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Final Deadlines

March: January 21
June: April 21
September: July 21
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Cover: The planetarium in its advanced form vividly presents the heritage of our astronomical knowledge and highlights current discoveries by telescopes and spacecraft. Above and beyond the traditional 'star show' programming, the possibilities of fulldome projection are virtually limitless. We can visualize past civilizations as symbolized by the reconstruction of the Temple of Artemis in Ephesus; we can visit natural environments such as in the view of Monument Valley; and we can follow spacecraft as they conduct their missions of exploration. The theater design shown here is a tilted dome with a central laser projector, a likely common design for many future domed theaters. Artwork copyright © Don Davis.

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Planetarium Paradigm Shift

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Abstract

Immersive video represents a paradigm shift in the planetarium field: new opportunities for teaching and presentation will necessitate new ways of thinking about the medium. We can now present the discoveries of 21st-century astronomy with great fidelity and within an accurate three-dimensional context, but such possibilities expand our content area significantly and require creativity in their implementation. Furthermore, fulldome video also demands a new approach to planetarium production, as taking visitors on a "narrative journey" that places greater focus on the audience experience. The planetarium community must grow with the technology we use, and the future holds both great potential and tremendous challenges.

It is tempting, when writing an article such as this, to stick to the third person: authoritative, distanced, and "objective," third-person prose seems to offer greater impact than first-person musings. But my partisan passion for the fulldome medium does not permit such a strategy. I believe that emerging technology offers planetarians remarkable new opportunities that will benefit our profession and the educational goals we all share. I feel so strongly, so optimistically, about the potential, that I cannot easily express my views with mere "its" and "theys." To top it off, the promise of fulldome technology cuts to the very core of what I love about astronomy. So I hope you will not begrudge me the first person.

When I was a teenager growing up in Arizona, I would drive into the foothills of the Rincon Mountains, park my car and lie on the hood staring at the night sky. I didn't know many constellations, and I rarely used the department-store telescope my well-intentioned parents had bought me, but the sky fired my imagination. I had read Carl Sagan's *Cosmos*, and I gobbled up books on a variety of astronomical topics. And I had attended shows at the Flandrau Planetarium, roaming the exhibits (the light table, polarizing filters, and solar spectrum made strong impressions, as I recall) for hours on end.

Lying under Sonoran skies two decades ago, I considered why people had traveled to the Moon and no farther, and I wondered how far humankind might travel in the future. I looked at the stars and tried to imagine how far away they were, even the closest billions of times more distant than the Moon! I marveled at the concept that we could know so much about the Universe just by studying light. In short, the sky simply awakened in me the questions that modern astronomy attempts to answer – and challenged me to see the extraordinary activity beyond the apparent serenity of the constellations.

Earthrise over a planetarium audience in the Hayden Planetarium, during a showing of the Rose Center for Earth & Space's 2002 program, *The Search for Life: Are We Alone?* Courtesy American Museum of Natural History.

Today, tools have become available to connect the realms of sky and science in unprecedented ways. We can teach contemporary astronomy as never before, illustrating concepts with self-consistent, data-driven moving images that put elements in their appropriate and accurate context. Furthermore, such didactic accomplishments can take place in an immersive and stimulating environment, namely our planetarium domes.

Two technological streams have converged. First and more familiarly (because it has been discussed with such frequency in our profession), video projection technology now allows us to cover domed surfaces with increasingly high-resolution, full-color, full-motion imagery that creates an immersive environment to engage our audiences. But on the other side of the video cable, we also have unprecedented (and increasingly affordable) capability to bring real-time, high-resolution 3-D graphics covering sufficient size scales to accommodate the incredible dimensions of our Universe. Together, these technological innovations offer the promise of a planetarium paradigm shift – from the tools and techniques developed over the last eighty years to a host of new possibilities.

I would like to tackle the astronomical side of the equation first: to address the fundamental reasons why I believe the "Digital Universe" promises a new way of viewing astronomy. Then I want to get into some of the reasons why the fulldome medium offers an

ideal format for astronomical content. Finally, I would like to comment on some of the production challenges associated with fulldome video and end with a few thoughts on the future.

The Digital Universe

Inside the Hayden Planetarium, we have spent many late nights touring friends and colleagues through our 3-D atlas of the Universe. We offer a course for the general public that introduces the dome and describes how we developed the database we use – as well as a monthly program that tours audiences through a selection of datasets, based primarily on our digital atlas. In 2004, a few of us had the opportunity to take a similar program "on the road," presenting at various institutions nationwide. Our collective experience constitutes, I believe, a new way of contextualizing astronomical discoveries, facilitated by new technology.

On a typical "grand tour," we begin with the orbits of the planets and the trajectories of the Voyager spacecraft (the farthest humans have sent physical objects) and travel out to the Oort cloud (the distant reaches of our Sun's influence), past the exoplanetary systems we have discovered to see the "radiosphere" bubble sixty-some light years in diameter (the farthest humans have made our presence known through radio signals sufficiently strong to be detected), and out to the scale of the Milky Way Galaxy. We then use our extragalactic atlas to highlight the large-scale structure of the Universe, give a sense of the extensive mapping done by surveys such as 2dF and Sloan, and introduce the Cosmic Microwave Background. From each transition to the next, each previous step remains visible long enough to provide a visual and conceptual link to the ever-increasing scales we describe. Traditional planetarium tools do not allow such seamless integration of size and distance.

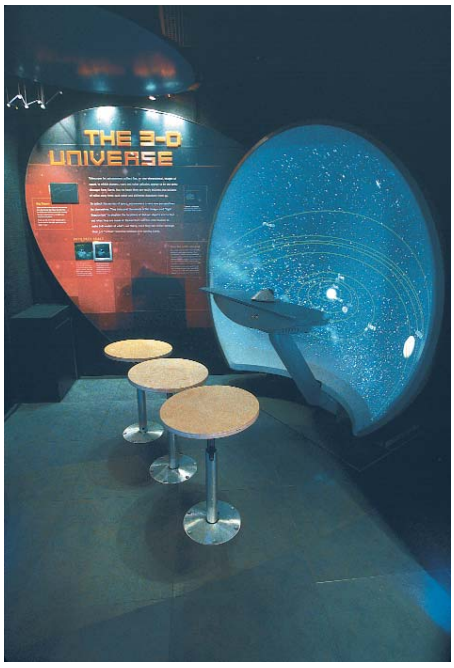
As we say in our advertising copy for the "Virtual Universe" program: "You'll tour through charted space – an experience that will redefine your sense of 'home.'" We wrote that sentence based in part on the reactions people have had to experiencing the atlas. People often leave an hour-long session under the dome expressing awe at the scale of the Universe and wondering at the magnitude of astronomical discoveries. My colleagues and I would love to attribute such impressions to impeccable presentation style, but we concede that it more likely reflects the power of showing people real data in a visceral, yet intellectually satisfying, context.

Indeed, context is the crux of the matter. What does it mean when a new planet is discovered around another star, if one lacks a sense of interstellar versus interplanetary distances? What is the Milky Way band that crosses through the night sky, and what connection does that have with the Milky Way "Galaxy"? How can we tell that we live inside a spiral galaxy, let alone estimate its size? Most contemporary discoveries require spatial and temporal context in order for our audiences to appreciate them.

> Cinema has had more than a century to develop a visual language (of pans, zooms, cuts, etc.) that allows viewers to understand the narrative flow of a piece. … But large-format film has been around only a third of a century, and it demands a new approach.

Traditionally, one gains a sense of where things are in the Universe by poring over text, photos, and diagrams – in recent years, a video or interactive element may help one along – but placing this varied information in a coherent 3-D construct can prove dauntingly difficult.

Three-dimensional visualization of digital datasets provides a context for the vast quantity of information churned out by astronomers – not simply as piecemeal images or videos, but potentially within a coherent 3-D construct that conveys a significant level of understanding about our Universe. Thus, you not only visit the Orion Nebula, but you travel the 1,500 virtual light years to get there. You not only fly around inside a computer simulation of a globular cluster; you lift out of the plane of the galaxy to see the distribution of globular clusters around the galactic center, then choose one to fly into. Basically, you can explore a "Digital Universe" that approximates and incorporates what we know about the actual one. With such tools, audiences can experience the relationships between different datasets, establishing a visual and conceptual framework that supports the acquisition of more detailed information.



A small domed surface immerses pilots in a digital model of the solar system in the American Museum of Natural History's "moveable museum," a traveling collection of astronomy-oriented interactive exhibits. Courtesy American Museum of Natural History.

To be perfectly blunt, a traditional planetarium can teach 19th-century astronomy very well, but our 21st-century audiences want to glimpse the broader horizons that modern astronomy has revealed to us. Modern computer technology allows us to do this, and fulldome video is the conduit by which it can reach planetarium-goers.

The Digital Dome

At its best, a planetarium immerses an audience in science stories. Although such stories have typically revolved around the night sky, planetarium technology today can represent the discoveries of space science (and other sciences) better than ever before. With immersive video technology, domes can be filled with computer-generated visuals that depict current astronomical discoveries with unprecedented fidelity.

In the most recent Rose Center Space Show, *The Search for Life*, each image (out of more than 42,000) covers about four million square inches of dome surface. Audience members view a show that fills almost half their field of view, at a rate of 30 images per second, which visually approximates an alternate reality – corresponding not to an experience under a dome, but an experience inside an environment. At its best, immersive video allows audiences to connect with a virtual environment in an exceedingly visceral way. An "immersed" audience member becomes part of the action – and part of the science! New technology expands the natural planetarium environment from the night-sky diorama of traditional projectors to a universe of topics limited only by rendering resources.

Award-winning large-format-film director Ben Shedd's article, "Exploding the Frame," describes an approach to large-format cinema that seeks a new cinematic language to work in this medium. He writes, "The whole group of giant screen film formats have one thing in common: the gigantic images extend the edges of the projected film image to the edge of our peripheral vision or even

beyond it. I believe we are not just talking about bigger films here, but a new cinematic world. It is a frameless view, an unframed moving image medium."

Fundamentally, Shedd offers a way of thinking about what every large-format film-goer has experienced – the catch in the throat as the camera dives off a cliff, the sinking feeling in one's stomach as the motion on-screen seems disturbingly real. The "frameless" perspective gives audiences a very visceral experience, engaging a more physical, more primitive part of the mind than the intellectual or even affective responses other media might provoke.

With computer-generated, geometrically-correct imagery, fulldome video continues the trend established by large-format film over the last several decades. Unlike film, however, the use of digital imagery allows for relatively low-cost production and playback, with the ability to experiment relatively cheaply (e.g., previewing real-time or low-resolution experiments in-dome) and no need to print to film! However pricey fulldome productions seem to planetarians, the budgets come nowhere near the amount spent on an average large-format film, and digital technology has the potential to become increasingly affordable. More importantly, it has a democratizing aspect to it as well: digital tools already offer tremendous access to a large cross-section of the population (again, compared to film), and they get cheaper as time goes on.

For example, working with my laptop and low-cost or free software, I have had the opportunity to produce two short fulldome pieces that have appeared as part of the LodeStar Astronomy Center's annual fulldome festival, "DomeFest." Other shorts in the festival have included student projects, work by Native American artists, and visual musings on the nature of perception and memory – not the stuff of ordinary planetarium shows, but very much the work of individuals. The experimental nature of "DomeFest" underscores another important aspect of fulldome video: its production challenges as an emerging medium.

The Narrative Journey

I will consider fulldome video in the context of its filmic predecessors, rather than attempting to contrast fulldome presentations with traditional planetarium shows.

Central to my argument is the idea of a filmic language. Cinema has had more than a century to develop a visual language (of pans, zooms, cuts, etc.) that allows viewers to understand the narrative flow of a piece. A variety of styles have evolved over time, film schools have developed well-honed curricula, and scores of books describe how to construct films and television shows. But large-format film has been around only a third of a century, and it demands a new approach.

Shedd contrasts the "framed" experience of traditional cinema with the "frameless" experience of large-format film. In particular, he compares the third-person style of traditional filmic language with the first-person nature of an immersive experience: "The movement sensation of the theater must be accounted for throughout a frameless film, in shots and from shot to shot. Either the audience is having a first-person experience or it isn't. This idea represents a complete shift of approach in filmmaking, where the audience experience is the first order of focus, where all of the action occurs on the audience's side of the screen."

In many discussions of fulldome technology, people bring up "the story" and the need to tell good stories in the dome. I take issue with the term "story," in part because it has very specific connotations in films and in literature; furthermore, the term misses an essential element of the production challenges associated with immersive experiences. Because the medium shifts emphasis from story to environment, a fulldome planetarium show is more about taking a journey than watching a story.

I believe that an approach to the medium that follows Shedd's philosophy not only makes good use of fulldome's strengths, but also stands in refreshing contrast to the media most people experience on a day-to-day basis: more than a sales pitch or a plotline being pushed at a viewer, a "frameless" experience can involve people in a way that television or movie screens do not. Furthermore, producing from a "first-person," viewer-oriented perspective requires a respect for the audience that bodes well for content creation. If we create programs that focus on the audience experience, we effectively invite people to appreciate the scientific content in a new and deeper way.

One of the effects of the audience-oriented approach is the need to consider how a viewer moves from one scene to another: rapid cuts become jarring experiences because one's sense of place is disrupted. Also, too-swift motion can either nauseate viewers or distance them from the action: images moving too quickly onscreen lose their coherence as an environment and instead function merely as wallpaper. And maintaining the sense of dimensionality on the dome demands maintaining a sense of motion – of foreground relative to background – that yields a parallax effect. Continuity and carefully-orchestrated movement characterize the most effective fulldome productions. Again, this kind of pacing and editing stands in stark contrast to the rapid-fire, "MTV-style" video and film that people see elsewhere, and I think there is strength in that difference. In the same way that planetarium domes have long offered the solace of the night sky, fulldome presentations can offer an exhilarating and inspiring glimpse into new environments.

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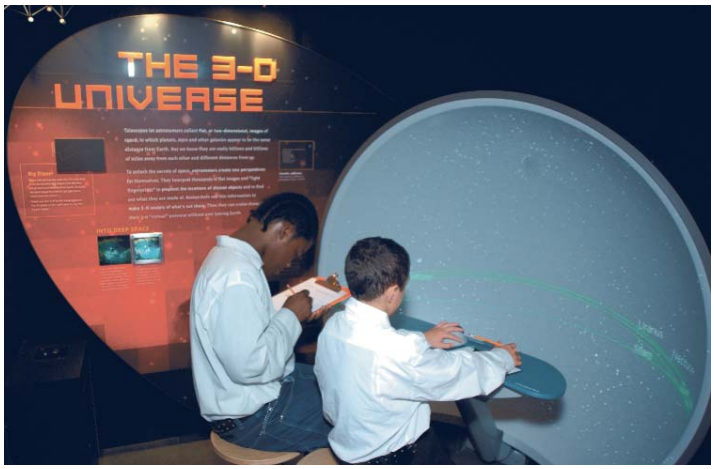

Harlem students interact with a digital model of the solar system in the American Museum of Natural History's "moveable museum," a traveling collection of astronomy-oriented interactive exhibits. Courtesy American Museum of Natural History.

tarium show is more about taking a journey than watching a story. At the end of a trip, fellow travelers may compare notes and find they have gleaned very different experiences from the same itinerary. Likewise, at the end of a planetarium journey, every audience member takes home something unique to him or her.

In short, a successful fulldome presentation takes the audience on what I call a "narrative journey." In its simplest form, this takes the shape of a guided tour, traveling from place to place with a bit of wit and wisdom to make the trip pleasurable and more meaningful. In a more sophisticated sense, one can carefully structure a sequence of locations to incorporate and illustrate a sequence of elements in a storyline. In a narrative journey, a viewer is taken along on a tour of virtual sites that parallel an intellectual and affective excursion reinforcing the itinerary. I do not intend to suggest that it is the only means by which a fulldome presentation can succeed, but I will say that the best fulldome content I have seen fits the bill.

In short, a successful fulldome presentation takes the audience on what I call a "narrative journey." In its simplest form, this takes the shape of a guided tour, traveling from place to place with a bit of wit and wisdom to make the trip pleasurable and more meaningful. In a more sophisticated sense, one can carefully structure a sequence of locations to incorporate and illustrate a sequence of elements in a storyline. In a narrative journey, a viewer is taken along on a tour of virtual sites that parallel an intellectual and affective excursion reinforcing the itinerary.

Keep in mind that natural history museums developed as storehouses of objects returned from distant journeys – localizations of exotica that became stand-ins for traveling to the places whence they came. Long after 17th-century "curiosity cabinets" grew into museums that allowed visitors to experience realms to which they could not travel in person, 20th-century science centers initiated a completely visitor-oriented experience that allowed for exploration and inquisitiveness of a different sort. In the sense that museums allow for travel without leaving a building, or science centers offer opportunities for exploration, the planetarium "journey" mirrors other paradigms in informal education.

A three-dimensional model of the Orion Nebula, based on the research of astronomers C. Robert O'Dell and Zheng Wen, formed the cornerstone of the Rose Center for Earth & Space's premiere program, *Passport to the Universe*. Courtesy American Museum of Natural History / San Diego Supercomputer Center.

The Audience Experience

The individuality of the experience presents challenges to those of us who would like to evaluate the quality and effectiveness of planetarium programs – a challenge throughout the realm of informal education. Somehow, one would like to account for the matrix of reactions from the cognitive to the aesthetic to the visceral, while probing further than, "So, did you like it?"

To that end, the American Museum of Natural History conducted pre- and post-viewing surveys of audiences who attended the Rose Center's debut space show, *Passport to the Universe*. Those surveyed responded positively to the show and showed significant gains in comprehending many of the show's underlying concepts: an understanding of humanity's "cosmic address," the relative size and location of stars, the structure of the Milky Way Galaxy, and the origin of heavy elements through nucleosynthesis. Further surveys of audiences who saw *The Search for Life* indicated that the immersive feel of the show had broad appeal, from eight-year-olds to adults. As one teenager commented, "It was much better than seeing it in a movie theater. The special effects were like actually being there."

Every survey helps, but overall, greater attention needs to be paid to the learning process that occurs under the planetarium dome. Carolyn Sumners at the Houston Museum of Natural Science has shown that immersive video sequences show greater gains in student understanding than other media, but her research barely scratches the surface. Increased evaluation can help pinpoint what works and what does not – an especially important step as the technology driving the shift in planetariums reaches an increasing number of theaters and the audience for immersive video widens. Implementation of the technology in new theaters should take advantage of what their predecessors have taught.

Another challenge planetariums face is a variety of audience expectations that range from sitting under the stars with a lecturer to watching slide shows with pre-recorded narration, from listening to rock music accompanied by laser projections to (perhaps) an large-format-film-style immersive production. Audiences do not understand the diversity of experiences that take place under planetarium domes, let alone the changing nature of the medium, and most people's expectations are defined by the trips that they took to planetariums as elementary-school students. The typical planetarium-as-experience (as opposed to planetarium-as-venue, where a changing slate of programs might be more expected) places most visitors in a "oh, I've done that before" mode of thinking that curtails return visits to a facility. According to

a frequently-quoted planetarium adage, the typical person visits a planetarium three times in their life: as a child, with their children, and with their grandchildren.

Unfortunately, because most data about planetariums are approximately as anecdotal as the child-to-grandchildren adage, it is difficult to identify means by which planetariums can help define expectations and attract a wider audience. With any luck, immersive video will help attract more people into planetariums and perhaps increase the visibility of the field in general.

The Future

Our culture is immersed in science – science inextricably linked to people's everyday lives. Astronomy and space science have proven to be an appealing and effective inroad to science education, and planetariums are part of that success. As planetariums continue to immerse audiences in increasingly realistic scientific visualizations and narratives, they can help people contextualize complex science stories.

Immersive video productions began as the purvey of a small number of sizable venues associated with fairly large-scale institutions. But as the medium evolves, smaller theaters have gained access to similar technology, and the variety of presentations (from prerecorded to real-time, fairly passive to highly interactive) will increase dramatically.

For example, Small Digital Planetariums (affectionately called "SDPs") will soon offer unprecedented interactivity with the cosmos, in a format that permits each participant to control their own experience. In the spring of 2001, AMNH rolled out its astronomy-oriented Moveable Museum, featuring a 1.5-meter-diameter vertically-oriented dome running software that allows students to pilot around the solar system. The Adler Planetarium uses the same projection technology in one of their galleries. Although similar opportunities for one-on-one interaction may be rare, the same single-lens projectors work in small domes, and with the appropriate software, an experienced pilot can offer tours through space and time.

Particularly as the medium continues to evolve, the quality of tools and access to supporting media need to improve. With an increasingly large audience of planetarians (with varying technical expertise) interested in incorporating immersive video in their presentations, hardware and software tools need to support easy acquisition and inclusion of materials into fulldome programs.

Ideally, our community will begin to support the idea of an "open-source universe," in which contributors can add to an existing collection of 3-D data that would be shared by users of different systems. The idea has particular merits for the real-time systems that have come online in the past few years. Most fulldome systems include real-time displays – of traditional planetarium functions such as sidereal motion and orrery simulation as well as 3-D data and virtual spaces. Real-time solutions gain particular importance in light of the fact that pre-rendered, high-resolution fulldome video will remain relatively expensive to produce for the foreseeable future. But with user-friendly, real-time digital planetarium technologies, we open up a new realm of possibilities.

To choose one example, think of the revolution that can take place in school planetariums. First off, I have always seen (mostly real-time, interactive) fulldome video as an opportunity to revitalize the unused domes in schools across the country (some couple dozen in New York City alone): with the possibility of addressing more universal topics in a domed classroom, perhaps many school boards would invest in the equipment to reopen them. Plus, the generation of teachers being trained now probably feels more at home with a computer than with a knob-and-lever planetarium projector, so perhaps the transition to newer technology will come as a welcome step to them! But what is most key in my mind is the kind of science we can begin to teach with new technology: not just night-sky motions and slides or videos of isolated objects, but an integrated view of our 3-D Universe. The experience offers a paradigm shift in the way students think about the cosmos, even as it represents a shift in our own community.

During my nights up in the Rincon foothills, I asked questions that I like to convey to an audience now, if not under desert skies, then under a digital dome where I can try to answer some of the queries that kept me awake as a kid. Computer databases and software tools allow for the exploration of a Digital Universe that reveals relationships otherwise difficult to convey. And fulldome video allows me to immerse audiences in the exploration – perhaps not yet with the crisp clarity of a desert sky, but with sufficient impact to create a memorable experience. I am simply pleased that technology is finally catching up to my imagination!

References

Ben Shedd is currently working on a book, but in the meantime, his "Exploding the Frame" article is available online at http://members.aol.com/sheddprod2/ExplodingtheFrame.html

Carolyn Sumners presented her research at the NASA OSS Conference in 2002, and you can find her article in the published proceedings: Sumners, C., and Reiff, P., "Creating Full-Dome Experiences in the New Digital Planetarium," ASP Conference Series Volume 319, *NASA Office of Space Science Education and Public Outreach Conference*, p. 155.

Download the Hayden Planetarium's Digital Universe at www.haydenplanetarium.org/hp/vo/du.

Also, take a look at "Virtual Universe," which appeared in the April 2004 issue of *Natural History* magazine; also available online at www.nhmag.com/0404/0404_feature.html. ☆

Not all fulldome programming focuses on astronomy: entertainment programs such as the American Museum of Natural History's *SonicVision* allow for a more experimental approach to the medium. Courtesy American Museum of Natural History.