The University of Washington Mobile Planetarium: A Do-it-yourself Guide

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Summary

The University of Washington mobile planetarium project is a student-driven effort to bring astronomy to secondary schools, and the community, in Seattle, USA. This paper presents the solution that was designed and built in order to use the World-Wide Telescope — a computer program created by Microsoft that displays the astronomical sky as maps, the 3D Universe, and earth science data — from a laptop and an off-the-shelf high-definition (HD) projector located in an inflatable planetarium.

In the first six months of operation, undergraduates at the University of Washington presented planetarium shows to over 1500 people, and 150 secondary school students created and presented their own astronomy projects in our dome, at their school. This paper aims to share the technical aspects of the project so that others can replicate the model or adapt it to their needs. This project was made possible thanks to a NASA/ESA Hubble Space Telescope education/public outreach grant.

Introduction

Digital planetariums are becoming a mainstay in astronomy education. They allow the presenter to enhance their lessons with the incredible imagery that has become commonplace in the modern age and to use visualisations of astronomical systems from moons to galaxies.

Free software, in particular WorldWide Telescope (WWT)[1] has brought high-quality, up-to-date astronomical imagery to the screens of anyone with an internet connection. Furthermore, the WWT contains its own image-warping software, putting do-it-yourself planetariums with HD imagery within the reach of smaller budgets. In fact, the method described here costs roughly $14 000 in parts (all purchased new). The costs would have been about $1500 less had the laptop and projector already been available. The largest costs are the planetarium dome and the first-surface mirror ($12 000).

The mobile planetarium project grew from an existing planetarium outreach programme. The graduate students at the University of Washington Astronomy department maintain a weekly outreach programme where they organise and present free planetarium shows to any school or astronomy group that makes a reservation. In 2009, organisers noticed that over a three-year period, this outreach programme had served, on average, 1000 students per year. However, in the same period, no public secondary schools in Seattle had made reservations, despite being located within 16 kilometres of the planetarium. It was decided that a proactive solution to the lack of engagement with these schools was to bring the planetarium shows to the schools.

With WWT software it quickly became clear that there was no need to lecture, and that the planetarium presentations could be flipped. In other words, the students could create and present their own planetarium shows. The initial plan to turn the planetarium outreach programme into a road show became simplistic and outdated in the face of new technology. Now the project engages students not by presenting to them, but by helping them to produce their own planetarium content and providing a mobile planetarium for them to stage their astronomically themed presentations.

Below is a description of the technical decisions made and the advice that we wish

Figure 1. The University of Washington mobile planetarium dome.

had been available when starting the project from scratch. A very useful starting point is to become a member of the Yahoo groups full_dome and small_planetarium. There is a lot to be learnt by diving into their archives.

1. Timeline

This project was planned over nine months of part-time work to gather equipment, design and build optics housing, and test the optical alignment. Three months were also allocated to offer a seminar to train undergraduates in setting up and operating the planetarium. Finally, two meetings with a pilot classroom were set up before launching into full operation.

2. Budget

2.1. Equipment

This project received a Hubble Space Telescope education/public outreach grant of $40 000 to increase access to the University of Washington planetarium and build a mobile planetarium. This was limited to spending no more than half of the funding on mobile planetarium equipment. In total, the mobile planetarium cost $14 000 in parts, including the purchase of a $1500 laptop.

2.2. Insurance

Insurance is an important element to remember to include in a longer-term budget.

2.3. Transportation

We rent a minivan for the project members to travel in groups of at least three people, but we have transported our entire planetarium and a passenger inside a four-door sedan. Depending on the range over which you expect to travel consider budgeting for rental vehicles and mileage costs.

2.4. Personnel

This project never occupied anyone full time. The initial overhead is the highest concentration of labour. This is the period when the planetarium is built, the first team of undergraduates is trained in the WWT software and the technical details of the planetarium are planned and implemented. For this initial ramp-up a graduate student was hired for approximately 300 hours in total, during the nine-month period, and one undergraduate assistant was hired for approximately 240 hours total, over a one-year period.

The hired graduate student ordered and led the planetarium assembly as well as mentoring the undergraduate assistant. The undergraduate assisted by leading the building and design of the optics housing, writing lessons, and training prospective undergraduate presenters at the seminar.

There is now a team of approximately ten undergraduate volunteers who are capable of transporting the planetarium. One full-time lecturer is in charge of the mobile planetarium, although we recommend keeping this position as an advisory role and funding 1–2 undergraduate assistants to manage scheduling and communication with the schools.

3. Essential equipment

3.1. Projection type

At the time of ordering equipment, a fish-eye lens solution would have been prohibitively expensive as a single purchase and difficult to replace. In addition we wanted a projection system that would sit on an edge of the dome, rather than at the centre, where the students entered the dome. In the end two first-surface mirrors, one convex, and one flat, were purchased to project imagery on to the dome.

3.2. Inflatable dome, fan and hemisphere mirror

The biggest equipment cost is the inflatable dome. The decision of which size dome and which company to use should be made with care. We will not reproduce the clearinghouse of knowledge and experience in the Yahoo groups, *small_planetarium* and *full_dome*. We made heavy use of their email archive as well as asking specific questions of the group at large.

Listed below are the main concerns and solutions arrived at with the help of the Yahoo groups. Advice from the experiences of members in the Yahoo groups positively mentioned Go-Dome, Digitalis, and Stargazer. In the end, a standard sized Go-Dome was purchased through eplanetarium.com[2], which came with an inflating fan and the hemisphere mirror.

3.3. Concerns and solutions

3.3.1. Dome size

Concern: The dome must be transportable by 2–3 undergraduate students, able to fit a class of around 30 students inside, and be able to fit within a classroom.

Solution: Limiting the search to domes no more than three metres high.

New issues raised by the solution: The horizon will be low, most students will need to sit on the ground, some chairs or perhaps two wheelchairs can be placed around the back and sides of a dome this size.

Why constrain the presentations to a classroom?

A taller dome could have been purchased, requiring the set-up to be in a gym, cafeteria, or theatre. Outside is not an option as any wind will cause the dome to lose its shape. The choice not to do this was based on the following two issues:

1. The assumption was made that there would be no internet access outside the classrooms. In fact, it transpires that there is rarely internet access in schools.
2. The assumption was made that it would be more difficult for a science class to take over the other locations and one aim was for the imprint on the school to be as small as possible. For example, the presentation could be too loud to share a space in a library, even though librarians are often very happy to share their space. However, it was very helpful to have the option of using a classroom.

Figure 2. *The optics box in the mobile planetarium. The do-it-yourself guide to building the above optics box is available on our website[4].*

The recommendation would be to phone different schools to see what options are available. In the end, we would have made the same decision on the dome size, and purchased the standard Go-Dome.

3.3.2. Dome entrance

Concern: Needs to comply with the Americans with Disabilities Act (ADA).

Solution: We have not found an excellent solution for inflatable domes. The best option seemed to be to purchase a standing dome (one that does not require constant inflation) that has an open entrance. In our research, these domes were well beyond our equipment budget. Advice from experiences of members in the Yahoo groups positively mentioned Go-Dome, Digitalis, and Stargazer as ADA-compliant options.

3.3.3. Dome material

Concern: Will the dome let in outside light? Is it safe to bring into schools? Has it been fire tested?

Solution: All the above domes are light-tight. The three companies listed above all seemed to have dark domes and the necessary documentation.

3.3.4. Mirror costs

Concern: First-surface hemisphere mirrors are expensive, and seem to be only produced in Australia. How can we limit the cost as we are based in the USA?

Solution: First-surface mirrors are a must. Coated mirrors produce blurry images as some of light from the projector is reflected by the interior surface of the coating back to the mirror, and travels to the dome at a new angle. This is only made worse if more than one mirror is used. ePlanetarium ships a first-surface hemisphere mirror for an additional cost with the Go-Dome.

3.3.5. Dome fan

Concern: How portable is the fan, given how much other equipment there is?

Solution: It is simple to purchase a small-wheeled attachment for the fan, or a two wheeled luggage accessory. It was not found necessary to purchase them for this project.

Fan speed, fan control, and fan noise are important factors. The fan speed needs to be turned up while people enter and exit the dome, since the fan control is often found on the fan itself, one must control the fan speed from inside if giving the show alone. In practice, there was always someone on the outside to assist with crowd control, and they were able to adjust the fan speed to communicate to the presenter. The fan is turned up when it is time to wrap up the show.

In a small room, a large fan can create a lot of background noise. Look closely into the specifics of the dome fan to make sure it fits your needs.

3.3.6. Projector

Concern: Need a projector that is good for high dark–light contrast (stars and nebulosity), easily portability, has small replacement costs, and all on a small budget.

Solution: An off-the-shelf, 1920 × 1080 p (16 × 9) HD, high-lumen projector was purchased. The website *projector central*[3] is a powerhouse of information when it comes to choosing projectors. The search for this project was limited to 1920 × 1080 p (16 × 9) HD projectors under $1000. High-lumen projectors were found to be better suited for mobile planetarium purposes. Large planetariums can make use of dark adaption in conjunction with a low-lumen projector, so the eye can better pick out details like constellations after seeing a bright image. However, in the portable planetarium the line of sight to the image is never more than 15 ft, and usually around 10 ft. Dark adaption of students' eyes cannot be depended upon after, for example, flashing an image of the Hubble Space Telescope's mosaic of the Crab Nebula spread on the entire dome. Finally, no attention was paid to the quoted contrast ratio, since dynamic irises and other technologies make the quantity non-uniformly defined from projector to projector.

3.3.7. Laptop

Concern: A HD video card, large hard drive space, and a Windows PC or Mac running Windows on a dual boot or as parallels (for WWT) was needed.

Solution: Any laptop with a video card capable of extending an HD display and dedicated hard drive space for WWT to cache imagery is fine. Look for one with a backlit keyboard so the presenter can type in the dark (a USB powered reading light would be an affordable workaround to a backlit keyboard). Based on personal experience (and not industry comparison) we have been happy with a near top-of-the-line NVIDIA GeForce video card. In simpler terms, the laptop should have a built in (mini) DV or HDMI output. For lower quality imagery, VGA can be used, but is not recommended.

3.3.8. Optics assembly

Concern: Mainly durability, size, cost and a preference to limit the handling of the first surface mirror(s).

ePlanetarium.com sell their own Transport Security Approved (TSA) optics solution, which was beyond this project's budget, and may have limited the projector choice to a projector with a lens in its centre.

Solution: To save money, an optics solution was built from scratch by the project team. Full details of the solution are posted on the website[4] and are available from the authors.

4. Essential accessories

4.1. Power

The laptop, the projector, the lights, and perhaps other accessories such as speakers and public address (PA) systems, require power. It is often against fire code regulations to connect a power-strip to an extension cord, so it was important to purchase a single unit.

4.2. Display

Not all HD projectors come with Digital Visual Interface (DVI) or High-Definition Multimedia Interface (HDMI) cables, and some laptops need a cable to convert HDMI. Using only the Video Graphics Array (VGA) cable that comes with an HD projector is like buying a sports car and never taking it out of second gear.

5. Non-essential equipment

5.1 Secondary mirror

A secondary flat first-surface mirror comes recommended. It allows the projector to be safely placed underneath the hemisphere mirror, and thus takes up less physical space in the planetarium, meaning more places for people, and a smaller chance of being bumped and jostled. However, it adds more variables to the alignment.

5.2. Equipment cases

5.2.1. Dome

A rolling equipment bag made for hockey goalies was used for this project. It is large enough to fit extra smaller equipment and does not require expert dome repackaging. With some extra budget, we would have had a logo option!

5.2.2. Mirrors

The hemisphere mirror is the most delicate and difficult to replace item, as there is no repair for scratches. For this project the housing was built as part of the box it was transported in, to avoid the number of times it would be handled.

The secondary mirror is less than 20.5 cm in diameter and kept in a picture frame, which is covered and sealed with rubber bands, so that nothing touches the mirror surface.

5.2.3. Laptop

A simple laptop backpack is enough to hold the laptop, lots of cables, a mouse, an Xbox controller, non-essential accessories, and any paperwork (such as the fire retardancy certificate and contact information). A laptop cooling pad is a good idea.

5.2.4. Projector

Most off-the-shelf projectors come with a carrying bag. In light of the amount of travel — in and out of cars and schools while carrying other equipment —a heavy-duty pelican case was purchased for the projector. We included the cost in the projector budget.

6. Non-essential accessories

6.1 Audio and public address equipment

WWT can play pre-recorded tours with audio, which requires some sort of amplified speaker system. Speakers placed outside the dome work well, as do higher quality computer speakers placed near the presenter.

6.2. Tickets and seating

Tickets are particularly useful when presenting at school science nights, which typically involve doing many short shows in a row. They let people know when to return and aid crowd management.

6.3. Lighting

For effect, rope lights were placed around the edge of the dome with a small switch so that the presenter has easy access to turn the house lights on and off. A battery-powered camping lantern is useful for setup and takedown.

7. Non-essential equipment and accessories for WWT

7.1. Internet access

WWT caches imagery from servers around the world. A 30-ft-long Ethernet cable was used as back up for internet access. Another possibility is using a wireless card in the laptop. Neither were found to be essential. If weak or no internet is available, see the WWT documentation housed on their website.

8. Initial assembly

8.1. Optics box construction

Justin Gaily, who designed and led the building of our optics box, has written a separate do-it-yourself guide, posted on the website and available from the authors.

8.2. Testing and alignment

With the optics box ready, it was great to have high-ceilinged rooms to align and test the system and train undergraduates. The Dance and Theatre Departments of the University of Washington graciously provided these spaces. WWT makes warping very easy in several scenarios, including a 16 × 9 mirror dome (see WWT documentation for details). The rest of the setup involves adjusting the components of the optics box, positions of the projector and angles of the mirrors until the entire dome is filled with light. It is helpful to project a grid during this process.

9. Presentation

9.1. Flipping the planetarium

It seems that the one measure of a successful education or public outreach project is how well it can be adapted to the specific needs of the target market. We wrote our grant with the simple idea of bringing our successful planetarium programme directly to the Seattle schools and community, but we have discovered that students can create their own tours of the Universe in the planetarium.

The model is to support teachers during a planetarium presentations unit lasting one or two weeks. The unit begins with small groups of students choosing a topic in astronomy and creating a storyboard for a short (3–5 minute) presentation using imagery from WWT. If the teacher is not trained in WWT, an initial visit is made to the classroom to demonstrate WWT tour creation and check in with each student group. After this visit, students work together to create WWT tours. Finally, the team returns with the mobile planetarium and the students present their work to their peers.

Students create a story as they research their topic, and then practice their communications skills to present it. On the presentation day, everyone gets to see their tour projected inside the dome.

Students were found to have no problem creating tours that showed well in the planetarium, as long as they avoided projecting text. They were advised to consider that only the middle third of their computer's screen will be in front of them when they are inside the dome and there is no reading from scripts inside the dome, so they could either record a voiceover or memorise what they wanted to say.

9.2. Creating tours

General information on creating tours and teaching WWT in the classroom is available on the excellent WWT Ambassadors' site[5].

Conclusion

Digital planetariums are immersive spaces that have the potential to increase students' enthusiasm for learning science. We have described the path we chose in designing and creating the University of Washington mobile planetarium in the hopes that others will adapt it to suit their needs. The main components are a laptop, a projector, a dome, a hemispherical mirror, and software that will warp the projected image (we recommend WorldWide Telescope). Our equipment budget was under $15 000 with everything purchased new and 80% going to the inflatable dome and first-surface hemisphere mirror. Our initial aim was to bring planetarium shows to local classrooms. We are excited to report that our mobile planetarium has gone beyond this and become an undergraduate-driven stage for secondary school students to teach their peers about the wonders of the Universe.

Contact

Email our team: uw.mobile.planetarium@gmail.com

Find us online: http://www.astro.washington.edu/groups/outreach/mplanetarium/

Links

1. www.worldwidetelescope.com
2. www.eplanetarium.com
3. www.projectorcentral.com
4. http://www.astro.washington.edu/groups/outreach/mplanetarium/about.html
5. https://wwtambassadors.org/

Biographies

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Oliver Fraser is a lecturer in astronomy at the University of Washington, USA. In addition to serving as faculty advisor for the University of Washington Mobile Planetarium group, Dr Fraser teaches introductory astronomy classes, along with classes that focus on how to write in the natural sciences.

Justin Gailey is a recent graduate of the University of Washington, USA, with a double major in Physics and Astronomy, and minors in Music and Mathematics. He designed and built the optics box for the mobile planetarium, and is currently teaching mathematics as a Peace Corps volunteer in Mozambique.

John Wisniewski is an assistant professor in the Homer L Dodge Department of Physics and Astronomy at the University of Oklahoma, USA. He was a co-principal investigator of the mobile planetarium project and currently serves as co-principal investigator of Oklahoma University's new "Sooner-tarium", a similar mobile planetarium project to the one reported here.