astrological sign and an astronomical constellation. He appears to use the terms interchangeably, yet believes Mr. Melville was obsessed with detail. This is not a pattern Melville would have overlooked.

Birk uses a definition of astrology as ‘…the study of the influence of celestial bodies on humankind’ [4]. Melville’s use of the sky is the opposite of classic astrology. In chapter 36, The Quarter-
Deck, Ahab gets the crew to join him on his quest to kill Moby Dick. In addition to the verbal theater between Ahab and gathered crew, Ahab nails a gold doubloon to the mainmast of the ship and promises the doubloon to that crewmember who first sights Moby Dick. Banter then ensues between first mate Starbuck and Ahab, but is interrupted by a total eclipse of the sun directly above the main mast. After totality narrator Ishmael remarks: “Ah, ye admonitions and warnings! why stay ye not when ye come? But rather are ye predictions than warnings, ye shadows! Yet not so much predictions from without, as verifications of the foregoing things within. For with little external to constrain us, the innermost necessities in our being, these still drive us on.”[5]. Rather than an influence of celestial bodies on human behavior, Melville realizes the opposite of astrology. We project ourselves into the sky.

THE GAMS

Stacked number lines allow an astronomical analysis of the gams (see Figure 1). The lowest layer are Birk’s blocks as constellations and aligned to the above chapter number line, chapters 1 through 135. The arrows are placed and labeled to the appropriate chapter number for each gam. The arrowheads touch a line that represents the ecliptic, and above the ecliptic line is the ecliptic scale marked in degrees.

Chapter 81 –
The Pequod meets the Virgin

The Jungfrau (the Virgin) is a German ship so desperate for oil, Derick De Deer her captain, rows over to the Pequod with empty container begging Captain Ahab for oil. The Germans haven’t enough oil to fuel the ship’s lights at night. Just as Derick leaves the Pequod eight sperm whales are spotted. The largest of the whales is a physically deformed old bull, trailing bubbles from his posterior. Both ships lower boats to chase after the old bull. Flask, the third mate of the Pequod darts the fatal harpoon, though when the whale is fastened to the Pequod, the whale’s enormous dead weight nearly capsizes the ship.

In 1851 there were 8 known planets. Jupiter being the largest was known as the “gas giant”. We can associate this gam to the planet Jupiter. In Mr. Melville’s universe a flatulent whale is the planet Jupiter and can be so labeled on our chart.

Chapter 91 –
The Pequod meets the Rosebud

As the second mate Stubb rows over to the French ship he reads – Buton de Rose-near the ship’s bow. Stubb does not understand French so he cannot interpret the name of the ship. It is when he pulls close enough to the bow of the French ship and sees a copper rosebud that he is able to interpret the name. Mr. Melville is being very kind to his readers. He provides instructions on how to interpret this chapter. He is telling the reader it is important to understand the graphic of what is being told in this chapter. Consider the graphic. Stub notices two whales alongside. One of the two is “blasted” which means it died “unmolested” at sea, died of natural causes. The other whale may be one that was harpooned by the Pequod days ago. As Melville explains in an earlier chapter, when whales die and sink, days later gasses in their bodies built

FIGURE 1. The Gam Ecliptic.
up so they rise as huge animal balloons of their previous shape. Stubb is able through deception to obtain the blasted whale from the captain. The second mate believes the blasted whale may contain ambergris, a more valuable commodity than whale oil. Stubb, we are informed, “diddled” the French captain out of this whale. Further, the French are such poor whalermen they often leave port with ample candles because they aren’t going to get enough whale oil “to dip the captain’s wick into.” To “diddle” and “dip one’s wick” are slang terms for the sexual act.

Since Mr. Melville references the graphic in this chapter, a plan view of the French ship and whales compared to the female genitalia is striking (contact the author for further information).

What permeates the chapter is the smell of 100 tons of rotting fish. The Pequod smelled the rotting fish before the French ship was spotted. Melville’s description of the smell adds further to the association of the graphic to female genitalia. “It may well be conceived,” Melville writes, “what an unsavory odor such a mass must exhale; worse than an Assyrian city in the plague, when the living are incompetent to bury the departed. So intolerable indeed is it regarded by some, that no cupidity could persuade them to moor beside it. Yet there are those who will still do it…” Note use of words “conceived” and “cupidity” in the description. Mr. Melville describes a true medical condition called Gardnerella Vaginitis, or more commonly Bacterial Vaginitis. The fishy odor is caused by or results from a change in the pH of the vagina. We can associate the Rosebud gam to the planet Venus.

**Chapter 100 –**

**Leg and Arm**  
**The Pequod meets the Samuel Enderby of London**

Captain Ahab boards the English ship Samuel Enderby. The English Captain sports an ivory arm, Ahab an ivory leg, both disabled from their respective encounters with Moby Dick. Ahab wants to hear the story behind the Englishman’s encounter with the white whale. The one armed captain introduces Ahab to his ship’s surgeon and first mate; all play a role in the yarn. As the Englishman informs Ahab of the details of his encounter the English captain and surgeon joke about matters in the story. Ahab looses his patience with the surgeon, and after pushing him aside departs the Samuel Enderby.

The astronomical association to this gam is realized when the next chapter “The Decanter” is analyzed. The two chapters are connected by the opening sentence in The Decanter. “Ere the English ship fades from sight, be it set down here…” we read of the history of the whaling industry in Great Britain, the good food and good times Ishmael had while aboard an English ship. A list of food and drink consumed aboard the Dutch whale industry in one year is noted and analyzed. The theme of good times and food consumed suggest the Roman celebration of the Saturnalia. We can link the Samuel Enderby gam to the planet Saturn.

Additional insight is achieved when we incorporate the theme to chapter 100. It is mainstream thinking to compare and contrast the dark and gloom aspect of the one leg Ahab with the jovial one-armed captain. One cannot help but feel the cultural magnet toward the English captain. We should strive to survive through life’s trials and tribulations with a positive attitude no matter what obstacles are placed in our way. This may not be Melville’s interpretation if we incorporate the theme of food consumed and time to the names of the three aboard the Samuel Enderby. The captain’s name is Boomer, English slang for a bowel movement. The English captain is full of shit. The surgeon is named Bunger, English slang for an asshole. In keeping with this flow, the first mate’s name Mounttop signifies a pile of crap.
Chapter 115 –
The Pequod meets the Bachelor

The crewmen aboard the ship Bachelor are celebrating a most successful whaling voyage. The ship is so laden with whale oil they gave away barrels of beef and bread to make room for all the barrels of sperm whale oil. Then they had to barter for empty barrels from less successful ships to store all the oil they harvested from the sea.

A second notable characteristic of the Bachelor were the “signals, ensigns, and jacks of all colors… flying from her rigging, on every side” [7]. Before radio, telegraphy, and cell phones whale ships would communicate at distance by the arrangement of flags and ensigns in their rigging.

Without hesitation we can connect the Bachelor to the planet Mercury. Every school child is taught Mercury was the messenger of the gods, noted in Melville’s description of the flagged rigging. To those who go beyond elementary school lessons Mercury was foremost the god of trade. This dominion survives in our language in such words as merchant, merchandise and if you want to move your business to the land of milk and honey, Tempe Arizona, you should contact the chamber of commerce.

Chapter 128 –
The Pequod meets the Rachel

The Rachel’s Captain Gardiner is searching for his lost son whose whaleboat was either dragged off or destroyed by Moby Dick the day before. His second son is aboard the Rachel but escaped the encounter with the white whale. The masts of the Rachel were manned by the crew searching for the lost whaleboat as looking like “three tall cherry trees, when the boys are cherrying among the boughs”[8].

Before Mars was the god of war, Mars was a god of agriculture. It is the agricultural dominion of Mars Melville chose to emphasize. Not only does the captain’s name Gardiner suggest this, but also Mars had two sons, as did Captain Gardiner. Melville’s imagery of cherries against the sky is an interesting visual image of red spheres skyward. We can associate the Rachel gam to the planet Mars.

Chapter 131 –
The Pequod meets the Delight

The Pequod meets the last ship “most miserably misnamed the Delight”[9]. The ship encountered Mob Dick the day before and was in the process of burying one of the dead from that encounter when the Pequod appears. Of the other dead the captain of the Delight cries to Ahab “…the rest were buried before they died; you sail upon their tomb”[10]. A few lines earlier Ishmael comments, and is somewhat echoed later by the Captain of the Delight the strange “life preserver” the Pequod has at it’s stern… a coffin. After considerably more astronomy is applied to the novel than what can be accounted for in this short presentation, we learn this gam occurs Christmas day, 1839. A life preserver as a coffin, a death afflicted ship titled the Delight, buried before death, a funeral on Christmas, all signify a direct opposite of the usual sense - irony.

For millennia the sky consisted of seven wondering objects, the sun, moon and five planets. The case can be made that the number seven in world class mythology and religion occupies a greater importance than simply a point on a number line because the number resonates in part to these seven mysterious objects in the sky. The echo “On Earth as it is in Heaven” can be observed by the names of the seven days of the week. The discovery of the planet Uranus in 1781 however, disrupted the normal order of earth and sky. The planet Uranus then can be associated to the gam The Pequod meets the Delight.
THE LAST VOYAGE OF THE PEQUOD

Sufficient gams have been examined to determine with confidence which year of activity is described in Moby-Dick. Add the planetary associations of Mercury to the gam Bachelor, Venus to Rosebud, Mars to Rachel, Jupiter to Virgin, Saturn to Enderby and Uranus to Delight in Figure 1, then Figure 1 is complete. Draw a line in your mind eye from the tip of the arrow labeled Bachelor –Mercury downward. We see it occurs in the novel as chapter 115. Draw down further and we find the planet-gam is within the block labeled “Scorpius Sagittarius.” When we perform the same scan with the other examined gams, we can ask the question. Was there ever a time when Mercury was in either the constellations Scorpius Sagittarius, Venus in Virgo Libra, Mars in Capricorn Aquarius Pisces, Jupiter in Virgo Libra, Saturn in Scorpius Sagittarius, and Uranus in Capricorn Aquarius Pisces? The answer to these questions is yes. All the above conditions are met beginning about December 17th, 1839, when Mars moves from Block 5, Scorpius Sagittarius into Block 6, Capricorn Aquarius Pisces (Fig.3). The conditions no longer exist after January 5th 1840 when Venus moves out of Block 4, Virgo Libra into Block 5 Scorpius Sagittarius (Fig 4).

Mr. Melville provides the reader with a window from December 17 1839 through January 5, 1840. It must have some relevance to the novel. We read this last voyage of the Pequod will last about a year and the Pequod leaves Nantucket noon Christmas Day. Does this mean the Pequod begins the fatal voyage Christmas day 1839? No. In chapter 22 Merry Christmas we read how during that first evening at sea, as day merged into night, the whale teeth that decorated the bulwarks shone in the moonlight [11]. The moon December 25 1839 was past full some 70 percent illuminated but will not rise until about 10:30 at night, too late for this observation. If the window occurs at the end of the voyage, then the Pequod left Nantucket Christmas day 1837. The moon that evening was 70 percent illuminated before full and would have been visible to Ishmael high in the southern sky. We can now state the Pequod started on the fateful voyage Christmas 1838.

Figure 2. Planet Positions December 17, 1839.

Figure 3. January 5, 1840.

New Moon

The reader is left with a window that opens December 17 1839 and closes January 5 1840. The significance of the window is how it can be interpreted to provide the next level of refinement to the time line in the novel. The last three chapters of Moby-Dick represent the final battles between Moby Dick and Captain Ahab. They are:

Chapter 133 The Chase First Day
Chapter 134 The Chase Second Day
Chapter 135 The Chase Third Day

The sequence represents a time line of two nights and three days. A period of times whose mythical tradition represents the dark of the moon, and is interpreted in world class mythologies and religions as
death and regeneration. Astronomically it is that period of time centered on new moon when the moon is not visible to the unaided eye. Melville combines the mythical with the astronomical. The window does involve a new moon sequence. The Chase First Day the whale is spotted “...some mile or so ahead,” which corresponds to January 2 1840[12]. Astronomically the moon was about 24 degrees west of the sun. The Chase Second Day the whale is seen “…less than a mile ahead,” while the angular distance between the sun and moon had decreased to some 13 degrees [13]. The second day corresponds to January 3 1840. The Chase Third Day opens with no whale in sight. At noon Ahab realizes he may have passed the whale and so turns the Pequod around and an hour later Moby Dick is spotted for the third and last day [14]. Astronomically new moon would have occurred the morning of June 4 1840, which places the moon just to the east of the Pequod at noon.

This final whale encounter occurs during new moon. Can we assume whale encounters occur during new moon? Yes. Now the year of the voyage is known we can date the whale encounters to new moon. That is but for one exception near the China Sea, whale encounters can be dated to within two nights and three days. They relate to a death and regeneration in the respective chapter.

A special case of the new moon is a solar eclipse. We discover solar eclipses relate not only to the mythical thyme of death and regeneration, they can be linked to Ahab’s lost limb.

EPILOGUE

There is an astronomical explanation for an epilogue following chapter 135. Ahab and the Pequod are destroyed just before sunset January 4 1840. Narrator Ishmael is saved by hanging on to the life preserver coffin for “…almost one whole day and night I floated on a soft and dirge-like main.” That places the action to near sunset January 5. “On the second day a sail drew near…” the sail was the wandering Rachel [15]. Ishmael is plucked from the sea by the wandering ship Rachel, which places Ishmael’s rescue on January 6 1840, the traditional date of the Epiphany. Recall the Rachel is assigned to the planet Mars. Ishmael not only floats on a soft and dirge – like main, but "The unharming sharks, they glided by as if with padlocks on their mouths; the savage sea hawks sailed with sheathed beaks [16]. It is as though Ishmael and floating coffin can be associated with the favor of Neptune. On January 4 Mars and Neptune passed about one degree from each other in the sky. The Mars-Neptune rescue, which occurred on January 6, may be Melville’s recognition of the break in time flow. Had the conjunction between Mars and Neptune occurred on January 6, the epilogue would have been chapter 136.

The Pequod

First time reader of Moby-Dick may note that some chapters describe the Pequod as being steered by a tiller made from the jawbone of a whale, and in other chapters the steering mechanism is a standard spoke wheel. Mainstream Melville scholarship explains these discrepancies as Melville’s inattention to detail. There are many of them in the Novel. This author agrees with John Birk’s observation that actually Melville was obsessed with detail [17].

Ishmael describes this ship as having a “…claw-footed look about her, “ and “Her venerable bows looked bearded [18]. No one knows which sky map(s) Melville used as reference for Moby-Dick. Constellation drawings in circulation before 1851 could range from Bayer’s Uranometria (1603) to the very popular A Celestial Atlas (1822) by Alexander Jamison. In both these examples the head of Draco is drawn bearded. The constellations of Lyra, Aquila and Cygnus are clawed. Melville’s
constellation of the Pequod consists of the head of Draco as the bow; the star Vega is where the foremost touches the main deck. Deneb is the top of the mainmast and Northern Cross completes the mainmast. Altair marks where the mizzenmast meets the deck. Support for this constellation of the Pequod was Ishmael’s description of “…a strange sort of tent, or rather wigwam, pitched a little behind the mainmast. It seemed only a temporary erection used in port. It was of a conical shape, some ten feet high…”[19]. This tent corresponds to the constellation Sagitta, the arrow.

There is a problem with where the ship is when in the Nantucket port. Mornings the ship is docked to a pier, while at noon it is anchored in the middle of the Nantucket harbor. There is only one ship named Pequod. When it is described as an ordinary ship she sports a steering wheel. With embellishments such as a tiller made of the jawbone of a sperm whale, she is a constellation. The summer triangle is rising late December at sunrise; the ship is moored to the dock. At noon the summer triangle is nearly directly overhead, the ship is anchored in the middle of the Nantucket harbor. All such discrepancies are solved when it is realized the one and same Pequod can be described as a standard whale ship or can be a constellated symbol.

**CONCLUSION**

The sky is the long sought structure in Moby-Dick. When the sky is incorporated the novel, it reveals a hidden structure that allows with certainty the year the action in the novel takes place. The association of new moon to whale encounters can provide a time line with almost daily to day resolution. The gams are astronomical objects. Melville pictured a constellation of the Pequod among the stars of the summer triangle. When the constellation is realized the many discrepancies attributed to his inattention to the Pequod’s detail evaporate. Herman Melville was a far greater artist than Melville scholars appreciate.

**REFERENCES**

4. Birk, p26
6. Hayford, Moby-Dick, p337.
9. Hayford, Moby-Dick, p441
10. Hayford, Moby-Dick, p441
11. Hayford, Moby-Dick, p95
12. Hayford, Moby-Dick, p446
13. Hayford, Moby-Dick, p455
14. Hayford, Moby-Dick, p461
15. Hayford, Moby-Dick, p470
16. Hayford, Moby-Dick, p470
17. Personal communication
18. Hayford, Moby-Dick, p67
19. Hayford, Moby-Dick, p68
The Making Of Black Holes: The Other Side of Infinity

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Abstract. An original production of the Gates Planetarium at the Denver Museum of Science, Black Holes: The Other Side of Infinity features the latest scientific visualizations of runaway gravity and the inevitable results. This paper will give a behind-the-scenes look at the people and processes that created this ground breaking show. Two years, national sponsorship and the collaborative efforts of an international team made this show possible. Designed for playback in digital dome theaters of any size, the show appeals to all audiences. The challenging production process combined live-action footage and super computer simulations to take audiences on an engaging thrill ride into the heart of a black hole. Star formation, galactic collisions and a journey to the center of the Milky Way Galaxy are featured utilizing the latest scientific models and simulations. The finale shows the results of the Black Hole Flight Simulator created by Dr. Andrew Hamilton which employs a mathematical re-creation of the inner workings of a supermassive black hole.

CONCEPTUALIZATION AND FUNDING

"We can use my Black Hole Flight Simulator software to show people what it would be like to visit one in person" said Dr. Andrew Hamilton, astrophysicist from the University of Colorado, and thus began our odyssey to develop this original show featuring the latest scientific visualization of black holes. [1]

Hamilton's dream was embraced by the Denver Museum of Nature & Science (DMNS) [2] and championed by Spitz Inc. With input from director Thomas Lucas, we submitted a proposal to the National Science Foundation's (NSF) informal science education program to make the digital planetarium show a reality. It was a grandiose vision and the project grew to include some of the best and brightest talent available.

Initial support came from the education and public outreach programs at NASA's SWIFT and GLAST satellites. NSF decided, after review of the proposal, to fund the 23 minute, fulldome planetarium show and sponsored the bulk of the production's cost as well as underwriting an HDTV production for NOVA that featured many of the same scientific visualizations titled: The Monster of the Milky Way.

STANDARDIZATION

Because no universal standards existed for fulldome planetarium programming, the team requested funding to sponsor workshops and collect input from the planetarium community. [3] We developed preliminary guidelines which would enable wide distribution of the show in multiple formats, including high definition television. Because the majority of digital planetariums are unidirectional, including Gates Planetarium, the team settled upon designing the show with a forward looking view that is 17 degrees above the edge of the dome.

We specified the fulldome frames at 4000 x 4000 pixels. This matched the native resolution of the Gates theater—which requires frames that are many times
larger than an HDTV broadcast, and is beyond the resolution of the majority of digital planetariums operating at the time. Starting with this high-resolution dome master frame, Spitz technicians are able to resize the program to customer needs. Following newly proposed fulldome guidelines, each of the 41,360 frames were labeled with reference and synchronization information just outside of the viewable area of the dome master frame.

BUILDING A TEAM

The DMNS team managed production logistics to ensure that the final product worked at the Gates Planetarium as well as at digital planetariums around the world. DMNS executive producer Joslyn Schoemer, worked relentlessly to ensure that the show was engaging, scientifically accurate and completed on time and on budget.

In a departure from most planetarium show production, the DMNS management team chose to work with a director having no prior experience in a planetarium. Documentary television and film director Thomas Lucas [3] brought years of production experience to the group as well as a clear vision for the final product.

The team at the National Center for Supercomputer Applications (NCSA) had the daunting task of converting scientists' research data into an accurate and compelling visualization for the dome. This was probably the largest and most complex project ever undertaken by the NCSA team. NCSA also provided Reblender, a new open source software that we used to modify the perspective of live action footage.

The team at Spitz took on a different visualization challenge. As described by Hamilton, "imagine paddling against an immense waterfall as an analogy for an encounter with a black hole." Spitz animators created a most engaging rendition of the scene, demonstrating on a human scale an encounter with an event horizon. Live actors were filmed and composited into an immense computer generated waterfall. Kayakers are depicted paddling for their lives against the raging torrent. Try as they might, the gravitational forces overwhelm them, as well as the audience, and they all plunge to their fate inside of the swirling vortex.

SIGHTS AND SOUNDS

Through some luck and a lot of persistence we were able to secure actor Liam Neeson to narrate the program. Neeson rehearsed while watching visuals from the show, and his skill and enthusiasm made his recorded performance quite memorable. DMNS cut the voice to the visuals and turned over the edited version to composer Richard Fiocca.

Fiocca orchestrated an original score and added deep layers of sound effects to the mix. Discussions with him often centered around the sound of a black hole, but in actuality we explored how you feel when witnessing the monster. Final audio mixing was performed in the Gates Planetarium to ensure that the sonic experience was as captivating as the visual immersion. Although mastered in all-encompassing 16.1 surround sound, the distributed version of the mix is in 5.1 surround.

FOLLOWING THE RULES

The script evolved in the capable hands of Jonathan Grupper who wrote dozens of iterations as we finalized the storyboards. We prioritized the teaching points and learning outcomes for the show after extensive testing of audience interest and misconceptions.

We identified concepts that we hoped the audience would grasp such as: What is a black hole and event horizon? Where do they come from? How and where do we find them? Each point was repeated and
demonstrated in multiple ways throughout the show. We allotted several months for formative evaluations of the show to verify the effectiveness of the script and visuals to accurately portray the concepts. We were astonished to discover how many basic audience misconceptions persisted through initial edits of the show. Without our allowance for these formative assessments, the final show might have been much less effective.

We sought out the latest scientific visualizations, and consulted with the research scientists who made them possible. We included stories about the scientists and what they discovered along the way. We also did make extensive use of Hamilton's Black Hole Flight Simulator to visualize the astounding phenomenon of gravitationally warped space time at the center of the Milky Way.

Thorough summative evaluations (see Figure 1) indicated that audiences did leave with a much improved understanding of black holes as well as a heightened curiosity about the bizarre physics involved.

IGNORING THE RULES

Some tried and true planetarium production rules were ignored when fast action, abrupt transitions and bright scenes were utilized to disorient the audience, just enough to engage them in the action.

The production was guided by the skilled eye of Lucas. Moving to the giant screen gave him the opportunity to immerse audiences in his ideas and really push the art form to a new level.

Lucas insisted on humanizing the galactic story by including live action scenes. We tested many ideas, adding to the demands on the production team. Editing and modifying the original 35 mm film footage of a rocket launch and scientists added months of work to the process. Judging from the positive reaction of audiences, it was certainly worth the effort.

CHALLENGES

Significant challenges arose as the production deadlines loomed. It was especially difficult for us to manage timely delivery from all of the contributors, some of whom had never done work for a dome before. Coordinating the tremendous amount of data that had to be transferred between facilities added to our challenges.

Multiple renditions of each scene had to be viewed on the dome for feedback and approval. Over time our schedules and assignments became more manageable, as we created a well defined workflow and filing system.

Editing and touching up the tens of thousands of frames fell to the DMNS producers. A range of software programs was applied to modify the content for flawless hemispherical projection including: Adobe After Effects, third party plug-ins, and NCSA's rebender tool.

Before the final frames were rendered, we did a number of tests at planetariums across the country to verify that the show looked good on every system. Much of this work was facilitated by the Spitz staff who were designated as distributors of the show and would handle all of the licensing and file conversion required for individual facilities.

CONCLUSION

We were fortunate to have found the right professionals to work with. Organizing everybody was no trivial task however, and innovative project management techniques used by DMNS made the show practical. We were able to remove obstacles and agree to a consistent workflow. Everybody was committed to delivering their best work and the results speak for themselves.

Working with this highly skilled team was an honor. Sharing this ground
breaking, collaborative work with the planetarium community has been a highlight of my professional career.

ACKNOWLEDGMENTS

Black Holes: The Other Side of infinity is made possible through funding by the National Science Foundation, and is a collaboration of Denver Museum of Nature & Science, National Center for Supercomputing Applications, Spitz E&S, Thomas Lucas Productions, and NASA's SWIFT and GLAST Education and Public Outreach Programs at Sonoma State University.

The "Black Hole Flight Simulator", copyright University of Colorado, was created by Andrew Hamilton, an astrophysicist at the University of Colorado, for the Denver Museum of Nature and Science.

This material is based upon work supported by the National Science Foundation under Grant No. ESI-0337286. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Funding provided by:
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With special thanks to:
Ed Lantz, Visual Bandwidth
The Keck Observatory
NASA Kennedy Space Center
JILA, U. of Colorado, Boulder
Dept. of Astrophysical and Planetary Sciences,
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Tom Brightwell
B.B. Schmidt, 2B Productions
Images:
Atlas Image mosaic obtained as part of the Two Micron All Sky Survey (2MASS), a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by NASA and the National Science Foundation (NSF).
Distribution and Licensing by Spitz E&S.

NOVA's Monster of the Milky Way broadcast in the USA on October 31, 2006.

REFERENCES

1. Andrew Hamilton's BHFS:  
   online.itp.ucsb.edu/online/colloq/hamilton1/
2. DMNS BHS web site:  
3. Standards workshop:  
   extranet.spitzinc.com/reference/IPS2004/default.aspx
4. Thomas Lucas Productions:  
   www.tlproductions.com/inproduction.htm
FIGURE 1. Summative Evaluation Results. Percent correct responses for each true-false statement before and after viewing *Black Holes: The Other Side of Infinity.*
Public Exploration Of Current Astrophysical Data

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Abstract. Cosmologists at the University of Chicago have successfully integrated current astrophysical data into fulldome visualizations. The digital planetarium environment offers an unprecedented opportunity to bring exciting, complex and ongoing research to the public, in a manner that is both visually compelling and appropriate for the science (e.g., data is the authentic artifact of observational and computational science). Astronomy is in the midst of a data revolution as large surveys and computationally intensive simulations are producing vast quantities of data. The confluence of these enormous datasets and advances in visualization technology allow visitors to watch science as it evolves and researchers to share the excitement of discovery with the public.

THE PLAYERS

KICP

The Kavli Institute of Cosmological Physics (KICP) performs research at the forefront of cosmology, with particular emphasis on the connection between the micro and macro universe. There are three profound questions that form the primary scientific focus of the Institute: What is the nature of the Dark Energy that dominates the Universe and what is its impact on the evolution of the Universe? Was there an inflationary epoch in the first moments of the Universe, and if so, what is the underlying physics that caused it? What clues do nature’s highest energy particles offer about the unification of forces?

COSMUS

COSMUS, which is short for cosmology in museums, is the name of an informal scientific visualization group at the University of Chicago. The group had its origins in the 2003 – 2004 MSCOPE program, a graduate internship program that gives students an introduction to museum studies and the presentation of scientific information to the informal science education audience. At the conclusion of the program a subset of the participants and mentors continued to collaborate, primarily producing scientific visualizations that incorporate current research data and target public audiences.

FIGURE 1. The KICP’s External Advisory Board enjoys interactive 3D visualizations displayed on a GeoWall.
**THE VISUALIZATIONS**

COSMUS’s data-driven visualizations are produced for an assortment of media (e.g., GeoWall, web, PlayStation Portable, video, etc.). At IPS a combination of interactive and pre-rendered fulldome visualizations were woven into one presentation.

The two interactive datasets spanned enormous scales and illustrate the versatility of digital systems. The first dataset was a simulated air shower caused by a cosmic ray particle hitting the Earth's atmosphere. At times this was as dramatic as fireworks, while it made the invisible visible. The second explored the large-scale structure of the universe contained in the hundreds of thousands of galaxies mapped by the Sloan Digital Sky Survey.

These and other COSMUS interactive datasets are in a format designed for Partiview, a free open-source software real-time renderer. This format is also readable by some planetarium packages such as Sky-Skan's DigitalSky. The COSMUS datasets are freely downloadable[1].

The pre-rendered visuals presented at IPS were from simulations of large-scale structure formation made by KICP theorists Andrey Kravtsov and Nick Gnedin.

**Cosmic Ray Showers and The Pierre Auger Project**

The Pierre Auger Cosmic Ray Observatory (www.auger.org) is studying the universe's highest energy particles \(10^{19}-10^{20} \text{ eV}\), which shower down on Earth in the form of cosmic rays. The Universe is a giant particle accelerator which enables particles to have energies that are 30 million times higher than those found in terrestrial accelerators. While cosmic rays with low to moderate energies are well understood, those with extremely high energies remain mysterious. By detecting and studying these rare particles, the Auger Observatory is tackling the enigmas of their origin and existence.

When a high energy cosmic particle impacts the Earth’s atmosphere, the collision creates daughter particles which in turn undergo collisions. The result is an air shower filled with a cascade of particles. The air showers used in our visualizations were simulated using the AIRES[2] package of astrophysicist Sergio Sciuttio. A single shower can contain a tremendous number of particles, for example the air shower initiated by a \(10^{18} \text{ eV}\) cosmic ray proton can contain \(10^{11}\) particles. To make both the simulations and visualizations possible, only a small but representative fraction of the particle tracks are followed. These thinned depictions still have a very powerful impact on the audience and help to convey the enormous extent, e.g., the many square kilometers, of any given shower.

**FIGURE 2.** A visualization of a particle air shower simulation initiated by a 1.5 TeV (1.5x\(10^{12}\) eV) proton. The shower progresses from upper left to lower right, points show the positions of the particles at a given instant and lines indicate their paths. Different particle classes are represented by distinct colors (purple: gamma rays; yellow: electrons/positrons; red: muons; green: pions; blue: protons; cyan: neutrons).

**Flying Through The Universe With The Sloan Digital Sky Survey (SDSS)**

At the vanguard of the astronomical data revolution is the SDSS[3], the world’s largest cosmic mapping project. When it
concludes in 2008, SDSS will have mapped one quarter of the sky centered at the northern Galactic cap imaged in five bands spanning from the near-ultraviolet to the near-infrared. Additionally, spectra will be measured and redshifts determined for the brightest million galaxies in that region. The immense SDSS dataset also includes spectra of quasars, stars and a luminous red galaxy sample.

The visualization presented at IPS features SDSS observations from the fifth data release, DR5, which contains nearly three quarter of a million objects. It combines these SDSS objects with the CMB sphere measured by WMAP. All objects are projected in terms of the co-moving distance (the distance you would measure if you could freeze the expansion of the Universe). The visualizations were performed in Partiview and ported to DigitalSky 2 for fulldome display. Objects are rendered with two levels of detail, each of which has different luminosity vs. distance behavior. Persistent points illustrate the large-scale structure, while galaxy images provide a feeling of immersion and three dimensionality with their 1/r size dependence. Approximately 100 representative images were used, chosen to represent galaxy spectral classes (which is independent of redshift, unlike color). Each galaxy is assigned a representative galaxy image of its measured spectral class, and for visibility the image size is increased by a factor of 100.

**Philosophical Note: Leaving the CMB Sphere**

During the meeting in Melbourne there were several meaningful discussions about the philosophical issues behind the public presentation of scientific data. A key issue examined was the nature of a cosmological map and the difference between a world map and a world picture (the onion skin model of the universe where each layer is observed progressively further back in the past). It was noted that misconceptions, can result from viewing such a model from outside the CMB sphere. Additionally, some KICP faculty had previously expressed concern that in this world picture the Universe should be opaque beyond the CMB sphere (the surface of last scattering).

In the fulldome presentation of our visualizations we dealt with these concerns by flying through the CMB sphere and into a swirling mass of color. The narrator then explained that we were leaving the realm of observation, and entering the realm of theory. This provided an elegant transition to the pre-rendered simulations of large-scale structure formation. Still in other contexts we have found it useful to show the model from the “outside” vantage point. Such a view allows us to point out the fraction of the observable universe that has been mapped, and the regions in space that our present day CMB observations come from. In these cases we leave it to the presenter to dispel any possible misconceptions.

One point that we are all in agreement on is that the latest generation of astrophysical visualizations are powerful, both in their ability to teach and to misinform. A visualization is by necessity a representation of a particular aspect of reality containing assumptions and
shortcomings. As communicators of scientific information it is our responsibility to make those assumptions and shortcomings absolutely clear.

The Growth of Structure in the Universe

Theoretical simulations reveal other aspects of the large-scale structure contained in the SDSS data, e.g., the underlying dark matter skeleton. The visualization presented at IPS is based on a highly accurate n-body simulation performed by Andrey Kravtsov and Nick Gnedin. It is a cosmological simulation of dark matter distribution in a Lambda CDM cosmology run with the ART code[4]. The fulldome pre-rendered movie provides a fly-through of a vast region of space with a volume of tens of megaparsecs, which then slowly zooms in onto a Milky Way sized object.

FIGURE 4. Visualization of the formation of a large galaxy cluster.

The spatial distribution of dark matter clumps in this simulation, the assumed sites of galaxy formation, is a very good match to the observed clustering of galaxies in the Sloan Digital Sky Survey. This simulation was run at the National Center for Supercomputing Applications.

THE VENUES

Stereoscopic Projection

Virtual Reality (VR) has often been touted as an excellent way of presenting scientific data to the public. However, there are two major obstacles to widespread adoption of VR for public consumption. First, a standard VR setup, such as a CAVE, is cost prohibitive for most institutions. Second, Head Tracking, which is a vital component of standard active VR, makes it inappropriate for presenting data to large audiences. Head tracking allows the virtual environment to react to the movement and changing gaze of one user. This provides an excellent immersive experience for that one user, but a highly suboptimal experience for anyone else watching.

We have been exploring an alternative that has proved highly successful in interactively presenting large scientific datasets to audiences ranging from half a dozen to two hundred people wearing 3D glasses. A stereoscopic system called a GeoWall [2], by the active user community of Computer Graphics and Science Outreach educators who use it (http://geowall.org).

A GeoWall consists of a computer with a dual-output graphics card, two projectors, two monitors a rack for the projectors, polarizing filters, and a projection screen that preserves the polarization of light projected on it. Such a system can be put together for under US $8,000 and can be set up within an hour.

Fulldome Theaters

The fulldome work was a collaboration between COSMUS and Sky-Skan, Inc. The Partiview format used for many of the interactive visualizations is easily imported into Sky-Skan's DigitalSky 2 planetarium software. However to meet the challenge of displaying the large number of objects in the SDSS DR5 dataset (three quarter of
a million) individually textured polygons prompted Sky-Skan to further optimize their software. The creation of the animations was similarly straightforward, Nick Gnedin was able to quickly modify his custom rendering software to accommodate a five-camera rig. The five views were then stitched together with Sky-Skan's stitching software.

THE SHOW

The visualizations described above were originally woven together for a custom, single viewing, 40-minute, fulldome, sky show, which was presented at the closing banquet of the New Views of the Universe, Kavli Institute Inaugural Symposium in memory of David Schramm. As such, it was designed to appeal to an audience of approximately two hundred professional cosmologists. The show was prepared in collaboration with Steve Savage and his team at Sky-Skan Inc. A Sky-Skan system was shipped to Chicago and temporarily set up in the Adler Planetarium StarRider theater for the presentation.

Steve Savage developed the story outline and Joshua Frieman authored the script (which was improvised over). The show started by flying into Chicago and seeing the cosmic ray air showers taking place overhead. Next we flew through the SDSS galaxy distribution, visiting a galaxy in which a supernova had recently been detected, and flying around the Sloan Great Wall, the largest structure in the universe. We then flew through the quasars and out the WMAP CMB sphere. Passing beyond the limit of our observations, we entered the “realm of theory” where we watched visualizations of Andrey Kravtsov's large-scale structure formation simulations.

The show was extremely well received and went a long way towards demonstrating to scientists the power and value of fulldome visualizations. Although the show was constructed for that single showing, it has since been reproduced twice: both at the Melbourne IPS and a few months later at the Great Lakes Planetarium Association meeting in Merriville, Indiana, although each time taking on its own flavor.

CONCLUSION

We have demonstrated the power of scientific visualizations in presenting current astrophysical research. These visualizations are all the more powerful when combined with immersive display solutions such as stereoscopic and fulldome projection. Software applications such as Sky-Skan's DigitalSky 2 make it very easy to explore datasets in these environments. Research institutes such as the KICP have a responsibility to share their work with the public. The cutting edge digital display solutions found at museums and planetaria make them ideal places to accomplish this goal.

ACKNOWLEDGMENTS

This work was supported in part by the Kavli Institute for Cosmological Physics through the grant NSF PHY-0114422. We would also like to thank Sky-Skan for their help in putting together the fulldome visuals, and for providing us with dome time to present them at the Melbourne meeting.

REFERENCES

A Partnership Model For Building Critical Mass

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Abstract. The wide open spaces, the fine weather and the clear skies make the Western Australian night sky an awe inspiring sight for anyone taking the time to look to the heavens. These qualities combined with mankind’s natural instinct to understand the surrounding environment has led to an underlying thirst in the population of WA to better understand astronomy and space science. As such, numerous astronomy based resources, products, amateur groups, societies and professional facilities exist in WA but with no real exchange of information or network to link them all. This paper will discuss the AstronomyWA project, an initiative undertaken by Scitech and the Office of Science, Technology and Innovation, to not only consolidate astronomy based resources and space science teaching in Western Australia but also to encourage a constructive, collaborative space science community throughout the state. The AstronomyWA model shows how partnerships and collaboration can provide improved teaching and learning outcomes in the general community.

WESTERN AUSTRALIA & ASTRONOMY

With its fine weather and clear skies the average person can’t help but be inspired by what can be found by looking up and observing the awesome view that is the Australian night sky.

In Western Australia these qualities have led to the establishment of many astronomy orientated amateur groups, societies, professional facilities, websites, educational resources, a cutting edge planetarium and a myriad of other things.

As well as what does exist, strangely enough, what doesn’t exist also works in favour of Western Australia. The abundance of open spaces that make up the majority of the WA landscape contain little more than kangaroos, snakes, red dirt, rocks and the odd hopeful prospector. These attributes or lack of them make for a region of extreme radio quiet and an ideal location for projects like the Square Kilometre Array, which in the future could see WA play host to a vast array of radio telescopes mapping the southern sky and helping us all to understand more about the early Universe.

The AstronomyWA Initiative

With this astronomical potential clear and present in WA, Scitech identified the need to do all it could to play its part in encouraging interest and participation in this specific area of science, with particular focus given to educators and their students.

To that end an initiative was undertaken with the Department of Education and Training, the Office of Science, Innovation and Technology, a number of secondary schools and several astronomy based organisations including Perth Observatory and the Australian International Gravitational Research Organisation. The objective was to construct a website that would become a one-stop shop for everything related to astronomy and space science paying particular attention to anything happening in or related to Western Australia. That website is the AstronomyWA website which can be found at www.astronomywa.net.au.
As this website became a reality the AstronomyWA initiative gained momentum and other outcomes were identified by the group that could be tackled and delivered as long as the funding to do such things could be sourced.

Through the Australian School Innovation in Science, Technology and Mathematics (ASISTM) grants the government has funded and supported projects throughout Australia that have and are working towards bringing about real and permanent improvements to the way science, technology and mathematics are taught in our schools. With a view to gaining such funding for the AstronomyWA initiative a proposal was put together which proved successful and has since opened up numerous possibilities for the AstronomyWA initiative.

**Extended AstronomyWA Outcomes**

As well as continuing to build and maintain the AstronomyWA website, funding from the ASISTM project meant that AstronomyWA could look to achieving the following:

- The creation of astronomy based professional development opportunities for educators.
- Freely accessible space science resources.
- The creation of a collaborative network of astronomy and space science facilities.
- The creation of astronomy based student research projects.
- General public events.
- Online, interactive resources.
- A conference to bring together educators and space science facilities throughout WA.

Importantly, this initiative has created opportunities for teachers to visit the facilities in their local area that are providing educational activities for them and their students. Teachers not only get a chance to see first hand what exists to assist them in the teaching of astronomy and space science, but also get the opportunity to build useful relationships with those working in these fields and offer their suggestions as to how their needs can be better catered for by those respective facilities.

**Teaching In Remote WA**

In the more remote parts of our respective states in Australia, teachers are often called upon to teach beyond their training and/or their specific areas of knowledge. In my own experience for example, I have come across several
teachers in remote WA, who are in their first year of teaching and charged with the task of teaching secondary level classes even though they are wholly primary trained. For teachers such as these, who are faced with challenging roles and have had no specific training to tackle astronomy based subject matter, the AstronomyWA initiative aims to assist through making resources, opportunities and guidance available.

For this reason AstronomyWA has enlisted the help of a number of teachers. These teachers form a group known to the project as the “expert” teachers, all of whom have a particular passion and skill for teaching astronomy and space science in the classroom. Through this group we have created opportunities where they are able to impart their knowledge, methods and teaching tools to other educators that have expressed interest in better arming themselves to teach these subject areas to their students.

Also, we have employed the services of one of these “expert” teachers to create a series of space science modules which by Term 1 next year will be freely available to all educators throughout Western Australia and beyond via the AstronomyWA website. The modules include more than 40 hours worth of lessons, exercises, activities, conceptual information plus extension ideas in the form of open ended project work.

Research Based Astronomy Projects For Students

The AstronomyWA project has provided the funding necessary for two of the facilities involved with this initiative to develop student based research projects creating opportunities for schools to get students involved in conducting real, hands on astronomy. One such project involves Perth Observatory who will give students the opportunity to do some traditional astronomy with a large telescope called an “Astrograph” that for a number of years has been gathering dust since the onset of computers and a less romantic way of doing things.

In this project students will spend time with the astronomers at Perth Observatory learning how to operate the telescope, with their experience culminating in the chance for them to capture for themselves a celestial image onto a glass plate, a rewarding experience that will take them many hours of careful calculation and precise measurement.

Astronomy Lectures

AstronomyWA provides astronomy based lectures for the general public to attend free of charge, these have been very successful and well received. So far amongst others we’ve had Japan’s first astronaut in space Dr Mohir speak about his experiences aboard the Space Shuttle, Dr George Hobbs of the Australia National Telescope Facility (ATNF) talking about his efforts to detect gravitational waves through the observation and precise measurement of pulsars and later on in the year we’ll have Professor Fred Watson, Astronomer in charge of the Anglo-Australian Observatory.

CONCLUSION

As with any initiative of this nature and scope, beyond the specific outcomes and objectives listed here there exists a plethora of spin offs and ripples in the astronomical pond that make the AstronomyWA initiative a sustainable venture in building a critical mass for Western Australia in an area of science that captures the interest and imagination of people throughout the world.
Fire And Ice: Space Probes To Mercury And Pluto

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Abstract. The MESSENGER probe to Mercury launched in August 2004 and New Horizons lifted off on a 10-year trip to Pluto this year. NASA and the Carl Sagan Center for Earth and Space Science Education have developed some excellent materials, based on the U. S. National Science Standards, for science teachers to use in the classroom, museum or planetarium. The MESSENGER (MErcury Surface, Space Environment, GEochemistry and Ranging) mission is our first close-up exploration of Mercury this century, the first in 30 years. The extreme environment of the planet closest to the Sun requires new ways to keep cool. At the other end of the Solar System, tiny frozen Pluto has its own set of extreme conditions. The New Horizons spacecraft is designed to reach Pluto and other Kuiper Belt objects as early as 2015. This paper presents a comparison of the MESSENGER and New Horizons spacecraft, and describes the educational materials developed to accompany the missions, and explores some experiments and demonstrations for use in classrooms. Sizes and distances in the Solar System, temperature and radiation extremes, and the teamwork essential to science will also be included.

FIRE

MESSENGER is an unmanned NASA spacecraft launched in 2004 to arrive at Mercury in 2011. It is only the second spacecraft to study Mercury, and the first since the 1970s, when Mariner 10 rendezvoused with the planet.

MESSENGER is the first spacecraft to observe Mercury from orbit and not just fly by. Its observations will allow us to see the entire surface of the planet for the first time.

The acronym MESSENGER stands for MErcury Surface Space ENvironment, GEochemistry and Ranging. The name highlights the scientific topics of the mission, but is also a reference to the ancient Roman messenger of the gods, after whom the planet Mercury is named.

The MESSENGER spacecraft is built with cutting-edge technology. Its components include a sunshade for protection against direct sunlight, two solar panels for power production, a thruster for trajectory changes and fuel tanks.

The instruments aboard MESSENGER will take pictures of Mercury, measure the properties of its magnetic field, investigate the height and depth of features on Mercury’s surface, and in general observe the properties of the planet and its space environment in various parts of the electromagnetic spectrum and via particle radiation studies.

During its mission, MESSENGER will attempt to answer several questions about Mercury. How was the planet formed and how has it changed? Mercury is the only rocky planet besides Earth to have a global magnetic field; what are its properties and origin? What is the nature and origin of Mercury’s very tenuous atmosphere? Does ice really exist near the planet’s poles?

Mercury is an important subject of study because it is the extreme of the terrestrial planets (Mercury, Venus, Earth, Mars): it is the smallest, one of the densest, it has one of the oldest surfaces and the largest daily variations in surface temperature—but is the least explored.
Understanding this "end member" of the terrestrial planets holds unique clues to the questions of the formation of the Solar System, evolution of the planets, magnetic field generation, and magnetospheric physics. Exploring Mercury will help us understand how our own Earth was formed, how it has evolved, and how it interacts with the Sun.

Sending a spacecraft to Mercury is complicated. The planet is so close to the Sun that MESSENGER will be exposed to up to 11 times more sunlight than it would in space near Earth. To prevent the intense heat and radiation from causing catastrophic consequences, the mission has been planned carefully to make sure the spacecraft can operate reliably in the harsh environment. In orbit around Mercury, MESSENGER’s path will carry it closer to, then farther from, the planet, to allow instrumentation to function optimally.

To rendezvous with Mercury on its orbit around the Sun, MESSENGER will use a complex route: it will fly by Earth once, by Venus twice, and by Mercury three times before entering orbit around Mercury.

TABLE 1. MESSENGER Mission Timeline.

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004, Aug 2-13</td>
<td>Launch</td>
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<tr>
<td>2005, Jul 29</td>
<td>Earth Flyby</td>
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<tr>
<td>2006, Oct 23</td>
<td>Venus Flyby I</td>
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<tr>
<td>2007, Jun 4</td>
<td>Venus Flyby II</td>
</tr>
<tr>
<td>2008, Jan 14</td>
<td>Mercury Flyby I</td>
</tr>
<tr>
<td>2008, Oct 6</td>
<td>Mercury Flyby II</td>
</tr>
<tr>
<td>2009, Sep 29</td>
<td>Mercury Flyby III</td>
</tr>
<tr>
<td>2011, Mar 18</td>
<td>Enter Mercury Orbit</td>
</tr>
</tbody>
</table>

For more information about the MESSENGER mission to Mercury, visit messenger.jhuapl.edu/.
rate and composition of Pluto’s atmosphere.

Pluto isn’t the only Solar System object New Horizons will image. During the 2007 Jupiter fly-by and gravity assist, there may be opportunity to image the surface of several Jovian satellites, map their compositions and study their atmospheres.

When the craft arrives near Pluto in 2015, scientists will have six months to study Pluto up close, at higher resolutions than ever (including Hubble) and to choose other Kuiper Belt Objects (KBOs) for fly-by and examination.

As Dr Weaver put it, “The most exciting discoveries will probably be the ones we can’t even anticipate!”

For more information about the New Horizons mission to Pluto, visit: pluto.jhuapl.edu/. Anyone interested in receiving the packet of materials distributed during the workshop is welcome to contact me at the address above.
Successful Public Programming and Outreach

methods for attracting and maintaining audiences
What A Difference Evaluation Makes

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Abstract. The Melbourne Planetarium has undertaken qualitative audience research based on Museum Victoria's visitor motivation model. The results of this research have helped to develop a framework for analyzing a planetarium show that is usefully able to inform production decisions. These results will also guide future audience evaluation. Instead of evaluating components of the show corresponding to the functional division of labour within the production team we will now focus on assessing the qualities perceived by the audience.

BACKGROUND

The Melbourne Planetarium is located at Scienceworks Museum, a campus of Museum Victoria. As a large Museum organization we have the privilege of having a dedicated Audience Research and Evaluation program across the Museum, including the Planetarium, to inform the development of locally produced content.

For some years Museum Victoria has run quantitative assessments of Melbourne Planetarium productions. These measured overall satisfaction with the planetarium shows and attempted to assess key elements of each show. Our thinking centered on components of the shows such as the information, the narration, the visual effects, the sound effects and the overall style or genre. Furthermore, we wanted to be able to compare one show to another using these elements. The message from our work was clear; some shows rated more highly than others but between 80 and 90% of visitors were satisfied or very satisfied with our content and around half could not think of anything they would change.

Nonetheless, we were left wanting more. Although such results let us know that our overall standard was good, they did not necessarily provide the kind of information that could be used to guide our production decisions. Without understanding the qualities by which audiences themselves interpreted our content we were left to rely on our own framework for analysing show content. However, a diverse range of people provide input into planetarium productions and each approaches the production with a different perspective; finding a common analytic framework is not necessarily simple.

MOTIVATION

The planetarium show production process involves continual decision-making at different phases of production – concept, script, storyboard, design and post-production – typically involving different kinds of questions. Examples of decisions to be made include: "What is the range of content for the show? Is it developing one idea in detail or making many connections?" (concept); "How many special effects sequences can be used and when?" (script); "How can visuals best illustrate an idea? Will photographs or diagrams be better?" (design).

Production team members include the astronomer, script-writer, producer and designers. The different role of each of these means that establishing a shared basis for decision making is not always
straightforward. Nor are the frameworks embodied within each role always obvious. Science advisors who will not tolerate magnifying the size of planets but who do not blink an eye over false-colour images, and designers who worry about small continuity errors in characters but are unconcerned by spacecraft flying in unphysical paths are not unknown.

These seeming contradictions are not evidence of poor practice nor are they resolved easily or algorithmically. For example, it is not the case that these questions can be properly resolved by applying a framework of literal realism. Creating a comprehensible, memorable and enjoyable show always involves some departures – otherwise we would not travel very far in a half-hour show! Instead such decisions involve interpretive choices and knowing how to make them is the art of show production. The Melbourne Planetarium production team saw further research of its audiences as a key tool for informing our professional judgement.

UNDERSTANDING OUR AUDIENCE

In November 2005 we had the opportunity to undertake this next level of research. Our aim was still the same: to identify qualities of a planetarium show that create a positive visitor response in order to inform the development of future shows.

This differed from previous research in that it was assisted by our visitor motivation model which the Museum had been researching since 2003. Motivation models are designed to segment markets based on key needs and motivational drivers within those markets. The core need is to feel engagement which can be defined in a number of ways. The motivation model is applied by Museum Victoria to help create engaging experiences across all segments of the market. Some products will tap into certain needs more fully than others but other needs will be at least partially met.

The structure of the model is based on two intersecting behaviours. The Stimulate/Absorb driver – which tells us that engagement can vary in nature – and the For Me/For Others driver – which is concerned about the museum catering for those who are involved.

FIGURE 1. The two axes used in modelling the drivers of audience engagement.

In each quadrant are the four motivational segments as the audiences of Museum Victoria’s venues, including the Planetarium. These segments are consistent with previous research. They are denoted Inspirers, Informers, Duty Bound and Easy Rider.

FIGURE 2. The audience segments within the visitor motivation model.

All of the needs segments can be found at Scienceworks but in response to varying motivations.

Inspirers see the Scienceworks space as big and exciting, and everyone takes their children there.
Informers value science as important to our understanding of the world, and it is beneficial to take the kids to a place where learning is optimized by making it fun.

Duty Bound think it is important for the kids to learn something about science and the world around us, so it makes me feel like a good parent when the kids have a fun day at Scienworks and maybe learn something as well.

Easy Rider see Scienworks as somewhere the kids and I can play and enjoy ourselves.

All participate in the Scienworks experience but different parts of the audience have different motivations and different expected outcomes.

Research has shown that overall, the Scienworks experience has the greatest appeal to the Easy Rider segment, so the entertainment offered by the Planetarium should not be neglected. However, the Planetarium offer sits across the border of the Inspirer and Informer need spaces, delivering to an audience that combines these two need sets (not to two separate audiences). It is important to ensure the needs of both are addressed – needs such as challenge, empowerment, reward, social superiority, immersion, quiet, thinking and intellectuality.

Expressed in words, the Planetarium's core offer is an inspiring and informative 'scientific' journey. Every show needs to deliver inspiration through surprising facts and absorbing, realistic visuals.

UNDERSTANDING THE PLANETARIUM'S ATTRACTION

To further understand these segments, market research company Colmar Brunton undertook qualitative research on our behalf in which five focus groups were each shown a range of planetarium content and then prompted to give their feedback.

This research found that the key to the appeal of the Planetarium is the range of different qualities offered within its unique and spectacular venue. Moreover, viewers use multiple criteria to assess the overall value of a show and actively choose their focus depending on the occasion and need. For example, at one time a viewer may choose to ignore the detail of the information in favour of enjoying and being absorbed by visuals. Conversely, at another time the information can be the key engaging element with the visuals playing a support role.

The research team identified a number of related qualities of planetarium shows: learning; uniqueness; shared; personal; memorable; absorbing; realistic; universal; and entertaining. (Note that this is not a taxonomy; many of these qualities are overlapping while some, like memorability are largely a function of the other qualities.) While there are lessons from the research in relation to each of these qualities, we will describe only a few here.

Quality: Learning

The planetarium is expected to be an educational experience about stars and planets. Underpinning this is an expectation that the experience is primarily about factual, scientific knowledge, not 'fantasy' or 'fiction'. However, the later recall of information and interpretation of viewers varies and can be out of step with the intended objective of the content.

This reinforces to us the importance of a strong thematic storyline. While specific facts are crucial to developing a story, and seen as such by the audience, the recall of specific facts after a show is quite low. On the other hand, the perception and recall of a storyline is strong, even if it is a storyline not intended by the production team.

Interestingly visitors rarely describe their experience as being about 'astronomy'. Instead visitors refer to the tangible elements of the content and their relationship to known reference points, such as planet Earth. This emphasizes to us the importance of making sure that abstract scientific content is grounded in a more familiar context. Melbourne Planetarium
visitors in particular respond well to the use of historical content as a way of presenting scientific ideas.

Quality: Realistic

A key quality of the Planetarium is the realistic experience of being ‘in space’. This realism is important in supporting the fact-based, ‘scientific’ experience our audience expects and is a key differentiator of the Planetarium from films. People frequently speak of the visuals as ‘real’ and this is important as viewers want to be ‘transported’ somewhere and feel like they have actually seen planets (not graphic representations).

However it is worth noting that the interpretation of what is realistic may be quite different between non-specialist audiences and professionals. For example, seeing a starfield fly past as you travel through space is seen as realistic by many visitors, but (hopefully!) by few planetarians. Conversely conventionalized depictions of astronomical data are realistic to scientific professionals but may be difficult to decipher for lay audiences.

Because this sense of realism is largely visual it is considered important to maintain an even visual style. Cartoon or diagrammatic images should be carefully used to match the more ‘natural’ elements of the show.

Quality: Absorbing

The immersive visuals and surround sound create a feeling of being absorbed in the show. This contributes to a viewer’s perception of being a participant in a ‘real’ experience, and experiencing a ‘real’ journey which can contribute to the impact (and consequently memorability) of the content. As a result we feel that visual or narrative devices that separate the viewer from the experience of being directly in the space of the show should be minimized.

Moreover, the immersive qualities of the dome and the dark environment create a strong physical as well as emotional and intellectual experience. It is important to remember the power of this effect as it can be overwhelming for some viewers. Hence we feel it useful to carefully timetable moments of awe within a show to maximize effect and enjoyability.

CONCLUSION

Audience research has given us valuable insights into the way visitors interpret Planetarium shows. These insights provide a shared framework for production team members to approach interpretive decisions during the production process. This framework is not a substitute for our professional judgement, nor will difficult choices necessarily become easy. However, by providing a common language with which different members of the production team can approach a question we allow the different skills to collaborate more effectively. For example, rather than asking whether design continuity or scientific precision is more important at a particular moment we now ask how design and content both contribute to the sense of realism of the scene.

This research will also inform the process of future evaluation. While previously we evaluated components of the show that corresponded to the functional division of labour within the planetarium production team – content, visuals, music, etc – we now appreciate that this is not necessarily how the audience interprets their experience. By evaluating qualities of the experience we hope to get more informed and informative feedback.

ACKNOWLEDGEMENTS

Due credit must go to Sam Parker and David Watts from Colmar Brunton for their analysis of the focus groups. Thanks to Nicole Oke and Tanya Hill for their comments on an earlier draft of this paper.
The Sir Thomas Brisbane Planetarium

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Abstract. An overview of the Sir Thomas Brisbane Planetarium detailing the facility’s equipment, services and history. Production of fulldome content at the facility is also discussed.

PLANETARIUM EQUIPMENT

The planetarium is a stand alone facility consisting of a planetarium theatre, an observatory, a small lecture theatre, a foyer area, gallery and gift shop. There is also a large sundial located in an adjacent courtyard. It is located in one of Brisbane’s botanic gardens.

The main theatre is known as the Cosmic Skydome. It is a 12.5 metre (41 foot) dome with 128 seats arranged concentrically. A Zeiss Spacemaster is located in the centre of the theatre (it is not on a hoist). Sky-Skan’s SkyVision and DigitalSky (ver. 1.7.6) system has also been installed. Normally such a digital system would incorporate 8 computers and 6 Barco projectors. Due to the central location of the Zeiss Spacemaster, the digital projectors must be offset and project to one side of the Zeiss Spacemaster. This has resulted in using 10 computers and 8 Barco projectors.

The observatory houses three telescopes; a 15cm (6 inch) Zeiss Coudé refractor, a 40cm (16 inch) Newtonian on a Dobsonian mount and a 20cm (8 inch) Meade LX90. The observatory is used only for the public and not for research.

The lecture theatre has seating capacity for 40 people. A data projector and electronic white board are available.

The foyer has static displays concerning some of the planets and an open theatrette with a plasma screen displaying astronomical content. The gallery runs around Cosmic Skydome and has large images detailing the Solar System and deep sky objects.

FIGURE 1. The Sir Thomas Brisbane Planetarium - observatory dome in the foreground and planetarium dome in the background.

PLANETARIUM SERVICES AND HISTORY

The Sir Thomas Brisbane Planetarium provides both public shows and school shows. The public shows consist of a pre-recorded presentation using Sky-Skan’s SkyVision followed by a live presentation using both the Zeiss Spacemaster and DigitalSky systems. A public show will run for 45 minutes.

School shows are completely live and are therefore capable of being tailored to the appropriate level of the students. School shows run for 45 minutes, including question time.
In 2006, the planetarium attracted approximately 55,000 patrons (60% public and 40% school groups).

The planetarium is named after Sir Thomas Brisbane who was a Governor of the colony of New South Wales. Sir Thomas instigated the survey which found the area where the present day city of Brisbane is located. Sir Thomas was, more importantly, a highly regarded astronomer who built Australia’s first significant observatory. He also produced a catalogue of 7,385 star positions.

FULLDOME PRODUCTION AT THE SIR THOMAS BRISBANE PLANETARIUM

Fulldome content produced at the planetarium is limited in terms of time availability, staff availability, staff skills and software constraints.

Content is limited to what can be displayed on the dome using Sky-Skan’s DigitalSky (ver. 1.7.6) system. The skills needed to produce this content is limited to one staff member (the author) and the time available to this staff member is also limited.

Two very basic public shows have been produced to date. These shows are based on the traditional slide presentation style with some digital enhancements that could not be achieved using the traditional system. The shows were presented in a live format. Neither show has been offered for sale; they are purely for in-house use.

Content has also been produced for the school shows. Again it is in the traditional slide presentation style but with digital animations of rotating planets and extensive use of all sky imagery.

CONCLUSION

As far as this planetarium is concerned, fulldome production which occurs in-house will be quite limited in scope. Any advancements will be made via upgrading to a system which has inherently better content such as DigitalSky 2.

ACKNOWLEDGMENTS

I wish to thank Ryan Wyatt for instigating the Fulldome 101 session for IPS 2006 and for moderating it. I also wish to acknowledge the experiential insights given by fellow panellists, Mike Murray, Tim Horn and Drew Foster.
Lobby Exhibits On Planet Transit Finding And Using Remote Robotic Telescopes

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Abstract. Lawrence Hall of Science has worked for three years on two new lobby exhibits designed to create highly engaging hands-on astronomy experiences for visitors. One was created for the NASA Kepler mission as a model of the process by which the Kepler mission will find potentially habitable terrestrial extrasolar planets by detecting planet transits. The exhibit has an orrery, light sensor, and computer display of real-time light curves. There are two versions we have created: one a large, rugged, heavy-duty, and costly museum exhibit, and the other a small tabletop low-cost version employing a LEGO orrery that we custom designed. The other exhibit is our Hands-On Universe National Science Foundation funded Real Astronomy Experience that allows museum visitors to use a robotic telescope in Australia in real time. Activities include observing Jupiter's moons, movement of asteroids, measuring sizes of planets, naming nebulae, and classifying galaxies. This presentation gives key details of the development process, obstacles we had to overcome, and lessons learned. It also contains information about how the exhibits can be replicated at other planetariums, museums, and science centers.

THE GRANT PROJECTS

Lawrence Hall of Science (LHS) received funds in two grant projects to create the exhibits described in this paper. NASA Kepler Mission Education and Public Outreach funded a museum exhibit on the transit method of planet finding. The LHS Hands-On Universe (HOU) project received NSF funding to create an exhibit called the Real Astronomy Experience (RAE).

THE REAL ASTRONOMY EXPERIENCE

FIGURE 1. LHS, HOU logos and Kepler banner.

FIGURE 2. The RAE exhibit located just outside the Holt Planetarium at LHS.

The goal of RAE is to enable museum visitors to use real telescopes with CCD cameras to capture astronomical images and to analyze those images with image processing software to experience the excitement astronomers feel (Figure 2).
Visitors have their choice of using three different sources for astronomical images:

1. The LHS Scope (Figure 3) to obtain images from an indoor simulated starfield.
2. The Australia Scope at Perth Observatory to obtain images from a real nighttime sky, weather and mechanical conditions permitting.
3. Scopey's Laptop, an archive of images previously obtained for the RAE exhibit.

The visitor's control kiosk (Figure 4) is a touch screen with speakers. Adjustment of sound volume for the speakers is carefully done to minimize "crosstalk" where a visitor might be distracted by sounds from other kiosks.

Early on we found a need for an animated cartoon character, Scopey (Figure 6), to explain RAE and ask questions that guide visitors through the RAE activities.

The indoor star field simulation (Figure 7) has small images of deep sky objects among the stars, as well as planets. We decided to use two LCD monitors to display changing objects like asteroids, the moons of Jupiter and supernovae.
FIGURE 8. Visitor is notified that their command to control the telescope is sent.

FIGURE 9. Drawing attention away from the kiosk towards the telescope.

A special problem of a kiosk control system that is connected to a separate physical component (the telescope) is that visitors are so absorbed in the kiosk that they may not realize that something is happening outside the kiosk, e.g. the telescope moving. So we have Scopey point towards the telescope and say "Look!" when the telescope will be moving (see Figs. 8 and 9).

FIGURE 10. Waiting for the requested image to come.

The 3 or 4 minutes that it takes for the command to be executed by the robotic telescope and for the image to be returned is potential "dead time" that could drive visitors away from the exhibit. To prevent this, we have Scopey invite the visitor to try out using some of the image processing tools on a practice image from Scopey's notebook.

At the middle bottom in Figure 10 are brightness and contrast controls. Drawing tools are in the lower left. At the lower right is the color palette tool that offers a variety of possible false color schemes (Figure 11).

FIGURE 11. Color palette tool.

Some activities require special tools such as a ruler that has a scale automatically set for correct distance measuring (Figure 12). In the "Measure a Planet" activity, a key challenge is for the visitor to quickly understand the concept that the farther away an object is, the larger the distances between objects in the scale of the image. Astronomers refer to this as plate scale, but we do not tell the visitors that.
FIGURE 12. Special tools: ruler and numeral entry keypad.

FIGURE 13. The elephant and the beach ball.

Comparisons between a cartoon elephant and a beach ball (Figure 13) are used to show the need for the special ruler tool that has a scale automatically set to measure correct size for the object distance. The elephant can look the same size as a beach ball if it moves far enough away.

Some activities require a numeral keypad. There can also be a "keyboard" that allows visitors to enter their e-mail addresses to send themselves the images that they have captured and worked with in the RAE exhibit.

The observatory in Perth, Australia, has a web-cam called SkyCam which shows conditions at the observatory. Figure 14 shows cloudy sky condition (left) and clear starry sky (right). There is also a page at the observatory's website that gives detailed current weather conditions.


We are looking into establishing more observatories at different locations in the world to serve an RAE network which could also add more museums with RAE-style exhibits. Other sites under consideration: Australia (James Cook University), Morocco, Pakistan, Nigeria, South Africa, Japan, China, Chile, Argentina, Germany, and USA (Hawaii).

FIGURE 15. The RAE activity choice page.

In addition to a choice of telescopes for source of images, RAE currently has five activities for visitors to choose from (four of which are shown in Figure 15):

- Measure a Planet!
- Name a Nebula!
- Jupiter’s Moons!
- Follow an Asteroid!
- Grouping Galaxies.

Each activity has a short (under 2 minutes) animated introduction by Scopey to explain any special background the visitors need to do the activity.
FIGURE 16. Introduction to Jupiter’s Moons activity.

In the Jupiter’s Moons activity, the introduction is about Galileo’s discovery of the Galilean moons.

FIGURE 17A. Animation to show Jupiter’s moon system edge on.

FIGURE 17B. Animation to show Jupiter’s moon system from top view.

Part of the introduction to the Jupiter's Moons activity is an animation in which an edge-wise view of the system morphs into a top view of the system (Figure 17) to give visitors a clear idea of the concept of how observations of the moons relate to three dimensional reality.

A MUSEUM EXHIBIT ON PLANET FINDING BY TRANSITS

A second lobby exhibit is the one funded by the NASA Kepler Mission Education and Public Outreach (EPO). It is intended to clearly illustrate the concept of how planets are found by the transit method.

FIGURE 18. Traveling exhibit: Alien Earths.

The planet finding exhibit is part of a large travelling museum exhibit, Alien Earths, produced by the Space Science Institute with funding from NSF. Figure 18 shows the entrance to Alien Earths, which was first test at Lawrence Hall of Science in February 2005.

Besides the Kepler mission, other missions collaborating in the Alien Earths development were Navigator/PlanetQuest, STScI OPO, Spitzer, SOFIA, NASA Astrobiology Institute, and the Search for Origins Education Forum.

FIGURE 19. Hand crank powered orrery.
There are two parts to the planet finding exhibit. The part shown in Figure 19 is a three-planet orrery operated by the visitor using a hand crank.

**FIGURE 20.** Light sensor aimed at orrery.

A light sensor (from Vernier), carefully aligned in the plane of the orbiting planets, is aimed at the model star (a light bulb) at the center of the model star system (Figure 20).

**FIGURE 21.** Light curve.

The light sensor is connected to a hidden computer which generates the light curve on the "Star Brightness Meter" display shown in Fig 21. The light curve is a continuous feed of real time data, so it instantly records changes as the visitor turns the crank and planets move between the "star" and the light sensor.

**FIGURE 22.** Challenge question.

A sign to the right of the orrery poses a key challenge question: "Can you create this red line on the Star Brightness Meter by arranging Planets around the Star and turning the Crank?" (Figure 22). This sign also has an illustration of the Kepler photometer / spacecraft and a sentence of explanation about the Kepler mission.

**FIGURE 23.** Part B: analyzing a light curve.
The second part of the exhibit shown in Figure 23 displays a light curve and poses the question: "Which planet system below does this red line represent?" We actually don't use the expression "light curve".

**FIGURE 24.** Part B answers.

Flip up cards (Figure 24) have the answers (right and wrong) for the visitors to see once they make their decision about which planet system created the light curve.

**FIGURE 25.** Multiple users.

In one set of observations, evaluators of the Planet Finding exhibit found that the exhibit is very attractive to visitors: nearly 90% of the groups that came near the exhibit stopped to engage with it.

Groups spent anywhere from 1 to 12 minutes at the exhibit, with an average dwell time of over three minutes (above average for hands-on exhibits). Over 90% spent two minutes or more.

A wide range of ages were observed using the exhibit successfully and about 15% of users were under the age of 7.

Although only about 10% of groups attempted to reproduce the pattern from the orange panel, most groups were engaged with the exhibit past simply turning the crank (100% of groups). They were:

- switching the planet positions (53% of groups),
- watching the read-out screen (86% of groups) and
- reading the signs (48% of groups).

This suggests that visitors were not simply manipulating the exhibit, but were drawing meaning from it.

For Part B, about 48% of visitors lifted the "answer" panels associated with the blue panel. However, no group attempted to determine the planet arrangement that created the pattern shown (probably because of the orientation and position of the panel).

The builders of the exhibit can reproduce it for approximately US$23,700 (latest quote was in January 2006). Kepler EPO has a set of the design plans.

*Alien Earths* is on tour around the US at the venues given in Table 1. Information regarding future venues can be found at [www.astc.org/exhibitions/alien/dalien.htm](http://www.astc.org/exhibitions/alien/dalien.htm).

**TABLE 1.** *Alien Earths* tour details.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb 1 – Oct 30, 2005</td>
<td>Lawrence Hall of Science, Berkely, CA</td>
</tr>
<tr>
<td>Oct 1 – Dec 31, 2005</td>
<td>Science Museum of Western Virginia, Roanoke, VA</td>
</tr>
<tr>
<td>Feb 1 – Apr 30, 2006</td>
<td>Louisville Science Center, Louisville, KY</td>
</tr>
<tr>
<td>Jun 1 – Aug 31, 2006</td>
<td>Museum of Science and Technology, Syracuse, NY</td>
</tr>
<tr>
<td>Oct 1 2006 – Apr 30 2007</td>
<td>Yale Peabody Museum of Natural History, New Haven, CT</td>
</tr>
<tr>
<td>Jun 1 - Dec 31, 2007</td>
<td>Turtle Bay Exploration Park, Redding, CA</td>
</tr>
</tbody>
</table>
FIGURE 26. A LEGO Orrery Transit Model.

A smaller exhibit for demonstrating the transit technique of planet finding has an orrery made of LEGO parts. It can be either hand cranked or motor driven. The one shown in Figure 26 (right) has four planets. An earlier three-planet model, shown on the left, has the complete system shown: light bulb model "star", light detector, and computer with a real time light curve display. This system works very well as a facilitate demonstration table in museums and at conference and public events (Figure 27).

Plan for the LEGO model can be found on the Kepler mission website (kepler.nasa.gov) and a list of other Kepler projects is given in Figure 28.

FIGURE 27. Professional astronomers and professors (left to right): Andrea Dupree, Harvard Smithsonian Center for Astrophysics; Dave Duncan, University of Colorado; and Dave Koch, Deputy PI of Kepler mission.

FIGURE 28. Other Kepler EPO projects.
A Digital Science Partnership For Southern Skies In The Classroom

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Abstract. A collaboration between the University of Louisville, the University of Southern Queensland (USQ) and Northern Kentucky University, is developing remotely and robotically operated astronomical facilities for educational outreach, teaching and research. Telescopes in the Southern and Northern Hemispheres, with a longitude difference that enables students to observe the night sky in daytime classes, are linked by high speed Internet to campuses in Louisville and Kentucky, USA, and Toowoomba, Queensland. Mt. Kent Observatory in Australia also offers the center of the Milky Way, the Magellanic Clouds and transient events not visible from mid-latitudes in the Northern Hemisphere. Moore Observatory near metropolitan Louisville, Kentucky, is isolated from local lighting by a forested nature preserve, and offers complementary remote services and the occasional northern comet and supernova to students at USQ. In addition to other instruments at both sites, the robotic operation will use corrected Dall-Kirkham f/6.8 0.5-meter telescopes designed and manufactured for us by Celestron International. The optical system provides a well-corrected 27' x 18' field of view with 0.54" pixels when coupled with a Kodak KAF-6303E CCD. Open source software supports the weather stations, sky condition monitors, and remote operation of the telescope, cameras and dome. The southern telescope in Australia will be used through an Internet2 connection from the University of Louisville Belknap Campus, with dedicated control facilities in the Physics and Astronomy Department for University of Louisville students, and in the Gheens Science Hall and Rauch Planetarium, for an outreach educational program to local schools. The northern telescope at Moore Observatory allows engineering and software development, provides hands-on experience for students, and may be operated remotely by students and collaborators in Australia as well. We expect to install the telescopes in January 2006. This presentation describes our work to develop the hardware and open source software, a preliminary analysis of telescope performance, and the anticipated impact of remote network facilities on astronomy education.

PURPOSE

The University of Louisville (UofL) is Kentucky's metropolitan research university serving a diverse student body, primarily with daytime classes on its urban Belknap Campus. Its Physics and Astronomy Program offers courses and laboratories satisfying the General Education requirement for students in all majors, as well as astrophysics courses for undergraduate and graduate students. A +14 hour difference from Louisville to Toowoomba brings a dark sky into their classes. Remote access from several sites similarly benefits University of Southern Queensland's (USQ) distance education astronomy program. UofL's Rauch Planetarium is offering an opportunity for middle and high school students to participate in group learning experiences with the remotely operated telescopes. A curriculum to meet the goals of the AAAS Project 2061 is being developed (see www.project2061.org/).

SITES

The Australian telescope is at USQ's Mt. Kent Observatory, near Toowoomba, approximately 130 km from Brisbane. At 682 m altitude on the Great Dividing
Range, in a pastoral area of the Darling Downs, and at latitude -27° 47' 52", it offers frequent clear skies, good seeing and an established secure infrastructure.

FIGURE 1. The Mt Kent Observatory, Toowomba, Queensland, Australia.

At Moore Observatory, near metropolitan Louisville, Kentucky, we operate a site for graduate and undergraduate research where the northern robotic telescope is located. At +38° 20' 40" and only 230 m altitude it is a typical light-polluted midwestern site, but it has good stable seeing and is accessible by students on short notice. Moore Observatory also has a 0.6 meter Ritchie-Chrétien research telescope and a wide field spectral imager.

FIGURE 2. The Moore Observatory, Louisville, Kentucky, USA.

TELESCOPES AND INSTRUMENTATION

Celestron’s C20 0.5 meter, f/6.8 corrected Dall-Kirkham telescope has been under development for several years. It features a temperature-stabilized optical system using a light weight conical Pyrex ellipsoidal f/3 primary, and a spherical secondary, multilayer coated for 98% reflectivity in the visible. Their design adds a 90 mm diameter field-flattening coma corrector inside the baffle to produce a 6 μm RMS spot size over a 42 mm diameter (0.7°) field. The German equatorial mounting responds to the NexStar command set. It tracks with 5% accuracy without error correction, and sub-arcsecond accuracy with automated guiding. Pointing accuracy with low-order correction is sufficient to place a target near the center of a CCD field of view.

FIGURE 3. The telescope and instrumentation.

We use two SBIG CCD cameras and filter sets: an STL-6303 has a Kodak KAF-6303E, 3072 x 2048 9 μm, pixel device for RGB color imaging with a 5-filter wheel over a 27' x 18' field. It is well matched to the field of the C20 with 0.5" pixels. Somewhat better oversampling of the images is achieved with the ST-10 camera's 2184 x 1472 6.9 μm pixels at the
expense of a narrower field of view. The ST-10 has the advantage of a 10-filter wheel so that it may be switched remotely from RGBL imaging to UBVRI photometry without a manual change of filter sets. The cameras are designed with internal tracking CCDs and can make use of SBIG's tip-tilt corrector and drift-scan imaging modes. Both telescopes will have long-slit spectroscopic capability, although this requires a manual change. Auxiliary cameras provide a wide f/1.8 color image of the acquisition field and a real-time video image of the entire sky. A cloud sensor based on the Omega industrial infrared pyrometer records the 10 μm signal from the sky and a weather station monitors local environmental conditions.

NETWORK, SERVERS AND SOFTWARE

Mt. Kent is connected to the Toowoomba campus by a 4.8 Mbit/s radio network link (soon upgrading to 34 Mbit/s), then to Brisbane on optical fiber at that quality of service guaranteed during their nighttime. The connection from Brisbane to Louisville is over Internet2. The pipeline is adequate not only for remote operation and data transfer, but also for real-time video and audio with an acceptable latency when the dome video is transmitted using an Axis 241 video server, and video conferencing is through a Polycom VSX 7000.

Dual redundant 0.5 TB IBM x346 servers running Suse Linux operate at Mt. Kent and at Louisville to buffer and archive the data flow. Multiple users in Louisville, for example, connect to the local server. Automated sensors provide web-based information on current conditions that bear on telescope operation such as wind, temperature, dew point, cloud cover and instrument status.

Moore Observatory is connected by a T1 (1.5 Mbit/s) link to the main campus network, a slower speed that is still adequate for real-time compressed image transfer and video conferencing while running remote control and data acquisition software. The telescopes and instrumentation are controlled through dedicated PCs running Suse Linux. The open source XmTel user interface is built on top of XEphem. The network is responsive enough to permit running the software on the remote computer and displaying on the user's console, but the system works best when a remote daemon controls the telescope while the display and communication software is at the user end. XmTel is being developed to utilize the excellent graphical interface and databases of XEphem while allowing us to add the specialized drivers for telescope and dome control without the overhead of intermediate “standards” or Windows-based commercial software.

Figure 4. The Graphical Interface.

Cameras are controlled by XmCCD, built to operate SBIG hardware remotely. Images are processed and displayed locally using a pipe to SAOimage DS9. In addition to the usual astronomical analysis software packages, we use CinePaint for 32-bit color image processing. Details on software will be on our website at www.astro.louisville.edu/moore/software.
EXAMPLE IMAGES

FIGURE 5. This image of M51 was recorded by R. Hedrick, D. Rowe, J. Fournier, and J. Haberman using the prototype C20 at their Pinto Valley Observatory on May 8, 2005. It is a composite of 4 exposures, 10 minutes each for RGB, and 60 minutes for L, taken with an ST10 camera.

FIGURE 6. On July 5, 2005, J. Haberman, R. Hedrick, J. Kielkopf, and R. Moore recorded this test image of the 14th magnitude type-II supernova SN2005cs. It is a sum of 6 x 15-minute exposures with an ST10 camera.

IMPACT

The opportunities for hands-on discovery and exploration this project offers should, in the words of Project 2061, “bring back the sky – not the same sky, but one that is richer and more varied than people's eyes alone had ever led them to imagine.”

ACKNOWLEDGEMENTS

This project is a collaboration of the University of Louisville and the University of Southern Queensland as part of a Digital Science Partnership with Northern Kentucky University. It is supported in part by a grant from NASA. We are grateful to many who are helping to bring this from a concept to a useful operation, including Rhodes Hart who handles the operations at USQ's Mt. Kent, and Drew Foster who directs UofL's Rauch Planetarium. Dr Ronald Moore, Vice President for Information Technology at UofL, has given the project his enthusiasm and hands-on support, and has provided the servers and IT infrastructure. Rick Hedrick, Senior Vice President of Celestron International, and Joe Haberman, Optical Engineer, helped with optical and software design issues, and provided access to the prototype telescope at Pinto Valley Observatory. Helen Kielkopf, Andy Newton and Karen Collins in Louisville are contributing creative ideas and assistance at Moore Observatory.
i-Can See The Stars – Watching The Real Night Sky In Your Classroom

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Abstract. Since 2001, the Science Museum, Tokyo, in collaboration with Yerkes Observatory has been utilizing Internet Telescopes in education and public outreach. "Live observing" of the night sky is possible by utilizing time differences, mostly from the Yerkes Observatory through the collaboration with Hands-On Universe (HOU). Real-time sky watching is an effective way of fascinating people about astronomy and is proven to work in school classrooms as well.

CAN WE SEE THE STARS IN THE DAYTIME?

We can see the stars in the daytime through the Internet Telescope which is on the night side of the Earth. The KITANOMARU Internet Telescope (KIT) is the most successful example of the educational use of a robotic telescope and was installed atop the roof of the Science Museum, Tokyo, in 2001. With the Internet Telescopes Network, it is expected that teachers participating to the Hands-On Universe (HOU) project, will be able to plan and complete more efficiently a session of observing a real night sky in classrooms during the day. In the future students will be able to make their own research program.

High school students during school hours in the US State of Illinois can study night time astronomy using the time difference between the USA and Japan. According to the results of pre- and post-tests, students have the chance to better understand geometry and IT technology by participating in the project, thus it is clear that their consciousness can be changed. Furthermore, they can focus directly on the celestial bodies that they observe with the telescope instead of dealing with purely abstract concepts.

i-CAN SEE THE STARS

A Course Of Study For Astronomy In Japan

In Japan, astronomy subjects are taught in the 4th grade in the Elementary school and the 9th grade in the Middle school. 4th grade children learn about the color of stars, and the brightness and motion of the Sun, Moon and stars. Middle school students learn about the Sun and Solar System in 9th grade. Most elementary school teachers cannot teach astronomy because they do not have a strong enough background of science (especially astronomy). Many teachers give homework in the form of “See the stars
from your garage”. Many students have an interest in astronomy at an early stage in their life, but they do not have information from teachers on how to study and observe celestial objects, so they lose interest in many cases.

**Images From Telescopes**

Images from telescopes are good for observing the terminator of the Moon, planets, nebulae, and star clusters. These beautiful images make students excited.

The image requests of which objects students want to analyze is accepted with HOU. Once the images are taken, they can be downloaded from the HOU website. HOU started as an astronomy education program for High School students, so the images from the Internet Telescopes are suitable for High Schools and also as activities for museums.

However, Japanese National Standard allocates a considerable portion of time to the study of the motion of celestial bodies (stars) for astronomical subject in Elementary and Middle schools. As an observational tool, Internet Telescopes are used often in Elementary school, but telescope images of planets, nebulae and star clusters are not subjects for Elementary school students. Thus, they are not suitable for Elementary school from the perspective of the teaching standard. We aim to develop a new wide-field camera for observing stars and constellations at the Elementary school level.

**System Of Interactive Camera Network (i-CAN)**

There are existing all-sky camera networks; Michigan Technical University has already provided a night sky view by CONCAM, the CONtinuous CAMera. There are 11 cameras across the world with fisheye lenses that watch the entire sky every night.

Since 2005, we have been working on a project with Kumamoto University, Japan, to develop a wide-field camera that is named the Interactive CAmera Network or i-CAN. Dr. Satoh who is the leader of the i-CAN project designed four points that a new camera requires to meet the following conditions with i-CAN.

1. Real-time images
2. Interactivity
3. wide-field of view (70° FOV diagonal)
4. Color images

i-CAN is designed to fit the National Standard for Elementary School. The wide-field of view is perfect for recognizing constellations and asterisms. The color CCD camera is useful for showing the colors of the stars.

**TABLE 1. System of i-CAN**

<table>
<thead>
<tr>
<th>Camera</th>
<th>Lens</th>
<th>PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mintron</td>
<td>CBC</td>
<td>E-Let’s</td>
</tr>
<tr>
<td>MTV-63V1N</td>
<td>3.8mm, F0.8</td>
<td>OS: Linux</td>
</tr>
</tbody>
</table>

**FIGURE 2. System of i-CAN.**

The other features are:

1. High-sensitivity color video camera.
2. Fantastic view of star-fields and the Milky Way.
3. “Live broadcast” in Real Video format.
5. All-in-one weather-proof case with a transparent dome atop for viewing sky.

FIGURE 3. Inside of i-CAN.

Worldwide i-CAN Network

Seven i-CANs are working for the result of project members and local staff as of November, 2006. Everyone will be allowed to operate the camera, if operation is not already occupied.

The first i-CAN, named William, was installed at the Yerkes Observatory, USA. The second one, named Roberta, is in Atacama in Chile, the third, named Luna, is in Kumamoto, Japan, and the fourth, named Rose, is in the Rosemary Hill Observatory in Florida, USA.

The fifth i-CAN, named Sacra, is at the Sloan Digital Sky Survey site of Apache Point Observatory, the sixth, named Santa, is in Tenerife (Canary Islands), and the seventh, named Merope, is at the SUBARU site in Hawaii.

ACTIVITIES USING i-CAN

We already provide programs using i-CAN for Elementary Schools and Museums. We have visited many schools in Japan and have developed the classes which use i-CAN. Furthermore, we have also visited Elementary Schools and High Schools in the United States and we have shown a night sky through the eye of i-CAN for teachers and students. We have a good evaluation of these classes on the National Standards for the Elementary School. In addition, after school programs provided by the Science Museum, Tokyo are not swayed by National Standards, thus we are providing the distinctive program combined with computer simulations.

We also have a program to watch the real time night sky at the Science Museum, Tokyo. The program operates twice a month. It is called Science Liveshow “UNIVERSE” and includes “Live Observation” using the Solar System Simulator and 24 inch Telescope at the Yerkes Observatory. Furthermore, we are starting to work on teacher training at planetariums and science museums.

FIGURE 4. World Wide i-CAN Network.

Since the IPS Conference in Melbourne, Australia, we have installed 3 more i-
CONCLUSION

The usefulness of i-CAN and how it works to increase the students' interests in astronomy has been statistically proven through the comparison of pre- and post-class surveys. We are now evaluating how i-CANs improve students' understandings of the science itself, such as celestial motion.

A common problem realized since the advent of i-CAN is that teachers need more familiarization with astronomy. They face difficulty finding constellations in the field of view of i-CAN because the camera is "too sensitive", thereby showing too many stars on the screen. In response, we have prepared new star charts for teachers. This is an example of how the i-CAN project always evolves.

Now the problem which we face is that IT technology is improving rapidly, so it is difficult to find some of the parts for i-CAN. Also this project ended in the 2006 financial year, so from now on, we will need to consider who does maintenance and how it is managed.

Collaborating institutions of the i-CAN project are spread over the world. With such a network of people, i-CAN could ultimately provide 24 hours and 7 days of real-time/interactive night-sky viewing!

For more information see the project website: rika.educ.kumamoto-u.ac.jp/i-CAN/

ACKNOWLEDGMENTS

Thank you to all collaborators for installed i-CAN. Yerkes Observatory, National Astronomical Observatory Japan, LUNA Observatory, University of Florida Rosemary Hill Observatory, University of Chicago SDSS Team, New Mexico State University, University of Bradford and many friends in the world.

I appreciate Alan Gould having checked my English manuscript patiently.

REFERENCES


Designing For Diversity: The Implications Of Cognitive Style For The Instructional Design Of Planetarium Shows And Exhibits

Naomi Knappenberger

Abstract. One of the greatest challenges facing science museums and planetaria today is how to produce educationally effective shows, exhibits and instructional materials that address the needs of a diverse audience. In any audience visitors may vary widely in age, experience, education, interests and motivation. They may also differ in cognitive style, the characteristic, self-consistent mode of selecting and processing information that an individual displays in perceptual and intellectual activities. Cognitive style has a broad influence on many aspects of personality and behavior: perception, memory, problem solving, interest and even social behaviors and self-concept. It is the basis for essential individual differences among visitors and is a critical variable in the instructional design process. This paper will describe how knowledge of cognitive style, science learning and instructional design was applied to an experimental study at the Adler Planetarium. The results of the study indicated that learning by all visitors increased significantly when the cognitive style of the visitors was matched to instructional strategies employed in an astronomy exhibit.

INTRODUCTION

When we gaze up into a clear night sky, we see what appears to be an ocean of stars, each point of light seeming very much like every other point of light. However, as astronomy educators, we know that a closer examination would reveal vast differences among the individual stars in terms of size, brightness and composition. Just as it would be a mistake to assume that all stars are alike, it would also be a mistake to look at the faces in a planetarium audience and assume that all visitors are alike. Aside from the rather obvious differences in age and sex, visitors may vary widely in experience, education, interests and motivation. They may also differ in cognitive style. Cognitive style is important because it has a broad influence on many aspects of personality and behavior including perception, memory, problem solving, interest and even social behaviors and self-concept. It is the basis for essential individual differences among visitors and should be a critical variable in the instructional design process. This paper discusses an experimental study of cognitive style conducted at the Adler Planetarium as an example of how science education research can be used to inform the instructional design process and improve the educational effectiveness of shows, exhibits and instructional materials.

COGNITIVE STYLE

What is cognitive style? Simply put, cognitive style refers to how an individual selects and processes information. This includes the formation of ideas and judgments. It is also the pattern of attitudes and interests that influence what a person will attend to or find interesting in a potential learning situation. It is a disposition to seek out learning environments compatible with one’s cognitive style, attitudes, and interests—and to avoid environments that are not.
Similarly, it refers to the ways in which an individual enjoys learning, as in which learning tools an individual will use and which ones they’ll avoid [1].

There are many conceptions of cognitive style in the research literature. You are probably familiar with some of them—left-brain vs. right-brain, global vs. analytic and so on. We now recognize that the differences are largely semantic and that the basic definitions are quite similar [2]. The most extensively investigated conception of cognitive style is field dependence. It has been researched in the biological, psychological and socio-cultural disciplines, with several thousand references in the literature. I chose to investigate field dependence-independence in the study at the Adler because of the impressive body of research concerning field dependence-independence and science learning.

**Field Dependence-Independence**

The instrument used to identify field dependence-independence is the Group Embedded Figures Test. The test consists of 18 figures embedded in a background or field. Field-independence is quite literally the ability to see the figures independent of the field surrounding them. The number of figures successfully disembedded within a specified time determines an individual’s final score on the test [3]. While it may seem too simple to be true, thousands of studies in diverse disciplines have demonstrated that the ways individuals differ on performing this perceptual task is related to many aspects of personality, human development, social functioning, psychopathology, neuro-physiological processes and even cultural adaptation [4].

The distinguishing characteristic of field-dependent individuals is their reliance on external referents. Field-dependent individuals are very social and rely on others to provide them with standards for judgment and action. They gravitate towards the humanities, social sciences, teaching and human service professions—fields that require greater interpersonal skills.

In contrast, field-independent individuals use internal referents to achieve solutions. They have greater skill in cognitive restructuring and are quite successful at segregating and manipulating abstract concepts. They function autonomously of others. They move towards the fields of mathematics, science, engineering, art and music—disciplines that require restructuring skills [5].

**RESEARCH METHODOLOGY**

There were two questions investigated in the study. The first had to do with the numbers of field-dependent and field-independent visitors to the Adler. The research suggests that field-independent individuals are more interested and successful in the scientific domain [6]. If those individuals pursue their interest in the sciences in their leisure time as well, then that should be reflected by a higher proportion of these individuals in the planetarium audience than would be expected given their estimated numbers in the general population. The second question concerned whether or not it was possible to affect the learning of these visitors once their cognitive style was identified. Many studies have demonstrated that matching cognitive style to instructional strategies in formal learning environments results in increased learning for both field-dependent and field-independent individuals [7]. It seemed probable, therefore, that matching cognitive styles to instructional strategies in an astronomy exhibit should have the same result.

The exhibit chosen for the study was the Ameritech Space News Center. This exhibit was developed as a vehicle to interpret and present current astronomy news stories to the public. It was designed to resemble a TV newsroom with a news desk in the center. To either side there
were two computer kiosks with touch screen monitors where visitors could access information and images related to recent discoveries in astronomy. Several news stories were presented in a series of 3 to 5 screens that combined text, photos, video and computer animations. The entire program had a total of 19 screens and 1566 words.

Figures 1 and 2 are examples of screens from the original version of the exhibit that was used for the Baseline Treatment in the study. The text in the original version, though accurate and interesting, was quite dense and the accompanying images often were not captioned.

![FIGURE 1. Main menu screen for the Baseline Treatment.](image)

The challenge was to modify this content for field-dependent learners while maintaining the educational objectives for the exhibit. The research on field dependence-independence and science learning indicates that field-dependent individuals make less effective use of mediational processes like analysis and restructuring, in fact they are not very proficient readers. They adopt a passive, spectator role in learning. They are also more dominated by salient cues in learning and more influenced by extrinsic goals, reinforcements and forms of motivation. In general, field-dependent learners are less effective on a number of processes critical to learning, specifically analyzing, organizing, encoding and memory processing [8].

So, how do we translate what we know about field-dependent learners into instructional strategies? A crucial research finding is that field-dependent learners are less likely to impose a meaningful organization on a field that lacks structure and are less able to learn conceptual information when cues are not available. That meant that the instructional strategies employed in the exhibit needed to accommodate these deficiencies. As much as possible, the field-dependent version needed to be a guided experience, provide structural organizers, and include concise information with clearly stated critical points emphasized.

![FIGURE 2. An example of a text screen in the Baseline Treatment.](image)

Figure 3 is the menu screen for the field-dependent version of the program. The icons were numbered so that a sequence for movement through the program was suggested. The icons on the text screen were also numbered to suggest a sequence and dimmed once they were accessed so the visitor would always know which screens he had already visited. An advance organizer screen (Figure 4) was added to orient the field-dependent learners and provide a brief overview of the topic.
The next challenge was to take the same content and modify it for the field-independent version of the program. Research in science learning tells us that field-independent learners make greater use of mediational processes such as analyzing and restructuring. They adopt an active hypothesis-testing role in learning. They are less governed by the most obvious or salient cues in learning. They operate more from internally defined goals and reinforcements and they are more likely to be motivated by intrinsic or task-oriented incentives. Field-independent learners are more adaptive in an educational context. In fact, they embody the characteristics that educators value or attempt to promote in their instructional efforts: analyzing and structuring information and adopting an active, hypothesis-testing role. In general, field-independent individuals are better learners and achievers because of their greater analytical skills [9].

These findings suggested that the field-independent version should, as much as possible, have an exploratory format, encourage hypothesizing, provide more contextual information and allow for some autonomy in the learning experience. Figure 6 is the modified version of the original text in Figure 2. The numbers were removed from all icons throughout the program so it would feel more exploratory. The bold factual statement...
seen in Figure 5 was replaced with a question to encourage hypothesizing and more contextual information was added. The text was also blocked in this version, important terminology was bolded, and image captions included because these are instructional strategies known to be effective for all learners. There were 16 screens and 1675 words in this version, slightly more than in the Baseline Treatment and double the words in the Field-Dependent Treatment.

**FIGURE 6.** An example of a text screen for the Field-Independent Treatment.

A random sample of 400 visitors were divided into four groups of 100 subjects each: a control group who did not see the exhibit, a baseline group who used the original version of the program, a group who used the field-dependent version and a group who used the field-independent version of the program. All visitors were tested for cognitive style using the Group Embedded Figures Test, interacted with the exhibit (with the exception of the control group) and then completed a 20-item post-test of exhibit content and a short demographic survey.

**RESULTS**

The first question investigated was whether there was a significant difference between the number of field-dependent visitors and the number of field-independent visitors to the Adler. The field-independent visitors (N=269) significantly outnumbered the field-dependent visitors (N=131) by a ratio of 2 to 1. This result supports the hypothesis that field-independent individuals are more interested and successful in the scientific domain and pursue this interest in their leisure activities. The presence of field-dependent individuals in lesser numbers is an indication that the Adler attracts this type of learner as well, although their interest may lie more in the social aspect of a museum visit rather than the educational activity that takes place there—but we don’t know this. What’s most significant is that both types are present in our audience. This has important implications for the instructional design of shows, exhibits and instructional materials if we are to provide meaningful experiences for both field-independent and field-dependent visitors.

The second question had to do with whether or not matching visitor cognitive styles to instructional strategies would result in increased learning. The results indicated the field-independent visitors significantly and consistently outperformed field-dependent visitors in all treatments. In looking at the regression plot (Figure 7) it can be seen that there was a significant interaction between cognitive style and instructional strategy that affected visitors’ post-test scores. Both field-dependent and field-independent scores showed a similar and significant improvement from the Control Treatment to the Field-Independent Treatment, resulting in more than a 40% increase in learning overall. This was accomplished through reformatting the content.
In the Control Treatment, where visitors had not seen the exhibit, the field-independent visitors seem to have had more prior knowledge of astronomy content, which resulted in higher scores than those of the field-dependent visitors. In the Baseline Treatment, the text density and lack of structure in the original version of the program put the field-dependent visitors at a disadvantage so that they didn’t score much higher than the field-dependent visitors in the Control Treatment. However, the text density didn’t seem to hinder the field-independent visitors. In the Field-Dependent Treatment, the differences between field-dependent and field-independent scores in the Baseline Treatment were somewhat mitigated by the instructional strategies employed in the treatment. However, it is the results of the Field-Independent Treatment that are most surprising. This treatment was most effective for both field-dependent and field-independent visitors and had the least differences along the FD/FI scale. Obviously enough structure remained with blocking and cueing that the density of the text did not overwhelm the field-dependent visitors. This indication that it is possible to mitigate some of the effects of cognitive style with instructional design is good news for museums and planetaria since it is highly impractical to create two versions of everything to accommodate different cognitive styles.

**CONCLUSION**

Although more research in this area is needed, it is highly likely there are a greater proportion of field-independent visitors than field-dependent visitors in planetaria audiences. For the most part, these field-independent visitors come to us with the attitudes, interests, motivations and skills necessary to have meaningful experiences in our institutions. We must, however, maintain awareness that the less well-prepared field-dependent visitors in our diverse audience may need more instructional support. We know learners favor different strategies in important areas such as cue salience, the use of mediators in learning, and reinforcement. All of these needs can be accommodated by thoughtful instructional design and lead to greater educational effectiveness of our shows, exhibits and instructional materials.

In closing, I’d like to leave you with this thought. There are two kinds of people; those who think there are two kinds of people and those who do not. Of course we are not really talking about two kinds of people when we talk about field-dependence. We are instead referring to many individuals who range along a continuum and possess certain skills and characteristics to a greater or lesser degree. How we address these skills and characteristics in our shows, exhibits and instructional materials determines the quality and educational effectiveness of all that we do. If we want to attract and support a diverse audience, then we must maintain awareness of the manner in which cognitive style affects all aspects of the visitor experience. This study provided empirical evidence that matching instructional strategies to visitors’ cognitive style can enhance learning from
astronomy exhibits. This is information that can be applied to the instructional design of shows, exhibits and instructional materials to create experiences that are intellectually engaging and memorable for all of our visitors.

REFERENCES

1. G. Lawrence, *Journal of Psychological Type*, 1984, 8, pp. 2-18
Formalwear For Planetarians: Integrating Formal Education Elements Into Informal Venues

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Abstract. Teachers who run school planetariums and informal education venues that provide activities for teachers and classes, increasingly need to provide experiences that meet specific standards- and curriculum-based goals for their formal education visitors. Recognizing this need, the education and public outreach staff of the Space Telescope Science Institute (STScI) in Baltimore, Maryland, USA, has been working to make its formal education resources known to the planetarium community and suggests strategies for planetarium educators to use to incorporate these elements into their activities, programs and workshops. The presenter will continue this effort by reviewing STScI’s available formal education resources and practical strategies for effective use of these materials in meeting the educational goals of the informal planetarium educator and classroom teacher alike.

INTRODUCTION

During my many years as a planetarium director and educator, I found — as I’m sure many of my former planetarium colleagues still do — that teachers in the formal education universe increasingly need “field trips” (that is to say, experiences at informal science education venues) that meet their formal education objectives as laid out by curriculum requirements and education standards. We in the Office of Public Outreach at the Space Telescope Science Institute (STScI), with feet in both the formal and informal communities as we provide Hubble Space Telescope-based educational materials and services for planetarium and classroom alike, have asked ourselves how we can help to bridge this need.

DEVELOPMENT OF EDUCATIONAL RESOURCES

We already help “informally” by providing Hubble images and data to the planetarium/museum community for programs and exhibits attended by K-12 classes, by establishing a network of more than 100 ViewSpace installations that provide updated content on HST and other NASA missions via esthetic video displays, by providing special mural-sized prints of Hubble images to facilities for simultaneous unveilings with the official releases of these images on special occasions, and by other means. But we have formal education resources as well that can be incorporated into programs for formal education groups which can help to resolve the field trip dilemma for both classroom and planetarium.

In developing our formal K-12 resources, we’ve asked the same basic question that the planetarian no doubt asks — and certainly needs to ask to remain relevant to the prospective formal field-tripper: what issues do educators face in teaching space science?

To answer this question, our Office conducted regional and national assessments, and surveyed thousands of teachers at gatherings of the National Science Teachers Association (NSTA), the
National Council of Teachers of Mathematics (NCTM), and the International Technology Education Association (ITEA) between 1997 and 2003 to find out. What K-12 educators told us was:

- They’re intimidated by technology.
- They lack science background knowledge.
- They’re largely unaware of student misconceptions.
- The K-4 community has specific needs and issues.
- It’s difficult matching HST science with K-4 curriculum standards.

They also told us what they want and need:

- Resources that can be modified for the classroom.
- Supplemental space science materials that can engage students.
- Tools ranging from modular activities to unit plans.
- User-friendly resources.
- Specific topics students have difficulty understanding.

Based on our research of K-12 educator needs, the Office assembled teams of educators and scientists to work together to develop resource materials for the classroom teacher. These curriculum support tools and activities are accessible through the Office’s “Amazing Space” website.

An examination of the website will show that some resources are designed for everyone — including students. Some resources are designed specifically for teachers. These include science background in Q&A format; extensive teacher pages addressing misconceptions, national education standards, technology, integration, etc.; strategies to use materials in the classroom; tips on how to prepare for using online education activities; interdisciplinary approaches with an emphasis on literacy and real-life connections; and process and critical thinking skills.

![Amazing Space](amazing-space.stsci.edu)

Online activities for use in the classroom use Hubble data and imagery to support the teaching of fundamental and standards-based content such as gravity, light and color, and classification, employing such Hubble classics as the Shoemaker-Levy 9 images and the galaxy Deep Field and Ultra Deep Field data. Solar System and Galaxy Trading Cards for Grades 4-8 and 5-8 respectively have proved to be popular ways to sort, classify and learn about celestial objects; a Solar System Junior set for Grades K-3 has been added recently to the mix. Graphic Organizers offer comparisons of different types of objects (such as asteroids and comets), and the popular lithographs of images and descriptive information are available for printing and now include educational activity guides.

The Office has delved particularly into the topic of student misconceptions and offers a series of “myths vs. realities”
sections to help teachers address common misconceptions in astronomy. Furthermore, in response to calls from U.S. educators to provide science content reading as a way to infuse science into curricula heavily focused on reading and math in the era of “No Child Left Behind,” the Office has developed a “Star Witness News” feature that provides grade-appropriate content reading on Hubble discoveries.

**OPPORTUNITIES FOR PLANETARIA**

Our studies show that the Amazing Space curriculum support tools have been adopted by schools and school districts, state education offices and colleges of education across the U.S. to help improve the teaching of science. If teachers find these resources useful in the classroom (and we find them used in all 50 U.S. states), they may also be useful for planetarium educators to use in their efforts to serve formal education group visitors — not only in the U.S., but in informal education venues in other countries facing similar challenges in supporting formal education uses of their facilities.

These formal resources may serve as:

- *Materials/lessons for interactive planetarium shows or docent-led activities.*
- *Resources for pre- and post-visit activities.*
- *Images/activities for exhibits or computer kiosks.*
- *Useful supplementary resources.*
- *Ways to help teachers align formal education group visits to curriculum and education standards.*
- *Resources for teacher workshops.*

One example of such use comes from the Denver Museum of Science and Nature: the museum uses the Amazing Space “online exploration” activity and misconceptions section for black holes as online resources for teachers to use in post-visit classroom activities following their museum visit.

**CONCLUSION**

Informal science education venues (like planetariums) can help teachers meet their formal education goals — and the Space Telescope Science Institute, through its Office of Public Outreach, has formal education resources that can assist. Check out our websites, contact us, and let us know what you need and how we can help.

The Office’s main website is HubbleSite.org; the formal education site is at amazing-space.stsci.edu (contact our formal education lead Bonnie Eisenhamer, at bonnie@stsci.edu for more information). The informal site, managed by informal science education lead John Stoke (stoke@stsci.edu) can be found at hubblesource.edu.
Whadja Think? Asking For Audience Feedback And Then Deciding What to Do With The Results

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Abstract. It can be scary to ask your audiences how you’re doing. But considered constructively, it can also reveal a wealth of insight into what really grabs the public and keeps them coming back. For years, the Hayden Planetarium has been assessing reactions of attendees to its many and varied programs. By modifying the questions and method of feedback, we continue to hone our offerings to meet and exceed the public’s expectations. We’ll explore some of the surveys and review a lot of enlightening answers.

PUBLIC PROGRAMS

The Hayden Planetarium offers a wide range of public programming for adult audiences. For the purpose of this paper, we will look at only our Lectures and Monthly Programs.

Lectures

Distinguished Authors In Astronomy

Distinguished Authors in Astronomy Lectures introduce our audience to authors who have published popular-level books in astronomy; after each of these lectures, books are on sale and the author is available to sign copies of his or her book.

Frontiers In Astrophysics

Frontiers in Astrophysics Lectures bring to our audience the latest advances in our knowledge of the Universe, presented by the scientists working at the cutting edge of the field.

Monthly Programs

Virtual Universe

On the first Tuesday of each month, you’ll be immersed in the Hayden Planetarium’s three-dimensional atlas of the Universe and tour through charted space — an experience that will redefine your sense of “home.”

This Just In... The Latest News From The Universe

On the third Tuesday of each month, we present discussions of hot topics in astronomy and astrophysics. Find out what’s in the news, what it means, and how it fits (or doesn’t) with current thinking.

Celestial Highlights

On the last Tuesday of each month, enjoy a live presentation under the brilliant stars of the Zeiss Mark IX Star Projector. This tour of the heavens offers a view of the constantly changing night sky.
E-MAIL SURVEY FOR THE ACADEMIC YEAR 2005-2006

Since 2000, the Hayden Planetarium has been engaged in a more concerted effort to evaluate our programs than ever before. We've done this by a number of methods, including cards at the end of programs, cards to be mailed back to us, and informal queries in elevators.

This past spring, we decided an e-mail survey might capture more responses. We sent out a questionnaire to our e-list of about 700 subscribers. We had 47 respondents, who fell into the categories as outlined in Table 1.

**TABLE 1.** Survey Respondents.

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>26</td>
</tr>
<tr>
<td>Female</td>
<td>9</td>
</tr>
<tr>
<td>New York City</td>
<td>22</td>
</tr>
<tr>
<td>New Jersey</td>
<td>7</td>
</tr>
<tr>
<td>Long Island</td>
<td>6</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
<tr>
<td>Average Age</td>
<td>50.5</td>
</tr>
</tbody>
</table>

So it seems that older gentlemen from within New York City are our core audience — or at least the most respondent to this e-mail survey.

We asked some basic questions this time around. Again, concerning our Lectures and Monthly Programs, we asked the following questions and got these answers.

**Q.1 — How many of the following programs did you attend?**

- AUTHOR LECTURE: 73
- FRONTIER LECTURE: 80
- VIRTUAL UNIVERSE: 37
- THIS JUST IN…: 91
- CELESTIAL HIGHLIGHTS: 19

**Q.2 — Whadja like best/least about…?**

This is obviously an open-ended question. The following is only a sampling of the answers.

**Author Lectures**

"There are some REALLY GOOD lectures that make suffering through some poor ones worth it."

**Frontiers Lectures**

"Getting to hear from the scientists first hand. I remember some years ago, watching a documentary on TV, I realized as different scientists spoke: ‘Hey, I heard them in person at the Hayden!’ That was very special! And that's why I continue to really enjoy those lectures."

**Virtual Universe**

"Demonstrating the size of space."

"A great display of technology."

"Ability to experience what written material cannot convey."

"amazing, best show in town"

"It's overwhelming."
This Just In…

“It is always an adventure.”

“The interesting spin on everything that is going on, and the use of the planetarium to explain it all.”

“It is always an adventure.”

“Up-to-date information”

Celestial Highlights

“Being in a planetarium that is giving a real planetarium show.”

“Seeing what the sky ought to look like.”

Q.3 — Howdja most often buy tickets?

at the door 20
call AMNH Ticketing 5
advance sale ticket counter 3
online 3

Q.4a — What do you hope to gain from attending Hayden Programs?

education/information/understanding 30
fun/entertainment 5
science from scientists 2
awe & fascination 1
being in the dome 1
Neil deGrasse Tyson 1
relaxation/relief from NYC stress

Q.4b — What do you most value about Hayden Programs?

exposure to science/information 13
dome/technology 8
enthusiastic/great speakers 8
hearing direct from scientists 5
professionalism/objectivity 5
convenience 4
Neil deGrasse Tyson 4
low-key/friendly staff 3

wonder/existence 3
enjoyable 2
inexpensive 2

“That this great museum is going out of its way to get me to go there.”

Q.5 — What would you do to improve Hayden Programs?

they're just great as is 5
don't keep us waiting 3
lower prices/have special deals/combos 3
have more (just more) 2
add weekend programming 2
better promotion/marketing 2
continue/more challenging 2
entrance/exit door info 2
more Q&A 2
security 2
ticketing 2
always in the dome 1
announce presenter in advance 1
better advanced scheduling 1
better coordination between presenter and operator 1
expand graphics 1
keep shop open 1
keep to advertised time 1
later start time 1
longer sessions 1
make information more accessible 1
make presentations downloadable 1
Neil deGrasse Tyson 1
reduce restroom location restrictions 1
shorten introductions 1

“Insulate elders from young children.”

“I'm having trouble thinking of anything, but it would be cool to see the Digital Universe outfitted with an Electromagnetic Spectrum Slide Switch, so as you slid it over X-Rays, you would see whatever you were looking at in X-rays, etc.”
“the process of obtaining tickets either by mail or in person; last minute changes in which museum entrance to use — the whole administrative process is a mess!”

CONCLUSION

The response to this survey, both in terms of numbers and in actual answers, is consistent with other means by which we evaluate our programs. We generally hear from only a small fraction of the total number of people who attend and they tend to be of the “I love it” or the “I hate it” club. Those that hold a middle-ground view seem far less likely to comment at all. The fact that they come means you’re doing something right.

Over time you get to know your audience. You speak with them before or after any given program. You grow a relationship with them that allows them, individually and as a group, to let you know what’s good and what’s not.

The Hayden Planetarium plans to continue our evaluative process — looking at new ways to obtain audience feedback, and changing the questions we ask. But the most insight comes from attending your programs and experiencing them with your audience. Then trust your instincts about what works.
A Planetarium Is Not Enough!

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Abstract. Everyday our senses are overwhelmed by situations that confound logic. On television we see chimpanzees driving taxis, eating chocolates and talking. In movies we hear explosions in space and in planetaria we can see stars during the day. Frequently we desire the impossible in order to be entertained. Virtual reality has become a norm but is it enough when communicating science?

INTRODUCTION

Nearly 150,000 people per year come through Australia’s oldest observatory to experience both worlds where neither virtual reality nor telescope viewing reign alone. Virtual reality, in the form of a 3-D Space Theatre and a small planetarium, operate daily regardless of the weather but the public also want reality. They want to look through a telescope, to be the only one looking across space at a star, nebula, planet or galaxy. Active and real participation is the key to engagement. Whether in the form of workshops, games, discussion, questioning and input to program pathways, engagement is essential. Clearly a planetarium is not enough when it comes to exploring the universe!

Sydney Observatory opened in 1858 at the end of an era of great Observatories. It was modeled on the Royal Observatory Greenwich with its original purpose to signal to ships in Sydney Harbour the exact time by dropping a time ball by which they could set their chronometers. This was a time when Observatories were built in major cities, on the highest piece of land, and astronomers were consulted by royalty and government. Early Sydney astronomer Henry Chamberlain Russell attained international recognition through participation in a project to map the entire sky by photography at different observatories and measurement of the 1874 transit of Venus from the State of New South Wales. Until 1982 Sydney Observatory conducted research, and then the focus shifted to public education when it became part of the Museum of Applied Arts & Sciences (known now as the Powerhouse Museum).

FIGURE 1: Sydney Observatory (photograph by M. Anderson 2005).

Today, Sydney Observatory (shown in Figure 1) is the oldest existing observatory in Australia. It is in a magnificent location, enough to still attract Royalty
(the Prince and Princes of Denmark visited in 2005). The site has a sense of heritage and authenticity. A nationally significant collection relating to the Observatory’s history in Australian timekeeping and astronomy is exhibited. The historic time ball drops daily, there is an education program, holiday programs and night tours, which include telescope viewing. There is a very small planetarium (3.5 metres in diameter) with a Starlab fibre-arc projector seating 20 people on squishy beanbags. Though this may seem like a quaint experience for those who run planetariums with the latest digital and optical technologies don’t dismiss its ability to do great things for the visitor! The small planetarium has a vital role in the observatory’s education program, reaching 15,000 students per year, and is frequently noted by teachers as a highlight, primarily because it is not ‘plug and play’. As there is no choice for the presenter to press a switch and sit back, he or she has to entertain and involve the audience. The success of the show is based on its intimate nature and the opportunity it provides for the presenter to engage with the audience.

A priori hypothesis would have been that the heritage building, the informative, but somewhat conservative exhibition of heritage items and lack of a large modern planetarium would have stymied visitor and revenue growth at the Observatory.

However, over the past decade, Sydney Observatory’s annual attendance has grown from 65,379 visitors (1994/95) to almost 150,000 visitors (2005/06) (see Figure 2). Our revenue has more than trebled and our profile has grown (see Figure 3). To put this into perspective, the Observatory currently attracts 50% of the number who visit the Australian Museum, 50% of visitors to Scienceworks in Melbourne, and close to 30% of the visitors to the Powerhouse Museum and a similar percentage of visitors to Sydney’s IMAX theatre. Growth has been experienced in night visitors (approx 57% of paying visitors), schools students (22% of paying visitors) and daytime 3D theatre and holiday program visitors (21% of paying visitors). Lifelong learning astronomy education courses also have consistent attendances. We have to look beyond the planetarium to arouse visitors away from their homes, desks and computers.

Visitor growth is due to a cultural change within the Observatory, partnered with investment in projects and technology such as the Swinburne University Department of Astrophysics 3-D Space Theatre, and a honing of what was already working. Furthermore, studying visitor and leisure trends has guided a creative approach to our programming. We decided to take-on a certain amount of risk by embracing major astronomical phenomena with major public events and exhibits.
(wherever possible) and creating popular astronomy attractions with significant audience appeal and controversy wherever possible.

EMBRACING OPPORTUNITIES (MARS)

The 2003 Opposition of Mars could have passed us by and made small impact, however, we invested in equipment, a new exhibition, and seized the moment. We took risks that the public and media would engage in these phenomena and turn-up. We stayed up late for 16 nights and produced educational Mars events, including one major supper event which began at midnight, and the profile of Sydney Observatory was raised locally, nationally and internationally. This was not only due to publicity, but the public desire for an authentic experience, that is to see, to witness these events for themselves, through their own eyes. This first-hand experience is something not to be underestimated!

One of us, Dr. Nick Lomb, developed an exhibition with only one non-paper object, a piece of Mars rock the size of an Australian 10 cent coin, yet people were fascinated! This tiny exhibition focused on the controversial nature of past and present theories of life on Mars including science fiction and the infamous Orson Welles War of the Worlds radio hoax which had America preparing for an invasion from Mars and in panic. It included the publications of respected astronomers who were wrong. The Mars lecture series was also designed to be controversial and questioning. It began with two British “astronomy celebrities”, Heather Cooper and Nigel Henbest. They had a theory that if the recent exploration of Mars discovered methane gas, even in small quantities, then these ‘mini-fartlets’ would be proof of life and possibly proof that life on Earth originated on Mars, that we are actually all Martians. By courting the extremities, stepping outside the comfort zone and combining real experience (of viewing Mars) with an ideas-based approach we created a media frenzy. This culminated in 16 nights of viewing with 22,000 visitors, the front page of newspapers and television reports around the globe. Visitors experienced more than looking at an interesting object through a telescope, they had the opportunity to go to Mars in our 3D Space Theatre, meet NASA experts, astronaut Dr. Franklin Chang-Diaz, and find out the latest about Mars exploration. The local radio station, ABC702, broadcast a live radio quiz featuring well-known astronomy identity Dr Fred Watson and well-known quiz-master James O’Loughlin. The evening was enlivened by musicians and everyone was kept warm and awake with plenty of good hot coffee.

The event allowed Sydney Observatory to consolidate its position as the place to go for the media and the public to find out about astronomy.

THE POWER OF THE AUTHENTIC EXPERIENCE

Astronomy is one of the most powerful and real adventures and we should not be shy to tap into this wonderment. Experiences like the 2004 Transit of Venus, a lunar eclipse and, viewable from Sydney Australia in 2028, a total eclipse of the Sun have the drawcard of being “once in a lifetime” opportunities. They are meaningful to the general public who want to understand and experience them. The transit of Venus became a hot ticket in Sydney. Like many other Observatories we had dignitaries like the NSW Governor, Professor Marie Bashir, turning up unannounced, a government minister, society’s elite, office workers, families with young children, keen science students, history buffs, and people who just love a big event and want to tell their friends about it.

A small exhibition was developed which included Captain James Cook’s
clock taken on the voyage to measure the transit of Venus, on loan from the London Science Museum. This was a major effort, a major cost, a major coup and a key element in the tangibility of the experience in the lead-up to the transit and well after the event. Additionally, we secured Cook’s original drawing of his observations of the 1769 transit on loan from the State Library of NSW. This piece of paper, measuring only 24 by 20 cm, was evidence of Cook’s success, very exciting and important for visitors to see with their own eyes!

**LEISURE THEORY IN THE POSTMODERN ERA**

We are indeed living in an age where leisure time is scarce and there is much competition for how it is used. Planetaria, museums, science centres and public observatories are all competing with the television, computer game, beach, shopping centre and cinema.

Once upon a time, in the modernist era, leisure theorist Chris Rojek [1] defined leisure as a means of filling in time, a distraction to balance the working life, ideally meaningless. Hence people would rarely visit observatories, planetariums or museums for leisure, these experiences were educational, only for schools or those who had a dedicated interest. This has changed. In the postmodern era, Rojek views leisure as something far more dynamic and socially based. There is no such thing as high and low culture; there is “irresistible eclecticism, the mixing of codes, the pre-eminence of pastiche, gesture and playfulness in social interaction; and the collapse of the distinction between the author and consumer”. To put it in terms of what an Observatory can do, it means visitors will come to us if we offer a “buffet” experience which is not just the bread and butter, but the meat, veggies, chocolate mousse and other tasty items we all love to sample. Imagine being at an early morning Lunar eclipse viewing the eclipse through a telescope and binoculars, experiencing a 3D show about the Moon, its craters, and its exploration as well as finding out why we have eclipses by listening to a knowledgeable astronomer. Throw in the thrill of being part of a live morning television program, delicious warm croissants (like a crescent moon) with jam, excellent coffee and service, and an opportunity to discuss what is happening and take photographs while watching sunrise over Sydney’s beautiful harbour and seeing the city come to life. This is a postmodern leisure experience all before 7am, so there is still time to go to work or school afterwards!

**CREATING OPPORTUNITIES**

The International Year of Physics in 2005 was a wonderful opportunity to create education experiences and have fun. At the Observatory’s *Einstein Extravaganza* visitors got to meet famous physicists and astronomers and see Newton (played by one author Dr Lomb) take on Galileo (a remarkable resemblance to another author, Geoff Wyatt) man to man in a 10 minute play by scriptwriter Alana Valentine titled “Leap of Faith”. Einstein (played by staff member Dr Paul Payne) spoke about his theory and Marie Curie (staff member Melissa Hulbert) measured visitors’ radiation.

The Valentines Night Viewing under the Stars is another major attraction each year with couples of all ages eating heart shaped blinis, fruit and chocolates, being serenaded by live music, sipping champagne and enjoying stargazing. For three years in a row we have had a sellout program.

**TOPICAL ISSUES AND CONTROVERSY**

Astronomy communicators have many opportunities to be controversial and topical. It is not enough to keep doing what we routinely do, our regular night visits,
and education programs – we must press the boundaries.

At Sydney Observatory we have courted discussion and controversy by asking major buildings to turn off their expensive external lighting and neon signs for two nights of the year. Our first Festival of the Stars, held in June 2005, gained significant media attention and significant visitor numbers 2,570 over 2 nights, one of which was cloudy, as well as generating considerable income. The “lights-off” agreement for the Sydney Harbour Bridge was the catalyst for many buildings to respond in support. The Sydney Morning Herald, Sydney’s major newspaper, featured a front page article by journalist Richard Macey with the heading “Will the last one out please switch off the lights” setting the tone for office workers across the city.

This weekend, 21st and 22nd July 2006, was the second Festival of the Stars. The major coup this year was lights off the Sydney Opera House. Despite rain and cloud we still had eight hundred visitors. What we want to highlight is that the main reason we have been able to sustain and grow visitor figures has been by keeping the Observatory top of mind as a place where people have a unique and authentic experience. Astronomy expertise is non-negotiable and has underpinned all our programs.

**RISK: THE BELLY OF THE BEAST**

"Only those who will risk going too far can possibly find out how far one can go."

T. S. Eliot

Risk is a word used often these days because money is involved in everything we do. Sydney Observatory is run on a very tight budget, open seven days per week from 10am to 10pm with a total of six full-time staff and the equivalent of another four positions filled by part-time and casual staff. Since 2002 we have increased our revenue from $200,000 per annum to $550,000 per annum. Our non-staff budget is only $60,000 per year; we are supported by the Powerhouse Museum in providing publicity, maintenance and night security. However, we are not in a position to take huge risks financially.

If your main business is indoors, such as a Planetarium or Science Centre, you may not be affected by the weather factor. We have stressful days before a major event constantly looking up the Australian Bureau of Meteorology website for the latest forecast. If Rojek’s leisure theories are correct then by offering more than telescope viewing we have a small buffer on numbers by the strategies adopted for our Festival of the Stars, holding the event over two nights, building infrastructure over a period of time, developing partnerships with organizations who will help us for free and also benefit such as a local Ghost Tour who did a ghost torchlight tour of part of the Observatory site, providing expertise at first hand through talks by well-known astronomers and involvement of amateur groups and commercial operators with their expertise and wares. The Festival is also becoming a socially endorsed event through publicity and the sense of “sharing” an experience. Turning the lights off a number of large buildings has a sense of community and participation for people who don’t actually attend. Pre-bookings and pre-payment, via the Internet and phone, as well as the opportunity to turn-up on the night, created a visitor base and commitment.

**YOUNG CHILDREN – INSPIRING THE IMAGINATION AND BEING IRREVERENT**

“...if the next generation is to face the future with zest and self-confidence, we must educate them to be original as well as competent”

Mihaly Csikszentmihalyi [1]
As part of Sydney Writers Festival Andy Griffiths, children’s author of “Zombie Bums from Uranus”, entertained 250 children. It was a big pizza night and children were able to see through telescopes as well as listen to their favorite author talk about disgusting things.

One of the major success stories has been in attracting families with young children through astronomy-themed party days held quarterly, which combine tangibles with virtual experiences to excite the imagination. Silly things like “Search for Life on Mars”, where children used manipulators to dig through Martian-like red soil, searching for a stretchy plastic ‘alien’ figure, provide opportunities to discuss “is there life on Mars?”, “how robust the Rovers must be” and “what would humans need to survive on Mars?”. This is what the children will tell the adults, not the other way around. One message is not to take yourself too seriously as humour and a little silliness are wonderful learning tools. Children also get to dress-up as astronauts and float in space using chroma key, make space origami, launch a water-fuelled rocket and voyage into space via the 3D Space Theatre.

A comment from a recent participant to our Lost in Space family fun day is revealing as to how success can be measured:

“Congratulations for a very special and wonderful Lost in Space day today. It was just all so good... my seven year old grandson (and his Grandma) had a wonderful day ... and a special part too was that small Grandson wanted to talk about it all when we were home this evening... I am amazed how much he learned today”

**CONCLUSION: REWARDS AND FURTHER INVESTMENT**

Associating what an observatory does with contemporary Leisure theory has changed our way of thinking about how we do what we do by offering a “buffet” of experiences, utilising latest technology to tailor experiences for people, focusing on the authentic experience of using a telescope and giving the visitor ownership of the experience (increasing their interaction and negotiation). A large planetarium would be a tremendous asset. Sydney needs one and at Sydney Observatory we would like at least one of a modest scale. The historic site could have an underground planetarium, like the one being built at the Royal Observatory Greenwich.

However, should this happen, the planetarium will never become the only focus of public programs.

We will endeavour to keep major programs diverse, authentic and tangible, the doing, feeling, touching essential part of the content. The buffet approach. There are many great opportunities ahead.

In the lead-up to Sydney Observatory’s 150th anniversary in 2008, with support from the Powerhouse Museum, more of the historic site-up will be accessible and the third dome, removed two decades ago, will be re-installed to provide a real dome experience for those with disabilities.

2009, the International year of Astronomy, will be an opportunity for exhibitions and programs for science centres, planetaria and observatories around the globe. Now is the time to start thinking about object loans, like Newton’s telescope, even Galileo Galilei’s finger from the collection in Florence and perhaps an exhibition of Chinese astronomy from Beijing, as well as major programs. In 2012 there is a transit of Venus fully visible from Sydney, another major opportunity.

In the late fifteenth century Leonardo Da Vinci drew a lunar eclipse. He saw this with his own eyes and it is that sense of real observation that is powerful, to be encouraged and not to be underestimated or wholly replaced by a virtual experience.
REFERENCES

Learning In An Interactive Digital Theatre

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Abstract. The Houston Museum of Natural Science in collaboration with Rice University has traveled portable digital theaters for over three years and conducted research on student learning in this immersive environment. This paper documents interactive techniques and learning strategies in full-dome digital theaters.

EVALUATION STRATEGIES AND RESULTS

Two external evaluation studies were undertaken in 2006. One involved a field trip to the Burke Baker Planetarium and the other an experience in a predominantly Native American school in the portable Discovery Dome. Both studies used the same experience, a full dome show called Earth’s Wild Ride. This show features children born on the Moon learning about Earth as an alien planet and an evening watching an Earth transit (solar eclipse from Earth) with their grandfather. The child characters ask the questions that students in the audience would ask and the grandfather becomes the patient and enthusiastic teacher, parent, and tour guide. In this experience, students see the Earth in stark contrast to the Moon and compare the conditions on both worlds.

The evaluation instrument consisted of 17 multiple-choice items, displayed on one page in which students circled the correct responses. Each student took the instrument as a pre-test within three days of the full-dome experience. The same instrument was administered as a post-test within a day of the experience. Two studies were conducted using this instrument: (a) Inner city student assessment in the Burke Baker Planetarium and (b) Rural student assessment in the portable Discovery Dome. Although the instrument was the same for both studies, different evaluation protocols were employed with the different groups.

STUDY A: INNER CITY POPULATION IN THE BURKE BAKER PLANETARIUM

The Houston Independent School District funds a planetarium experience for seventh graders in many of its schools. Jane Long Middle School was chosen for this study. The pre-test was given to all of the seventh graders on the day before their field trip to see Earth’s Wild Ride in the Burke Baker Planetarium. Students were post-tested using the same one-page instrument at school immediately after their planetarium experience. The Jane Long Middle School student population is 96% free or reduced lunch and primarily underserved minorities (African American: 7%, Asian: 6%, Hispanic: 83% and White: 4%).

Data Analysis

Pre- and post-test results were paired for 221 students and the difference was evaluated using a t-test. The Kuder-Richardson 20 reliability for the test is 0.72 – an appropriate value considering the low number of items (17). Difficulty
factors for items range from 0.33 to 0.94 on the post assessment and discrimination indices ranged from 0.3 to 0.7 for 13 of the 17 items. All items showed gains between pre- and post-tests.

The seventh grade of Jane Long Middle School has two science teachers, labeled Teacher B and Teacher C in Table 1. Teacher B is a veteran science teacher while Teacher C is new to the field. The student performance indicates that the students of Teacher B had more prior knowledge than the students of Teacher C. However, both groups showed highly significant ($p<0.001$) gains equivalent to approximately one standard deviation. The better prepared students of Teacher B showed greater learning gains than the students of Teacher C.

**TABLE 1.** Results Obtained From $t$-Tests For Paired Samples For Long Middle School Students.

<table>
<thead>
<tr>
<th>Results</th>
<th>Teacher B</th>
<th>Teacher C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>127</td>
<td>94</td>
<td>221</td>
</tr>
<tr>
<td>Pre-test</td>
<td>Mean 11.03</td>
<td>8.77</td>
<td>10.07</td>
</tr>
<tr>
<td></td>
<td>SD 2.49</td>
<td>2.87</td>
<td>2.88</td>
</tr>
<tr>
<td>Post-test</td>
<td>Mean 13.51</td>
<td>11.50</td>
<td>12.66</td>
</tr>
<tr>
<td></td>
<td>SD 2.41</td>
<td>3.16</td>
<td>2.92</td>
</tr>
<tr>
<td>$t$-value</td>
<td>13.01</td>
<td>9.05</td>
<td>15.34</td>
</tr>
<tr>
<td>$p$-value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>$d$</td>
<td>+1.00</td>
<td>+0.95</td>
<td>+0.90</td>
</tr>
</tbody>
</table>

Item analysis yielded additional information on the most effective teaching strategies for full-dome experiences. The 17 questions were classified by how students received the knowledge required to answer the question: by hearing, by seeing, through discussion between characters, and/or by experiencing the concept through a full dome simulation. Table 2 shows the effectiveness of the different modalities. Most questions involved more than one teaching modality. The percentage corrected score reflects the percentage of the questions answered incorrectly on the pre-test that were answered correctly on the post-test.

**TABLE 2.** Effectiveness Of Different Learning Modalities.

<table>
<thead>
<tr>
<th>Learning Modality</th>
<th>Number Of Items</th>
<th>% Corrected On The Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hearing</td>
<td>11</td>
<td>40%</td>
</tr>
<tr>
<td>Seeing</td>
<td>13</td>
<td>39%</td>
</tr>
<tr>
<td>Discussing</td>
<td>3</td>
<td>49%</td>
</tr>
<tr>
<td>Experiencing</td>
<td>6</td>
<td>45%</td>
</tr>
<tr>
<td>Item using one modality</td>
<td>5</td>
<td>36%</td>
</tr>
<tr>
<td>Item using 2-3 modalities</td>
<td>12</td>
<td>40%</td>
</tr>
<tr>
<td>Item using more than 3 modalities</td>
<td>4</td>
<td>59%</td>
</tr>
</tbody>
</table>

Discussing and experiencing a concept are more effective in teaching students than just hearing or seeing the answer. It is also most effective to use more than one modality in teaching a concept – in this case the combination of hearing, seeing, and experiencing. In developing presentations for the full-dome, these results encourage the use of interactive narration that supports illustrations and immersive experiences. Perhaps the most surprising result is that student learning improved when characters discussed the content with each other. The power of discussion in teaching has led the authors to develop the use of discussion points within a show in the portable dome where the action can be stopped for discussion purposes. This interactivity will be discussed later in this paper.
STUDY B: NAVAHO RESERVATION IN THE DISCOVER DOME PORTABLE THEATER

As part of its Astronomy Road Show, the Houston Museum of Natural Science sent its portable Discovery Dome to the elementary, middle, and high schools of Tohatchi New Mexico (population 1,037). Tohatchi (located in northern New Mexico near the Arizona border) is 92% Native American, 6% White, and 4% Hispanic with 2% reporting two or more races.

Data Analysis

Students in grades 3-12 were pre- and post-tested immediately before and after watching Earth’s Wild Ride in the portable Discovery Dome using the 17 item multiple-choice instrument. The tests have been lost for grades 6 and 10, but all other grades have been scored and analyzed. The results are presented by grade level in Tables 3-5.

TABLE 3. Pre- and Post-test Performance for Grades 3-5.

<table>
<thead>
<tr>
<th>Results</th>
<th>Grade 3</th>
<th>Grade 4</th>
<th>Grade 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>32</td>
<td>36</td>
<td>31</td>
</tr>
<tr>
<td>Mean Pre-Test Score</td>
<td>6.531</td>
<td>7.333</td>
<td>9.323</td>
</tr>
<tr>
<td>Mean Post-Test Score</td>
<td>9.563</td>
<td>10.389</td>
<td>12.387</td>
</tr>
<tr>
<td>Gain</td>
<td>3.032</td>
<td>3.056</td>
<td>3.064</td>
</tr>
<tr>
<td>SD</td>
<td>3.814</td>
<td>4.035</td>
<td>2.362</td>
</tr>
<tr>
<td>t-value</td>
<td>4.496</td>
<td>4.543</td>
<td>6.930</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Highly significant gain scores were posted for grades 3, 4, 5, 7, and 8. In high school, the significance drops because the students have more prior knowledge, making the testing instrument less sensitive to content gains. Also the sample size of students drops significantly in the higher grades – giving less significance to the results. At all grade levels, gain scores range from over half of a standard deviation to over a standard deviation.


<table>
<thead>
<tr>
<th>Results</th>
<th>Grade 7</th>
<th>Grade 8</th>
<th>Grade 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>34</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Mean Pre-Test Score</td>
<td>8.971</td>
<td>7.500</td>
<td>10.905</td>
</tr>
<tr>
<td>Mean Post-Test Score</td>
<td>12.618</td>
<td>12.650</td>
<td>14.095</td>
</tr>
<tr>
<td>Gain</td>
<td>3.647</td>
<td>5.150</td>
<td>3.190</td>
</tr>
<tr>
<td>SD</td>
<td>2.473</td>
<td>4.332</td>
<td>3.530</td>
</tr>
<tr>
<td>t-value</td>
<td>8.600</td>
<td>5.317</td>
<td>4.142</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>

TABLE 5. Pre- and Post-test Performance for Grades 11-12 and all Grades combined.

<table>
<thead>
<tr>
<th>Results</th>
<th>Grade 11</th>
<th>Grade 12</th>
<th>All Grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>10</td>
<td>17</td>
<td>201</td>
</tr>
<tr>
<td>Mean Pre-Test Score</td>
<td>10.600</td>
<td>11.824</td>
<td>8.721</td>
</tr>
<tr>
<td>Mean Post-Test Score</td>
<td>14.400</td>
<td>14.118</td>
<td>12.070</td>
</tr>
<tr>
<td>Gain</td>
<td>3.800</td>
<td>2.294</td>
<td>3.348</td>
</tr>
<tr>
<td>SD</td>
<td>2.616</td>
<td>4.089</td>
<td>3.491</td>
</tr>
<tr>
<td>t-value</td>
<td>4.593</td>
<td>2.313</td>
<td>13.597</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.001</td>
<td>0.034</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

The most unexpected result of this study is the age range of educational viability for the Earth’s Wild Ride program. Normally educational products are tightly tied to specific grades and ages.
This product is successful in grades 3-12. The authors postulate that the immersive quality and high activity level of the full-dome experience makes it appropriate for many different student populations. That fact that it was developed for general public audiences also contributes to its wide acceptance by different audiences. Very different live interactions and accompanying curriculum support materials can customize the experience for different ages.

**INTERACTIVITY STRATEGIES AND RESULTS**

The portable theater offers unique opportunities for interactivity that are not available in a large planetarium theater with a linear video presentation. The full dome show, *Earth’s Wild Ride*, was chosen for this research effort for several reasons:

- **Relevance to national and local education standards.** Since it spans both Earth and space science, this program meets at least 15 of the proficiencies required in Texas for the fifth grade standardized science test.

- ** Appropriateness of segments for group discussion.** *Earth’s Wild Ride* divides into chapters – moon base, solar eclipse, ice ages, volcanoes, impacts with dinosaurs, and canyons produced by clouds and rain. Each of these sections presents and illustrates different concepts where students can identify cause and effect and can compare the Earth and Moon.

- **Availability of specimens that could be examined by students.** The Houston Museum of Natural Science maintains teaching collections of specimens that relate directly to the program.

  The Museum has employed two types of interactivity: pausing the show for discussion and pausing the show to distribute manipulatives or specimens while students are in the dome. The pause function can be used with any audience. When the discussion between the grandfather and grandchildren finishes, the operator can stop the show and ask students the same question that the child characters asked or discuss why the child characters asked a particular question. Table 6 lists the different manipulatives that can be used with the *Earth’s Wild Ride* program. Other full-dome shows would lend themselves to other manipulatives.

  In addition to the specimens related directly to the show and listed in Table 6, we also distribute rocks that students must classify as: (1) must be from Earth or (2) could be found on the Moon. Rocks with imbedded fossils and petrified wood are certain signs of an Earth origin. Sedimentary rocks are also only found on Earth. Igneous rocks such as basalts and breccias could be found on the Earth or Moon. From the content in *Earth’s Wild Ride*, students are able to make these comparisons between the two worlds.

**TABLE 6. Manipulatives For Interactive Experiences *Earth’s Wild Ride* Program.**

<table>
<thead>
<tr>
<th>Show Content</th>
<th>Manipulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammoth</td>
<td>Mammoth tooth</td>
</tr>
<tr>
<td>Tyrannosaurus Rex</td>
<td>T-rex tooth cast</td>
</tr>
<tr>
<td>Volcano</td>
<td>Samples of lava and pumice</td>
</tr>
<tr>
<td>Meteor Impact</td>
<td>Stony and iron meteorites, tektites</td>
</tr>
<tr>
<td>Canyon with rain</td>
<td>Sedimentary rock with layering</td>
</tr>
</tbody>
</table>

**CONCLUSION**

In summary, the full-dome video format, especially as it is used in the portable digital theater, has greatly expanded the content we can present for schools and for the general public. Evaluations of concept acquisition indicate
that the digital dome theater can be successful in teaching non-astronomy concepts and can expand its roll as a tool for learning at all grade levels.

ACKNOWLEDGEMENTS

This research was funded in part by NASA’s Office of Earth Science under cooperative agreement NCC5-316 (“Immersive Earth”). The authors appreciate the cooperation of the schools involved in the study.
Innovations in the Dome

the latest innovations and technologies, relating to the planetarium dome
From Analog To Digital: A Case Study

Dale A. Etheridge

Abstract. The staff of The Planetarium at the Community College of Southern Nevada realized by 2003 that show production using film technology was becoming more and more difficult. This case study reviews the process by which we determined that converting our small theatre (9.1 meter dome, 70 seats) to all digital was feasible and outlines the process that eventually led to the replacement of our 30-year-old Spitz opto-mechanical planetarium and its associated special effects projectors with the latest Evans & Sutherland Digistar 3SP technology. It also describes how we accomplished the change-over in just 4 weeks during the Summer of 2005.

INTRODUCTION

By 2003 it was becoming evident to our staff that the traditional show production techniques based on film was becoming increasingly more difficult. Duplicating film was becoming harder to obtain. Custom film processing was more difficult to find. Kodak had stopped making and selling slide projectors. Nikon recently announced it was discontinuing production on all but its top two professional film cameras. Our conclusion was that film technology would no longer be supported within a decade.

A Little Background

The Planetarium at CCSN was built in 1976 and presented its first public show in February, 1977. The initial installation was a Spitz 512 with ATM-2 automation. It was later improved with some of the first field upgrades to ATM-3 and then ATM-4.

In 1986, we added a 35 mm film projector with a fisheye lens to begin presenting films in the C-360 format. We repainted our dome at that time to be 30% reflective to improve the appearance of the films. The C-360 projector was removed in 1996 when new films ceased to be available.

The Transition

Shortly after the Millennium we began to realize that the traditional analog planetarium technology was on its way out. Before 2000, color duplicating film was available in stock from several sources in town. The same was true for Kodalith. There were at least three processing facilities that could develop these films.

After 2000, all the various film stocks we normally used were only available by special order in bulk quantities and there was only one facility in Las Vegas that would process duplicating film. Slide projector parts were becoming difficult to acquire and glass slide mounts were nearly impossible to find.

The Decision

In 2003, we concluded that the show production techniques we had been using were becoming untenable. However, we were not entirely sure that a digital system would work in our dome. The typical digital system for small domes produces less light than the 4KW film projector we had used earlier. The question was: would such a system be bright enough on our 30% reflective dome? In late 2003, we invited Evans & Sutherland, Spitz and
Konica-Minolta to a “shoot-out” to be held in our facility in late January, 2004. Spitz (SciDome) and Evans & Sutherland (D3SP) were able to attend. Konica-Minolta was unable to get some necessary equipment through customs and could not participate. Both systems demonstrated that a single projector digital system would work well on our dome.

We immediately prepared our final proposal to our administration with a projected budget. We had estimated that a new system would cost in the vicinity of US$200,000 and that other desired modification to our theatre would add another US$100,000.

We received approval from our Board of Regents in March and immediately prepared a Request for Proposals (RfP) that was sent to about a half dozen manufacturer/distributors of small digital systems. The RfP was a detailed description of the level of performance and capabilities that we desired. Two of the proposals met most of our requirements and also came within our budget.

Both Spitz and Evans & Sutherland had proposal very similar in cost and capability. After very careful consideration we finally settled on the E&S Digistar 3SP as coming closest to meeting our needs and planned programming.

Going For It

Once the decision was made, we prepared the order and negotiated a likely installation date. Our goal was to present our last public shows with the old system on the first weekend of July, 2005 and be ready to open the new system the first weekend in August. Immediately after Independence Day (4th July), we began ripping all the old systems out. John Hare from Ash Enterprises arrived and began removing the Spitz and special effects projectors. Our staff began removing the seats and carpet. The theatre was totally stripped by the end of that first week. A general contractor came in the second week to fill the elevator pit, construct a level area at the back of our sloping floor for better wheelchair access and extend the console footing for the new console.

Once the concrete work was done, the new carpet came in. When it was done, we began reinstalling our seats while the crew from Jeff Bowen’s Technical Innovations began installing the sound system and control rack.

In the last week, E&S came in with the Digistar. The D3 SP installation went fairly quickly, but there was a little interference from our general contractor who was still finishing the detail work and painting. This was a result of the usual number of glitches that can occur in a project of this magnitude. The only downside, our only possible accommodation, was to reduce our training time. We did get the basic training to operate the system for the activities we were planning, but some more would have been nice.

While we were at it, we also included a smart classroom configuration. We use the planetarium extensively for college classes. Since it would not be very effective to use the Digistar for PowerPoint presentations, we installed a separate high luminosity video projector at the back of the theater. That projector is controlled from the front of the theater from a separate console with a Mac G5 computer and an Elmo Presentation system (no chalk board). This enables us to use the theatre as a classroom independent of the planetarium systems.

Everything was finished and officially turned back over to the planetarium staff at 2 pm on Friday, August 5. We gave our first public show that evening at 6 pm. See the accompanying PowerPoint presentation for before, during and after pictures.

CONCLUSION

In retrospect, another week or two for the conversion would have been nice.
However, one of our goals was to minimize our down time because we depend on our ticket revenues for operating expenses. Running an all digital system is much more effective than the older opto-mechanical system. Show acquisition costs are higher, but staff time is much less to prepare a show for presentation. Change over from one show to another is now very quick. A couple of mouse clicks and the next show is ready to go, regardless of the previous show. In the end, we are very pleased with the results.

ACKNOWLEDGMENTS

The author wishes to thank the administration of the Community College of Southern Nevada for their support in the upgrade to The Planetarium and their support in making this presentation possible.
Seeing The Texture Of The Cosmos Inside A Planetarium

Anthony Fairall

Abstract. The spatial distribution of galaxies reveals a labyrinth of interconnected large-scale structures, sometimes known as the ‘cosmic web’ because of the prevalence of filamentary features. Yet few planetarians, let alone members of the public, have familiarity with the universe on this scale. A software package ‘Labyrinth’, which encloses large-scale structures within ‘Tully bubbles’, has been developed at the University of Cape Town. It is used here, in conjunction with the 6dF Galaxy Survey, to show a ‘zoom-away’ from our Galaxy, thereby revealing the remarkable texture exhibited by the Cosmos. While the images are currently ‘flat screen’, they appear even better when projected onto the planetarium dome. Chromo-stereoscopy also allows the images to be seen in 3D.

INTRODUCTION

The public at large is generally ignorant of the nature and scale of the Universe beyond the Solar System. Few of their number would know where we lie in our Galaxy, while the greater Universe beyond is only understood in the vaguest fashion. It is clearly the role of planetariums to educate the public as to where we lie in the Universe and what its character is like on ever-larger scales. Such is the case with the now well-known Hayden Planetarium production Passport to the Universe. It has also been an ongoing theme for more modest productions at our planetarium in Cape Town, since the late 1980s, following a personal quest of mine. For instance, improved visualizations of our Galaxy, as seen from within, were presented at IPS 2002 [1].

But our Galaxy is a dominant member of the Local Group, itself an outlying protuberance of the Local (Virgo) Supercluster (as first reported by Sir John Herschel in the mid-19th Century). That supercluster is in itself an apparent appendage of a larger irregular conglomeration (the Centaurus Wall), itself a small portion of a labyrinth of interconnected large-scale structures, percolated by a network of interconnected voids – not dissimilar in character to the texture of a bath sponge! Somewhat akin to the Crab Nebula, where a shell of filaments surrounds a hollow cavity, the galaxies that form these large-scale structures tend to lie along filaments, giving rise to the term ‘cosmic web’. Conveying this texture of the cosmos – even to fellow planetarians, let alone the general public – is therefore the challenge.

LABYRINTH

Visualizations of the spatial distribution of galaxies and their large-scale structures are made possible using ‘Labyrinth’ software developed for the author by Carl Hultquist and Samesham Perumal of the Department of Computer Science at the University of Cape Town. While galaxies are depicted as dots, large-scale structures are made visible by enclosing concentrations of galaxies within irregular, but transparent, surfaces. This concept was pioneered by Brent Tully – a leading researcher in the field – and it seems appropriate to dub them as ‘Tully bubbles’.

The software creates these bubbles by wrapping surfaces around ‘minimal spanning trees’. Currently the images are
‘flat screen’, but experiments have shown them to be very effective when displayed on a planetarium dome. In addition, colouring is introduced so that the nearest galaxies and surfaces are depicted white and the most distant blue. This has the advantage that when viewed with ChromoDepth™ spectacles, the visualizations are seen in three dimensions.

![Image of galaxy visualization](image)

FIGURE 1. A sample image showing the remarkable texture of the Cosmos, as revealed by Labyrinth software operating on the 6dF Galaxy Survey. This view looks back towards our Galaxy from almost 1.5 billion light years out. The dark wedges pushing in from either side are not real, but caused by the foreground obscuration in our Galaxy.

**NED DATA**

Labyrinth is used here to show two ‘zoom away’ sequences from our Galaxy. The first employed galaxy redshift data from the NASA Extragalactic Database (NED). Once 100 million light years out, large-scale structures were ‘switched on’ and the position of our Galaxy on the fringe of the Virgo Supercluster became apparent. The zoom-away continued to a point 340 million light years out.

**THE 6DF GALAXY SURVEY**

A second zoom-away sequence conveyed much more detail and took the audience far deeper into space. This is made possible by the ‘6dF Galaxy Survey’ (to be released in full by late 2006) [2]. Target galaxies for this survey have been extracted from the 2MASS (Infrared) survey. Redshift observations have been carried out using the UK Schmidt Telescope at the Anglo-Australian Observatory. The 6dF system enables almost 140 galaxies to be measured simultaneously over a ‘6 degree field’. Although not penetrating anywhere as deep as the 2dF Galaxy Redshift Survey and the products of the Sloan Digital Survey, 6dF covers the entire southern sky, except for the obscuring band of the foreground Milky Way. I have been privileged to receive preliminary versions of this survey, one of which provides the database in the accompanying ‘zoom-away’.

A sample image – one of a sequence of fifty – is depicted in Figure 1. The sequence depicts a ‘zoom away’ from our Galaxy to reveal the Universe of an ever larger scale, eventually showing a view from 2.3 billion light years out.

That the Universe should reveal such a curious texture was quite unanticipated. The seedings for these structures are traced back to the weak fluctuations (anisotropies) found in the Cosmic Microwave Background. But where did the seedings come from? Currently many researchers go along with the idea that they are the smallest structures possibly grossly enlarged during the ‘inflationary’ era of the very early Universe.

The visualizations described here and others may be downloaded from [www.mensa.ast.uct.ac.za/~fairall/](http://www.mensa.ast.uct.ac.za/~fairall/).

**ACKNOWLEDGMENTS**

NASA/IPAC Extragalactic Database is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA.

**REFERENCES**

Flight Of The Pixel

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Abstract. Large spherical and hemispherical screens provide a unique opportunity to display multimedia content of our Universe. The ability to visualise accurate representations of our cosmos and overlay entertaining multimedia and live data is transforming the industry and opening the science of space to a larger audience on a worldwide basis. However, as in any new market dependent upon technology, standards and terminology for determining acceptable performance and comparing systems based upon different technology are still evolving. The challenge to define standards for assessing performance, quality and for determining an interchange format to allow content to be generated independent of the visualization system is one that needs to be addressed at this early stage of market evolution to ensure that the compelling content being created today will appear in planetariums around the world at the quality that they were intended. This challenge is heightened because the issues that affect system performance are diverse and complex covering optics, electronics, physics and human factors relating to vision perception. Each of these issues is an expert subject in their own right, when combined into a visualization solution these factors interact to add further complication. This paper seeks to introduce three key performance metrics which define a hemispheric visualization system suitable for planetarium applications; these being spatial resolution, luminance and contrast.

SPATIAL RESOLUTION

Spatial resolution is the total quantity of pixels displayed at any point of time. Spatial resolution can be described in many ways including the total number of pixels available from the media storage and delivery system, or the total number of pixels available at the projection system, or more importantly the pixel density across the screen surface or the final resolution perceived by the viewer.

Of course, the perception of resolution depends upon three factors: the total number of visible pixels, the total area over which those pixels are displayed and the distance from the viewer to the screen.

In a (true) hemispheric visualization system, the total screen area is defined by the diameter of the dome screen. By using a common view point, dome centre, the perceived spatial resolution of the visualisation system can be defined simply by calculating the subtended angle to the eye at dome centre by two adjacent pixels on the screen surface.

This method has the advantage of being able to compare spatial resolution of a visualization system independent of screen size.

Typically the human eye can perceive a spatial resolution between two adjacent pixels of 3 arc minutes (3 x 1/60° of a degree). Higher resolution is perceivable but typically only if there is a visible reference point available (i.e. comparing 3 arc minutes with 1 arc minute on screen).
To distribute equally spaced pixels across a hemisphere at 3 arc minutes would require a total spatial resolution of around 10 million pixels. A 6 arc minute resolution would require approximately 6 million pixels distributed equally across the hemisphere. Importantly, as described earlier, this total pixel count is independent of screen size, thereby providing a meaningful comparison of perceived spatial resolution.

**LUMINANCE**

Luminance is a measure of the amount of light reflected from a surface over a given area. Expressed either in foot lamberts (ft-L, imperial) or candela per meter square (cd/m², metric). The luminance of a visualization system determines the maximum brightness of the white point of an image.

Using luminance as a metric takes into account the combined effect of the total light output of the display device/s, the total area of the screen over which the light will be distributed and the resultant gain of the screen surface.

Importantly again, this measurement is a useful comparison between hemispheric visualization systems using different projection technologies, dome sizes and screen gain and normalises these widely varying factors into a simple metric.

For comparison, typical luminance for a multimedia dome can range between 0.5 to 1.5 ft-L.

A 20 metre diameter dome may need in excess of 40,000 lumens to produce a system luminance of 1 ft-L with sufficient system contrast (note: 1 ft-L = 3.43 cd/m²).

**CONTRAST**

Probably one of the most important measures of a hemispheric multimedia visualization system is contrast, or more importantly, system contrast.

Contrast is simply a measure of the difference in luminance of black and white, expressed as a ratio. However there are so many factors that determine the level of black and there are inherent system wide factors which are specific to spherical screens which affect contrast, that it becomes critical to express system contrast in a common way.

Firstly it is important to understand contrast and its impact in our daily lives. It is generally accepted that the human eye can perceive an instantaneous contrast ratio of around 100:1 and that it can perceive differences in contrast levels of around 1%.

However we are constantly exposed to light levels ranging from a few hundred Lux of illumination in a dark room right up to 100,000 Lux of direct sunlight. Fortunately the eye and the brain adapt to a near infinite contrast ratio by dynamically adapting to the prevailing light level (this is why, when standing outside on a sunny day it is difficult to see through a shop doorway, but once inside the shop the detail is clearly visible).

To understand the contrast of a hemispheric visualization system it would be a mistake to simply look at the performance specification of a single component. For instance projector contrast ratios (CR) are often stated as anything from 500:1 CR up to 1,000:1 CR. This in itself is misleading simply because this is a sequential contrast measurement (a full black image is measured and then a full white one). A more meaningful measurement of projector contrast is the ANSI (American National Standards Institute) checkerboard contrast. This applies equal black and white squares across the image and a measurement is taken from this. A typical ANSI contrast ratio is around 100:1. The reason why the ANSI CR is so much reduced is that now the projector black is being measured at the same time that the projector is outputting full white across 50% of the image area. Through internal scatter at the imaging device and the projector optics the white light contaminates the black areas thereby raising the black level and reducing CR.
This is only part of the story. Stray ambient light within the environment adds light to the black level of the system and further reduces system CR. Once an image is projected onto the hemispheric screen, cross screen illumination occurs. Diffuse light from the screen surface reflects around the hemispheric screen adding light to the ‘black’ areas of the screen and further compromising system CR.

With checkerboard content displayed in a hemisphere, measurements of around 10:1 CR are expected. For reference, a television will typically have a 40:1 CR in a normally lit room, as will a matt photograph. Newspaper print typically will have a 15:1 CR.

Interestingly, it follows that because cross reflectance affects system CR then so does content. In other words if a few star points are displayed then cross reflectance is low and CR is higher, however if a large planet occupies half the screen area, then system contrast will be reduced.

This system contrast ratio provides the range from black to white within which the content will be displayed.

**CONCLUSION**

Industry standard metrics that relate spatial resolution, luminance and contrast for the complete visualization system which would be independent of dome size or technology employed, would allow sensible performance comparisons to be made between different systems for the purposes of evaluation.

Content could be configured according to these specifications and expectations could be set of how the content quality will be perceived by the audience.
FIGURE 2. Contrast in our every day life.
Mitaka – An Interactive 3D Viewer Of The Hierarchical Structure Of The Universe

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Abstract. Modern astronomy has been extending our knowledge of the Universe greatly. In the Four Dimensional Digital Universe project (4D2U project) of the National Astronomical Observatory of Japan (NAOJ), we are developing software which provides a three-dimensional view of the hierarchical structure of the Universe based on the latest observational data, such as the Hipparcos catalogue and the Sloan Digital Sky Survey (SDSS) galaxy data, together with theoretical models of astronomical objects, for example the Milky Way Galaxy and a globular cluster. By using this software, one can explore the Universe seamlessly and interactively across a huge range of scales, from the surface of the Earth to the large scale structure of the Universe. The software, which was named “Mitaka” after the location of NAOJ’s headquarters, Mitaka City, is being developed by astronomers in the 4D2U project mainly for demonstration in flat-screen theatres and digital dome theatres, but especially for the stereo-projection dome theatre that is being constructed in the NAOJ Mitaka campus. The software Mitaka also runs on stand-alone Windows PCs and it can be downloaded as free software from our website (4d2u.nao.ac.jp/). In this paper, we summarize the features of Mitaka and its applications to flat-screen and digital dome theatres.

WHAT IS “MITAKA”

Mitaka is software for viewing up-to-date theoretical, computational and observational astronomical data, in real-time with interactive operation. It integrates various observational data and theoretical models in astronomy and users can seamlessly navigate across the Universe, from Earth to the edge of the known Universe (Figure 1). The methods of visualization for some objects, for example the Milky Way Galaxy and Earth’s atmosphere, are based on physics.

Mitaka runs on Windows PCs; it runs not only on a single PC, but also on multiple PC systems such as those found in digital theatres that consist of multiple PCs and multiple video projectors. We use Mitaka in our stereoscopic flat-screen theatre in the NAOJ Mitaka campus.

FIGURE 1. Mitaka visualizes various observational data and theoretical models in astronomy and you can seamlessly navigate across the Universe, from Earth to the edge of the known Universe.
One can operate Mitaka interactively with a keyboard, a mouse or a game-pad. As shown in Figure 2, you can do, for example, the following operations by game-pad: (1) change the viewpoint, (2) zoom in and zoom out, and (3) change the viewing time. Other detailed settings can be set up through the on-screen menu (Figure 3).

**FIGURE 2.** One can operate Mitaka interactively with a keyboard, a mouse or a game-pad.

**FIGURE 3.** Detailed settings can be set up through the on-screen menu.

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**DATA, MODELS AND VISUALIZATION IN MITAKA**

In this section, we summarize the data, models and the visualization methods used in Mitaka from small scale to large scale in turn.

### Earth

The Earth’s atmosphere is visualized by using a physics-based ray-tracing method in which a radiative transfer equation with the Rayleigh scattering model is solved in real-time (Figure 4). In the calculation, we include the effect of multiple scattering off the molecules in the air. One can also view the reflection of sunlight off the oceans (Figure 5). If the topography data is installed, you can see the topography of the Earth (the topography data for Mars is also available).

**FIGURE 4.** Earth’s atmosphere is visualized by using a radiative transfer equation with the Rayleigh scattering model including multiple-scattering effect.
The Earth and the Sun. Here, you can see the scattering light of the atmosphere at the rim of the Earth and the reflection of sunlight off the oceans in the vicinity of Melbourne.

Solar System

You can view the Solar System changing the viewpoint and the viewing time back and forth by game-pad (Figure 6).

Several spacecraft (Pioneer 10, 11, Voyager I, II, and Cassini) can be seen (Figure 8). One can also trace the trajectories of the spacecraft by proceeding the time.

Mitaka also simulates eclipses of some objects. In the latest version, one can see the shadow of the Moon on Earth and vice versa, and the shadows of the Galilean satellites (Io, Europa, Ganymede and Callisto) on Jupiter.

Stars

Mitaka uses the positions determined by the Hipparcos satellite [1] in three dimensions to show nearby stars (see Figure 9). We use data only for stars with accurate distance measurements, generally within 3,000 light years of the Sun. The colours of the stars are determined based on their temperature with a blackbody approximation (Figure 10).

You can visit several stars and star clusters including Alpha Centauri, Sirius, Castor, and the Pleiades star cluster (“Subaru” in Japanese).
Milky Way Galaxy

As the accurate structure of the Milky Way Galaxy is not yet known at present from observations, Mitaka shows a theoretical model of the Milky Way Galaxy. The model is based on axisymmetric models of distributions of stars and dust together with a greyscale image of the spiral pattern of the Milky Way Galaxy, which was constructed referring to various observational data and the results of numerical simulations, to modulate the axisymmetric distributions. For visualizing the model, Mitaka uses a real-time ray-tracing method that is based on a radiative transfer equation, like that used for the visualization of the Earth’s atmosphere. Figures 11 and 12 show the Milky Way Galaxy visualized by Mitaka. You can see the dust lane if you are viewing the Galaxy from side-on.

In addition, Mitaka shows hundreds of globular clusters surrounding the Milky Way Galaxy. In particular, one can approach the globular cluster M13 to view a three-dimensional model of the globular cluster, which consists of hundreds of thousands of stars.

Distribution Of Galaxies

Mitaka shows the distribution of nearby galaxies within 100 million light years of the Milky Way Galaxy (Figure 13). One can approach the large elliptical galaxy M87 which lies at the centre of the Virgo Cluster of galaxies to view the theoretical model of the elliptical galaxy.
Beyond 1 billion light years from Earth, we see the distribution of galaxies observed by the Sloan Digital Sky Survey (SDSS) [2] (Figure 14). Since astronomers have only been able to observe the universe partially, the galaxies are seen in fan-shaped wedges. However, even the uncharted parts of the universe must be full of galaxies. If you look closely, the distribution of galaxies has denser and sparser regions; these variations are the large scale structure of the universe.

STEREOSCOPIC PRESENTATIONS WITH MULTIPLE PCs

Mitaka can work not only on a single PC, but also with multiple PCs that are connected by a TCP/IP network to synchronize with each other. In that case, each PC takes charge of a different portion of the view or a different eye channel, namely, the left eye or the right eye, for stereoscopic projection. Each PC is connected with a video projector and projects the image generated according to its configuration. One of the PCs, the controller PC, is connected to a game-pad and controls the other PCs by sending commands through the TCP/IP network. Figure 15 illustrates a configuration of a multiple-PC system.

4D2U Flat-Screen Theatre

In the Mitaka campus of the NAOJ, we have a stereoscopic theatre that consists of three flat screens (each 1.8m by 1.8m), six PCs, and six video projectors. The configuration of the theatre is illustrated in Figure 16. In this theatre, we use Mitaka to perform stereoscopic presentations with polarizing filters and glasses, every other month.
**4D2U Digital Dome Theatre**

The 4D2U dome theatre was built in March 2006 in the Mitaka campus of the NAOJ. The dome theatre system consists of a dome screen of 10m diameter, 15 PCs, and 15 video projectors (Figure 17). In this theatre, the stereoscopic projection is produced by using the Infitec filters and glasses. We are now in a test stage of several tools and software to correct the distortion of images projected on the dome screen. At present, we have succeeded in stereoscopic projection of Mitaka on the dome screen (see Figure 18).

**TABLE 1. Recommended Hardware Configuration for Mitaka.**

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<td>1024x768 pixels or more</td>
</tr>
<tr>
<td>Hard Disk Space</td>
<td>50 MB or more</td>
</tr>
</tbody>
</table>

**CONCLUSION**

We are developing the software Mitaka which provides a three-dimensional view of the hierarchical structure of the universe
based on various up-to-date observational data together with theoretical models. By using this software, users can seamlessly navigate across the Universe, from Earth to the edges of the known Universe. Mitaka is already used in some stereoscopic theatres and it will soon run in the stereoscopic digital dome theatre recently built in the NAOJ Mitaka campus. Mitaka also runs on a single PC and it can be downloaded as free software for personal use from our website.

ACKNOWLEDGMENTS

Funding sources of the project are: “Construction of 4-Dimensional Digital Universe and Its Application to Research and Education” funded by Research and Development for Applying Advanced Computational Science and Technology of Japan Science and Technology Agency (ACT-JST: 2001-2004), and “Construction of an Image Distribution System for the 4-Dimensional Digital Universe” funded by the Special Coordination Fund for Promoting Science and Technology of the Japanese Ministry of Education, Culture, Sports, Science and Technology as part of their Program for the Effective Promotion of Joint Research with Industry, Academia and Government (2004-present).

REFERENCES

Shooting Movies For The Dome – A Report From The Field

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Abstract. This paper offers an alternative to the almost imperative use of computer animation in modern fulldome video production. allsky.de developed the technology of traditional slide based allsky photography into various tools to create moving fulldome video content based on photographic live capture: the situation in the field governs the postproduction workflow and vice versa. Different capture technology may be applied to accommodate varying budgets and visualization goals.

INTRODUCTION

The use of photographic material has a long standing tradition within the planetarium field, particularly as a medium for fulldome content. During the last few years we have seen the conversion of domed projection towards digital technology, and as it feeds from high resolution media formats, this trend is dominated by computer generated content. As digital imaging technology advances, we witness the return of photographic content to the dome.

allsky.de started as a media agency for slide based allsky projection. Ever since, we have developed or applied a suite of digital and analog fulldome capture technology, with the goal of creating the same intriguing views of the real world that IMAX delivers, while maintaining the immersive perspective and philosophy of fulldome video production.

The original talk at the IPS conference focused on the choice of camera equipment and offered a brief look at the way we carry out the field work. Since then, we have been able to more than double the amount of stock material, which is why we include a discussion of our post-IPS fieldwork in this paper.

RENDERED VS. PHOTOGRAPHIC CONTENT

Although it may appear rather self evident, it may be helpful to look at some of the fundamental differences between rendered and live-captured content regarding the production workflow and the reception of the result by the audience.

Rendered content bears some convenient aspects during production, as it allows perfect freedom of resolution, duration and camera movement within the scenes. One can also adjust the exposure and lighting and therefore accommodate the unique features of individual projection systems. A great commodity in that respect is the ability to render at an increased bit depth (when enough digital storage space provided).

On the other hand, production is very often influenced by hardware limitations and long render times. Apart from procedural animation techniques, most detail in the scene requires the personal effort of an animator, limiting the amount of achievable realism simply by manpower (Figure 1). Therefore, the biggest yet often overseen drawback, is the unreal simplistic look of rendered content compared to photographic media. Computer generated (CG) content has led to a widely accepted
style and its dominance on the fulldome market suggests that it is the only style the digital planetarium industry has to offer. In many institutions, it even marks the most obvious difference to the IMAX experience running in a parallel theatre. Computer animation celebrates its triumph in the field of astronomy and abstract entertainment shows, where the naked eye has no direct comparison available. Yet as many fulldome theatres are broadening their scope of topics to include all of natural science, audiences may judge the appearance of the productions against print and television media on the same topics.

Photographic content has other problems during production compared to CG content. It is at times even more expensive, as the hardware employs high-end technology and, at the time of writing, often needs to be custom-adapted for outdoor use. Travel expenses quickly amount with the possibility of bad conditions on site. The film set is difficult to handle as there is no way for the film logistics to be hidden behind the fulldome camera. Returning from the field, the postproduction can be comparable to or even more extensive than for rendered content. The control over exposure and lighting is not as ideal as in virtual space; capture hardware is not as readily available as render power. Finally, the projection systems form a bottleneck in terms of the required high resolution paired with varying projection quality and homogeneity of multi-projector setups. The average audience tends to compare photographic content to movies or large format film, not appreciating the technological differences or the huge jump in budget.

A clear advantage of photographic content is that it usually is in accordance with the traditional viewing habits of the audience. Most audiences should be able to distinguish between a computer animation and a photograph or movie. Real scenes can be more complex than the most elaborately modeled animations. This leads to a direct identification of the viewer with the content. Competition among the projected environment and the real world and comparison to familiar perspectives can lead to a very strong learning experience.

Combining CG And Photographic Content In A Show

A challenge is posed by combining both kinds of content. The blend has to be achieved in terms of image quality and resolution, the change between the “real” and “virtual” look as well as the break between moving and still content in the case of allskies.

In the case of a slide based low budget planetarium show production, one often faces the challenge of mixing media of different styles and layouts, with the goal to maintain a uniform look throughout the production. Applied to the above question, this would serve as an argument against the use of photographic content in a fulldome show, yet the different esthetics of both kinds of imagery may also be applied in a fruitful way.

Doing so, one has the choice of weaving the content together (as in Stars of
the Pharaohs by Evans & Sutherland) or dividing the media into separate scenes (as in Black Holes: The Other Side of Infinity by the Denver Museum of Nature and Science). As these two examples show, the change in media offers a good occasion to underline different aspects of the topic discussed (now, past and present epochs), or mark a turning point in the storyboard (scientists on Earth exploring far away cosmic phenomena).

**Rules Inferred From Dome Projection**

At most times, the actual filming of live capture sequences needs to be done far away from any means to check the production results as dailies on a dome. This requires a thorough understanding of what a flat polar dome master will look like on the dome, along with empirical experience regarding the flow of perspective when objects move across a curved screen.

**Camera Movement**

Generally, one has to make a difference between tilted and leveled dome designs. Although the seating architecture further refines this division, we simplify for the purpose of this discussion into unidirectional tilted and omnidirectional leveled arrangements. Both designs have slightly different goals regarding the immersive effect that is to be achieved. This strongly reflects in the way fulldome live capture has to be prepared for them.

Tilted theatres offer a natural level of the horizon that only intersects with the spring line at the left and right ends of the theatre. Depending on the degree of tilt, the audience enjoys unrestricted view on lower parts of the scene. This also means that there is a definite preferred direction of view.

Therefore, although the immersive effect due to the large field of view is highly increased, the language which the cinematographer needs to apply still has much resemblance with traditional visual storytelling techniques developed for cinema. Since there is a definite neglected part of the surrounding scene (the rear where the audience is seated), the camera can be tilted away from the vertical during capture. This eases the production workflow: there is limited room for infrastructure behind the camera, and a lens of 180° or even just 160° field of view will create a geometrically accurate dome master for projection. This again greatly simplifies the choice and price of equipment.

Leveled domes steer into a slightly different esthetic realm, which is generally connected to more problems since the capture technique is further away from established visual storytelling language.

The spring line of a leveled planetarium layout is meant to resemble the horizon. This would mean that there is no screen to display parts of the image that lie below the horizon, so the image receives a compression. There are two ways to achieve this. A linear compression results in the dome master being scaled down so parts formerly below the spring line show up. By this technique, the objects in the scene receive a compression by which their vertical angular size on the screen is diminished.

Another way is to discard the top section of the image (for example, if there is nothing but blue sky) and to fill the gap by stretching the lower part, with the effect of scaling parts of the image to approximate their original angular size.

To do this, the dome master’s field of view needs to exceed 180° in the first place, which poses a major logistical problem to the producer, since the lenses capable of producing such an image are very rare to find and expensive.

The default orientation of the camera is straight up, which is a major change for every cameraman. Then of course, there is no room for the cameraman himself, let
alone lighting, rigging or other elements not belonging to the scene. The scene surrounds the camera just as it shall surround the audience [1].

Since the leveled dome architecture does not favor any direction of sight, the director will have to guide the audience’s view, and in order not to bore the party who is sitting beneath the current point of interest, one has to ensure that there are multiple events in a scene primarily addressing different parts of the audience.

The leveled concept of an immersive scene has the drawback of happening entirely above the heads of the viewers, which forces somewhat uncomfortable head motion upon them. [2] In order to make sure no part of the audience becomes unsatisfied, one still has to guide the view, but now back and forth between multiple parallel events which may lead into each other, mix, intersect or cancel each other out.

Using a lens which delivers more than 180° on a leveled camera rig has the big advantage of limited compatibility with tilted dome design through careful off axis cropping of the dome master. That way, a show producer may choose to primarily produce for leveled theatres, but he also has the ability to offer a re-mastered version for tilted theatres.

**Lighting and Exposure**

An issue inherent to both tilted and leveled setups is the problem of cross illumination on a curved screen by the projection itself. While the phenomenon is well known to fulldome computer animators as well, it shall be noted that the cinematographer actively has to obey the effect especially when planning outside shots with a bright sky.

Cross illumination is actually just part of the broader problem of exposure control during live capture. The camera-man has to decide on one exposure time. Based on the capture sensor he uses, it might be critical either in bright (overexposed film) or dark (digital noise) situations. The dynamic range of an outside fulldome shot is governed by the sky (where the bright sun is to be preferred over clouds) and the area below the horizon. Since the sky fills the largest percentile area of the image, it generally receives the most weight in choosing an exposure, resulting in a slightly underexposed ground.

**Angular Elevation**

Fulldome video capture and playback employ the principle of tracing the lines of sight towards one viewing point and (in theory) expanding it back from there during projection. This means that the dimensions of objects are transferred from the point at which they were captured to the screen, but the mind plays a trick with the producer trying to capture a scene. We perceive an environment differently than the camera does, because personal experience adds additional information to objects ("this is a steep cliff, so it must be large in my picture"). The size of objects depends on their distance to the camera. Objects further away will cover a smaller angle on the dome than when they are closer. Therefore only the angular elevation of an object is relevant to fulldome capture, not its absolute height. This is a problem we often experienced while filming natural landmarks or monuments, where the actual motive was much smaller in the image than it was actually perceived on-site. It also means that only objects close to the camera have a chance to fill the screen to a reasonable extent, which results in the requirement to arrange scenes in a very compact way. Panoramas and sweeps bear the danger of condensing beautiful landscapes to a line at the horizon. Again, this may be an argument to apply high resolution projection.
CASE STUDIES OF DIFFERENT IMAGING TECHNIQUES

When we started to think of fulldome live capture, we had the same quality standard in mind that we maintain for our allskies: 8k resolution at lossless 24bit with a field of view around 240°. This goal stood in harsh contrast to all available capture formats, so we looked for a compromise at around 4k. Most capture devices would either offer fast frame rates or adequate resolution. We decided in favor of the latter and gradually increased the frame rate over the course of several projects.

Choice Of Equipment

When choosing a camera, there are a number of aspects that may run against each other due to technical limitations:

1. **Resolution.** Apart from a few exceptions, current fulldome video projection hardware can play back at a maximum resolution level of 4k.

2. **Frame Rate.** The motive, its size on the screen and the velocity of its movement govern this parameter. Of course, higher frame rates grant more creative freedom.

3. **Field Of View.** The filmmaker wants to create an immersive effect, therefore the field of view should naturally be wide. An orthodox exegesis of the word fulldome suggests a field of view of at least 180°.

4. **Dynamic Range.** Especially when shot outside, fulldome video covers the entire dynamic range of our environment within one exposure. If one does not want to settle for a compromise in the light or the dark areas of the image, the dynamic range has to lie beyond the average capability of available capture equipment.

5. **Camera Size.** Since the goal is to create unusual views, the camera and recording device should not exceed certain dimensions to allow it to be operated by a small crew of preferably one or two under difficult conditions.

6. **Funding.** Hollywood and IMAX with their enormous budgets put fierce pressure on fulldome production teams to produce comparable quality at a small percentage of those funds.

In case of digital capture devices, the common bottleneck for all these factors is the required data storage space and the advanced hardware involved in the data treatment. Moreover, a larger field of view requires better resolving capture media to reproduce the same level of detail on the dome. Analog media with the highest resolution are inflexible on the film set and require expensive post-production, namely, developing and scanning the raw material. This leads to a reluctance in experimenting with the new medium because of the high production costs. The ideal fulldome camera should offer inexpensive operation, or at least the means to preview and edit scenes before the final investment of treating and storing the data.

An Argument For High Resolution

Appreciating the relatively large number of small domes under 10m in diameter compared to the number theatres above this size, one may ask whether the strive to increase resolution should be eased in favor of other aspects of image quality or price of equipment.

The answer to this question may be highly dependant on the content involved. The concept of eye limiting resolution and its implementation to fulldome projection quietly assumes that the content holds enough detail to appreciate that resolution. One valid argument against high resolution is that often this is not the case.

Live captured fulldome content overcomes this discrepancy. The dimensionally accurate depiction of natural phenomena may require those high resolutions generally attributed to the needs of scientific visualization. An
example for this argument may be our dome vendor session at the IPS Conference in Melbourne this summer. We had recorded a time lapse sequence of the solar eclipse in Turkey on March 29th, using a 4k digital medium format camera and the Nikon 6mm f2.8 fisheye. In the projection through DigitalSky2 feeding the Sony SXRD Projectors, one could see the coronal ring with the Moon in the centre. With the known apparent diameter of the Moon in the sky, one can easily estimate that the resolution must have been better than 0.5°.

Applications like this may certainly fill a niche compared to the broad spectrum of esthetically appealing and instructional content which does not require resolution beyond 2k. Nevertheless they show the need for specialized equipment capable of depicting the real world realistically on a dome.

To maximize the number of potential customers, a show should be produced at a resolution neighboring the highest available projection resolution. With the expected advances of technology in mind, the resolution should be even higher, to create material that does not become outdated in a matter of a few years.

**Multiple Choices For A Camera**

Ultimately none of our team was a camera technician and constructing hardware was not our goal. So we decided to combine existing technology for a proof of concept and to see how close one could get to an acceptable result without custom technology development.

Our first choice fell on digital equipment and we distinguished several options. The optical path could be either a single wide angle fisheye lens or an array of lenses with narrower fields of view. The demanded high resolution could again be achieved with a large single or an array of smaller capture devices.

There are a number of available capture devices [3] that each fall under a combination of these categories. Multi-lens, multi-sensor camera manufacturers:

- First Person Immersive Video
- Immersive Media Company
- iMove
- IPIX Corporation
- MICOY
- Point Grey Research Inc.

Single lens, single sensor cameras:

- Digital cinematography
- Machine vision/camera link systems
- 35mm cinema cameras
- 1080i/720p HD cameras
- Time lapse photography

The first camera we examined consisted of an array of several individual cameras. Their streams were later stitched together. Apart from problems regarding the resolution, the biggest deficiency lay in the inadequate stitching of the cameras. The individual units had been mounted into a cage-like array so that crossing of their lines of sight would produce parallax.

The second shortcoming was the uneven exposure of the units when used outside. The Sun would glare into one unit, causing blooming, while the others would only produce individual lens flares.

We soon decided that the multi-lens approach would not be able to produce cinematic appealing footage and we started to experiment with the single lens, single sensor set of alternatives.

**The Set Of Cameras Used At allsky.de**

Below follows an account of the observations we made using a total of 7 different cameras over the course of the last two years.

*Nikon D100 with DX 10.5mm fisheye*

Inspired by the DomeFest04 award winning contribution “Optical Nervous
System” by D. McConville [4], we investigated digital photography. It quickly became clear that we wanted to stay true to our leveled dome approach with the option of dome tilt adaptation via an increased field of view, the way we produce our assortment of allskies.

The easiest way to produce a film was simply to shoot very many allskies. This meant that we had to produce time lapse. Time lapse photography is the art of matching the frequency of exposures to rhythms of the scene. One can distinguish three different types of rhythm that need to be treated separately:

1. Repetitive events, like blades of a windmill or pulsing lights, run through a cycle of motion after which they repeat. By matching these intervals but exceeding them by a small amount, one can theoretically record an event that apparently plays back in real time.

2. Chaotic events like a waterfall or a flag can be captured at any reasonably fast capture rate, as long as peripheral factors such as lighting do not change fast. They may deliver agitated but still credible sequences that are not perceived as running faster than life.

3. Linear events like waves on the beach or cars at rush hour always reveal the interval at which they were captured. Therefore, the capture rate should be high in order to avoid under-sampling.

During October and November of 2004, we assembled a 2 minute trailer out of 950 allskies. Each image consisted of 6 exposures acquired with a qtvr head, and was consecutively batch stitched together using the same algorithm for every frame.

The clip was played back at 15 frames per second, uninterpolated. It featured high resolution as the camera in theory allowed for 6k dome masters, as well as the usual field of view between 240° and 260°.

Unfortunately though, the tripod head mechanically induced alignment errors which caused the allsky segments to wiggle. Nevertheless we could study appropriate velocities of relative and absolute camera motion in a time lapse movie.

Our production included stationary shots of cloud layers, a drive through the nearby woods on a camera dolly and even a walk below the Eiffel Tower (Figure 2). It also offered the possibility to examine the behavior of moving objects on the dome.

The results were manifold. Unlike many fulldome productions we had studied so far, this one gave us an awareness of the presence of the domed screen while at the same time resolving it completely. The feeling of immersion and identification with the content was much stronger than with planetary nebulae and similar sequences.

The center of our test dome is completely free of equipment. As soon as the spectator left this position, the curved nature of the projection became noticeable. When the video was stopped, the eye adapted again to the perspective. The mind’s predicted motion of familiar objects on a curved screen deviated considerably more than in the case of rendered content.

![Frame from the first trailer](image.png)
To carry out more research, we needed to stabilize the image and to reduce the amount of work to produce sequences. The solution was to use a single lens which would capture approximately the same view in just one exposure.

The only available lens of its kind is the Nikon 6mm fisheye series, which produces a field of view of 220°. This is still close enough to 180° so that linear compression does not lead to obvious distortions on the dome. The lenses were developed for meteorological science on Antarctic expeditions during the late 1960s. Since they are discontinued, they are quite rare to find and very expensive. Nevertheless we managed to acquire two lenses of the f5.6 series (Figure 3). The fact that the lenses are slow is compensated by the very bright skies we usually photograph. They are also a few kilograms lighter than the very large f2.8 series. We kept this type of lens and subsequently only varied the cameras.

**FIGURE 3.** The Nikon 6mm f5.6 fisheye lens.

**Sinar S44 Back With Medium Format Camera**

Since the Nikon camera had not provided enough resolution, we switched to a 16 mega-pixel medium format camera that finally delivered 4k resolution.

Apart from serious technical issues running a studio camera on mountaintops, it performed well. Unfortunately we could not capture faster than five seconds per frame. The distribution of light across the large area of the sensor led to long exposure times, while the sensor itself was intended for studio lighting conditions.

The jump in resolution became rather obvious with the work we did using this system (Figure 4). Leaves in the treetops showed up, just as clouds on the horizon were suddenly distinguishable. We first saw the aforementioned corona of the eclipse on the dome in Melbourne – it had not been visible during post-production on the monitor.

Meanwhile we have switched to a more modern and integrated camera model that reaches 2 second intervals and is much more compact than the old system.

**FIGURE 4.** A frame captured with the Sinar S44 back. In the original resolution, small twigs at the treetops are visible.

**35mm Camera**

By the time we had successfully explored high resolution capture, we also wanted to try real-time capture. The only affordable way to achieve roughly a 2k resolution at real-time was to use 35mm film together with the 6mm fisheye.

We inscribed the dome master’s circle into an anamorphic film format, which was closest to a square, achieving a diameter of 16.5mm. We shot on Kodak Vision 50D film, a sensitive negative film for outdoor use. The camera was a relatively inexpensive Konvas 2M which we had...
previously tested for image stability. Since we were on a budget, the test locations were chosen in northern France and the Canary Islands so we could use the footage in production in case they turned out well.

Most scenes yielded good results over a surprisingly large dynamic range, so we scanned part of the material for the IPS vendor session (Figure 5). The film grain justifies the use of the content for playback resolutions around 2k. Different film types might still produce better results.

FIGURE 5. B. Voss opens the dome of the Northern Optical Telescope (35mm film sequence, duration approx 30 sec).

The use of a camera pointing vertically up into the air is unusual, especially since it is not meant to be held in such a way. Still many motives require a considerable tilt of the camera to be within the visible frame at all, or the camera has to be kept very low above ground. Even with the 6mm fisheye, the field of view often was too limited for our scenes. In the end, we almost always deviated from a truly vertical setup. Due to the elaborate production process we had to discontinue the development shortly before IPS in favor of other projects, but more work is planned.

Canon 5D

Just prior to the conference we formed a collaboration with the Hamburg Planetarium to jointly use their Canon 5D camera with our optics to create a field setup that could be carried on a trip around the world following the IPS meeting. After the conference, we went on a 30 day tour through Australia, Hawaii, Chicago and New York, producing a total of 50 minutes of time lapse at 15fps playback rate. The first results of this work form our entry at this year’s Domefest (truthfully called First Screening) and a few scenes in the adaptation of the E&S show The Future is Wild by the Hamburg Planetarium.

The capture rate could be increased to 2fps at medium resolution, while at the same time the system was the most portable of all solutions we tried. After all, the 3k image the camera produced was a good compromise between image quality, portability and capture rate, recording the scenery along our way in the best way imaginable.

One issue which has not been solved yet is the bad quality of extremely dark shots, especially of the starry sky. Tests with the 6mm f2.8 lens could not significantly improve the result we achieved with the small series. Obviously an individual star becomes too small in the wide angle lens to create a sufficient signal and usable exposures, if any, take much too long for time lapse.

The next step will be to incorporate high dynamic range technology into the scope of our production techniques. Time lapse offers some attractive applications for this concept, either by applying bracketed exposure every frame or by stacking different time slices of changing lighting conditions. Computer aided exposure control might also help manage difficult lighting conditions like sunsets.

In our company tradition of covering many areas of the globe, we gathered live capture sequences from Germany, Italy, Norway, France, Spitsbergen, Australia,
the US and the Canary Islands so far. We intend to release the first suite of readily usable clips in the first quarter of next year.

Certainly encouraged by the use of live action footage in *Black Holes: The Other Side of Infinity*, we chose to start and end our upcoming show on the history of spaceflight with live captured content from our own stock. It will be combined with rendered elements, but will also serve as a framework linking past events and technological marvels to the here and now. As we are still in production, we cannot comment on first hand experiences we may gather at that point. The show release is planned for January.

**CONCLUSION**

Most of our work on photographic live capture technology has been a proof of concept. A lot of time was consumed by establishing technology in the first place rather than working out the filming language needed to use it. Yet the results appear promising. Now it will be important to raise the awareness of alternatives to rendered content for show production.

At the moment the fulldome video community struggles to define its role and style against IMAX, Hollywood and the idea of a traditional planetarium. Live content may help in that respect, opening possibilities to express original ideas through unique content.

For example, the use of presenters as acting figures within fulldome video is almost unexplored. Imagine the potential of a presenter being filmed in the Brazilian jungle, later talking from a screen to an audience in San Francisco, directly connecting them to the topic of deforestation like no live lecturer or pre-rendered video could achieve on its own!

As technology advances, we may get affordable tools that will let us do things like canopy walks – until then, it will be important to develop the skills to use these new tools.

**ACKNOWLEDGMENTS**

allsky.de is a team of seven people, although not all of us appear at conferences. We would like to express our deep appreciation to Lars Wind, our friend who co-developed the different camera adaptations with us and joined us in Australia. The Hamburg Planetarium became a fortunate partner of ours. The Mediendom at the University of Applied Sciences in Kiel is not just our test facility but also our professional origin. The staff of Sky-Skan, Inc. untiringly helped us prepare our demo – many thanks to everyone!

**REFERENCES**

Development Of A Portable 3D Projection System Using Spectral Filters

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Abstract. The science museum of Tokyo has developed a portable 3D projection system for science visualizations. 3D projection systems ordinarily use a polarized filter, but they need screens that can keep the plane of polarization of the incident wave when the light reflects at the surface of the screen. Our museum, the National Astronomy Observatory Japan and Riken developed a new system using spectral filters: Infitec. With this system you don't have to use such a special screen and you can obtain a clearer and wider viewing angle.

PURPOSE OF DEVELOPMENT

Schools, museums, science museums and planetariums have been known to hold classes or lectures using 3D content provided by a system that combines a sound system, projection system and PC according to each site’s specific conditions.

FIGURE 1. Formation of a Spiral Galaxy.

The presentations have been well received everywhere they were held. Conventional systems (using polarizing filters requiring a special screen) have difficulty with curved surfaces and wide fields of view. Furthermore, it is not easy to transport and set up a large screen, so it is extremely difficult to have a presentation with the large screen.

FIGURE 2. A Four-Dimensional Universe Viewer.

Even though planetariums are equipped with a huge wide-field screen, it can’t be used for such presentations. A transportable projection system that can produce powerful large-screen images using existing screens or dome screens at planetariums and the like, has therefore been developed.

An important matter in the development of this system is the selection of a projector and the selection of a 3D system. The projectors which can be used are DLP, D-ILA (JVC), and LCD. The main types of 3D systems are polarizing filter, liquid crystal shutter and Infitec.
Selection of the 3D system is the more important of the two, so comparison tests were conducted. A comparison of the features of these systems is shown in Table.1.

**Table 1. Comparison of the 3D systems.**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Polarization System</th>
<th>Liquid Crystal Shutter</th>
<th>Infitec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-talk</td>
<td>Usual</td>
<td>Usual</td>
<td>Extremely</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>Angle of View</td>
<td>Poor</td>
<td>Good</td>
<td>Extremely</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>Attenuation</td>
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<td>Approx. 50%</td>
<td>Approx. 70%</td>
</tr>
<tr>
<td>Cost</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

As the primary selection conditions, fading rate, view angle and viewing ease were compared. The polarization system is economical and the fade rate is low, but the image brightness is uneven for curved surfaces and wide viewing angles.

The liquid crystal shutter has a wide viewing angle compared to the polarization system, but the attenuation rate is about the same. However, it is expensive and requires a dedicated infrared transmitter.

The Infitec system can handle an extremely wide angle of view. However, the attenuation rate is extremely high and therefore should be combined with a bright projector.

Based on the results of the various comparisons, tests were conducted with different combinations of projectors and 3D systems, and the combination with the best results was adopted.

The DLP projector was selected for the following reasons:
- some products are comparatively small and offer high lighting intensity.
- offers good color.
- adapts to various 3D systems.

The Infitec system was selected for the following reasons:
- any screen can be used including a wide field of view and curved surfaces. The wall can also be used.
- viewers can see from any angle.
- 3D glasses are not electronic or mechanical, so you don’t have to worry about failure.

The DLP projector also offers the high lighting intensity required by the Infitec system.
FIGURE 5. The assembled system.

Figure 5 shows the assembled system. The system consists of a DLP projector, stack stand, and the Infitec filter. The PC is connected via a converter for signal correction.

FIGURE 6. Projectors in the transportation case.

Figure 6 shows the projectors in the transportation case and Figure 7 shows the keyboard, mouse, glasses and cable in the case. A special transportation case was made just for the projector so it could be shipped easily and safely.

Figure 8 shows the stack stand of projectors disassembled. When disassembled, it can be carried compactly.

FIGURE 7. Keyboard, mouse, glasses and cable in the case.

FIGURE 8. Disassembled stack stand.

FEATURES OF SYSTEM

The main features of this system are as follows:

- It can use the existing screen at the site.
- The system can use dome screens that cover a wide view field or curved screens like at a planetarium, because it doesn’t depend on the polarization reflected by the screen.
- The 3D view can be seen at wide angles, and because it doesn’t require a special screen, transportation and setup is easy.

These features enable you to easily conduct classes or give lectures at other sites using 3D content whether using a simple screen at a school or a curved screen like at a planetarium.
We are currently using the system for open lectures and so forth. According to our surveys, the system is effective and well received. Along with having the system used, we hope to further enhance and improve it in the future.

ACKNOWLEDGEMENT

I am thankful to the members of the 4D2U Project who supported the development of this system. I am also thankful to Mr Tsumori and Mr Ando who cooperated with us in this project.

The 4D2U Project is funded by the Special Coordination Fund for Promoting Science and Technology of the Japanese Ministry of Education, Culture, Sports, Science and Technology as part of their Program for the Effective Promotion of Joint Research with Industry, Academia and Government (2004 – present).
Interactive Virtual Reality In A Planetarium Environment For Research And Education

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Abstract. A low cost interactive virtual reality environment is presented for conducting research and education in a planetarium. The projection system solution presented is for both traditional and stereoscopic viewing on dome surfaces. Examples from both research and education paradigms illustrate the uniqueness, benefits and cost effectiveness of retro-fitting existing planetariums with the required hardware and software tools. A series of software tools are incorporated into a workflow pipeline called Virtual Reality for Programming Interactive Planetarium Environments or VRPIPE. The VRPIPE workflow allows for high-resolution objects and scenes to be composited together to produce natural illumination environments. A new graphical user interface is implemented that provides a VR experience allowing both the presenter and audience to interact with the immersive environment. The traditional control devices for virtual environments include: glove, HUD’s and 3D mouse devices. By integrating a wireless WiFi (IEEE 802.11b/g) network protocol, wireless graphical control devices can be added that could include: PDA’s, Smart Phones, Tablet PCs, Portable Gaming consoles and Pocket PCs. The Virtual Reality Data sets (VRDATA) which we will investigate include simulation and scientific visualization tools, and educational training tools. The Virtual Reality Simulator (VRSIM) data sets presented will emulate the NASA Mars Exploration Rover within the Mars environment and the Lunar Roving Vehicle from Apollo 15-17. The Virtual Reality Educational Training Tools (VREDUCTT) case study is for veterinary medicine, where virtual interactive life-sized models of horses will be examined using MRI data. This can enhance learning and teaching goals for biological mechanisms where hands-on experience can be difficult or even dangerous. In addressing these issues our new VR tool provides a unique learning and educational experience in both formal and informal contexts.

INTRODUCTION

A low cost interactive virtual reality environment is presented for conducting research and education in a planetarium. The projection system solution presented here is for both traditional and stereoscopic requirements. This workflow pipeline requires a series of software libraries to develop a specific virtual reality application. The virtual environment consists of the theatre screen which is a 50 ft. diameter hemisphere (see Figure 1).

Examples from both research and education paradigms are presented to illustrate the uniqueness, cost effectiveness and efficiency of retro-fitting existing planetariums with the required hardware and software tools.
ADDING VR TO PLANETARIUMS

Many concepts in science require three-dimensional visual representation to provide spatial relationships in order to orient the viewer. 3D virtual simulations can provide this context. Virtual environments generated through computer software and hardware provides the 3D visual representation that allows a user to interact with and navigate through a place or phenomenon that would otherwise be difficult, dangerous or impossible to observe in the real world. An example is in veterinary medicine where virtual interactive life-sized models of horses can be examined using magnetic resonance imagining (MRI) data sets. Both students and teachers can explore horse anatomy and physiology in a virtual “hands-on” environment thus enhancing the learning experience for both. Typically, formal and informal education situations involve instruction and learning through the use of lecture, textual information and 2D image representations of ideas and concepts.

A study at the Houston Museum of Natural Science showed considerable improvement in the comprehension of concepts conveyed using immersive fulldome 3D visualization over non-immersive and 2D teaching methods. Perhaps a similar effect can be achieved through large format non-fulldome video display running 3D virtual reality environment presentations. By adding VR to planetariums we can establish an environment immersion, which will enhance “correct” instruction and allow a frame of reference that would otherwise not be possible [1].

Environment Immersion

Large display systems increase the level of immersion, thus they increase the sense of presence of the viewer as being “right there.” Outcomes for the learner from the increased immersion of virtual reality include increased engagement, extra insight into the phenomena, and increased motivation to pursue further learning. Large audiences in an immersive environment can help promote social and collaborative learning.

Enhanced Correct Instruction

Misconceptions of science concepts, especially in astronomy (i.e. Moon phases or astronomical distances) are common among the general population. 3D visualization can help dispel these misconceptions by allowing people to build mental models from new experiences that displace older incorrect models that were based on their past experiences. For new conceptualizations to become firmly rooted in people’s minds they must be presented in a way that is intelligible, that makes sense to them, and that allows them to realize the concept as a “new” discovery in their way of understanding the concept.

Frame of Reference

Many concepts in science require spatial relationships in order to orient the viewer. Changing the frame of reference allows the model to be viewed from different perspectives. The observer can
interact with and navigate through an environment that would be difficult, dangerous or impossible to observe in the real world. A key component to virtual 3D environments is the ability to change the frame of reference allowing the user to view the model from either outside or inside the model providing a more localized level of interaction.

THE 3D VR ENVIRONMENT

Any 3D virtual environment will contain a number of modules with which our 3D workflow pipeline must integrate. The core components of the 3D virtual environment are the VR\_ARENA, VR\_DATA, VR\_ENVIRO, VR\_TOOLSET, VR\_GLUE, and VR\_INTERFACE. VR\_ARENA consists of the projection system, motion tracker, audio system, multiprocessor computer driving the data pipe, and a computer for the interactive environment control system. VR\_DATA is comprised of either panoramas or individual objects and these elements can be real or computer generated. VR\_ENVIRO encompasses all of the CAVE assets, HDR image sets, or using the CAVE as a 3D authoring tool. The backbone for both VR\_DATA and VR\_ENVIRO is the Procedural animation tool, Houdini, rendering tools from Mental Ray, and the compositing software NUKE™. These software packages form the pieces of VR\_TOOLSET which consists of modelers, animation, rendering, OpenGL and compositors. This toolset can be used for storytelling, training or research visualization and examples of each of these datasets will be discussed. The lower level software assets which form the VR\_GLUE include: CAVELib, FIE, Java, J2ME. Finally, the VR\_INTERFACE consists of the interface hardware like the 3D mouse, WiFi devices, and Heads Up Display’s (HUD). The WiFi devices employed here are unique in that they provide optical feedback to the user for interface control. Figure 2 shows the system diagram of the 3D virtual environment.


To develop and author virtual reality environments for exploring 3D objects and navigating through 3D worlds, this process requires custom user interfaces. The virtual reality environment architecture is different from the classic CAVE environment where all the imagery is displayed by a rear projection system with semi-transparent screens. In the dome environment of the planetarium the projectors are placed at the base of the dome along the perimeters circumference. The optical projection system is then the classic front projection with reflection off the dome surface rather than a transmissive path. The dome of the planetarium has a diameter that has a typical length of 50 ft. To drive a completely immersive fulldome requires at least six video projectors at a minimum. There are installations that have up to eleven projectors. It is also possible to use one or two fisheye lenses but the resolution will be less than for multiple wide angled projectors.

The environment can be set up for either classical projection or stereoscopic projection with extra hardware required for stereo imagery. The boundaries of the 3D space can be such that 3D stereoscopic data is only generated in select regions of the dome if the resources for fulldome are not available. The projected images are edge-blended multiple projector tiles with a resolution of at least 1600x1200 pixels at a 96 Hz refresh rate. A Silicon Graphics Onyx system with eight processors, drives each of the projection video pipes. The software library tools being used on the
Onyx system are Open GL performer [2] and CaveLib [3]. A Linux cluster has also been under development that uses four dual processor computers with dual head NVIDIA graphics cards. The software libraries for the Linux system are Diverse [4] and OpenSceneGraph [5] which are the equivalent packages to OpenGL Performer and CaveLib.

One of the main advantages of the dome virtual environment over the CAVE environment is the significantly larger audience that the dome theater can hold which is up to 130 people. Thus, a large group can be immersed in an environment for either scientific exploration or for training and educational purposes.

Stereo Projection Systems

The classical way of stitching multiple projector images together can only take you so far. For the viewer to have a sense of depth it becomes vital to create stereoscopic projections formed from stereo image pairs for the left and right eye. The viewer will have a strong sense of depth as it is experienced in every day life. The stereoscopic display requires the observer to view the scene with special glasses which can be optical or electro-optic in function otherwise known as passive or active.


Depth Cues Needed For Stereo Content

To provide a convincing stereoscopic 3D environment the human visual system accumulates depth cues to form the perception of depth. These cues are present in 2D and others only in the 3D realm.

The 2D depth cues include: perspective, size of known objects, detail, occlusion, light/shadows and relative motion. With perspective, objects appear smaller the farther away they are and parallel lines will converge with increased distance. When we know the relative size of objects if we see them having the same size, the known larger object is expected to be farther away. As objects appear to have more detail they are perceived as being closer. The idea of occlusion is it defines foreground objects being the ones that block other objects. This is also evident with lighting/shadows as the closer objects are brighter and the shadow cast defines a form of occlusion. The relative motion of objects implies the closer objects have more speed.

The depth cues that you only experience in the 3D realm include: accommodation, binocular disparity, and convergence. The human visual system uses accommodation to change the muscle tension on the eye so that the focal length of the eye changes in order to maximize focus at a particular distance. Our eyes are separated by an intraocular distance and thus different images are projected on the back of the eye and then on the visual cortex of the brain. The convergence of each eye to a fixed focal point is provided by the muscles rotating the eye.

Passive Stereo System

The passive stereoscopic system (see Figure 4) relies on the color or polarization of the right and left eye lens. There are two projectors required for the stereo pair images. The output from the two projectors passes through two linearly polarized filters which are orthogonal to each other. The viewer must keep their head fairly level.Circularly polarized filters can also be used and provide a better contrast ratio than their linear counterparts,
and the viewer can tilt their head. The right projector's image passes through to the right eye filter but not the left eye because of the orthogonal polarization. The same scenario applies to the left projector and left eye lens. The screen must be coated with a non-depolarizing screen.

**Active Stereo System**

The active stereo system (see Figure 5) use an LCD (liquid crystal display) electronic shutter and electronics that switch the optical state of the glasses from transparent to opaque. The output can be viewed with the head tilted and you can use standard screen materials. The disadvantage of this system is more relative expense and the glasses are more bulky, fragile and expensive.

The stereo system setup and supported projectors for shutter and polarizing type glasses are shown in Tables 1 and 2.

**TABLE 1.** Shutter Glasses based Stereo Systems.

<table>
<thead>
<tr>
<th>Setup</th>
<th>Supported Projectors</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Projector</td>
<td>CRT, Film (DLP, LCD)</td>
<td>Standard Projector, Sensio3D</td>
</tr>
<tr>
<td>1 Glasses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 3D DLP Projector</td>
<td>3D DLP</td>
<td>Barco, ChristieDigital, InFocus/Lightspeed</td>
</tr>
<tr>
<td>1 Glasses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Projectors</td>
<td>Film, DLP</td>
<td>Sony IMAX 3D</td>
</tr>
<tr>
<td>1 Glasses</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 2.** Polarizing Glasses based Stereo Systems.

<table>
<thead>
<tr>
<th>Setup</th>
<th>Supported Projectors</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Projector</td>
<td>CRT, Film (DLP, LCD)</td>
<td>Standard Projector, Sensio3D</td>
</tr>
<tr>
<td>1 Glasses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 3D DLP Projector</td>
<td>3D DLP</td>
<td>Barco, ChristieDigital, InFocus/Lightspeed</td>
</tr>
<tr>
<td>1 Glasses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 LCD Projectors</td>
<td>Pre-polarized LCD</td>
<td>Sony IMAX 3D</td>
</tr>
<tr>
<td>1 Glasses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Standard Projectors</td>
<td>CRT, DLP, Film, certain LCD</td>
<td>APEC, Cyviz, DigitalImage</td>
</tr>
<tr>
<td>2 Polarizing Filters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 LCD Projectors</td>
<td>Polarizing Filters</td>
<td>LCD Advisol</td>
</tr>
</tbody>
</table>

**Stereo 3D Projection Dome Environment**

The addition of 3D stereo to dome environments like a planetarium will have three potential seating configurations. These types include a non-tilted dome with unidirectional or concentric seating, or a
tilted dome with unidirectional seating. Since the audience will have different perspectives based on the dome configuration each layout will have a different solution. The real challenge is to accommodate all of the viewers in this environment.

Presenting 3D stereo content to the viewer should be staged so that the 3D stereo objects enter the field of view of the viewer looking towards the front of the domed theater. For example, with a six projector system the boundaries of the five horizon projectors and the central projector form two concentric pentagons. The screen projections flatten onto the dome to form a center, left, right, and top field. With our compositing tools that are actually 3D compositors, the primary objects will maintain a 3D stereo perspective in these regions. The two projectors forming the left and right rear fields can allow 3D stereo but only in the case where the 3D objects are being tracked along the spring line of the dome so we can maintain stereo along this panorama level. This paradigm will reduce the cost of having a completely 3D stereo which is actually outside the peripheral vision of the viewer.

**VRPIPE: VR CONTENT CREATION**

A series of software tools are incorporated into a workflow pipeline called Virtual Reality for Programming Interactive Planetarium Environments (VRPIPE). The VRPIPE workflow allows for high-resolution objects and scenes to be animated and composited together in natural illumination environments and presented in a dome virtual reality environment using Houdini and NUKE. These two powerful tools allow the user to create and composite any visual effect that is needed and scripting languages like Python or Tcl/Tk can be used to create and automate custom workflows for the final desired result.

**3D Stereo Modeling**

The stereoscopic requirements for a production dynamically affect how objects and backgrounds are placed in the 3D modeling environment. The most important thing to keep in mind is what can be put into the scene to accentuate the feeling of depth. In the 2D regime this is easily done because we can control this with shading and color or a particular layer. However, within 3D stereo this is not enough, and the relationship of the position between objects is the most important relationship that will give the illusion of true 3D stereo. Then the effect can be accentuated by the backgrounds being modified in color with respect to the primary objects that we want the viewer to track. This will keep the audience focused on the part of the frame that has the important 3D stereo information. By way of keeping the background less colorful it helps maintain what the viewer will be focused on.
can also use surfacing tools like revolve and loft to create polygonal geometry directly. Houdini can use its polygonal geometry as a subdivision cage. When modeling you can subdivide or you can render the whole object as a subdivision surface to render perfectly smooth surfaces. To avoid surface tessellation at rendering time, Houdini supports NURBS and Bezier geometry which are supported by Mantra’s micro-polygon.

**3D Stereo Animating**

A typical animating sequence will use motion blur to enhance the feeling of speed, timing, anticipation, follow through, and essentially all the 10 fundamentals of the animation process. Trying to create motion blur in a stereoscopic image is actually very problematic. For the audience to feel a convincing stereoscopic effect it is imperative that they feel the edges of the object. Now by creating motion blur, these sharp edges will be destroyed for the viewer, which will in turn destroy the 3D effect, and herein lays the fundamental problem. Therefore, normal motion blur can not be employed as would be done in 2D productions, due to the fact that we will be losing the 3D effect of the moving object. The one silver lining in this is that with reduced motion blur, rendering time for each frame will be significantly reduced.

The animation tools in Houdini can be broken down into tools for: Keyframing, Posing, Channel Groups, Playbar Editing, Dope Sheet and Graph Editor Manipulation.

**Keyframe Workflow**

Houdini supports keyframes in any parameter. With this feature you can animate all aspects of your scenes even if it is deep in the Houdini network. Digital assets can be utilized that put all the animatable factors at a high level for easier access. This handy feature allows directors to easily set things up while the animators can focus on setting and refining keys.

**Pose Tool**

Houdini’s networks can have many levels and the Pose tool lets animators select visible objects at any level. It is important to pose and use set keys. With the Houdini pose tool this is a single tool. It works with an object’s handles and can be switched to rotate, translate or scale handles for moving objects. This tool works with digital asset-based characters and props that have been set up for quick access. It allows animators to select visible objects at any level.

**Channel List**

Houdini’s channel list provides a tool for rapidly setting keys, which provides a great organizational tool. The list displays animatable parameters as they are selected. The keyframe hotkey when pressed scopes all channels keyed. This helps to organize channels in complex scenes by creating channel groups that can be scoped and keyed easily or even pinned so that the scope is not lost.

**Playbar Editing**

The playbar allows the animator to select keyframes and to be re-timed in the playbar. Quick access is allowed to the animation channels before refining in the graph editor. The playbar also is used to copy and paste keys to allow for ease in the cycle of your motion.

**Graph Editor and Dope Sheet**

The full-featured graph editor allows the display of one or more channels and then allows modification of the interpolation between the keys. Keys can be moved, scaled and refined using this tool. The editor can be turned into a dope
sheet for re-timing a shot or a spreadsheet for fine-tuning the keyframe values.

**3D Stereo Compositing/Editing**

It is important that the compositor/editor be set up so that the stereoscopic material is viewed in real time without the need for any additional post processing. This will allow for simultaneous editing of both the left and right eye clips which will minimize the potential errors in the time sync between the two channels with respect to the audio channels. Also, any color grading, color correction or any other optical manipulation can be done to both eye channels simultaneously.

With the scenes rendered, we composite the various image layers into image sequences with a new image-based keyer (IBK) called NUKE. Typically keyers are based on algorithms where color channels are locked together so there is no independence between channels. Traditional keying software algorithms are based on a weighted relationship between the color channels involved in creating a key. Then by locking them together and adjusting one color channel this will, in turn, adjust another color channel proportionally. In contrast to traditional keyers, the IBK algorithm allows the artist to modify each color channel individually without affecting the other channels.

**FIGURE 7.** The Nuke Compositor Interface.

NUKE provides never before seen capabilities in environment creation and contextual manipulation of 3D objects with a node based interface (see Figure 7). The software is built upon a node based operator workspace that allows for complicated 2D and 3D setups, and scripting in Tcl/Tk (see Figure 7). This becomes particularly useful when the rendered panels of the hemispherical must be edge blended and seamlessly fit together. The left and right eye images can be easily stitched together since NUKE is able to deal with 3D geometry and numerous layers can be composited together.

**3D Stereo Rendering**

Obviously, with 3D stereoscopic rendering there is a huge amount of CG that needs to be processed, thus ways of improving render time become vastly important. Therefore, if the director’s decision was to render photo-real images rather than a polygon gaming look, the significant increase in rendering time will be evident. As you go toward a true photo-real render, techniques like baking, texture maps, lighting effects, shadow, specular, diffusion and render passes become extremely important.

To create the stereo pairs requires rendering the left and right eye views from two camera positions based on the chosen eye spacing. The frustrum will be asymmetric from each eye to the corner of the projection plane. The frustrum extended from both eye cameras FOV needs to be trimmed off. The geometry of the cameras is shown in Figure 8.

**FIGURE 8.** Camera positions for off-axis projection plane.
The rendering features of the program Mental Ray [7], include global illumination, caustics, final gathering, ambient occlusion and image-based lighting (see Figure 9). These techniques can be used to render fluids, particles, fur, geometry based paint effects, blurry reflections and refractions, area lights, contour rendering, and High Dynamic Range images.

**FIGURE 9. Mental Ray Interface.**

**AUDIENCE RESPONSE SYSTEM**

Audience Response Systems (ARS), also known as Classroom Response Systems, come in two basic formats. One uses Infrared (IR) communication protocols and the other uses basic Radio-Frequency (RF) protocols. (There is also at least one Digital RF system.) The IR systems must operate line-of-sight due to the restrictions of infrared light. The RF systems are more flexible and arguably more reliable as they claim to allow for a greater number of responses per unit of time with fewer data errors in reception of responses.

One example of a typical IR system is from Hyper-Interactive Teaching Technology (H-ITT) at [http://www.h-itt.com/](http://www.h-itt.com/). Their remotes are made of bright fluorescent plastic with easy to read buttons that allow multiple alpha-numeric responses to be given. Simple binary responses such as Yes/No or True/False can be programmed as well. Communication is two-way in that responses are confirmed to the remote transmitter by triggering a green LED to come on.

An example of a typical RF system is from Qwizdom [8]. Their remotes operate by RF and are made of durable plastic in an ergonomic design to facilitate ease of use. Communication is two-way with the host computer transmitting confirmation information as well as support information directly to the LCD screen on the users remote. According to Qwizdom their system utilizes “2-way Radio Frequency remotes that use a network system designed not to interfere with other network standards (like WiFi and Bluetooth)”. One other system worth considering is from IML [9]. This system
uses a “Communicator” response device that appears to be based on cell phone technology. It communicates using digital radio frequency (DRF) and claims to be immune from RF interference.

**WiFi**

Both the WiFi and Bluetooth (BT) technologies lend themselves as technology that works well with the control of virtual environments. The possible handset clients chosen as control devices include the PDA, PocketPC and portable gaming consoles. The most common type of handheld computer is a PDA that runs either the Palm or WindowsCE OS. Now several cell phones incorporate a Palm or SymbianOS with BT capabilities like the Treo 650 and Nokia Communicator.

![WiFi Data Path](image1)

**FIGURE 11.** WiFi Data Path.

One of the primary limiting factors for displaying 3D data on a PDA is the amount of built-in memory required, and thus PocketPCs handle these larger data sets better.

The communications over BT differs from the WiFi method in the location where the IP is introduced. The IP packetization occurs under WiFi where the link ends at the client and host, while the BT model brings in IP at a mid-point using the BT communications controller. Note that from the client to this controller the IP is absent, the link being held up by mapping BT MAC addresses. After the BT controller, both methods use IP over an Ethernet LAN.

![Bluetooth Data Path](image2)

**FIGURE 12.** Bluetooth Data Path.

**Rover Display And Control**

The rover display and control follows the design from the original Lunar Rover Vehicle (LRV), which had the following indicators and controls: position, heading, distance, range, attitude, sun shadow, speed, gyro-torquing, navigation power, system reset, power, steering, drive enable, power, temperature and warning system.

These control parameters can be overlaid on the front projection screen or be the interface control of the portable handset. We have incorporated a variety of handsets to allow the customization of the graphical user interface to the handset that best suits that interface design.
Figure 13 shows the layout of the display panel that is overlaid on top of the perspective of the VR camera shown in Figures 15 and 18.

FIGURE 13. The LRV control and display panel.

VR DATA SETS

The Virtual Reality Data sets (VR\textsubscript{DATA}), which will be investigated include simulation and scientific visualization tools, and educational training tools.

Virtual Reality Simulator

There are three worlds that have been constructed for the Virtual Reality Simulator (VR\textsubscript{SIM}). This includes the Lunar Rover simulator for the Apollo 17 exploration site, the Mars Rover for the Spirit and Opportunity regions, and finally the first canyon regions from the High Resolution Imaging Science Experiment (HiRIS\textsubscript{e}) Mars Reconnaissance Orbiter (MRO). All of these data sets are built from photographs and topological data from radar mapping mission.

Lunar Rover Simulator

The virtual world built around the Lunar Rover Vehicle (LRV) is constructed at the landing site of Apollo 17. The details pertaining to the rover were modeled from the Apollo 15 and 17 missions.

FIGURE 14. Panoramas from Apollo 17.

The use of original footage presents an initial problem in that the photography taken by the astronaut has a floating nodal point which requires a series of preliminary corrections prior to the application in a VR environment. Each panorama must be stitched together from a collection of photographs. When stitching the panorama together the fluctuations in nodal point becomes sharply evident, in which one of two techniques can be employed to solve the problem. The first and more faithful representation is to place the individual frames in a composition capable of doing its own motion tracking or having an animation capable camera to compensate for the shifts in position. The second option is within a post photo-editing software such as Photoshop, to remove and soften any slight augmentation when motion tracking is not a feasible option.

The first VR exploration that can be simulated follows the path that was taken by the original mission. The second option for exploration is completely free wandering but critical obstacles are avoided if collision detection is turned on. In a pure simulation mode collision detection can be turned off.

Figure 15 shows the perspective of the VR camera that the tele-operator would see. The controls and system feedback response is overlaid on top of this image so that the driver can see all important
instruments while not losing concentration on the projected image on the screen. The control of this simulator is an exact digital replica of all the data that was on the original control and display panel on the LRV.

**FIGURE 15.** Virtual view from the Lunar LRV.

*Mars Rover Simulator*

The Mars Rover VR world is built from the Spirit and Opportunity missions. With this world, again, the VR experience can follow an autonomous tour via the path that JPL made. Then the free wandering exploration can be made with obstacle collision turned on or off.

**FIGURE 16.** Panorama from Mars.

In Figure 17 a typical screen shot of the Mars Rover and the controls that JPL used for its virtual guidance is shown. For convenience our control and display console for the Mars Rover used the same display information as the LRV.

**FIGURE 17.** Virtual Guidance of the Mars Rover.

The Mars Rover’s perspective that would be seen by the VR camera is shown in Figure 18. The control screen is turned off for the photo, but would normally show up with a yellow font color.

**FIGURE 18.** Image seen through VR camera perspective and controls.

*Mars HiRISE and MRO Data*

The MRO is in a low and nearly circular orbit about Mars. On board is the HiRISE camera which has a resolution of sub 1m. The camera will take stereo image pairs of regions with a vertical precision of better than 25 cm per pixel.

This data is converted to 3D topological data with help from the Mars Orbiter Laser Altimeter Science Investigation (MOLA) and the image is then used as a texture map. Using our workflow pipeline we have generated these data sets for the VR environment in a planetarium.
Virtual Reality Educational Training Tool

The Virtual Reality Educational Training Tools (VR\textsuperscript{EDUCTT}) case study is for veterinary medicine, where virtual interactive life-sized models of horses are be examined. This has many implications in the learning and training of equine anatomy and by employing virtual environments students can see how problems affect the motion of the animal.

An interdisciplinary approach towards research for veterinary medicine, biomechanics and virtual reality is currently being developed at the University of Arizona. The project’s main emphasis is on combining medical data and anatomical information in a virtual setting to help teach and research the effects of ailments such as Laminitis in horses. Meshing of different fields was required to create a virtual and interactive model, which both students and professors can deconstruct layer-by-layer to view specific areas that are captured through MRI or 3D modeling. To make the virtual horse a reality it first requires a realistic model that is not just anatomically correct, but geared to be used as a teaching and research tool.

The construction of the horse did not take place in a 3D modeling program such as Maya or Houdini, but in an artist’s mind. The horse used was sculpted from plasticine clay, which was then molded into resin by sculpting artist Stacy Tumlinson.

From this point the model was then taken to PRISM labs at Arizona State University. There the Cyberware 3030 model 3D scanner carefully made stereo lithographic scans of the model at 30-degree increments. A total of 3 complete scans were made featuring the vertical profile of the model and poll-to-poll. Once all the scans were completed it was then brought through the SGI stitching pipeline set forth by PRISM. Along with the use of Cyberwares propriety software CyDir, this aids not only the scanning processes, but the initial stitching of the 3D model. The roughly stitched model was taken into Houdini to close any gaps that were in the skin of the model. From this point the model was formatted into an acceptable 3D data file (such as .obj) so it could be edited in the desired platform.

After all the gaps were cleaned and any deformities removed, the model went through various phases of the medical modeling process. The first and most important step was to set up a proper rigging structure known as “bones.” Each system of bones must behave properly as they would in a real animal, including forward and inverse kinematic constraints, limitations and flexibility. Once this is done, then substructures can be added, like musculature, a modeled skeletal system, and organs. This is then attached to the

FIGURE 19. First HiRISE Mars images to be mapped in 3D.

FIGURE 20. Shaded and Wireframe images of Desperado.
model and made to interact with animation or programming for virtual reality use.

The goal of placing these various structures together in a virtual environment allows for both broad and focused educational opportunities. For students of pre-veterinary, or even a basic biology course, they can now view the virtual horse in a safe conducive environment, which is both interactive and can be customized to fit into the already defined course material. Students who wish to view anatomical features can now do so in the safety of a CAVE Environment or Planetarium.

Research which is currently in its case study phase is being conducted based on a new standing MRI machine, which now allows horses to be able to stand during the imaging process. This is a dramatic leap forward in diagnosing crippling diseases, which affect the hoof and leg of large domesticated animals.

Conventional MRI procedures were not only difficult to do but also dangerous to both the animal and human. The MRI images offer a slice-by-slice view of a diseased and healthy leg and hoof, through which virtual reality will be applied to the virtual horse so that students and teachers can see just how it impacts the animal’s biology.

By calculating or filming the movement of real horses this motion data can be translated into datasets for the educational model. The horse in a dome setting can now go through various paces around the students as though they are actually in a real round pen observing the animal.

**CONCLUSION**

Incorporating virtual reality into the planetarium is now realizable and depending on the required level of 3D immersion over the dome, there are multiple avenues that can be taken based on budgetary constraints. By expanding production techniques to accommodate the workflow pipeline for 3D stereo content we have created a workflow for authoring 3D content for Dome virtual environments. This workflow is currently being demonstrated on planetary flyby simulators, natural phenomena, and 3D animation.

**ACKNOWLEDGMENTS**

Our thanks to Kim Davidson at Sidefx Software Inc., Dominick Spina at D2 software, Andy Kopra and Bart Gawboy from Mental Ray Software, Dan Neufus and Dr. Ka Chun Yu from the Gates Planetarium, Denver Museum of Nature and Science, Dan Collins at PRISM, Arizona State Univ., Maria Schuchardt at Lunar and Planetary Labs, Univ. of Arizona, Alan Caskey at SEOS, Loretta McKibben at the HiRISE Project Lunar and Planetary Labs, Univ. of Arizona, Mark Toth and Bernie Kuhn.

**REFERENCES**

Innovative Sound In Dome Theaters

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Abstract. Stereo and 5.1 systems have been established as standard formats for sound systems in planetaria. In order to compensate several disadvantages of these conventional systems, an alternative surround sound technology has been developed. This audio system captivates through natural spatial sound reproduction. The acoustic stability is guaranteed everywhere in the listening area. This paper will describe a perceptual 3D sound system and will introduce methods for sound reinforcement and production, based on Wave Field Synthesis incorporating conventional sound systems. An intuitive control-interface allows interactive interventions into shows and builds the basis for professional audio productions. Within the production process, audio objects can be easily assigned to related video objects. Common work with audio tracks will be replaced by an intuitive handling of sound objects. Sound does not need to come from the front, center or surround speakers, nor does it need to be represented by phantom sources. In combination with the visual content, the perceived impressions for the audience become more realistic and natural. The supplement of object-based video with audio objects sets a basis for future audio production applications. The described technologies show new ways to create natural and simulated sound environments, and when associated with the possibilities given by digital video editing systems, an impressive experience will emerge that can captivate the audience in a remarkable way.

MOTIVATION

To guarantee high quality sound impressions in dome theaters, a lot of special requirements must be implemented. These requirements are decisive for the listening experience of the audience.

To obtain a good sound impression, the following needs must be considered:
• A complete sound immersion for all members of the audience.
• No preferred seats.
• No catching of technical equipment.
• Feeling the ambiance as natural.
• Picture and sound should be a unity.

Particularly with regard to the new possibilities of fulldome projection, a more spatial and natural sound environment is needed.

Another important fact that must be considered is the reduced angle of human viewing (Figure 1). In contrast to the ability of an entirely 360 degree listening area, we can only view pictures until an angle of 180 degrees. Beyond that we have to turn the head to view the whole scenario.

With the new fulldome projection, the visual requirements for an immersive effect are achieved very well. But previous sound systems could not fully serve the ability of human spatial hearing.

FIGURE 1. The human listening angle.
**REQUIREMENTS**

The goal of high sound quality (music and speech) at every seat in the dome becomes more and more important for the new generation of planetarium shows.

For an authentic acoustical perspective, the audience expects a complete immersion with sound. This kind of natural sound perception can be realized with a spatial sound dispersion in the whole dome.

The pictures in the dome are placed in a 360 degree perspective around the visitor. For a high-quality reproduction, the audiovisual coherence is an essential requirement. The quality depends on the acoustical information of the position of a sound object and its environment.

**Requirements For Sound Reproduction**

Today, multimedia fulldome shows comprise natural & artificial soundscapes and lots of special effects. Furthermore, the audience expects an adequate audibility for speech, music or live action.

For the rendition of different formats like DVD or hard disk, the sound compatibility regarding existing sound formats, e.g. 5.1 or x.x. multi channel audio, has to be given.

In addition, the sound system requires a connection to live inputs like musicians, artists or speakers.

**Requirements For Sound Production**

Produced show content often has to be changed and adapted for special user requirements. For this scenario, an easy to use interface for the placement of audio and video content is necessary.

Additionally producers need the opportunity for programming complete show sequences and a functional audio and time code connection to peripheral sound and video systems must exist.

The produced content can also be shown in other planetaria with an equivalent setup.

**BASICS**

**Building Acoustics**

The acoustical properties of a building are a fundamental criterion for high-quality sound reproduction. The most critical point to realize good acoustics is the hard reflective surface of the dome screen. Furthermore, from the acoustic perspective, the dome cupola is regarded as a parabolic mirror.

On a few seats on or in the middle of the dome a “spot” can be found where the acoustical energy is focused. This focused energy can also “walk” under the horizon (“whispergallery”).

An important criterion which describes the acoustical qualities of the dome is the reverberation time (RT). The reverberation times needs to be in the following range:

<table>
<thead>
<tr>
<th>Good RT for speech</th>
<th>0.5-1.0 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good RT for music</td>
<td>1.5-2.5 s</td>
</tr>
</tbody>
</table>

The RT mainly depends on the material of the dome. For example a 23m cupola with a reverberation time of 0.6s is a good compromise for speech and music. For a good audibility of speech and music a “dry acoustics” with RT < 0.5s is recommended.

In the case of live music, it is best to use a room simulation system to enhance the room acoustics.

**Audibility And Sound Dispersion**

Another important criterion for the audio quality in the dome is the sound pressure level (SPL).

The SPL should be in the range of 85-105dB (C). This specification is based on the Dolby cinema standard. That means that the minimal possible SPL must be 85dB with headroom of 20dB.
At the moment there are no existing binding specifications for planetaria sound systems. A good but not binding orientation is the cinema standard.

Furthermore, the sound dispersion should be as homogeneous as possible and the sound energy must be controlled (Figure 2).

The quality of sound will be reduced by the incorrect placement of the loudspeakers themselves or by using the loudspeakers with incorrectly set directivity.

![FIGURE 2. Homogeneous sound distribution in the dome.](image)

**TECHNICAL SOLUTIONS**

To realize a realistic acoustical perspective at all seats there are different technical possibilities:

- A sound system based on Wave Field Synthesis (IOSONO).
- Vector based time and amplitude panning (VBTAP).
- A combination of Wave Field Synthesis (WFS) and vector based time and amplitude panning (VBTAP).

**Wave Field Synthesis**

The listening area of a dome is surrounded by a closed array of loudspeakers (speaker panels) at the height of the horizontal line.

On the basis of the Huygens’ Principle of wave propagation, virtual audio objects can be emulated in a realistic way through a closed array of speakers. By means of the interferences of wave fronts reproduced by the loudspeaker arrays, natural sounding virtual audio objects can be synthesized.

This means that every loudspeaker is driven by a unique signal that depends on the position of the speaker and the virtual source in the room.

To perform the complex task of controlling such a huge number of loudspeakers, special software is needed. To store and distribute the audio sources and their positions and characteristics, the 3D-Audio profile of the MPEG-4 standard is used.

![FIGURE 3. The principle of Wave Field Synthesis.](image)
Vector Based Time And Amplitude Panning

This sound reinforcement technology is based on the “precedence effect” and provides the basis for directional hearing \([4, 5, 6, 7]\). The principle is shown in Figure 5.

Directional hearing means that the first wave front that reaches the human ear determines the localization of the sound source.

For the definition of specific directional areas in the dome (see position A and B), different groups of loudspeakers must be driven. The signal of the sound source will be reproduced over the amplitude and time scaled loudspeaker groups which are permanently adjusted to the position of the sound source. Particular loudspeakers in such a group will be provided with different delay times of the source signal.

As a result, the first wave front reaches the seats of the auditorium with time adjustment and the audience perceives the sounds from the correct direction.

Combination Of Vector Based Time And Amplitude Panning And Wave Field Synthesis

The integration of both systems in one setup is a suitable solution to create perfect sound in planetaria. The audience has the experience of a complete immersion of sound in combination with the unlimited possibilities for positioning certain sound objects ie. around, inside and on the top of the dome.

Both systems work with an integrated user interface for intuitive sound editing as shown in Figure 6. Such an integrated system opens the door to new creative possibilities in the field of positioning sound sources and realizing effects. Producers can create or reproduce soundscapes with an unlimited number of individual sound objects in time with the video content.

Every listener on every seat in the dome will get a realistic sound experience without hearing discrete loudspeakers. The fulldome video will be augmented with
moving sound sources for a more realistic and spatial presentation.

…Imagine, a spaceship starts in the middle of the audience and disappears slowly towards the universe.

CONCLUSION

We present a novel system for spatial sound reinforcement for planetariums. Starting with the requirements for good quality sound in the dome, we present three technical solutions for spatial sound environments for planetaria.

Using our preferred system solution the audience will be involved in the show through spatial enveloping. Audio and video can be perceived in perfect unity from the horizon to the zenith.

Some of the benefits of the used technologies are homogeneous sound fields and stable sound impressions at all seats within the auditorium. Furthermore, you can animate sound objects and move them within or outside the listening room.

As a result, every listener is able to enjoy their own sonic sphere, where sounds and effects are perceived as coming from the right acoustic perspective.

There are several applications worldwide that make use of this technology, e.g. the planetarium at the "Shafallah Center for Children with Special Needs" in Doha (Qatar) or the Bregenz Festival Theater (Austria).

ACKNOWLEDGEMENTS

The authors would like to thank all researchers, developers and friends who had a part in developing this amazing technology.

A special thank goes to the Bregenz Open Acoustics team, especially Prof. Fritz und Alwin Bösch.

REFERENCES

5. W. Ahnert, Problems of near-field sound reinforcement and of mobile sources in the operation of the Delta Stereophony System (DSS) and computer processing of the same, 82nd AES Convention, February 1987, preprint no. 2426.
**IOSONO® Sound For Planetaria – Listen To The Sound Of The Future**

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**Abstract.** The realistic reproduction of the starry sky in planetaria deeply impresses visitors all over the world. Yet the sound quality unfortunately does not match the visual experience. No matter which sound system you use, only the listeners in a small area called the “sweet spot” have a good sound experience. IOSONO® is a revolutionary sound system which solves this problem. The purpose of this paper is to give you an understanding of how IOSONO® is structured and how it functions. Furthermore, the paper will highlight the advantages of IOSONO® as compared to conventional sound systems, especially for planetaria (shown in an example: The first IOSONO® Planetarium in Qatar).

**BASICS: THE PRINCIPLE OF WAVE FIELD SYNTHESIS**

IOSONO® is a sound technology that allows the accurate reproduction of spatial sound and gives a more natural sound experience for nearly the whole presentation area. IOSONO® is a breakthrough spatial audio technology for the projection of amplified sound both recorded and live. For the first time in audio history the whole listening area can be filled with completely natural, realistic, spatial sound.

IOSONO® is based on the principle of Wave Field Synthesis (WFS) which has been developed at Fraunhofer, Europe’s largest research organization. Sound waves that are created by a (virtual) sound source can be reproduced by manipulating multiple speakers. This means that a listener at Position B has the impression that he is listening to sound originating from Position A (see Figure 1).

Speaker arrays encircle the listening space and operate in a coordinated, phased fashion to re-create each individual sound wave. As a result, the visitors can not only see the skyrocket starting, but you can give them the illusion that the rocket is starting in the middle of the planetarium right next to their seat.

**FIGURE 1. Principle of Wave Field Synthesis (WFS) [© Rinus Boone (TUD)].**
THE IOSONO® SOUND SYSTEM

IOSONO® – What Is Possible?

As speakers surround the listening audience, sounds can come from any direction just as they would in reality. Outdoor environments are complete and authentic.

Existing multi-channel audio technology has a significant limitation: it can offer the ideal surround sound experience to only a few listeners lucky enough to be sitting in the sweet spot. Outside of this area, there is an imbalance in the sound levels. With IOSONO®, every listener, regardless of where he or she is seated, perceives dialogue and sound effects from their intended direction and distance. The listener can also move around in the space and the sound source stays in its fixed position, as in real life. Individual speakers are not perceptible as sound sources. IOSONO® eliminates the major downsides of today’s multi-channel technology (see Table 1). [1, 2, 3, 4]

<table>
<thead>
<tr>
<th>Today’s Multi-Channel Sound Technology</th>
<th>IOSONO® Sound Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desired sound is limited to a very small area (the sweet spot)</td>
<td>Desired sound all over the auditorium (maximum sweet spot)</td>
</tr>
<tr>
<td>High volume in proximity to speakers</td>
<td>Homogeneous distribution of sound</td>
</tr>
<tr>
<td>Sonic sensation limited to speaker channels and arrangements</td>
<td>Sonic sensation is independent of speaker channels or arrangements (sound object based)</td>
</tr>
<tr>
<td>Positioning and movement of sound sources extremely limited</td>
<td>Positioning and movement of sound sources within and outside the listening space</td>
</tr>
</tbody>
</table>

IOSONO® Components

To realize the unique possibilities of Wave Field Synthesis the IOSONO® Sound System is equipped with:

- IOSONO® Rendering- and Control-Unit
- IOSONO® Loudspeaker Panels and state-of-the-art subwoofer
- Optional: IOSONO® Spatial Audio Workstation (see below)

The core of the IOSONO® Sound System is a PC-based Rendering- and Control-Unit (see Figure 2) that runs the IOSONO® software, plus dedicated audio hardware, all integrated into a rack. The excellent IOSONO® Software was developed by the well-known Fraunhofer institute. It combines many complex functions to create an individual audio perception for everyone. [5]

FIGURE 2. IOSONO® Rendering- and Control-Unit.

The control unit manages all central functions, which include the audio server functionality, the signal processing via the rendering unit, and a routing system to handle internal and external connections, for example to an existing studio set-up.
The powerful signal processor computes the Wave Field Synthesis algorithm in real-time, using several rendering PCs. Its scaleable capacity adjusts to different needs, depending on the number of loudspeaker panels and the quantity of simultaneous sound sources used. Each individual loudspeaker, or subwoofer, is driven by Wave Field Synthesis signals, which are generated by the IOSONO® software using the incoming audio signals and spatial parameter of the individual sound sources.

The audio files are stored and managed with the audio server, using an integrated hard-disk recorder. A graphical user interface guarantees ease of use. DVDs, CDs or hard-disks can be used as storage media.[5]

The IOSONO® certified loudspeaker panels (see Figure 3) are custom-built using premium components for the highest sound quality, and consist of speaker arrays (passive or active), plus electronic control-units. At this point in time both active 8-channel and passive 4-channel speaker systems are available. Depending on the specific application, different versions of the loudspeaker panels are offered, according to the characteristics of the amplifiers, as well as the electro-acoustic characteristics of the loudspeakers (e.g. directional characteristics, sound pressure level, and frequency response).

The IOSONO® Sound System uses state-of-the-art subwoofers to support the generated spatial and homogeneous sound field in the reproduction room and to reproduce the lower base frequencies.

The number of panels and subwoofers installed varies with the shape and size of the room. The speakers can be mounted on the wall, placed on the floor or suspended in space. [5]

**The IOSONO® Spatial Audio Workstation**

The IOSONO® Spatial Audio Workstation (SAW) was developed to fully utilize the creative potential and unique possibilities that Wave Field Synthesis offers. To ensure intuitive use and seamless studio integration IOSONO® SAW was designed in collaboration with well-known sound editors and re-recording mixers.

**FIGURE 3.** Example of an IOSONO® certified loudspeaker.

The IOSONO® Sound System uses state-of-the-art subwoofers to support the generated spatial and homogeneous sound field in the reproduction room and to reproduce the lower base frequencies.

**FIGURE 4.** IOSONO® Spatial Audio Workstation (SAW).

For individual sound production and dynamic control of “the soundscape” IOSONO® developed the IOSONO® SAW. The workstation provides the tools for object-oriented production, editing and mastering of auditory scenes for IOSONO®-equipped listening spaces. With it the re-recording mixer is able to mix sound by mapping the sources to the desired locations in the room, rather than to specific playback channels. With the workstation the position and all other parameters of the various sound sources can be automated and stored in a scene description. Once a sound source has been mapped it can still be changed easily, for example to link a sound position with
different sound files. The number of transmitted sound objects is independent of the number of reproduction channels.

The IOSONO® workstation uses sound files edited on standard industry mixing workstations such as Pro Tools®. During the mixing process, separate sound sources are composed to a sound scene. The resulting sound scene consists of the audio objects and a dynamic scene description. Up to 64 separate sound sources can be placed in a scene at any given moment. The audio data is imported in real-time into the workstation during the mixing process from any digital sound source. Within the workstation, spatial parameters are added to the audio objects. Audio objects can be organized in layers, permitting the re-recording mixer to manipulate groups like dialogue, sound effects or background music separately. [5, 6]

THE FIRST IOSONO® EQUIPED PLANETARIUM

The Shafallah Center for Children with Special Needs is a state-of-the-art facility, which provides education and therapy to children and youths with special needs. The educational and therapeutic programs offered to children ages 3–21 are supported by the most modern equipment and technology that is integrated into every part of the center. Thus the center features its own 208 seat planetarium, which is equipped with Evans & Sutherland 3D Digistar 3 laser projectors and the revolutionary IOSONO® audio system (see Figure 5).

The synergy of 3D audio and video provides the perfect tool for stimulating and educating the sense of hearing and the sense of sight. The multimedia dome also opens its doors to the public, for example to present artistic or educational films to students. This is one way the center can integrate with, and gain the support of, the community. [5]

FIGURE 5. IOSONO® Sound System at the planetarium at Shafallah Center for Children with Special Needs in Qatar.

CONCLUSION

In this paper the new creative potential of IOSONO® has been shown. The most important conclusions are that the creative possibilities of IOSONO® are nearly unlimited and the listeners/visitors are in a fully immersive environment.

The main benefits are that the sound has a new dimension; it has location and movement which can be used to support the story in new ways. For the first time listeners can determine the exact position of sounds. The sounds have a unique position and can be animated, that means virtual sound sources can be located within or outside of the listening space. IOSONO® enables an extraordinary spatial stability of the acoustic image and increases the creative control of the acoustic space.

IOSONO® has potential benefits for various venues such as planetaria, theme parks and movie theatres. Installations in Germany include the 4D Adventure Cinema at Bavaria Filmstadt in Munich (February 2006) and the one screen at the movie theatre in Ilmenau (2003). [5, 6]

REFERENCES


5. [www.iosono-sound.com](http://www.iosono-sound.com)

Tools for Creating Your Original Digital Dome System

Toshiyuki Takahei and 4D2U Project Team

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Abstract. In our 4D2U Project, we built a consumer based stereoscopic fulldome theater. During this challenging mission we made a workflow and tools to create pre-rendered and real-time content for various immersive environments. This report describes our workflow and tools in detail.

INTRODUCTION

The main purpose of our 4D2U Project is to create the latest ‘real’ astronomical science visualization content and distribute it to audience through various media, from lightweight online web content to the latest stereoscopic fulldome media.

We would like to distribute our content to immersive multi-projection theaters, such as domes, but their shape and size of screen, number of projectors and their layout (or theater setup) are different to each other. So we need a solution to create content that is independent from the actual theater setup. For this purpose we the defined ‘Projection Data Set’ format which represents the theater setup to make corrections such as geometry correction, edge blending and color correction. Once a theater’s setup has been measured as the projection data set, we can convert our content for your theater.

We have made an interactive projection setup tool ‘Projection Designer’. This tool can export parameters and layout of the screen and projectors as the projection data set.

For pre-rendered movies we made a movie converter which applies the corrections on the cube map movies.

For real-time content we made a real-time correction development library and tools based on the data set.

With this hardware-content separation we can distribute our content to various immersive theaters such as multi-projection wall, cylindrical, and dome theaters, stereoscopic fulldome theaters, CAVE and so on. It’s truly the one source multiple target solution we want.

FIGURE 1. Content Conversion Flow.
PROJECTION DATA SET

Projection Data Set consists of three files for each projector. ‘Distortion Map’ is used for geometry correction, ‘Blend Map’ for edge blending and color correction, and ‘View Matrix File’ defines a sweet spot and view frustum for real-time rendering.

Distortion Map

In geometry correction, we need to pre-warp the normal rendered image to make the projected image on a screen surface be undistorted as viewed from a sweet spot in the theater. Distortion map defines where each pixel in the projecting image comes from in the undistorted rendered image. The color value of each pixel in the distortion map image represents normalized coordinates in the rendered image.

\[
X = \frac{(B/255 + (R \mod 16))}{16} \\
Y = \frac{(G/255 + (R/16))}{16}
\]

Here, X and Y is the normalized coordinate (0.0-1.0) in the rendered image, R, G and B is the color element value in the distortion map (0-255). Software developers can use this formula in their shader code or texture mapping coordinate generation code to realize the geometry correction.

Blend Map

In multiple projector environments, we need to make edges of the overlapped projection area dark to flatten intensity on the screen surface. Blend map represents intensity distribution and color correction for the projection image. We multiply this blend map image to pre-warped projection image to realize the corrections.

View Matrix File

View Matrix File defines a sweet spot and view frustum which covers the projection area on the screen surface. Technically it defines model/view matrix and projection matrix in the real-time 3D application.

This file is a simple text file nested by ‘{‘ and ‘}’ blocks. The most outer block is ‘Channel’ like this:

Camera "CHANNELNAME" { … }

In this block, the following ‘Lens’ block represents a projection matrix of the view.

Lens {
    Frustum <left> <right> <bottom> <top> 
    <znear> <zfar>
}

Frustum’s parameter format is the same as glFrustum() function in OpenGL.

Model/View matrix is defined in an ‘Offset’ block, which may contain "Translate" and "Rotate" lines in order of operations.

Offset {
    Transform <x> <y> <z>
    Rotate <angle (degree)> <x> <y> <z>
}
These Translate and Rotate formats are the same as glTranslate*() and glRotate*() functions in OpenGL.

This View Matrix File format is a subset of Open Producer’s camera configuration file. So you can use it as it is in Open Scene Graph based applications.

CALIBRATION

To create the projection data set, we made an interactive projection setup tool ‘Projection Designer’. With this software we defined a screen shape, projector parameters and view frustums. All of these configurations should be done manually in the theater with actual projectors. This tool can handle a plane, cube and hemispheric dome screens and any other shapes modeled by a polygon mesh. It works over the LAN in server / client mode to setup many projectors. We aligned 13 projectors for our stereoscopic dome theater.

FIGURE 4. Projection Designer.

As you know the setup of such a number of projectors is a terribly difficult task. However, our early purpose is to develop and provide at least one way to create the projection data set for free. The more important thing is that we can use the same data set format for content portability. You can make the data set for your theater by yourself without any costs. In the other case your hardware vender might help you to make it with their more own elegant tools. Anyway once you have made the data set, we can use the same content, even including fulldome real-time applications.

PRE-RENDERED CONTENT

In our workflow we mainly use our own massive particle rendering tool ‘ZINDAIJI’ to create n-body simulation movies. In other cases we use 3D DCC tools such as Maya and Lightwave3D. All of them can render the scene as a cube map format, 90 degrees field of view for each face of a surrounding cube. So we made an image/movie converter ‘Cubic Movie Converter’. It splits and distorts cube map format content source for each projector by using the projection data set.

The cube map content source does not depend on the shape of a screen if it covers enough field of view. So we can make cubic map pre-rendered movies as a universal content source. Of course the dome master format is good for dome theaters, so we’ll make the converter also support dome master format sources.

REAL-TIME CONTENT

Real-time content is much more difficult to make portable.

For real-time 3D software developers there are some multi-projection cluster synchronization frameworks such as CAVE library, VRJuggler, Chromium and more. But all of them only support flat surface screens - not curved screen surfaces like domes. We made a small
library ‘GLRC’ (OpenGL Rendering Compositor) which helps to render the real-time scene in off-screen buffer, applies the projection data set and composites the results to display in real-time. If you are a software developer and you have source code of a real-time application, you can compile it with the GLRC library to make it support multi-projection correction for curved screens based on the data set.

Here is an example application: a web browser compiled with the GLRC library. You can use the FireFox based web browser undistorted on the dome screen surface.

For other applications when you don’t have their source code, we used the OpenGL dll replacement technique to realize the real-time corrections without modifying the application itself (named ‘Musashi’ dll in our project). This technique depends on the internal rendering process and while not always successful, in many case it is highly useful.

The first example of it is a simple movie player ‘GL StereoPlayer’. Just by placing opengl32.dll and the projection data set files in the executable directory, it displays geometry and intensity corrected movies on our dome surface.

The second example is our space viewer ‘Mitaka’. We added some functions to synchronizing and load ‘View Matrix File’ for optimized rendering, but we did not have to do anything about geometry correction and edge blending with it.

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The second example is our space viewer ‘Mitaka’. We added some functions to synchronizing and load ‘View Matrix File’ for optimized rendering, but we did not have to do anything about geometry correction and edge blending with it.

The last interesting example is a game engine. Epic Game’s ‘UnrealTournament 2004’ with CaveUT modification and our replacement dll also work in our fulldome environment. That’s one small trial, one giant leap for real-time graphics in the fulldome environment. It may become a bridge to the multitude of game industry resources.

FUTURE WORK

We just got our dome and have begun many trials. Some of them are still under development. We feel especially that it’s very difficult to realize edge blending and color correction manually with consumer based less controllable projectors. So we
are thinking about adopting some kind of auto-calibration in the process.

CONCLUSION

We have described our workflow to create pre-rendered and real-time content for our dome theater. In this workflow we defined a universal ‘projection data set’ format which generalizes the difference between projector setups among the immersive theaters. We have also made tools to realize this workflow. If you adopt some part of our approach, especially the projection data set format, we’ll get content portability and the possibility of sharing our immersive content.

ACKNOWLEDGMENT

The 4D2U project is funded by the Special Coordination Fund for Promoting Science and Technology of the Japanese Ministry of Education, Culture, Sports, Science and Technology as part of their Program for the Effective Promotion of Joint Research with Industry, Academia and Government (2004-present).

REFERENCES

1. Our 4D2U project website:
   http://4d2u nao.ac.jp/
2. ProjectionDesigner, GLRC library and additional software are available here:
   http://orihalcon.jp/
Visualizing Particle Simulation Data Of Astronomy

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Abstract. At the National Astronomical Observatory of Japan (NAOJ), for the 4-Dimensional Digital Universe Project (4D2U Project), we are developing a stereoscopic theater and a stereoscopic dome theater for astronomical shows. There, we make movies from raw simulation data provided by researchers. The output data of such simulations often contains information about millions of particles (galaxies, stars, asteroids, or planetesimals, etc.), so that it is unrealistic to use commonly-used general-purpose 3D-CG applications for visualizing all of simulation data. We have developed a single-purpose GUI application for visualizing particle simulations called ZINDAIJI, that is named after a location name near the NAOJ campus.

INTRODUCTION

At the National Astronomical Observatory of Japan (NAOJ), for the 4-Dimensional Digital Universe Project (4D2U Project), we try to visualize the most recent aspects of the universe, as revealed by modern astronomers. One of our main objectives is the visualization of astronomical computer simulations. In astronomy, the evolution of systems with many particles, such as stars, planetesimals or dust particles, are important, and many simulations of particle dynamics are performed all over the world. With the recent increase in computational power, these simulations use many, sometimes up to $10^8$ or more, particles. Thus, it is not realistic to use general-purpose 3D CG applications to visualize such data directly. In many cases, the number density profile of particles is used to visualize such data. Instead, we have developed a GUI application (for windows 2000/XP) which is specialized to visualize as many particles as possible with normal PCs. We named this application ZINDAIJI, after a location name near NAOJ Campus. This application will be published as freeware at the project’s website (4d2u.nao.ac.jp/).

DETAILS OF THE APPLICATION

Memory Control

The most important thing required by the application is the ability to draw as many particles as possible, and as quickly as possible. As a GUI application, simulation data should be stored in memory. However the memory capacity of a PC is limited and only essential information must be stored. Also, scientists often make snapshot data files less frequently than that required for smooth animation, and so interpolation of data is required. Here, we adopted the Hermite interpolation method, so that the required information are position, velocity, acceleration and jolt (acceleration and jolt are calculated from the position and velocity of two snapshot data) of each particle. Also needed is the visualization data such as size, color, and ID of each particle. All particles are grouped into categories (for example, stars, gas and dark
matter in the case of cosmological simulations), and the common information in the group is stored separately. In this way 1GB of free memory can store the information of up to about $5 \times 10^6$ particles for several time steps. For longer data sequences, one cannot store all the data at once, so that release process of memory, and access to HDD for new data (and some waiting) at a jump of time are inevitable.

**Rendering**

We decided to render the particles as GL_POINTS, or billboards – for smoothed particle hydrodynamics (SPH) gas particles or stars with glare – or spheres – for particles with a physical surface – represented by textured polygons. For shadowing, shadow volume and shadow mapping methods are implemented. Thus, the drawing process can be easily accelerated by graphic-boards. These methods are rather simple ones. However, the source data consists of a very large number of particles and the motion is remarkably realistic (since it is scientific simulation data!), so the simulation movies made by ZINDAIJI can be very impressive. Figures 1 and 2 are snapshots of two movies formed from simulations of the formation process of large scale structure[1,2] and a spiral galaxy[3].

In the case that a large number of nearly-transparent particles overlap, the details of color information can easily be lost within the normal dynamic range of RGB (0-255). Thus, we recently added the feature of high dynamic range (HDR) rendering to ZINDAIJI. With the newest graphic boards, one can use this feature. The movies shown in Figures 1 and 2 are rendered in HDR mode.

**FIGURE 1.** Snapshot from a movie about the formation of large scale structure. The original simulation uses $10^8$ particles, but about $3 \times 10^6$ particles are used for visualization. In the movie, the camera flies through the simulation box as the originally uniform universe evolves to the current clumpy one.

**FIGURE 2.** Snapshot of a movie about the formation of a spiral galaxy. About $2 \times 10^6$ particles are used in the simulation. Cubic movies are made by ZINDAIJI and distorted using Adobe After Effects (lens distortion with viewing angle of 135 degrees). The grid is superimposed as a guide.
Other Features

Originally ZJINDAIJI was developed to make movies for the 4-D theater at the NAOJ campus (stereoscopic movies with three screens) [4]. Thus, stereoscopic movies can be rendered easily (just check a checkbox). We added some functions to render cubic movies. Thus, using some commercial applications, dome-masters can be converted from ZINDAIJI movies (Fig. 2). Also, cubic movies with stereo disparity can be rendered in a similar fashion.

CONCLUSION

We have developed ZINDAIJI - a GUI application for the visualization of simulations with a large number of particles, which is often performed in astronomy. With this application, stereogram and/or cubic movies can be rendered. We have made movies using this application and used them in science shows as part of the 4D2U project. We will publish ZINDAIJI as freeware at the 4D2U website (4d2u.nao.ac.jp/) in the near future and anyone will be able to use them.

At the present time, ZINDAIJI works only on PCs with Microsoft Windows (2000/XP). We are developing a new application (called ZINDAIJI2) based on cross-platform GUI library wxWidgets[5]. This will also be published as freeware in future. Any help or suggestions for the code development are welcome.

ACKNOWLEDGMENTS

The 4D2U project is funded by the Special Coordination Fund for Promoting Science and Technology of the Japanese Ministry of Education, Culture, Sports, Science and Technology as part of their Program for the Effective Promotion of Joint Research with Industry, Academia and Government (2004-present).

REFERENCES

5. [www.wxwidgets.org/](http://www.wxwidgets.org/)
Human Interfaces In The Digital Age

Joyce Towne

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Abstract. It’s important to consider how you relate to your controls and theater software. Operators may have staff, in addition to themselves, who make presentations and use the theater delivery system. They also have to be effective and successful in live presentation, though their style of theater control, experience level, and desired set of visuals may differ from yours. What are the challenges with interface in any planetarium, and with any projection technologies? And how about the challenges unique to digital planetarium users with real-time sky software?

INTRODUCTION

Traditional planetarium control was (and is) one-to-one. One button, knob or slider caused one thing to happen on the dome. Digital control is “one-to-many”. One action, or type of action, can cause many different things to happen, or a sequence on the dome. So we need new skill sets as we switch to digital control.

How do we provide effective control for planetarium educators and presenters?

Simulating Traditional Tactile Controls

One approach is to reproduce the style operators are most familiar with: the one-to-one control of the tactile console or panel. There are now tactile controllers designed to go with digital systems. They can simulate hands-on consoles. An example, Spitz’ Nomad, has assignable sliders, buttons and knobs, as well as assignable touch screen elements – such as text button or picture (see Figure 1). This can be a part of a digital system, or can also control opto-mechanical projector functions, lighting and just about anything.

Mouse Control

If you think about it, mouse control is the closest thing in the digital world to one-to-one control. For every function in a system, there is a control – a virtual slider or button to click on. It’s a way to control a live presentation. Though some find this method challenging to adapt to, operators improve as they become familiar with the new control screen.

Still, some find this process is unwieldy, and prefer tactile control for traditional one-to-one operation, and it’s worth noting many people are comfortable with these methods for other software. This disparity raises a unique question (potentially the subject of another paper)
about whether planetarium control by its nature should be unique from other software control styles.

**Macro/Scene File**

Many digital systems offer a macro or scene file method of control. It’s a way of saving the conditions of time and space as a file. It’s a common, one-to-many control method. It allows you to work off line, if you like, to create a desired visual sequence – for instance, moving from Earth to another location in space. Then later, some other presenter (or you) can trigger this easily in a live presentation using the keyboard, or hand-held remote, perhaps a PDA. On a tactile device like Nomad, the macro could be a large button, or a series of buttons that are easily recognized.

**Graphic Control**

Graphic Control is something a bit rarer. Starry Night software responds graphically to your touch. In this case, the human interface can be *direct*. The operator hovers their mouse cursor over a preview screen showing the dome-scene, and can manipulate every aspect of the view (viewing direction, orientation of a 3D body, position of an object in space, number of constellations selected, etc). The cursor is adaptable, so if the operator hovers the cursor over a planet, it adapts to a function where the planet can be scrolled in 3 dimensions. If the operator right-clicks on an object in the sky, they are presented with information and options (see Figure 2).

A unique aspect of this approach is that control on this preview screen is graphically “disconnected” from the view rendered on the dome. The operator moves the object (ie: rotates a planet) roughly to position using the preview screen on the console monitor, then the rendering engine displays these motions very smoothly on the dome.

**FIGURE 2. Typical Starry Night Dome mouse control screen.**

Starry Night developed this feature since so many home users and non-experts wanted a natural-feeling interface, hence its existence in the dome version of Starry Night.

**HTML Browser Control**

This is just what it sounds like. It’s possible to create HTML browser pages which look like a website to the planetarium operator. But now this is neither one-to-one nor one-to-many control. It’s two-way communication between the user and the software. Browsing can provide the show script an operator reads from, information on how to run the show, data about space objects and the sky, or whatever you want to access. An operator can navigate through the HTML pages, and by clicking on a link, can launch a simulation, add-to a simulation, or bring in a Quicktime movie video. This approach challenges the methodology of “linear” show presentation and allows flexibility in show topics and order.

Expanding on the idea of two-way communication at the control desk - for any object in the sky - when operators right-click in the preview screen, pages of informative data are displayed for the selected object: size, distance, composition and type (see Figure 3).
Presentation Capture (or Performance Capture)

Using Starry Night Dome and ATM-4 software, you can perform a visual sequence, or a transition, and the automation system tracks and buffers these changes. Next, you can place this new action on the timeline of the show (the automation timeline). So it’s a simple matter of presenting something in Starry Night, and telling ATM-4 automation to accept what you did, and repeating this over and over to prepare your animated visual sequences, which can add up to a whole show (see Figure 4).

ACKNOWLEDGMENTS

We wish to acknowledge the software designers and programmers at Starry Night (Imaginova) Canada and at Spitz Inc, USA.

CONCLUSION

The human is what the control system needs to be designed around. Digital control differs from more traditional systems, in that it’s not about the controls dictating how you present a show. The old one-to-one paradigm meant you had to hit one button or slider to turn something on and off. Digital control is flexible and scalable, so you have a variety of ways to control each effect and each show.

One-way communication is a thing of the past. Digital systems allow two-way communication – so you can operate a show and simultaneously receive instruction on what to do next, or information about the universe itself.